Hydrogen 101 and 202

For the New Mexico Legislature's
Interim Water and Natural
Resources Committee

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Why Hydrogen?

What about the Hindenburg?

Hydrogen is the economy of the future . . . And always will be!
(Psst – and it's too expensive . . .)

The Future is Now!

Why is the Hydrogen Future Now?
Hydrogen as the “Swiss Army Knife” of Decarbonization

- For many decades our energy supply was separated into electricity (domestic sources) and transportation and other uses (domestic and foreign sources)

- States and nations are on a trajectory to decarbonize the energy that serves our society

- In this age of decarbonization, our transportation and electric energy systems are merging

- Hydrogen is critical to decarbonization and is/can be domestically produced

- It stores and carries energy from a variety of sources. It is flexible, adaptable, moveable to where the energy is needed - and when its energy is used, whether to generate electricity or power an electric vehicle motor, water is the emission

- And its energy (as electricity) can be used in the transportation, electric, industrial and virtually every other sector

- H2 is more energy dense than lithium as an energy storage medium

What the Heck is Hydrogen and why should we care?
Hydrogen Fast Facts

- Hydrogen is the most plentiful element (74%) in the universe

- The US currently uses 10 million tons/yr H2 - primarily for petroleum refining (68%) and fertilizer (ammonia) production (21%), + steel, cement, food processing, etc

- 95% of current H2 production is from methane (natural gas), 93 million tons of CO_2 emitted annually from Hydrogen

- Hydrogen Production is a mature technology that we have been using for 80 years or more in our society

- 1 kg of H2 provides roughly the same energy as one gallon of gasoline

- However, fuel cell electric vehicles (**and yes, fuel cell vehicles are electric vehicles!**) are 2 ½ times as efficient as gasoline powered, so $4/gal gas = $10/kg H2 => production and "moving" H2 goes into this cost, about 50/50

- Hydrogen for our purposes today is an energy carrier and energy storage resource

Hydrogen – What is it? How do we "Produce" it?

A Discussion for Legislative, Regulatory, and Policy purposes - not for chemistry class

3 criteria to understand in concept and for policy adoption:

1. The "source" of the hydrogen molecule – the **"feedstock"**
2. The **source of the energy** being carried by the hydrogen molecule (we isolate the hydrogen molecule and "stuff it" with energy;
3. And/or based on the **Carbon Intensity (CI)** of the production process

Fossil Feedstock and Energy Input

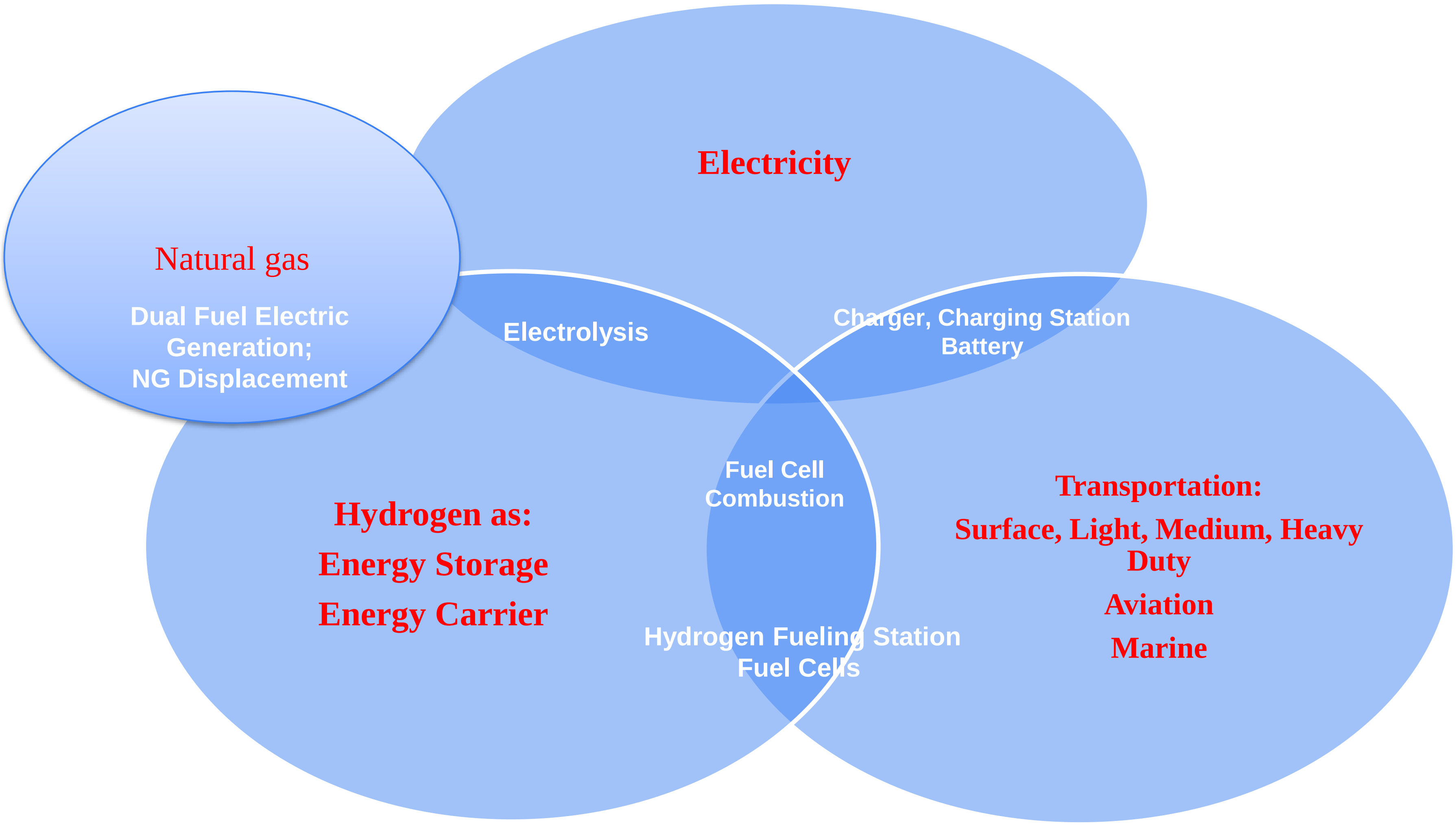
- **Feedstock and Energy source** – natural gas (methane) contains its own energy – source of 95-98% of H2 used today;
- **Production Process: Steam Methane Reformation** (SMR) – CO2 emitted as a gas
- **Production Process: Pyrolysis:** Up and coming technology – Heat without oxygen – carbon released as a solid
- Production Process leaves the energy packed Hydrogen molecule ready for use

Hydrogen – What is it? How do we "Produce" it (cont)?

"Green" Hydrogen

- "Green" Hydrogen is a term of art to describe hydrogen **produced with 100% renewable electricity** through "electrolysis".
- **Nonfossil Feedstock** for the electrolytic hydrogen is the water molecule H_20
- **Energy Input is electricity** – "Electrolysis"
- **Production Process -** Electricity is used to split water into hydrogen and oxygen, leaving the energy from the electricity in the hydrogen as a gas, and oxygen as the emission
- **Practical consideration:**
  - Sourcing 100% renewable electricity will make the H2 more expensive because, unless the source is a hydroelectric project, renewable energy, wind and solar are not available 24/7.
  - For states such as New Mexico, Washington, Oregon, California with laws placing their electricity on a decarbonization pathway, 100% renewable should not be a hard and fast requirement. For instance WA (and OR?) have nuclear in their eligible sources for decarbonization.

Electrolytic Hydrogen – Production and Uses
Existing and New Infrastructure



Hydrogen Uses - The Swiss Army Knife of Decarbonization

New and expanded uses toward Decarbonization – :

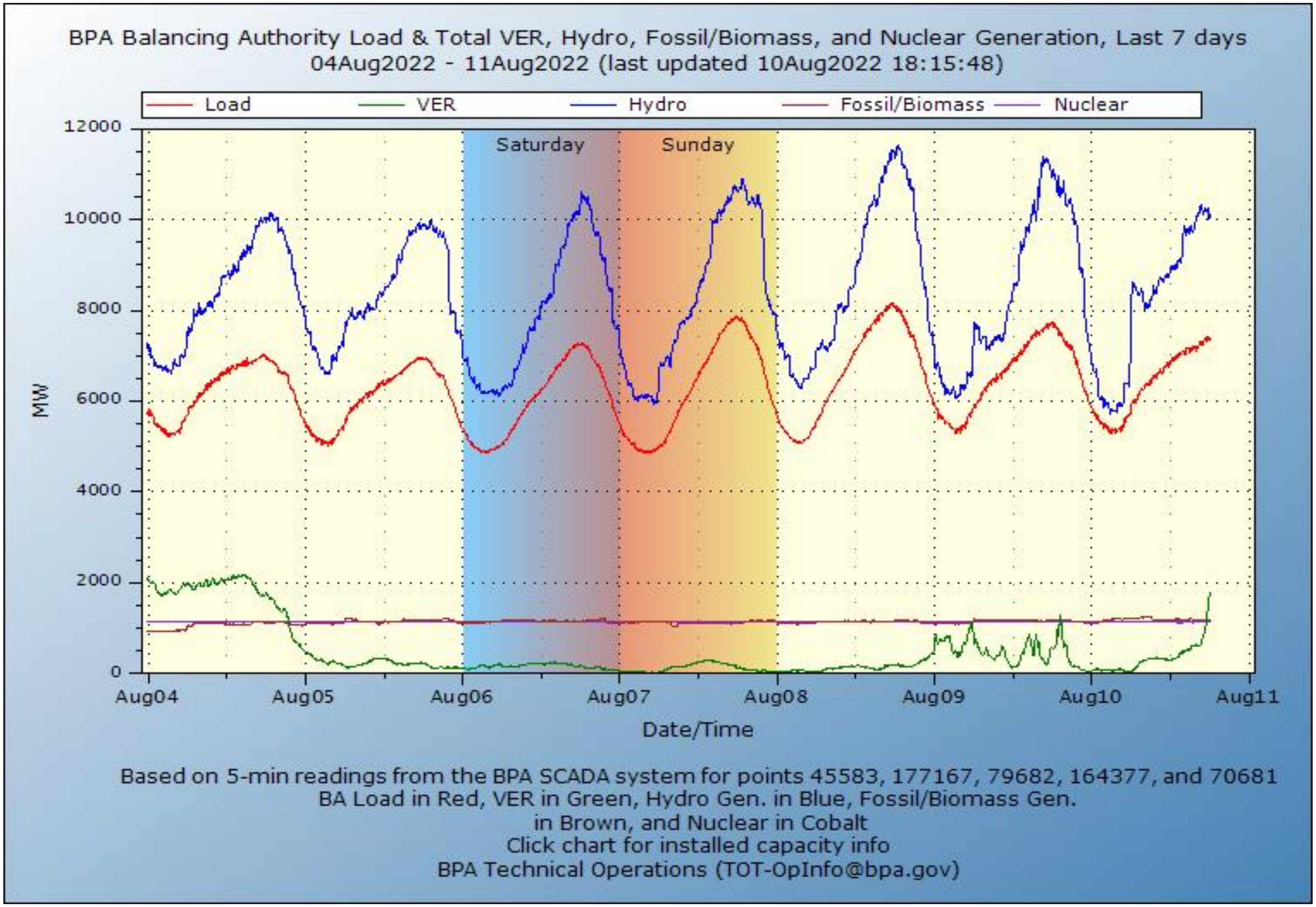
- Electricity - Storage of variable renewable energy and subsequent use
  - Fuel Cells
  - Combustion Turbines
  - Grid Operations, demand response, integration of variable renewables, contingency/spinning reserves, reduced wear and tear of generators from "ramping"
  - Flexibility of uses, transportation
  - Displacement of/portfolio standard for conventional natural gas
  - Can utilize/ repurpose existing energy infrastructure: pipelines, coal plant infrastructure, water

- Transportation –Fuel Cell vehicles are Electric, Zero Emission Vehicles ;
  - Surface vehicles – Light, Medium and Heavy duty
    - Longer ranges, MUCH quicker refueling times (3-5 minutes for LDVs), (no nearby amenities necessary), longer ranges
    - Initially - Public and Private fleets
    - Transit – buses and LDVs and MDVs for dial a ride
    - Heavy Duty – freight, locomotives, ferries
    - Retail LDVs
    - "Super commuters", agricultural, construction, freight vehicles, Fork lifts (35,000 in use today)
    - Apartment dwellers, renters, on-street parkers
    - Cold weather - no battery loss from heating – fuel cells emit heat
    - Avoided expensive distribution system upgrades necessary for BEVs (non-wires solutions)

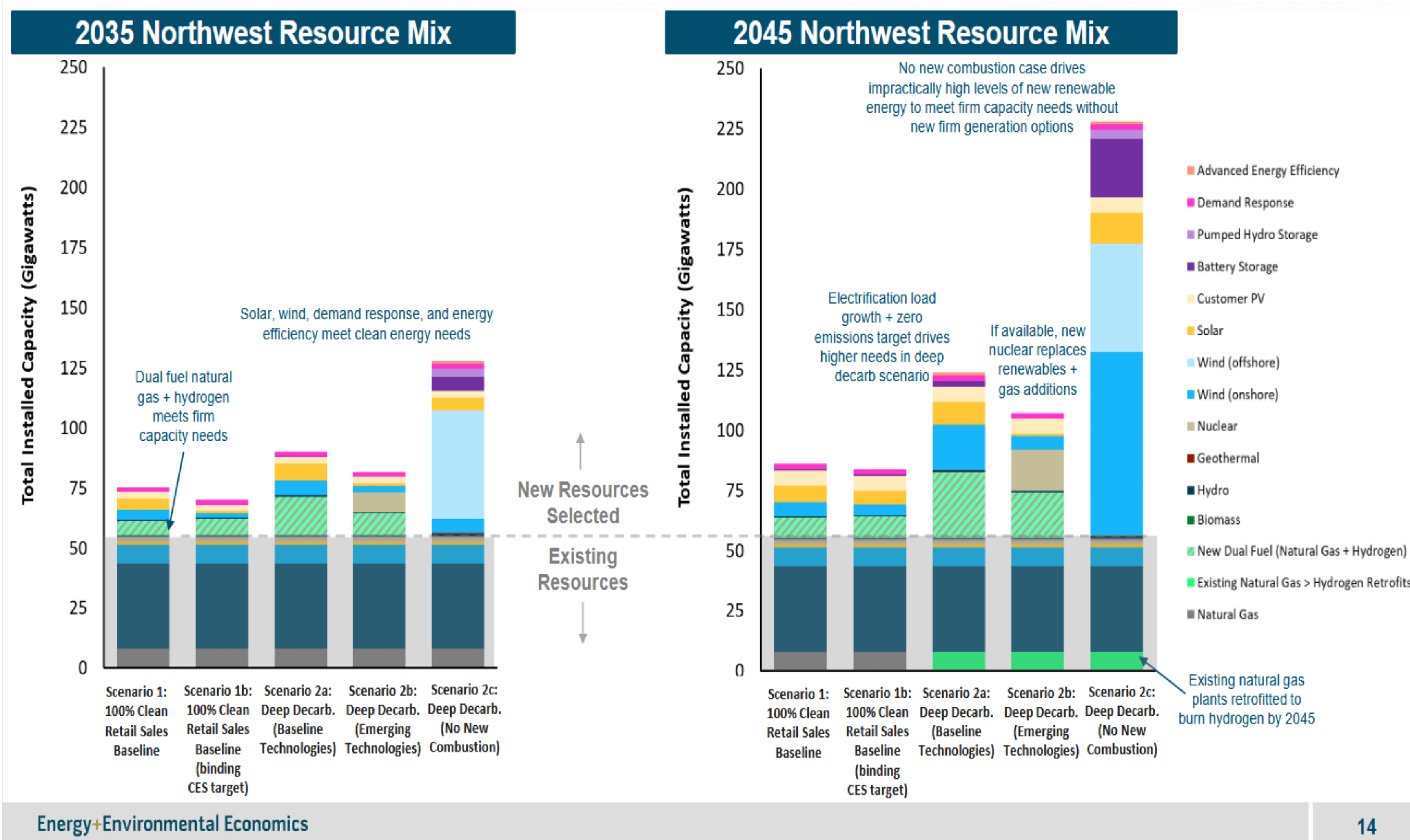
  - (Sustainable) Aviation Fuel – Universal Hydrogen, ZeroAvia, Airbus, Alaska Air/Twelve, American, many others
  - Marine (Maersk, etc)

Variable Renewables and Grid Storage needs

Electrical Grid benefits from electrolytic hydrogen production, and use of H2 for storage



Grid Reliability, Storage, Resource Adequacy, and Grid Integration



Legislative Definitions

Electrolytic: light green, dark green and everything in between; Carbon Intensity

Washington State Statute (2019):

"Renewable hydrogen" *means hydrogen produced using renewable resources both as the* ***source for the hydrogen*** *and the* ***source for the energy input*** *into the production process.*

"Renewable resource" *means: (i) Water; (ii) wind; (iii) solar energy; (iv) geothermal energy; (v) renewable natural gas; (vi) renewable hydrogen; (vii) wave, ocean, or tidal power; (viii) biodiesel fuel that is not derived from crops raised on land cleared from old growth or first growth forests; or (ix) biomass energy.*

California and Washington (2022) Statutes – equal treatment of electricity used to charge H2 and Lithium

"Green electrolytic hydrogen" *means hydrogen produced through electrolysis, and does not include hydrogen manufactured using steam reforming or any other conversion technology that produces hydrogen from a fossil fuel feedstock.*

Congress

Carbon Intensity – includes both fossil and non-fossil feedstock H2, derived from more complex and perhaps differing equations from state-to-state regulatory programs, and

IIJA – "Clean Hydrogen" 2kg CO_2/kg H_2 -currently 9-12 kgs CO_2/kg H_2 using SMR

IRA = "Clean Hydrogen" for PTC eligibility 3kg CO_2/kg H_2 "The Game Changer for Electrolytic Hydrogen"

Reasons for incorporating Hydrogen as a Transportation Fuel

- H2, produced upstream at the substation or generator, is a non-wires solution, avoiding potentially massive distribution system upgrades – transformers, wires, substations, and associated substation, line and transformer losses – required for full transition to lithium battery electric vehicles.

- EV batteries are not efficient for storing energy in the long term - To manufacture a battery takes around 200-400 charge cycles worth of energy. A 300 mile battery driven 200,000 miles uses up 700 cycles, so the efficiency cost to make the battery adds another ~40% to the total energy expenditure, which represents an efficiency loss of -30%.

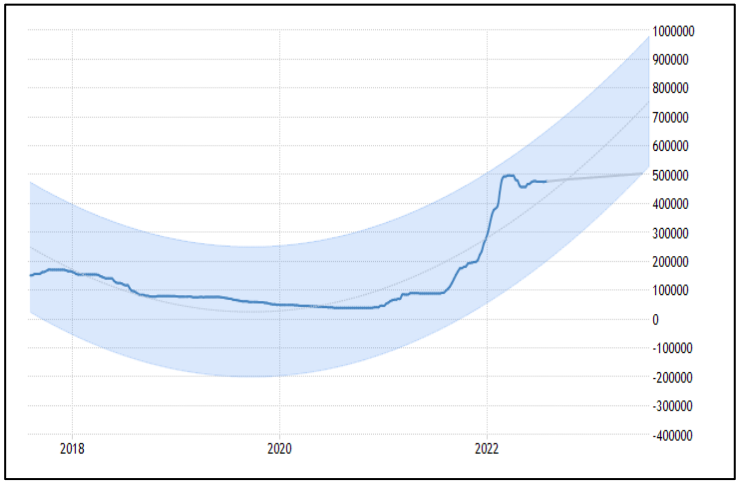
- We cannot expect lithium to supply all of our electric vehicle storage and utility scale storage that will be needed to bring all that renewable energy online. We will need a **very substantial** amount of new transmission **and energy storage** on the grid, short term medium and long term, bulk power and distributed storage, bulk power **and seasonal storage** to integrate the vast amount of renewable energy that will be required **– H2 is our only seasonal storage**

- We will need strategically located storage through out the distribution system to dispatch that electricity to the outlet when those multiple 50 kW batteries are plugged in to the garage outlet. H2 fueling stations will mitigate these upgrades and costs

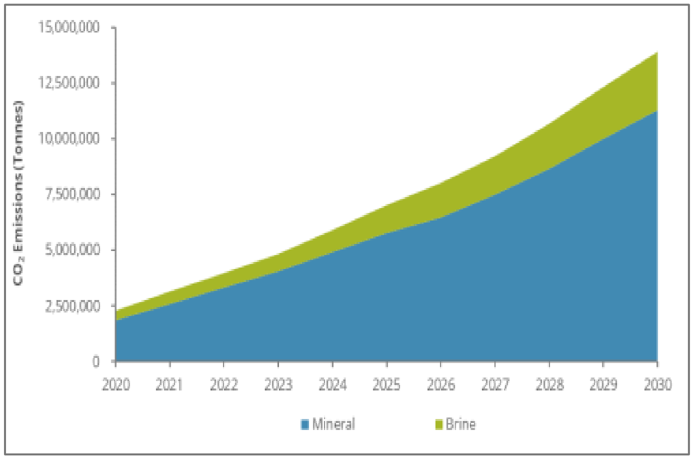
Transportation electrification requires hydrogen fuel cell electric options and battery electric options!

Its about market and technological neutrality (way too early to pick winners and losers!), total cost, mitigating supply chain risk, applicability, and availability . . .

Lithium Data
Costs, Life Cycle CO_2 Emissions, Supply Chain Considerations



Lithium Cost Curve 2018 - 2022



CO_2 emissions from the production of refined lithium.

Source: Roskill. https://www.greencarcongress.com/2020/10/20201006-roskill.html

Proposed Thacker Pass Lithium Mine

- Lithium's ore concentration at Thacker Pass runs as low as two-tenths of one percent; producing 60,000 tons of lithium could mean digging up as much as 20 to 30 million tons of earth.

- Removing the lithium from the ore is done with sulfuric acid. The mine plans to acidify molten sulfur on site, trucking it in from oil refineries. Hauling the material will require 75 tractor-trailer loads a day, according to Falk and Wilbert —running on fossil fuels

.

- The processing equipment plus mine tops out at more than a $1B.

- Turning over the US 275 M vehicles every 20 years will require 3-5 Thacker mines

Fuel Cell Components - Platinum Metals Group
Lithium/Cobalt Battery Components Supply Chain and Processing

Electrolyzers and Fuel Cells

The Platinum Metals Group includes:
Platinum – the catalyst and main critical material in Proton Exchange Membrane fuel cells and electrolyzers, the technology of choice for vehicles and many electrolyzers
Platinum Sources:

- South Africa - 68.3%
- Russia - 15.5%
- Zimbabwe - 6.8%
- Canada - 4.5%
- United States - 2.3%
- Other countries - 2.5%

And platinum has a mature recycling process

Lithium and Cobalt Battery

- China controls 60% of the worlds lithium processing capacity
- 74% of Mined cobalt comes from the DRC
- China Controls 60% of global cobalt reserves and 80% of the world's cobalt refining capacity.
- One Chinese company, CATL, controls 1/3 of the entire global battery market

Electrified Transportation Sector's Intersection with the Utility System
Hydrogen and Lithium are both Crucial to reliable, Cost Effective Electrification

- How to provide increasing amounts of wind and solar generation to the outlet **when vehicles are plugged in.**

- Utilities have to meet **peak needs** with power quality and reliability

- Load growth (new energy generation requirements only) for full BEV expected around 25-30% over several decades (resource adequacy). **Potential of a distribution system expansion to meet 4x the current peak loading**

- **5MW** electrolyzer running 24 hrs/day produces 2,000 kg of H2 per day, fueling 400 FCEVs per day at the "corner gas station". Mirai, Ford Lightning 50kW lithium battery. Assume all plug in simultaneously (utility meeting reliability and power quality requirements) 40kW x 400 BEVs = **16 MW peak loading – bigger faucets, pipes, pumps and reservoirs**

- **Faster chargers** will require from downstream to upstream, bigger and/or more transformers, panels and outlets (faucets), bigger pipes (distribution and transmission wires), larger storage facilities (reservoirs), and greater capacity infrastructure upstream all the way to the generation (pumps and water sources).

- States with electricity on a decarbonization pathway (NM, WA, CA, OR . . .) are seeing an increasing amount of variable wind and solar. Substantial amounts of energy storage, throughout the system: at the generator; in the transmission system; at the distribution feeder; the transformer level and even at the electrical panel level. Electricity is required to be delivered on demand (timing of delivery and reliability) to serve conventional load growth, charge vehicles, electrify buildings, and other demands placed upon the system as the transition to clean energy progresses.

- System upgrades to the distribution system will be spread among all ratepayers, higher income ratepayers benefit from increased charging capacity, low and moderate income ratepayers will be the last to benefit, if at all

Electrified Transportation Sector's Intersection with the Utility System

Hydrogen and Lithium are Both Crucial to Reliable, Available, Cost Effective Transportation Electrification

- If there are problems in electrifying the transportation system, ***"the distribution system will be the canary in the coal mine,"*** Ryan Stanton' TVA Senior Project Manager for EV Evolution

- **"There is a significant gap, a big void, between electric utilities and their knowledge of the electric system, and the transportation industry and their needs from that system"**

From The California Fuel Cell Partnership

- Supporting hydrogen mobility across all vehicle applications allows the state to bet on two technologies with minimal cost impact. In doing so, the region can significantly increase the chances of achieving carbon neutrality if limits or constraints on one technology come to fruition (e.g. raw materials, infrastructure, consumer adoption, public safety power shutoffs or blackouts, or cost).

- Given the advantages fuel cell vehicles offer for those living in multi-family dwellings, those who require fast-refueling and larger vehicles, the market will be much greater than modeled in the proposed plan. The Mobile Source Strategy forecast of fuel cells being upwards of 20% of the passenger vehicle market is a more likely scenario. When considering super-commuters, construction and agricultural workforce, and the growing role of transportation networking companies, demand for fuel cell vehicles will increase rapidly once sufficient infrastructure exists to allow statewide refueling. Data collected by the California Energy Commission supports this claim as, on average, FCEVs are driven between 10,000-14,000 miles per year while plug-in battery electric vehicles are driven between 6,000-9,000 miles per year.

Washington State Legislative Policy Adoptions
to Facilitate the Production, Distribution and End Uses of Non-fossil Hydrogen
2019 – 2022

2019

SB 5588 – Provided PUDs the authority to produce, distribute "renewable hydrogen", including owning and/or operating hydrogen refueling stations First state statutory definition of renewable hydrogen in the country

HB 2042 – Green Transportation Act – H2 added in Finance Committee Amendments

- Added fuel cell electric vehicles to the definitions of electric vehicles ("battery and fuel cell electric vehicles")
- Added hydrogen fueling stations (Hydrogen Refueling Infrastructure is becoming the term used – HRI) and renewable hydrogen production facilities to the definition of "electric vehicle infrastructure" and "alternative fuel vehicle infrastructure"
- Added HRI to the Zero Emission Vehicle Public Private Partnership Grant Program
- 50% Business and occupation tax credit for incremental costs above ICE vehicles and purchase, installation, and construction of alternative fuel vehicle infrastructure
- Sales tax credits for new and used alt fuel vehicles with value caps, batteries and fuel cells for electric vehicles, labor and services installing vehicle batteries and fuel cells and charging/fueling infrastructure
- Added "other than water vapor" to to the end of the definition of "zero emission vehicles"
- Leasehold excise tax exemption and other tax credits and grant programs for renewable hydrogen production and fueling equivalent to battery electric vehicle charging programs
- Established grant programs to facilitate and required additional studies to analyze opportunities to expand battery and hydrogen electric vehicle fueling infrastructure and vehicle purchase

SB – SB 5116 – Clean Energy Transition Act

  - Adds renewable hydrogen as a renewable resource, allows production of renewable hydrogen as an option for GHG mitigation – 2030-2045

Washington State Legislative Policy Adoptions
to Facilitate the Production, Distribution and End Uses of Non-fossil Hydrogen
2019 – 2022

2021

SB 5000 Addressing (only) fuel cell electric vehicles, limited to the first 650 FCEVs sold

- 50% sales and use tax credits, and 100% credits for used applied to the sale or lease of new used vehicles of "passenger, light duty trucks, medium duty vehicles powered by a fuel cell" – capped based on FMV or amount of credit

HB 1091 - Clean Fuels Program (Low carbon fuel standard)

- Added the concept of "gaseous fuels and their derivatives" to legislatively capture the various hydrogen carriers, such as ammonia, formic acid and methanol

- **Capital Budget**
  - Funded $2.55M for the first H2 fueling station "using renewable hydrogen or hydrogen produced electrolytically in WA" to a Twin Transit, a small transit agency, for sale to the public and for their own refueling (now has 3 FCEV buses on order) strategically located on I-5 halfway between Portland and Seattle
  - $3.05M to the small rural hospital in Goldendale for a 100 kW fuel cell as part of a microgrid pilot project and hospital backup generation replacement facility

- **Transportation Budget**
  - $1.5M (to be matched) for a collocated H2 fueling station and DC fast charging (Douglas PUD and East Wenatchee, WA)
  - Added $2M to the ZEVIP Program

Washington State Legislative Policy Adoptions
to Facilitate the Production, Distribution and End Uses of Non-fossil Hydrogen
2019 – 2022

2022

SB 5910 – Accelerating the availability and use of renewable hydrogen in Washington state

- Added the definition of "green electrolytic hydrogen" to the variety of tax credits and exemptions provided to "renewable hydrogen" in 2019's HB 2042; PUD authority to produce and distribute; provided municipal utility authority to produce and distribute renewable and green electrolytic hydrogen;

- Established the "Office of Renewable Fuels" in the state Department of Commerce to, among other duties: *"Support research into and development and deployment of renewable fuel and the production, distribution, and use of renewable and green electrolytic hydrogen and their derivatives, as well as product engineering and manufacturing relating to the production and use of such hydrogen and its derivatives"*

- Added a provision where a natural gas utility can file a notice with the Utilities and Transportation Commission (UTC) to replace natural gas with renewable or green electrolytic hydrogen, and include impacts to grid reliability, resource adequacy, and safety standards for blending into the natural gas distribution infrastructure

- Describes and defines the state's role in supporting a public-private regional Hydrogen Hub application. Op bud funds at $2M

HB 1812 –

- Streamlined the siting and permitting process for the entire value and supply chain for in-state manufacturing, storage, distribution, and dispensing of RH, GEH, and "green hydrogen carriers" (newly defined in this statute), and their components.

HB 1988 –

- Revised and extended, as remittances, sales and use and other tax credits for RH and GEH originally adopted in HB 2042, the state portion only, and adding tiers for labor and other standards

Questions and Discussion?

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Acronyms

- BEV – Battery Electric Vehicle
- CI – Carbon Intensity
- CO2 – Carbon Dioxide
- EIM – Energy Imbalance Market
- EV – Electric Vehicle
- FCEV – Fuel Cell Electric Vehicle
- GEH – Green electrolytic Hydrogen
- HDV – Heavy Duty Vehicle
- LDV – Light Duty Vehicle
- MDV – Medium Duty Vehicle
- RH – Renewable Hydrogen
- SAF – Sustainable Aviation Fuel
- SMR – Steam Methane Reformation
- VER – Variable Energy Resources (Wind and Solar)
- ZEV – Zero Emission Vehicle