Hydrogen Fuel Cell Experimental Aircraft Currently Flying In California

Hydrogen Fuel Cell In Aviation

ZeroAvia developed a hydrogen fuel cells airplane

Expanding the use of clean hydrogen in other sectors – trucks, steel and heating buildings – is another important challenge. In Fact, The aviation industry is taking the challenge to design an airplane to carry from 20 to 30 passengers.

Commercial Aviation Is Preparing to Scale Up Hydrogen As An Alternative Fuel.

September 21, 2020

AirbusZEROe Blended Wing Body Concept

AirbusZEROe Turbofan Concept

AirbusZEROe Turboprop Concept

https://www.airbus.com/newsroom/press-releases/en/2020/09/airbus-reveals-new-zeroemission-concept-aircraft.html

Fuel Cell Maritime Transportation

In 2016, IMO adopted mandatory requirements for ships of 5,000 gross tonnage and above will have to collect consumption data for each type of fuel oil they use, as well as other, additional, specified data including proxies for transport work.

These ships account for approximately 85% of CO_2 emissions from international shipping.

Japanese tug operator Tokyo Kisen

Hydrogen-powered tug planned for Japanese ports

Source: International maritime Organization

Kawasaki Pilot liquefied hydrogen carrier

From LNG to LH2

Nearly 40 years have passed since Japan's first LNG carrier was built. Kawasaki has been making steady progress in building a world's first liquefied hydrogen(LH_2) carrier.
The pressurized cryogenic cargo containment system specifically for LH_2 was developed successfully based on Kawasaki's existing technologies of LNG carrier building and of LH_2 land transportation and storage.
Currently, the LH_2 carrier is designed and under construction based on the safety requirements approved by the IMO* as interim recommendations. LH_2 needs to be maintained at a temperature 91° C below that of LNG and easily evaporates.
Kawasaki will continue making further progress toward mass marine transportation of LH_2.

*IMO: International Maritime Organization

Ballard Receives PO From Anglo American for 900kW of Fuel Cell Modules to Support Mining Truck Demonstration Project

The Mining Company is retrofitted evaluating an Ultra-Class Heavy Duty truck, with a 800KW Fuel Cell.

A car uses between 50KW to 125 KW Fuel Cell.

An Ultra-class heavy duty mining truck will be retrofitted with 800kW of Ballard fuel cell modules for a planned demonstration project in 2020

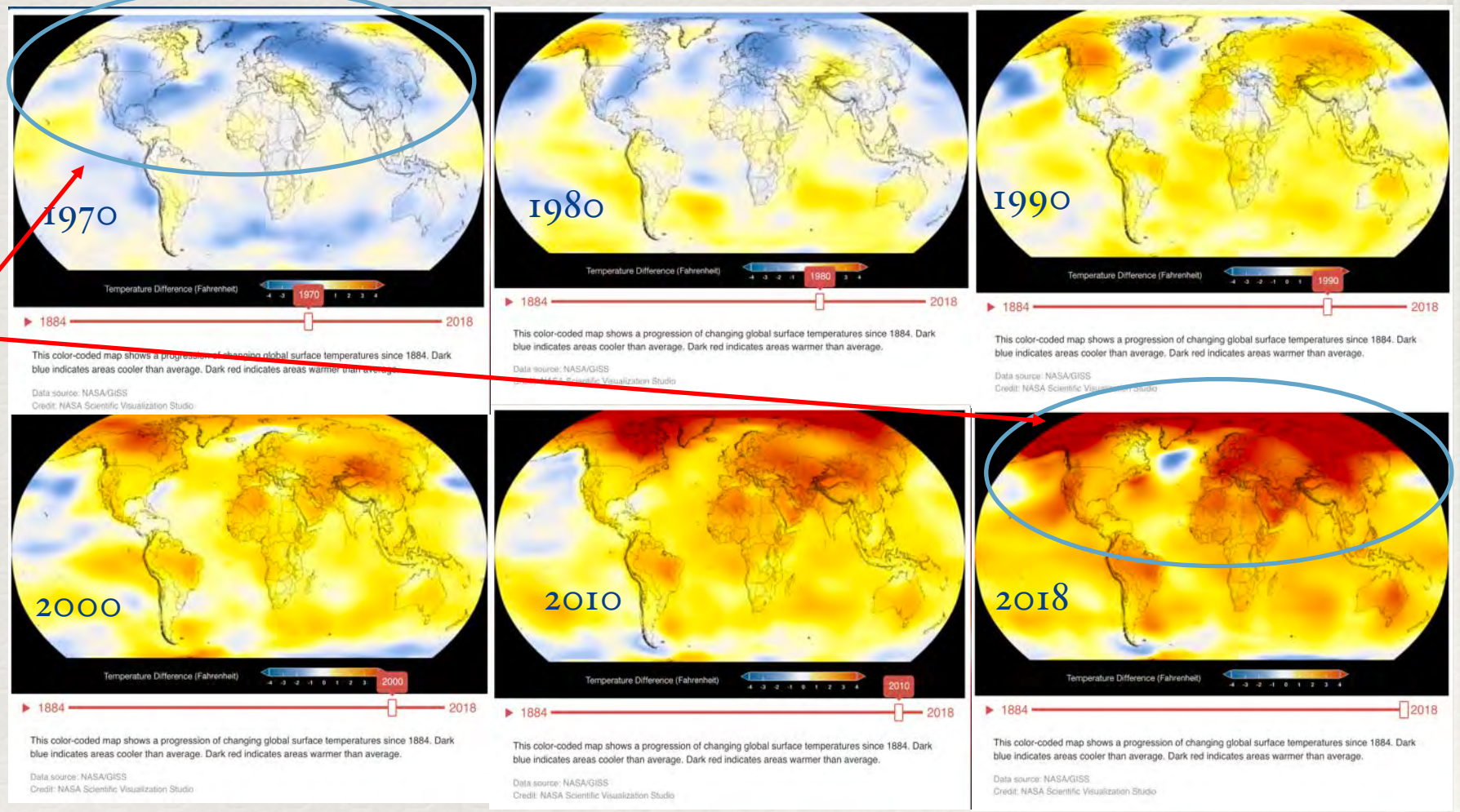
SOURCE: www.ballard.com.

"Hydrogen is today enjoying unprecedented momentum. The world should not miss this unique chance to make hydrogen an important part of our clean and secure energy future ."
Fatih Birol, Executive Director, IEA

Why Do We Need To Act Now?

Temperature data from the last 48 years. Source: Nasa Climate Change

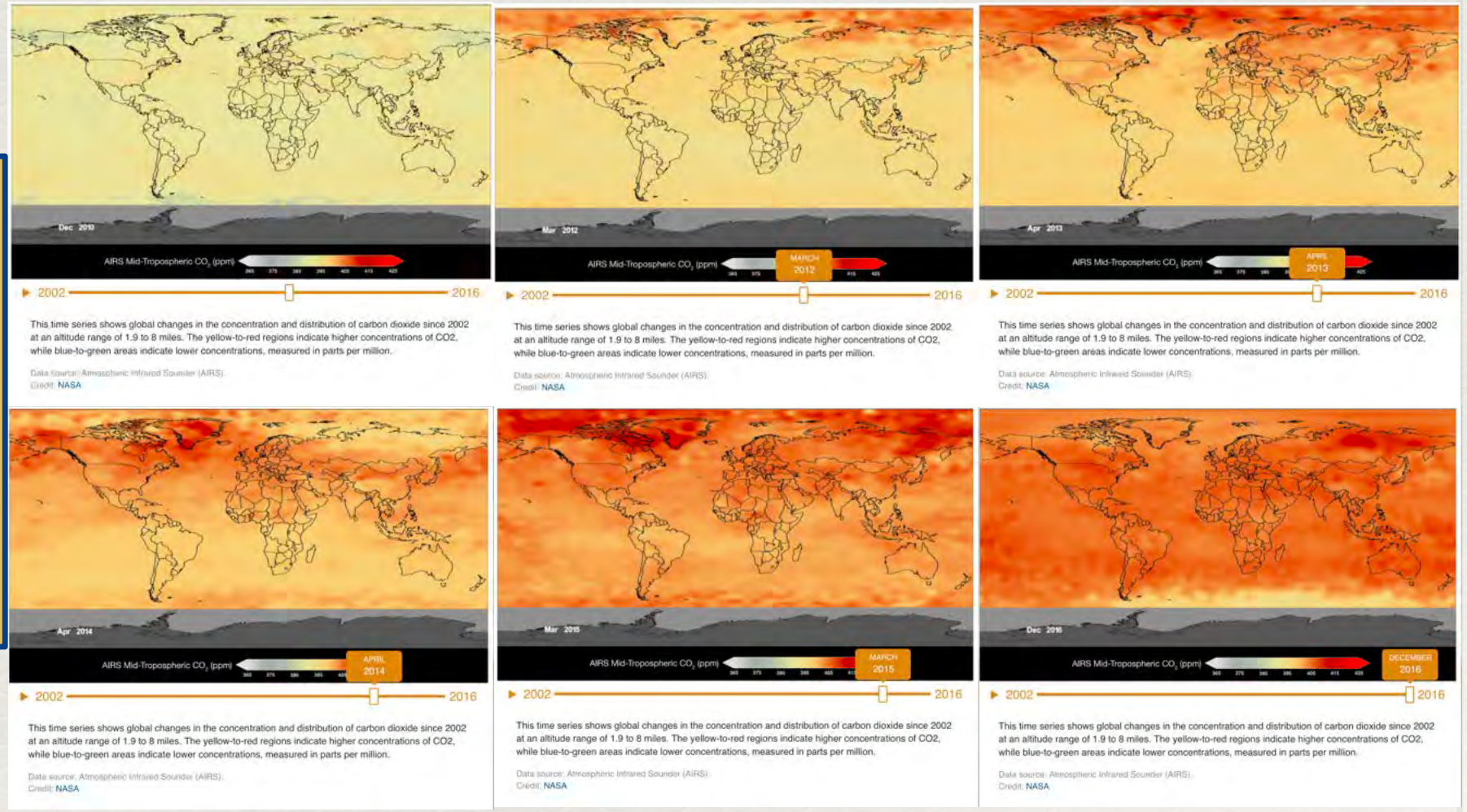
Huge Change in temperature from 1970 to 2018.
The transportation industry is one of the major contributors; however, electricity from coal is a larger factor.



Carbon dioxide since 2002 at an altitude range of 1.9 to 8 miles by NASA.

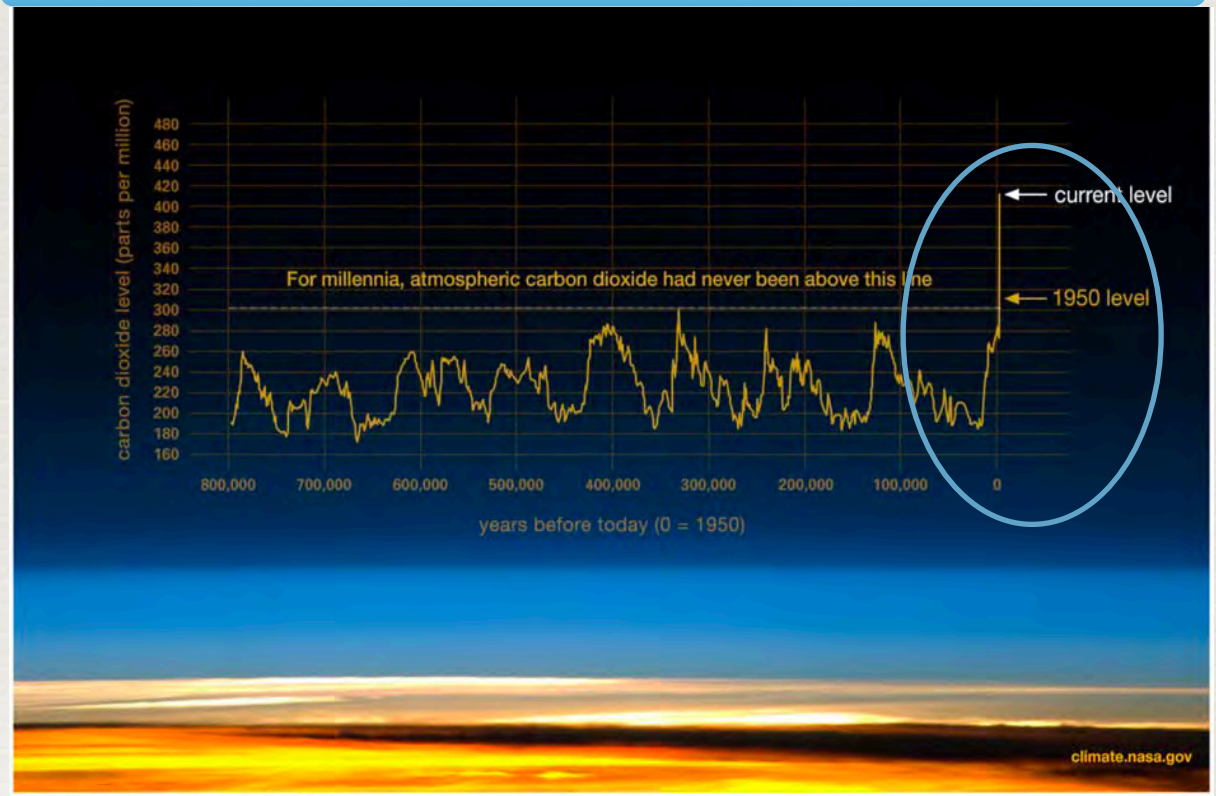
The yellow-to-red regions indicate higher concentrations of CO_2,

In Less than 10 years CO_2 has increased to highest levels. From 2002 to 2016 this data from "NASA Climate Change" shows an alarming increase in CO_2 Emission in the world.
There is not Planet B!



Paris, December 12, 2015: 195 countries signed a legally binding agreement to keep global warming well below 2°C – an ambitious goal that will require the economies around the globe to decarbonize large parts of the world's energy system.

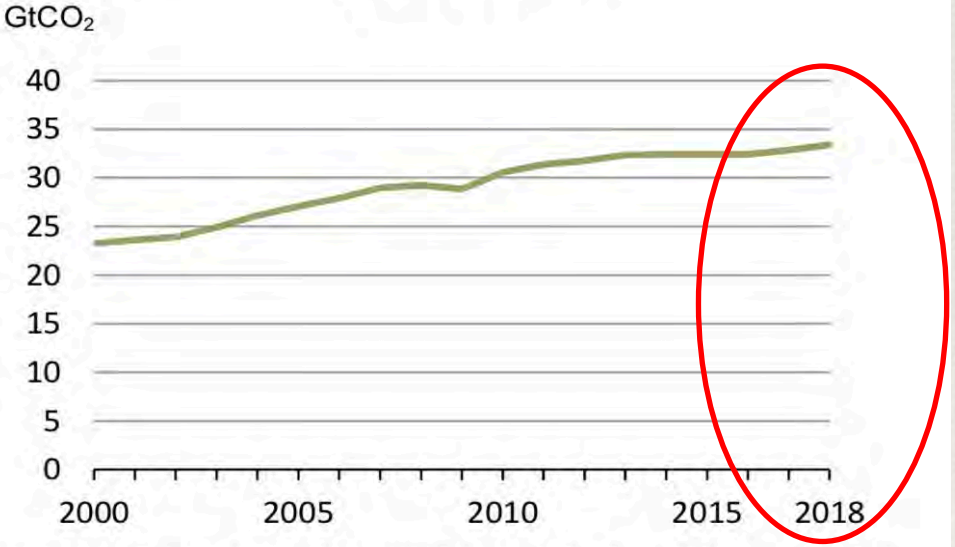
Highest levels of CO_2 Emissions. Data taken from Ice Tubes



This graph, based on the comparison of atmospheric samples contained in ice cores and more recent direct measurements, provides evidence that atmospheric CO_2 has increased since the Industrial Revolution. (Credit: Luthi, D., et al.. 2008; Etheridge, D.M., et al. 2010; Vostok ice core data/J.R. Petit et al.; NOAA Mauna Loa CO_2 record.) Find out more about ice cores (external site).

Transportation CO_2 emissions 32GTCO2

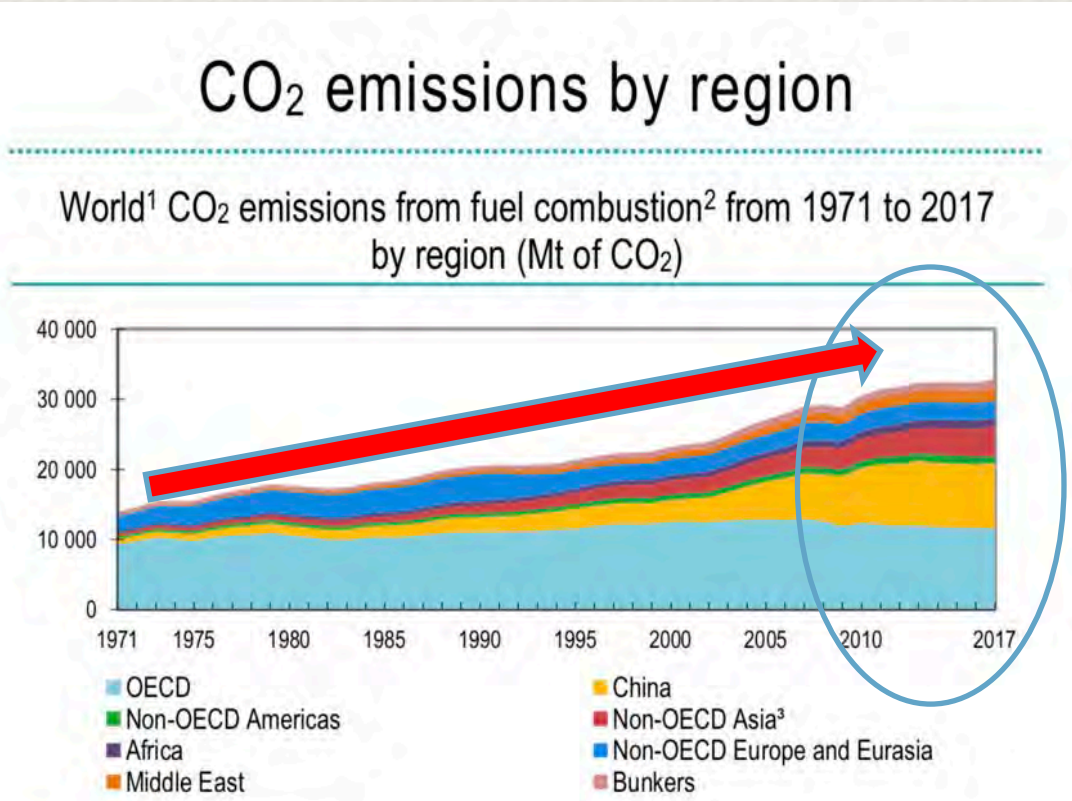
Figure 1. CO_2 emissions from fuel combustion: global trend

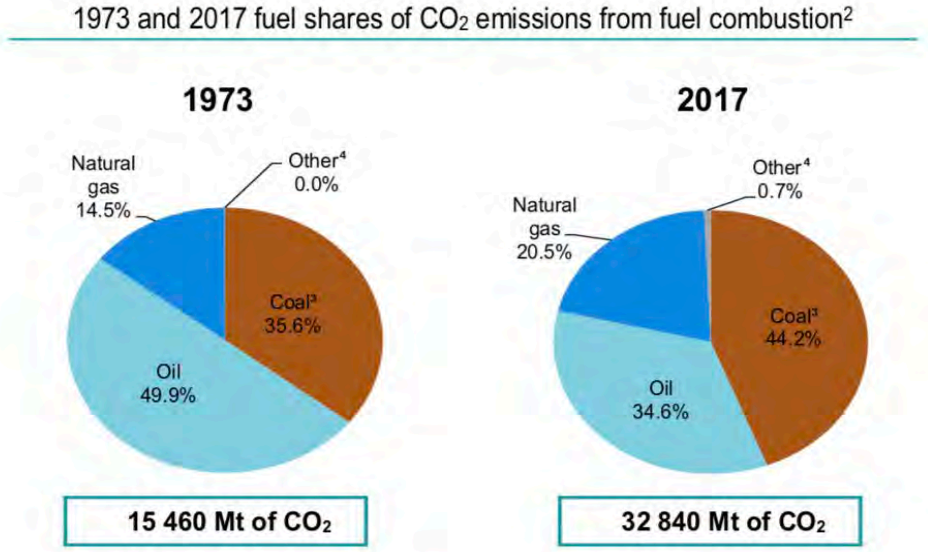


Source: values up to 2017 for World and 2018 for OECD are based on IEA (2019) *CO_2 emissions from fuel combustion*. The 2018 value for World is based on IEA (March 2019) *Global Energy & CO_2 Status Report* (https://www.iea.org/geco/).

Data from IEA (International Energy Agency) of the OECD.

(Organisation for Economic Co-operation and Development Countries, Members and Non-Members)



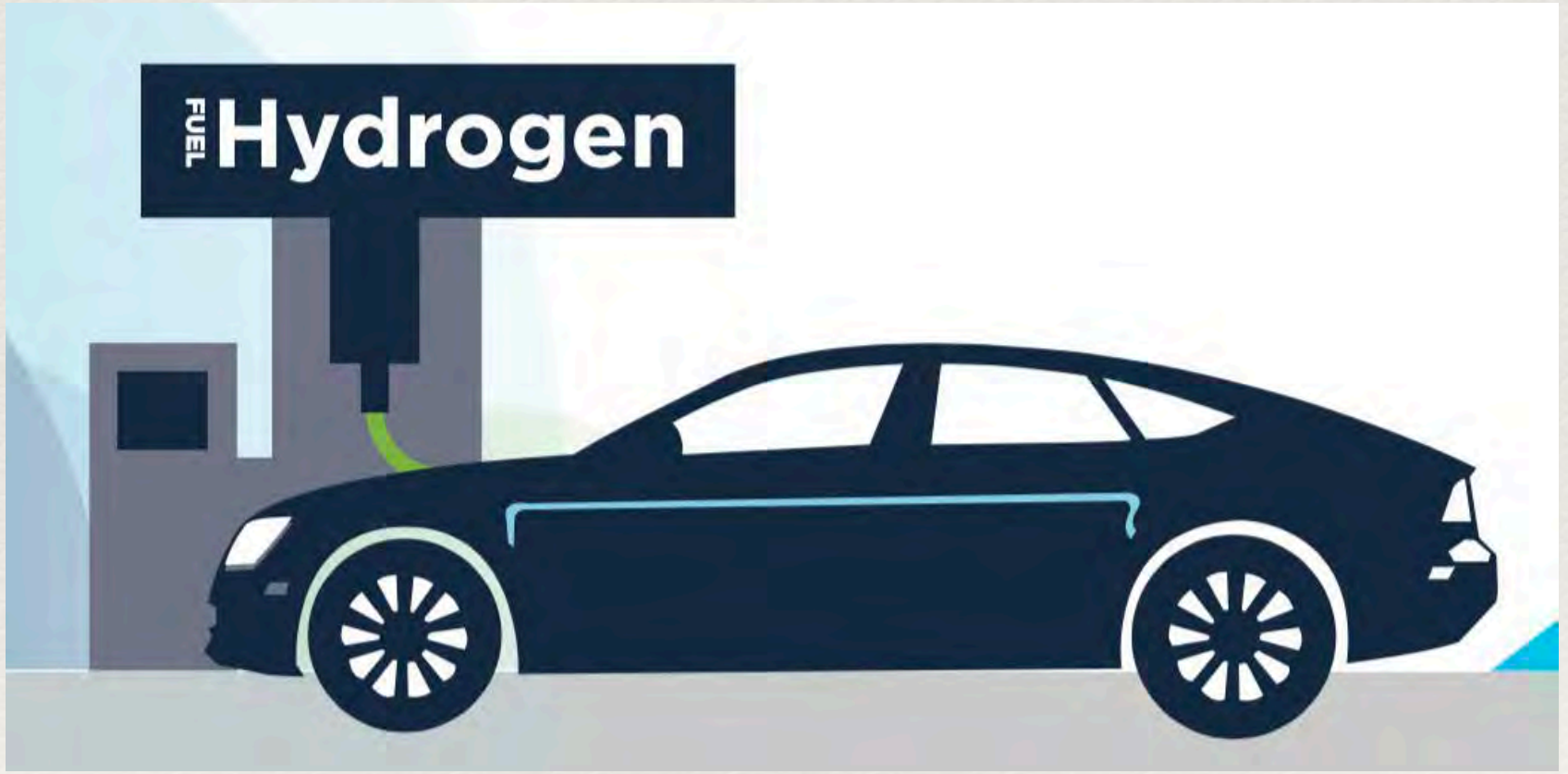


1. World includes international aviation and international marine bunkers.
2. CO_2 emissions from fuel combustion are based on the IEA World Energy Balances and on the 2006 IPCC Guidelines, and exclude emissions from non-energy.
3. In these graphs, peat and oil shale are aggregated with coal.
4. Includes industrial waste and non-renewable municipal waste.

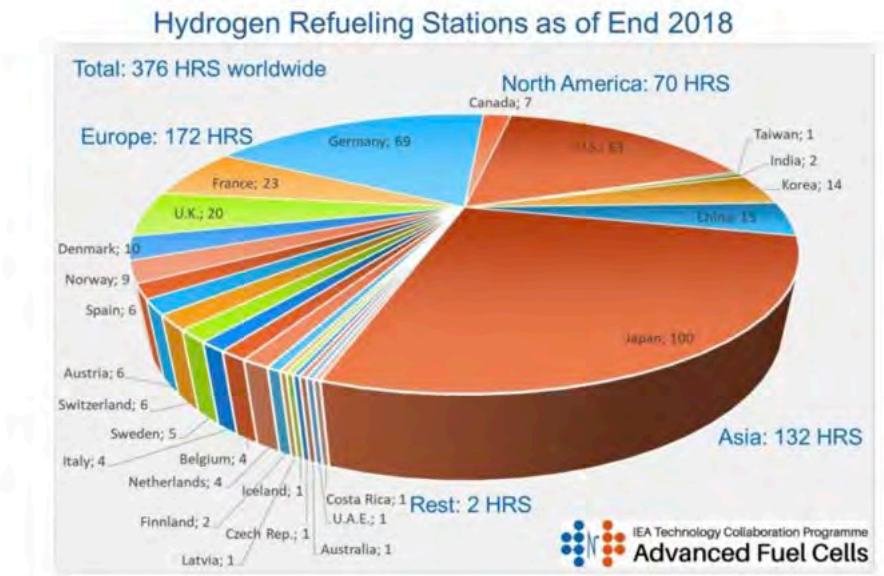
Source: IEA, CO_2 Emissions from Fuel Combustion, 2019.

54

WHAT ARE THE CHALLENGES AND OPPORTUNITIES?



HYDROGEN INFRASTRUCTURE



VERY ALARMING THE H_2 DEVELOPMENT IN SOUTH AMERICA USING RENEWABLE ELECTRICITY TO PRODUCE HYDROGEN

Worldwide HRS (Hydrogen Refueling Stations): **376 and increasing!**

Asia HRS: **132**

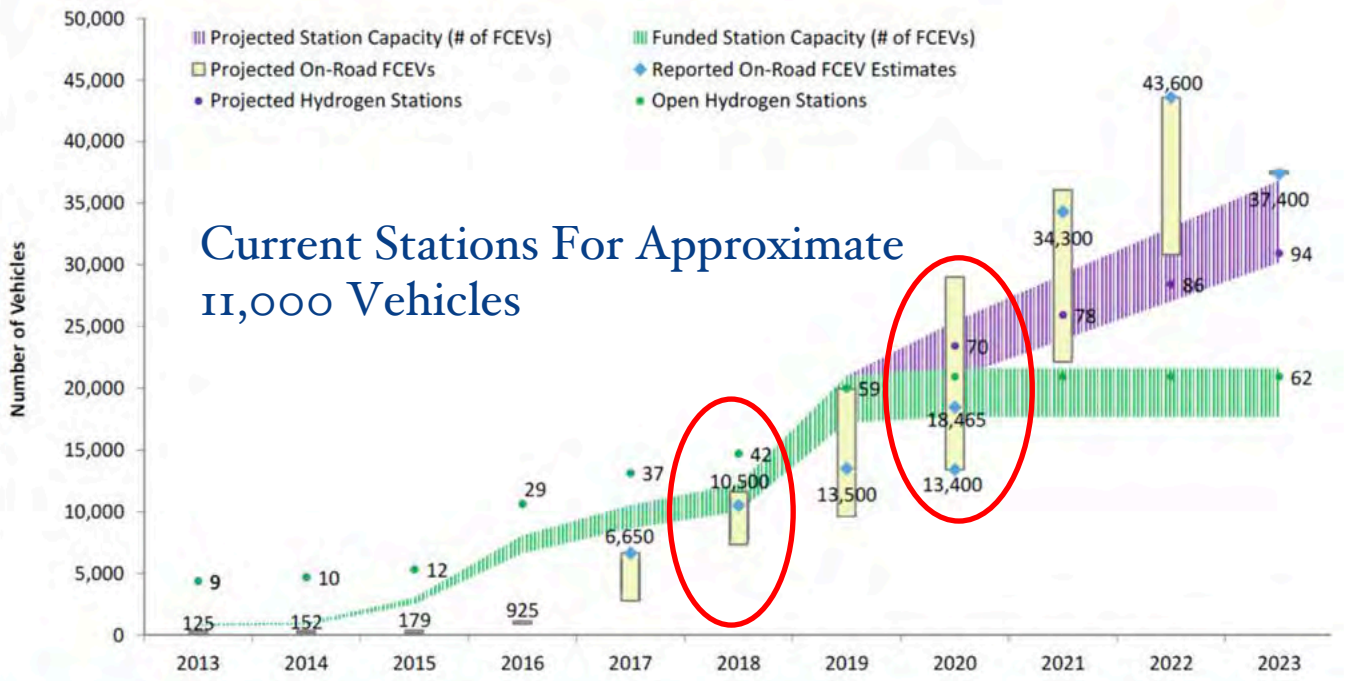
Europe HRS: **172**

North America HRS: 70

South/Latin America HRS Using Electricity from Solar and Wind: 1 (Costa Rica).

INFRASTRUCTURE MUST BE FIRST AND VEHICLES OEM WILL FOLLOW.

Hydrogen Refueling Infrastructure

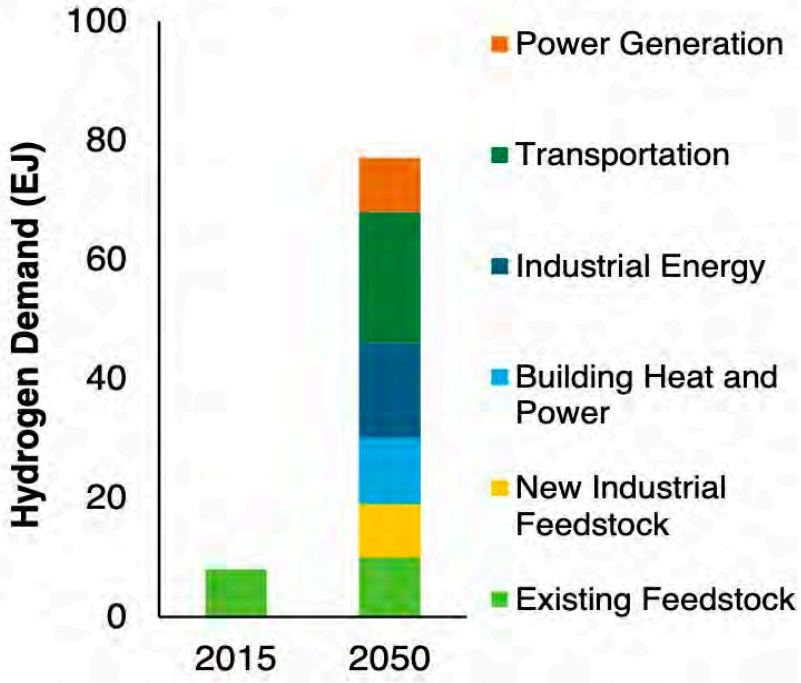


Current Stations For Approximate 11,000 Vehicles

Source: California Air Resources Board.

CALIFORNIA ENERGY COMMISSION 16

Hydrogen Demand EJ (ExaJoules)



2. Source: "Hydrogen Scaling Up." Hydrogen Council. November 2017. http://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf

California Estimated job creation from Hydrogen introduction

Challenge: Infrastructure Initial Investment

Opportunities: Hydrogen Create jobs as the technology is evolving

Figure 16. Job Creation Estimation from California Hydrogen Station Investment

	(100 Stations)	(200 Stations)
CA H2 Station Investment	$200,000,000	$400,000,000
Job Years ($92,000)	2,174	4,348
Direct and Indirect Jobs (64% of a job year)	1,391	2,782
Induced Jobs (36% of a job year)	783	1,566
Total Jobs from Station Investment	2,174	4,348

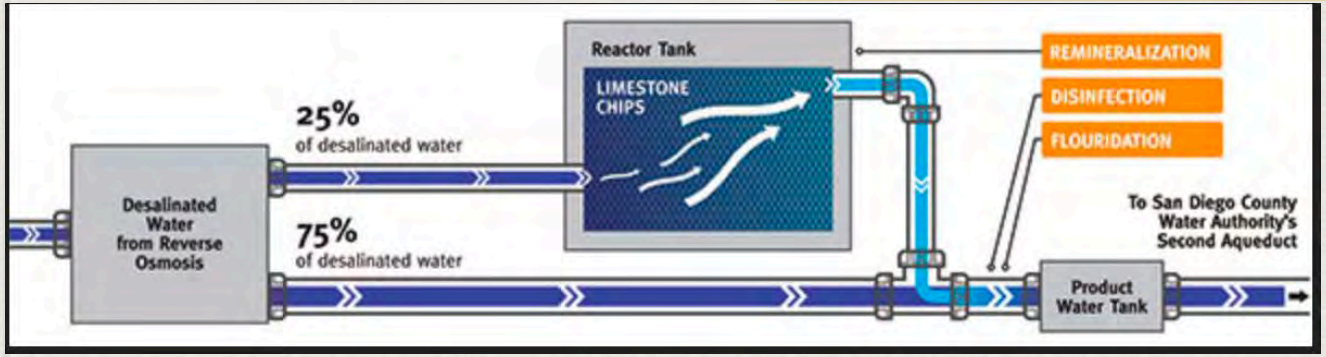
Source: *Calculated by EIN Using ARRA Methodology*

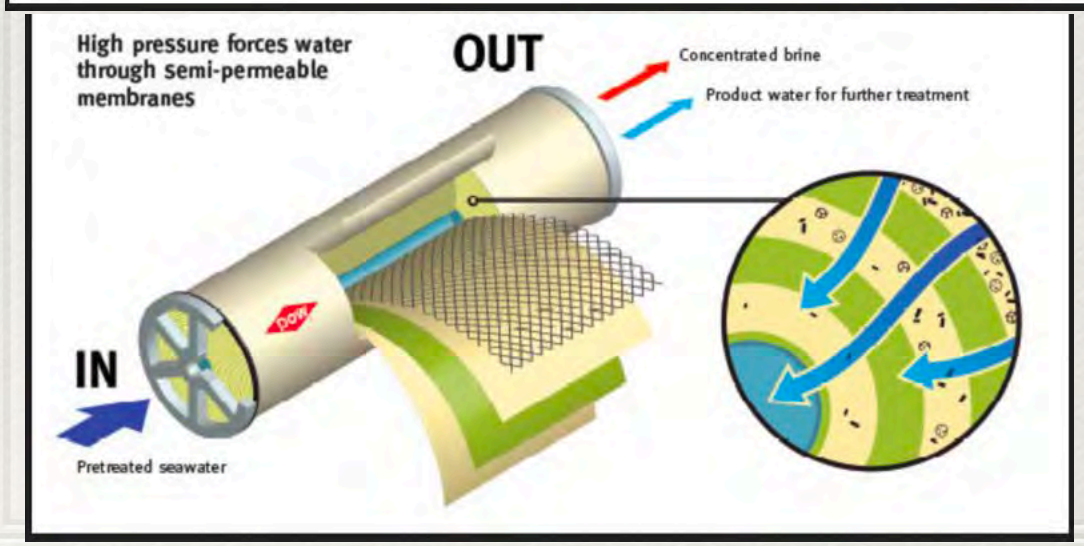
Source: CaFCP (California Fuel Cell Partnership)

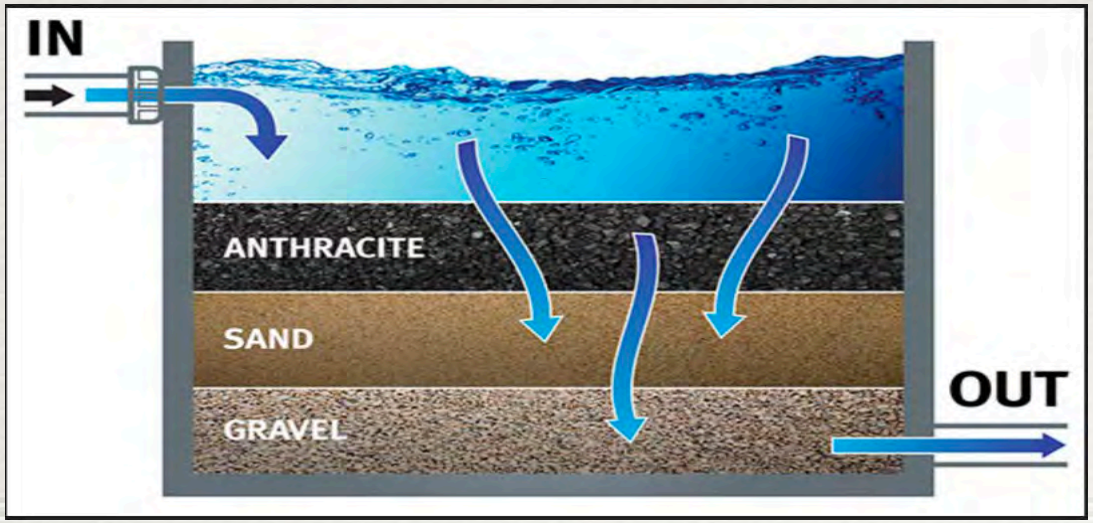
Use desalination plants to use water to produce hydrogen.

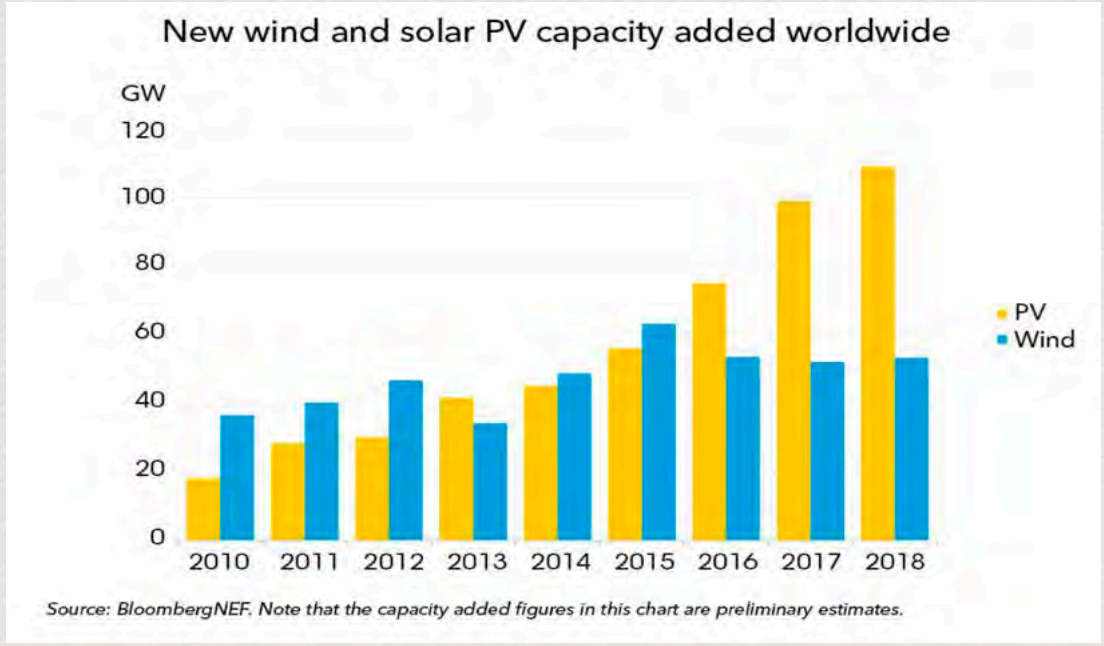
Use Renewable Electricity to run the desalination plant.

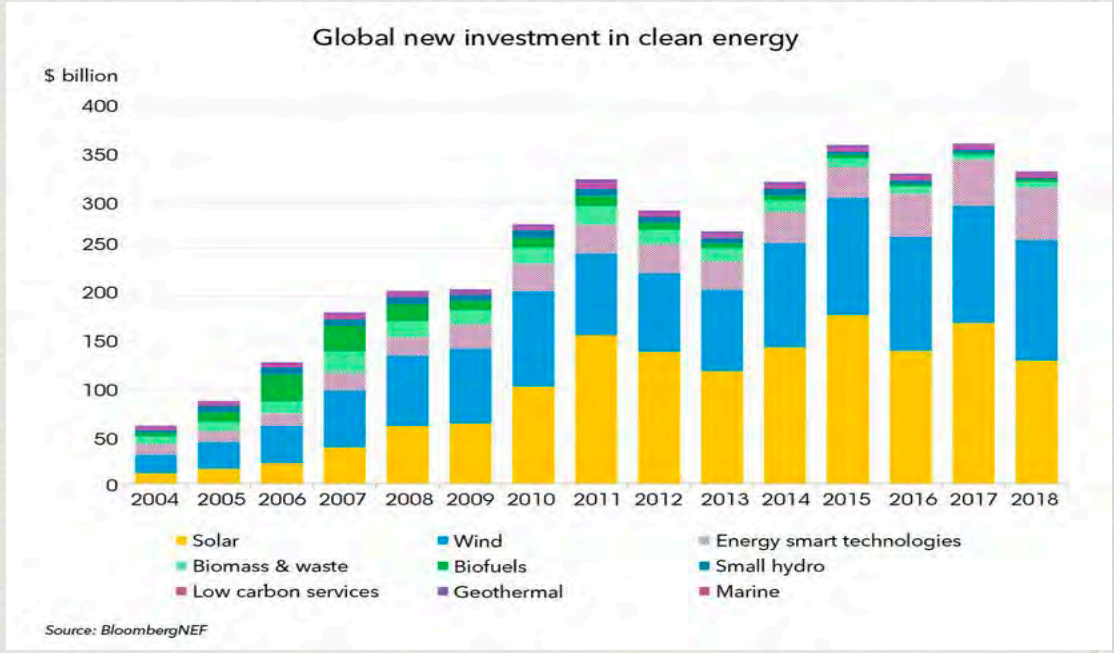
Carslbad Desalination Plant, California








New wind and solar PV capacity added worldwide
GW
120
100
80
60
40
20
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
PV
Wind
Source: BloombergNEF. Note that the capacity added figures in this chart are preliminary estimates.

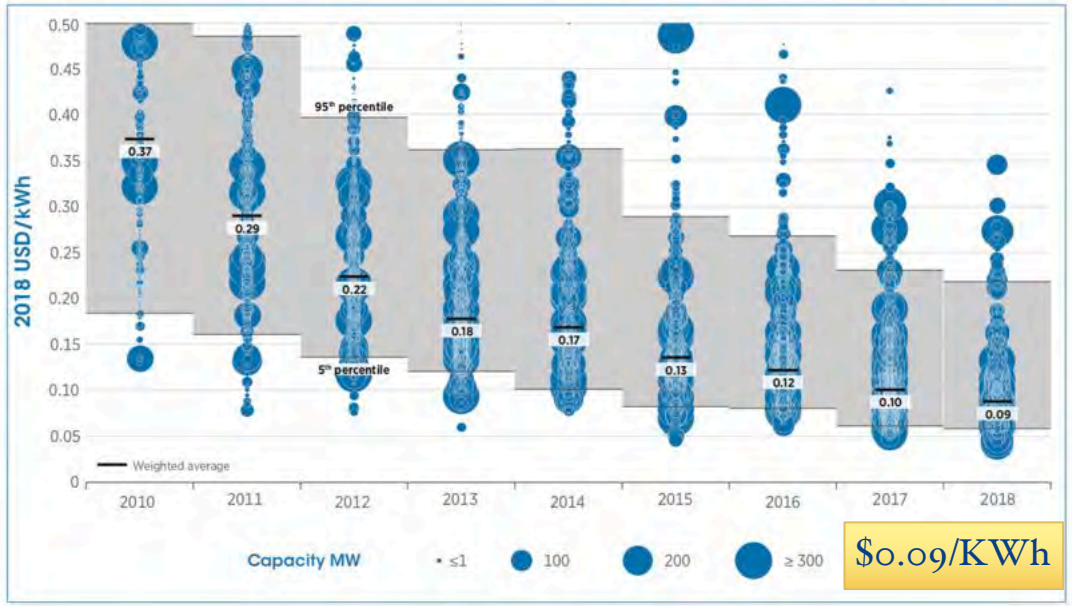

Global new investment in clean energy
$ billion
400
350
300
250
200
150
100
50
0
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Solar
Wind
Energy smart technologies
Biomass & waste
Biofuels
Small hydro
Low carbon services
Geothermal
Marine
Source: BloombergNEF

Cost of Electricity.

Challenge. The fluctuating Long-term cost of Electricity makes it challenging to model the lifetime cost of operating the electrolizer.

Opportunity. The lower cost of Wind and Solar electricity will help reduce the operating cost of the Electrolizer; as a result, lowering the cost of KG/H2 to the goal of $2.00 Kg/H2 from the current of approximate $12.00Kg/H2.

Figure 2.6 LCOE from utility-scale solar PV projects, global weighted average and range, 2010–2018



$0.09/KWh

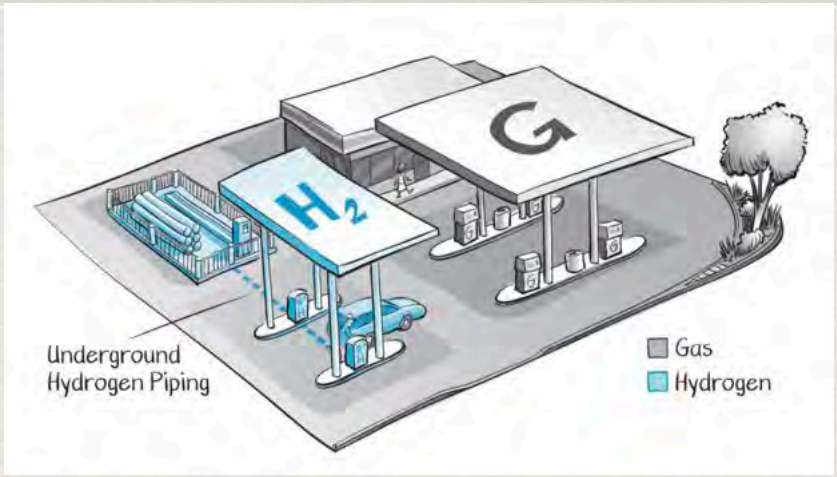
The global weighted-average LCOE of utility-scale solar PV declined by 77% between 2010 and 2018, from USD 0.371 to USD 0.085/kWh. Globally, although the range has narrowed, the 5th and 95th percentile for projects in 2018 ranged from USD 0.058 to USD 0.219/kWh.

Figure S.6 Global weighted average total installed costs, capacity factors and LCOE for offshore wind, 2010–2018

$0.13/KWh

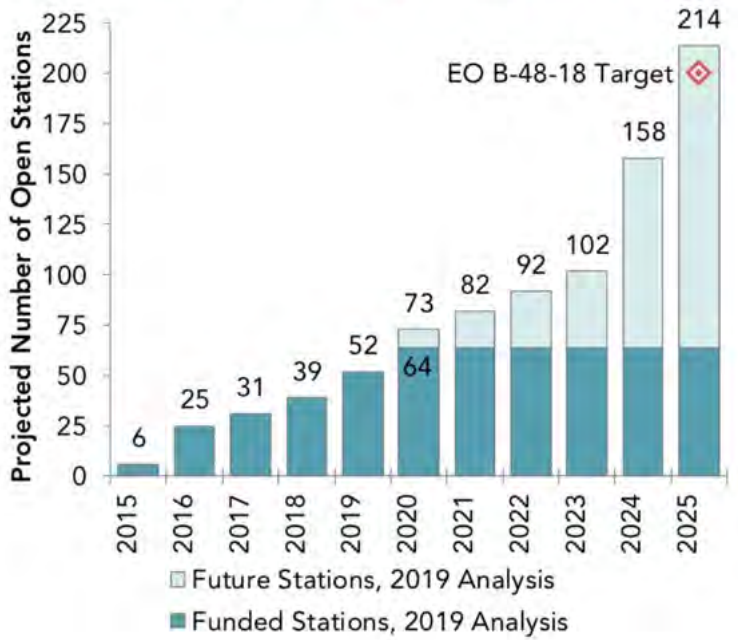
Source: IRENA Renewable Generation Power Cost 2018 report

FOCUS on infrastructure first



California goal is to have 214 working Stations by 2025

FIGURE ES6: PROJECTED STATION DEPLOYMENT TO MEET AB 8 AND EO B-48-18 GOALS



—CaFCP Goal—

Enable market conditions to support:

1,000 hydrogen stations

and

1,000,000 fuel cell vehicles

by **2030**