ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

Have Questions?

Type them into questions box!

"Why am I muted?"
Don't worry. Everyone is muted except the presenter and host. Thank you and enjoy the show.

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

@AmerChemSociety

@AmericanChemicalSociety

@AmerChemSociety

LinkedIn https://www.linkedin.com/company/american-chemical-society

Check out the ACS Webinar Library!
An ACS member exclusive benefit

Hundreds of presentations from the best and brightest minds that chemistry has to offer are available to you on-demand. The Library is divided into 6 different sections to help you more easily find what you are searching.

Professional Development
▶ View the Collection

Learn how to write better abstracts, deliver more engaging presentations, and network to your next dream job. Brush up on your soft skills and set a new career path by mastering what can not be taught in the lab.

Technology & Innovation
▶ View the Collection

From renewable fuels to creating the materials for the technology of tomorrow, chemistry plays a pivotal role in advancing our world. Meet the chemists that are building a better world and see how their science is making it happen.

Drug Design and Delivery
▶ View the Collection

The Drug Design Delivery Series has built a collection of the top minds in the field to explain the mechanics of drug discovery. Discover the latest research, receive an overview on different fields of study, and gain insight on how to possibily overcome your own med chem roadblocks.

Culinary Chemistry
▶ View the Collection

Why does food taste better when it is grilled or what molecular compounds make a great wine? Discover the delectable science of your favorite food and drink and don't forget to come back for a second helping.

Popular Chemistry
▶ View the Collection

Feeling burdened by all that molecular weight? Listen to experts expound on the amazing side of current hot science topics. Discover the chemistry of rockets, how viruses have affected human history, or the molecular breakdown of a hangover.

Business & Entrepreneurship
▶ View the Collection

How do ideas make it from the lab to the real world? Discover the ins and outs of the chemical industry whether you are looking to start a business or desire a priceless industry-wide perspective.

https://www.acs.org/content/acs/en/acs-webinars/videos.html

3

ACS Webinars®
CLICK • WATCH • LEARN • DISCUSS

Learn from the best and brightest minds in chemistry! Hundreds of webinars on diverse topics presented by experts in the chemical sciences and enterprise.

Edited Recordings are an exclusive ACS member benefit and are made available once the recording has been edited and posted.

Live Broadcasts of ACS Webinars® continue to be available to the general public several times a week generally from 2-3pm ET!

A **collection of the best recordings** from the ACS Webinars Library will occasionally be rebroadcast to highlight the value of the content.

www.acs.org/acswebinars

4

Advance YOUR CAREER

ChemIDP™

ChemIDP.org

Discover ACS PUBLICATIONS

Publishing Resources

ACS REVIEWER LAB™

ACS axial

ACS AUTHOR UNIVERSITY

ACS Authoring Services

publish.acs.org

Connect WITH CHEMISTS AND OTHER SCIENCE PROFESSIONALS

CAS SciFinder Future Leaders

171 alumni, 35 countries and over 120 institutions

acsoncampus.acs.org/resources

ACS Chemistry for Life®

CAS A DIVISION OF THE AMERICAN CHEMICAL SOCIETY

ACS Publications Most Trusted. Most Cited. Most Read.

5

ACS ON CAMPUS

From ACS Industry Member Programs

- **Industry Matters Newsletter**

  ACS Member-only weekly newsletter with exclusive interviews with industry leaders and insights to advance your career.

  Preview & Subscribe: acs.org/indnews

- in ACS Innovation Hub

  Connect, collaborate, and stay informed about the trends leading chemical innovation

  Join: bit.ly/ACSinnovationhub

ACS Career Navigator: Your Home for Career Services

Whether you are just starting your journey, transitioning jobs, or looking to brush up or learn new skills, the **ACS Career Navigator** has the resources to point you in the right direction.

We have a collection of career resources to support you during this global pandemic:

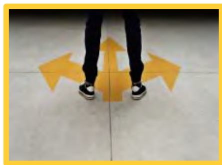

Professional Education


Virtual Career Consultants

ACS Leadership Development System


Career Navigator LIVE!


ChemIDP


College to Career

ACS Webinars

Virtual Classrooms

Visit www.ACS.org/COVID19-Network to learn more!

7

ACS Department of Diversity Programs

Advancing ACS's Core Value of Diversity, Inclusion & Respect

We believe in the strength of diversity in all its forms, because inclusion of and respect for diverse people, experiences, and ideas lead to superior solutions to world challenges and advances chemistry as a global, multidisciplinary science.

Contact Us:
https://app.suggestionox.com/r/DI_R
Diversity@acs.org

@ACSDiversity

ACS Diversity

ACS Voices Diversity Podcast
acsvoices.podbean.com/

www.acs.org/diversity

8

Grateful for your chemistry career?

Pay it forward with a donation
to the ACS Scholars Program today!

www.donate.acs.org/scholars

ACS Office of Philanthropy
Chemistry for Life®

ACS Scholars Endowment Founder Joe Vacca, retired Vice President of Chemistry, Merck & Co., meets with his 2018 ACS Scholar **Johanna Masterson**, now a grad student at Princeton University.

"Chemistry has been good to me…so I wanted to make a significant gift to provide that opportunity to others."

9

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS
Chemistry for Life®

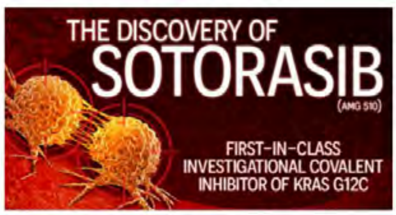
Date: Wednesday, February 24, 2021 @ 2:30-3:30pm ET
Speakers: Shane Crotty, La Jolla Institute for Immunology and Yizhou Dong, The Ohio State University
Moderator: Qiongqiong Angela Zhou, CAS

Register for Free!

What You Will Learn:

- Highlights of the most impactful research findings related to COVID-19 vaccines
- Technical considerations of mRNA, lipid nanoparticle and related technologies
- Future opportunities to build on learnings from COVID-19 to accelerate development of new vaccines and therapeutics

Co-produced with: CAS



Date: Thursday, February 25, 2021 @ 2-3:30pm ET
Speaker: Brian Lanman, Amgen, Inc.
Moderator: Ariamala Gopalsamy, AstraZeneca

Register for Free!

What You Will Learn:

- Why identifying a direct inhibitor of KRAS has proven so challenging
- How covalent inhibition helped to turn KRAS G12C into a tractable target
- What hurdles were overcome in turning initial KRAS G12C binders into potential human therapeutics

Co-produced with: ACS Division of Medicinal Chemistry, American Association of Pharmaceutical Scientists, and ACS Publications

Date: Thursday, March 11, 2021 @ 1-2pm ET
Speakers: Julie Mann, PURIS Holdings, LLC / Joshua March, Artemys Foods / Andrew Ive, Big Idea Venture
Moderator: Christopher Gregson, Greenstalk Food Consulting LLC

Register for Free!

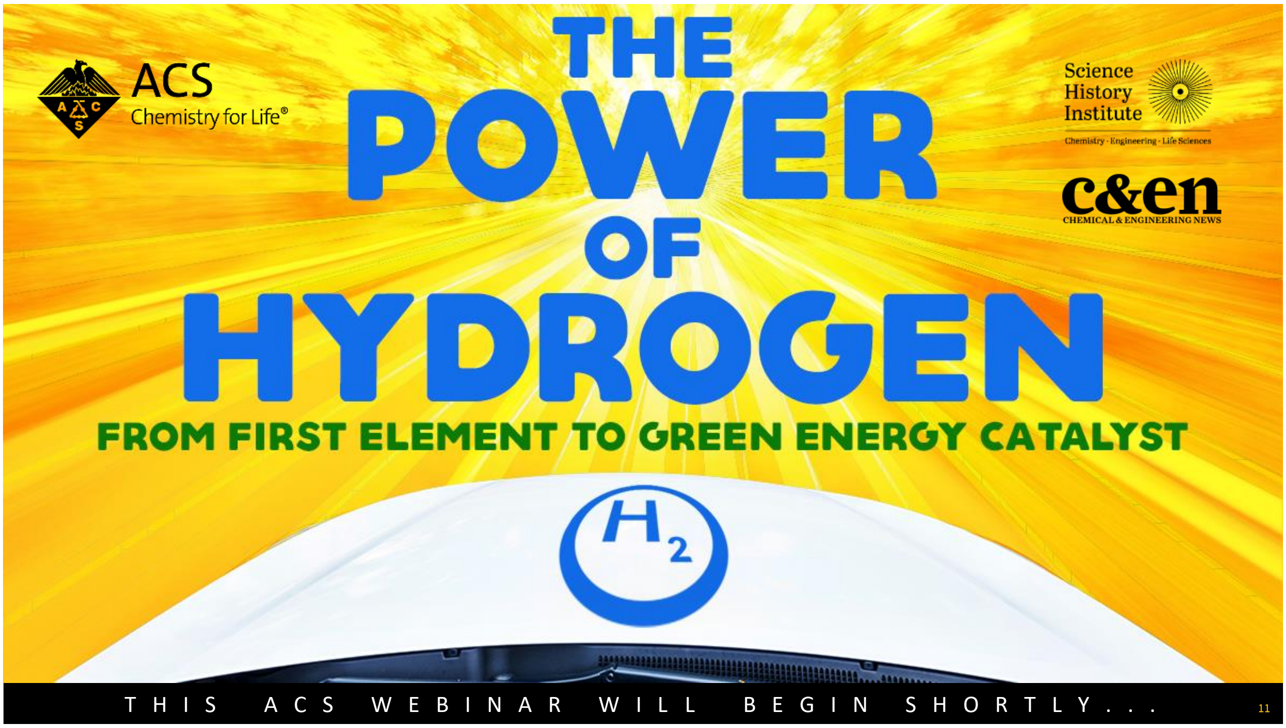
What You Will Learn:

- A better understanding of the most significant transformation of the food industry in decades
- The challenges of formulating plant-based products or using cell cultures to "grow" meat
- How it will affect peoples' dietary choices in the future

Co-produced with: Science History Institute and *Chemical & Engineering News*

www.acs.org/acswebinars

10



Science History Institute
Chemistry · Engineering · Life Sciences

ACS Chemistry for Life®

The Power of Hydrogen: From First Element to Green Energy Catalyst

Vijay Kapur
Retired CEO,
International Solar Electric Technology

Bill Tuszynski
Partner, The Unami Group LLC and JPS Program Committee Chair

Presentation slides are available now! The edited recording will be made available as soon as possible.

www.acs.org/acswebinars

This ACS Webinar is co-produced with Science History Institute and Chemical & Engineering News.

12

The Power of Hydrogen: From First Element To Green Energy Catalyst

February 11, 2021

Vijay Kapur

CEO (retired), International Solar Electric Technology

Science History Institute

Chemistry · Engineering · Life Sciences

13

Vijay Kapur

CEO (retired), International Solar Electric Technology

Bill Tuszynski

Partner, The Unami Group LLC and JPS Program Committee Chair

Science History Institute

Chemistry · Engineering · Life Sciences

14

Climate Change

Climate change is the main driver for hydrogen in the energy transition.

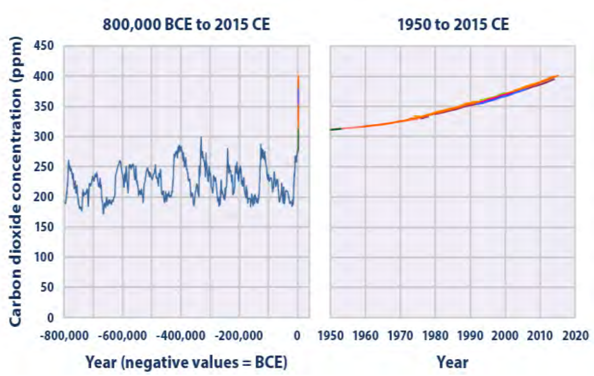
Limiting global warming to below 2 °C requires that CO_2 emissions decline by around 25% by 2030, from 2010 levels, and reach net zero by around 2070 (IPCC, 2018).

For a reasonable likelihood to stay below 1.5 °C of warming, global net anthropogenic CO_2 emissions should decline by around 45% by 2030, from 2010 levels, reaching net zero by around 2050 (IPCC, 2018).

Energy-related CO_2 emissions account for two-thirds of global greenhouse gas emissions. An energy transition is needed now to break the link between economic growth and increased CO_2 emissions.

15

Historic and Current Level of CO2 in the Atmosphere and the Impact of Climate Change



Oct.2020 CO_2 Level 411 ppm

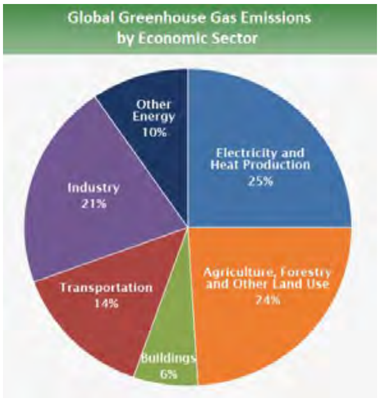
Cumulative CO_2 in the Atmosphere
3200 Billion MT
Annual Increase in CO_2 about
40 Billion MT

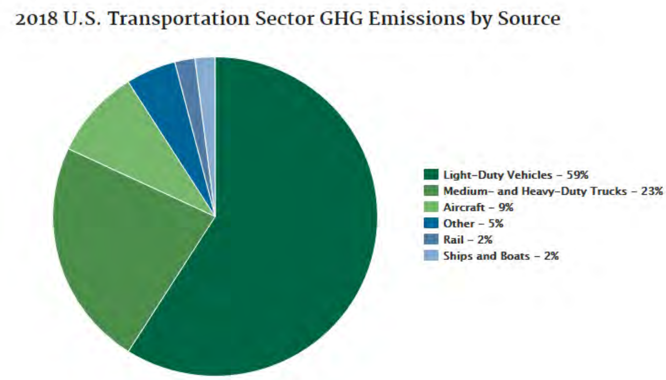
Major Climate Change Impacts

- More Frequent Extreme Weather Events
- Curtailed Fresh Water Resources (Melting of Glaciers)
- Rising Sea Levels
- Mass Migration of Climate Refugees

16

Contribution of Greenhouse Gases by Various Economic Sectors





Energy demand for most of these sectors can be met by using clean hydrogen as an energy carrier.

17

Urgent Actions Needed to Correct Climate Change

Curtail Local Emissions of Greenhouse Gases and Establish Systems for CO2 Sequestration

Minimize use of Fossil Fuels

Promote Clean Public Transportation

Replenish Lost Greenery by Planting Trees

Sustainable Agriculture and Promote Vertical Farming

Maximize the Use Renewable Energy via HYDROGEN as an Energy Carrier.

18

Hydrogen *is the simplest and* ***also the most abundant element in the universe.*** *Stars such as the sun consist mostly of hydrogen. The sun is essentially a ball of hydrogen and helium gases.*

- ***Hydrogen*** *occurs naturally on earth only in compound form with other elements, in liquids, gases, or solids.*
- ***Hydrogen*** *combined with oxygen is water (H2O).*
- ***Hydrogen*** *combined with carbon forms different compounds—or hydrocarbons—found in natural gas, coal, and petroleum.*

19

Hydrogen as an Energy Carrier

Hydrogen***, like electricity, is an energy carrier that must be produced from another substance.***

- ***Hydrogen*** *can be produced—separated—from a variety of sources including water, fossil fuels, or biomass, and used as a source of energy or fuel.*
- ***Hydrogen*** *has the* ***highest energy content*** *of any common fuel by weight (about three times more than gasoline),* ***but it has the lowest energy content by volume*** *(about four times less than gasoline).*
- ***Hydrogen*** *is versatile in terms of supply and use. It is a* ***free energy carrier*** *that can be produced by many energy sources, including renewables.*

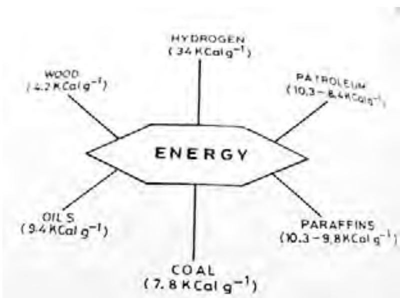
20

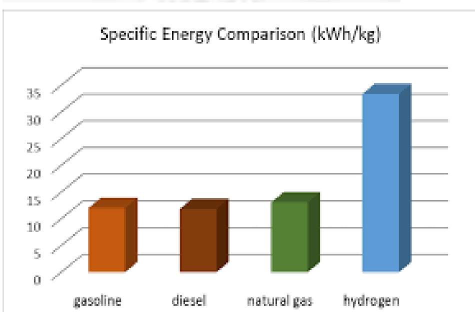
Properties of Hydrogen

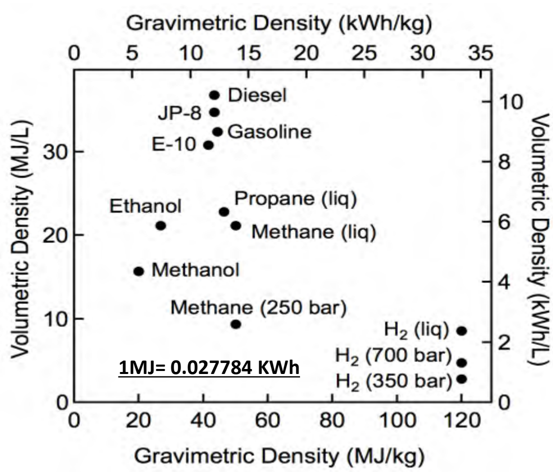
- First element in periodic table
- On Earth, found only as compounds
- Colorless , odorless and non-toxic gas
- Under NTP conditions it is a liquid at –253 C
- Fuel with highest energy density and lowest volume density
- Highly effective reducing agent for industrial processes
- Most abundant element in the Universe
- Mass fraction of Hydrogen is 739,000 ppm –about 75% of normal matter

21

Comparison of Energy Density Hydrogen vs. Hydrocarbons







22

Reasons Behind the Growth of the Hydrogen Economy

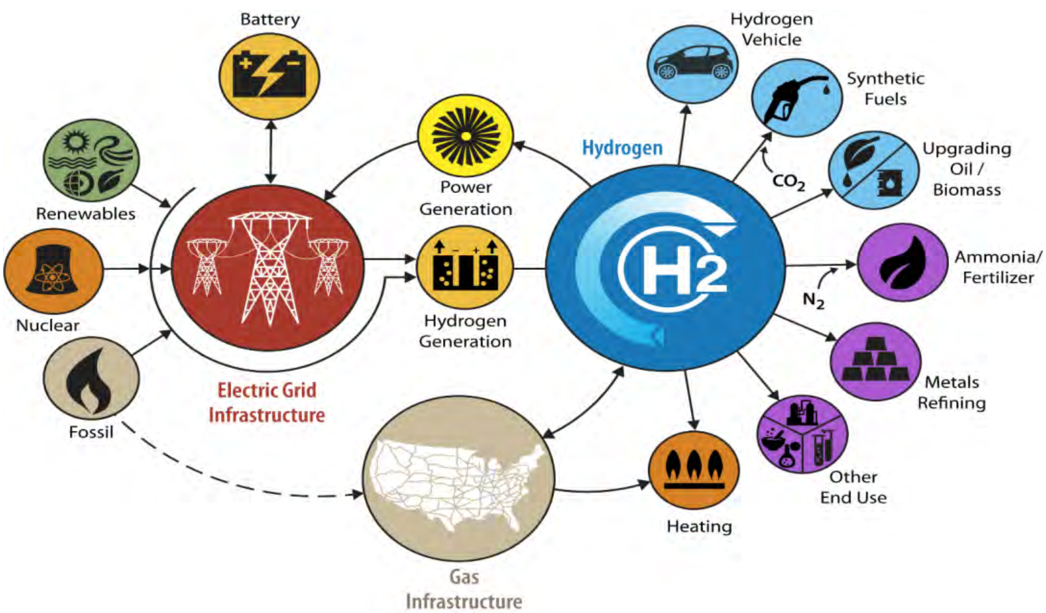
- Launched at the **World Economic Forum** in January 2017, the Hydrogen Council is a global, industry led effort to develop the **Hydrogen Economy**. The Hydrogen Council vision sees fuel-cell electric vehicles **(FCEVs)** playing a big role in both private vehicles and long distance commercial transport.
- **Renewable energy-produced Hydrogen** can replace "**Dirty**" Hydrogen currently used in industrial processes, and can supplement gas for **Heating**.
- **Hydrogen** is being heralded as **the solution to many issues** faced by our

Transitioning Global Energy, particularly when produced by renewable energy, including:

- The **Intermittency Risks of Renewables**, by storing their energy in the form of Hydrogen.
- **Emissions Reduction** in the transport sector thanks to FCEV's, which run on Hydrogen.
- **Wide Spread Decarbonization** of the manufacturing sector once Hydrogen technology substitutes for existing gas and coal fired generators.

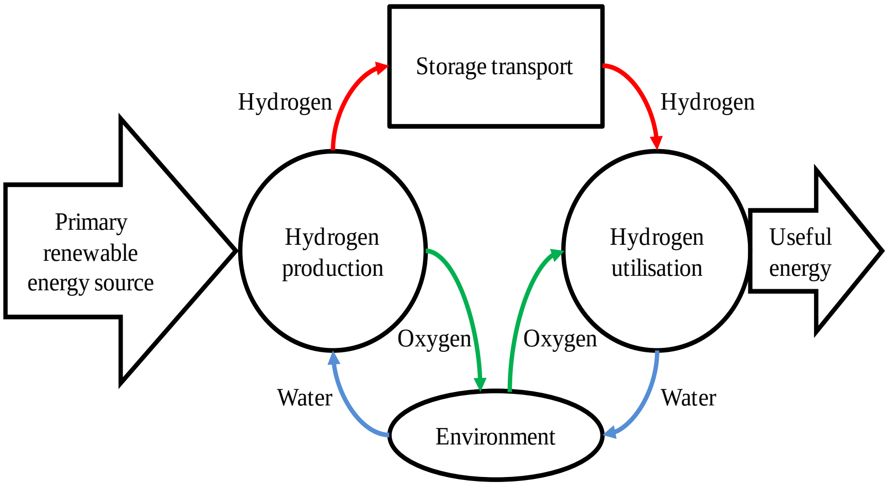
23

Production and Applications of Hydrogen



24

Hydrogen as an Energy Carrier



25

26

Audience Challenge Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

Which of the following are methods of the production of Hydrogen?

(Select all that apply)

- Hydrogen from Fossil Fuels
- Hydrogen by Electrolysis of Water
- Photochemical or Photoelectrochemical Production of Hydrogen
- Direct Thermal Decomposition of Water
- Trash to Hydrogen with High Temp. Plasma

** If your answer differs greatly from the choices above tell us in the chat!*

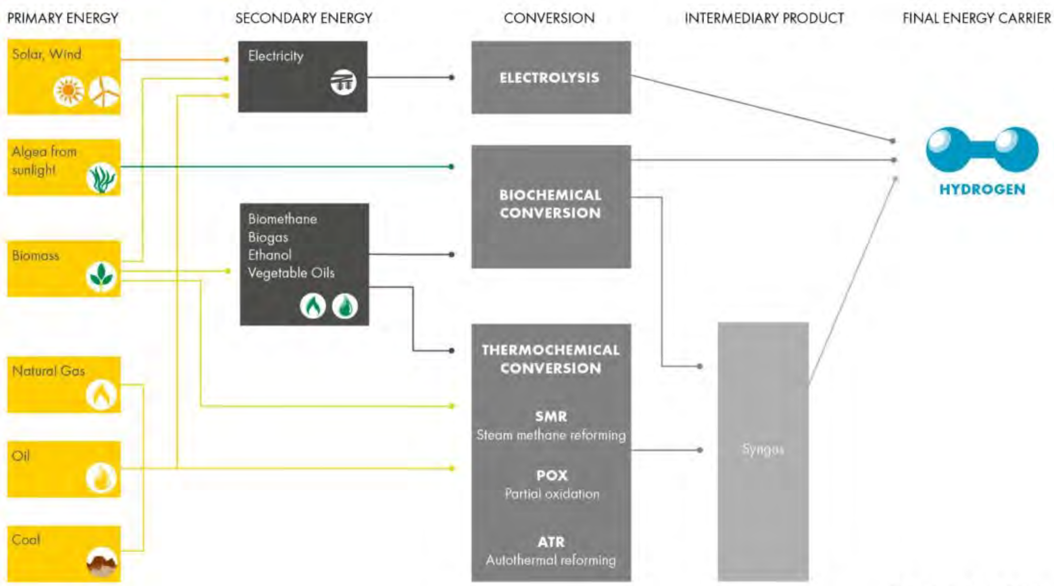
Methods of Production of Hydrogen

1. *Hydrogen from Fossil Fuels*
2. ***Hydrogen by Electrolysis of Water***
3. Photochemical Production of Hydrogen
4. Photoelectrochemical Production of Hydrogen
5. Biological and Biochemical Production of Hydrogen
6. Direct Thermal Decomposition of Water
7. Super – Green H2 SGH2 (Trash to Hydrogen with High Temp. Plasma)

In this presentation we will briefly discuss the top two methods.

27

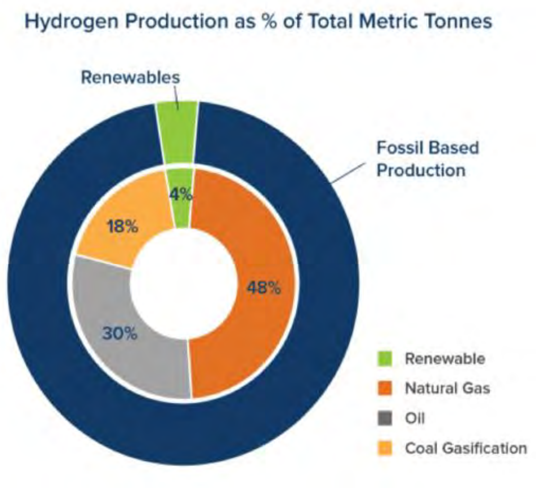
Production of Hydrogen



Shell Hydrogen Study © Shell

28

Current Production of Hydrogen



Current Global Hydrogen Production - 70 MMt

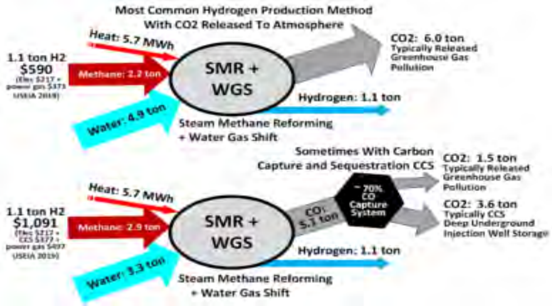
- From natural gas with SMR – 76 %
- Coal gasification (mostly in China) - 22 %
- Electrolysis – 2%.

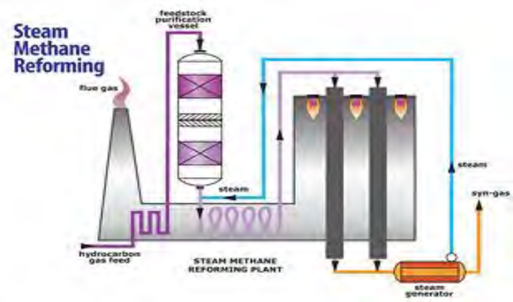
Presently, most Hydrogen is produced from fossil fuels

Cost and CO2 Contribution from Hydrogen Production by Different Methods

	HYDROGEN TYPES	CARBON INTENSITY (KG/H2)	PRODUCTION $ (KG/H2)
GREEN HYDROGEN	SGH2 Greener Than Green Hydrogen	-188 KgCO2eq/MJ (avoiding 29 kg of CO2 per kg of H2)	$2
	Green Hydrogen (Electrolysis)	0 kgCO2eq/MJ	$10-$13
HYDROGEN FROM FOSSIL FUELS	Gray Hydrogen from NatGas	+12 kg CO2	$2-$6 *(costs of natural gas)*
	Brown Hydrogen from Gasification of Coal	+20 kg CO2	$2-$3
BLUE HYDROGEN WITH CARBON CAPTURE & SEQUESTRATION	Gray Hydrogen	+12 kg CO2 (carbon captured)	$6-$10
	Brown Hydrogen	+20 kg CO2 (carbon captured)	$6-$7

Hydrogen from Fossil Fuels



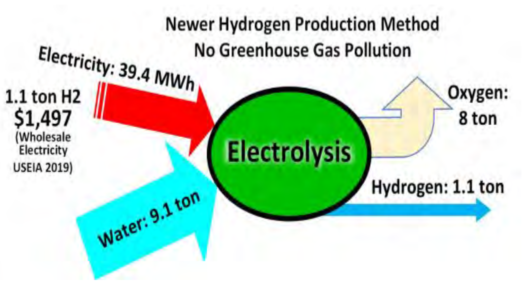


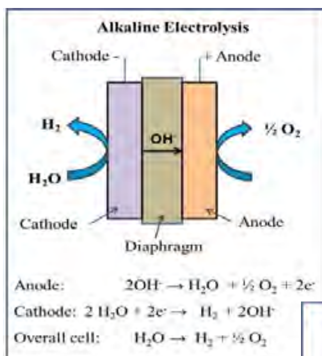
For the **Steam Methane Reforming (SMR)** process, high temperature (700–1100 °C) steam (H_2O) reacts with **methane** (CH_4) in an **endothermic reaction** to yield **syngas**: $CH_4 + H_2O \rightarrow CO + 3\ H_2$

In a second stage, additional hydrogen is generated through the lower-temperature, exothermic, **Water Gas Shift reaction** (WGS) , performed at about 360 °C: $CO + H_2O \rightarrow CO_2 + H_2$

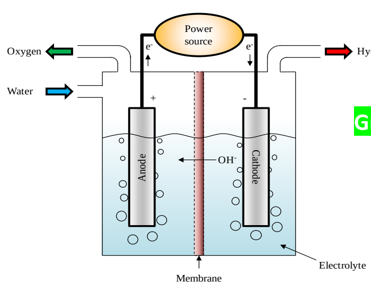
Essentially, the **oxygen** (O) atom is stripped from the additional water (steam) to oxidize CO to CO_2. This oxidation also provides energy to maintain the reaction. Additional heat required to drive the process is generally supplied by burning some portion of the methane.

Hydrogen Production by Electrolysis of Water



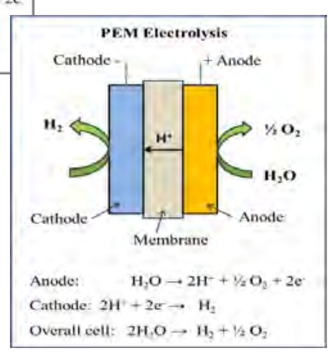


Operating temp. 333-363 K (60 – 90 C)

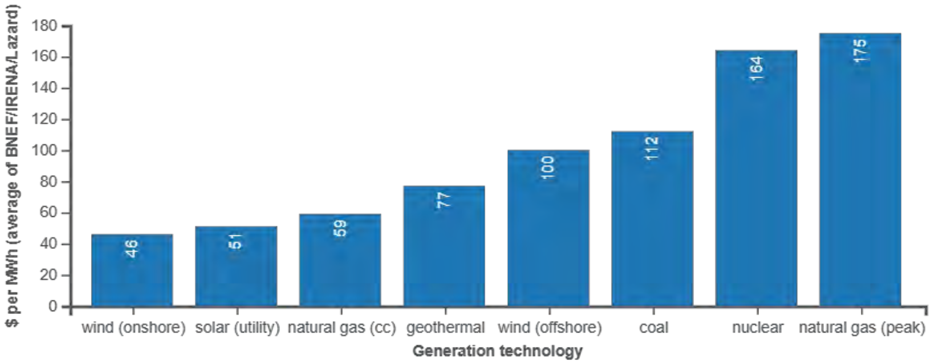


Green Hydrogen

Operating temp. 293-373 K (20 – 100 C)



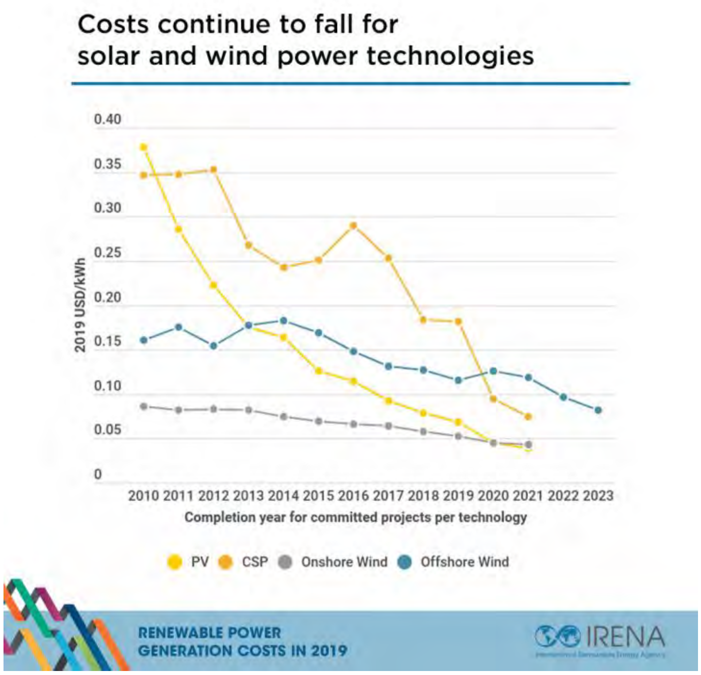
Cost of Global LCOE Electricity Generated by Different Technologies



Zero emission Green hydrogen produced by electrolysis using low-cost, renewable wind and solar generated electricity is the most promising. **The cost of renewable electricity is continually is being lowered**

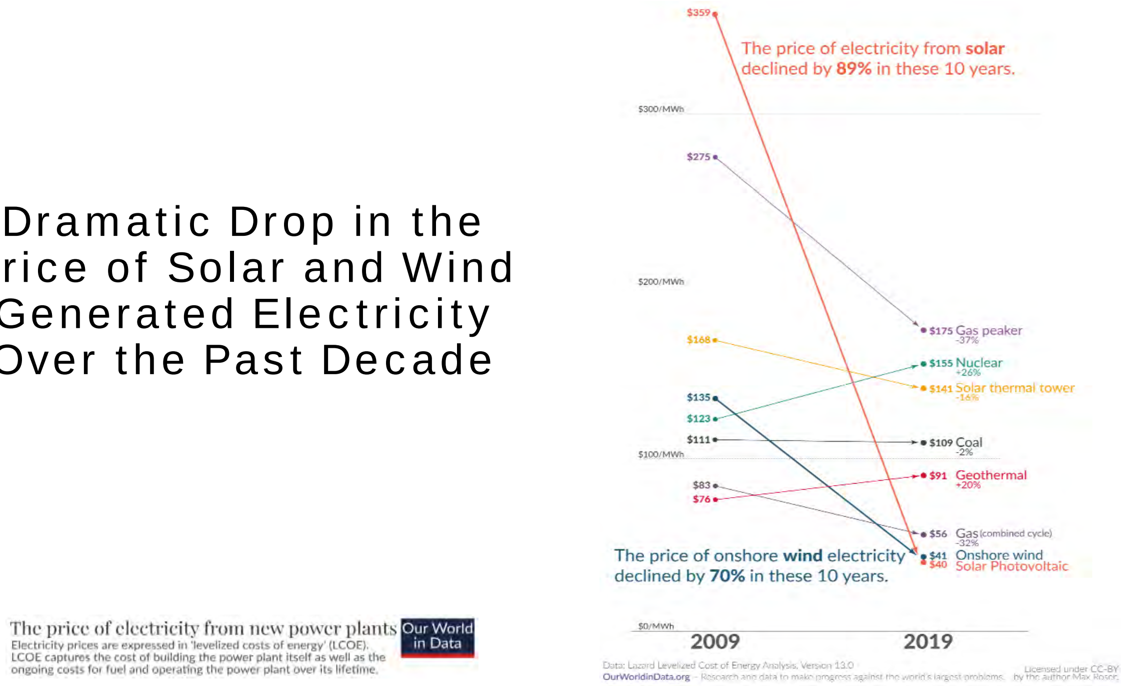
33

Drop in Cost of Solar and Wind Power Generation Makes Hydrogen by Electrolysis Even More Cost-Effective



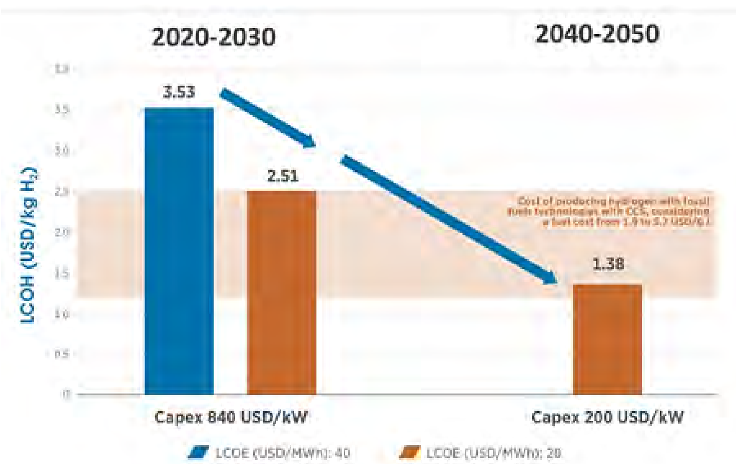
34

Dramatic Drop in the Price of Solar and Wind Generated Electricity Over the Past Decade



35

Projected Cost Reduction of Both Renewable Energy and Electrolysis Equipment Makes Green Hydrogen More Economical



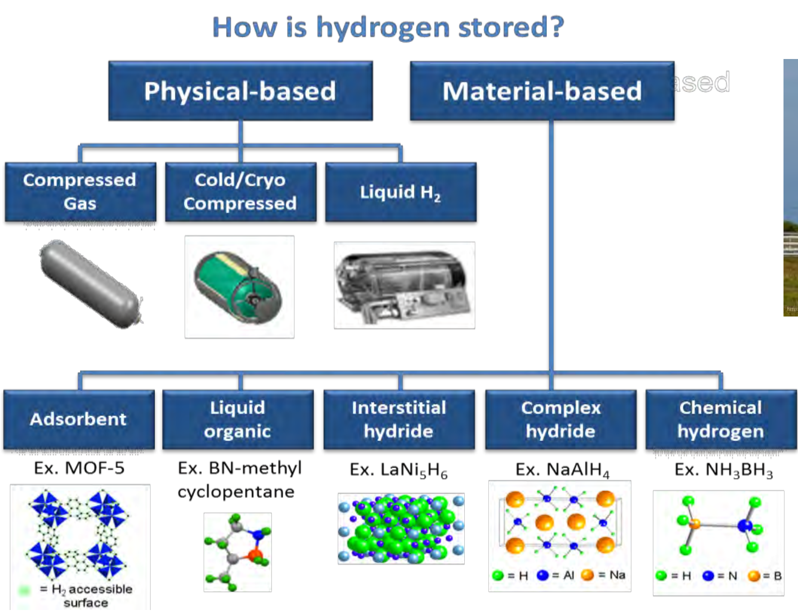
36

Existing and Emerging Demands for Hydrogen

	Transportation Applications	Chemicals and Industrial Applications	Stationary and Power Generation Applications	Integrated/Hybrid Energy Systems
Existing Growing Demands	• Material-Handling Equipment • Buses • Light-Duty Vehicles	• Oil Refining • Ammonia • Methanol	• Distrubuted Generation: Primary and Backup Power	• Renewable Grid Integration (with storage and other ancillary services)
Emerging Future Demands	• Medium-and Heavy-Duty Vehicles • Rail • Maritime • Aviation • Contruction Equipment	• Steel and Cement Manufacturing • Industrial Heat • Bio/Synthetic Fuels	• Reversible Fuel Cells • Hydrogen Combustion • Long-Duration Energy Storage	• Nuclear/Hydrogen Hybrids • Gas/Coal/Hydrogen Hybrids with CCUS • Hydrogen Blending

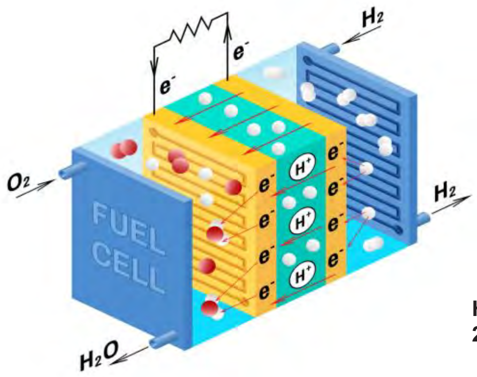
37

Hydrogen for Energy Storage



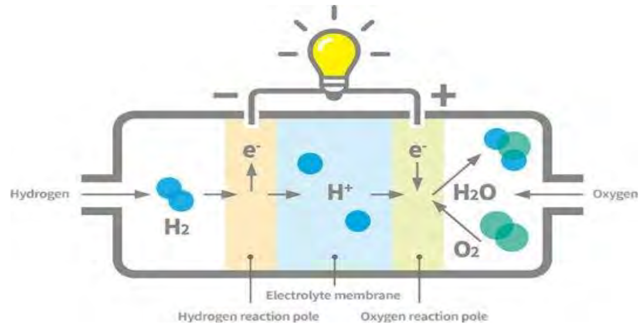
38

Schematics of a Hydrogen Fuel Cell



The principle of a hydrogen fuel cell.

Source: Airbus.



Hydrogen + Oxygen → Water
$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

Electrode half equations:

At the Anode (- ve) : $2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$
At the Cathode (+ Ve) : $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
The overall equation: $2H_2 + 4OH^- + O_2 + 2H_2O + 4e^- \rightarrow 4H_2O + 4e^- + 4OH^-$
Resulting in: $2H_2 + O_2 \rightarrow 2H_2O$

Fuel Cell Technologies

Comparison of Fuel Cell Technologies

DOE Hydrogen Program

Fuel Cell Type	Common Electrolyte	Operating Temperature	System Output	Electrical Efficiency	Combined Heat and Power (CHP) Efficiency	Applications	Advantages
Polymer Electrolyte Membrane (PEM)*	Solid organic polymer poly-perfluorosulfonic acid	50 - 100°C 122 - 212°F	<1kW – 250kW	53-58% (transportation) 25-35% (stationary)	70-90% (low-grade waste heat)	• Backup power • Portable power • Small distributed generation • Transportation • Specialty vehicles	• Solid electrolyte reduces corrosion & electrolyte management problems • Low temperature • Quick start-up
Alkaline (AFC)	Aqueous solution of potassium hydroxide soaked in a matrix	90 - 100°C 194 - 212°F	10kW – 100kW	60%	>80% (low-grade waste heat)	• Military • Space	• Cathode reaction faster in alkaline electrolyte, leads to higher performance • Can use a variety of catalysts
Phosphoric Acid (PAFC)	Liquid phosphoric acid soaked in a matrix	150 - 200°C 302 - 392°F	50kW – 1MW (250kW module typical)	>40%	>85%	• Distributed generation	• Higher overall efficiency with CHP • Increased tolerance to impurities in hydrogen
Molten Carbonate (MCFC)	Liquid solution of lithium, sodium, and/or potassium carbonates, soaked in a matrix	600 - 700°C 1112 - 1292°F	<1kW – 1MW (250kW module typical)	45-47%	>80%	• Electric utility • Large distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Suitable for CHP
Solid Oxide (SOFC)	Yttria stabilized zirconia	600 - 1000°C 1202 - 1832°F	<1kW – 3MW	35-43%	<90%	• Auxiliary power • Electric utility • Large distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Solid electrolyte reduces electrolyte management problems • Suitable for CHP • Hybrid/GT cycle

*Direct Methanol Fuel Cells (DMFC) are a subset of PEM typically used for small portable power applications with a size range of about a subwatt to 100W and operating at 60 - 90°C.

For print copies of this fact sheet, please call the DOE Energy Efficiency and Renewable Energy Information Center at 877-EERE-INF(O)/877-337-3463. December 2008

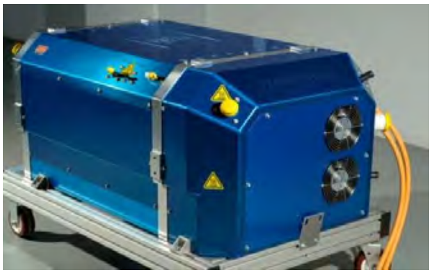
U.S. DEPARTMENT OF ENERGY

U.S. Department of Energy Hydrogen Program
www.hydrogen.energy.gov

Hydrogen Fuel Cell-Powered Buses, Trucks, and Cars

Van Hool A330 Fuel Cell Bus powered by Ballard (CNW Group/Ballard Power Systems Inc.)

Toyota Motor Corp. hydrogen fuel cell powered Semi-truck on display at the LA auto show



GM's Hydrotec fuel cell power cubes to Navistar for use in its production model fuel cell electric vehicle (FCEV) – the International RHTM Series.

Toyota Motor Corp. revamped Mirai hydrogen fuel cell car launched in Tokyo in Dec. 2020

Comparison of Energy Sources for Vehicles

Energy source	MJ / kg	MJ / L	Average Charging Time
Lithium batteries	0.31 – 0.49	2.5	2–13 hours (depending on available power)
Gasoline	23.65	34.78	3 – 5 minutes
Diesel	32.85	38.65	
Ethanol	30	24	
Hydrogen (690 bar, 15°C)	120	4500	4 – 6 minutes
Hydrogen (gas)	120	0.01005	

Hydrogen Fuel Cell Powered Yacht and a Home Power System

This system stores some 40 kilowatt-hours worth of energy, enough to run an average home for two days. When that energy is needed, it uses a Hydrogen fuel cell to deliver energy into the home, with a small 5-kWh lithium buffer battery for instantaneous response.

43

Safety in Handling of Hydrogen

- Hydrogen is **not toxic**
- It is **environmentally benign**
- H2 is a fuel. As such has **stored chemical energy and it has hazards associated with it.**
- **It is no more dangerous than the other fuels that store chemical energy.** It is just different.
- **Buoyancy:** H2 gas is about 14 times lighter than air in normal conditions (NTP) and this is why any leak quickly moves upward, thus **reducing ignition hazards.**
- The form of H2 used for renewable energy purposes in today's society is the most common hydrogen isotope, **Protium**. The technology that is required to create a hydrogen bomb involves the very rare hydrogen isotope, Tritium, which does not occur naturally and is created by a conventional nuclear reactor.
- H2 must be handled responsibly or it can behave dangerously under specific conditions. For this reason, it is imperative that appropriate materials are selected to design safe hydrogen systems.
- Hydrogen powered cars surpass standard mandated crash tests with flying colors.
- According to Toyota, the Mirai's tank is **"safer than a conventional fuel tank"** due to its multiple safeguards and **"extra-thick"** carbon fiber.

44

Key Developments

- Two key developments have contributed to the growth of hydrogen in recent years: the **Cost of Hydrogen Supply** when produced from **Renewables** (Solar and Wind), has come down and continues to fall.

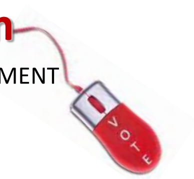
- While the urgency of Greenhouse Gas Emission Mitigation has increased, many countries have begun to take action to decarbonize their economies, notably energy supply and demand.

45

46

Audience Challenge Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



Which of country is currently the most active in the hydrogen economy?

- South Korea
- France
- United States
- Saudi Arabia
- India

** If your answer differs greatly from the choices above tell us in the chat!*

Countries Most Active in the Hydrogen Economy

1. South Korea
2. Japan
3. Germany
4. France
5. United States
6. UK
7. Canada
8. China
9. Norway
10. Denmark
11. Australia
12. Switzerland
13. Saudi Arabia
14. India

Countries around the world are already betting on Hydrogen as a viable renewable energy carrier.

The most active business sectors are:

- Energy
- Transport
- Heating
- Export
- Feedstock for metal refining, ammonia fertilizer, and oil upgrading.

47

Headline News about the Hydrogen Economy

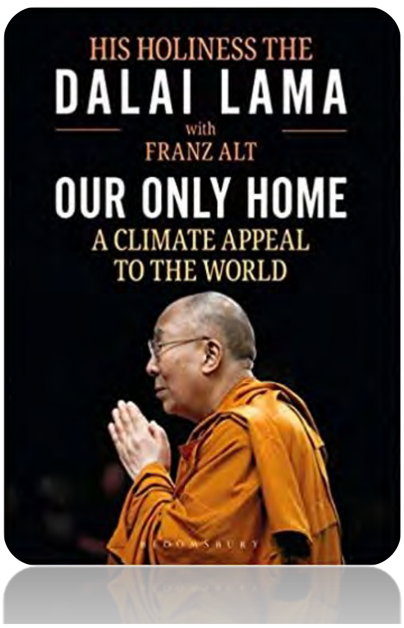
- Oil-Rich **Abu Dhabi** Targets Hydrogen as Future Export Fuel.
- Fossil Fuel Giant **Sinopec** Teams Up with Solar Firms on 'Green Hydrogen' Projects to Help **China** on Path Towards Carbon Neutrality.
- **China**: **Guangdong** Taking Lead in Clean Energy.
- **Lower Saxony** Regional Transport Company (LNVG) Wins Award for Hydrogen Train.
- **Scotland** Banks On Hydrogen Fuel Cell Trains For Zero Emission Railway.
- **Toshiba** to Accelerate Development of Pure Hydrogen Fuel Cell Module for Vessels and Railroad Vehicles.
- **Russia** Looks To Become Leader In Hydrogen Tech.
- **Siemens Energy** Wants to Earn Billions with Hydrogen.
- **Xiangyang**: First Hydrogen Station, Bus Line and the World's First Hydrogen Fuel Dust Suppression Vehicle.

48

Headline News about the Hydrogen Economy Contd.

- Korea: S-Oil Entering the Hydrogen Fuel Cell Business.
- TECO 2030 (Norway)Launches Stationary Fuel Cell Concept.
- Canada Unveils Hydrogen Strategy to Kick-Start Clean Fuel Industry.
- Air Liquide to Invest Billions in Bet on Hydrogen Boom.
- Japan to Make Hydrogen Major Power Source by 2030.
- Hydrogen Solaris Buses go to Sweden.
- Airbus Reveals Radical Design for Detachable Hydrogen Fuel Cell Wing Pods.
- Cummins: Take a Deeper Dive into the Power of Hydrogen Technology.
- The Fuel That Could Transform Shipping - BBC Future.
- UK Boosts Hydrogen With New Net-Zero Plan, EVs and Carbon Capture.

Climate Change



Acknowledgements

Thank you for your interest and attention!

Materials and data used in this presentation has been drawn from the reports & websites of the following:
U.S. DOE, NREL, EIA, IEA, IRENA,, WIKI-SOLAR ORG, AND OTHERS

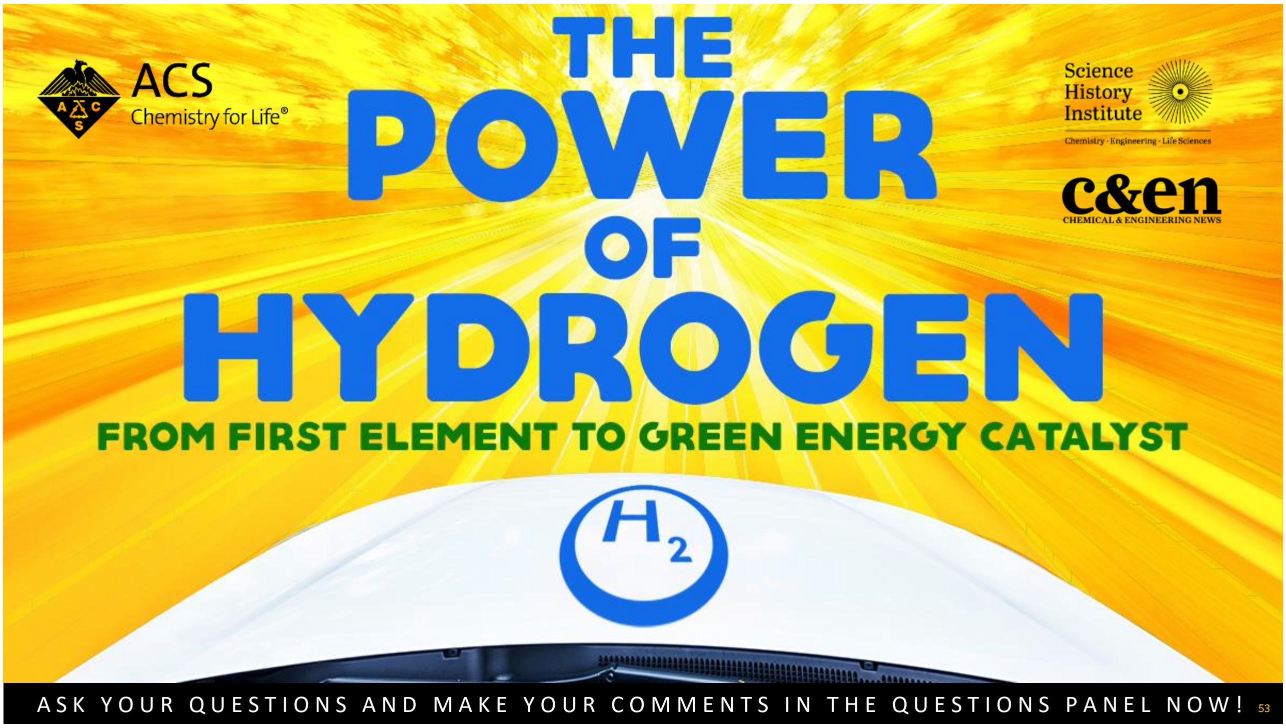
51

See you

March 11, 2021

Neither Fish Nor Fowl:

The Growth of Alternatives
to Animal-Derived Foods



Summary

- Access to renewable (solar and wind) electricity has made the **cost of production of green and clean Hydrogen by electrolysis competitive with Hydrogen from fossil fuels**. With new improvements currently being researched, this cost will be reduced further.
- **Technologies for Hydrogen storage** have established Hydrogen as an energy carrier that offers flexibility and portability.
- High efficiency of power generation by fuel cells, from conveniently stored, cost effective Hydrogen, has offered a **zero emission fuel for the transportation sector** of the global economy.
- Green and cleanly-produced Hydrogen used as a feedstock for steel, cement, fertilizer, and chemicals, will **help curtail greenhouse gas emissions**.
- Long term energy storage with Hydrogen, provides a solution to **capture the intermittency of power from wind and solar generators.**
- Hydrogen fuel cells provide **backup power and grid integration of renewables**.

The combined effect of these issues is to establish a clear approach to adopt the Hydrogen Economy, minimize the use of fossil fuels, and stop further degradation by climate change.

54

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

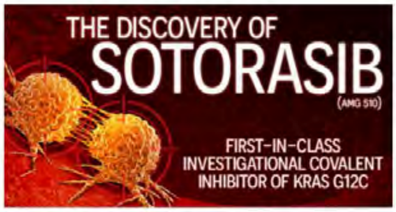
Date: Wednesday, February 24, 2021 @ 2:30-3:30pm ET
Speakers: Shane Crotty, La Jolla Institute for Immunology and Yizhou Dong, The Ohio State University
Moderator: Qiongqiong Angela Zhou, CAS

Register for Free!

What You Will Learn:

- Highlights of the most impactful research findings related to COVID-19 vaccines
- Technical considerations of mRNA, lipid nanoparticle and related technologies
- Future opportunities to build on learnings from COVID-19 to accelerate development of new vaccines and therapeutics

Co-produced with: CAS



Date: Thursday, February 25, 2021 @ 2-3:30pm ET
Speaker: Brian Lanman, Amgen, Inc.
Moderator: Ariamala Gopalsamy, AstraZeneca

Register for Free!

What You Will Learn:

- Why identifying a direct inhibitor of KRAS has proven so challenging
- How covalent inhibition helped to turn KRAS G12C into a tractable target
- What hurdles were overcome in turning initial KRAS G12C binders into potential human therapeutics

Co-produced with: ACS Division of Medicinal Chemistry, American Association of Pharmaceutical Scientists, and ACS Publications

Date: Thursday, March 11, 2021 @ 1-2pm ET
Speakers: Julie Mann, PURIS Holdings, LLC / Joshua March, Artemys Foods / Andrew Ive, Big Idea Venture
Moderator: Christopher Gregson, Greenstalk Food Consulting LLC

Register for Free!

What You Will Learn:

- A better understanding of the most significant transformation of the food industry in decades
- The challenges of formulating plant-based products or using cell cultures to "grow" meat
- How it will affect peoples' dietary choices in the future

Co-produced with: Science History Institute and *Chemical & Engineering News*

www.acs.org/acswebinars

55

ACS Webinars®
CLICK • WATCH • LEARN • DISCUSS

Learn from the best and brightest minds in chemistry! Hundreds of webinars on diverse topics presented by experts in the chemical sciences and enterprise.

Edited Recordings are an exclusive ACS member benefit and are made available once the recording has been edited and posted.

Live Broadcasts of ACS Webinars® continue to be available to the general public several times a week generally from 2-3pm ET!

A **collection of the best recordings** from the ACS Webinars Library will occasionally be rebroadcast to highlight the value of the content.

www.acs.org/acswebinars

56

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

ACS Webinars® does not endorse any products or services. The views expressed in this presentation are those of the presenter and do not necessarily reflect the views or policies of the American Chemical Society.

Contact ACS Webinars ® at acswebinars@acs.org

57

ACS Webinars
CLICK • WATCH • LEARN • DISCUSS

ACS Chemistry for Life®

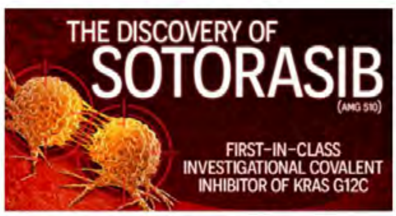
Date: Wednesday, February 24, 2021 @ 2:30-3:30pm ET
Speakers: Shane Crotty, La Jolla Institute for Immunology and Yizhou Dong, The Ohio State University
Moderator: Qiongqiong Angela Zhou, CAS

Register for Free!

What You Will Learn:

- Highlights of the most impactful research findings related to COVID-19 vaccines
- Technical considerations of mRNA, lipid nanoparticle and related technologies
- Future opportunities to build on learnings from COVID-19 to accelerate development of new vaccines and therapeutics

Co-produced with: CAS



Date: Thursday, February 25, 2021 @ 2-3:30pm ET
Speaker: Brian Lanman, Amgen, Inc.
Moderator: Ariamala Gopalsamy, AstraZeneca

Register for Free!

What You Will Learn:

- Why identifying a direct inhibitor of KRAS has proven so challenging
- How covalent inhibition helped to turn KRAS G12C into a tractable target
- What hurdles were overcome in turning initial KRAS G12C binders into potential human therapeutics

Co-produced with: ACS Division of Medicinal Chemistry, American Association of Pharmaceutical Scientists, and ACS Publications

Date: Thursday, March 11, 2021 @ 1-2pm ET
Speakers: Julie Mann, PURIS Holdings, LLC / Joshua March, Artemys Foods / Andrew Ive, Big Idea Venture
Moderator: Christopher Gregson, Greenstalk Food Consulting LLC

Register for Free!

What You Will Learn:

- A better understanding of the most significant transformation of the food industry in decades
- The challenges of formulating plant-based products or using cell cultures to "grow" meat
- How it will affect peoples' dietary choices in the future

Co-produced with: Science History Institute and *Chemical & Engineering News*

www.acs.org/acswebinars

58