

WEEK 1: Fuel Cell INTRODUCTION

MECH-526

FUEL CELL SCIENCE & ENGINEERING

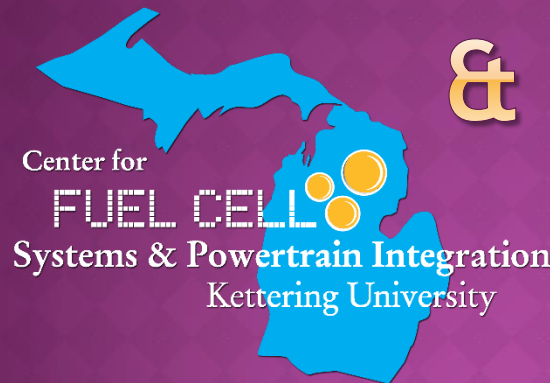
Dr. K. J. Berry. P.E.

Mechanical Engineering

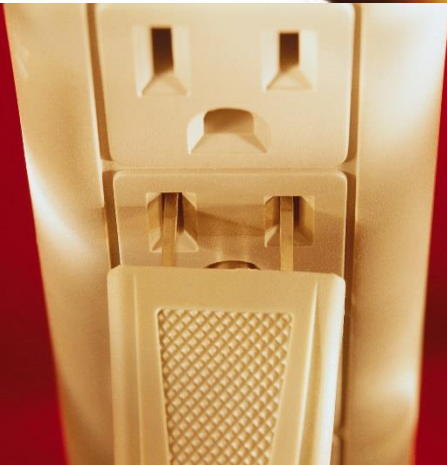
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Center for
FUEL CELL
Systems & Powertrain Integration
Kettering University

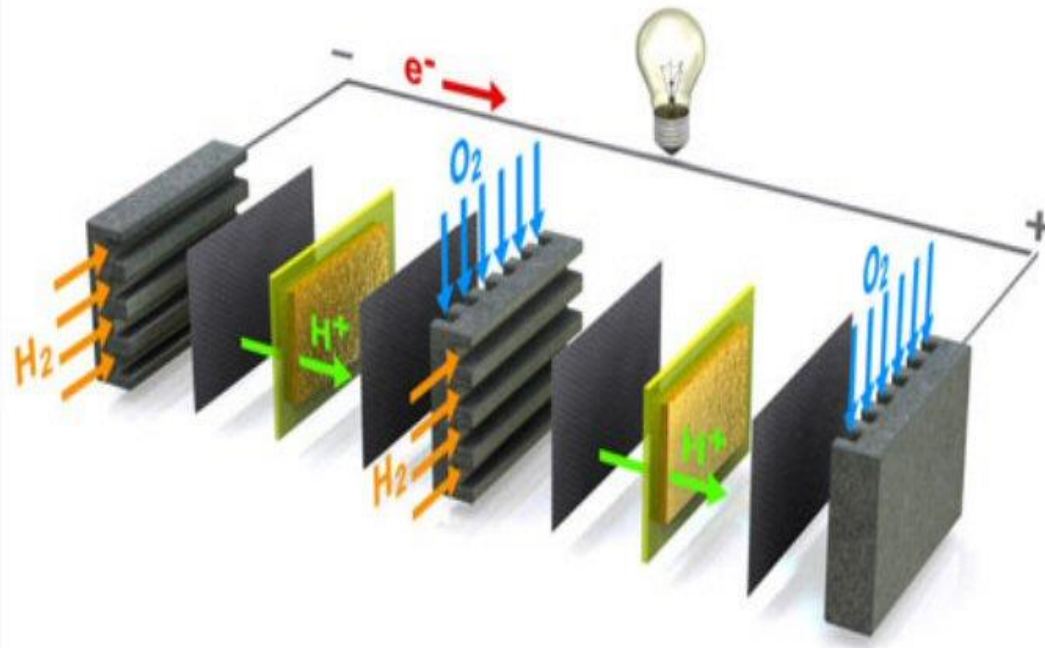
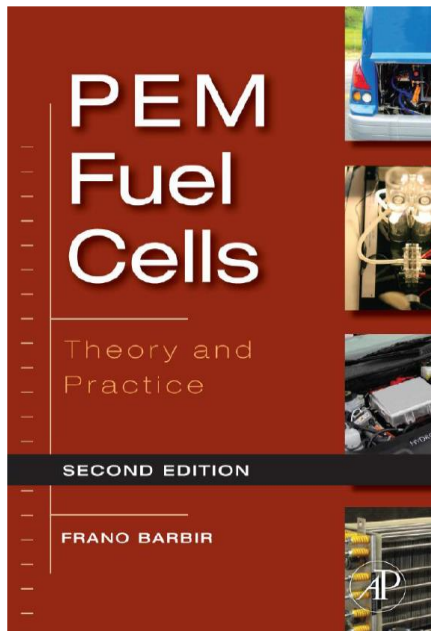


REFERENCES:



References

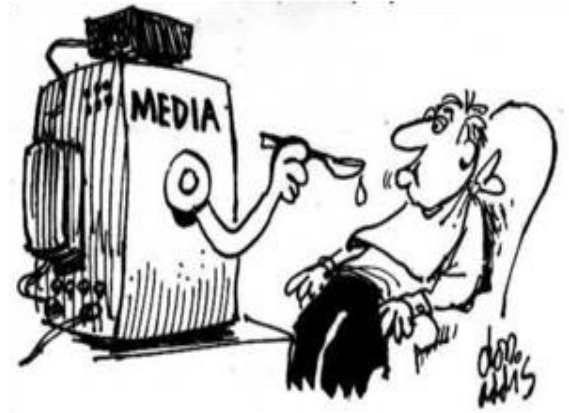
- ◉ PEM Fuel Cells: Frano Barbir, ELSEVIER.
- ◉ Fuel Cell Explained: Larmie & Dicks, WILEY.
- ◉ Fuel Cell Fundamentals: O'hayre, Cha, et al., WILEY.



CLASS FORMAT



- Senior & Graduate Level Expectations
- Weekly PowerPoint
 - *MUCHO INFORMATION!!*
 - *In-Class and Outside Learning*
- Outside Readings & Research Learning
- Grading
 - *Quizzes / Lab Reports: 20%*
 - *Mid-Term: 30%*
 - *Final Team Project: 50%*
- Spoon Fed! Don't Think So...



LAB/PROJECT TEAMS

TEAM	
1	Agrawal, Chowdhury, Danenberg
2	Habermass, Ramesh, McInerney
3	Nori, Sawyer, Sharpe
4	Su, Thompson, Tyree



WEEK #2 TUESDAY-ASSIGNMENT

- ⦿ Review Chapter 1 and Outside Literature, compare and contrast low temperature PEM (LTPEM) fuel cell per assignment below.
- ⦿ Each group will provide class with 15 minutes PP presentation (max 10 slides). Send PP to me by 11:00 PM Monday and I will provide handouts for class.
- ⦿ Be sure to include technology history, basic operations & chemical reactions, temperatures, applications, limitations, and all other relevant comparison with LTPEM fuel cells.
- ⦿ Group #1: Alkaline FC, #2: Solid Oxide FC, #3: Phosphoric Acid FC, #4: Molten Carbonate FC.

OVERVIEW

- ⦿ Environment & Global Warming
- ⦿ Fuel Cell History & Definition
- ⦿ Fuel Cell Operations
- ⦿ Fuel Cell Construction
- ⦿ Fuel Cell Types and Applications



EDUCATIONAL OBJECTIVES

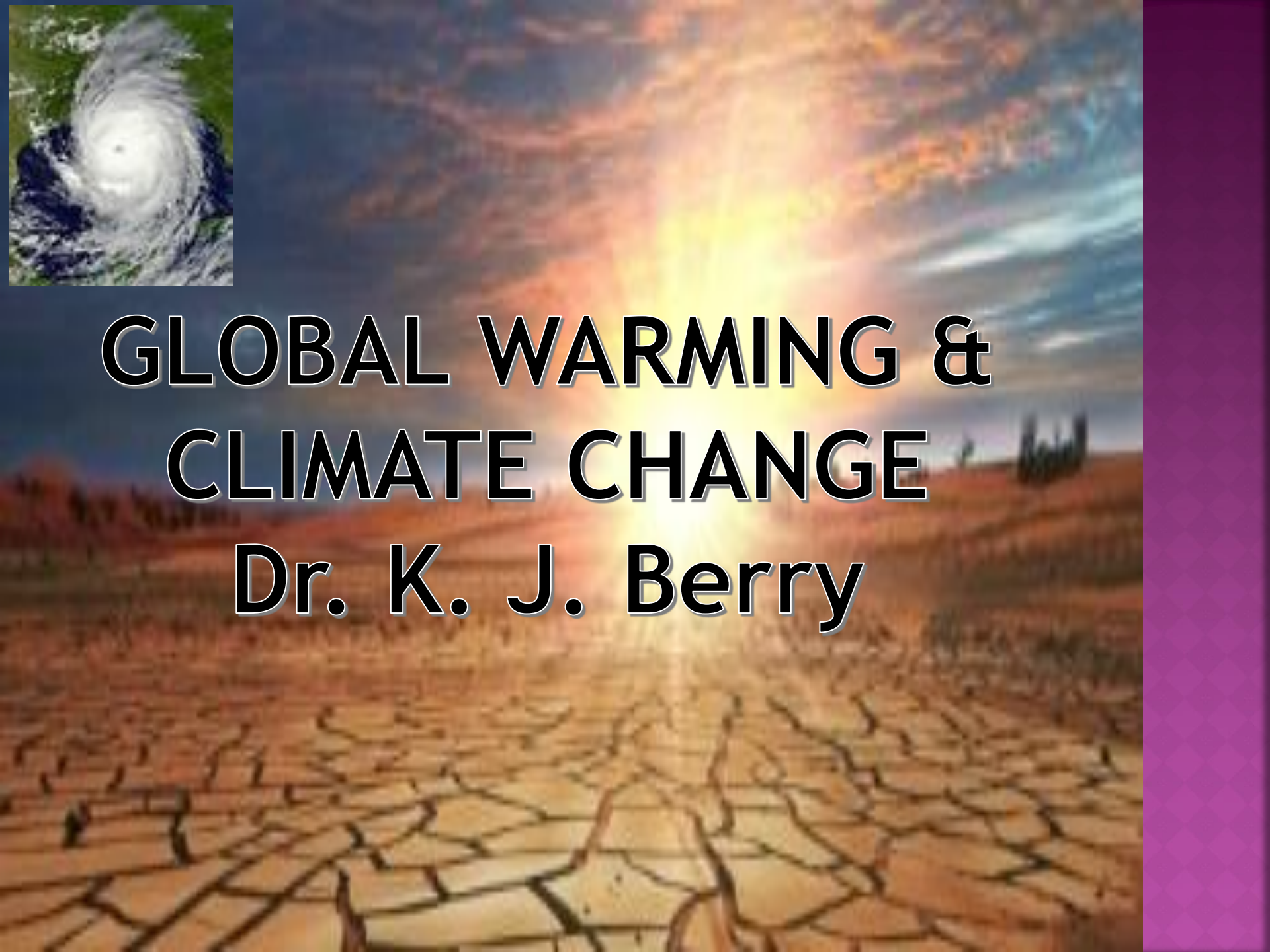
○ UNDERSTAND:

- Primary causes of **Climate Change** and impact for Future Generations.
- Basic fuel cell chemistry and operations, and fuel cell power systems and hardware.
- Fuel cell type differences and applications.
- Equations required to model and to simulate PEM fuel cells.
- How the '**hybrid**' fuel cell infrastructure "**IS**" the bridge to an energy secure sustainable future and is a technology to mitigate the impact of **Climate Change** .



GLOBAL WARMING & CLIMATE CHANGE

Dr. K. J. Berry



Statement of FACTS (UN 2019)



- **In last 50 years:**

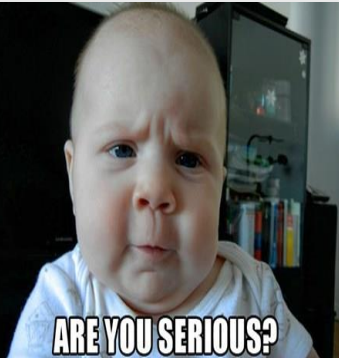
- Human population has doubled
- Global economy has grown 4X
- Global trade has grown 10X
- Driving up demands for energy and materials to keep up



- **Keep pace with this staggering growth, CO2 emissions are 150X higher than 1850.**
 - **Daily race to feed, clothe, heat and cool 7.5 billion generates huge amounts of CO2**
- **Each day in India 1,000 more cars appear adding to smog and health issues.**
- **UN says 1 million plant & animal species on verge of extinction linked to human activity.**
- **Since 1850's global temps rose 2.2F resulting in warmer oceans and will cause the collapse of commercial fishing industry and increased CO2 means less oxygen to breath.**



ENERGY AND THE ENVIRONMENT: *The Human Element ?...*



GLOBAL WARMING

- Most climate scientists concur that an increase in man-made emissions of **GREENHOUSE GASES** is contributing to an intensification of the **GREENHOUSE EFFECT**.
- Global warming refers to the increase in Earth's temperature above that caused by the **NATURAL GREENHOUSE EFFECT** as a result of the addition of anthropogenic (man-made) greenhouse gases and certain particles.
- It's a process by which **ABSORPTION** and **EMISSION** of IR radiation by atmospheric gases warm a planet's surface

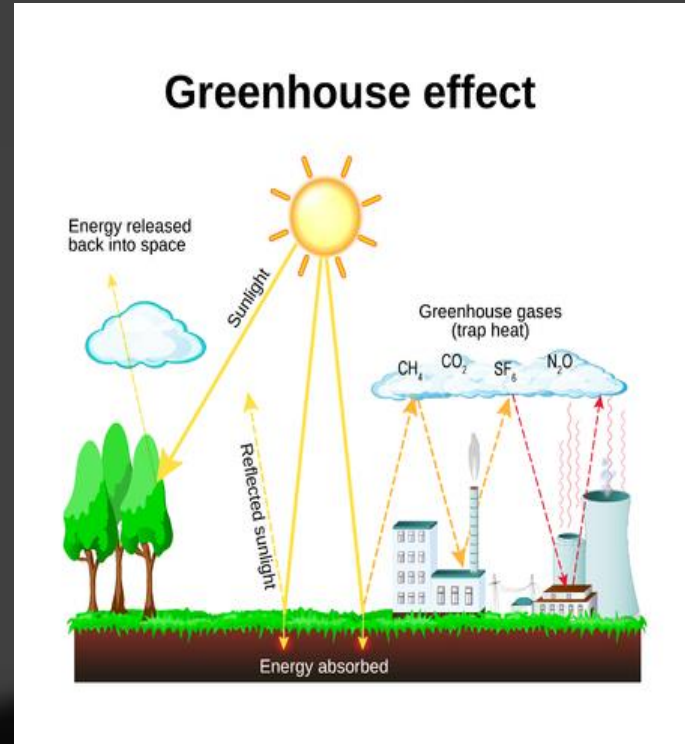




NATURAL GREENHOUSE EFFECT

The **NATURAL GREENHOUSE EFFECT** is the process by which gasses normally contained in the atmosphere, such as CO_2 and water vapor (H_2O), “*trap*” a portion of the Sun’s energy in the form of infrared (**IR**) radiation.

As a result, Earth’s temperature is high enough to support life as we know it.



A VICIOUS CIRCLE: GREENHOUSE EFFECT

- Addition of greenhouse gases into the atmosphere causes more water to evaporate (*extreme weather*).
- Water vapor is also a greenhouse gas; this causes more evaporation yet.
- Polar Ice Melting

- **Land and water are less reflective than ice.** Ice melting causes more sunlight to be **ABSORBED**, heating the earth and causing more ice to melt.



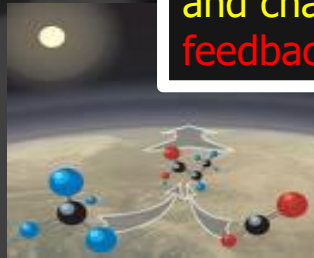
Ancient Sunlight vs Current Sunlight



GREENHOUSE GASES (MAN MADE)

- Anthropogenic greenhouse gases include Fluorine, CO_2 (Carbon Dioxide), CH_4 (methane), **H_2O Water Vapor**, and Nitrous Oxide. These gases, along with certain naturally occurring greenhouse gases, contribute to the greenhouse effect on Earth but through different mechanisms.

Water Vapor is the most important naturally occurring GHG. Human activities do not directly influence the amount of water vapor to any significant degree. However, the amount of water vapor in the atmosphere changes with temperature, and changes in water vapor are considered a **feedback** in the climate system.





The Melting of GREENLAND: July '19 *Is it REAL—SHOW ME?*



- **ARCTIC ICE**

- **1984:** 3,140,000 sq. km
- **TODAY:** 116,000 sq. km

- **Western Canadian glaciers** are projected to lose **85% of their volume by 2100**
- Glaciers and ice caps in Canadian Arctic will **lose 18% of total mass by 2100** and will be important contributors to global sea-level rise



11 BILLION TONS: 24 HOURS

Fuel Cells: Pathway to

WORLD WIDE CLIMATE STRIKE: 2019



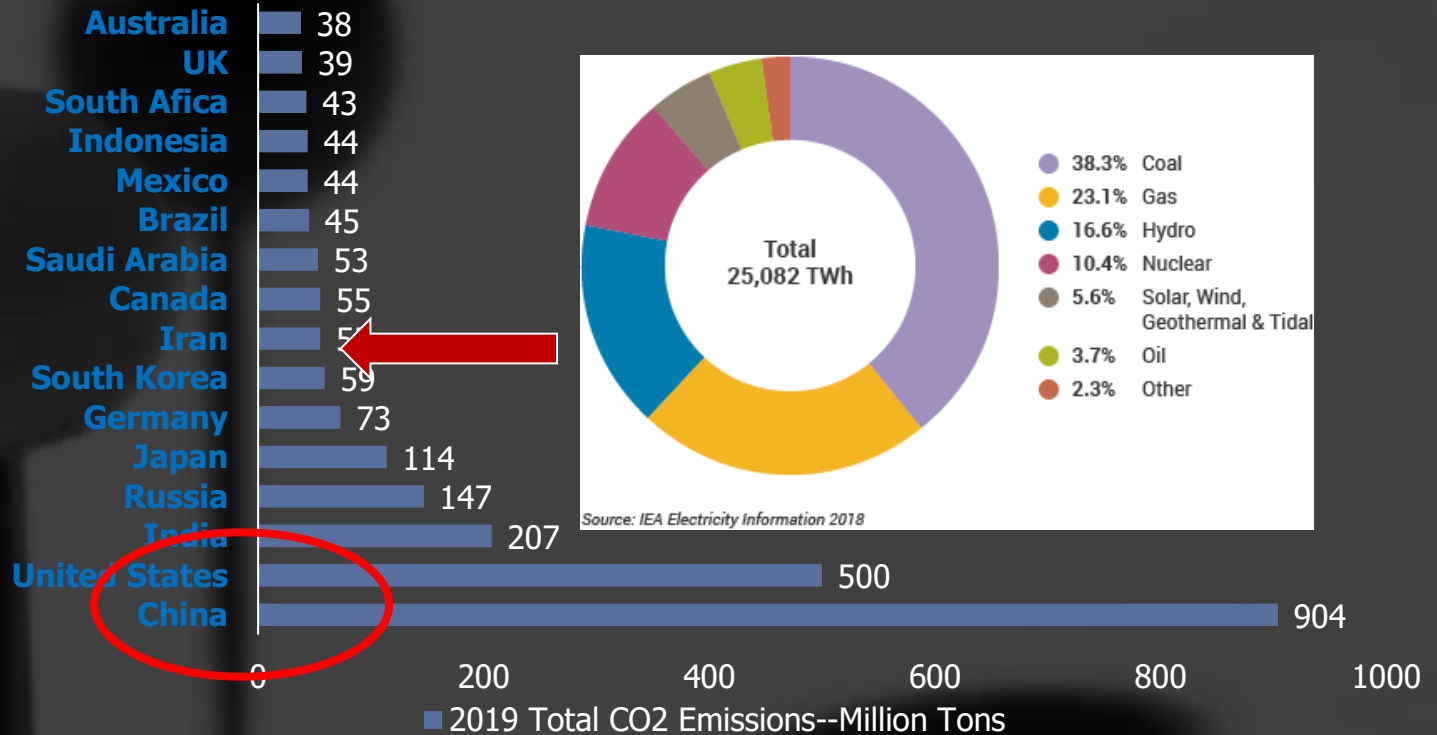
Global Climate Strike: September
Posted by 350.org
72,189 Views

CO₂ CONCENTRATIONS

With the start of the Industrial Revolution 200 years ago, people began to combust fossil fuels to provide energy for industrial processes and began releasing much larger quantities of CO₂ into the atmosphere than in previous times.

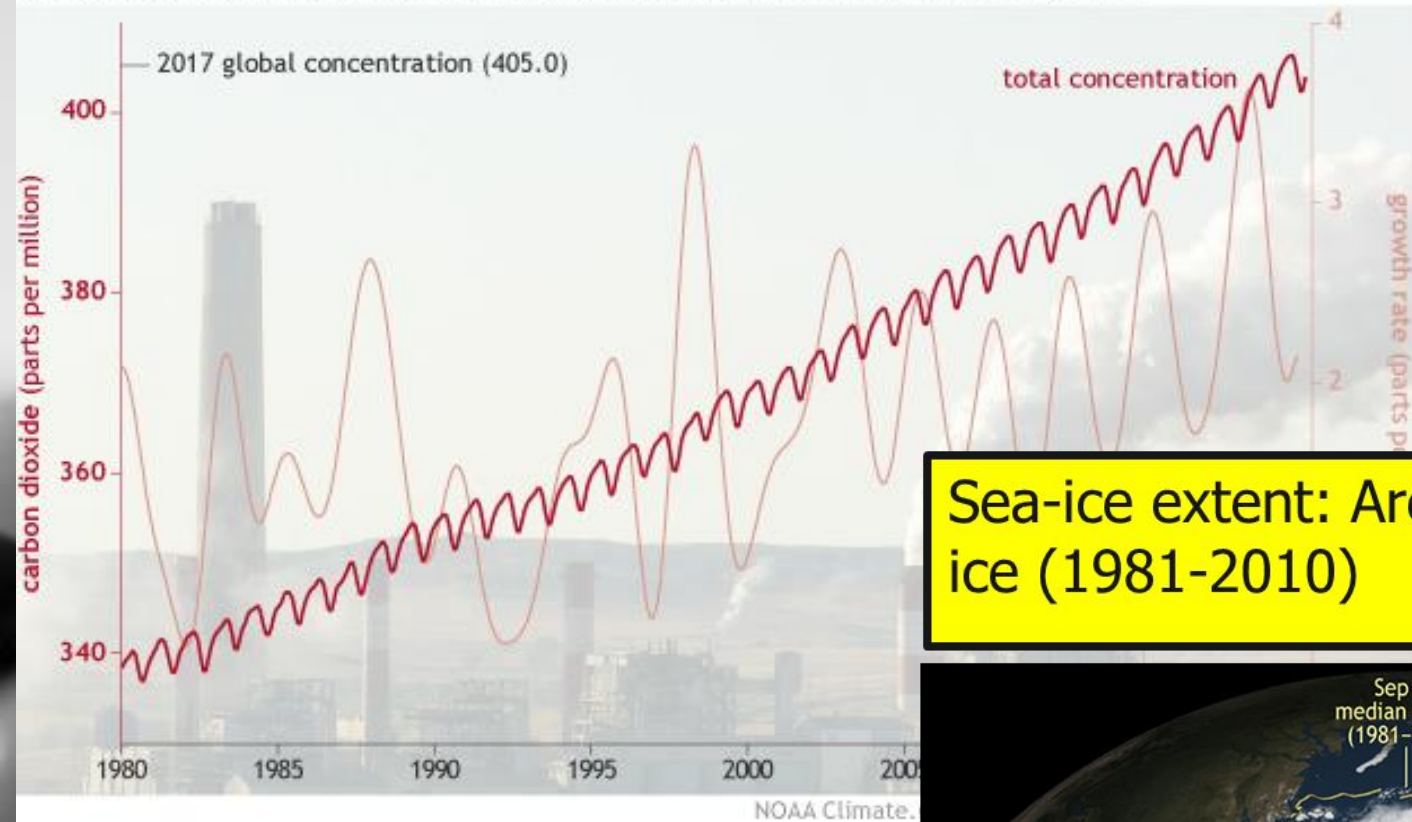


2019 Global CO2 *Total* Emissions

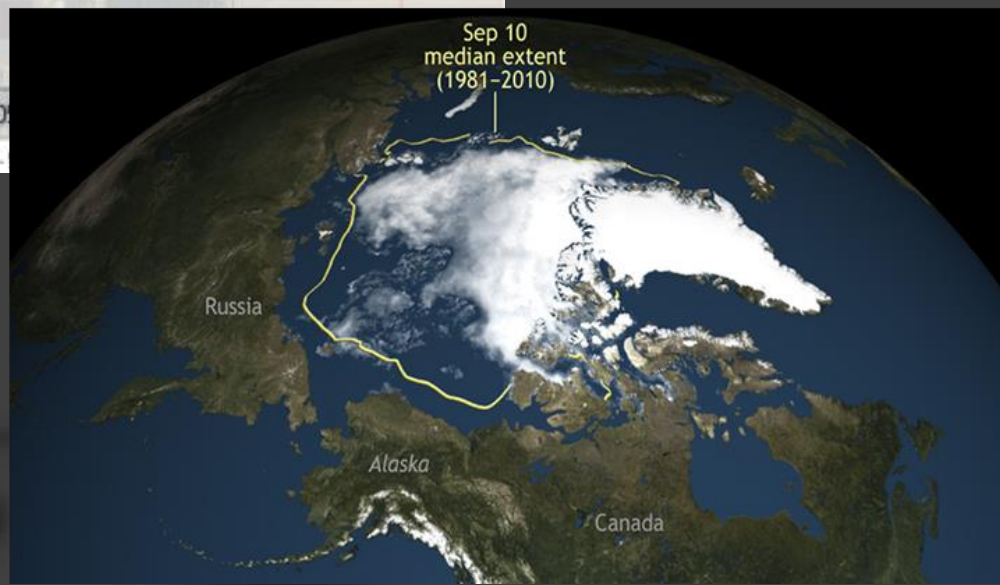


<http://worldpopulationreview.com/countries/co2-emissions-by-country/>

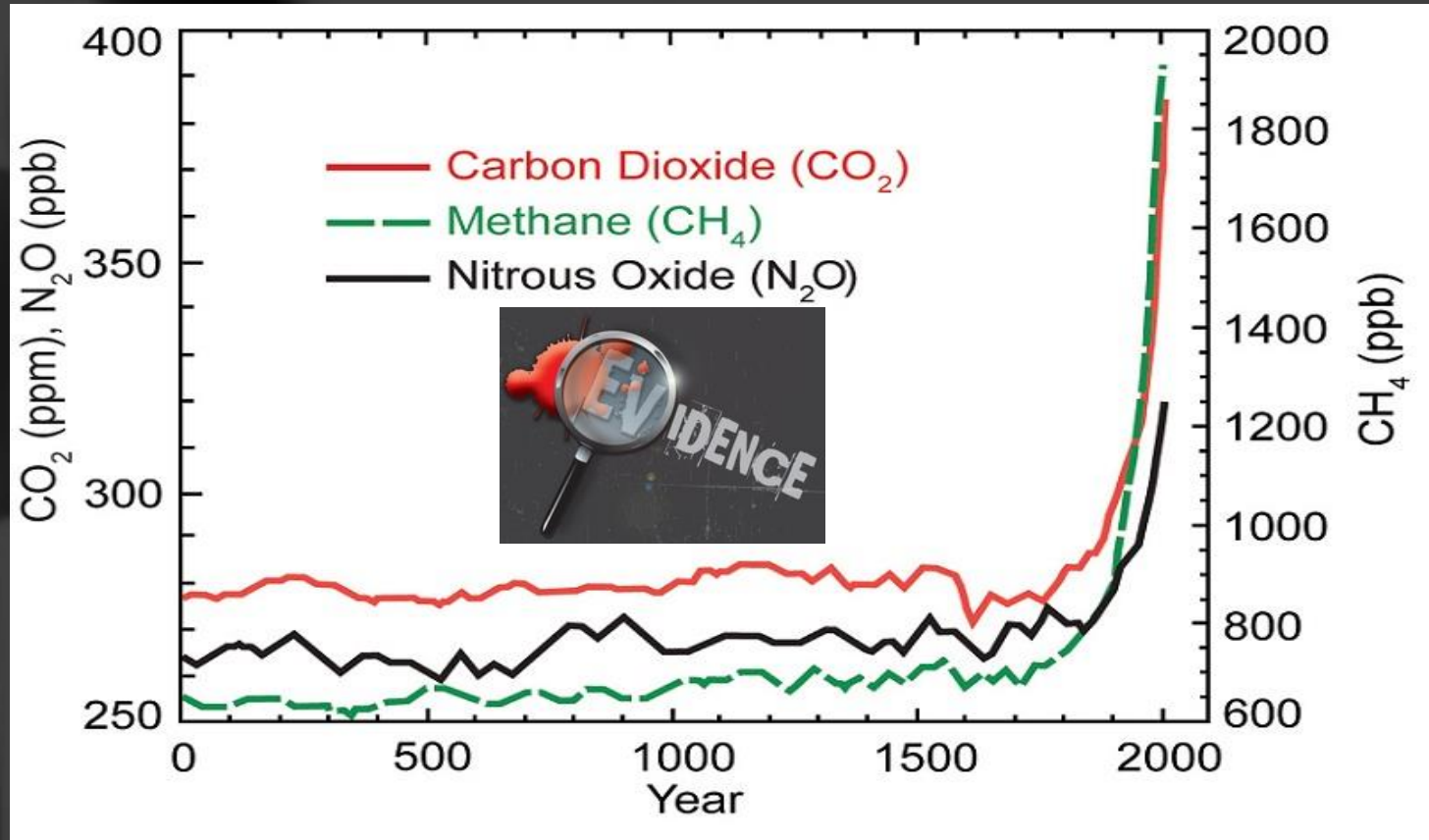
GLOBAL ATMOSPHERIC CARBON DIOXIDE SETS NEW RECORD HIGH IN 2017



Sea-ice extent: Area of sea with ice (1981-2010)



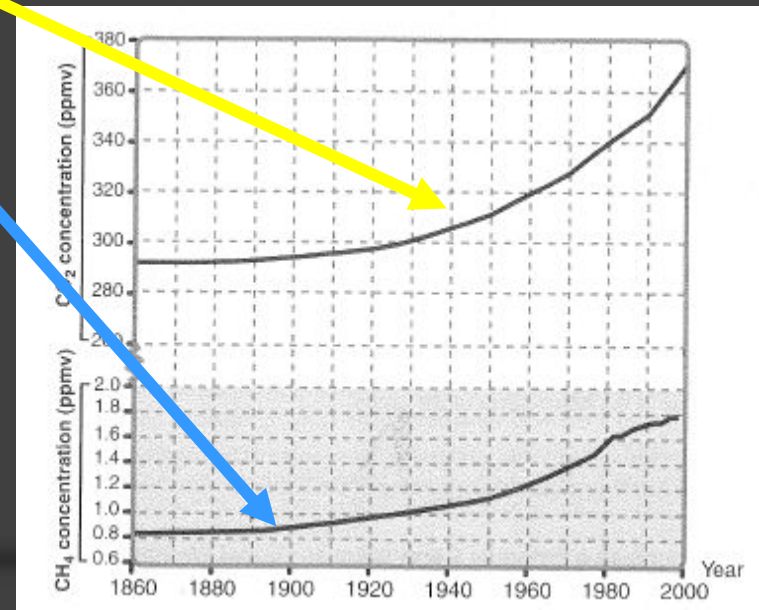
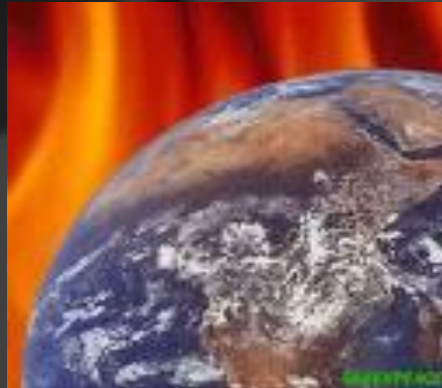
Greenhouse Gas Concentrations in the atmosphere over the last 2,000 years



<https://archive.epa.gov/epa/climate-change-science/causes-climate-change.html>

EVIDENCE OF GLOBAL WARMING

- Since the 1860s, the concentration of **primary greenhouse gases (CH₄, CO₂, and N₂O)** in the lower atmosphere has increased by **143%**, **30%**, and **14%**, respectively.

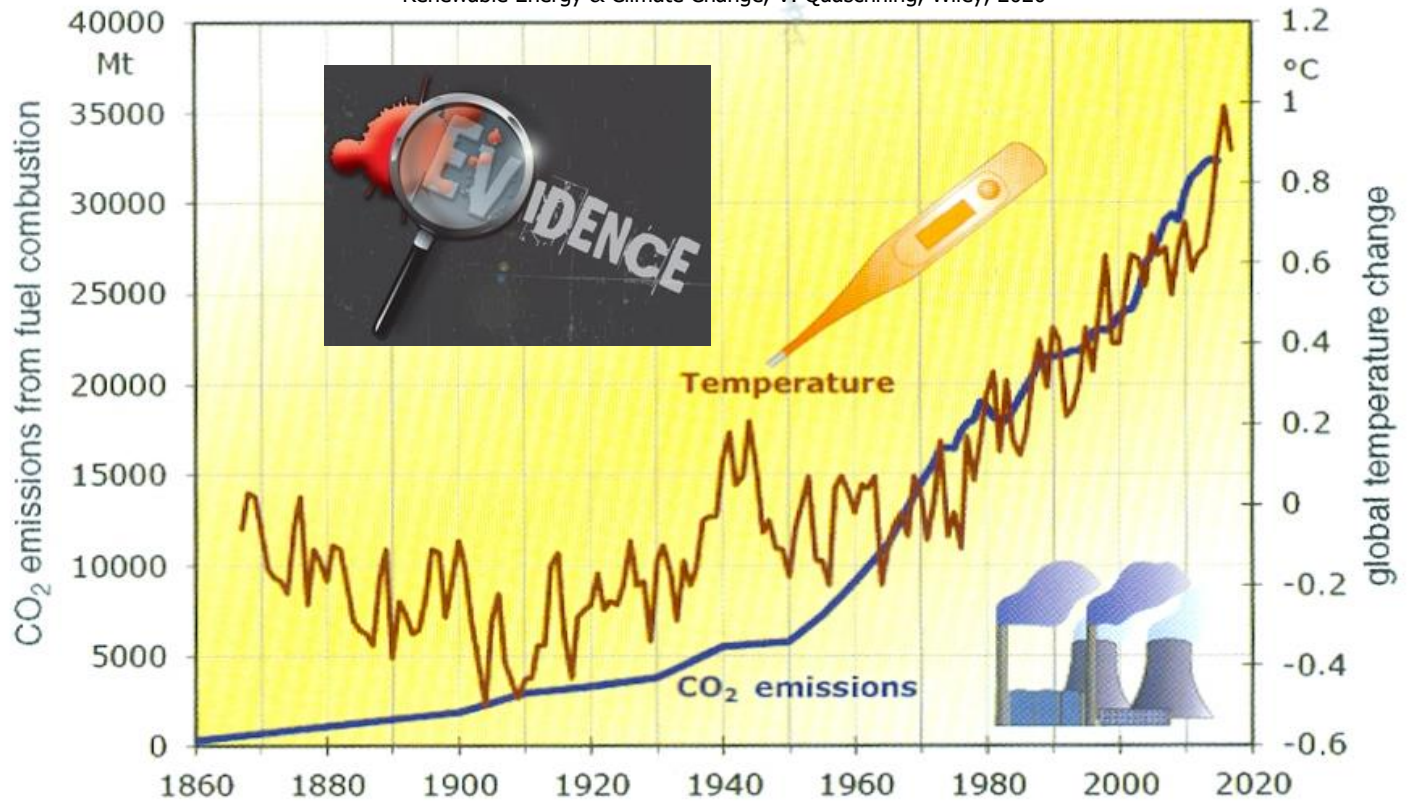


Source: R. O'hayre, S.-W. Cha, W. Colella, F.B. Prinz, "Fuel Cell Fundamentals," Wiley, 2006

Temperature and CO2 Increase Since 1860

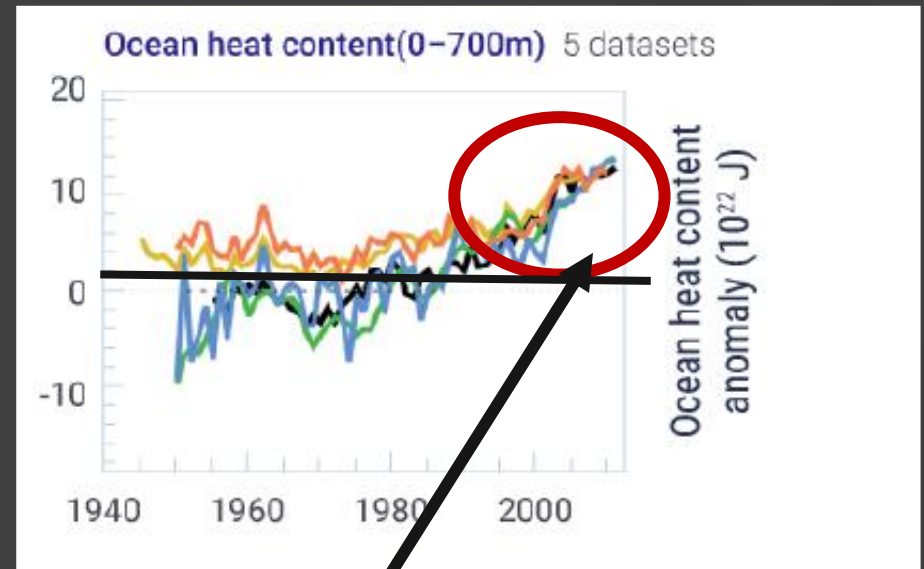
NASA, IEA

Renewable Energy & Climate Change, V. Quaschnig, Wiley, 2020



Ocean Global Warming 0-700 Meters

- Increasing ocean 'heat content' (absorbed heat that has been stored in the ocean) accounts for about 90% of the energy cumulated from 1971-2010.
- The accumulation of energy is "strong evidence" of excess energy in the Earth system, with less energy leaving than entering.
- Oceans 'absorbs' excess CO₂ from atmosphere, increasing acidity—impacting coral reef death & extinct species.



1×10^{12} Tera Joules (TJ) Energy Increase over 40 years \rightarrow 793TW (Tera Watts)

World Electric Generation 2020; 2.86 TW per year (25,082 TWh)

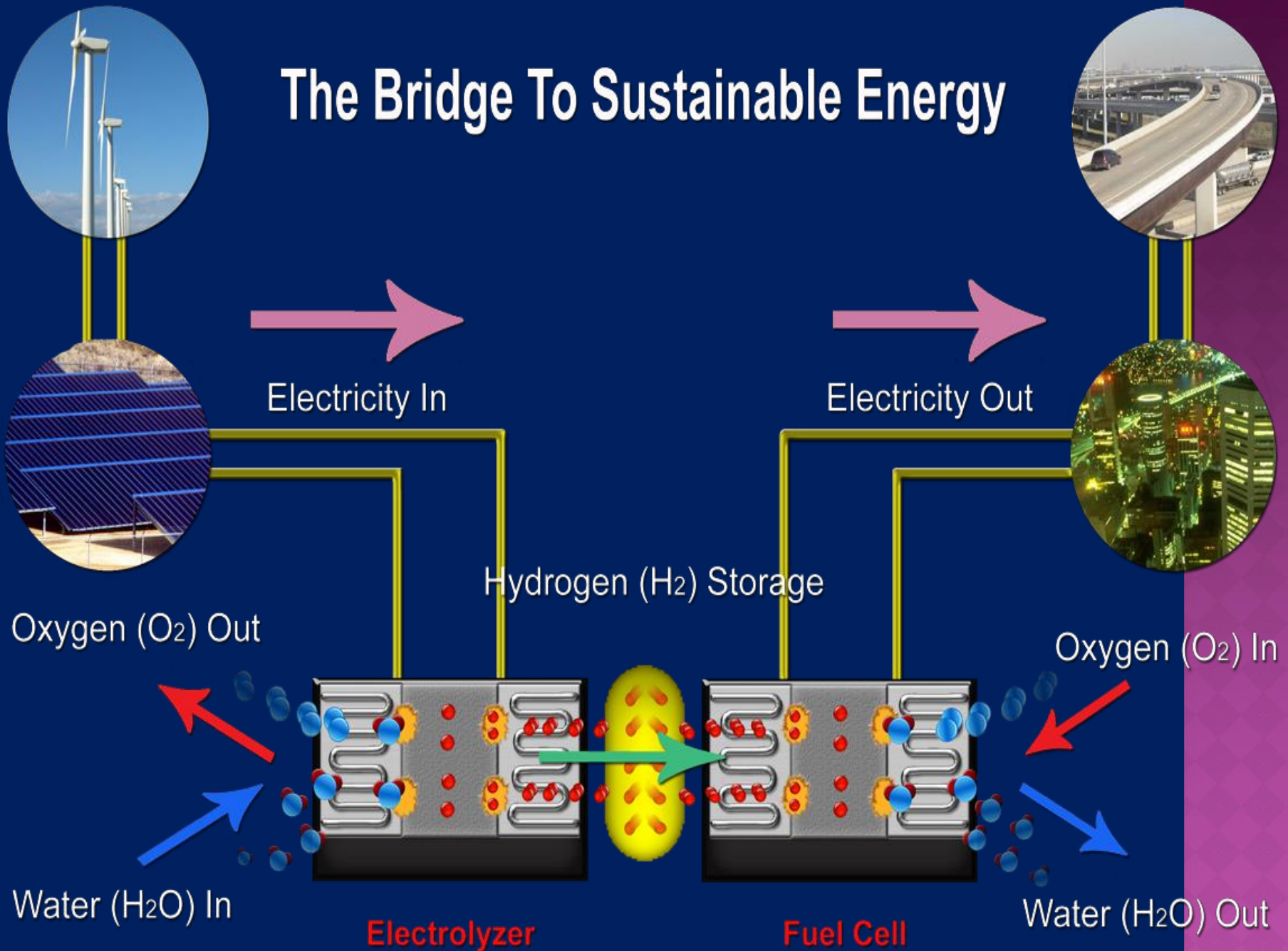
World Electric Generation Requires 277 Years

CLIMATE CHANGE

Climate scientists are now concerned that these natural fluctuations are being overtaken by **warm-side temperature changes induced by human activity**, specifically the **combustion of fossil fuels** that release **gasses and particles** that have a warming effect on the atmosphere and producing extreme weather i.e. **Hurricanes IAN 2022, Harvey, Irma, Dorian, and Maria.**



The Bridge To Sustainable Energy



THE FUTURE IS NOW!

- Laptop computers
- Cell phones, cordless phones
- Portable chargers for rechargeable cell phones
- Personal digital assistance (PDAs)
- Many military applications
- VCD/DVD players, MP3
- digital cameras
- Portable electronics
- Other portable consumer products
- MEMS devices and Sensors
- Emergency lighting
- Power tools
- DRONES



Fuel Cell Drone:
12 Minutes (Battery) to 70
Minutes Hydrogen

