


# The Quest: V & VI

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# Rebirth of Renewables

## Renewable Technologies:

- Wind: fastest growing; usually clustered in “farms”
  - Direct Sunlight: captured by PV cells or mirrors to concentrate the light
  - Biofuels: ethanol, biodiesel, advanced(algae, cellulose); subs for gas/diesel
  - Biomass: wood/plant material; burned in a power plant or for heating/cooking
  - Geothermal: hot water/steam pumped from the earth to spin a turbine
  - Hydropower: difficult to build; falling water drives turbines
  - Passive Solar: “green building”; use natural light
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# Rebirth of Renewables

- 1951: Paley Commission made by President Truman
  - Announced using solar energy to combat oil shortages during Korean War
- 1955: President Eisenhower declared another initiative for the development of solar energy
  - Again!! Not much happened
- 1970: Denis Hayes created Earth Day
  - 20 million Americans joined
  - Led to the creation of the Clean Air Act and the EPA by President Nixon



# Rebirth of Renewables

- 1973: Oil embargo
  - Showed everyone, including government, that energy is a major issue
- 1973: China's ag law called for solar and wind energy
- 1974: Start of implementing federal laws regarding solar energy and research
- 1975: 5000 people came to a solar energy conference during Ford's 2nd term
- Mid-Late 70s: two scholars wrote influential pieces regarding renewables vs. oil
  - Amory Lovins: article for Foreign Affairs ("soft" vs "hard" path of energy)
  - Denis Hayes: Rays of Hope: The Transition to a Post-Petroleum World
- 1977: President Jimmy Carter compares the nation's energy problems to preventing war
  - Coined it "Moral Equivalent of War" (MEOW)
  - Not well received by the public

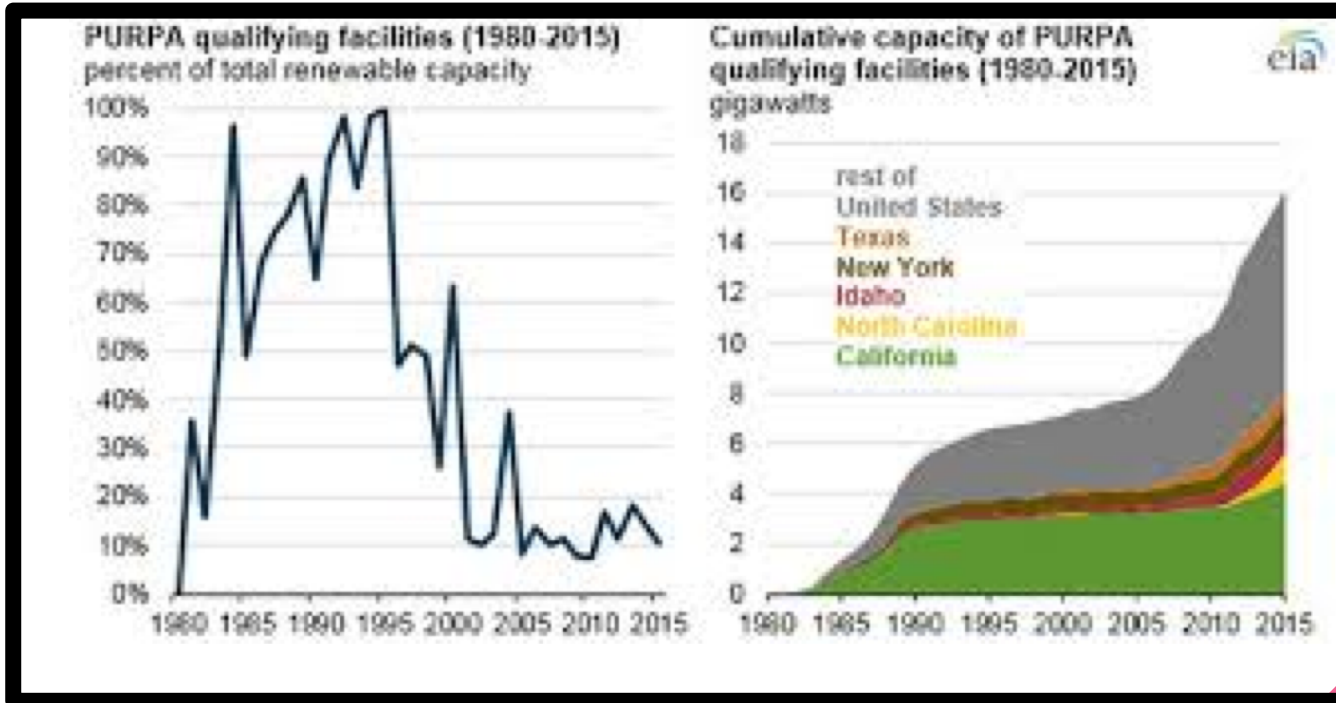
# Rebirth of Renewables

## “PURPA Machines”

- 1978: Public Utility Regulatory Policies Act
  - “Electric utilities were required to contract to buy the power output from what were called qualifying facilities (QFs)”
  - Compensation rate for generators was state-by-state basis (basically =MC of generator)
  - Created a market for electricity
  - Disrupted the natural monopoly that existed in the electric industry



# PURPA 1980 vs 2015



# Rebirth of Renewables

- Carter and James Schlesinger, former Director of CIA and Sec. of Def, form DOE
- June 20, 1979: Jimmy Carter announced the U.S. would get 20% of its energy from solar by the year 2000
  - Promised \$1B in 1980 to boost the initiative for renewables
- This mindset already existed after fears over the future of oil
  - Arab oil embargo and Iranian Revolution
- Decades of failures and frustrations followed
  - In 2011, only 9% of US energy supply was renewable
  - Much of which was hydro and biomass (ethanol)



# Rebirth of Renewables

- 1979: Taichi Sakaiya augmented Japan's presence in solar
  - Japan's experience with semiconductors helped make PV viable
  - Huge gov't subsidies
- 1981: Reagan in office and opposes Carter's views on energy (optimist vs. pessimist)
- Reagan lobbied for more economical markets
  - Led by supply/demand
- Supported production of domestic oil and natural gas
  - Renewables was low on the priority list
- 1986: Oil surplus hit a low of \$10/barrel
  - Made solar almost irrelevant





# Rebirth of Renewables

- 1989: Germany opened it the Berlin Wall
  - Led to redesigning East Germany energy
  - Helped Germany become renewable energy leader for the decade following
- Green Party (Germany)
  - Opposed Reagan and nuclear policies (both weapons and energy)
  - Fear rooted from Chernobyl in 1986
- 1990: George H. W. Bush restored tax incentives for renewables
  - Revitalized the National Renewable Energy Laboratory (NREL)
- 1991: Feed-In-Law created by Hans-Josef Fell (Green Party)
  - Identical to PURPA from the U.S.
  - Subsidizing rates and spreading costs
  - Allows renewables (typical uncompetitive) to be competitive
- 1993: Wind turbines installed throughout Germany



# Rebirth of Renewables

- 1999: George W. Bush signed Renewable Portfolio Standards into law
  - Required a certain amount of energy to be from renewables
  - Set off Texas Wind Rush
- 2000: Green Party (Germany) pushed Renewable Energy Law
  - Technology-based rates (PV most preferred)
- 2004-08: Investments in “Clean-tech” soared until the Great Recession of ‘08
  - Renewables did not go extinct like in the 80s
- 2005: China introduced Renewable Energy Law
  - Focus on technology and knowledge; supported entrepreneurs
  - Grew economy; 70% of parts for construction must be domestic
- Obama used renewable energy as the driver out of the recession
- 2010: Renewables account for 17% of Germany’s energy consumption
- 2011: Bush’s RPS provision helped 37 states and D.C. to have a renewable RPS

# Science Experiment

- VCs vs Big Oil
  - VCs look to fund the “Googles” of the energy industry
  - Big Oil companies fund R&D to create the technologies
- Pressure from quarterly reports decreased private R&D
  - Most funding is federal
- Federal funding positively correlates with oil prices
  - Fun Fact: total energy R&D spent in '08=Last two weeks of spending on the Iraq War
- R&D is about the “experiment”
  - VCs stay away from experiments



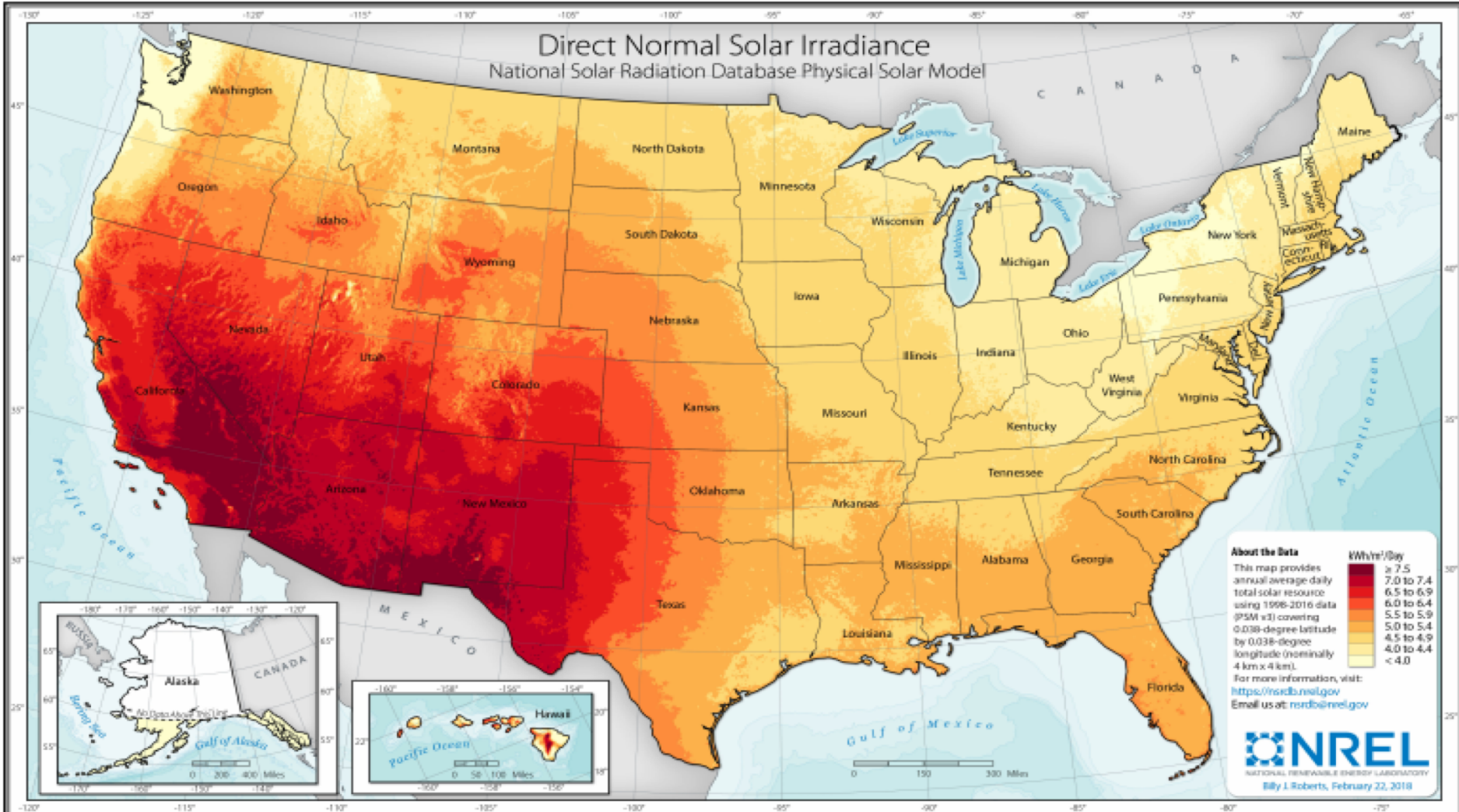
# Alchemy of Shining Light

- Einstein sparked the revolution of solar power
  - “On a Heuristic Point of View Concerning the Production and Transformation of Light”
  - Won Nobel Prize in 1922 for this paper
- Bell Labs created first solar cells in 1954
  - By using gallium, they were able to create the reaction described by Einstein
- Soviet’s Sputnik fuels Space Race in 1957
  - Nazi scientist, Hans Ziegler, convinced Navy to use solar panels for Vanguard satellite
- Three main markets for solar in the beginning: U.S. Gov’t, Oil industry, developing nations
  - Unanticipated black market (illegal marijuana) for PV panels
  - Big players: Solarex, ARCO, Solar Power Corp (Exxon), Suntech
- German Q-Cells cut costs by 50%
- First Solar cut costs by using thin-film tech
  - Founded by John Walton, son of Sam Walton
- Concentrated Solar (mirrors) to heat fluid for steam



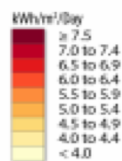
# Direct Normal Solar Irradiance

## National Solar Radiation Database Physical Solar Model



### About the Data

This map provides annual average daily total solar resource using 1998-2016 data (PSM v3) covering 0.038-degree latitude by 0.038-degree longitude (nominally 4 km x 4 km).



For more information, visit:  
<https://nsrdb.nrel.gov>  
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**NREL**  
NATIONAL RENEWABLE ENERGY LABORATORY

Billy J. Roberts, February 22, 2018

# Mystery of Wind

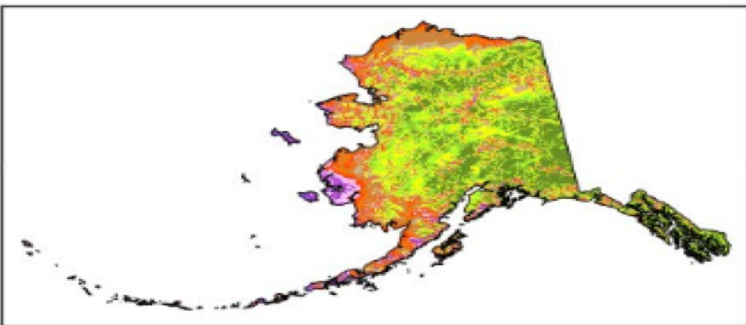
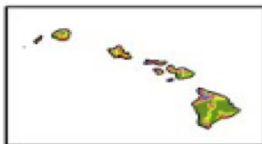
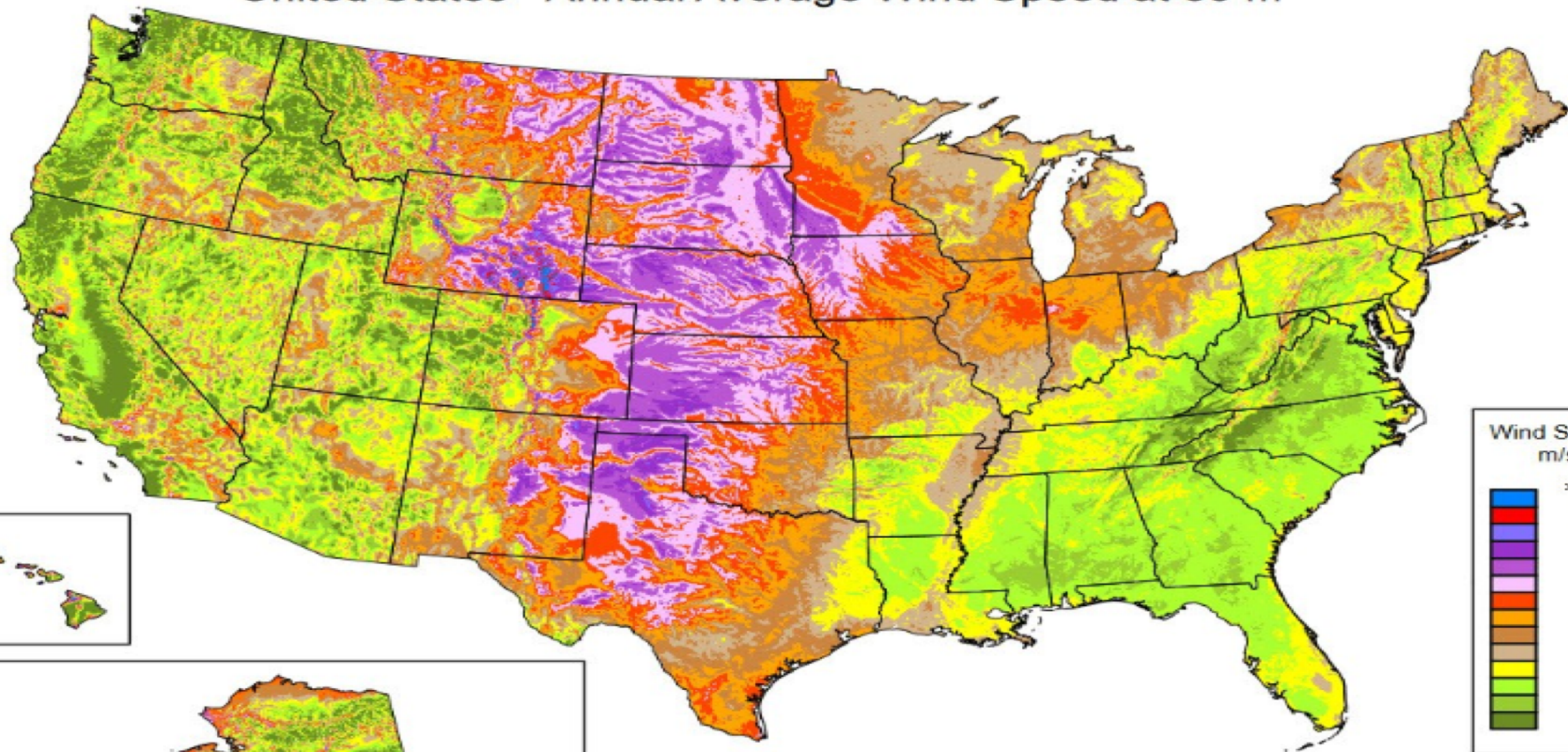
- Wind power in the United States has increased tenfold in a decade
  - But only 3% of total electricity generated
  - Ambitious prediction that it could increase to 22% of total electricity supply by 2030 (globally)
- Wind power in Germany has accounted for 60% of their renewable portfolio
- Charles Brush, Edison's rival, built a windmill for John D. Rockefeller in 1887
  - Powered his mansion
  - First time wind was practically used to generate electricity
- In 1941, Palmer Putnam built a 175ft windmill that fed into Central Vermont's grid
- California became "Saudi Arabia of wind"
  - Wind rush ended in the 90s; Jerry Brown no longer governor; tax credits disappeared.
  - 96% of US (90% of global) investment in wind was in Cali
- Oil crisis revamped the Danish research of wind power

# Mystery of Wind

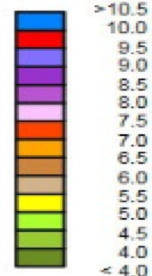
- Intermittency problem
  - Only generates electricity about 30-40% of the time
  - Wind peaks at night, demand peaks during the day
- Strong opposition to the aesthetics and noise pollution
- Offshore turbines can be as big as 6-7MW (compared to 3MW onshore)
  - Costs are almost 3x of onshore; protective equipment for cables/electronics



# United States - Annual Average Wind Speed at 80 m



Wind Speed  
m/s



Source: Wind resource estimates developed by AWS Truepower, LLC for windNavigator®. Web: <http://www.windnavigator.com> | <http://www.awstruepower.com>. Spatial resolution of wind resource data: 2.5 km. Projection: Albers Equal Area WGS84.




# The Fifth Fuel-Efficiency

- Global consensus to improve efficiency “C-change”
  - EU aims for 20% and Russia aims for 40% improvement in efficiency by 2020
- More efficient energy use means more efficient economy
  - Less energy per unit of GDP
- “Jieneng Jianpai!”
  - China’s 2006 initiative to “Save Energy, Cut Emissions”; pillar for economic development
- Airlines have researched jet fuel efficiencies in aircrafts
  - Significantly reduces operating costs



# Closing the Conservation Gap

- US consumes approx. 40% of total energy,  $\frac{3}{4}$  of electricity
    - Mainly space heating and cooling
  - 1970s: 91% of household electricity was consumed by 7 household utilities
    - Stoves, indoor lights, refrigerators, freezers, water heaters, AC, space heating
  - “Conservation Gap”: potential savings in energy efficiency
    - Many homeowners don’t know the potential of switching to energy efficient homes
  - Introduction of LEED (Leadership in Energy and Environmental Design)
    - Methodology of a set of guidelines for new buildings for both energy and environmental goals
  - “Mottainai” (Too Precious to Waste)
    - Basically, Japan’s cultural belief in sustainability
  - Smart Grids
    - More efficient way to get from generation to consumption
    - Find how investments to reduce MW must be the same as producing MW
    - Smart meter: detect peaks and reduce usage in the home
- 

# Big Take Aways

- Renewable future depends on geopolitical and domestic politics
- Biggest roadblock for renewables is cost
- Renewables are mostly for peak demand periods as marginal generators
  - Very very difficult to have as baseload
- Efficiency is a win-win; more efficient-less cost-less emissions
- Relationship between energy and technology will enable for greater efficiency and smarter ways to consume and produce energy



# Carbohydrate Man


- May, 1978: Admiral Rickover calls a researcher proclaiming wood as the fuel of the future
  - “Wood - Fuel of the Future. Wood! ..... Fuel of the Future!”
  - Seeing that the nation had just gone through an oil crisis and potentially another one in the years to come, Admiral Rickover sought that the future was about “growing fuels”
  - The best known growing fuel today is ethanol
  - Some may argue that there are better choices, such as biofuel
- Biofuels suggest the possibility of a new era
  - Only in the last decade has biology been applied systematically to energy
  - Has produced a large political swell in the United States
  - The air force is currently experimenting with green jet fuel
    - Goal is to have half of its liquid fuels to be Biodiesel by 2020

# Carbohydrate Man


- U.S. has mandated that the amount of biofuels blended with transportation fuel must almost triple from roughly 1 million barrels per day (2011) to 2.35 million barrels per day by 2022
- Brazil already uses ethanol as 40-60% of automotive motor fuel
- Out with the Hydrocarbon Man (20th Century) and in with the Carbohydrate Man (21st Century)
  - Agri-Dollars vs. Petro Dollars
  - In order for ethanol to continue growth in the United States, it must overcome the “wall” that is higher concentrations of ethanol harming engines




# Carbohydrate Man

- Henry Ford was keen on ethanol in an attempt to tie both the farmer and the city together
    - “If we industrialists want the American farmer to be our customer, we must find a way to be his customer”
    - Obstacle was that gallon of alcohol carried a \$2.08/gal tax that was imposed as a revenue measure during the Civil War
  - 1906: President Theodore Roosevelt eliminates the alcohol tax
    - Demand rose significantly and created the great race against gasoline as the “fuel of the future”
  - Prohibition restricted the use of alcohol fuels
    - Regardless if it was consumed as a drink or used as a fuel it was illegal
    - 1933: President Franklin Roosevelt repeals the 21st Amendment
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# Carbohydrate Man


- 1977: President Jimmy Carter launches his National Energy Plan
    - Attention was turned to ethanol through political support
    - Archer Daniels Midland (ADM) became the biggest producer of ethanol in the United States
  - 1981: Already 10,000 gas stations were selling gasohol (ethanol)
  - 1986: Agricultural Department dismisses gasohol as a very inefficient means of increasing more farm income
  - 1990: Clean Air Act Amendment required U.S. gasoline supply to include extra oxygen in an attempt to improve combustion and reduce pollution
    - Ethanol returned back on the rise under a new name “E10”
    - E10 - 90% gasoline, 10% ethanol
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# Carbohydrate Man


- September 11, 2001: terrorist attack provided a further impetus for ethanol
    - Provided as a temporary alternative to the oils of the middle east
  - Energy Policy Act of 2005: Banned MTBE (ethanol's major competitor)
    - Required 500,000 barrels per day of ethanol in the motor fuel supply by 2012
    - Affirmed a \$0.51/gal tax credit to incentivize additional supply
    - Tariff on Brazilian ethanol remained in place
  - 2005: After hurricanes Katrina and Rita knock out oil supply in the gulf, gas prices rise and create a huge political storm
    - President George W. Bush would go on to mention in his State of the Union Address that the U.S. was hooked on oil and needed to get off oil
    - Ethanol was now flowing in the mainstream
- 



# Carbohydrate Man

- Backlash against biofuels on environmental grounds has emerged
    - Centered on concerns for about the net carbon footprint of first-generation biofuels
    - Other concerns regarding water use and greenhouse emissions released from the soil
  - 2011: At the end of the year the tax credits for ethanol and biodiesel expire
    - Also expiring was the tariff placed on imported ethanol
    - Political support lost by Congress and the case for a “need” could no longer be made
  - The future of biofuels “The Holy Grail” is cellulosic ethanol
    - Dramatically capable of controlling the supply balance
    - Capable of significantly reducing carbon emissions
    - However, there exists a high cost of processing
  - Algae: highly efficient
    - On a per-acre basis, capable of producing 6 times as much as a corn farm
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# Internal Fire

- As emissions are a growing problem in cities around the world, concerns about climate change have arisen
    - New race to transform the auto fleet into cleaner vehicles that meet the price consumers are willing to pay
  - 1864: Herr Otto designs the internal combustion engine
    - Wins a gold medal at the 1867 Paris Exposition
    - Huge commercial success
  - 1890: Otto and Karl Benz found a German auto industry based on the internal combustion engine
  - 1893: First gasoline powered car was built in the United States
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# Internal Fire

- 1900: Thomas Edison concludes that the electric vehicle would be preferable to gasoline-powered cars
- 1904: Edison releases his “Type E battery”
  - Did not live up to the standards that he promised and thus he went back to the laboratory
- 1910: Edison releases the “Type A battery”
  - Capable of traveling 60 miles on a single charge
  - Took approximately 7 hours to recharge
- Ford’s Model T went on to become an instant success and by 1920 more than half the cars in the world were Model Ts.



# Internal Fire

- In the 1950's and '60s America was known as the land of the automobile
  - Oil Crisis of 1973 would change everything
    - Political outcry to regulate automobile fuel efficiency
- Regulations were able to save approximately 2 million barrels of oil per day
- 1980s: Chrysler releases the “minivan”, which increased the functionality of the modern day vehicle
- 1990: Ford releases the Ford Explorer and it became the most popular SUV in the world
  - SUV was 25% less fuel efficient than a new car, yet gas prices were very low at the time
  - Gasoline consumption saw a drastic increase of 50% between the years 1985 to 2003

# Internal Fire

- Energy Security and Independence Act of 2007
  - For the first time in 32 years, it raised fuel-efficiency standards to 35 MPG by 2020
  - Legislation needed to be signed into law by the President
  - Delivered to the White House via a Toyota Prius and Congressman were outraged
  - This incident resulted in sales of the Prius taking off and shifted the demand from SUV's to Hybrids




# The Great Electric Car Experiment

- 1948: Haagen-Smit discovers that emissions from the tailpipes of automobiles are the cause of smog in cities
- Oil had been dominant for a long time, but in 2010 the electric car concept began to take off
  - By 2010, the Obama Administration had already provided up to \$5 billion in grants and loan guarantees to battery makers in an effort to jump start the electric car boom
  - In the early 2000's, the electric car was not widely accepted by the public and sales were tanking
    - Toyota's all electric RAV4 sold roughly 5 vehicles per week
- With the bankruptcies of GM and Chrysler, the Obama Administration placed a large emphasis on advancing the electric car

# The Great Electric Experiment

- The emphasis drew interest by many entrepreneurs, such as AI Cocconi, who used lithium-ion battery cells to make the EV1 by GM travel 60 MPH in only 3.6 seconds
- Elon Musk and Martin Eberhard noticed that the electric car could not compete on the basis of economics
  - Go on to found Tesla, which would compete in an arena of style, performance, and hype
  - First Tesla delivered in 2008
  - 2009: Tesla wins a \$465 million loan guarantee from the U.S. government
  - June 2010: Tesla goes public
  - The Tesla Roadster was then released and could travel 0 to 60 in under 4 seconds, however it was priced at a starting price of \$109,000

# The Great Electric Car Experiment

- Backed by strong government incentives, the U.S. advanced battery industry is expanding rapidly
    - America is projected to host 40% of the world's advanced automotive batteries by 2015
    - The real challenge is charging the batteries
  - Concept of charging cars overnight, during hours of low demand
    - Movement to using wind and solar energies to charge vehicles
  - Several challenges for the growth of electric vehicles
    - The batteries need to be smaller and lighter, as well as charge more quickly and travel further on a single charge
    - Cost needs to come down substantially
    - Infrastructure needs to be changed in order to support the vehicles
    - Power Supply "What if everyone charges during peak demand?"
    - Low sound has raised concerns among visually impaired groups
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# The Great Electric Car Experiment

- The race for the “car of the future” is once again on
  - The true winner of this race will be the car that will not only be increasingly efficient, but a car that can also meet the tests of the environment, energy security, cost, and performance
  - Requires major advances in technology and multi-billion dollar investments
- To the future
  - It is almost certain that the transportation system of today will evolve significantly over the coming decades
  - Energy efficiency and lower emissions will continue to be major preoccupations
  - The internal combustion engine is unlikely to just “disappear”
  - The race is definitely on and the outcome will do much to define our energy world in the decades to come

