

Brightness → Luminosity → Magnitude

Absolute:

intrinsic brightness

Ex. 25W vs 100W light bulb



30 m away

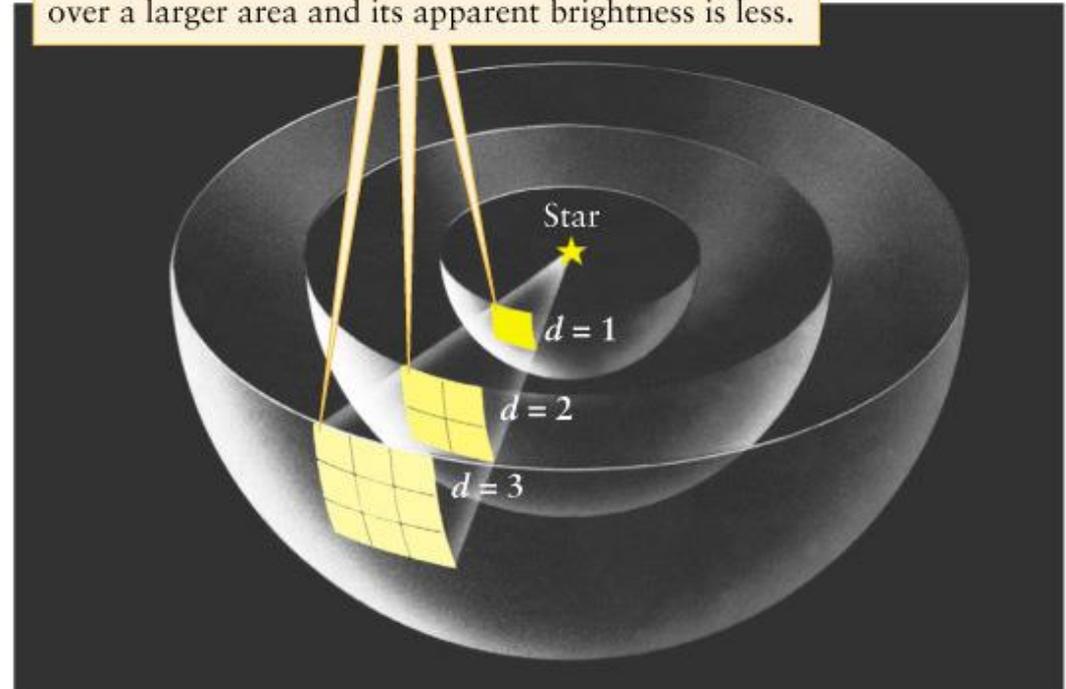


20 m away



10 m away

With greater distance from the star, its light is spread over a larger area and its apparent brightness is less.



Apparent:

observed brightness

depends on absolute brightness and how far away you are. Falls as $1/(\text{distance})^2$

Brightness → Luminosity → Magnitude Use for Stars

We will go over when discussing stars

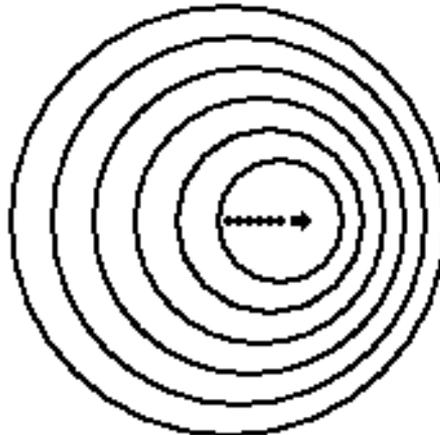
The Apparent brightness of a star is what we see by eye or in a telescopic image and it depends on the star's absolute brightness and how far away it is. One of the first things an astronomer needs to do is determine the distance to a star to then determine the absolute brightness after measuring the apparent brightness

Doppler Shift

Change in frequency of light due to relative motion of the source to the observer

- Red Shift - changes to lower frequency if source is moving away from observer
- Blue Shift - changes to higher frequency if source is moving towards observer
- Easy to measure even if object very far away. Mostly use Hydrogen spectrum for astronomy. Can measure a star's velocity to human running speed of 10 m/s

OBJECT RECEDING:
LONG RED WAVES



OBJECT APPROACHING:
SHORT BLUE WAVES

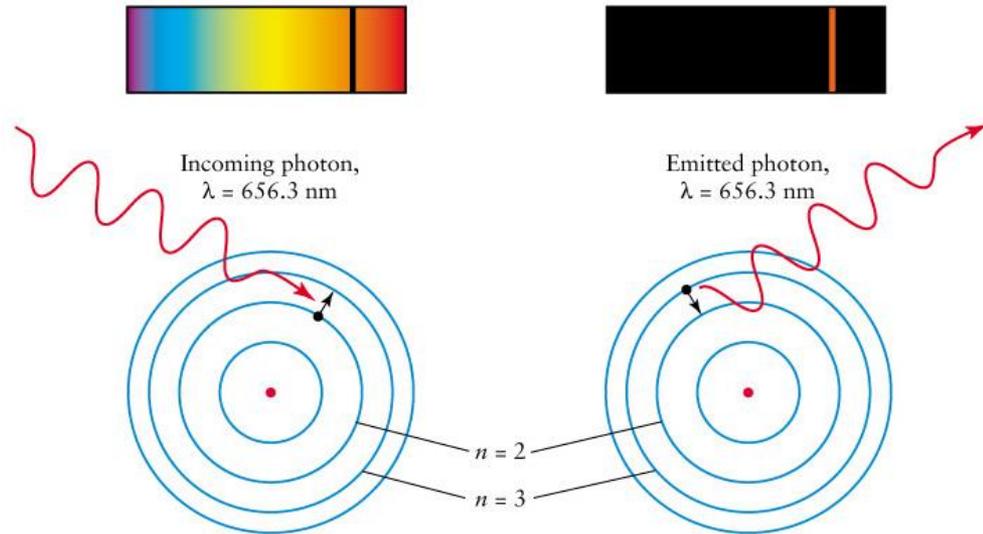
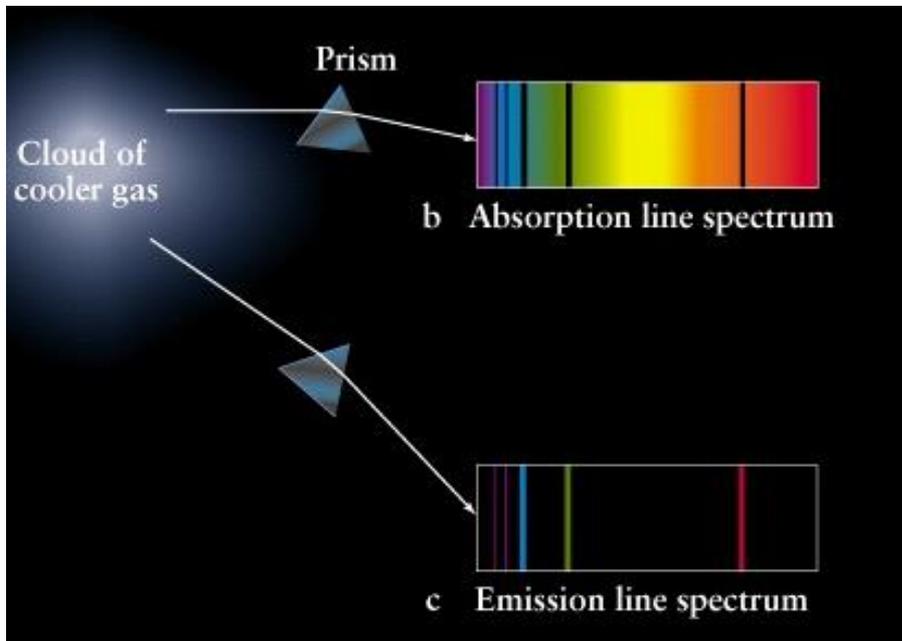


ABSORPTION OF LIGHT

- “clear” doesn’t absorb
- “opaque” absorbs
- depends on frequency. Glass is clear in the visible but opaque in the infrared. Can cause greenhouse effect
- Microwave ovens work by operating at a frequency near a water absorption line
- atmosphere only clear in visible, radio, and part of infrared → impacts observing using telescopes
- Absorption in atmosphere of stars used to help determine some star properties

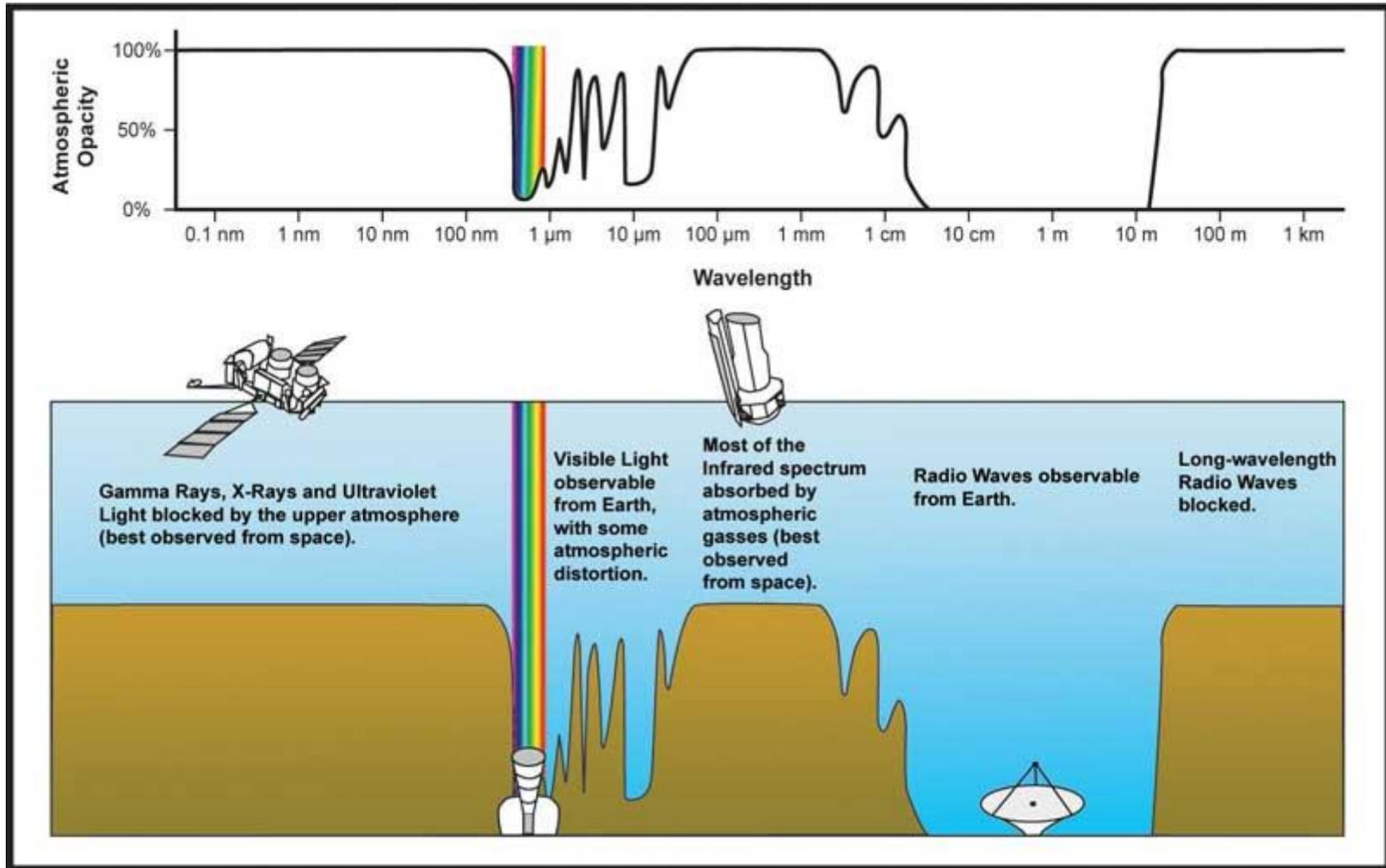
Absorption vs Emission

- Absorption means photon “disappears” in gas as causes transition in atom/molecule to higher energy. Emission is when light is given off ; an atomic transition is one example.

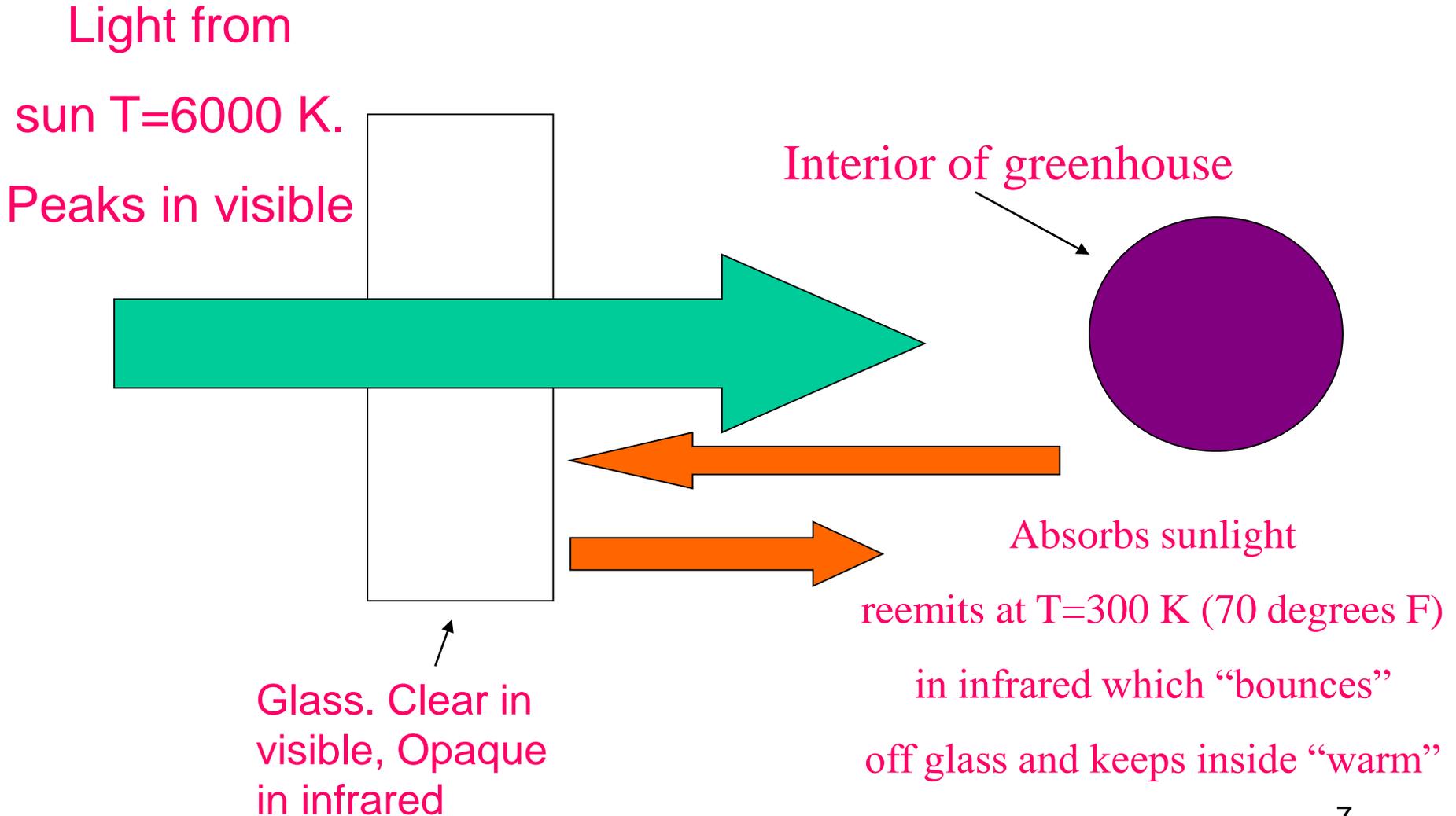


Absorption of Light in Atmosphere

100% means atmosphere completely absorbs. Atmosphere is mostly “clear” in visible, radio and parts of infrared spectrum: Earth-based telescopes
Poor transmission in X-ray, UV, and parts of IR: space-based telescopes

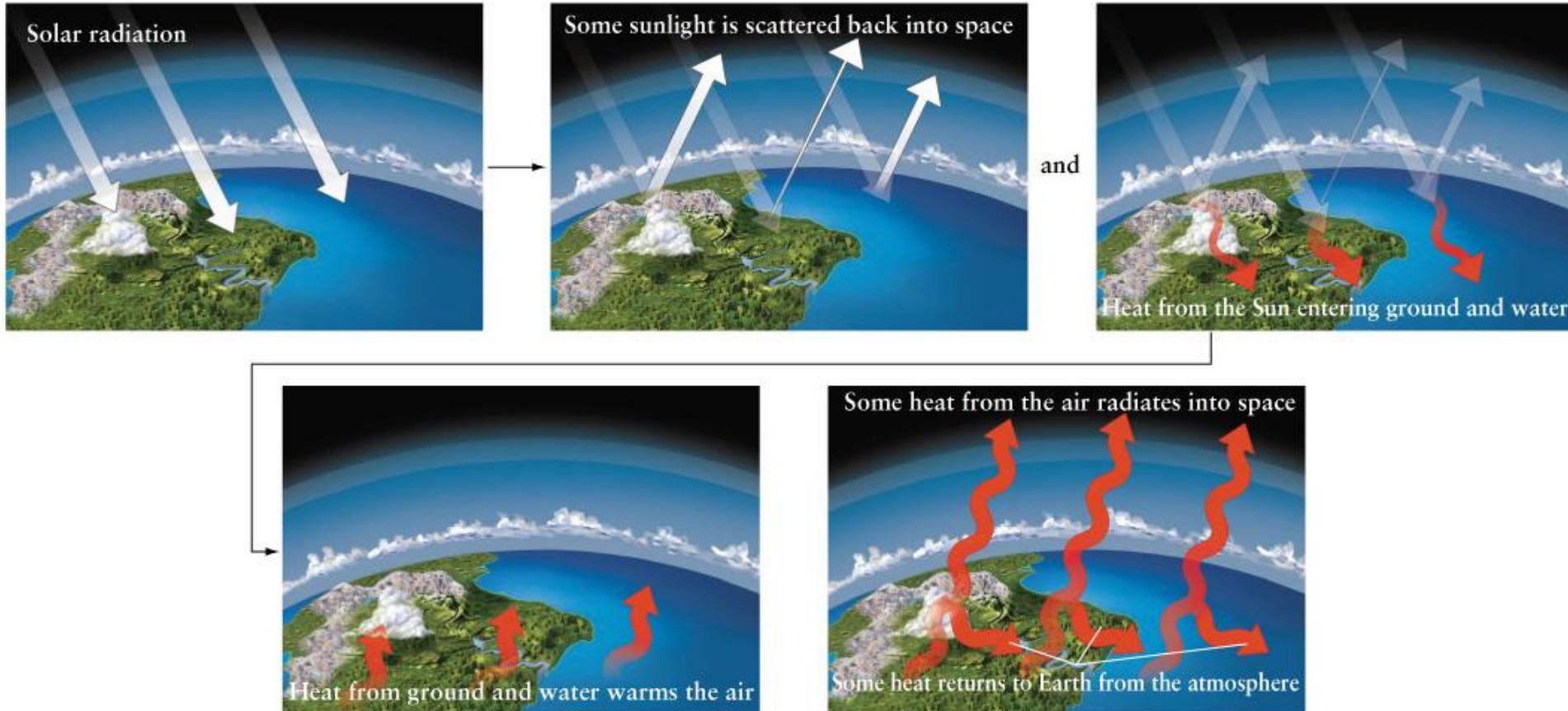


Greenhouse Effect



Greenhouse effect in Earth's Atmosphere

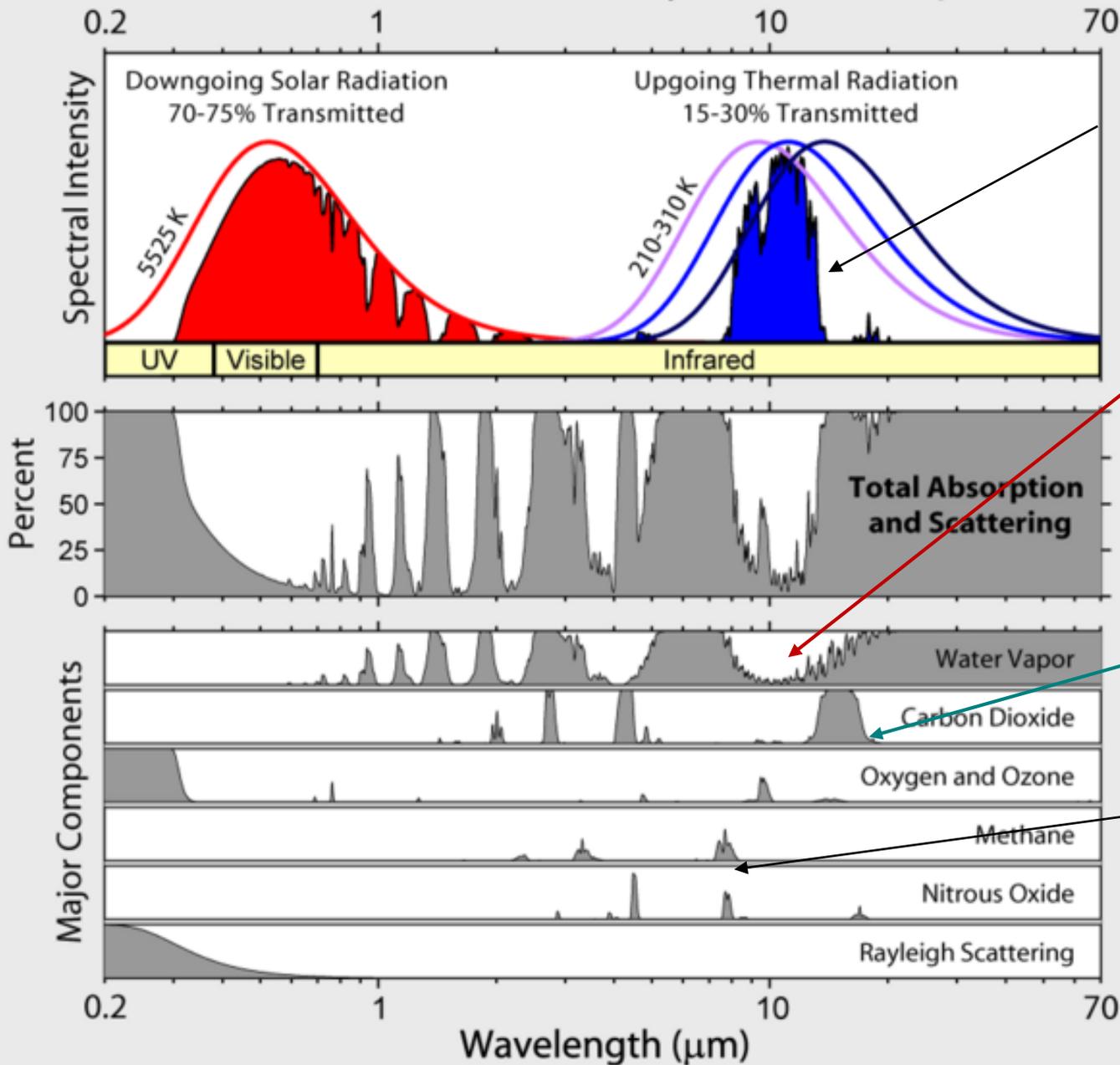
Some energy in Sun "trapped" by atmosphere and warms Earth (red lines going down)



Greenhouse Effect in Earth's Atmosphere

- Infrared absorption in atmosphere → greenhouse effect
- Primary “greenhouse gas” in atmosphere is water vapor; it helps to keep Earth's average temperature above freezing
- Water's absorption frequencies depend mostly on the mass of a Hydrogen atom (see link on course web page)
- Carbon Dioxide absorption frequencies depend on the masses of C and O atoms → different than water and “fill in” parts of the spectrum and so add to the absorption in the Infrared. Methane also absorbs in the IR – byproduct of production especially fracking. Increased levels in these two gases are increasing the Earth's temperature and we are already seeing significant and harmful effects

Radiation Transmitted by the Atmosphere



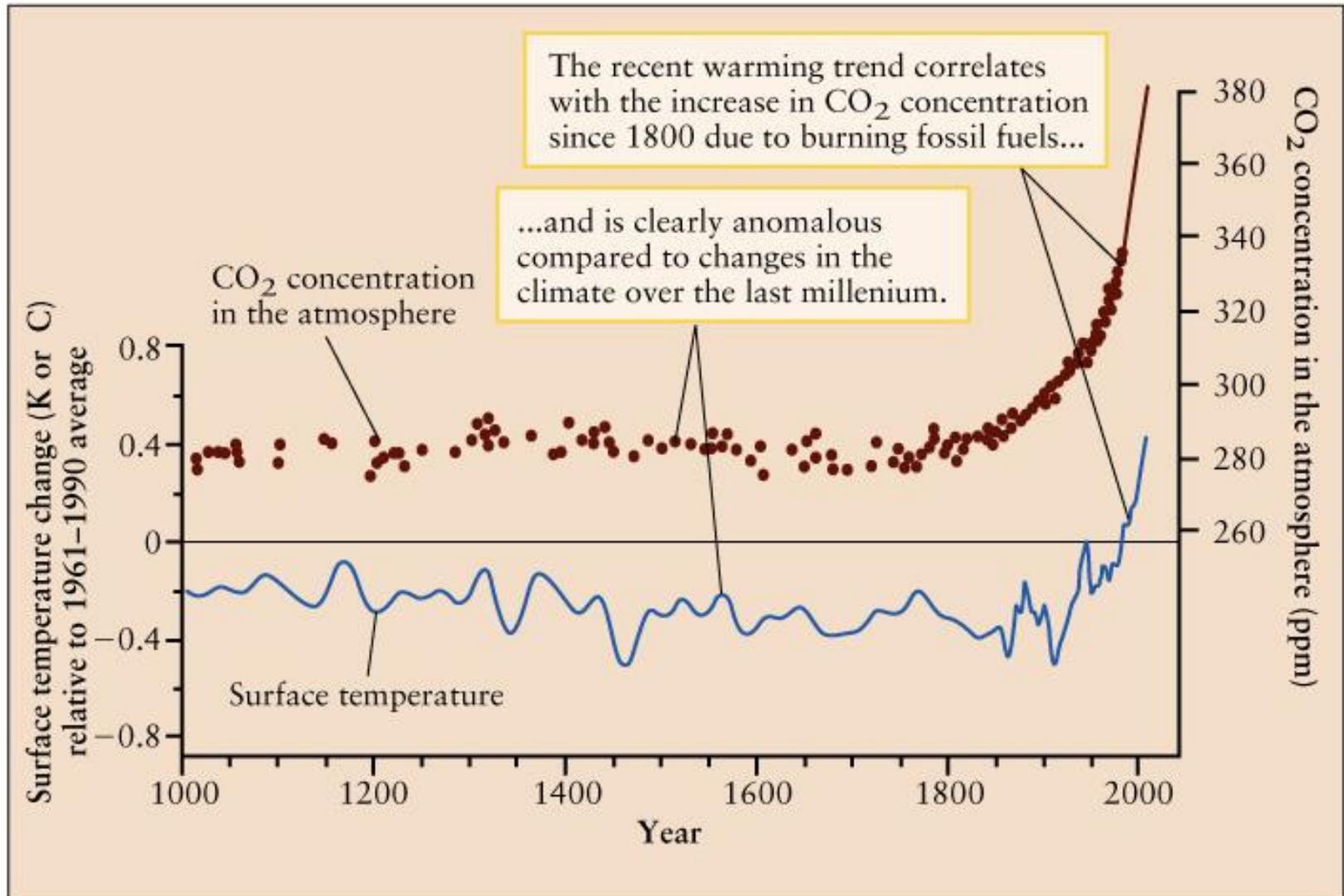
Transmission in IR mostly in “water hole” region

Infrared “water hole”

Partially filled in by carbon dioxide and a little bit by methane

Greenhouse effect in Earth's Atmosphere

Note year of this figure is about 2004. Climate scientists had predicted trend in 1970s (and even earlier)



Greenhouse effect and Carbon Dioxide

To slow the increase in temperature we (all humanity) want to reduce the amount of carbon dioxide released into the atmosphere. For a while the US trend was down, until 2018 where they increased.

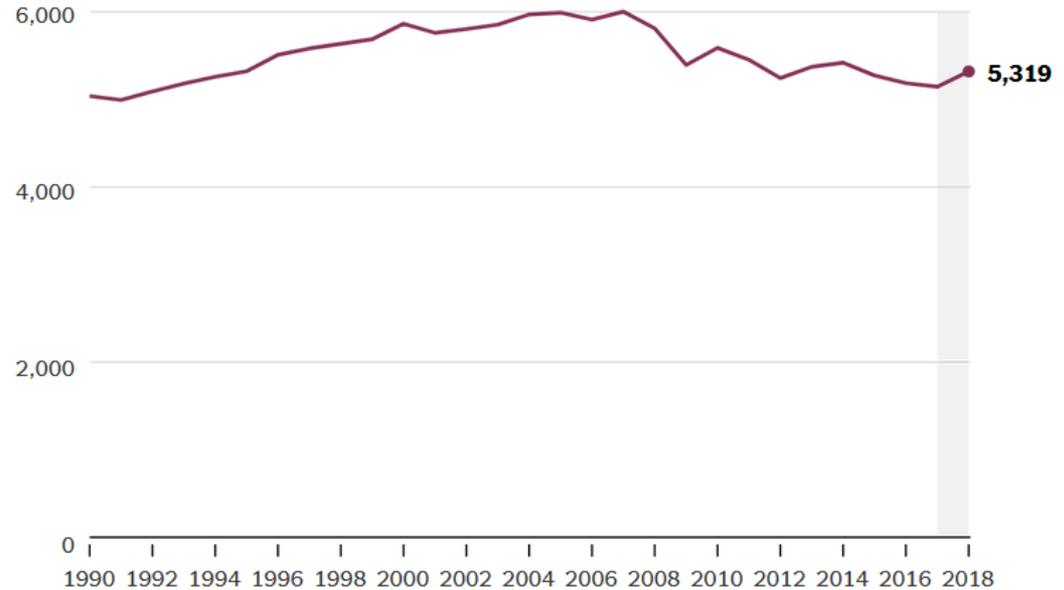
Figure 1: Annual change in US CO₂ emissions
Energy combustion only



Source: Rhodium US Climate Service, based on data from the EIA, Bloomberg and Genscape

U.S. Carbon Dioxide Emissions Rose in 2018

Million metric tons



Above, just energy
To right, all

By The New York Times | Rhodium U.S. Climate Service

Greenhouse effect in Earth's Atmosphere

The increase in average temperature will cause a large increase in the number of extremely hot days (and in violent storms)

Danger Days Heat Up American Cities

Projected number of days where heat index exceeds 105 °F

● 2000 ● 2030 ● 2050



The Rodney & Otamatea Times

WAITEMATA & KAIPARA GAZETTE.

PRICE—10s per annum in advance

WARKWORTH, WEDNESDAY, AUGUST 14, 1912.

3d. per Copy.

Science Notes and News.

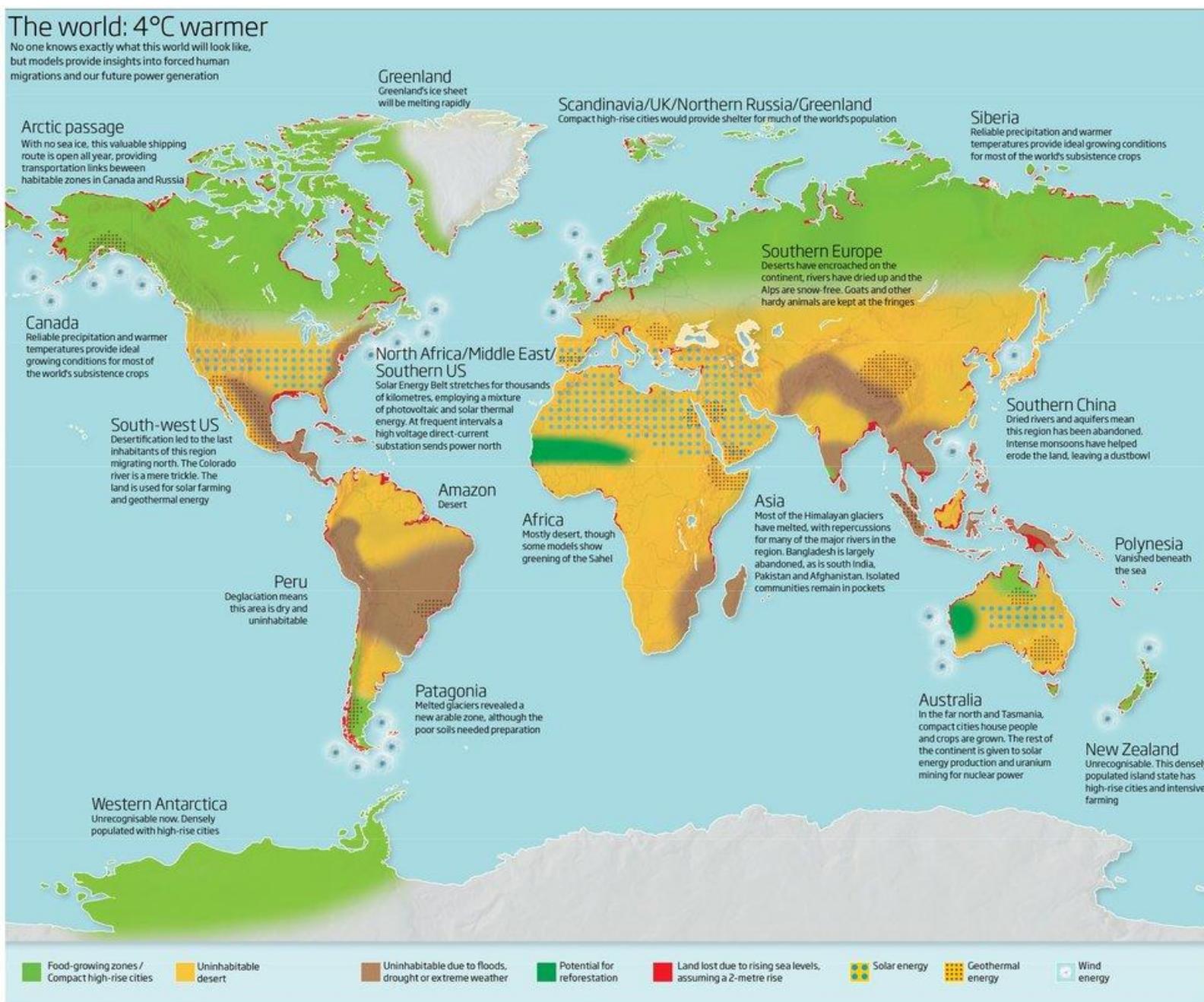
COAL CONSUMPTION AFFECT- ING CLIMATE.

The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.

Greenhouse effect in
Earth's Atmosphere
Note year of this article is
1912. The physics of
atmospheric absorption and the
greenhouse effect is relatively
easy. The difficult is the
climatology, for example the
oceanography as most carbon
dioxide is absorbed by the
ocean.

A New Zealand newspaper; 10
shillings per year or 3 pence per
paper when it was 12 pence = 1
shilling and 20 shillings = 1 pound

In 2100
most of the
world is
now desert.
Canada,
Siberia,
and maybe
Antactica
grow food
(in green)



Climate Change vs Special Interests

- In 1970s, two environmental problems understood by science (I learned about as undergrad ~1975. Have taught since 1990)
 - Freon → Ozone depletion, enhanced UV → quickly “solved”
 - Carbon Dioxide → climate change → still “not solved” but now see tangible impact predicted 40-100 years ago
- Carter started R&D national lab in 1978 on renewable energy (had solar panels on White House), canceled/removed during Reagan administration. Could now have much larger fraction of US energy from renewables, less reliance on coal/oil, reduced greenhouse effect, possibly fewer wars in Mideast (??)
- Not done. “I didn’t get it” then and still don’t but clearly due to influence of special interest groups. This is an astronomy class and so only give some info on renewable energy and links to “business” pages plus a comment on how the Catholic Church’s position on science changed since Galileo’s time (in extra slides)

Renewable Energy in 2018

- Large Scale electric: Quite cheap natural gas with wind turbine competitive (>40% of electricity in Iowa from wind). Many cities now installing municipal solar farms (2.5X more energy if tilt panels toward Sun during day). A 2 MW farm near DeKalb just approved.
- Small scale: solar energy cheap if install on homes ~15% return on investment include taxes. DH home 50% solar and 50% wind for electricity since 2015. Geothermal good source for heat/AC but larger initial investment in older homes

DH home: 10 solar panels. Will be paid for in < 7 years, then after just “profit” → Rapidly changing technology. 2018 panels are about 30% more efficient (more energy produced for same cost). If US government was concerned about jobs would be aiding R&D for the next generation of technology. Instead imposed tariffs on solar panels.

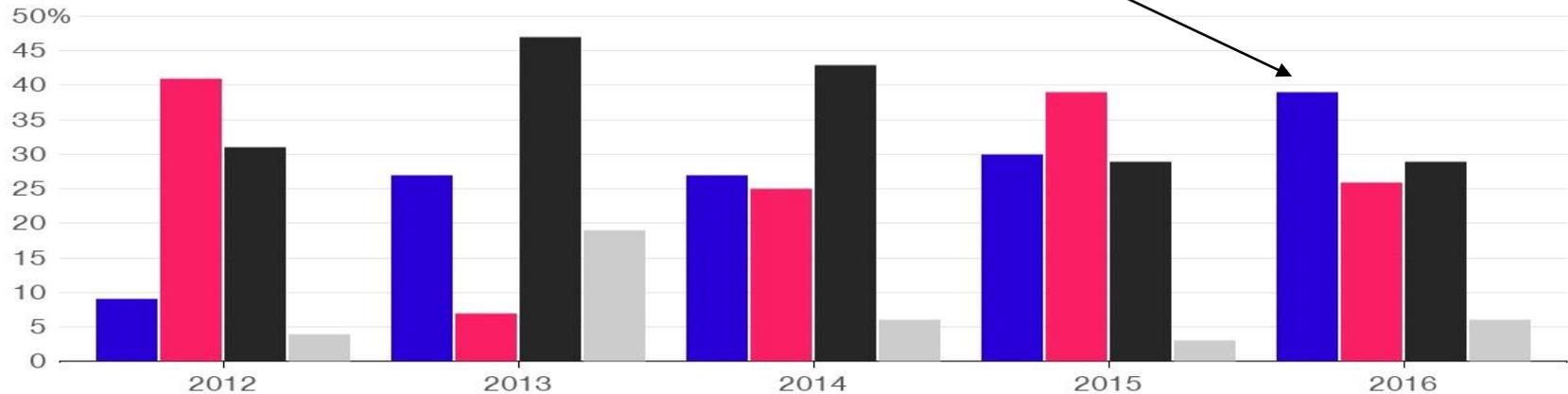


New US Electrical Energy 2010-2016 → driven by costs

Share of New U.S. Capacity

Solar energy beats both wind and gas for first time

■ Solar ■ Wind ■ Gas ■ Other



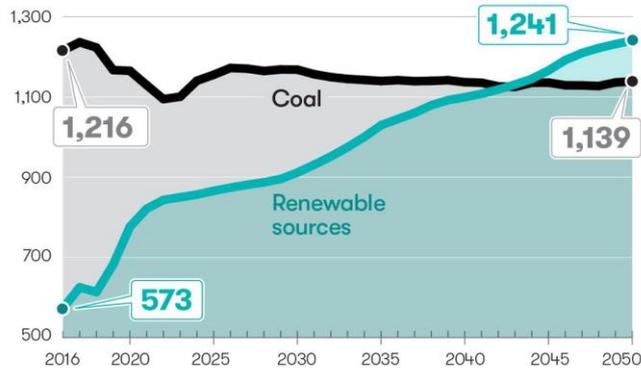
Source: GTM Research, SEIA

Bloomberg

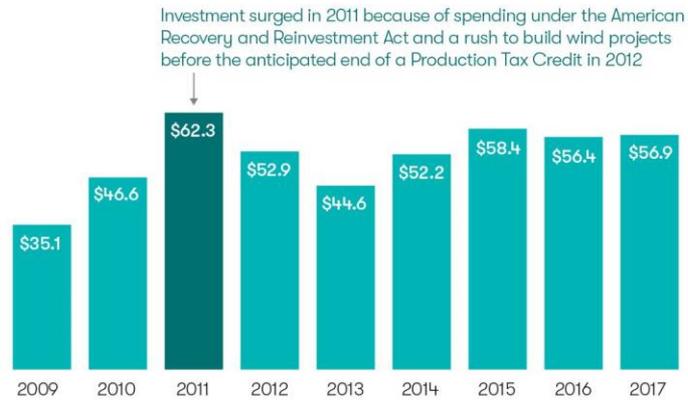
Jan-Feb 2018, renewables were 98% of new capacity; estimate 70% of new capacity 2018-2021 (see link on web page). Could be even more if federal government was proactive.

From April 2018 Smithsonian magazine (link on web page)

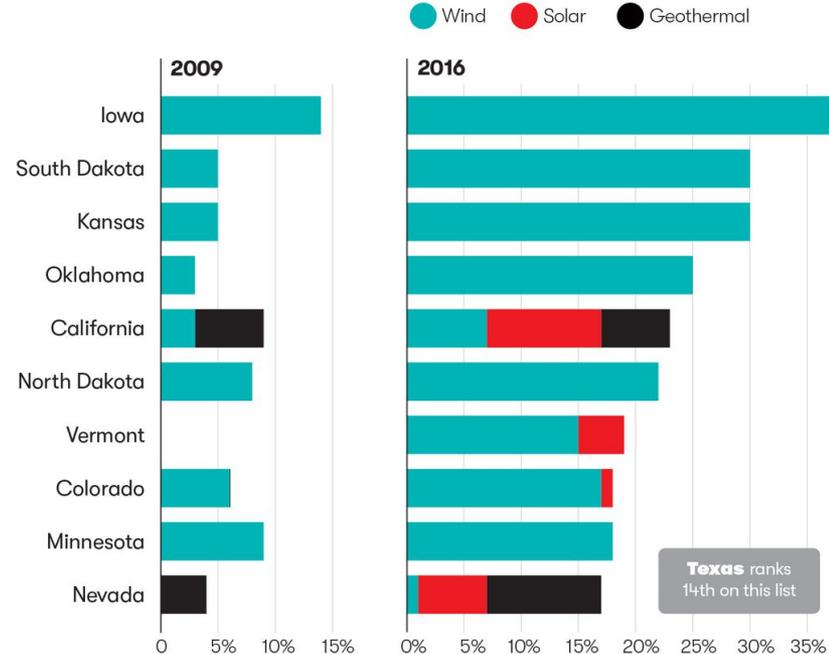
Projected sources of U.S. electricity generation, in billions of kilowatt hours



New investment in clean energy in the United States, in billions of dollars



States ranked by percentage of their electricity derived from renewable fuels
Solar includes only utility-scale solar



50,000
Coal-industry employees, 2016

102,500
Wind-industry employees, 2016

260,000
Solar-industry employees, 2016

The Long Island Power Authority voted today to formally approve the development of New York's first ever, and the nation's largest, offshore wind farm! Last week Governor Andrew Cuomo took an historic step towards expanding clean, renewable energy in the Empire State and accelerating the transition to 100% clean, renewable energy.

By Gov. Cuomo directing state agencies to study pathways to power New York with 100% renewable energy, New York becomes the first state in the Continental U.S., and the biggest state in the country, to commit to exploring a complete transition to 100% clean, renewable energy! #ReadyFor100 #BeyondCoal

in 2018, California sets goal of 100% electric from renewable by 2045; 50% in 2025

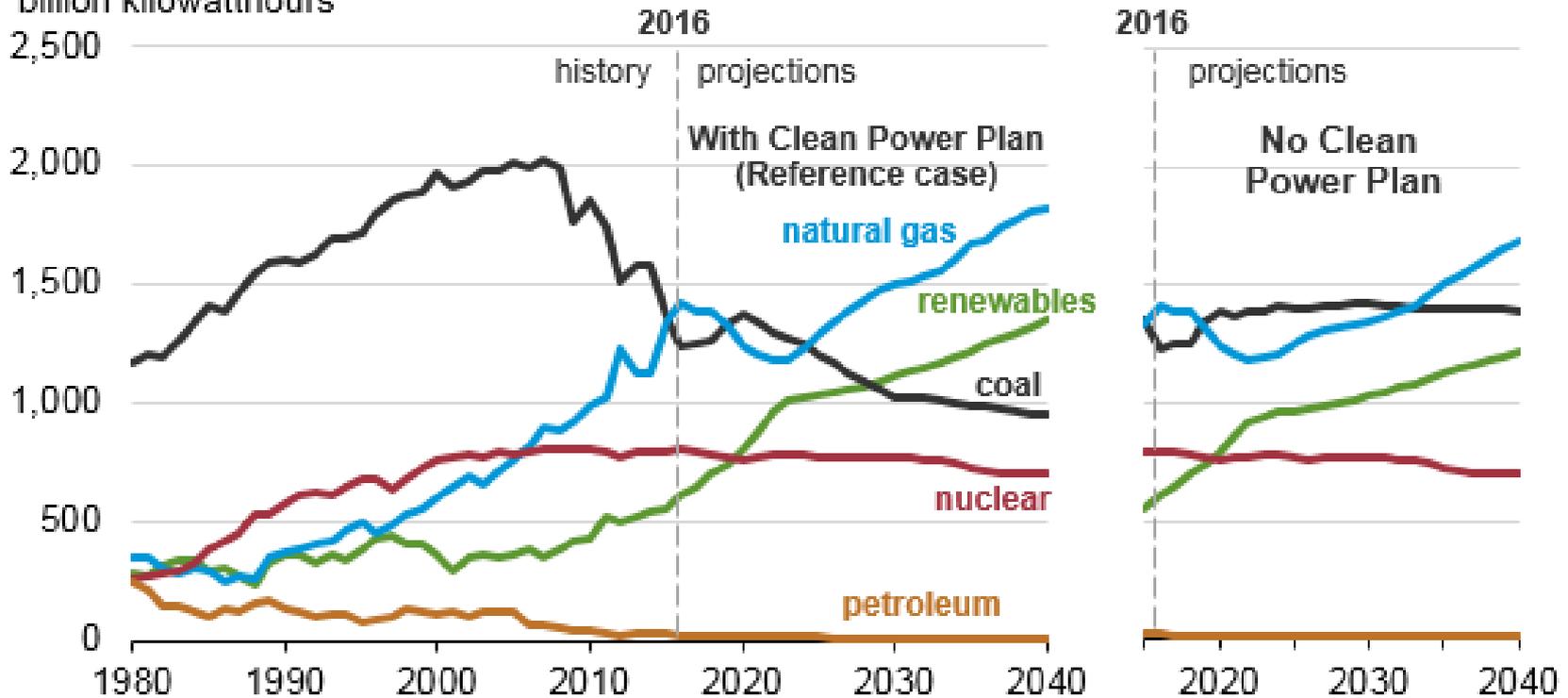
Wind farms very productive near ocean shore as essentially always windy. 140% of Denmark's electrical energy produced by wind in 2017, sell excess to other countries. This (small) country is a world leader in wind turbine technology.



Extra Slides

New US Electrical Energy 2010-2040 → driven by costs

U.S. net electricity generation (1980-2040)
billion kilowatthours



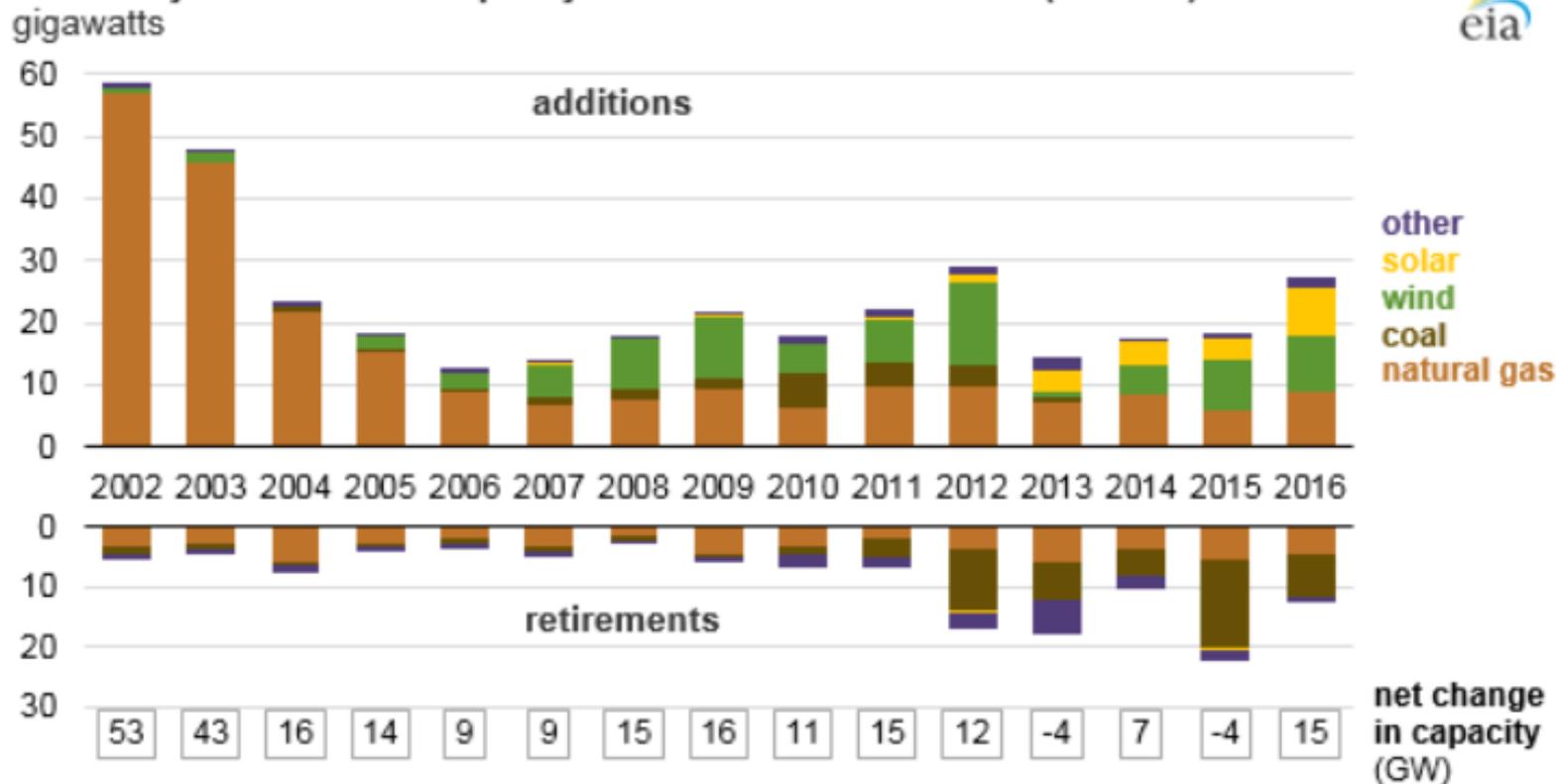
Renewables are the least expensive → new sources

Coal or Natural gas can both be used in many existing power plants and so “cost” (including need to pay for environmental damage) determines balance between the two. Renewables will keep increasing.

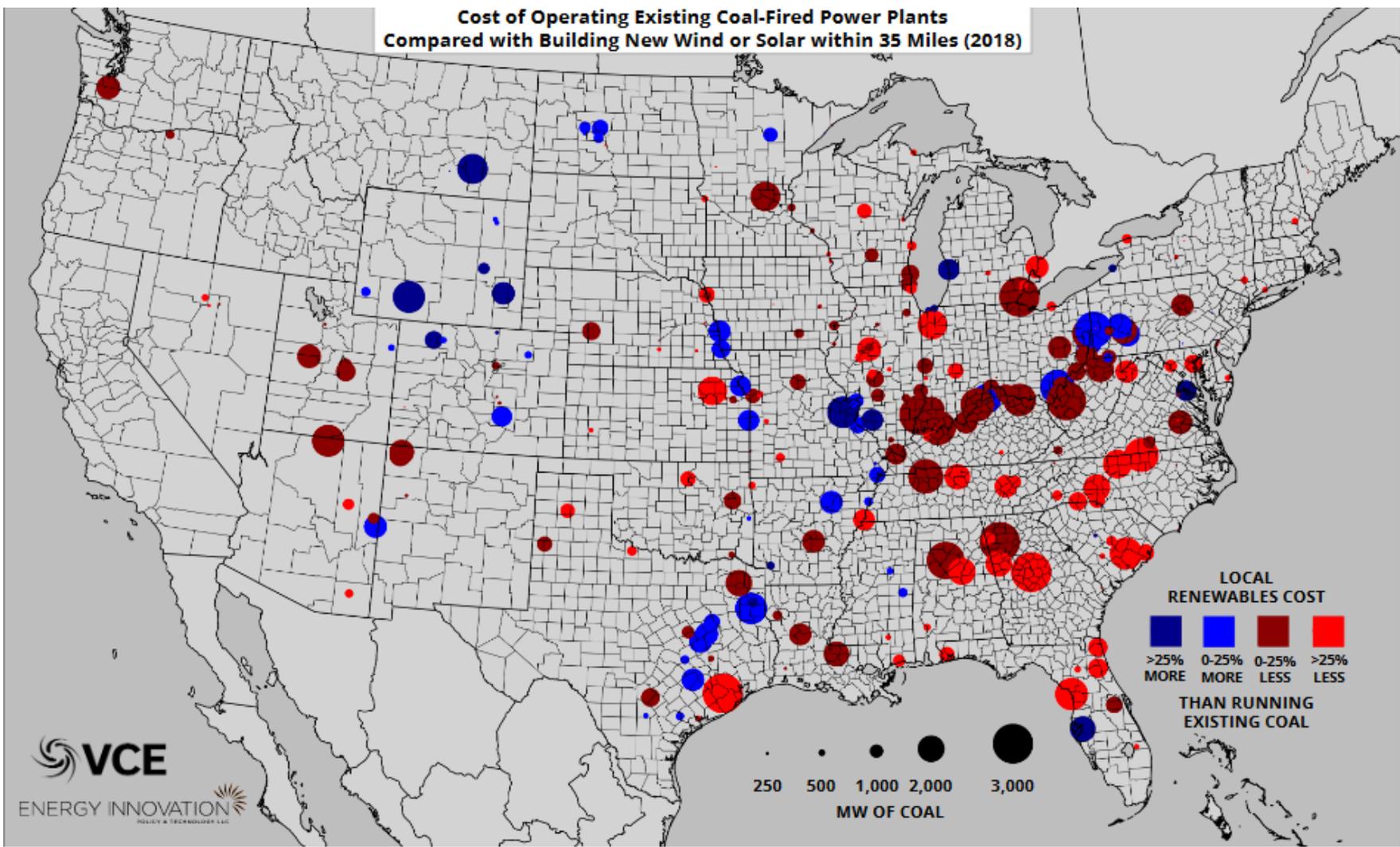
US Electrical Energy 2002-2016 → driven by costs. Note retirement of expensive coal-fired plants

U.S. electric generating capacity increase in 2016 was largest net change since 2011

U.S. utility-scale electric capacity additions and retirements (2002-16)



US Electrical Energy 2018 → cost of coal-fired plants vs renewable. If Red, renewable cheaper (does not include the cost due to damaging environment)



Climate Change vs Electrical Energy Source

- Accounting firm Price Waterhouse Cooper “20 years from catastrophe” link on course web page. Accounting firm Ernst & Young helps businesses on “Global climate change and sustainability” issues. For insurance companies, climate change is their #1 risk factor for property/casualty losses (note recent hurricanes)
 - “easy” solution: eliminate coal-produced electricity
 - saves money for more than (probably) 98% of Americans while good for the climate, and health of people living in coal producing regions or near coal plants.
- Natural gas, solar, wind, and geothermal all cheaper (and less dangerous). See link to Consumer Reports article. Even with 2018 tariff on solar panels, solar much more cost effective than coal; the tariff will cause US job loss and increased electrical power costs in the short run. See link on web page. In 2018, US administration plans on using 1954 defense related law to force utilities to purchase from coal plants. In 1954, was in case of Soviet attack/invasion. In 2018, who is “attack” threat (Canada, aliens?, real threat is cyber with North Korea have world’s best hackers). Best solution for “attack” or hurricanes is local electrical sources, especially renewable plus battery storage. Coal requires transport, for instance all the trains going through DeKalb. In 2018 US administration threatening to sue California and force them to use more coal/oil and reduce environmental protections. Why?

Historical Note on Acceptance of Science

- We saw that at the time of Galileo the Catholic Church “opposed” the new science discoveries. But today the Catholic Church says “trust the scientists” → the “world turned upside down”
- 2017 Pope Francis: "Anyone who denies [climate change] should go to the scientists and ask them. They speak very clearly ... climate change is having an effect, and scientists are telling us which path to follow. And we have a responsibility - all of us. Everyone, great or small, has a moral responsibility ... We must take it seriously ... history will judge our decision."
- In 2017-2018, US withdraws from Paris Climate Accord (only country not in it), reduces dramatically future funding for much of science, stops using science as input to decisions (like at EPA), and in January 2018 imposes a 30% tariff on imported solar panels. After ~70 years of leading the world in science and technology, US unilaterally decides to give up that leadership.