

How Clean is the Electric Car?

<http://economics.ucdavis.edu/news/how-clean-is-the-electric-car#>

Thanks Corey!

UC Davis study: "One thing to understand about electric vehicles (EVs) is that **they are not zero emission vehicles**," says Rapson, "**EVs are only as clean as the electric grid in which they are operating.**" The study finds great variation in the environmental benefits of EVs, reflecting the variation in electric systems around the country. In California, they estimate the net environmental benefits to be around \$450 per vehicle, based upon the current electric system. "Of course, **as the grid sheds coal and adds renewables, EVs will provide increasing GHG benefits nationwide.** But we should keep in mind that **conventional cars are also becoming much more efficient, making the total potential GHG benefits of EVs smaller than many people might think.**"

Living on Earth Podcast (<http://loe.org/>)

- Weekly environmental news and information program distributed by Public Radio International.
- This week:
 - US Supreme Court puts a hold on Obama's Clean Power Plan
 - Sierra Snows Ease, but won't end California drought

Last Time...

Electric Power Generation

- The human activity that emits the largest share of GHGs
- More than double the amount of any other source



Electricity Generation

- Coal-Fired Power Plants
- Natural Gas Power Plants
- Nuclear Power Plants
- Renewable Energy Sources
 - Hydroelectric, wind, solar, geothermal, tidal and wave

Coal Fired Power Plants

- Generate 50% of the electricity in the United States
- Provide over 60% of capacity in China and India
- In the next decade
 - China plans to build 500
 - India plans to double capacity



Coal Fired Power Plants

- Higher GHG emissions per unit of power generated than other types
- Cheaper to construct and operate
- US, China, and India have large reserves of coal
 - Much more than gas, oil or uranium needed for other types of power plants



Converting natural gas to electricity is simpler than converting coal

This means:

- Inexpensive and rapid to construct
- Efficient to operate
- Easy to maintain



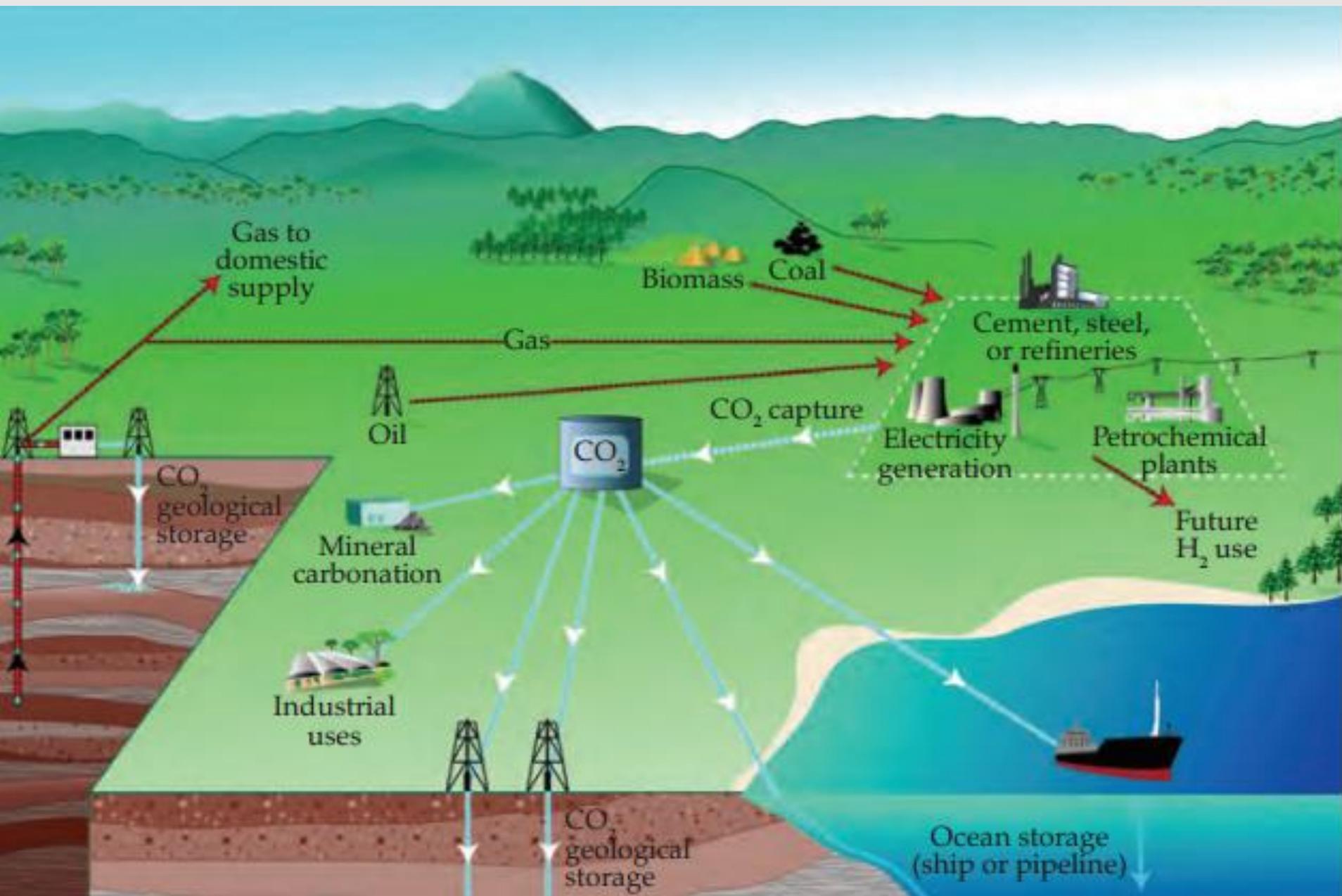
Natural Gas Power Plants

- Low GHG and pollutant emissions
- High fuel efficiency

Problem: natural gas is more expensive than coal, and also not a renewable resource

Carbon Capture and Storage

- Burning hydrocarbon fuel, both coal and natural gas, releases CO₂
- Carbon capture and storage (CCS):
 - Collect CO₂ released
 - Concentrate it
 - Transport it
 - Store it to prevent it from mixing with the atmosphere



CO₂ Capture

- Carbon capture almost doubles the construction cost of a power plant
- Adds 50% to the cost of electricity generation

CO₂ Transport

- Power plants not often near areas where CO₂ will be stored
- Transportation using pipelines and tanker ships



CO₂ Transport Problems

- Pipes and storage vessels must be made of carbonic acid resistant alloys. More expensive than steel
- Leaks from transportation will accumulate in depressions (denser than air). CO₂ is colorless and odorless. A leak sink could endanger people
- Transportation as a liquid is more efficient, but more dangerous (higher pressure and low temperature)

CO₂ Storage

- Conversion into mineral carbonates
- Storage in deep sea
- Storage in geological formations

Conversion into mineral carbonates

Calcium and magnesium silicon oxides (found in certain rocks) react spontaneously with CO_2 to produce limestone and magnesium carbonate



Wollastonite



Olivine



Serpentine, CA state rock

Conversion into mineral carbonates

Pros

- Offers long term storage. Stable at ambient temperature and pressure
- Can serve as construction material or fillers in abandoned mines

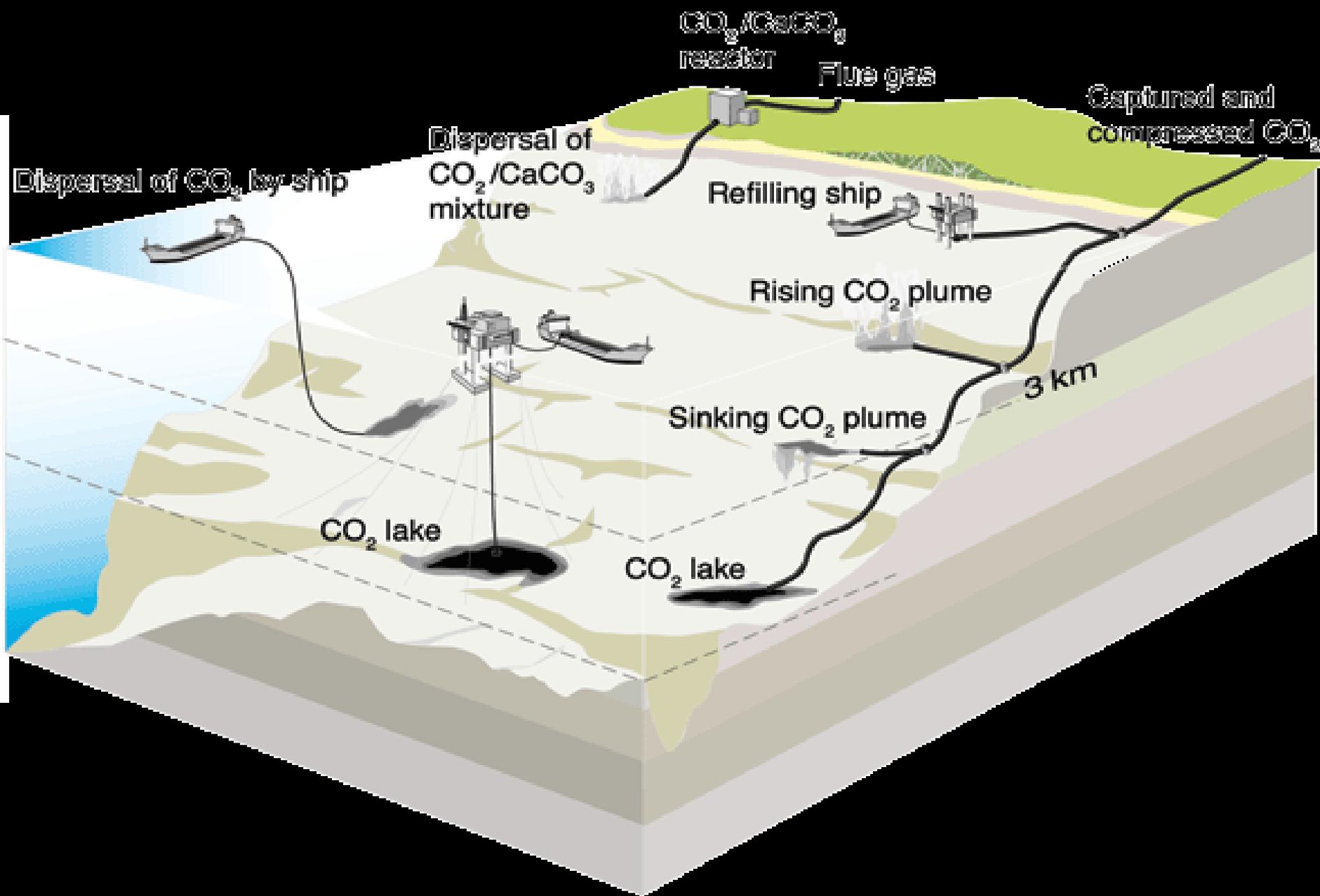
Cons

- Conversion into mineral carbonates is a slow process naturally
- Increasing the speed of reaction consumes 30 – 50% of the energy generated by a power plant

Storage in deep sea

Long term but not permanent solution

- Pumped down pipelines into deep ocean
- Tanker ships could release it at depth
- Convert into calcium carbonate then dissolve into deep sea water



At depths over 3km, forms CO₂ lakes

Denser than sea water, sinks

Delayed dispersal into surrounding environment



- Large scale injection of CO₂ into the ocean would influence sea life
- High concentrations can interfere with aerobic respiration
- Liquid CO₂ may be toxic to some organisms
- Dissolved CO₂ increases ocean acidity



Storage in geological formations

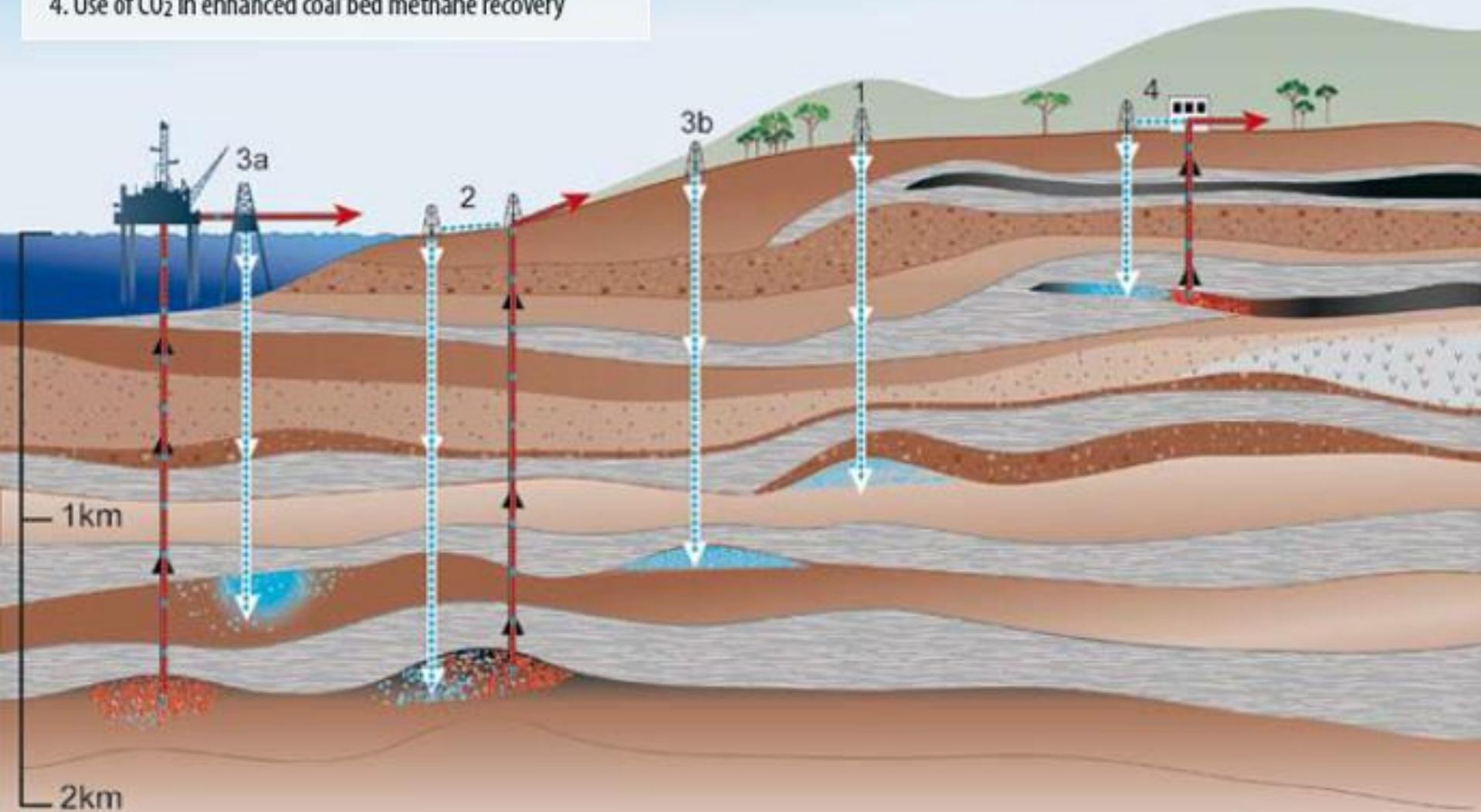
Storage in geological formations: Most practical option for long-term storage

- Large commercial facilities operating for several years at several sites including Algeria, Norway, and Canada

Overview of Geological Storage Options

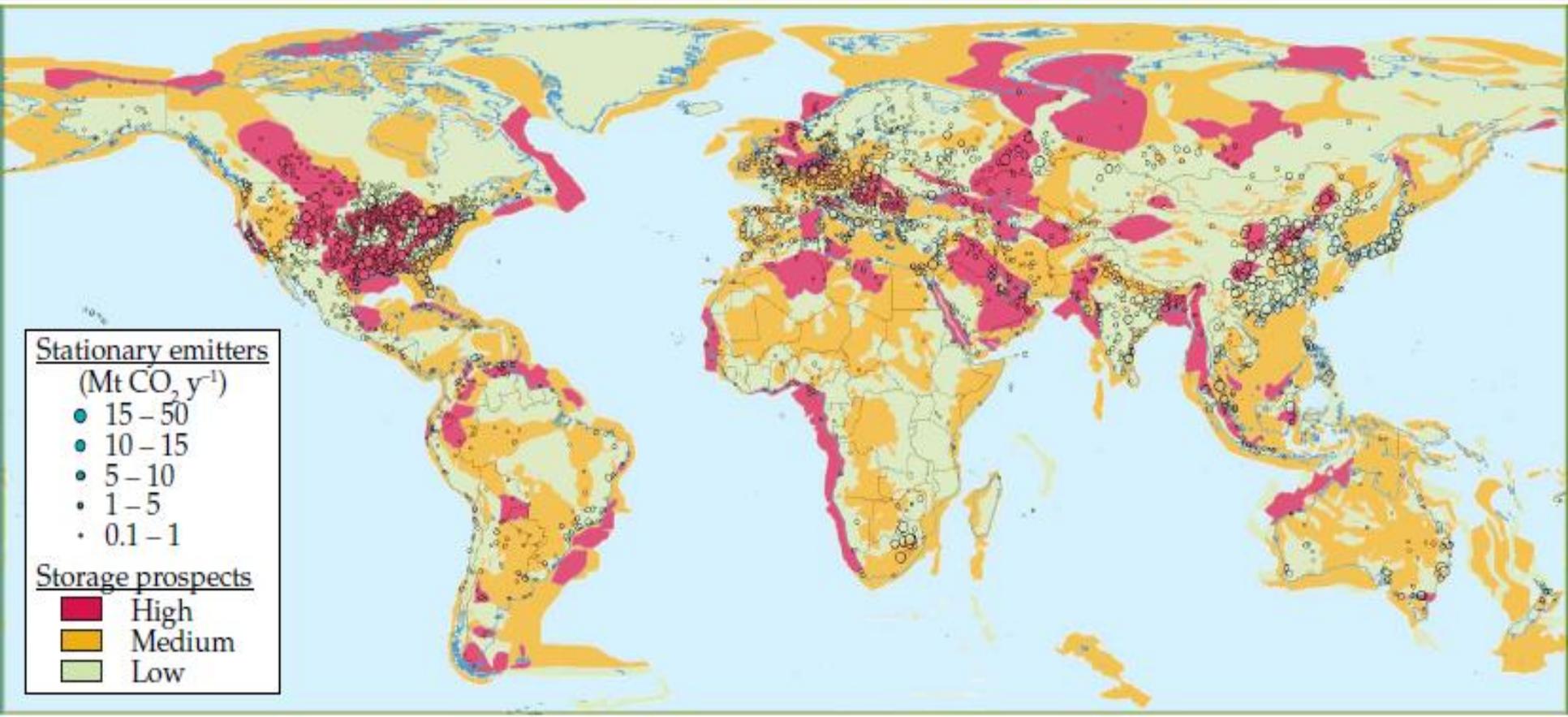
1. Depleted oil and gas reserves
2. Use of CO₂ in enhanced oil and gas recovery
3. Deep saline formations - (a) offshore (b) onshore
4. Use of CO₂ in enhanced coal bed methane recovery

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1. Produced oil or gas
2. Injected CO₂
3. Stored CO₂



CO₂ Storage

Potential storage sites widely distributed, near many of emission sources

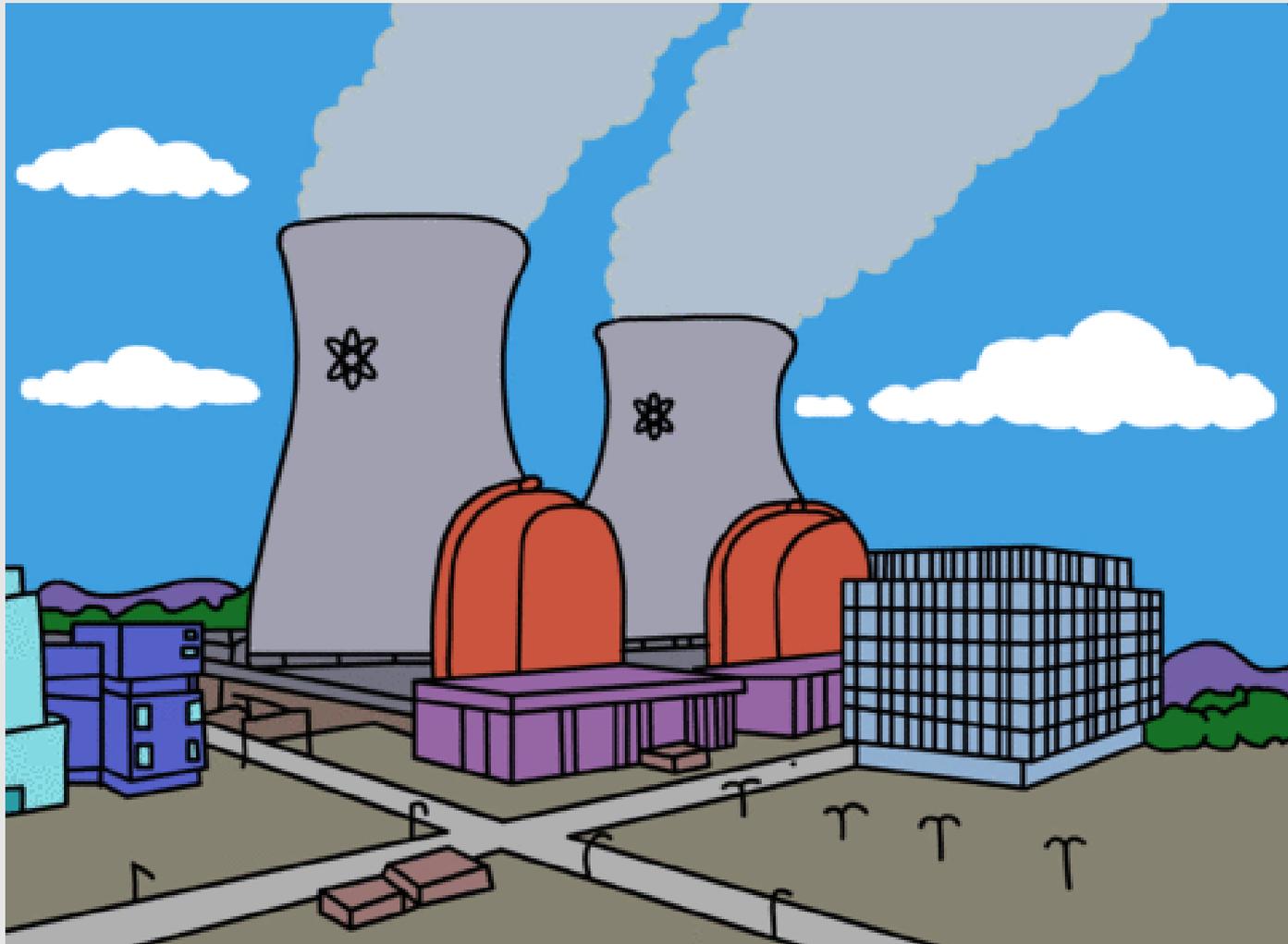


CO₂ capture and storage

- Possible for coal and natural gas power plants
- Still at preliminary stages of development
- Requires sophisticated equipment
- Puts constraints on location of facilities
- Additional costs are substantial
 - Cost should decline as new technologies become available

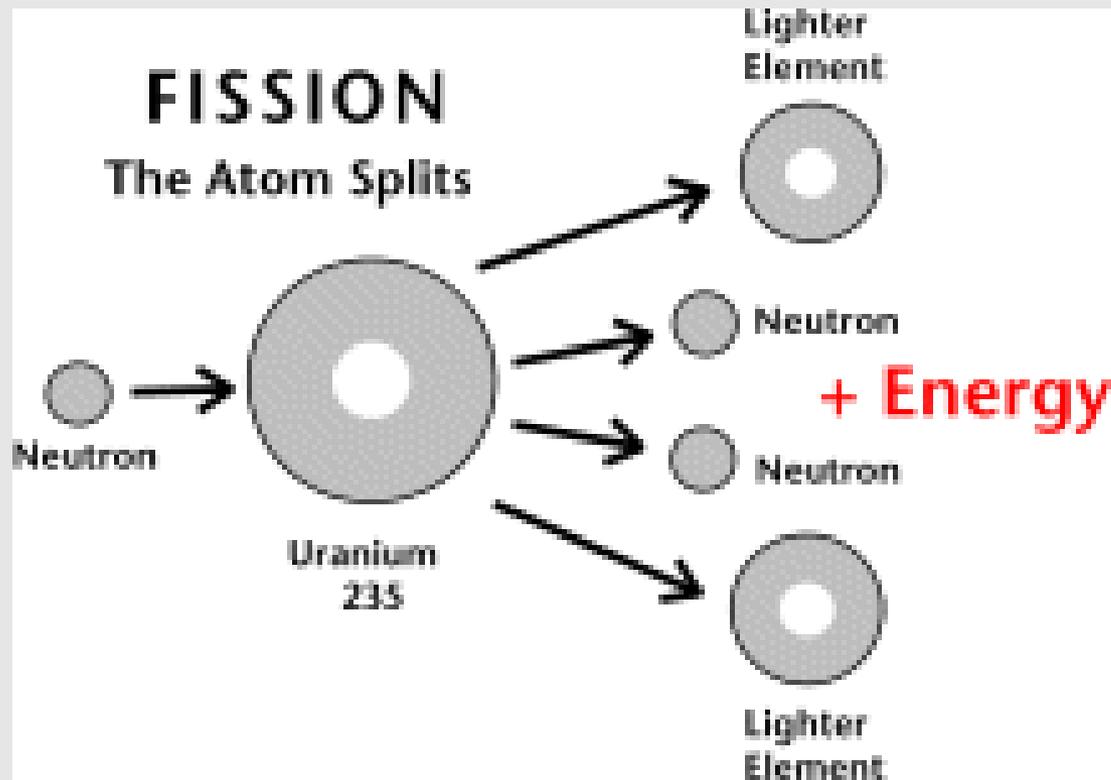


Nuclear Power Plants



Nuclear Power Plants

Nuclear fission: unstable (radioactive) isotopes of uranium or plutonium degrade, releases vast amounts of energy.



- Reaction generates heat
- Used to convert water to steam
- Drives turbines, spins electrical generators



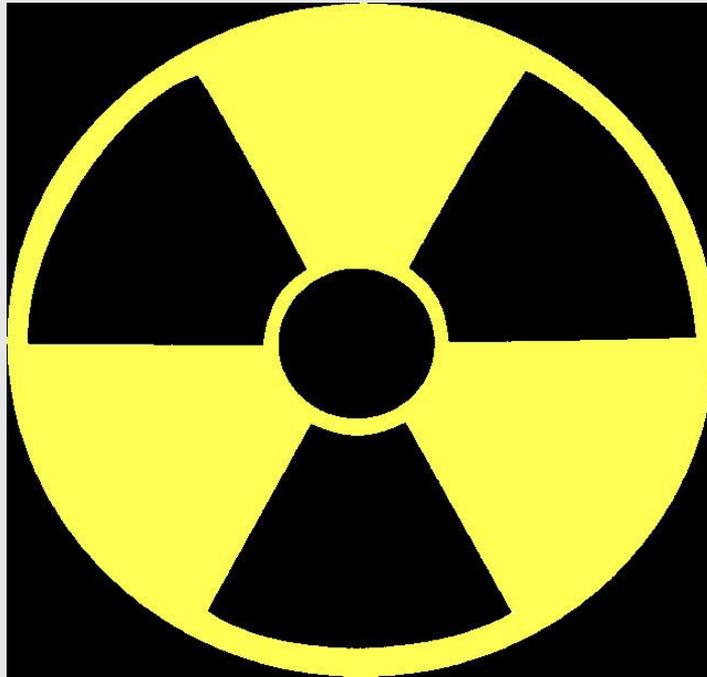
Nuclear Power Plants: Advantages

- Clean. Does not release significant amounts of GHGs or other air pollutants
- Reserves of fissionable materials adequate to supply nuclear power plants at current rate for roughly 50 years
- Exploration for new sources and new reactor technologies. Could supply power for several centuries

Nuclear Power Plants: Disadvantages

Radioactive waste

- After about 40 years, 99% of the radioactivity has decayed
- Remainder is still very dangerous and will be for 10,000 years



Radioactive waste

- Emit radiation when it decays
- Radiation striking DNA can cause changes in the coding sequence (genetic mutations)
- Usually lethal to rapidly dividing cells – radiation poisoning

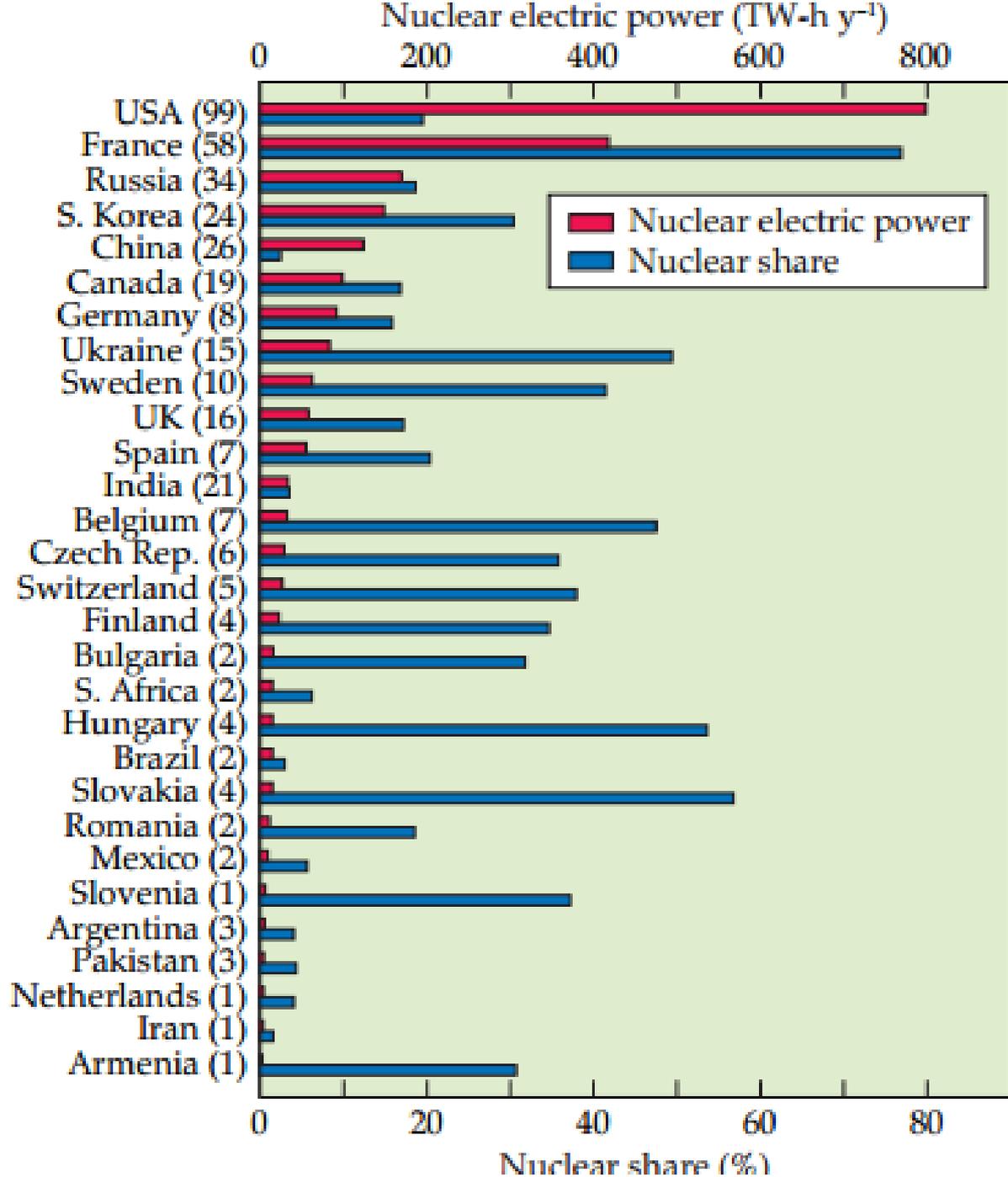


Radioactive Waste

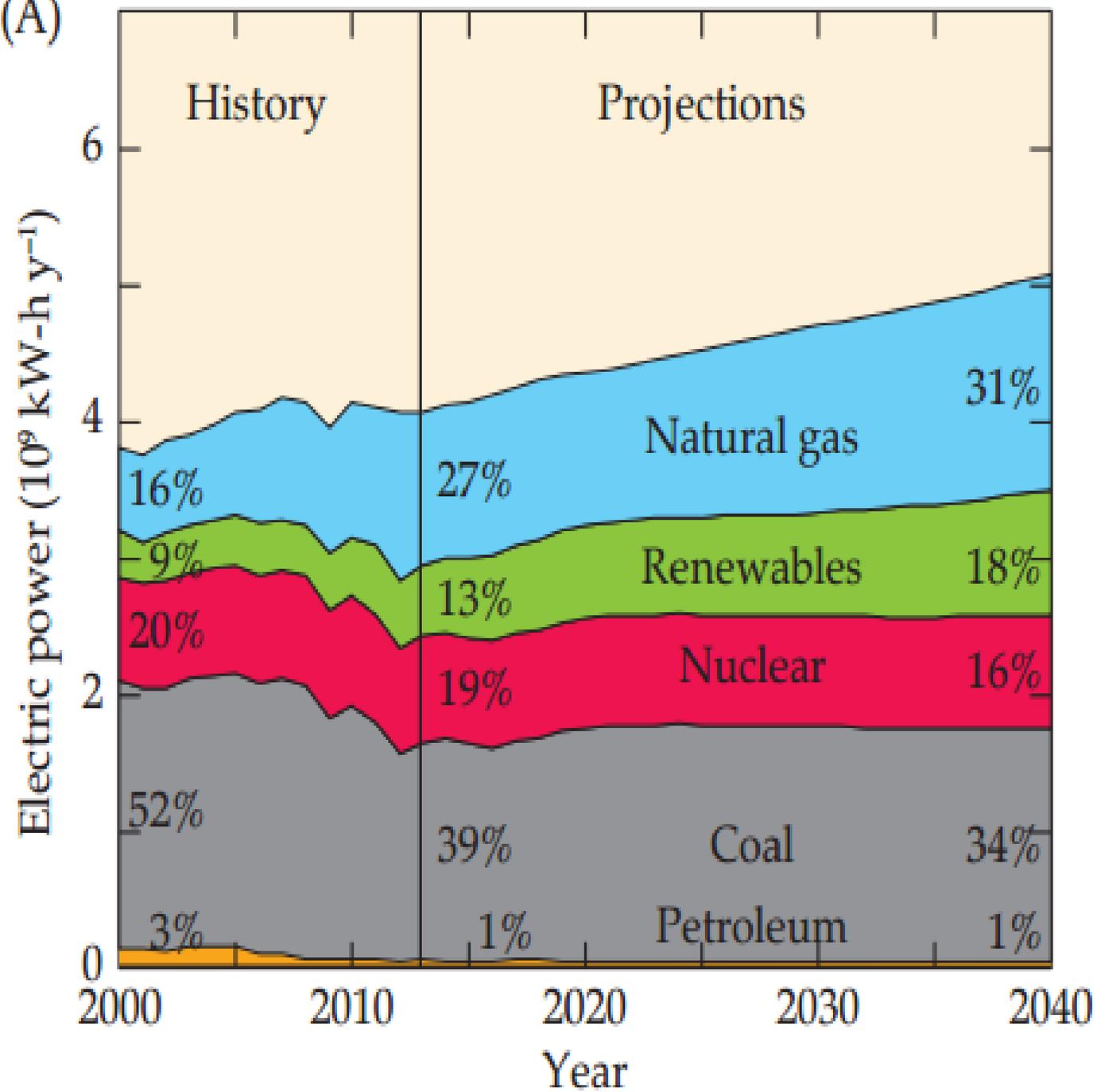


- Storage facility needed for long term
- Under construction at Yucca Mountain, Nevada. 100 km northeast of Las Vegas
- Stability of geological formations below the mountain?
- Risks of transporting radioactive material?
- Construction halted in 2010

- Red = amount generated in 2015
- Blue = share of total electricity that nuclear plants contribute
- USA: 99 nuclear plants, 19.5% of the total electric power



(A)



Climate Change May Speed Asthma Spread

<http://www.scientificamerican.com/article/climate-change-may-speed-asthma-spread/>

Thanks Yumi!

- In recent decades, **diagnoses of asthma have risen dramatically**. Between 2001 and 2009, the number of patients diagnosed with asthma rose by 4.3 million, according to CDC reports. It is a leading cause of school absences across the country. **Symptoms are often triggered by air pollution and allergies. Climate change may also exacerbate the problem. "Plants are starting their pollination season earlier, and it lasts longer."**
- Greenhouse gas emissions from **vehicles add particulate matter, which can aggravate asthma**.
- A federal **mandate to reduce emissions** from vehicles purchased after 2006 could result in **14 million fewer school absences from respiratory problems—especially among kids with asthma—annually**.

NIH call for research on health impacts of climate change

http://www.niehs.nih.gov/research/programs/geh/climatechange/health_impacts/asthma/index.cfm

Research Needs :

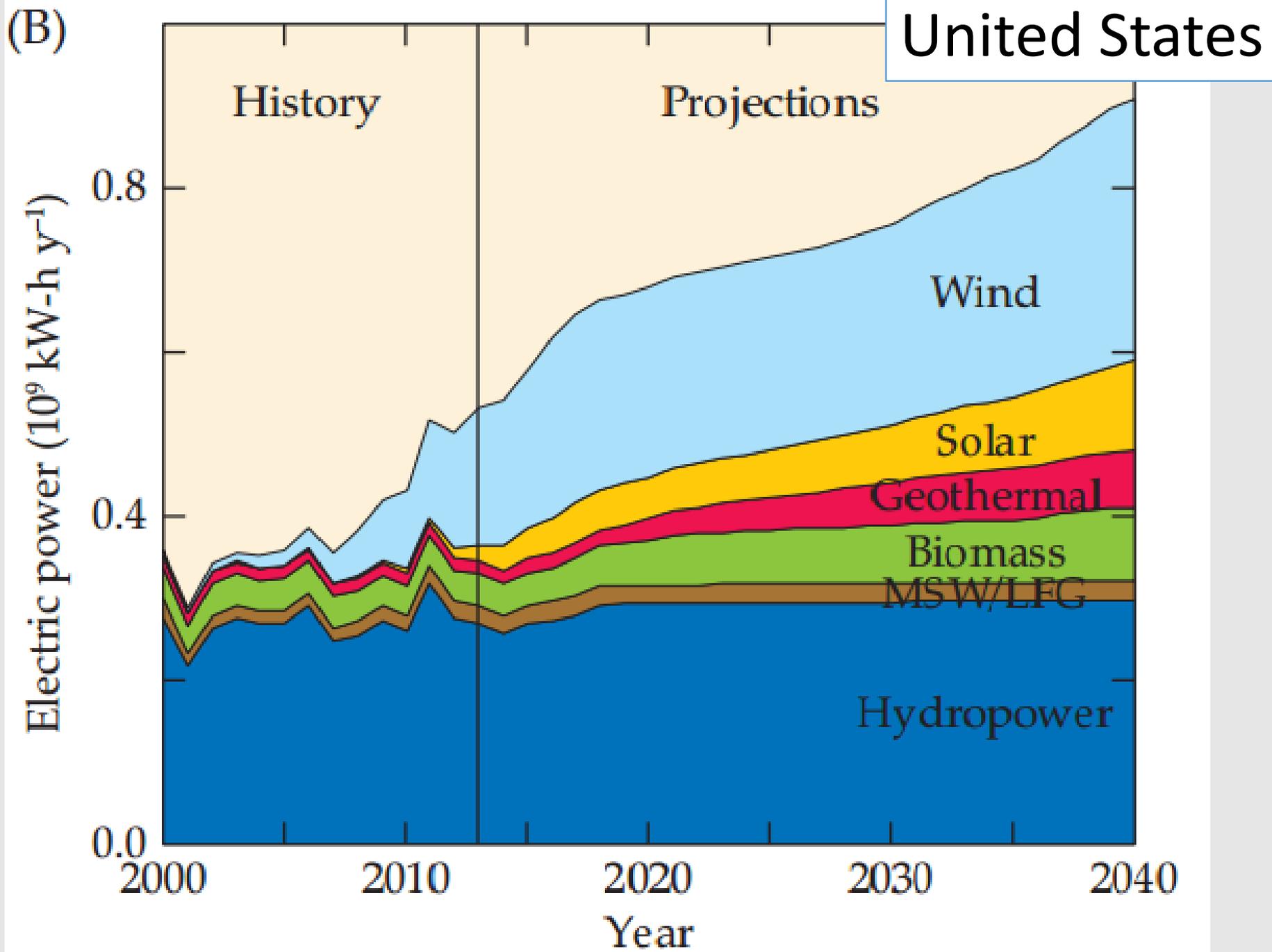
- Developing and validating real-time remote sensing and other in situ **monitoring techniques to evaluate air quality**, aeroallergens, aerosolized pathogens, dust burdens, and other climate-sensitive exposures directly linked to asthma and airway diseases
- Understanding and **modeling the impact of climate change on air quality, aeroallergens, and aerosolized marine toxins**, and the resulting effects on asthma and airway diseases including in vulnerable populations
- **Identifying and mapping populations and communities at increased risk of climate-related respiratory disease**, which will also help to identify populations at risk for other climate-related health impacts as many environmentally mediated diseases share common risk factors
- Studying the **health effects of airborne and indoor dust on asthma exacerbation**, including changes in dust composition resulting from climate change
- Understanding the acute and long-term **impacts of wild fires on asthma and other respiratory diseases**
- Examining **chemicals used in energy efficient technologies** to ensure that they do not contribute to lung sensitization, asthma, or other respiratory diseases
- Examining the relative **risks for respiratory disease based on chemicals with lower global warming potential than existing greenhouse gases**

Renewable Energy Sources

- Energy sources that are naturally replenished and do not directly emit GHGs
- Hydroelectric
- Wind
- Solar
- Geothermal
- Tide or wave

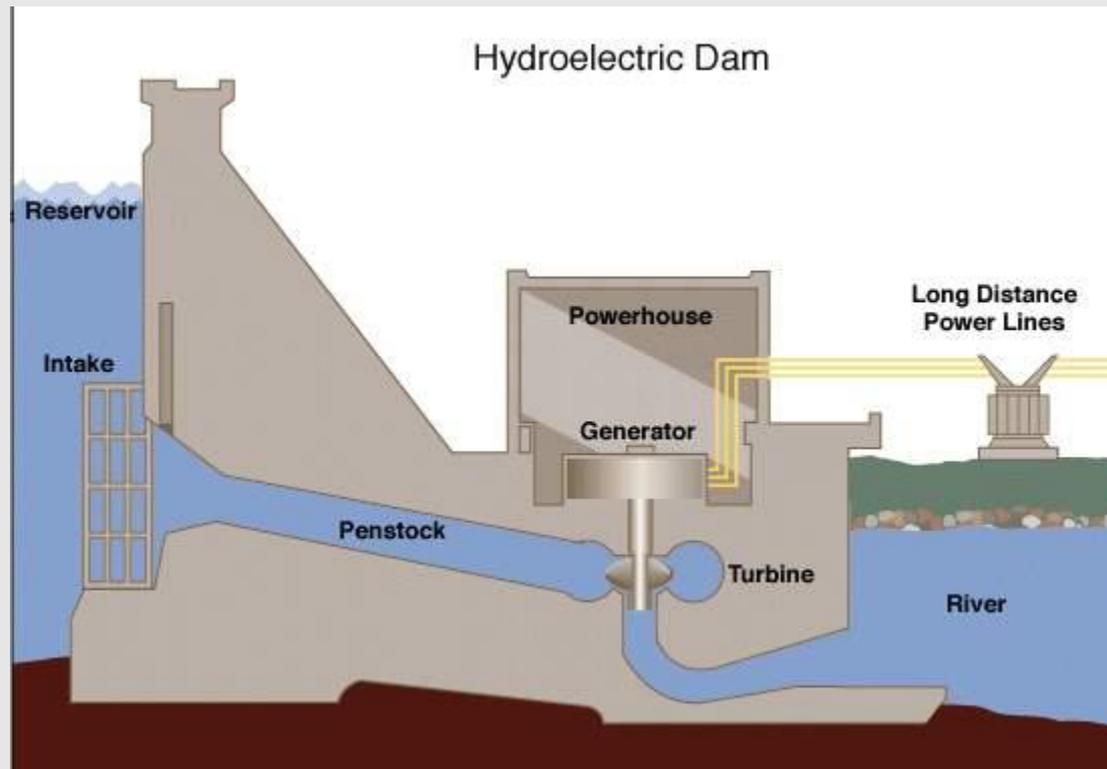


Clean Renewable Energy



Hydroelectric

- Provides the vast majority of renewable energy worldwide
- Water flows from a reservoir, through a generator turbine, and out to the streambed below



Hydroelectric advantages

- Predictable and flexible: can meet daily peak demands
- Low costs for operation and maintenance
- Reservoirs also serve as flood control, irrigation, and urban water supplies

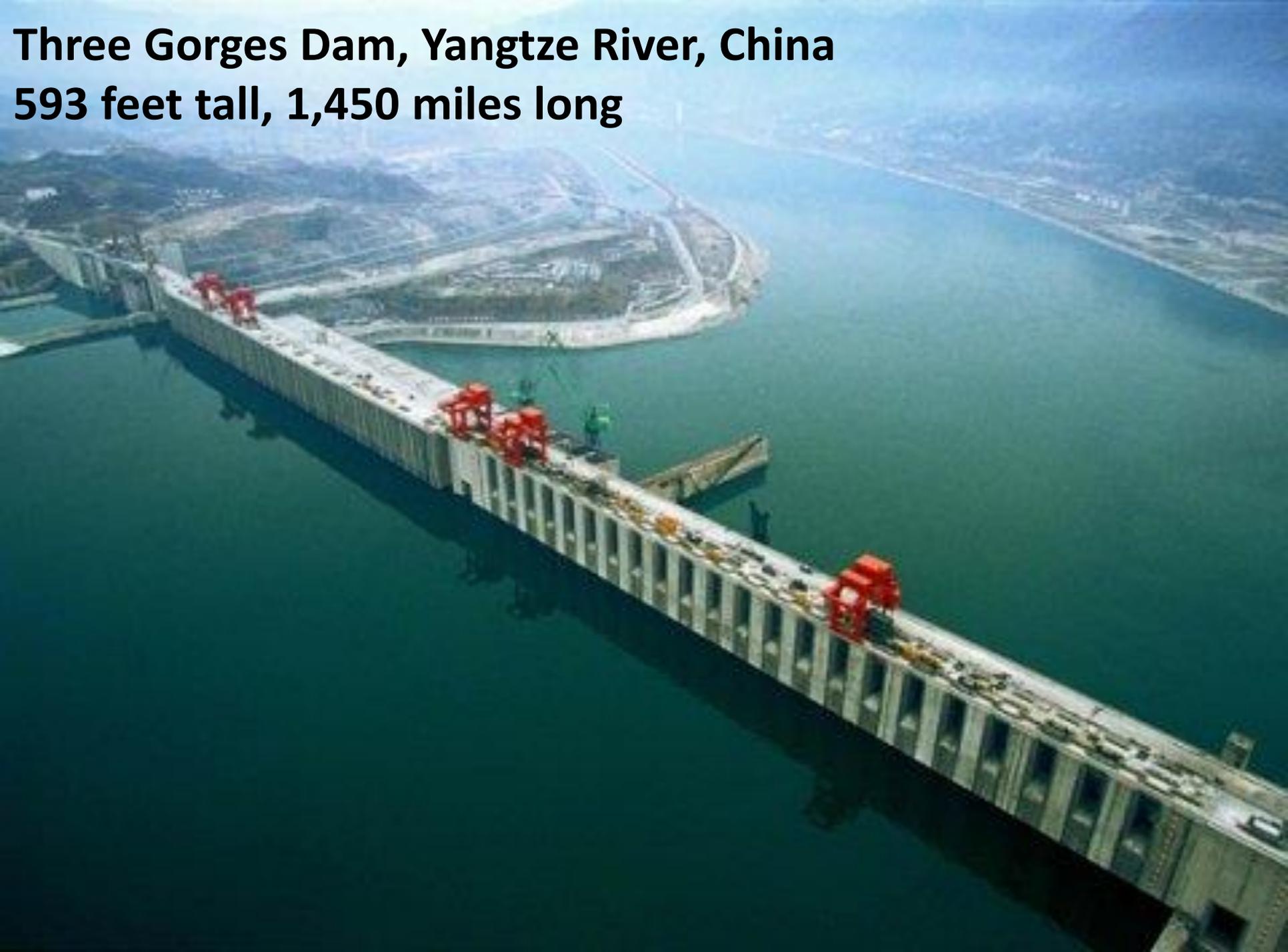


Hydroelectric disadvantages

- Enormous construction costs
- Displace communities that have developed along rivers
- Disrupt river ecosystems

Three Gorges Dam, Yangtze River, China

593 feet tall, 1,450 miles long



Three Gorges Dam

- Fully operational in 2012
- World's largest hydroelectric facility
- Cost about \$31 billion to build. Sale of electricity it generates should recover that cost in about 10 years.

Three Gorges Dam

- Displace more than 1.3 million people
- Submerged 1,300 archaeological and cultural sites
- Build up of silt behind the dam, lack of silt deposited below the dam
 - Will lead to erosion and sinking of land far downriver
- Dam slowed the flow of the river
 - Polluted areas not flushed out

Altered fish migrations and changes to river ecosystem

- Siberian Crane and Baiji Yangtze river dolphin likely to go extinct



Hydroelectric

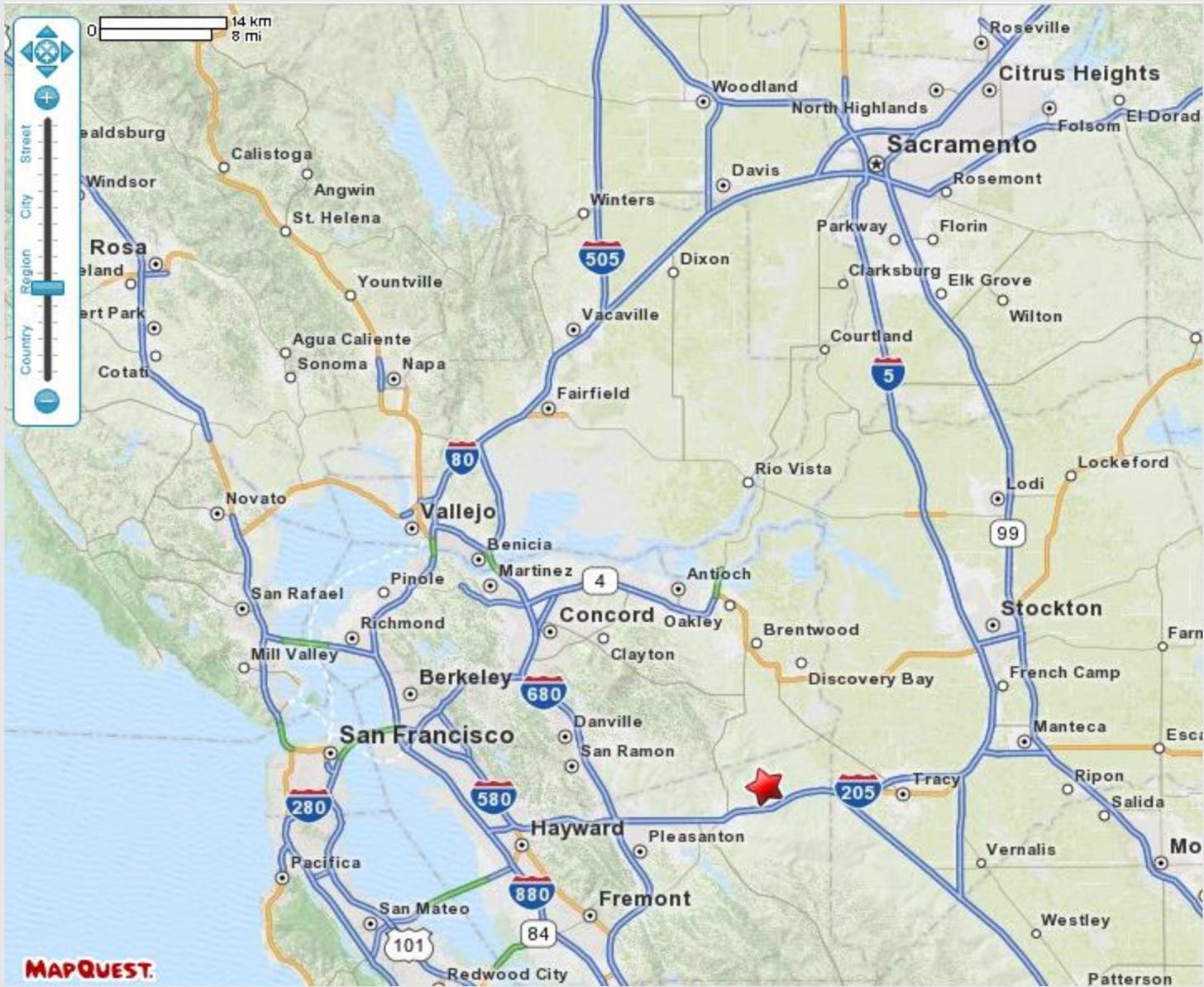
- Smaller dams: less efficient but more affordable and fewer social and environmental disruptions
- Less security risk: breach of the dam less catastrophic



Wind



Altamont Pass, California



MAPQUEST.

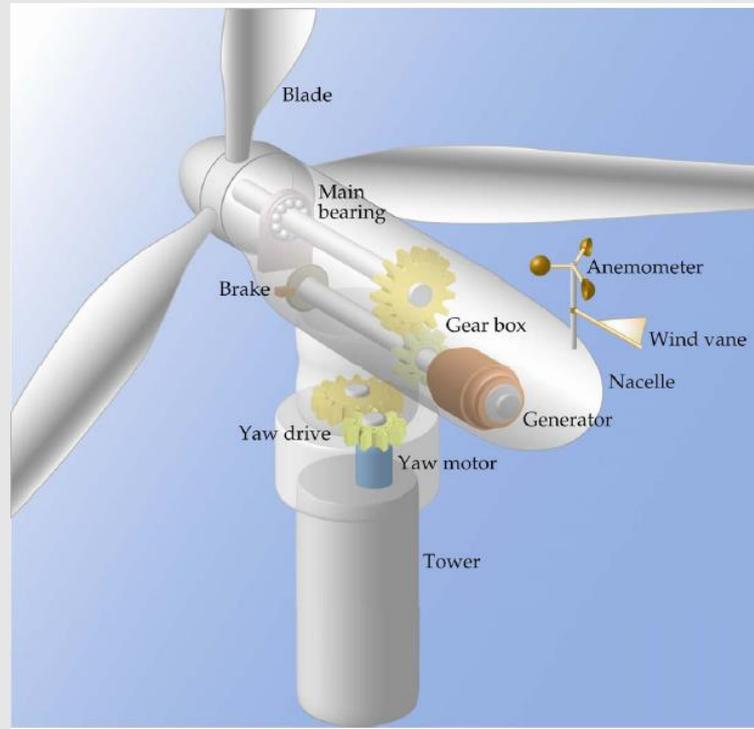
Wind

- Second-largest source of renewable energy that does not produce any GHGs
- Altamont Pass has more than 5,000 wind turbines
- Many countries are rapidly constructing wind power facilities. In a few decades, should provide 6% of global electricity

Wind

The power that can be extracted from wind is proportional to the wind velocity (speed)

- Turbines usually placed 40m to 80m above ground where wind velocity is relatively high



Wind

- Wind is unpredictable, so it is an unpredictable energy source
- Demand for electricity might not coincide with periods of high wind
 - Hottest days in Texas have peak demands for electricity to power air conditioning. Tend to have the least wind.
 - Need to store the energy



Wind Advantages

- Cost has gone down. Competitive with all other energy sources.
- Low maintenance costs



Wind Disadvantages

Concerns about birds and bats

- Collisions with existing wind turbines kill about 368,000 birds each year
- But, this is only 0.1% of bird deaths from collisions with human structures (buildings, high-tension lines, communication towers, vehicles)



Tidal/Wave disadvantages

- High costs: equipment has to work reliably under constant buffeting of the sea and saltwater corrosion
 - Only 3 tidal plants, no wave power plants yet
- Possibility of interfering with fish and marine mammals

