EEE116 (17/18)

Week 10 Introduction to sustainability

Climate change & Energy

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Previously…

- Concept of sustainability
- Growth curves
- Life cycle analysis (LCA)
- Sustainable development

Tradeoff between choice.

UN Definition

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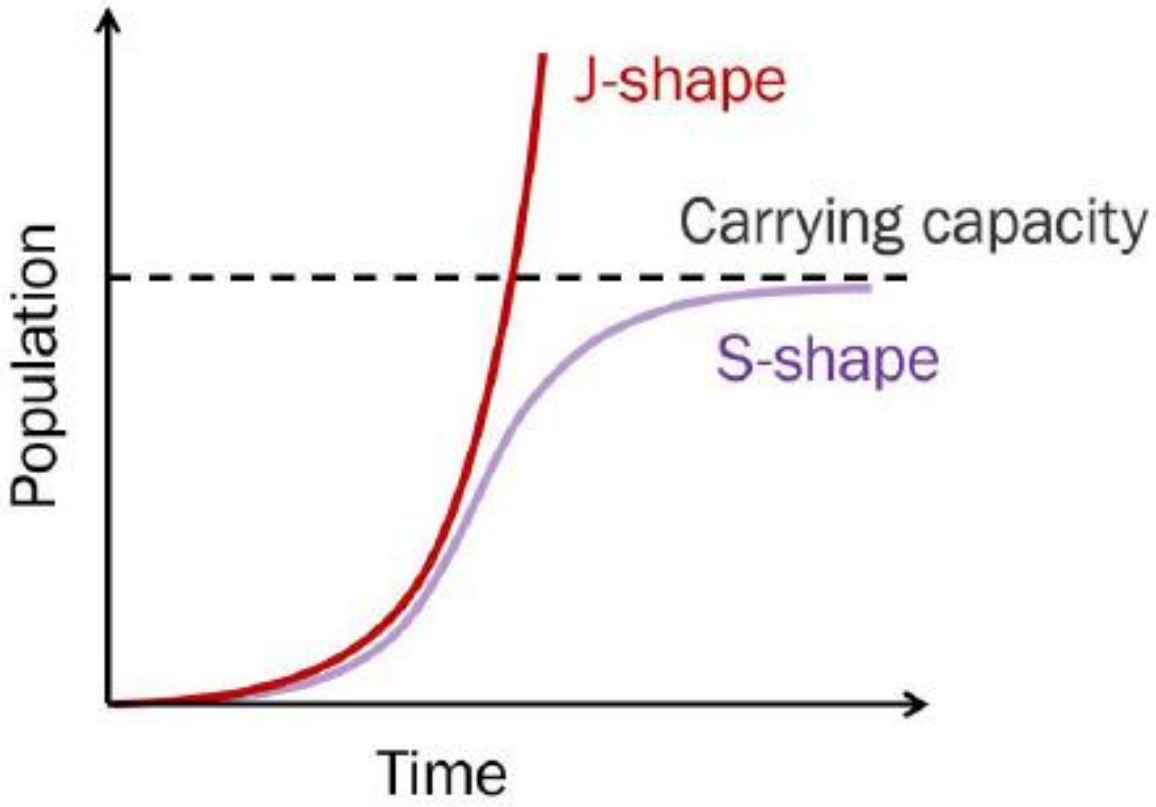
"*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. " [1]*

It contains within it two key concepts:

- *the concept of **needs**, in particular the essential needs of the world's poor, to which overriding priority should be given; and*
- *the idea of **limitations** imposed by the state of technology and social organization on the environment's ability to meet present and future needs.*

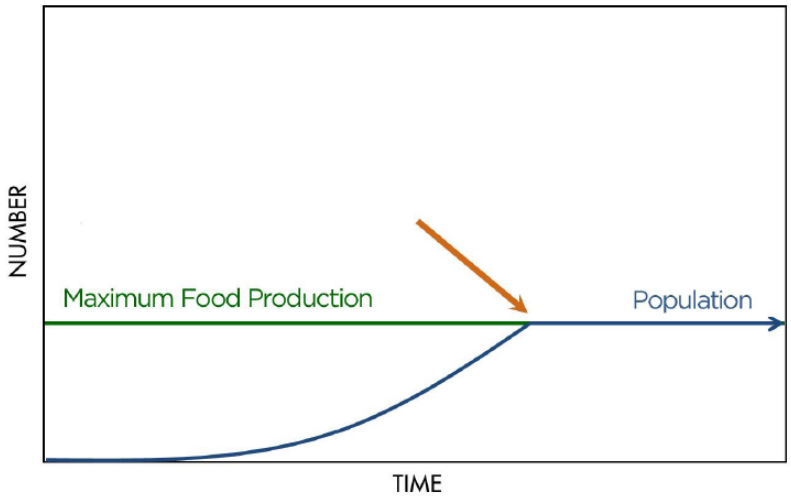
[1] World Commission on Environment and Development (WCED). *Our common future.* Oxford: Oxford University Press, 1987 p. 43.

Growth curves



Two types of "checks" that could reduce the population

- "preventive checks"— Population control
- "positive checks" — Malthusian catastrophe



Outline

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Climate change

- Insolation
- Albedo
- Greenhouse effect

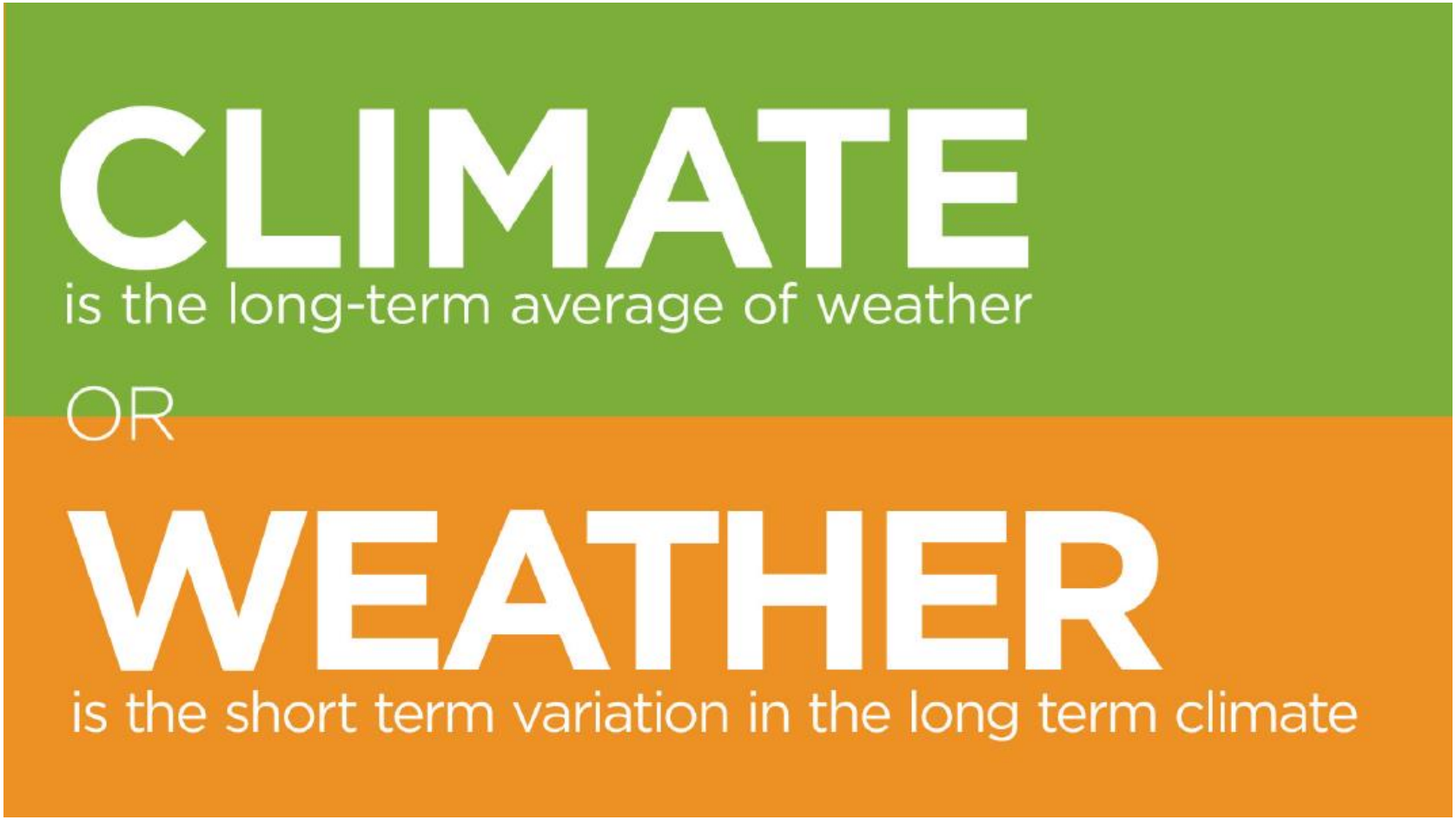
Energy

- Oil, coal & natural gas
- Renewable energy

CLIMATE CHANGE


"I'm not a believer in global warming... and I'm not a believer in man-made global warming. It could be warming, and it's going to start to cool at some point."
-Donald Trump
TRUMP
www.DonaldJTrump.com
Urbandale, Iowa
MAKE AMERICA GREAT AGAIN!
THINKPROGRESS
READ MORE AT: http://thkpr.gs/3704239
photo credit: AP Photo/Charlie Neibergall


The concept of global warming was created by and for the Chinese
in order to make U.S. manufacturing noncompetitive.
– Donald Trump
sheknows


CLIMATE
is the long-term average of weather
OR
WEATHER
is the short term variation in the long term climate

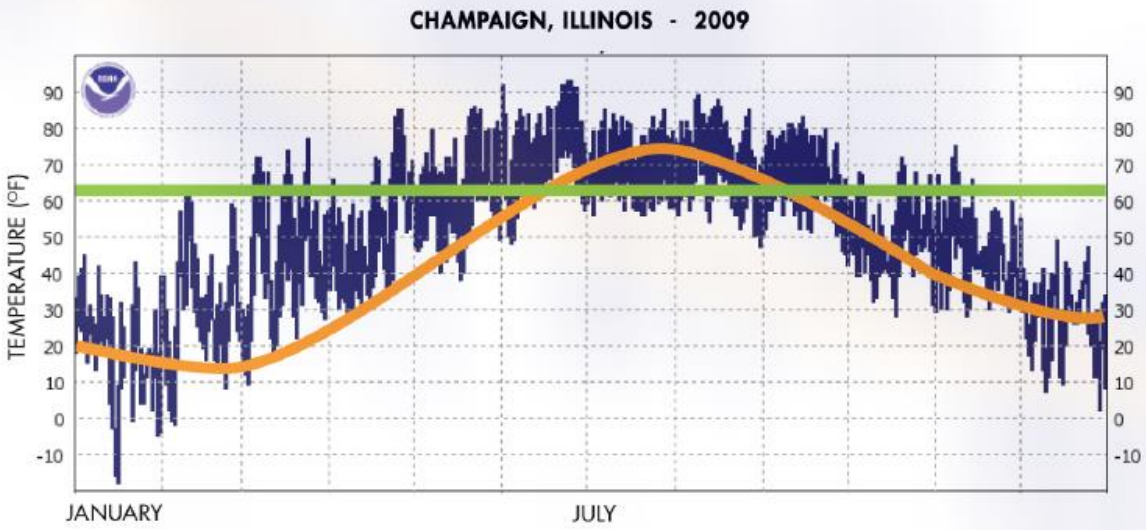
YEARLY AVERAGE:
CHAMPAIGN-URBANA in 2009

THE GREEN LINE is the average for the whole year (61° F, or about 15° C). The blue line is the data, and this is changeable in a single year – the same day has a different temperature year to year, but on average we know that summer is warmer than winter. The blue line is measuring the day to day weather. Whenever we average these values (either on a day basis, the orange line, or on a yearly basis, the green line) we are making a measurement of climate.

DAILY HIGHS

DAILY AVERAGE

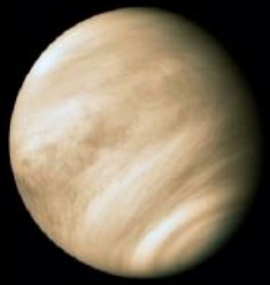
YEARLY AVERAGE



AVERAGE TEMPERATURES

THE DIAGRAM SHOWS THE AVERAGE TEMPERATURES of Venus (top), Earth (middle) and the Moon (bottom). What factors determine the climate of the Earth? Why are we different – hotter than the Moon, colder than Venus? There are several factors that determine a planet's climate, and in this section we will go over the most important ones. The Energy Balance determines what the average temperature will be, and this energy balance is influenced by the amount of sunlight received (insolation) , the amount of sunlight reflected back into space (albedo), and the amount of sunlight recycled by the atmosphere (the greenhouse effect).

VENUS



400°C

EARTH

15°C

MOON

-23°C

NASA/NSSDC Gallery

What if the sun gets hotter?

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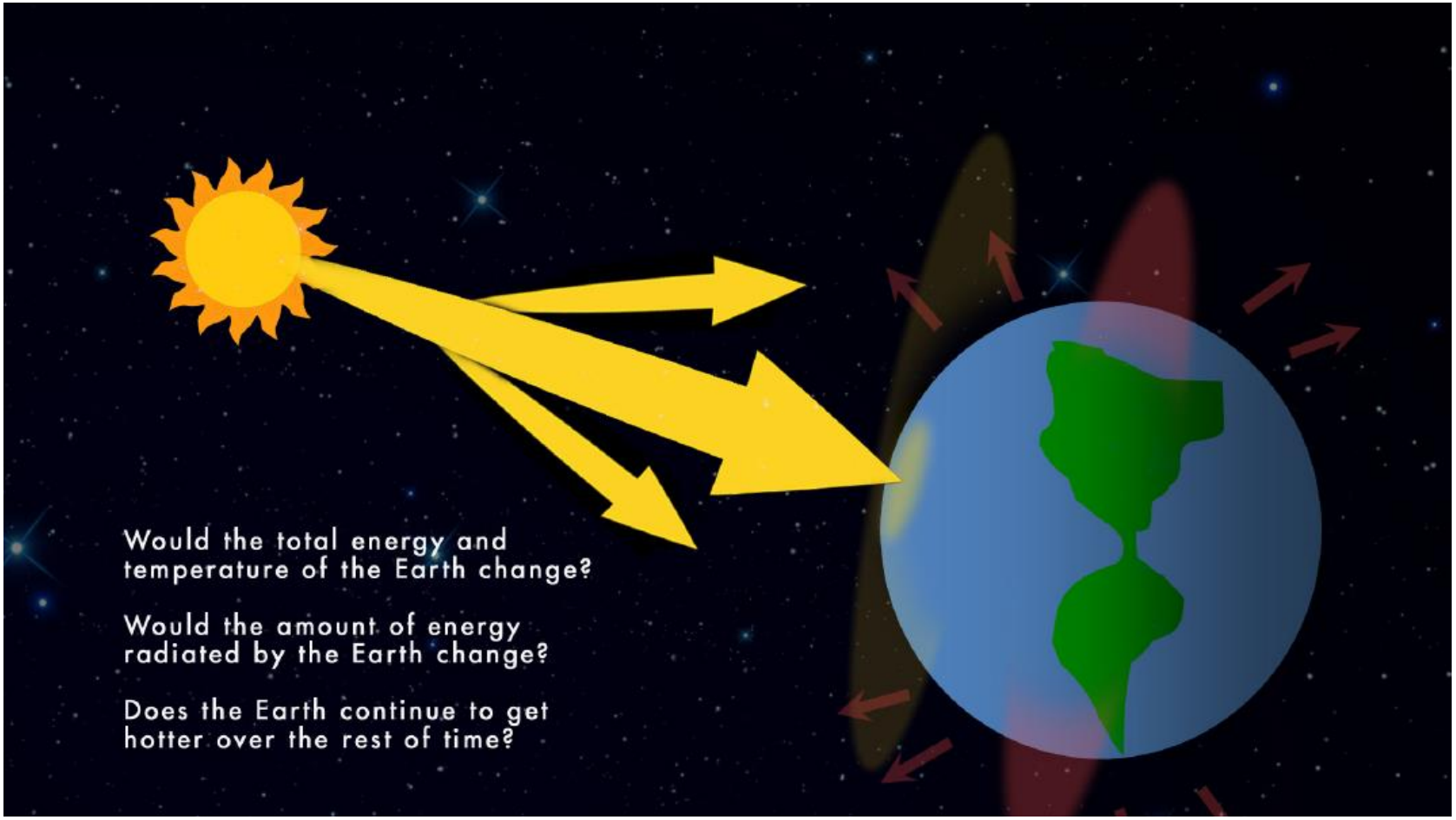


FACTORS DETERMINE CLIMATE

So why is there such a big difference between these three bodies? Insolation (the energy received from the sun) explains some of the difference - Venus, which is the hottest, is the closest to the sun, and receives the most energy. But the Moon and the Earth receive the same amount of sunlight. In addition to insolation, here are two very important factors that explains these differences: albedo and the greenhouse effect. So the three most important factors that determine climate are:

INSOLATION

ALBEDO

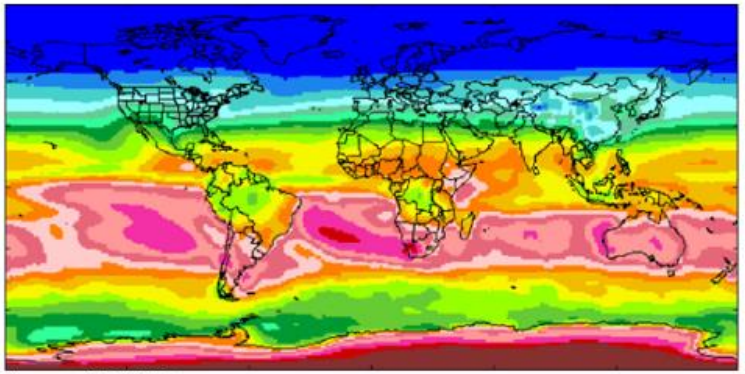
GREENHOUSE EFFECT

INSOLATION IS THE MEASURE of the amount of solar radiation falling on a surface. In this diagram, red colors indicate more energy from insolation on the surface of the Earth, while blue means that there is less. Look at the figure and make some general statements about the distribution of energy on the Earth's surface.

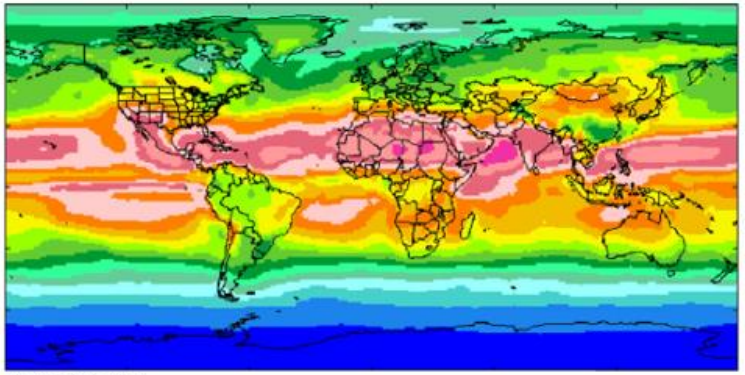
INSOLATION

Why is the equator redder (i.e. has more insolation) than the poles?

Why does the Arctic change between January and April?



January 1984-1993

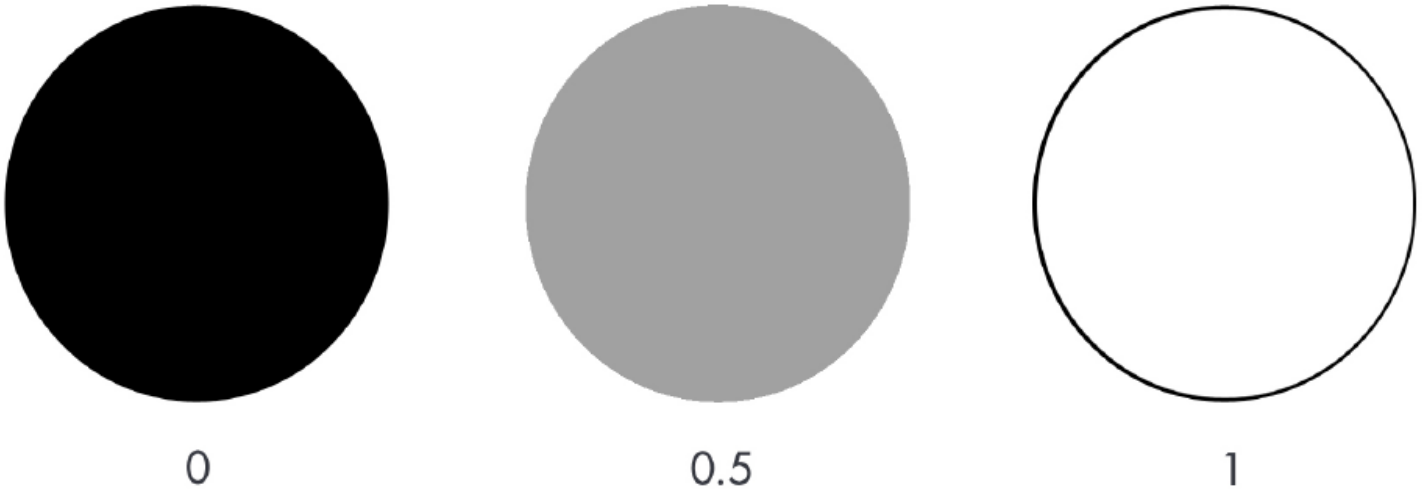


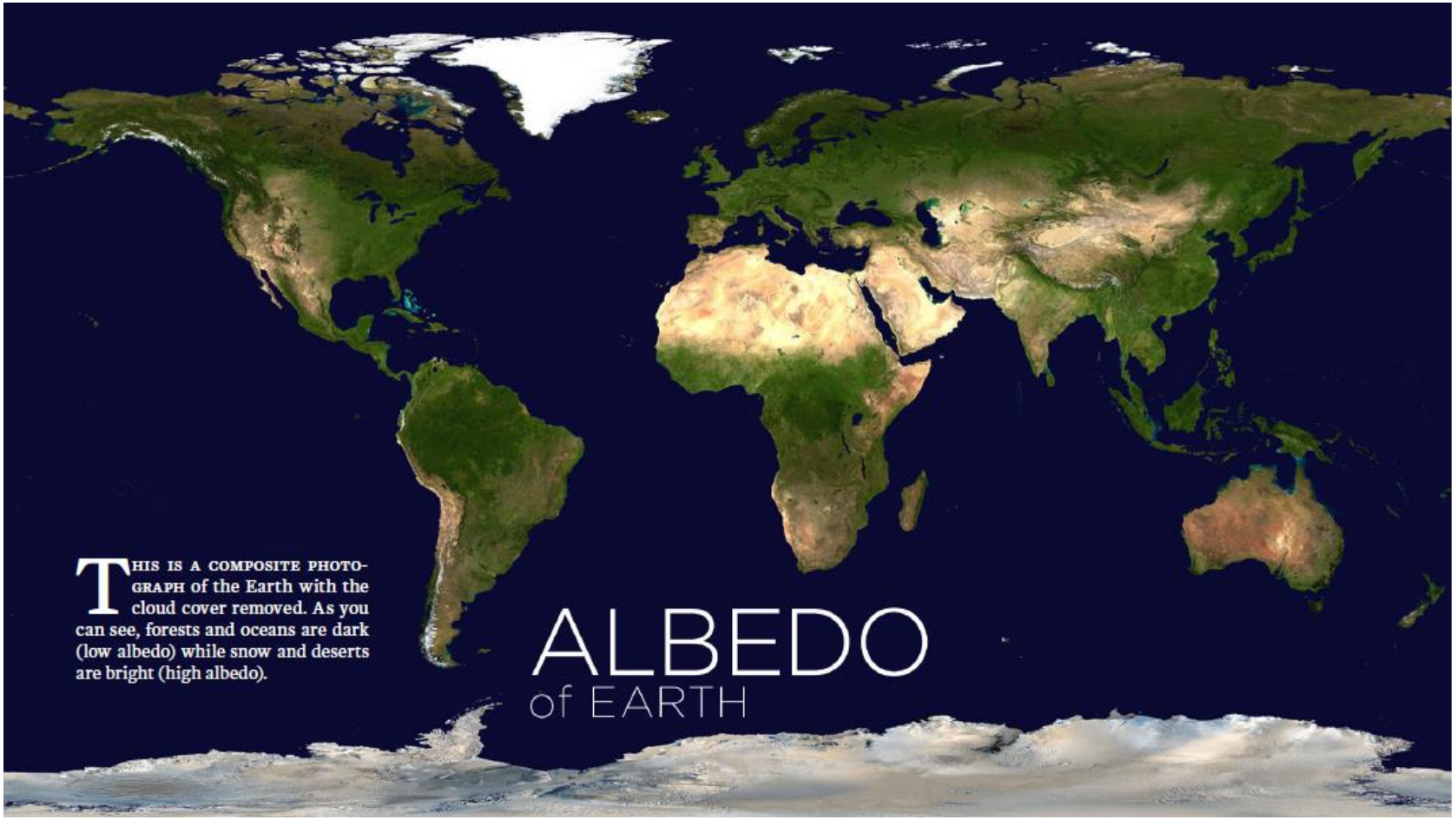
April 1984-1993

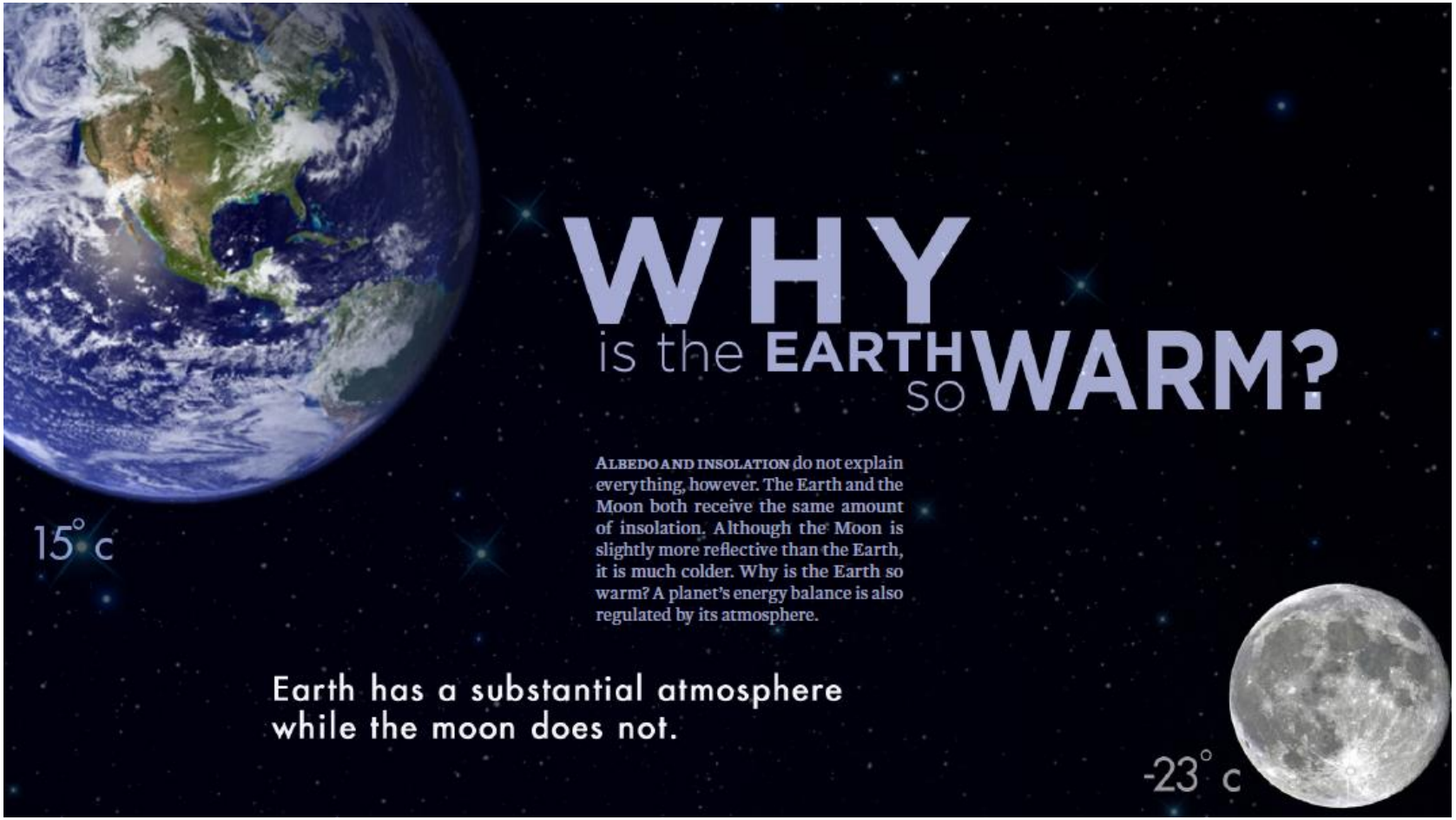
Roberta DiPasquale, Surface Meteorology and Solar Energy Project, NASA Langley Research Center, and the ISCCP Project

ALBEDO

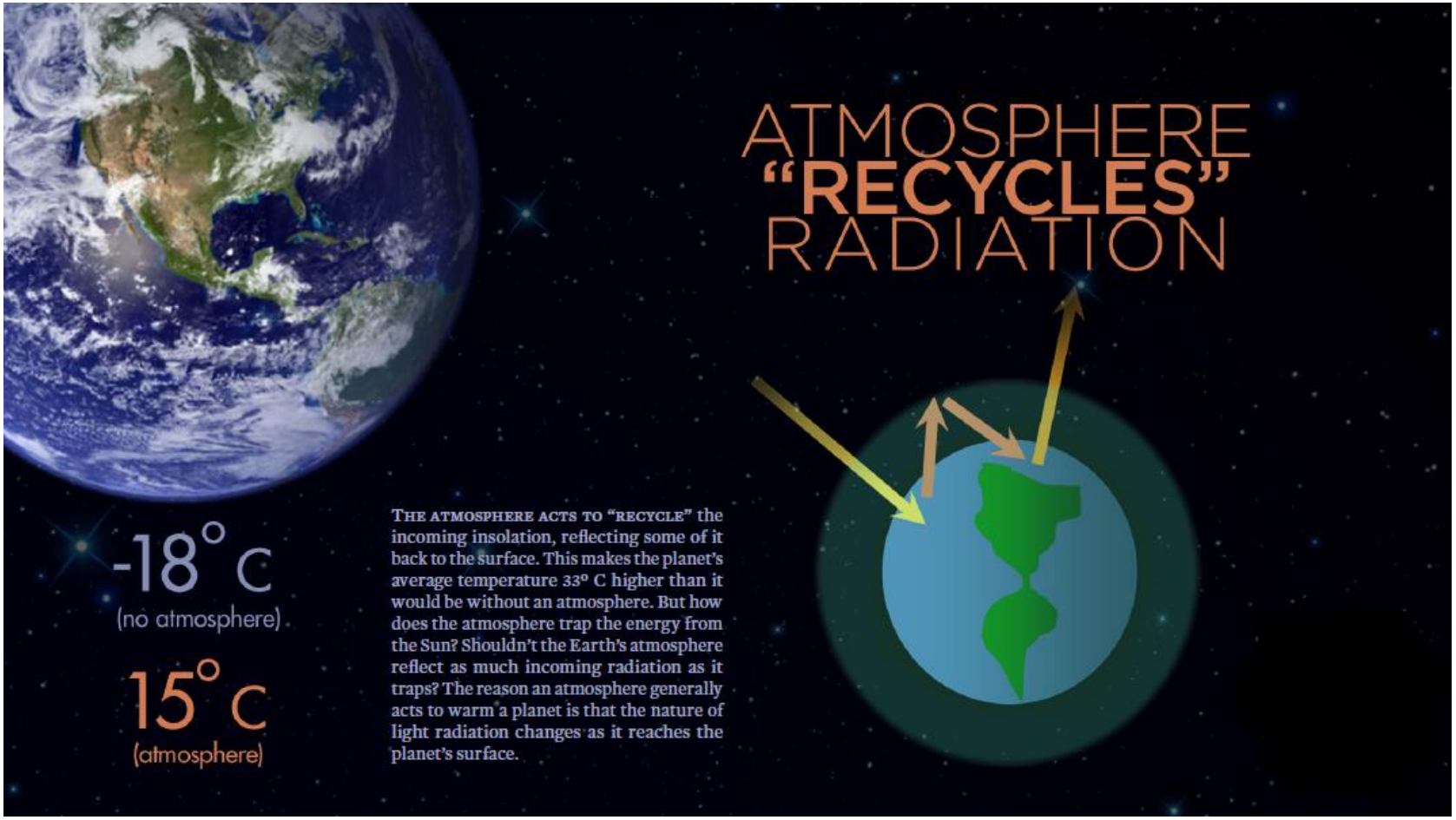
ALBEDO IS A MEASURE OF HOW REFLECTIVE A SURFACE IS. The higher the albedo the more reflective the material: a perfectly black surface has zero albedo, while a perfectly white surface has an albedo of 1 - it reflects 100% of the incident light. If a planet has a high albedo, much of the radiation from the Sun is reflected back into space, lowering the average temperature.




ALBEDO
of EARTH
THIS IS A COMPOSITE PHOTOGRAPH of the Earth with the cloud cover removed. As you can see, forests and oceans are dark (low albedo) while snow and deserts are bright (high albedo).

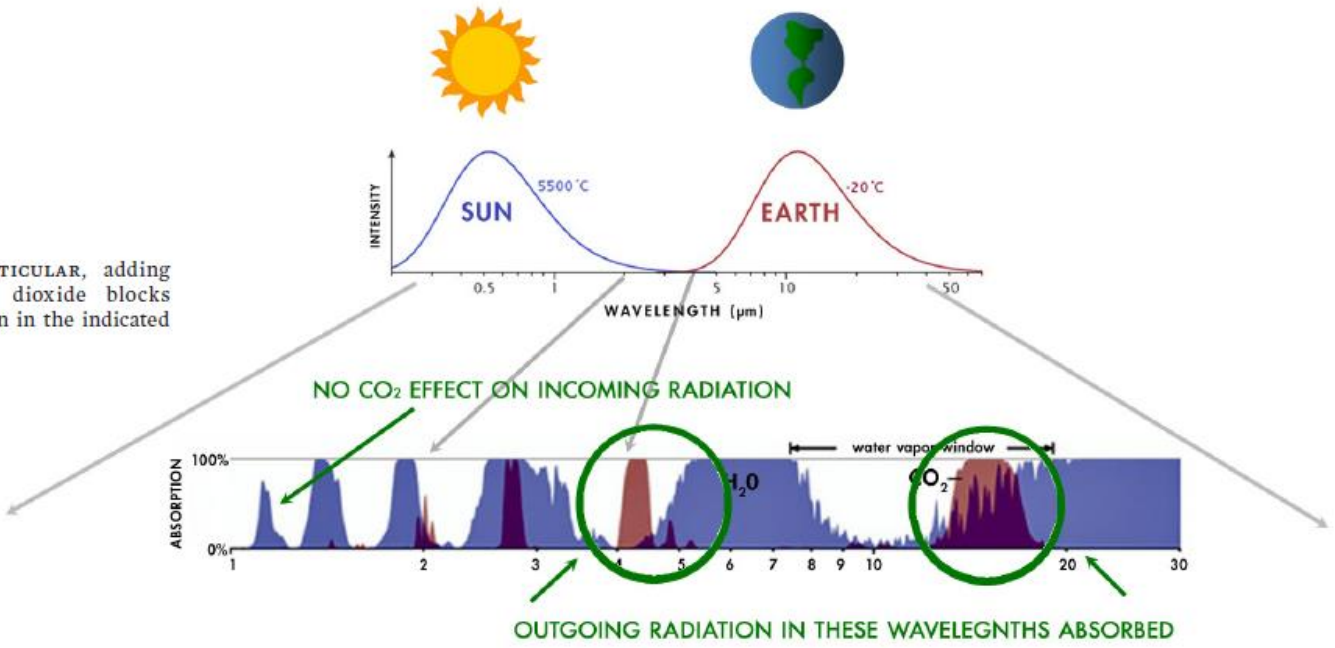

WHY
is the EARTH
so WARM?
ALBEDO AND INSOLATION do not explain everything, however. The Earth and the Moon both receive the same amount of insolation. Although the Moon is slightly more reflective than the Earth, it is much colder. Why is the Earth so warm? A planet's energy balance is also regulated by its atmosphere.
15° c
Earth has a substantial atmosphere while the moon does not.
-23° c

Greenhouse effect



Atmosphere is a Blanket?

RADIATION



In particular, adding carbon dioxide blocks radiation in the indicated areas.

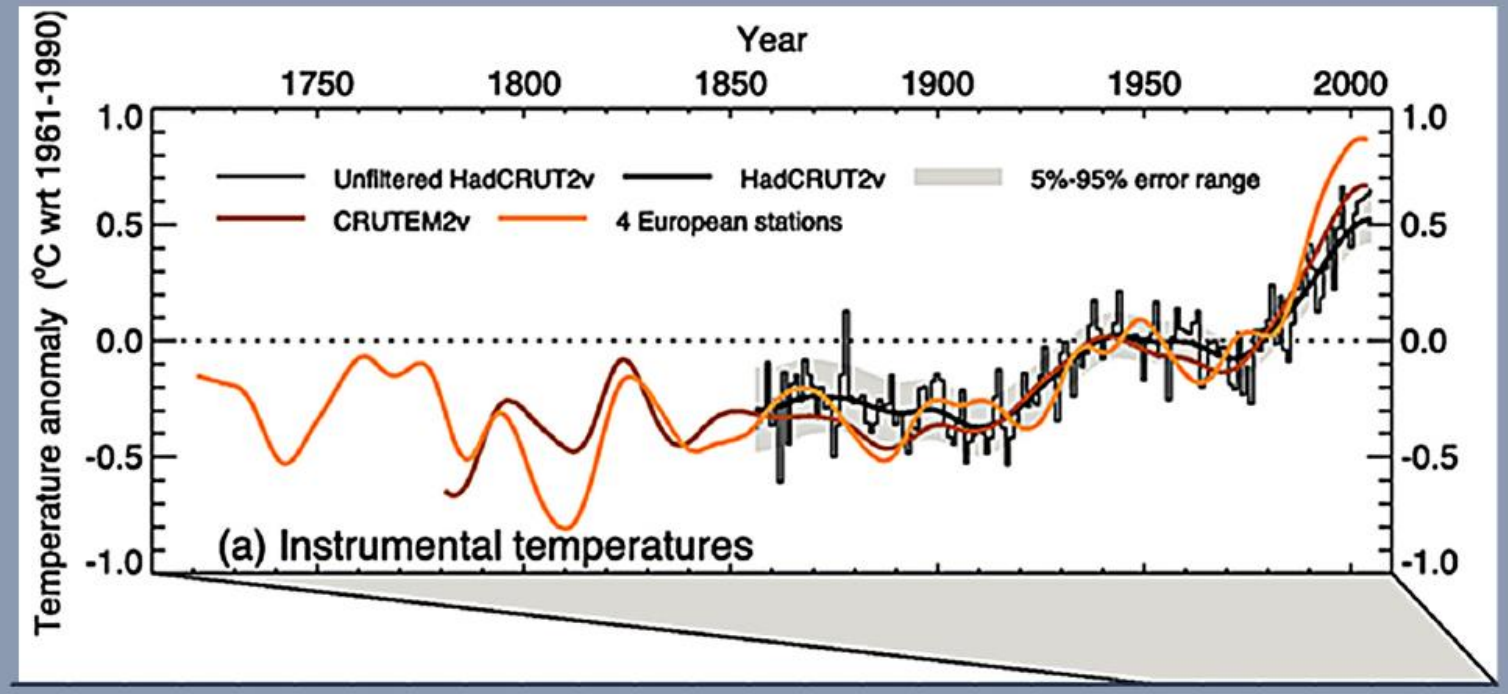
Look back in history

TO UNDERSTAND THE CLIMATE OF THE PAST, data needs to be collected. There are two general types of data.

INSTRUMENT DATA: Climate is measured directly. These measurements are very precise, but data is limited to the modern era. An example is measurements taken from a thermometer. Other types of instrumental data come from rain gauges, anemometers (wind direction and speed), tide gauges (sea level) and satellites.

PROXY DATA: Climate is measured indirectly. These methods are less precise and require an understanding of how climate interacts with natural systems, but these methods can record the deep past. An example is tree ring or tree core data (shown on right). The tree cores are the small wooden tubes below the metal drill. The size of the yearly growth rings indicate if the conditions were good for tree growth through time. There are many other types of proxy data, and these include ice cores, sediment cores, coral cores, landforms, and historical records.

Instrumental temperatures



THE BLACK, RED, AND YELLOW LINES are different calculations for the global temperature anomaly, based on instruments (including thermometer readings) from various sources. This shows the limitation of instrumental data – we have only had precise climate measuring instruments since industrialization, so the global instrumental record only goes back to around 1850, although there is a longer set of data from Europe (yellow line), where the technology was developed. Note the change in temperature over the last 150 years – the black line has increased from an anomaly of around -0.3° C in 1850 to around 0.5° in 2005. This means an increase of just under 1° C (or about 1.5° F), with most of the increase happening in the last 40 years.

Proxy data

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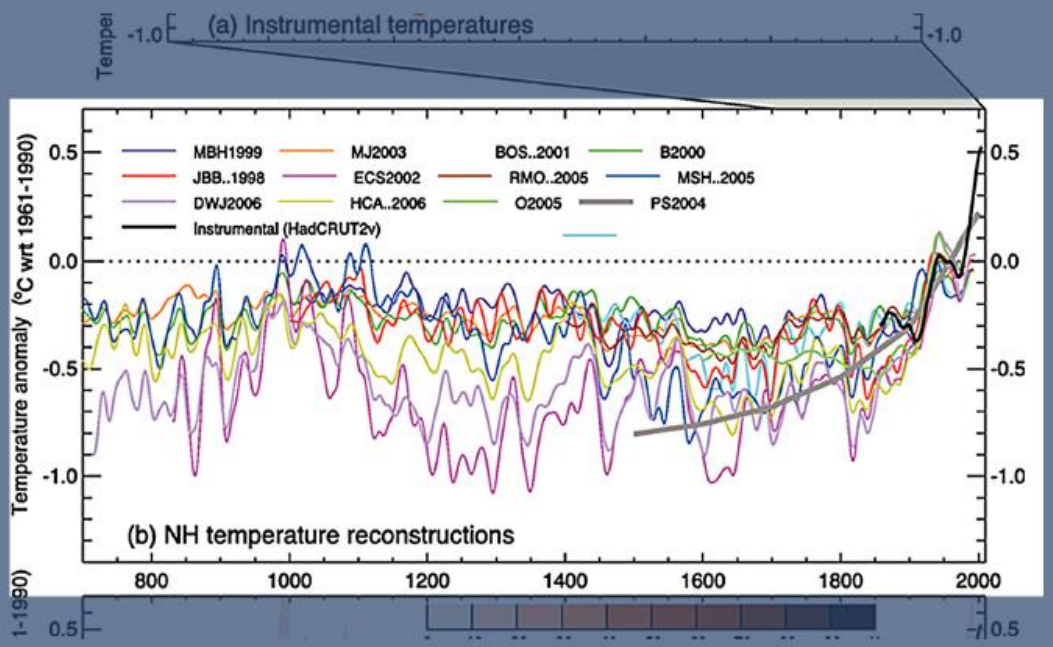
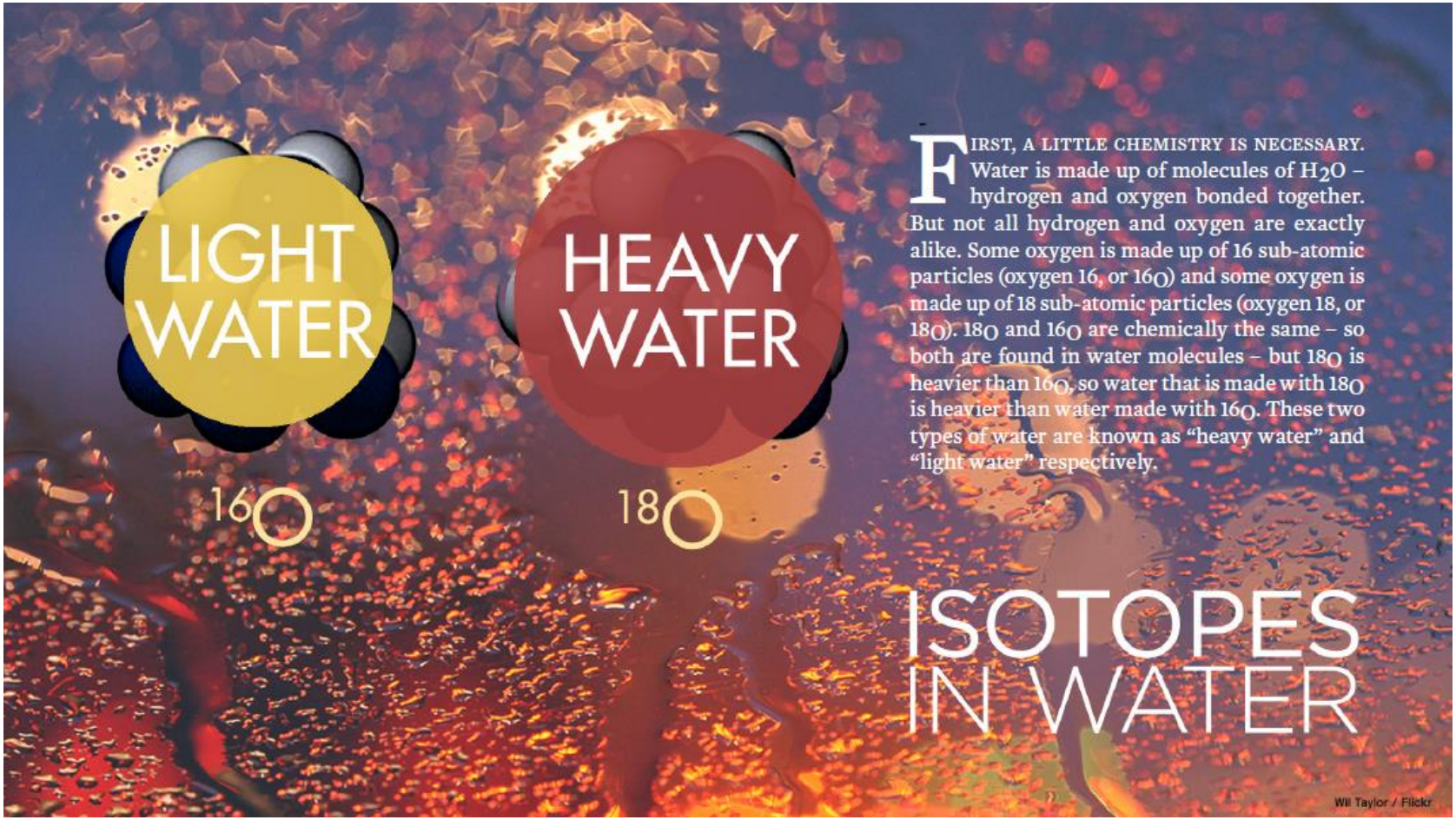
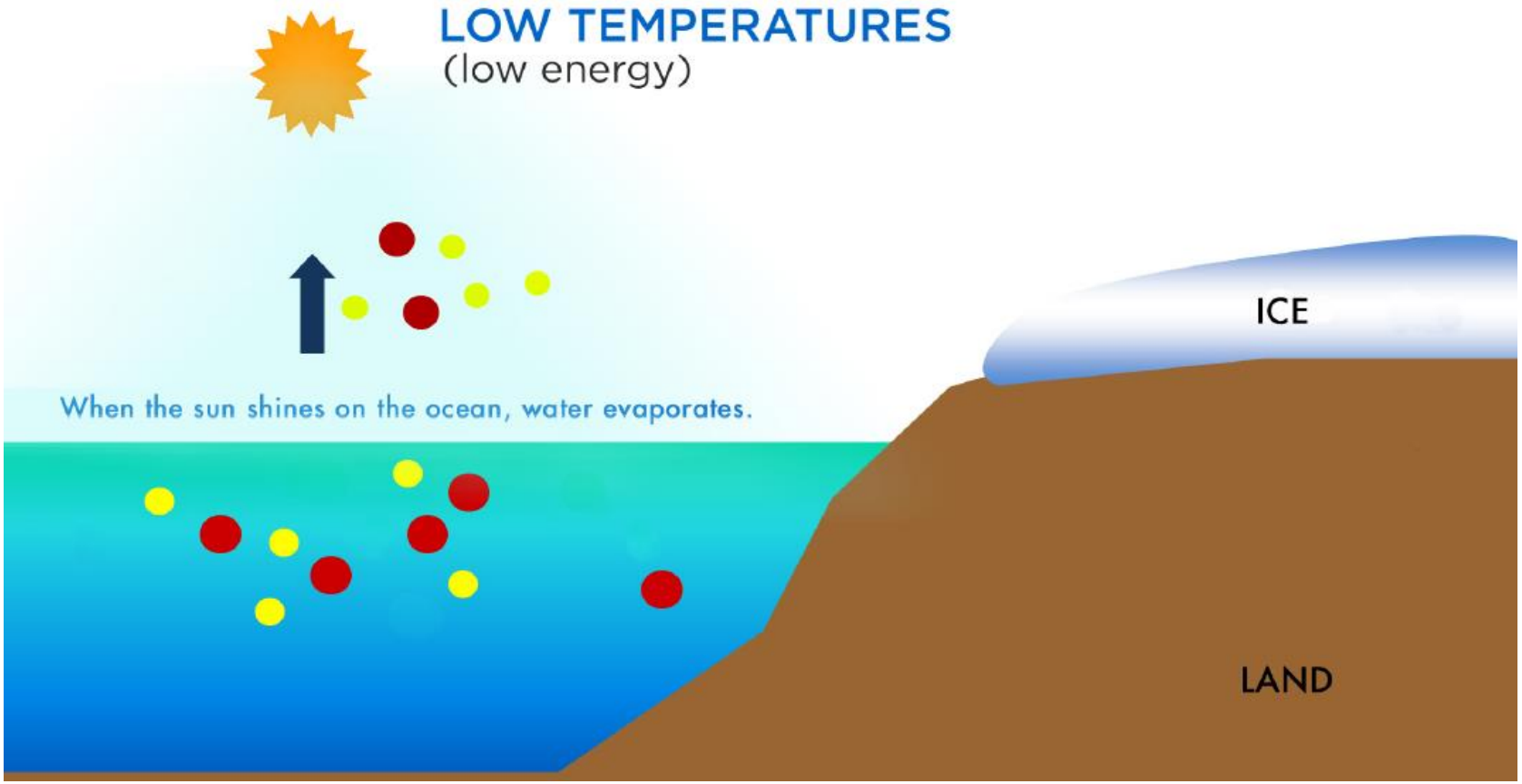
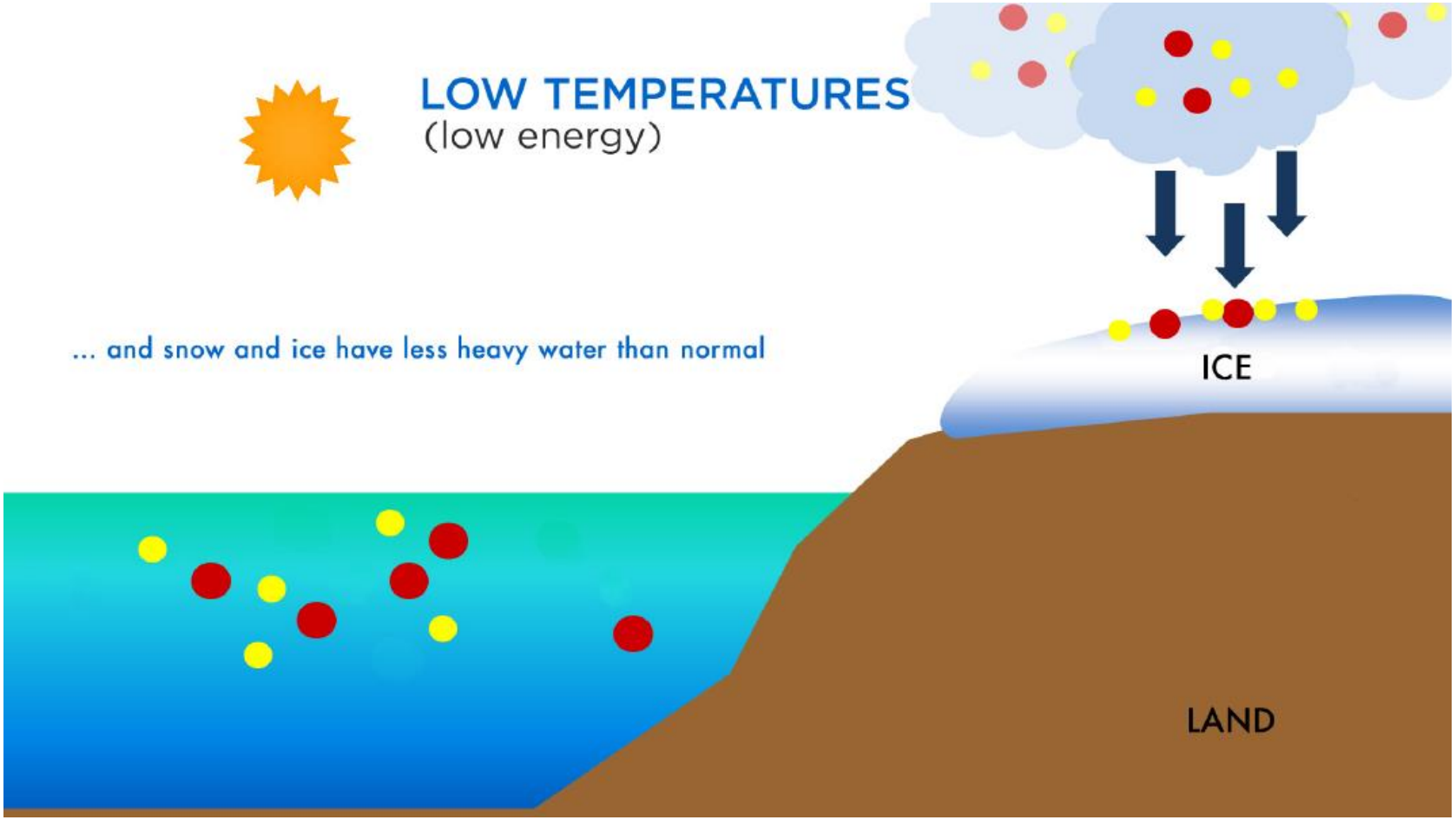
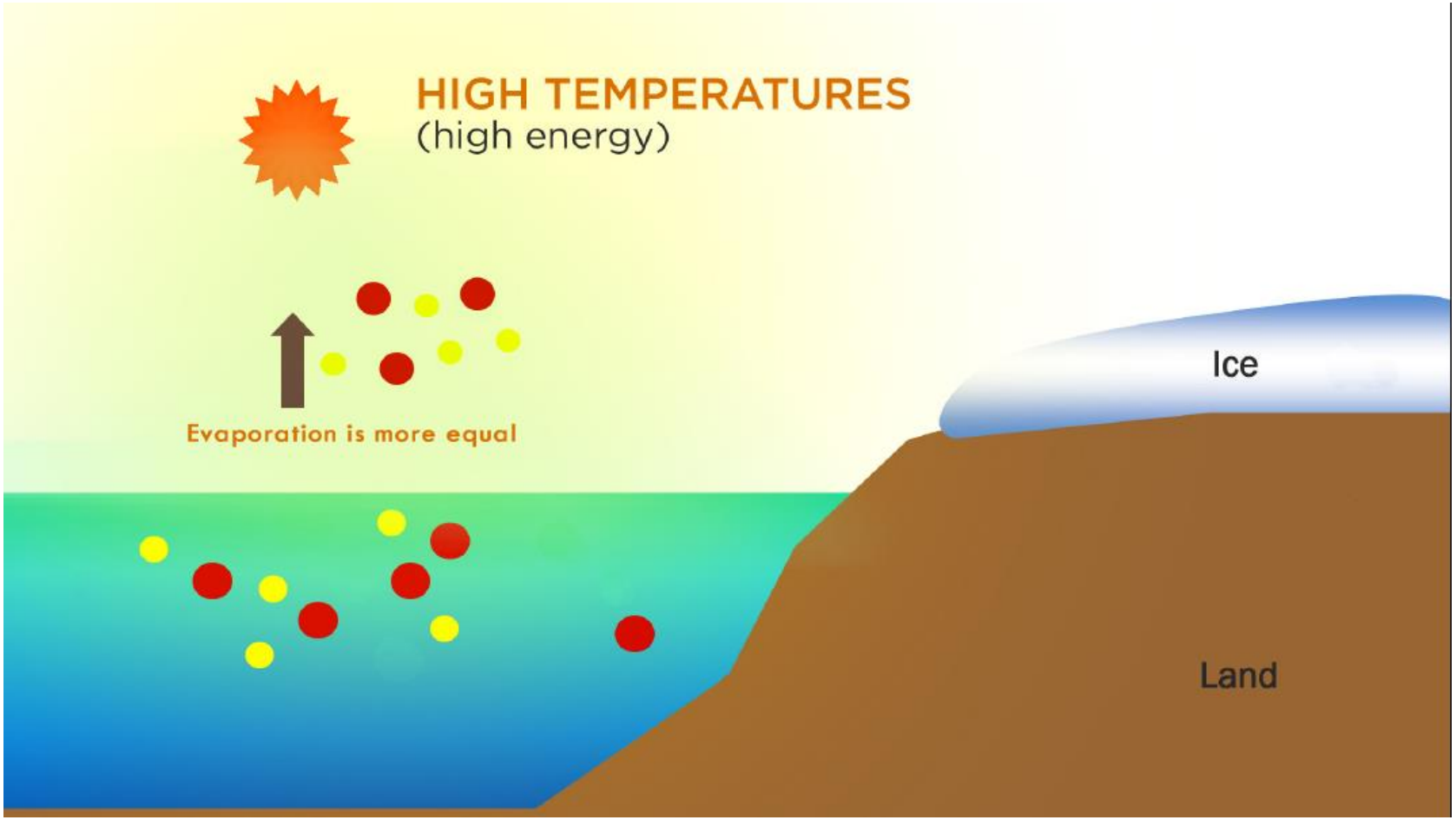
NOW LET'S FOCUS ON THE MIDDLE FIGURE. This goes much further back in time – to before 800 AD (over 1200 years ago). The black line is the instrument data – the same as in the previous figure. The colored lines are different proxy data sets, again from different places around the world. The proxies are less precise then the instrument data (although note how they are similar to one another, and the black line, over the last 100 years) but they provide climate data that goes back much further in time – not only to before industrialization, but even before the existence of humans. From this data, we can see that different proxies vary, suggesting that there is error in the measurements (which we would expect) and that climate might vary differently in different places around the world. The proxy data broadly agrees that the climate was between 0 and 1 degrees cooler than 1950 before 1850, after which the temperature increased, to the anomaly of around +0.5° that we have today. Why was there a sudden change in the average surface temperature about one hundred years ago?

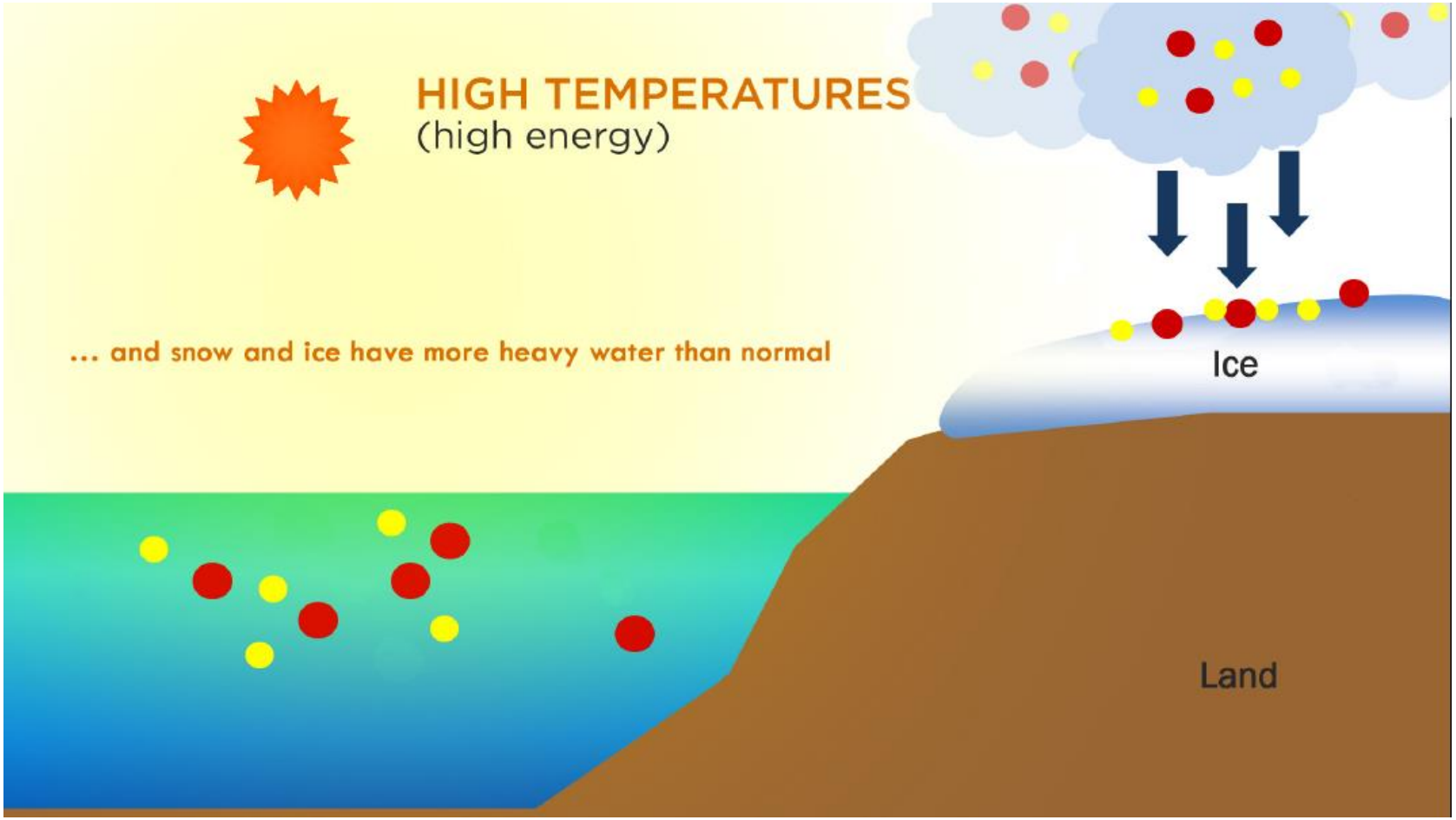



LIGHT WATER
HEAVY WATER
^{16}O
^{18}O
FIRST, A LITTLE CHEMISTRY IS NECESSARY. Water is made up of molecules of H_2O – hydrogen and oxygen bonded together. But not all hydrogen and oxygen are exactly alike. Some oxygen is made up of 16 sub-atomic particles (oxygen 16, or $16O$) and some oxygen is made up of 18 sub-atomic particles (oxygen 18, or $18O$). $18O$ and $16O$ are chemically the same – so both are found in water molecules – but $18O$ is heavier than $16O$, so water that is made with $18O$ is heavier than water made with $16O$. These two types of water are known as "heavy water" and "light water" respectively.
ISOTOPES IN WATER
Wil Taylor / Flickr

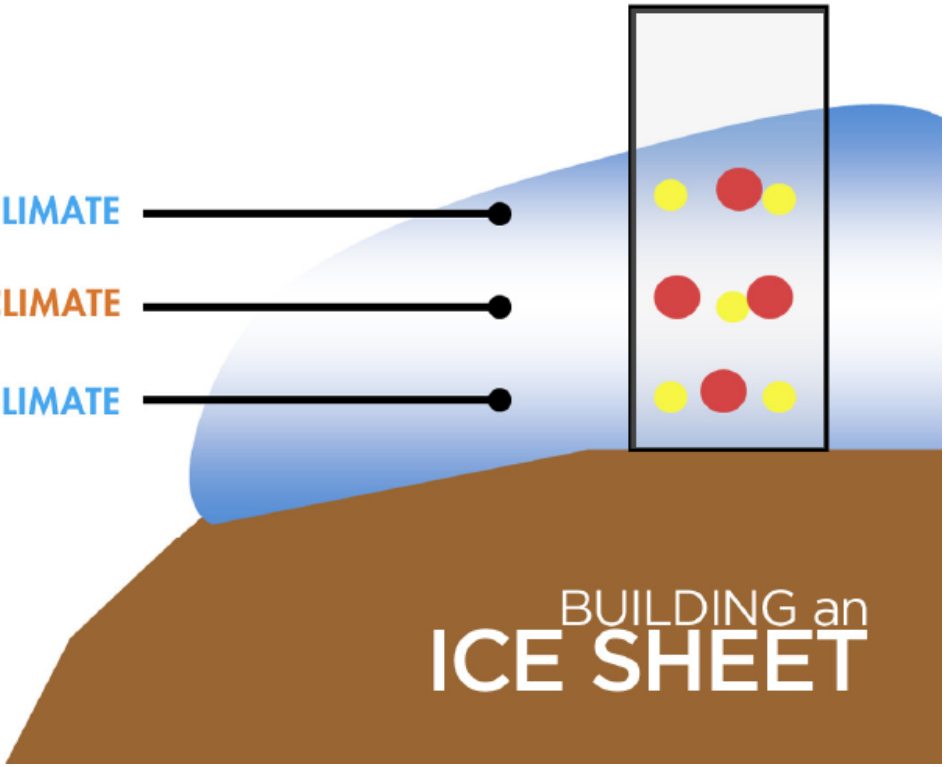

LOW TEMPERATURES
(low energy)
When the sun shines on the ocean, water evaporates.
ICE
LAND


LOW TEMPERATURES
(low energy)
... and snow and ice have less heavy water than normal
ICE
LAND

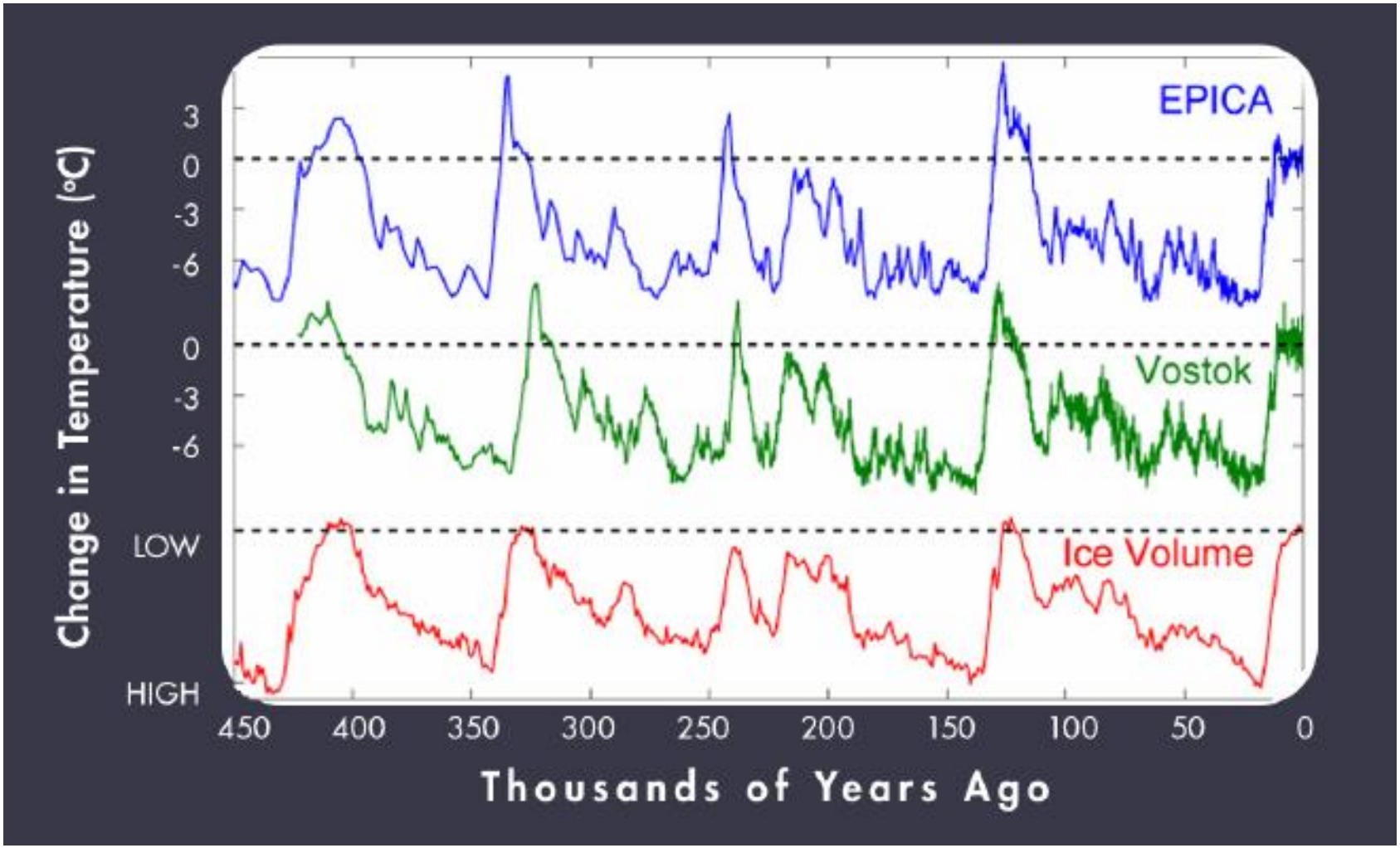

HIGH TEMPERATURES
(high energy)
Evaporation is more equal
Ice
Land


HIGH TEMPERATURES
(high energy)
... and snow and ice have more heavy water than normal
Ice
Land

NOW IF WE DRILL A CORE in the ice...



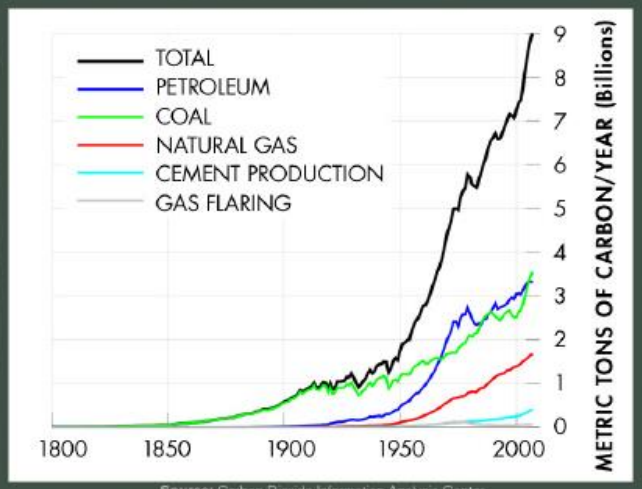
Temperature changes



NASA - Carbon and Climate Change in 90 Seconds [HD]

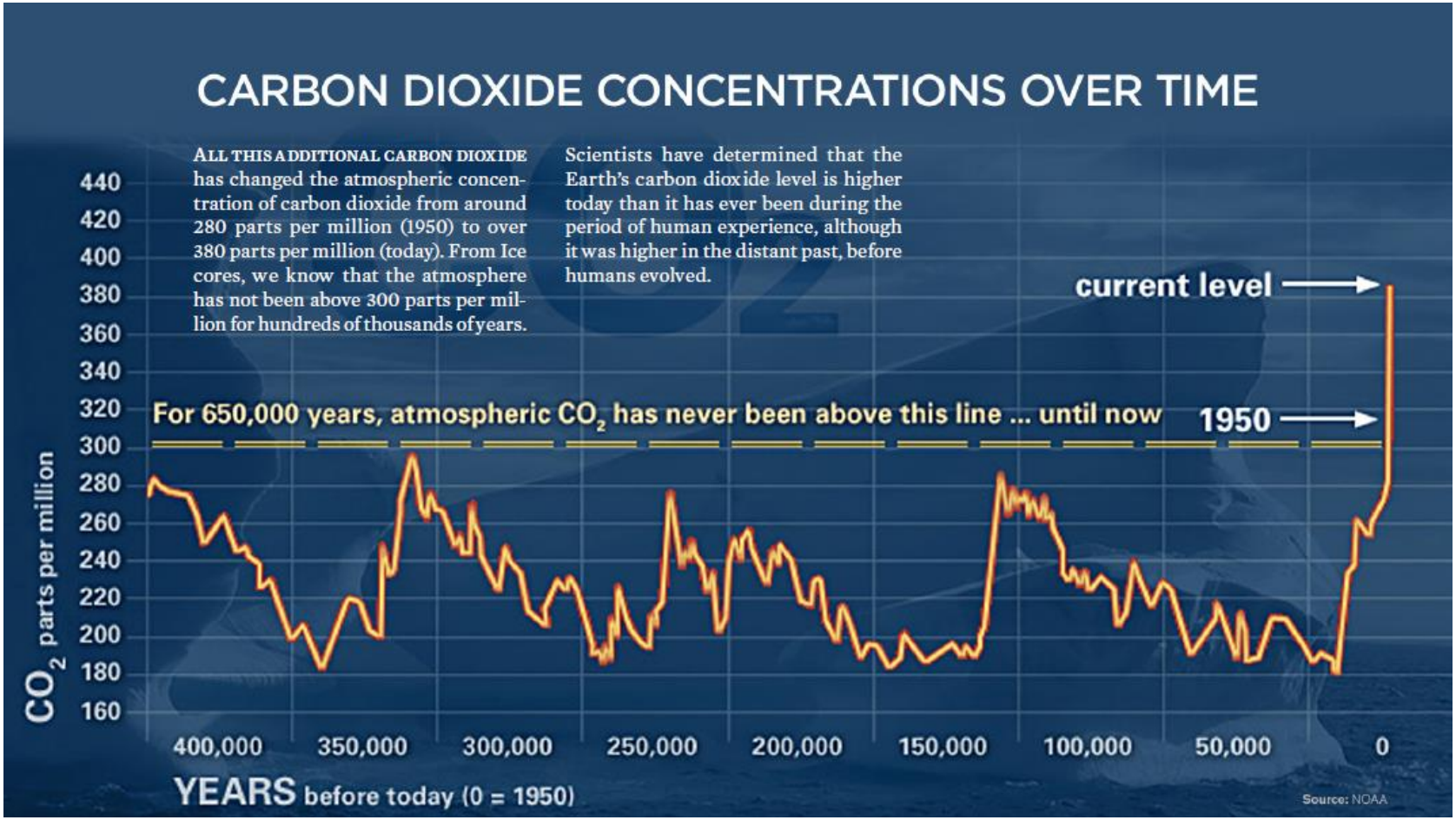
INDUSTRIALIZATION

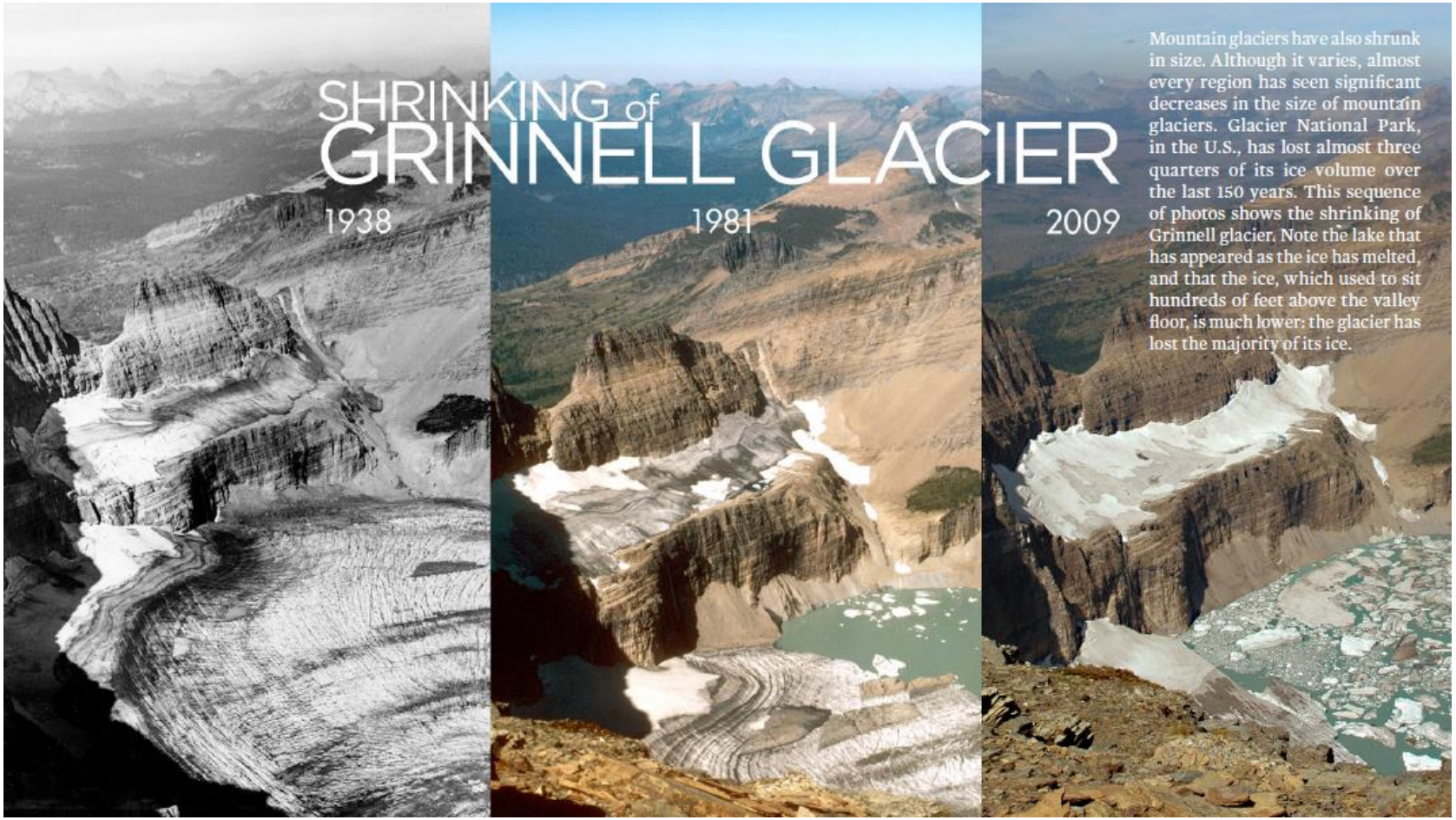
Industrialization adds additional carbon dioxide to the atmosphere. As we can see in this figure, for example, the amount of carbon dioxide produced from the burning of coal – a key early and current energy source – has increased steadily since 1850. The combustion of natural gas and petroleum have also become significant in the last fifty years.



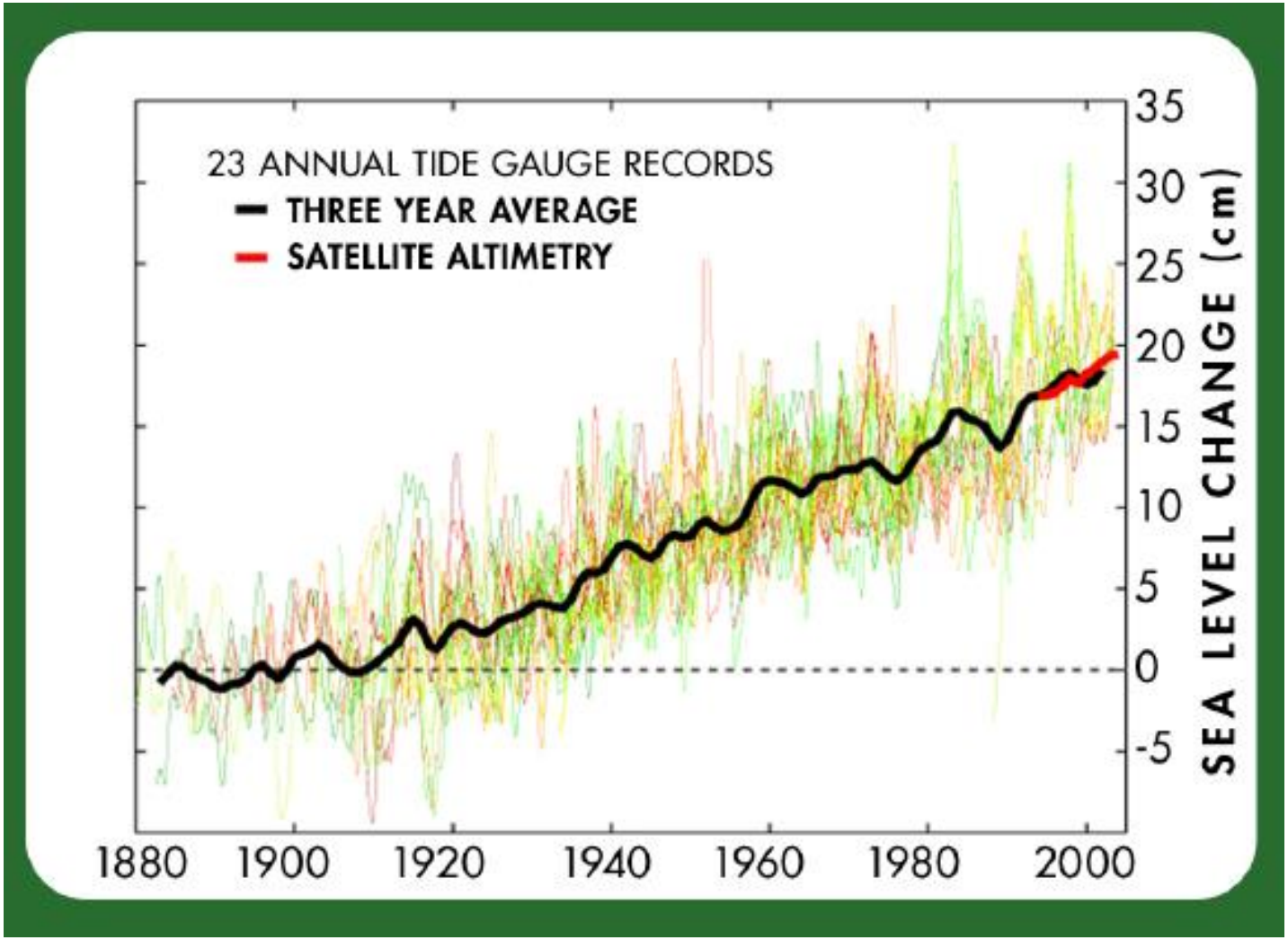
Source: Carbon Dioxide Information Analysis Center

CARBON DIOXIDE EMISSIONS AFTER INDUSTRIALIZATION


CARBON DIOXIDE CONCENTRATIONS OVER TIME
ALL THIS ADDITIONAL CARBON DIOXIDE has changed the atmospheric concentration of carbon dioxide from around 280 parts per million (1950) to over 380 parts per million (today). From Ice cores, we know that the atmosphere has not been above 300 parts per million for hundreds of thousands of years.
Scientists have determined that the Earth's carbon dioxide level is higher today than it has ever been during the period of human experience, although it was higher in the distant past, before humans evolved.
current level
For 650,000 years, atmospheric CO2 has never been above this line ... until now
1950
CO2 parts per million
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
YEARS before today (0 = 1950)
Source: NOAA


SHRINKING of
GRINNELL GLACIER
1938
1981
2009
Mountain glaciers have also shrunk in size. Although it varies, almost every region has seen significant decreases in the size of mountain glaciers. Glacier National Park, in the U.S., has lost almost three quarters of its ice volume over the last 150 years. This sequence of photos shows the shrinking of Grinnell glacier. Note the lake that has appeared as the ice has melted, and that the ice, which used to sit hundreds of feet above the valley floor, is much lower: the glacier has lost the majority of its ice.

Increase of sea level



Facts and Opinions

Facts:

CO2 emission is higher than ever.

Temperature is at a high level in history.

The sea level is increasing.

Opinions:

Climate change is a serious issue.

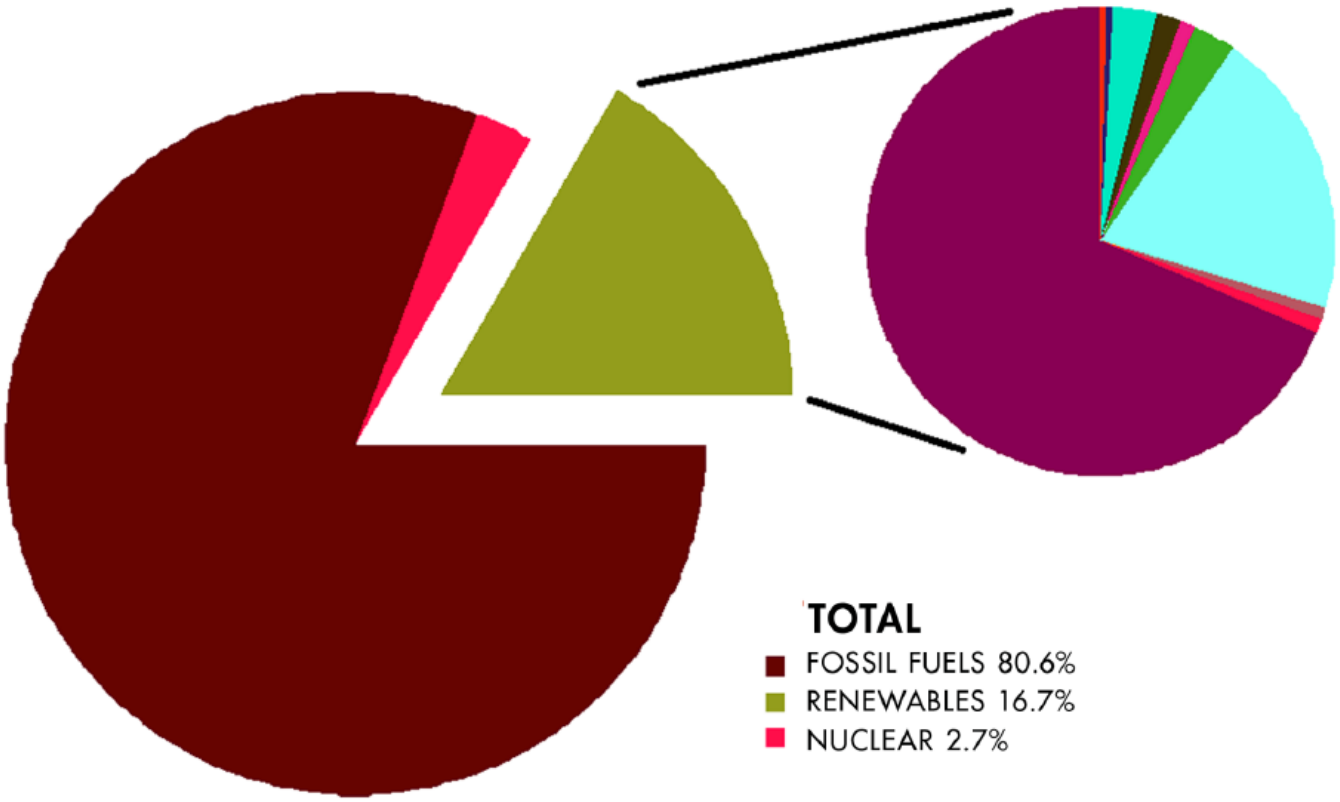
The climate change is caused by CO2 emission.

We should act immediately to reduce CO2.

Carbon tax is a effective solution.

ENERGY

Total energy consumption--US



Chinese case

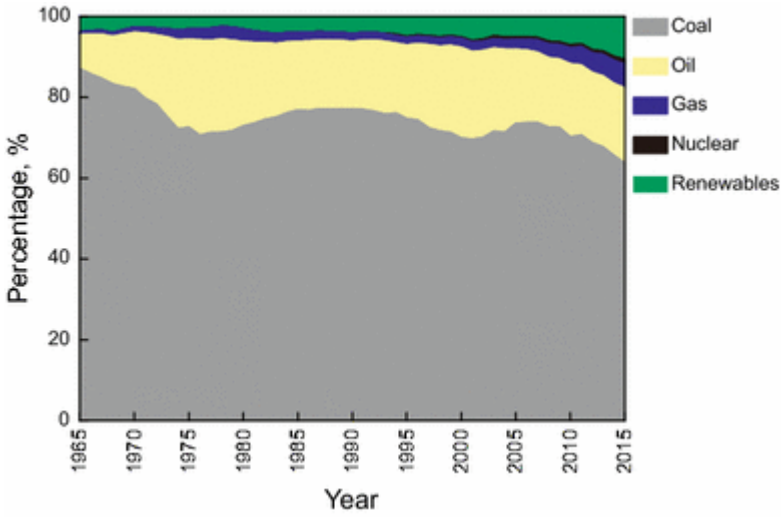


Fig. 1: Percentage of China's energy consumption structure by fuel types, 1965–2015.
Data source BP Statistical Review of World Energy (2016) and NBS China Statistical Yearbook (2015)

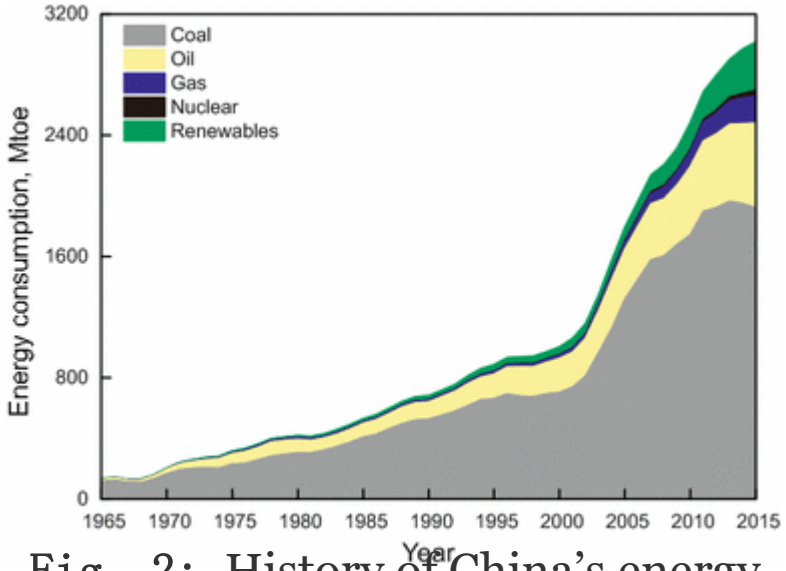
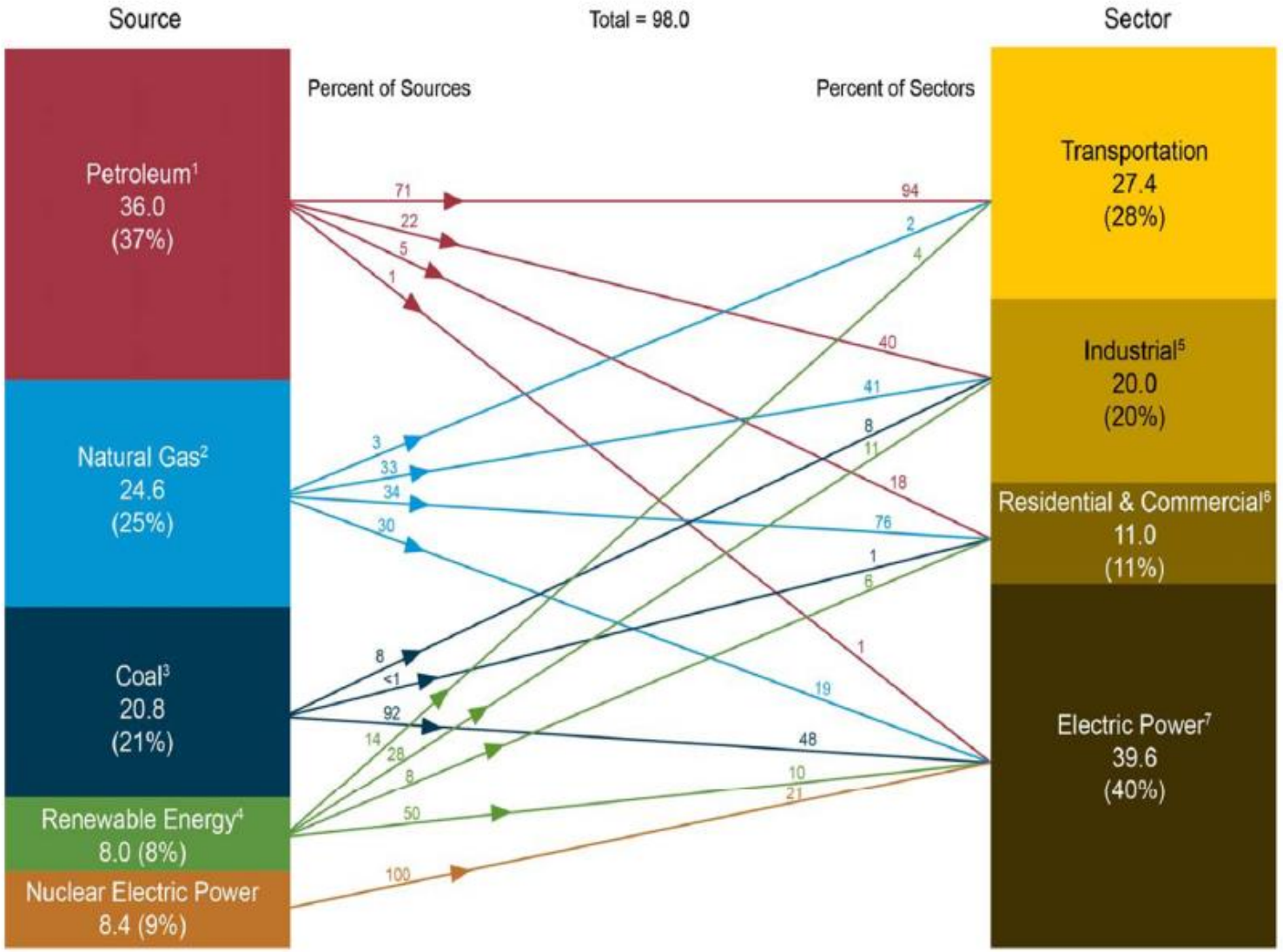
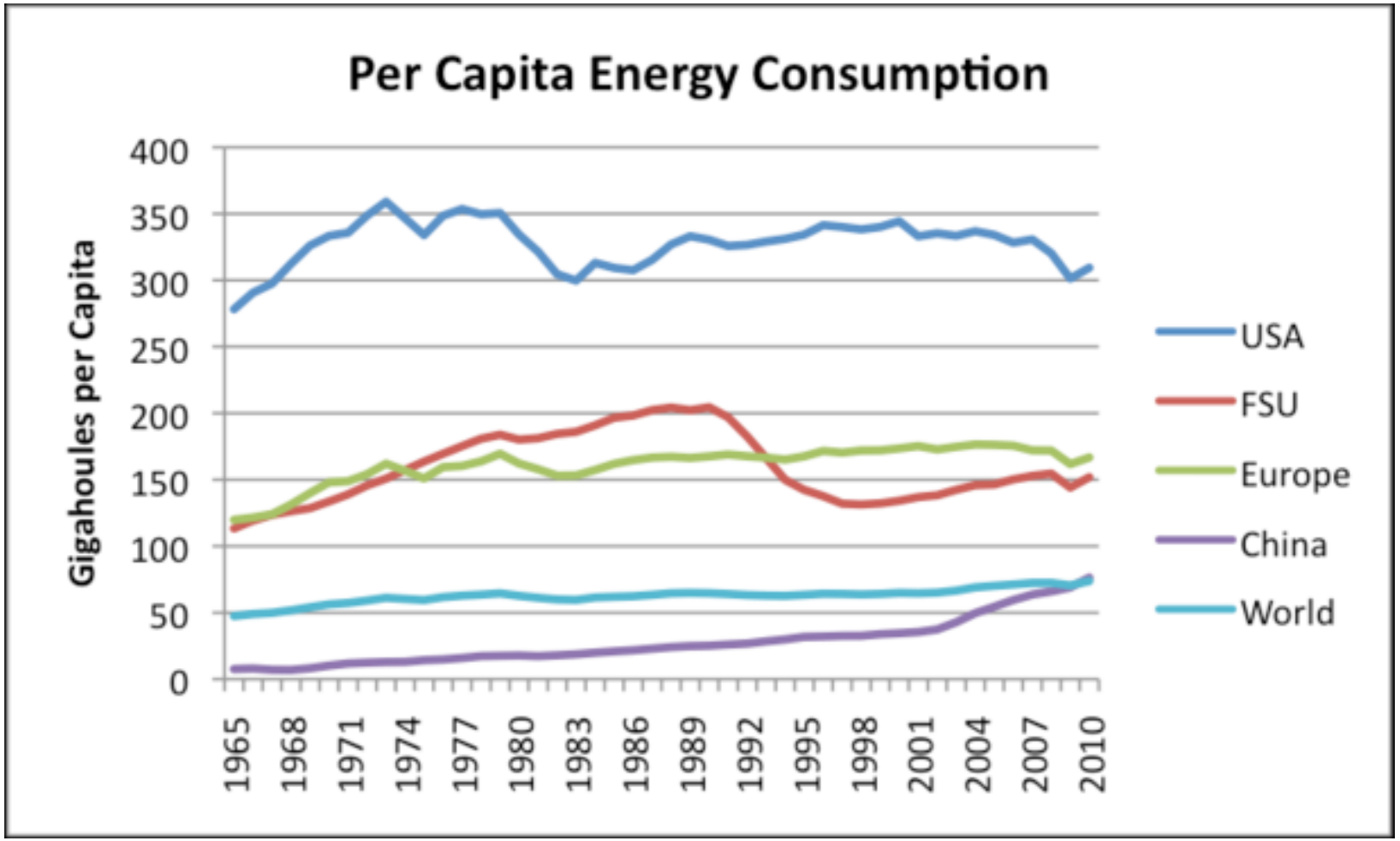


Fig. 2: History of China's energy consumption by different fuel types, 1965–2015.
Data source BP Statistical Review of World Energy (2016) and NBS China Statistical Yearbook (2015)

Energy sources and uses--US



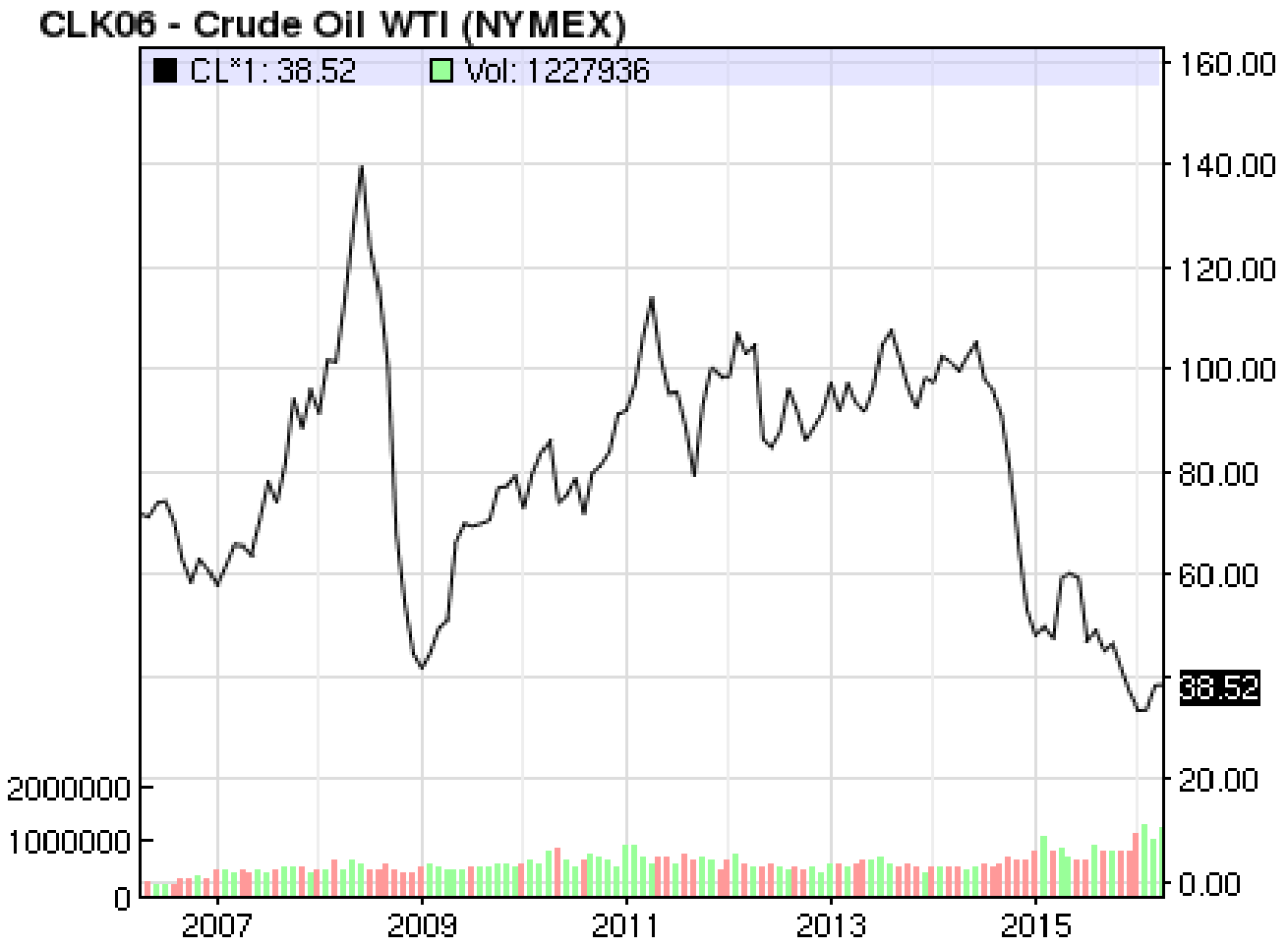


http://www.theatlantic.com/business/archive/2012/03/chart-of-the-day-a-short-history-of-200-years-of-global-energy-use/254909/

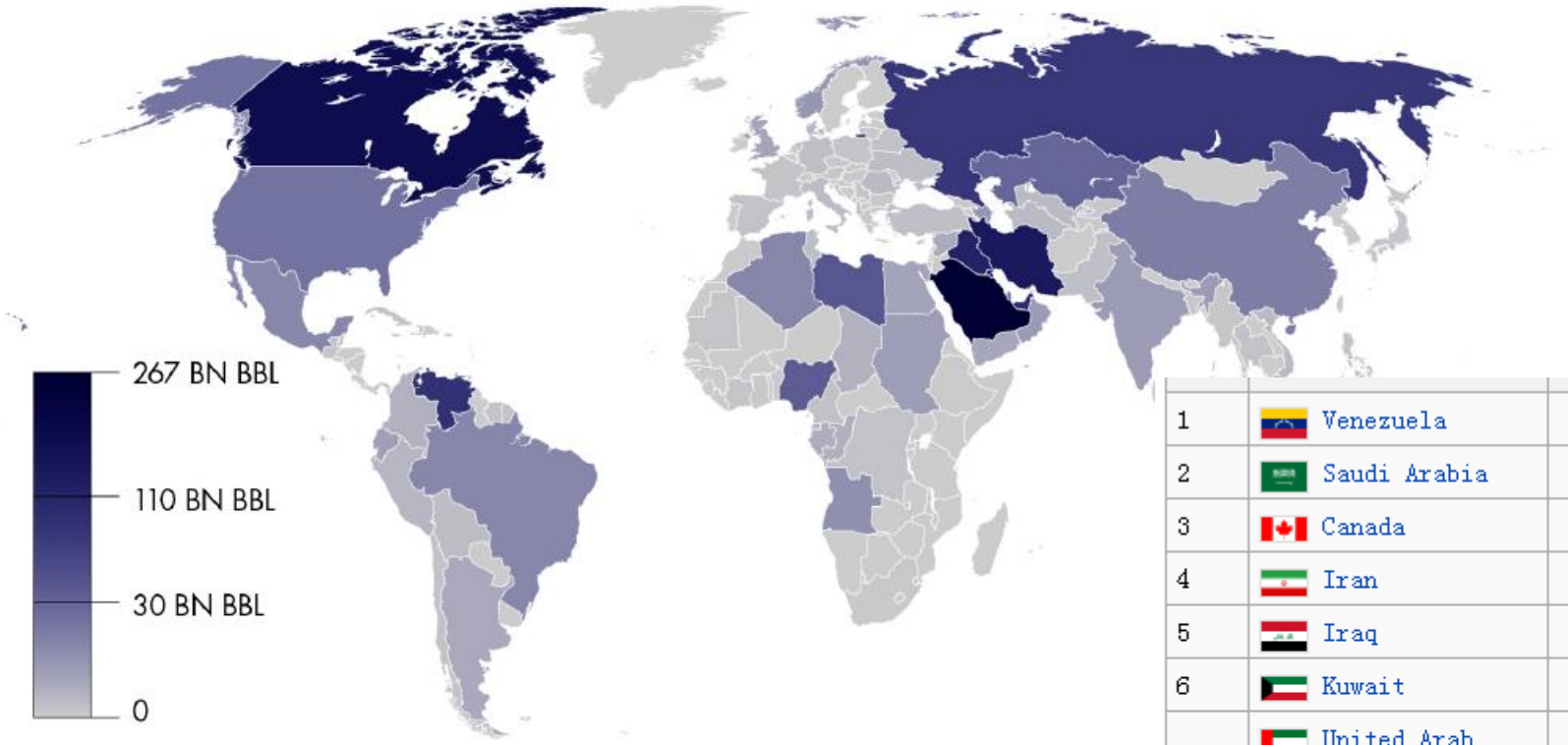
Fossil fuel

ENERGY

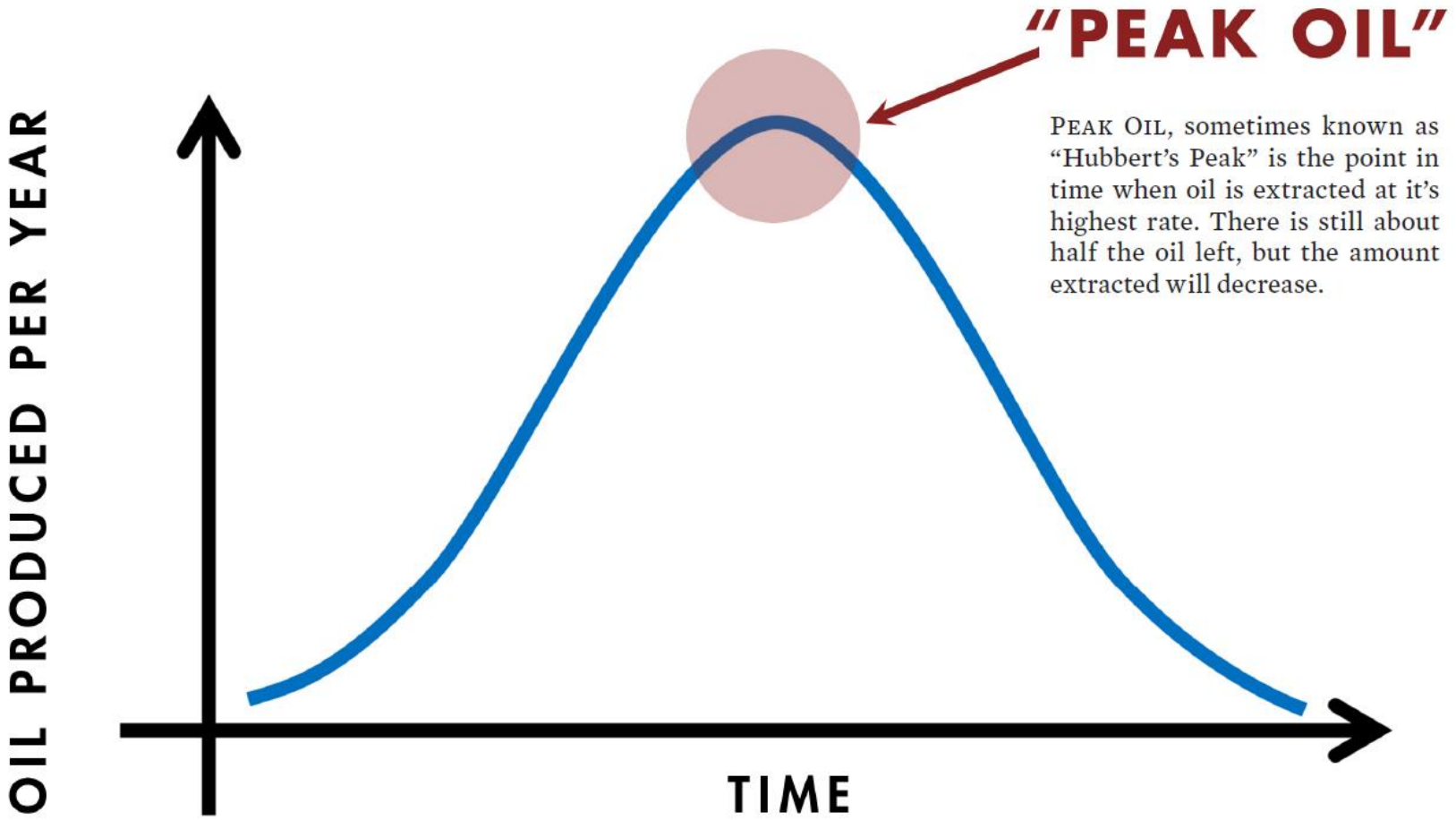
Oil price variation



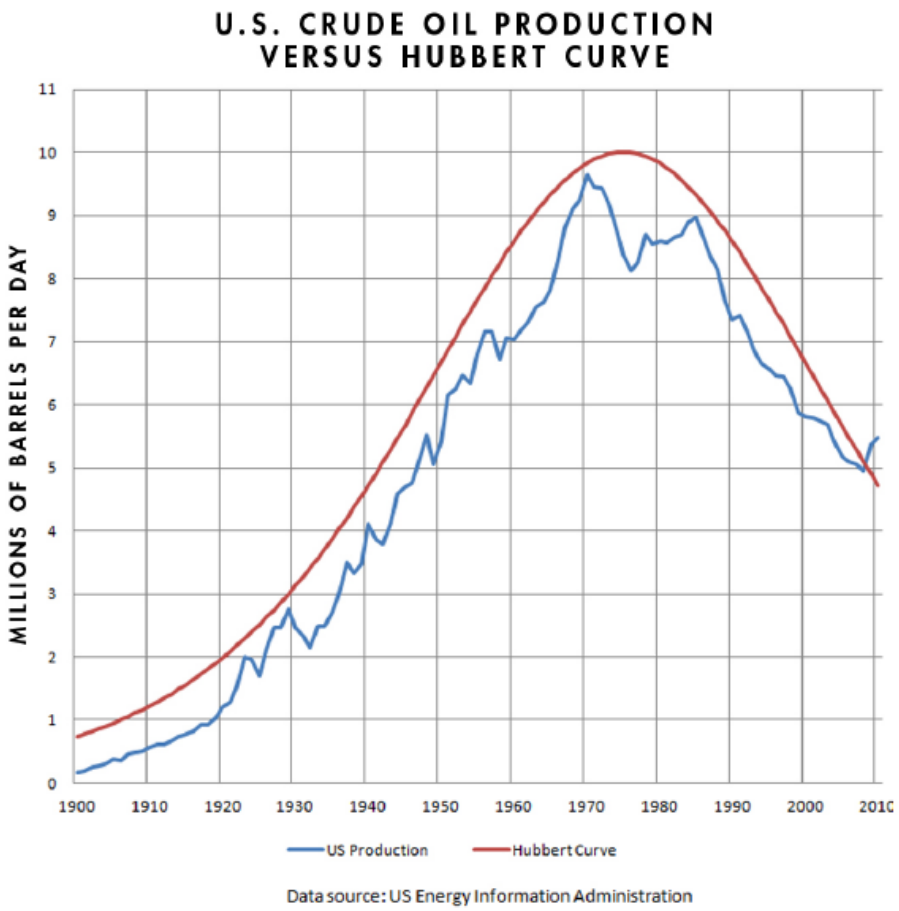
Oil reserve

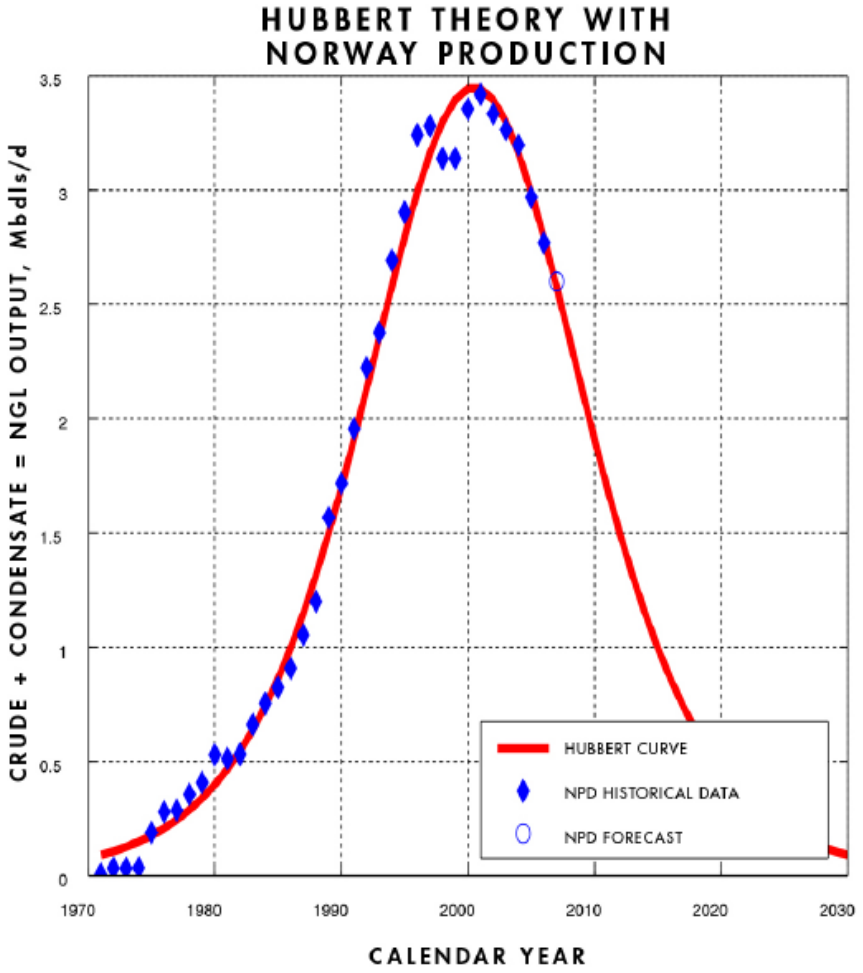


1	Venezuela	296.50
2	Saudi Arabia	265.40
3	Canada	175.00
4	Iran	151.20
5	Iraq	143.10
6	Kuwait	101.50
7	United Arab Emirates	97.80
8	Russia	80.00
9	Libya	47.00
10	Nigeria	37.00

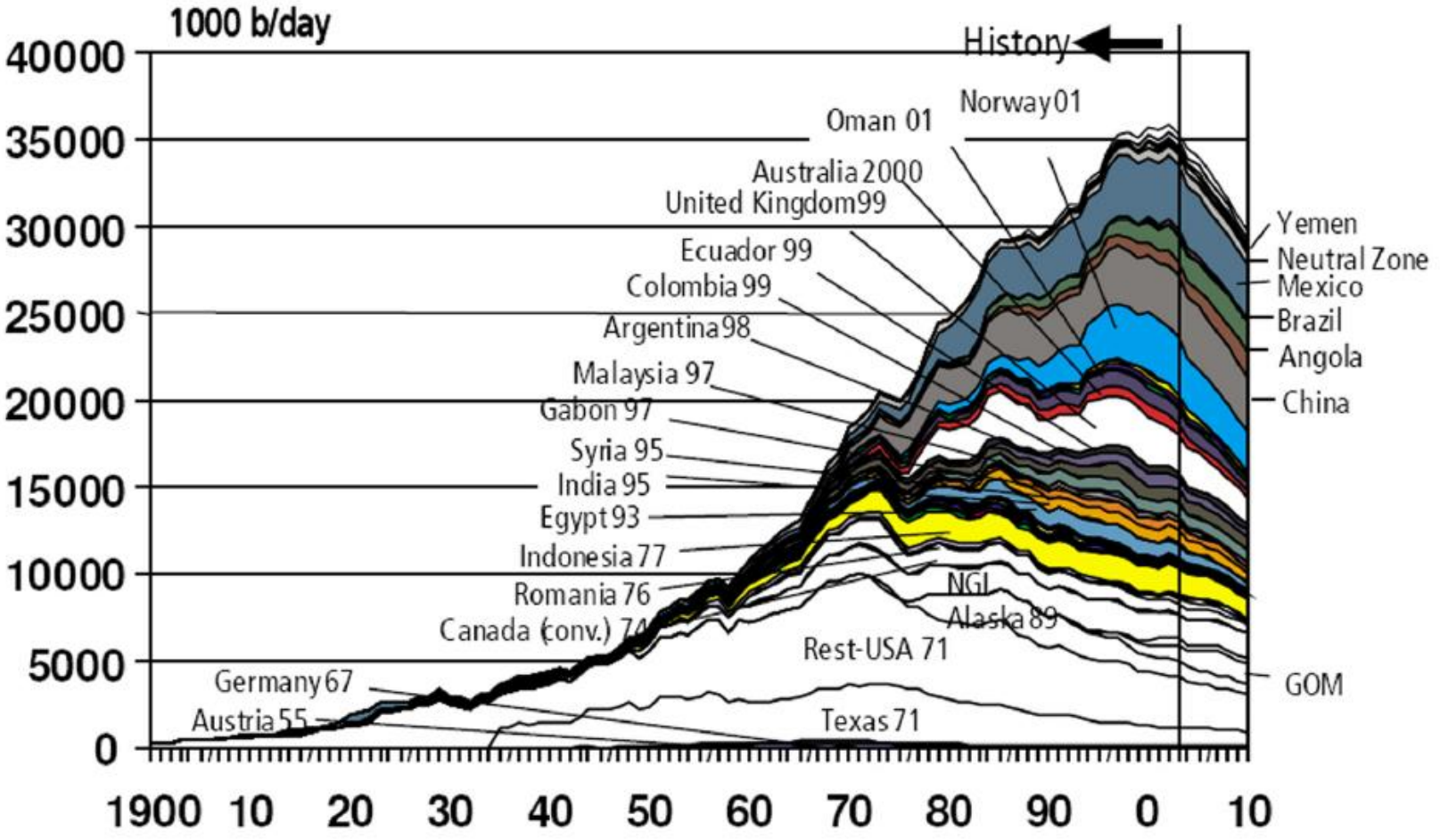

"PEAK OIL"
PEAK OIL, sometimes known as "Hubbert's Peak" is the point in time when oil is extracted at it's highest rate. There is still about half the oil left, but the amount extracted will decrease.
OIL PRODUCED PER YEAR
TIME

Peak oil


U.S. CRUDE OIL PRODUCTION
VERSUS HUBBERT CURVE
MILLIONS OF BARRELS PER DAY
0
1
2
3
4
5
6
7
8
9
10
11
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
US Production
Hubbert Curve
Data source: US Energy Information Administration

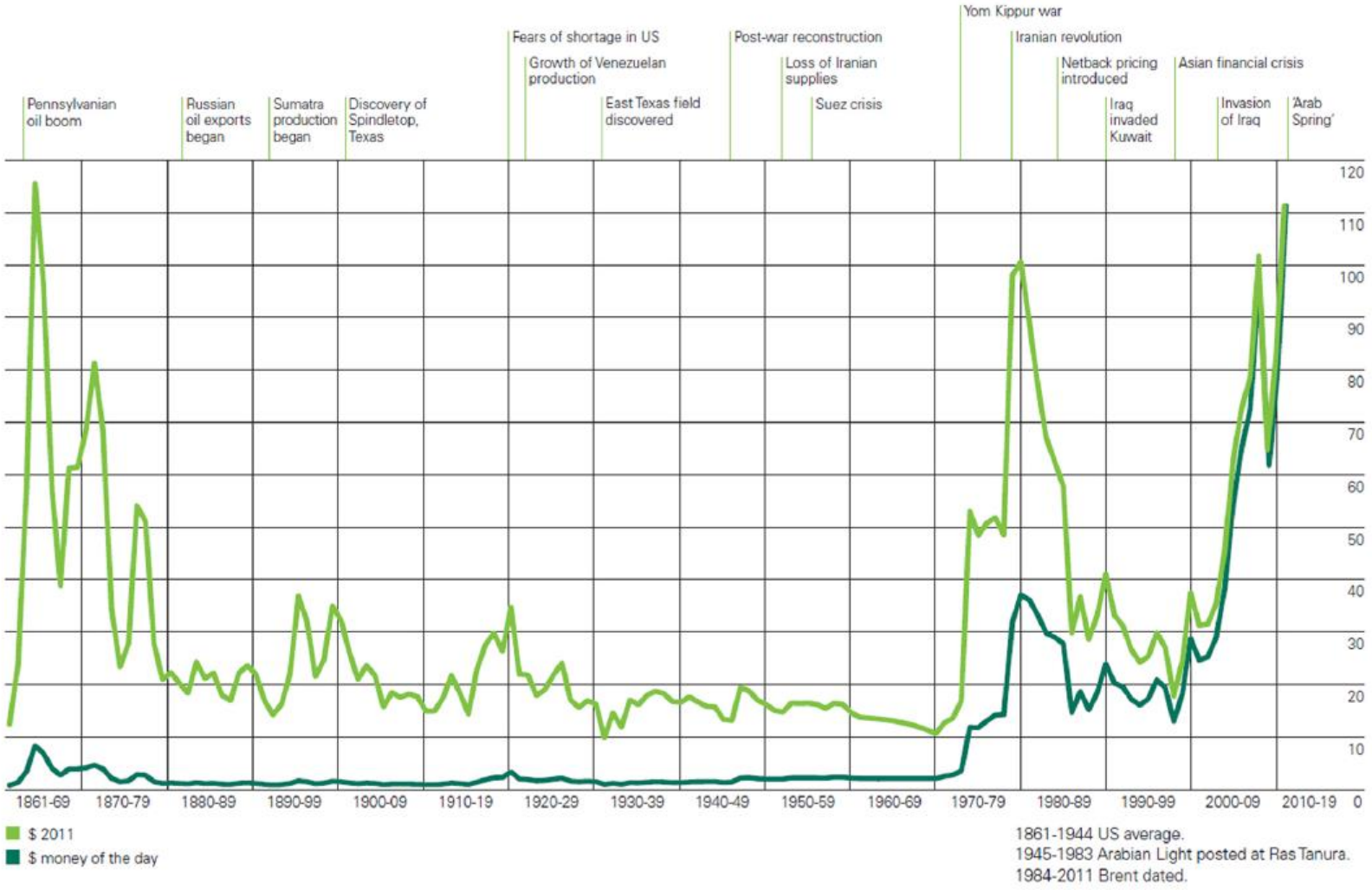

HUBBERT THEORY WITH
NORWAY PRODUCTION
CRUDE + CONDENSATE = NGL OUTPUT, Mbdls/d
0
0.5
1
1.5
2
2.5
3
3.5
1970
1980
1990
2000
2010
2020
2030
CALENDAR YEAR
HUBBERT CURVE
NPD HISTORICAL DATA
NPD FORECAST

Worldwide


1000 b/day
History
40000
35000
30000
25000
20000
15000
10000
5000
0
1900
10
20
30
40
50
60
70
80
90
0
10
Oman 01
Norway 01
Australia 2000
United Kingdom 99
Ecuador 99
Colombia 99
Argentina 98
Malaysia 97
Gabon 97
Syria 95
India 95
Egypt 93
Indonesia 77
Romania 76
Canada (conv.) 74
Germany 67
Austria 55
Rest-USA 71
NGL
Alaska 89
Texas 71
Yemen
Neutral Zone
Mexico
Brazil
Angola
China
GOM


POLITICAL
UNCERTAINTY
Lance Corporal Kevin C. Quihuis Jr.

Oil prices

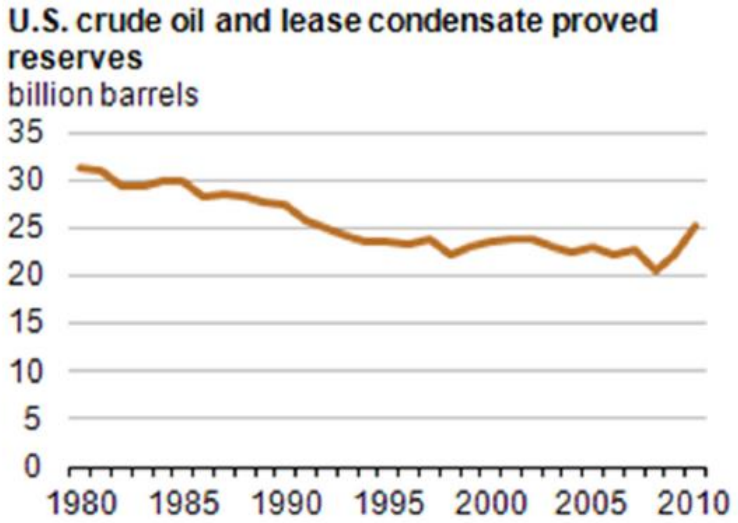

Pennsylvanian oil boom
Russian oil exports began
Sumatra production began
Discovery of Spindletop, Texas
Fears of shortage in US
Growth of Venezuelan production
East Texas field discovered
Post-war reconstruction
Loss of Iranian supplies
Suez crisis
Yom Kippur war
Iranian revolution
Netback pricing introduced
Iraq invaded Kuwait
Asian financial crisis
Invasion of Iraq
'Arab Spring'
120
110
100
90
80
70
60
50
40
30
20
10
0
1861-69
1870-79
1880-89
1890-99
1900-09
1910-19
1920-29
1930-39
1940-49
1950-59
1960-69
1970-79
1980-89
1990-99
2000-09
2010-19
$ 2011
$ money of the day
1861-1944 US average.
1945-1983 Arabian Light posted at Ras Tanura.
1984-2011 Brent dated.

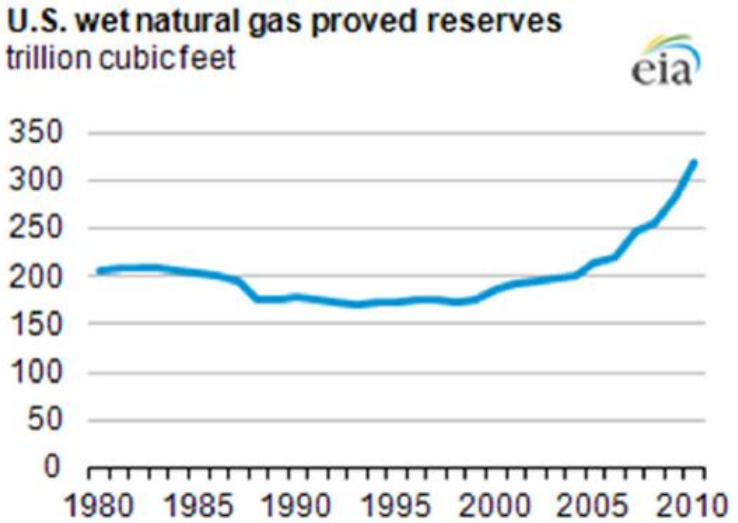
OIL SANDS

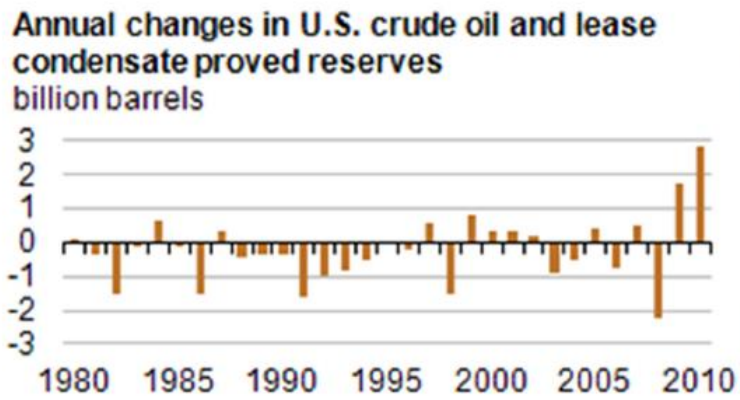
This is an image of an Oil sands mine in Alberta, Canada. A few years ago, it wouldn't have made sense to extract this oil, as it would be too expensive.

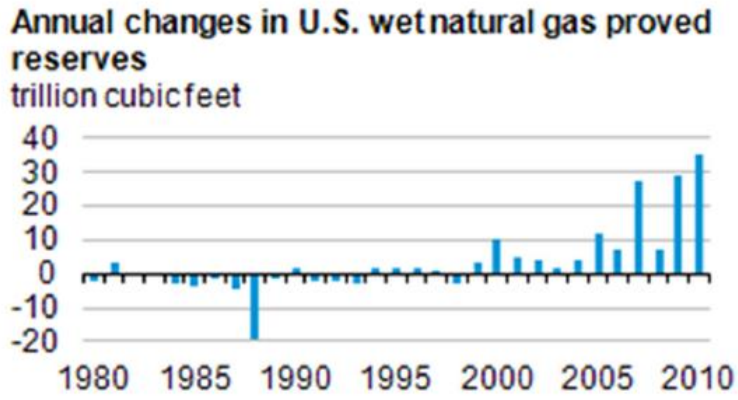
Alex Abboud / Flickr.

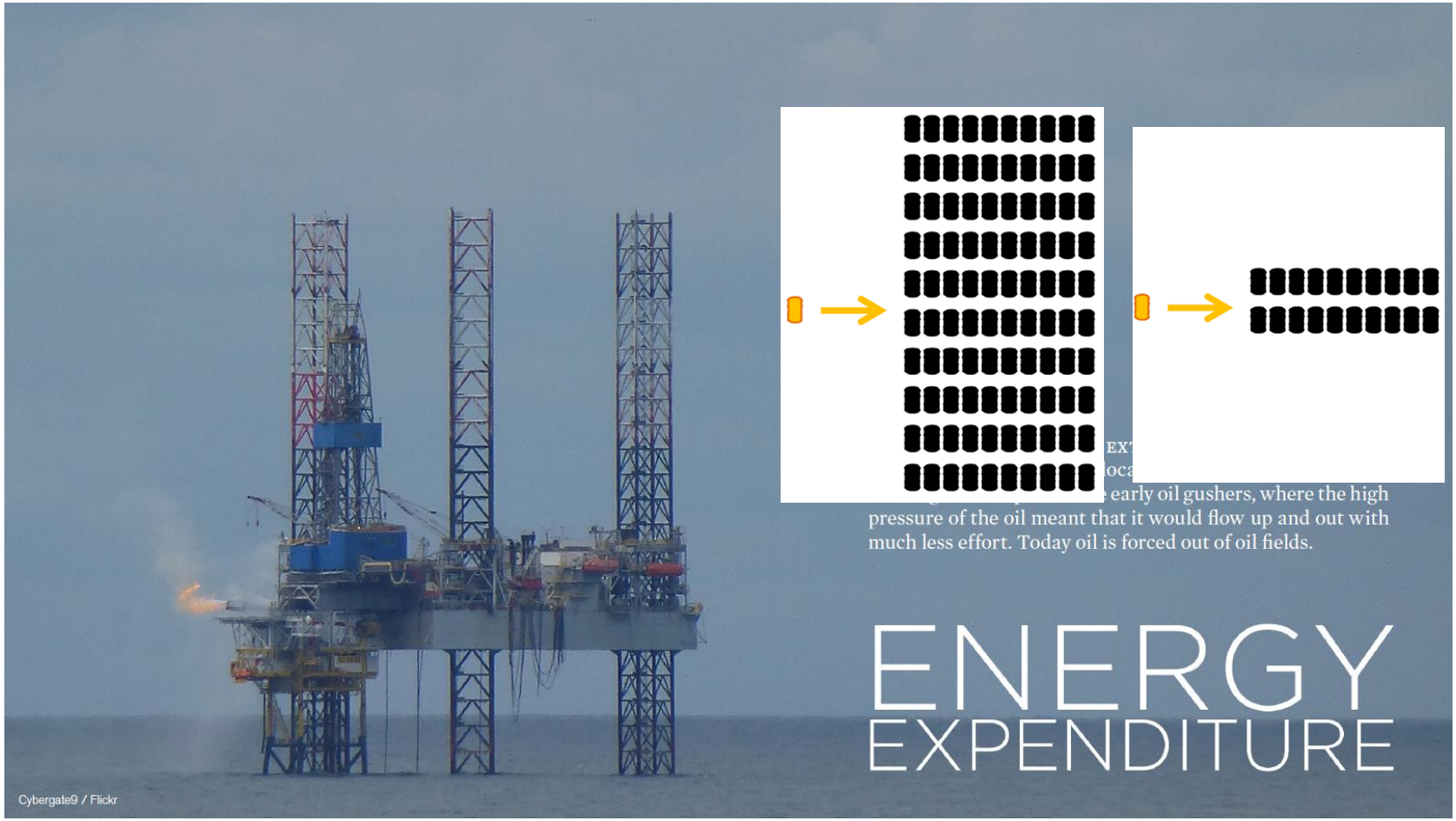
Oil reserves in US










early oil gushers, where the high
pressure of the oil meant that it would flow up and out with
much less effort. Today oil is forced out of oil fields.
ENERGY
EXPENDITURE
Cybergate9 / Flickr

EROEI

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ENERGY RETURNED ON ENERGY INVESTED

$$\text{EROEI} = \frac{\text{ENERGY RETURNED}}{\text{ENERGY INVESTED}}$$

It's the ratio of how much energy we get back on a given effort. So if need to use 200 MwH (megawatt hours) to construct a wind turbine, and it produces a net of about 200 MWH (megawatt hours) a year, and has a life time of 20 years, the EROEI is 20.

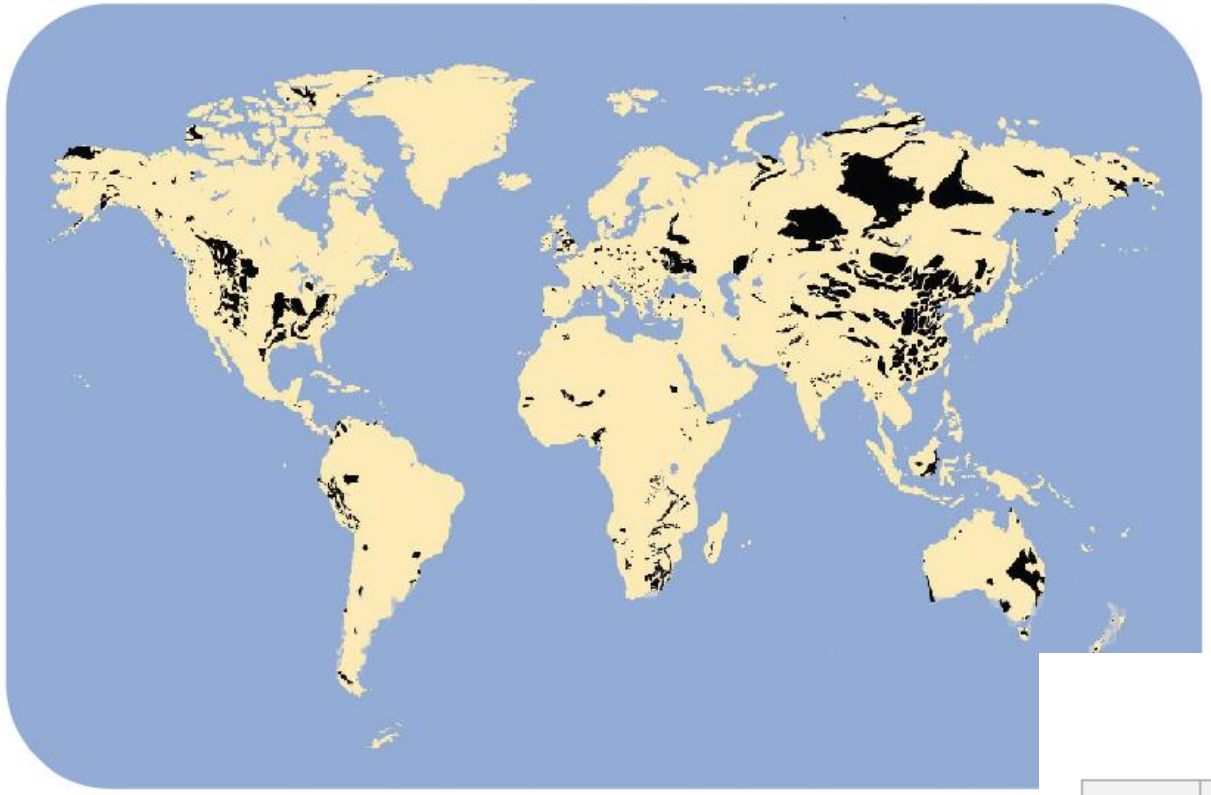
$$20 = \frac{\text{  }}{\text{  }}$$

EROEI

EROEI (for the USA)	Fuel
1.3	Biodiesel
1.3	Ethanol corn
1.6	Solar collector
1.9	Solar flat plate
3.0	Bitumen tar sands
5.0	Ethanol sugarcane
5.0	Shale oil
6.8	Photovoltaic
8.0	Oil discoveries
10.0	Nuclear
14.5	Oil and gas 2005
18.0	Wind
30.0	Oil and gas 1970
35.0	World oil production
80.0	Coal
100.0	Hydro


EROEI = 1?
WHAT HAPPENS AT ONE? Think for a minute.
You get the same out that you put in. Not worth the effort! Less than one is the same as losing money in a financial investment. Put in $10, get $8 back, would be like EROEI=0.8 Corn biofuel is an example of a technique that has an EROEI of about 1.
Fossil fuels have diminishing returns on investment. But oil and gas still look good. Can we rely on them?
Chris Worden / Flickr

Coal reserves



China ranked No. 4 in terms of coal reserves (12.6%)

Coal production in 2007 (million tonnes)[4]

Rank	Country	Production	Share
—	World	6,395.6	100
1	China	2,536.7	39.7
2	United States	1,039.2	16.2
—	European Union	590.5	9.2
3	India	478.2	7.5
4	Australia	393.9	6.2
5	Russia	314.2	4.9

Burning coal…

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Still have some reserves

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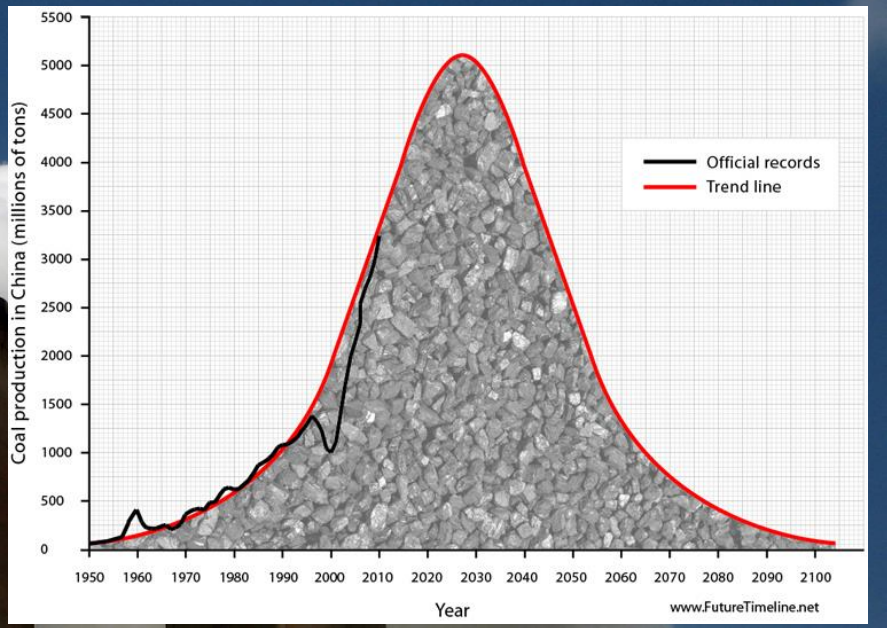
AND IT APPEARS THERE IS STILL A LOT LEFT. Although some countries – such as the U.S. (1998) – extract less coal then they did in the past, the total reserves are still thought to be very large.

Worldwide peak for coal may not happen for another couple of decades (probably). Most experts think enough coal exists through the century and into the next, based on current patterns.



NG found in many places

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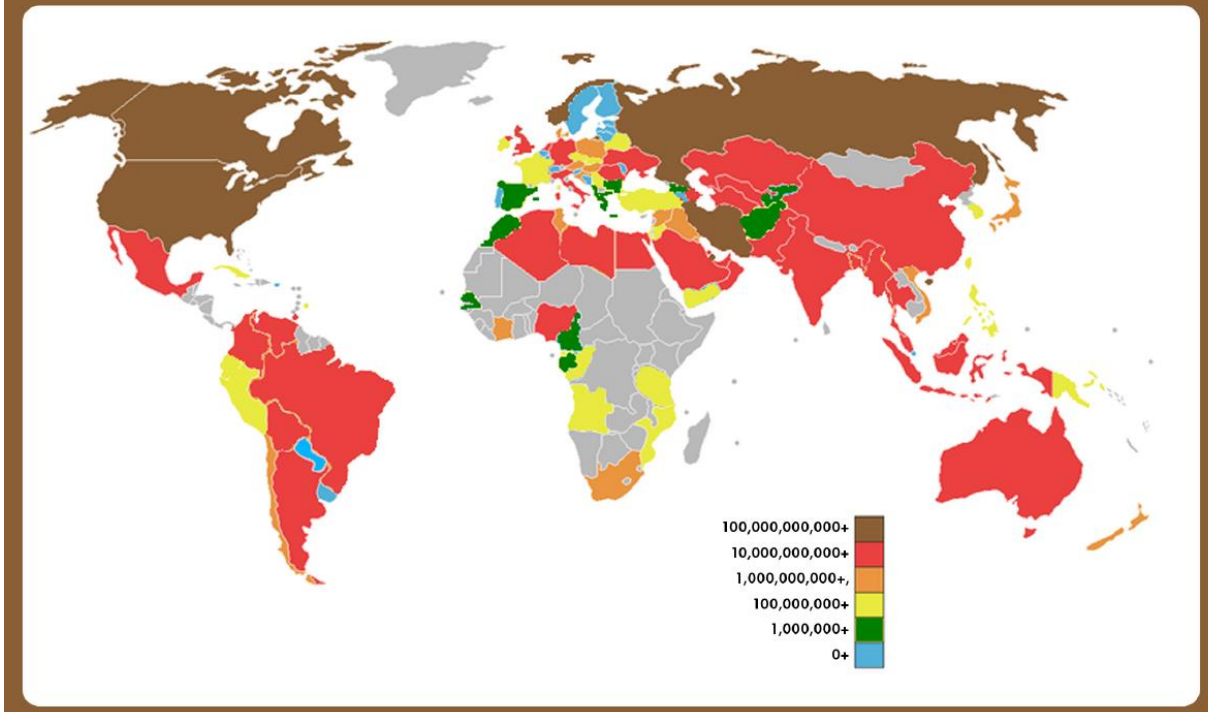
NATURAL GAS
PRODUCERS



NATURAL GAS is not quite as dirty and is also found in many places. There are some security concerns in Europe – the supply is from Russia – but plentiful shale gas possible.

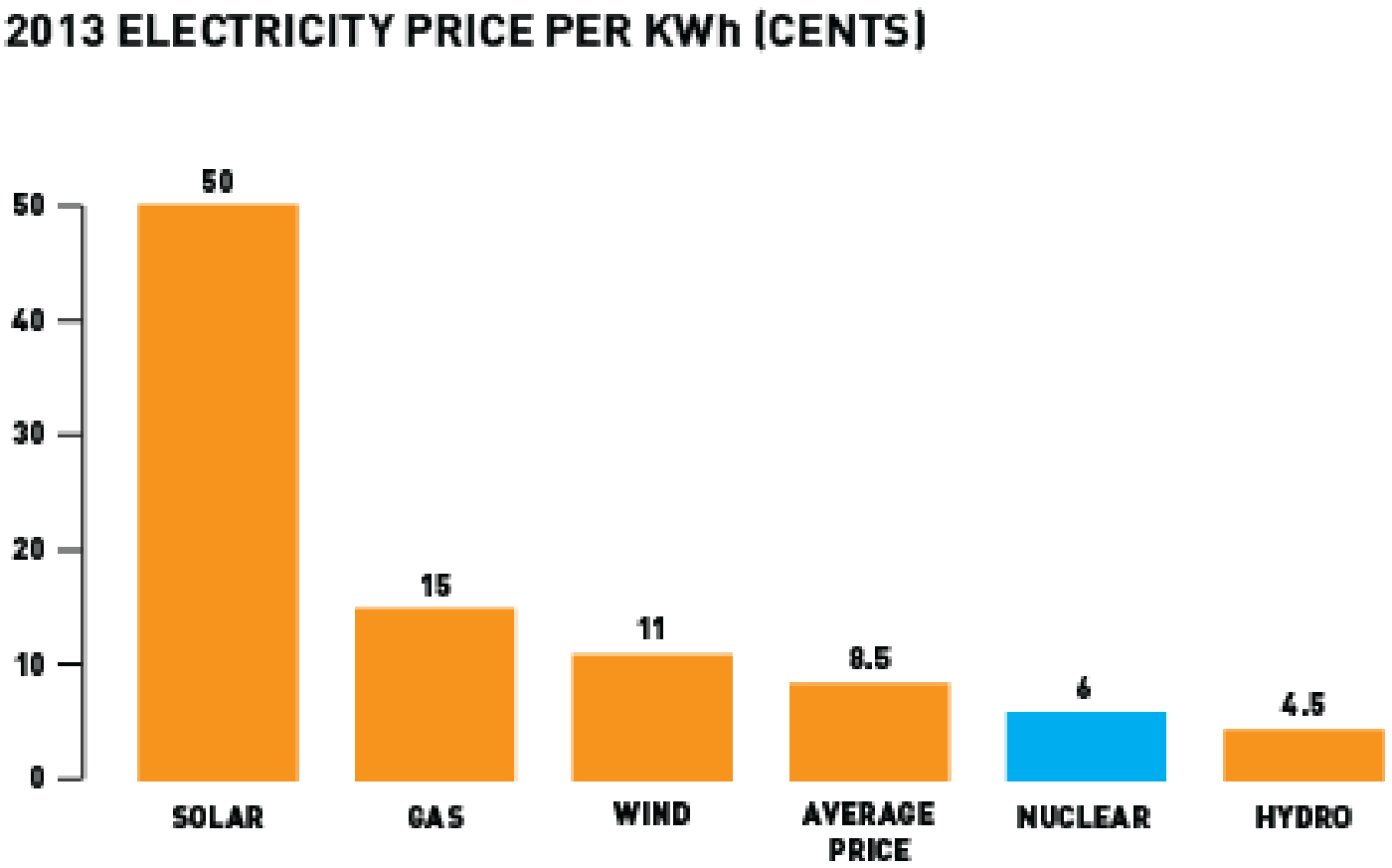
Nuclear energy

ENERGY


IS
NUCLEAR POWER
AN ANSWER?
Doug Bowman / Flickr

Non-renewable resource

Cost of energy by sources



Coal fire power station

100 万千瓦
100,0000,000 W
1000 MW
1 GW

Burn 6 trains of coal per DAY


CHERNOBYL
Trey Ratcliff / Flickr.


NIMBYISM
IDuke / Wikimedia Commons

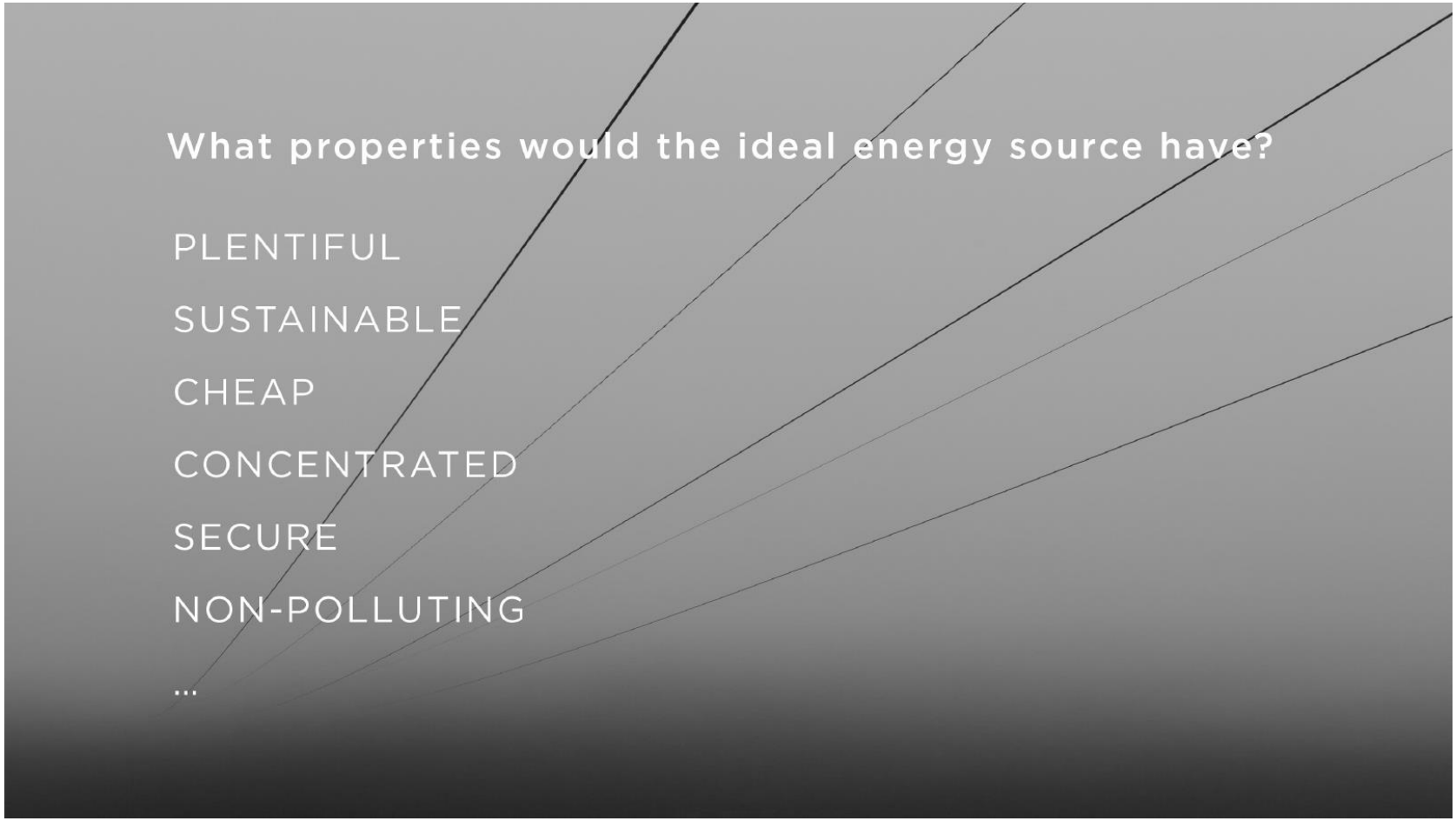

HELLO KITTY
脱原発
NIMBYISM
Matthias Lambrecht / Flickr.

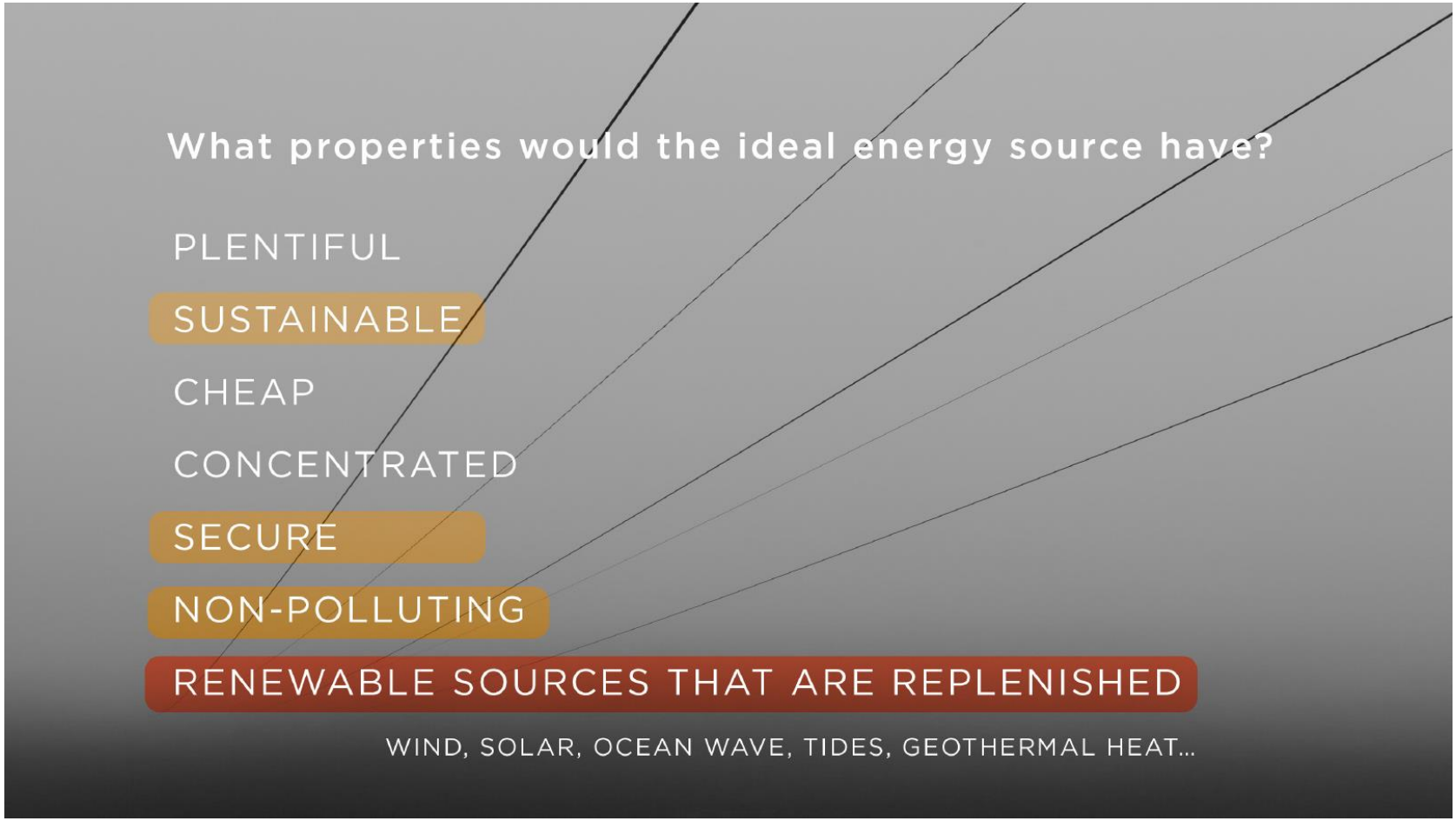

新北市
公投反對
核四運轉
非核家園
人人有責
我愛臺灣 拒絕核四
NO Nukes!
我是人我反核
核電
Nuclear go zerO
歸零
AP

Renewable energy

ENERGY


IMAGINE
What properties would the ideal energy source have?


What properties would the ideal energy source have?
PLENTIFUL
SUSTAINABLE
CHEAP
CONCENTRATED
SECURE
NON-POLLUTING
...


What properties would the ideal energy source have?
PLENTIFUL
SUSTAINABLE
CHEAP
CONCENTRATED
SECURE
NON-POLLUTING
RENEWABLE SOURCES THAT ARE REPLENISHED
WIND, SOLAR, OCEAN WAVE, TIDES, GEOTHERMAL HEAT...

Mainstream technologies

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Hydropower

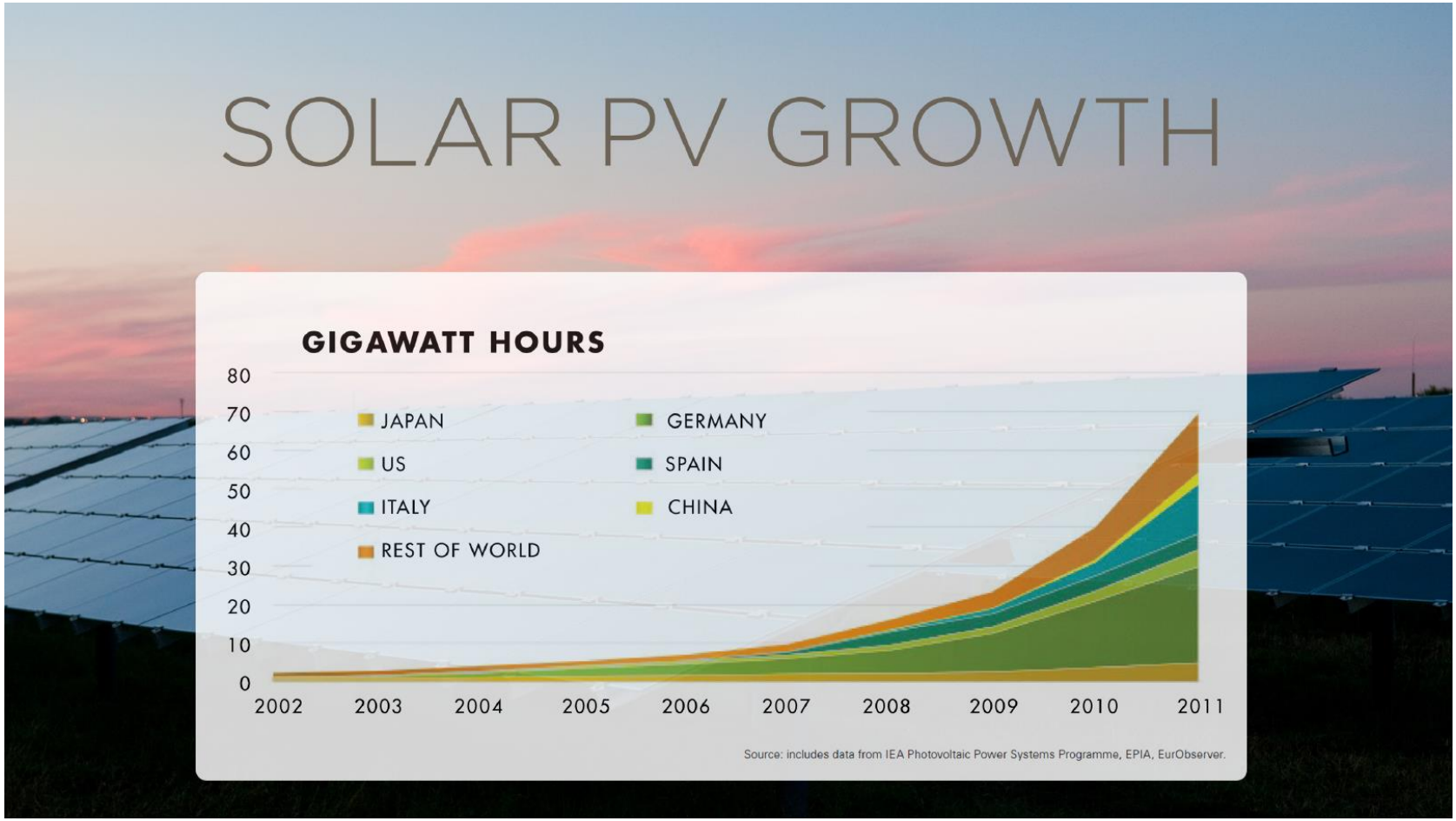
Wind power

Solar energy

Geothermal energy

Biofuel

Biomass


SOLAR PV GROWTH
GIGAWATT HOURS
80
70
60
50
40
30
20
10
0
JAPAN
US
ITALY
REST OF WORLD
GERMANY
SPAIN
CHINA
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Source: includes data from IEA Photovoltaic Power Systems Programme, EPIA, EurObserver.

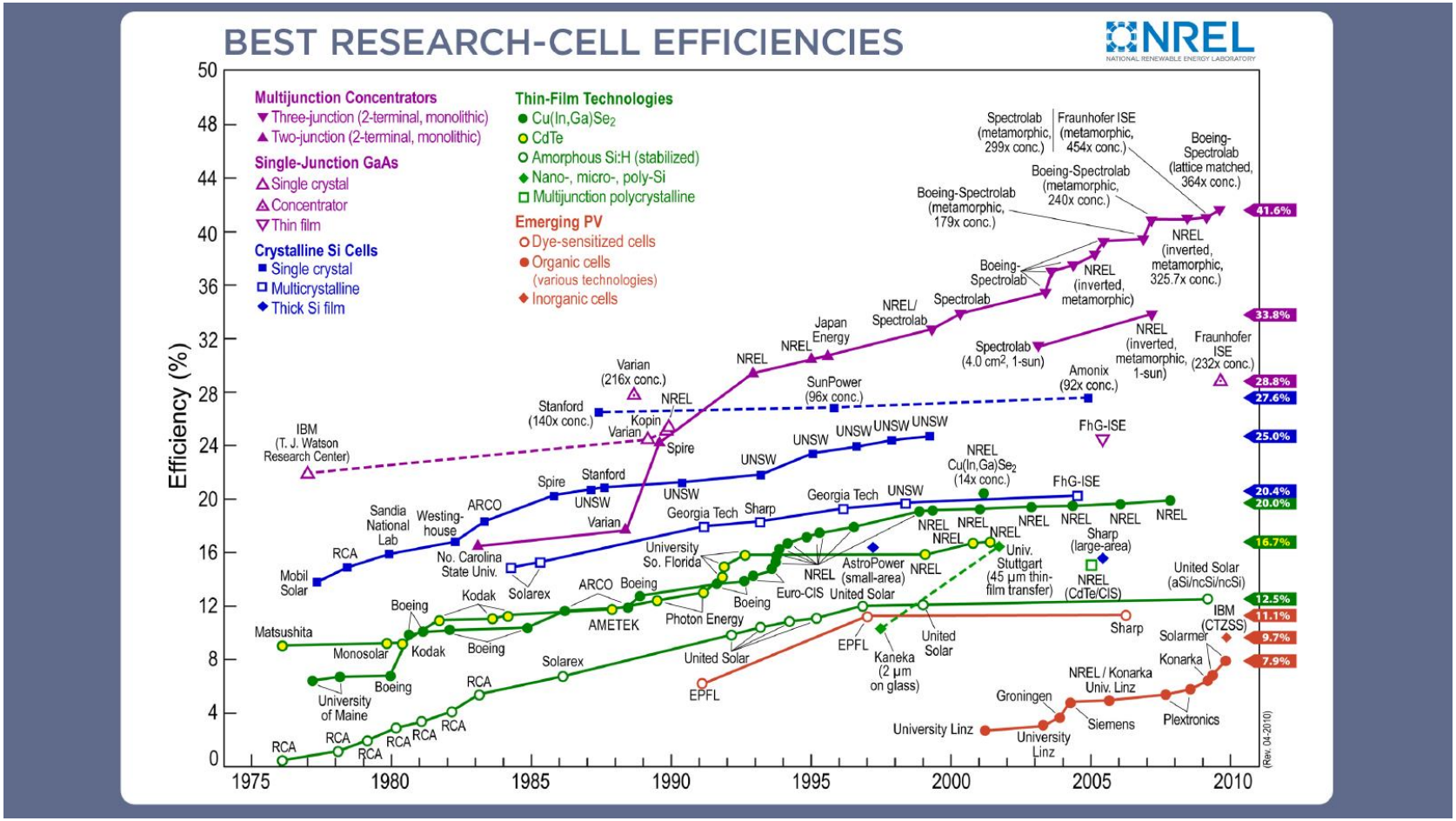
WIND POWER GROWTH

(1996-2011)

High cost


SOLAR POWER
IN THE US
SOLAR PV
COST PER WATT
$20
$15
$10
$5
1980
1990
2000
2010

Low efficiency



Low energy density

Mismatch of source and load

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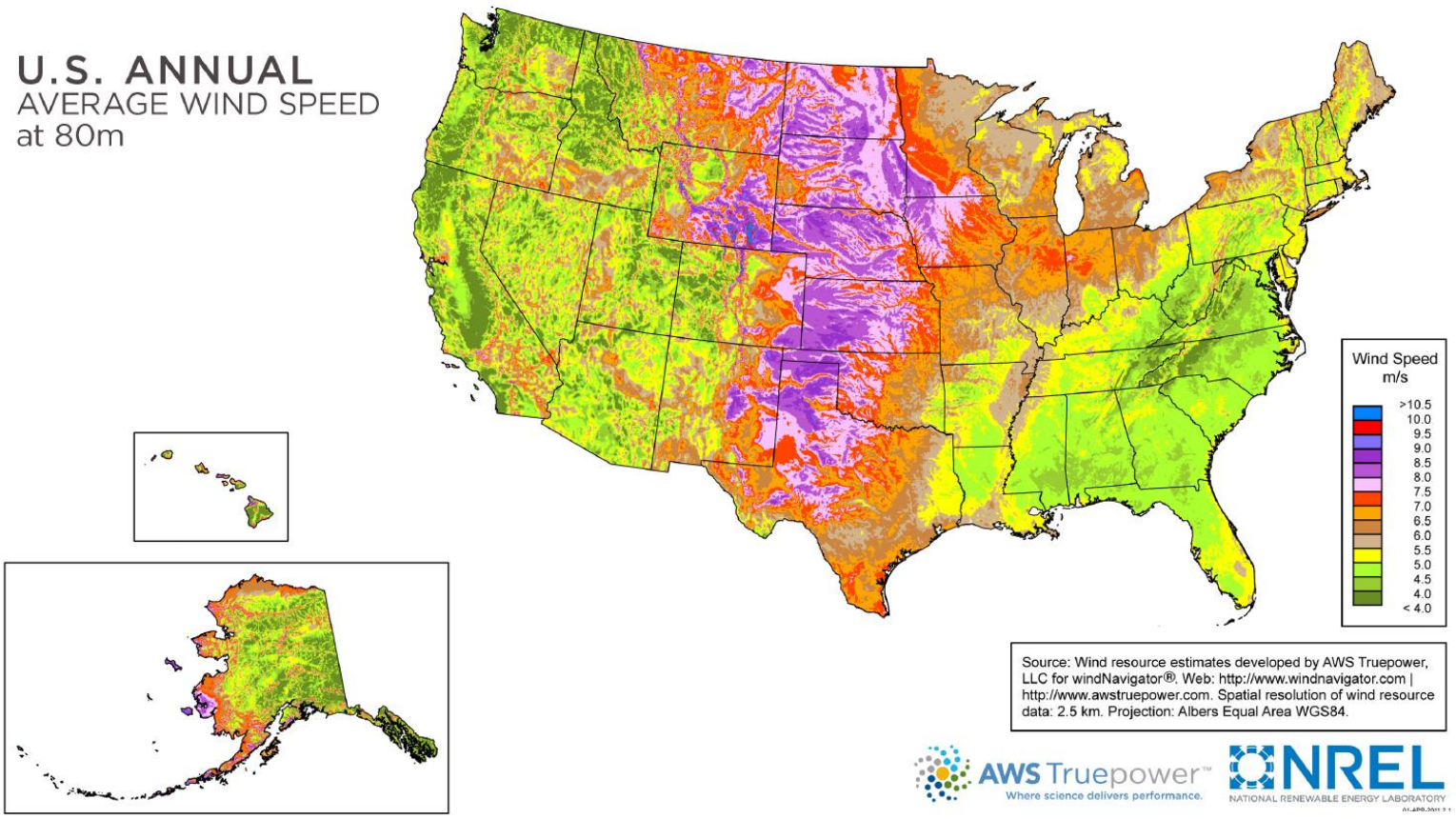

Intermittency

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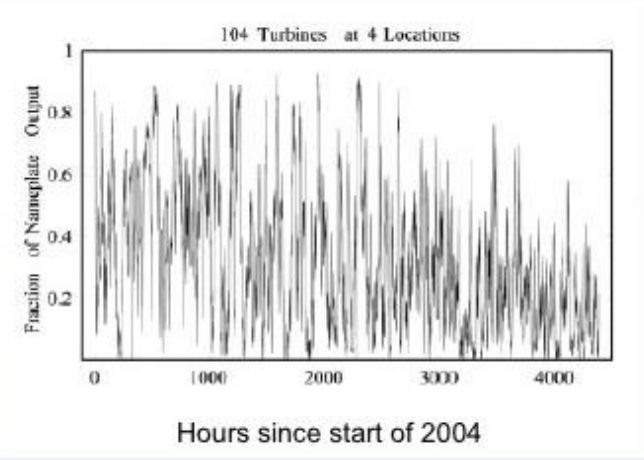
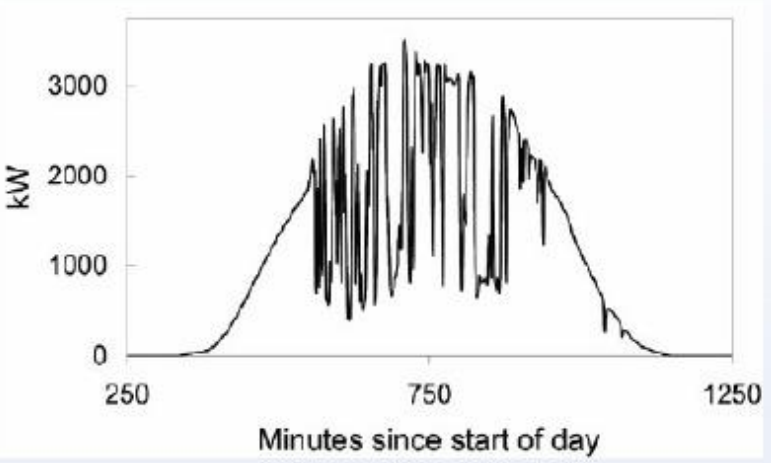
Wind/Solar Intermittency



Wind Intermittency



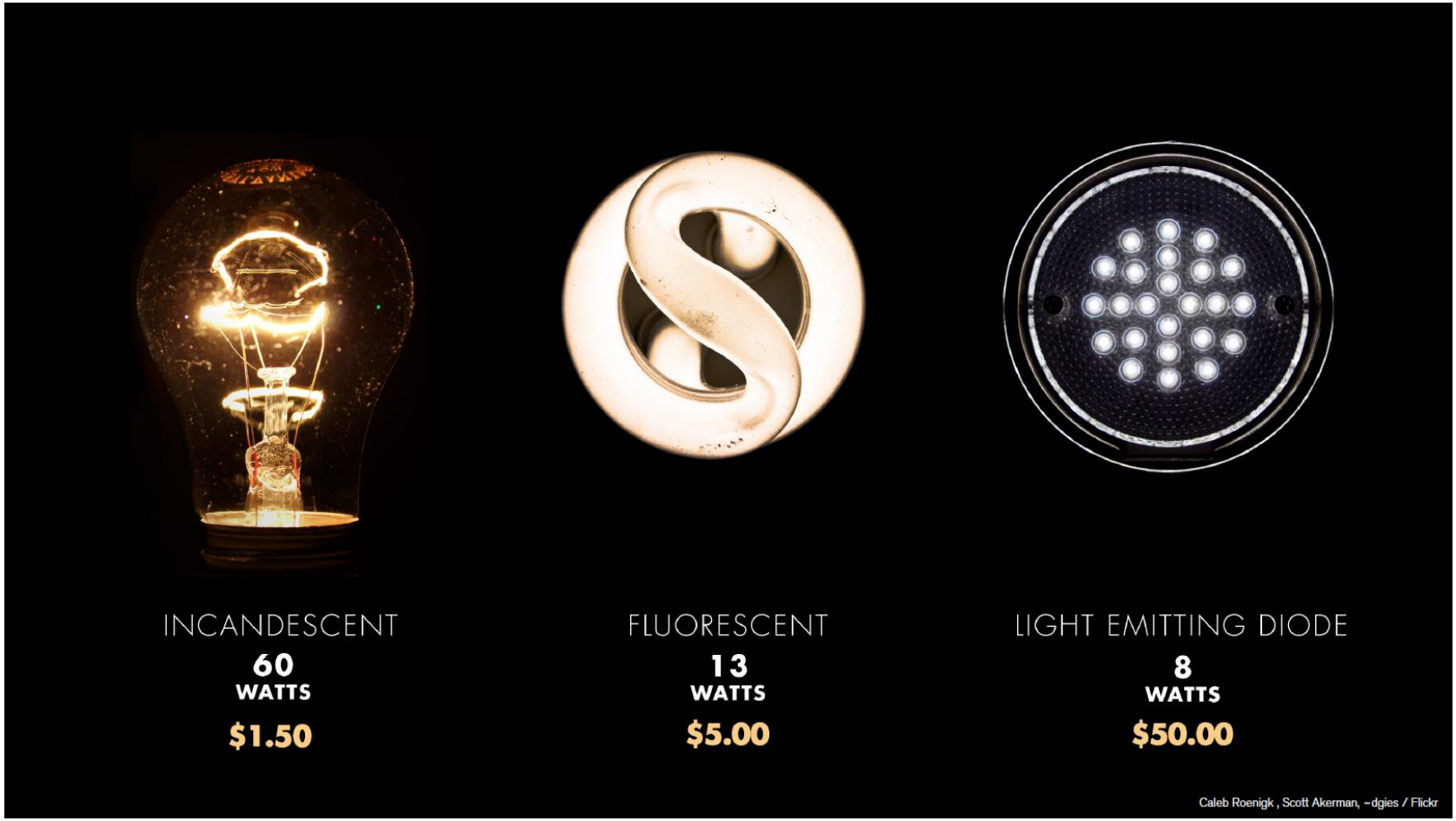
Solar Intermittency

NIMBY for Renewables

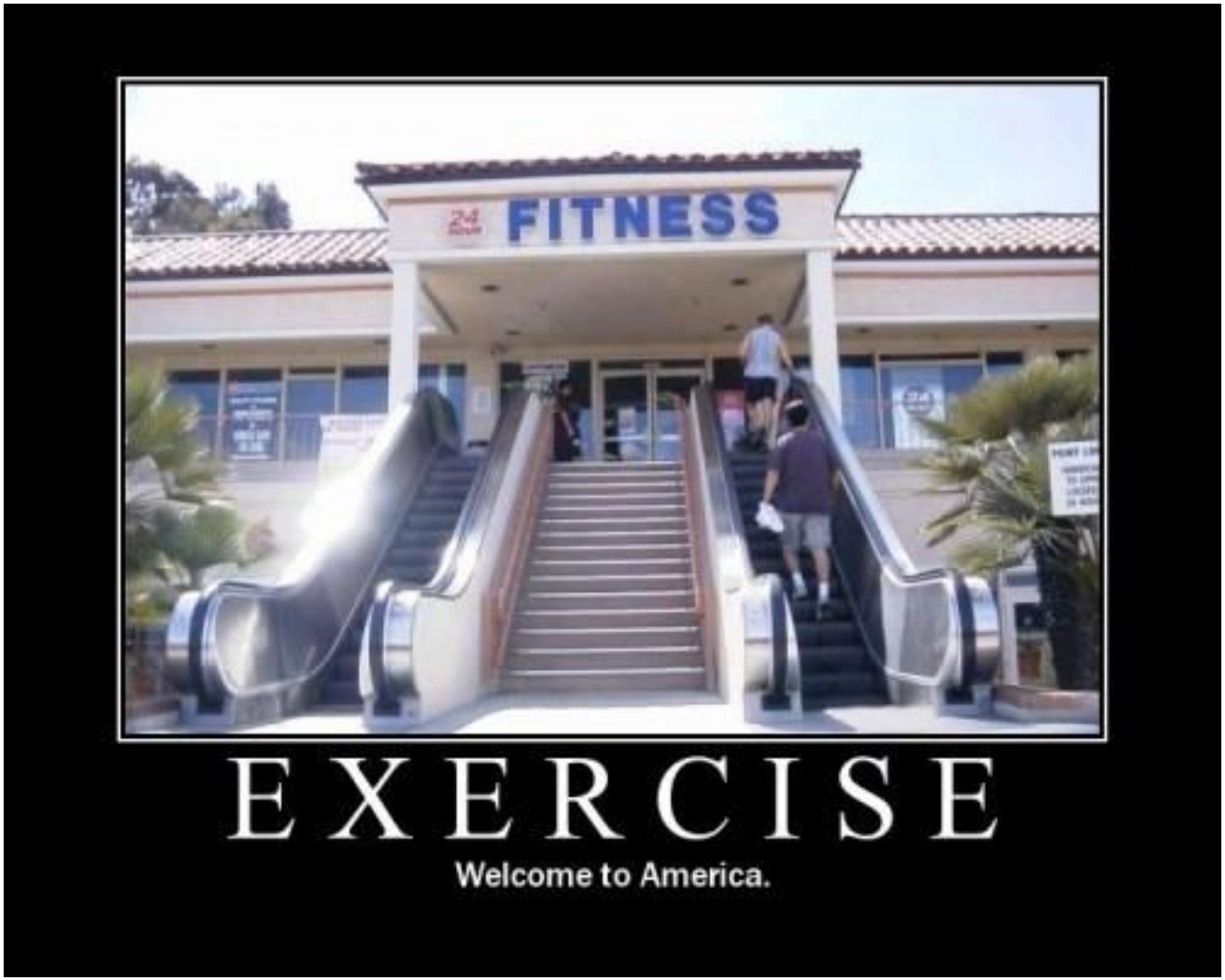
Energy conservation

ENERGY

Energy conservation




PERVERSE INCENTIVES
Efficiencies don't work as you would expect though. They act to increase consumption. This is sometimes known as a "perverse incentive". If the price of something goes down, we use more of it. We overeat at a buffet...
gailf548 / Flickr


24 FITNESS
EXERCISE
Welcome to America.

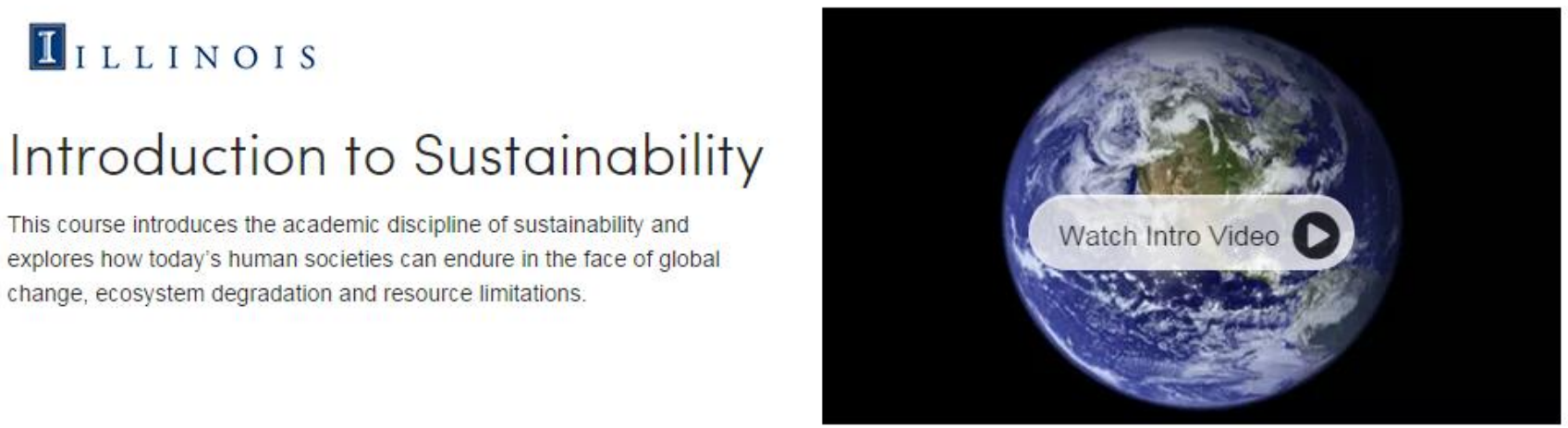
Take home points

- Climate change
  - Insolation
  - Albedo
  - Greenhouse effect
- Peak oil
- Fossil fuels
- Energy return on energy invested (EROEI)
- Renewable energy

Acknowledgment

Most of the materials in this slides are from the MOOC 'Introduction to sustainability' in Coursra offered by Dr. Jonathan Tomkin from UIUC (University of Illinois at urabana-Champaign)

https://www.coursera.org/course/sustain



THANKS

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