7. Energy production

7.1. CURRENT STATUS

Current patterns of energy usage

- **Dominated by non-sustainable fossil fuels such as petroleum, coal and natural gas.**
- **Current world energy use is ~500 EJ/yr.**
- **Industrial/agricultural/commercial energy use makes up over 60% of total in the US.**

ENERGY AND POWER

Energy is a resource, measured in joules (J) , that represents the capacity to do work, for example to produce 1 tonne of aluminum. One exajoule (EJ) = 1,000,000,000,000,000,000 J.

Another unit is the tonne of oil equivalent (TOE).

Power is the rate at which energy is used, and it is measured in or watts (W). 1 W = 1 J per second. A traditional light bulb uses 60-100 W. One terawatt (TW) = 1,000,000,000,000 W.

Energy production has risen continually

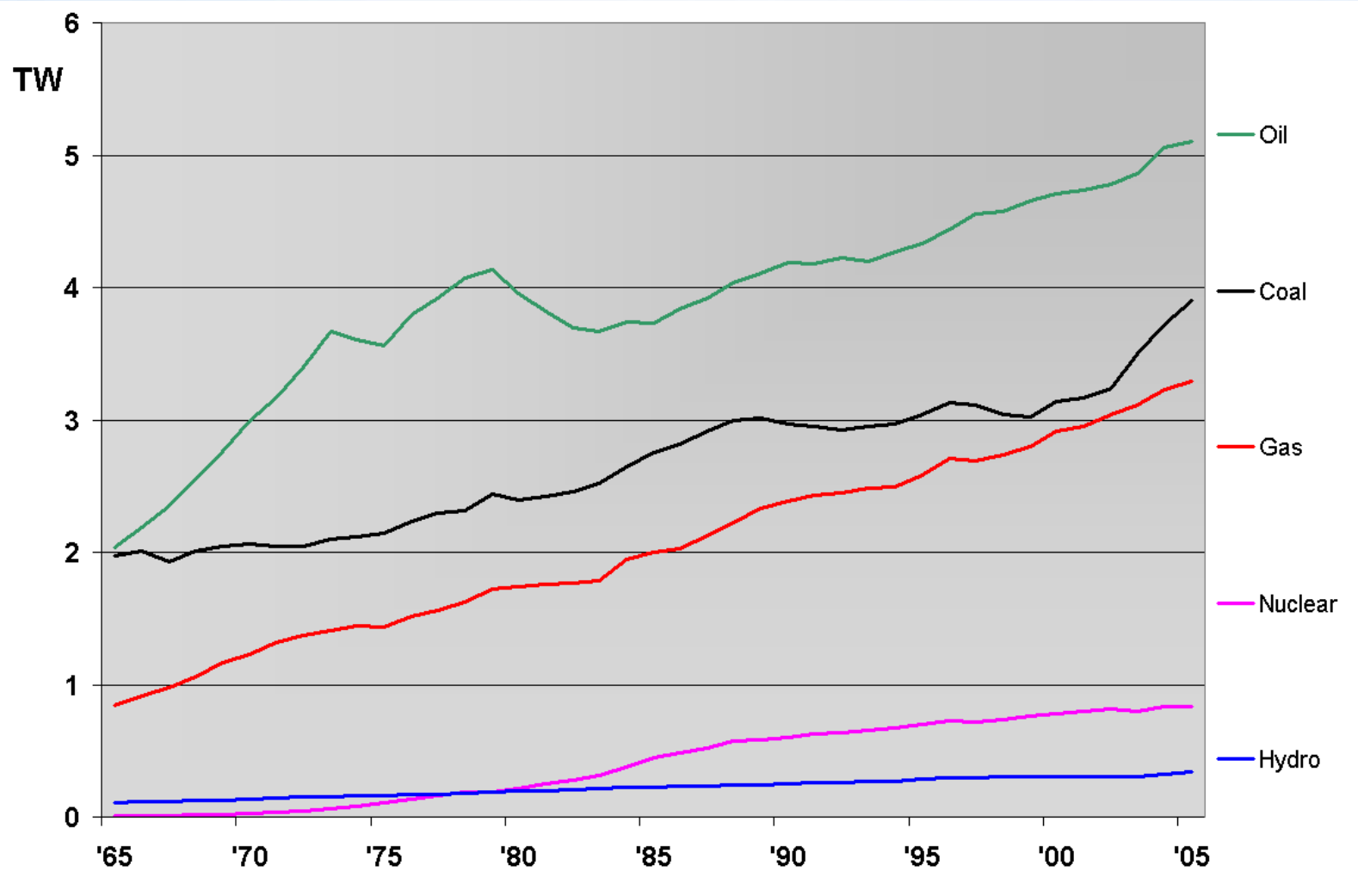

Image: Frank van Mierlo, from Wikimedia Commons
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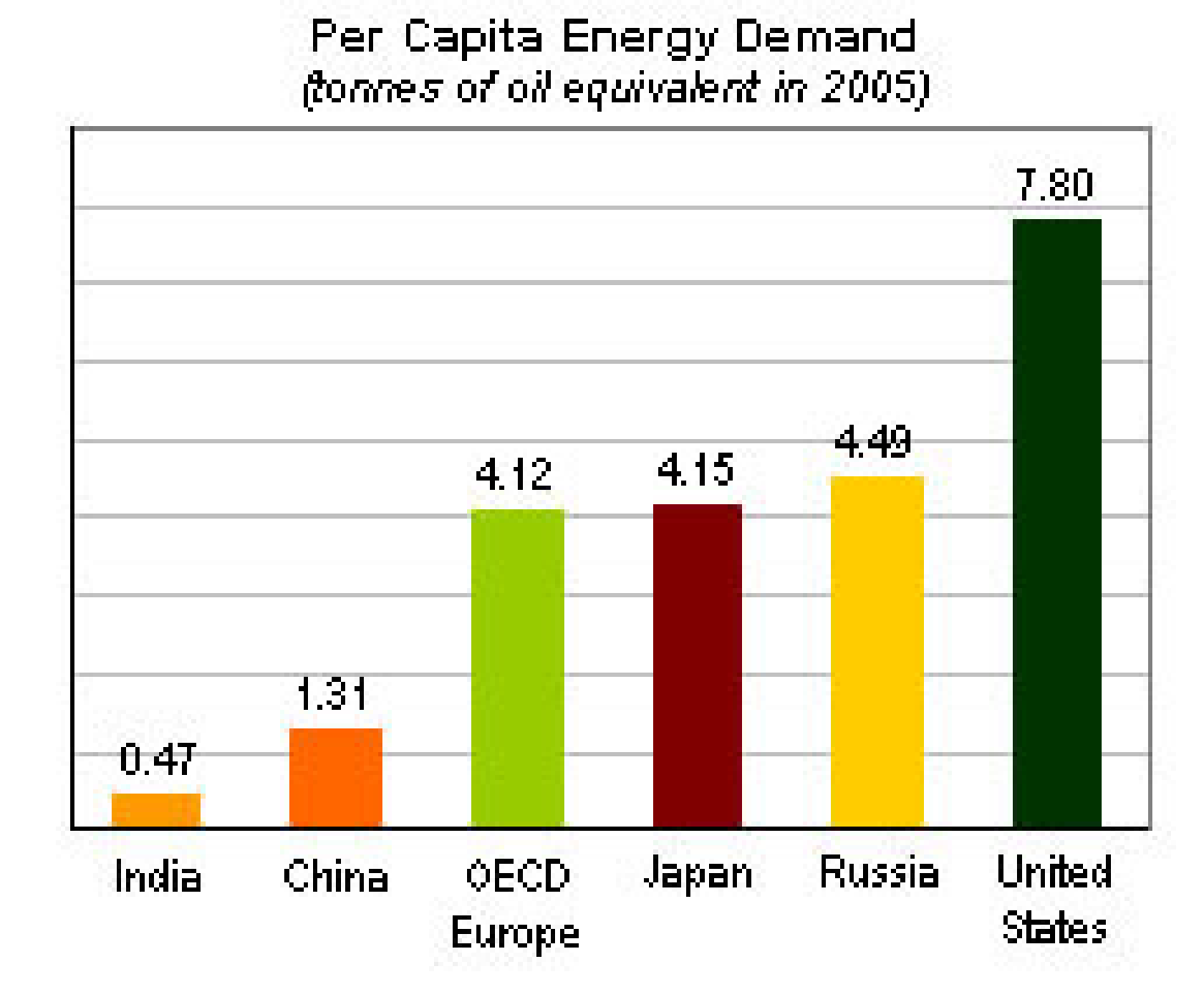
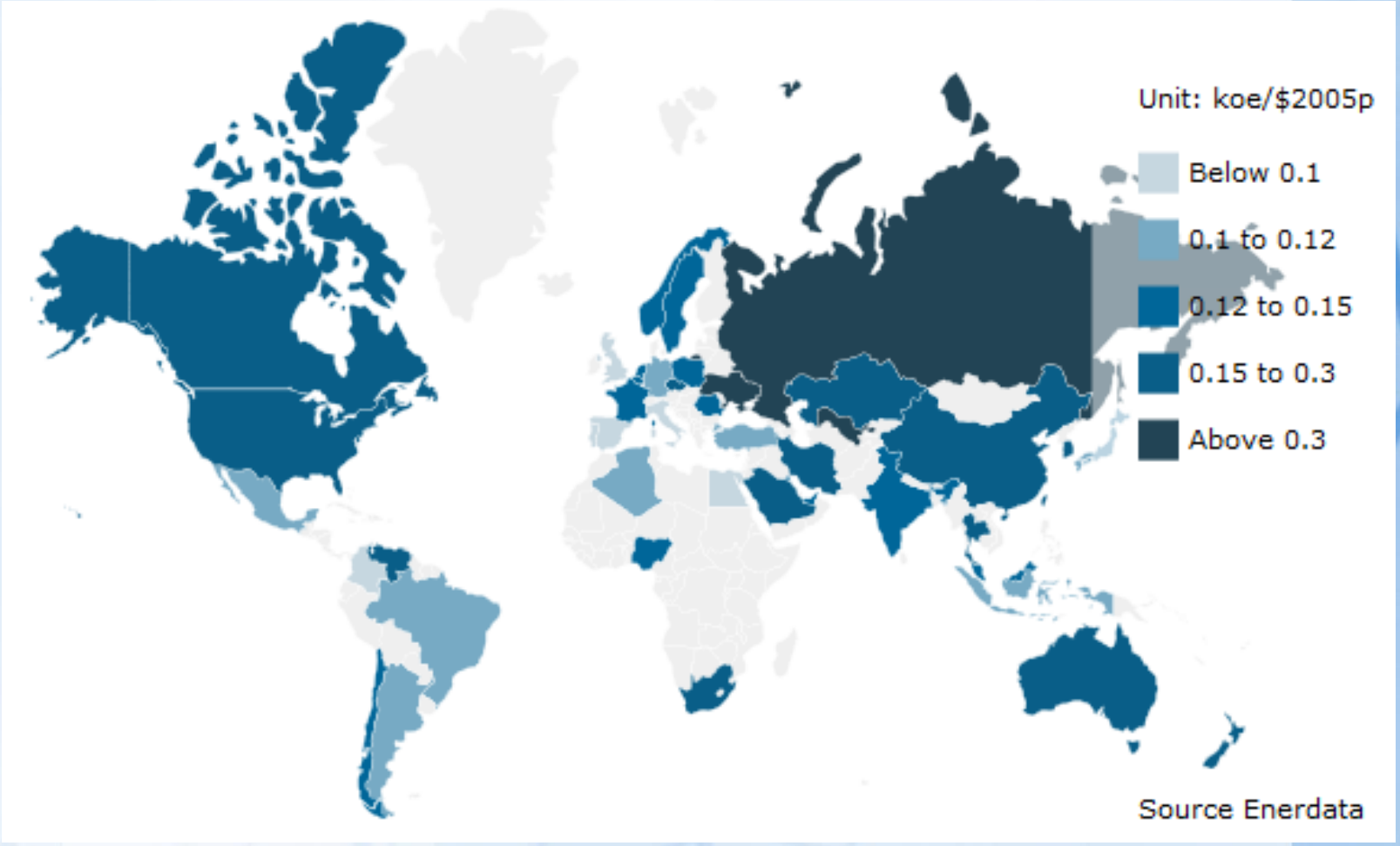
Per capita energy usage (uncorrected for GDP)_



Source: Earthtrends

Energy intensity reflects efficiency of use



Eastern Europe appears inefficient at present; Western Europe & Japan efficient. China is much better than it was

Image from Enerdata, **Global Energy Statistical Yearbook 2012**

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Energy usage: Japan

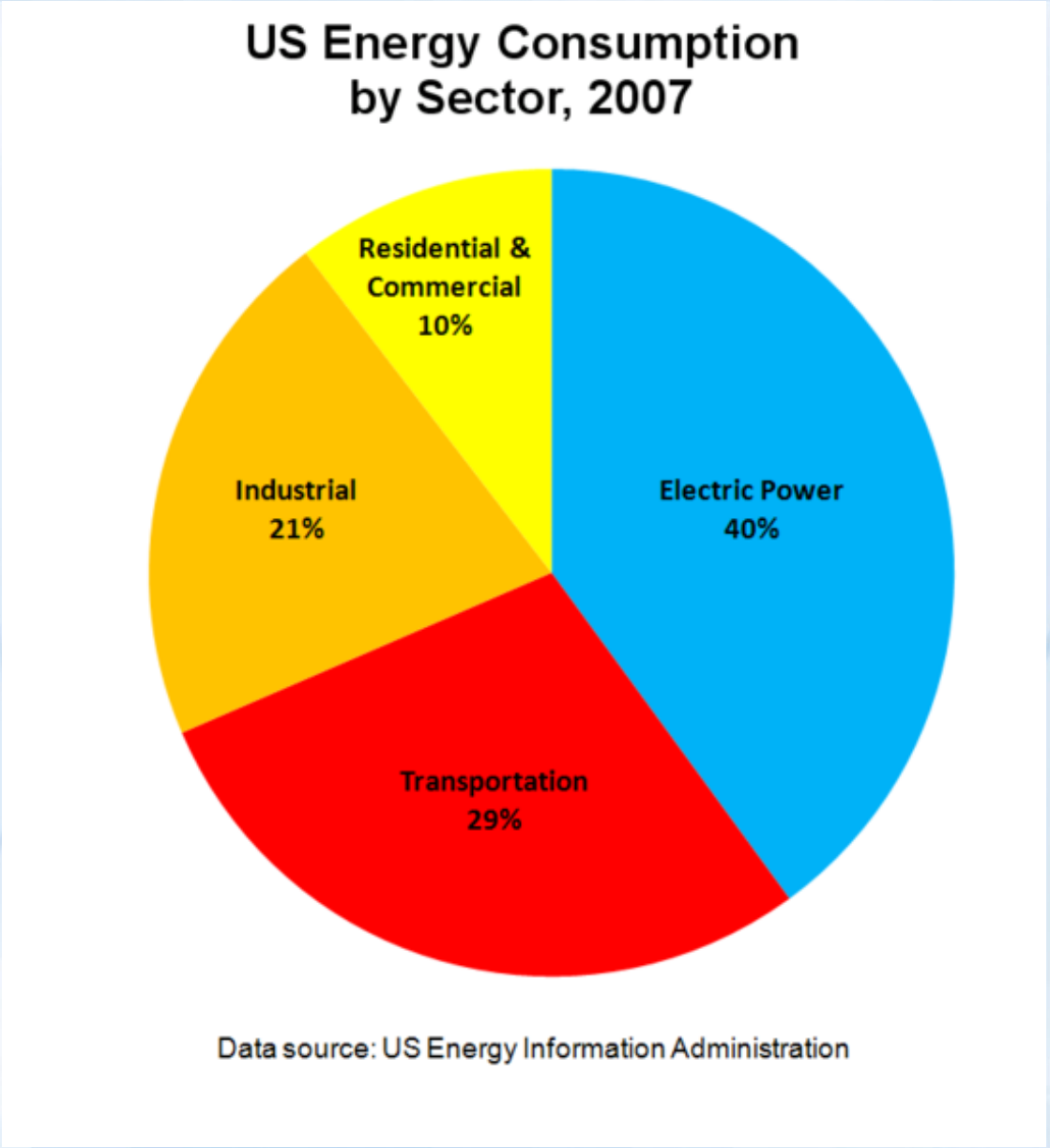
- **Total Japanese energy usage is around 18 EJ/year, of which ~3 EJ/year is electricity**
- **Japan lacks a domestic fossil fuel supply such as coal, oil or gas with 82% of its energy supply imported (2009). Along with environmental concerns, this drives Japanese energy policies.**
- **Around 50% of this comes from oil, and about 15% each for coal, natural gas and (until recently) nuclear. Renewables make up the remaining 5%.**
- **Electricity prices have risen significantly since the leak in 2011 at the Fukushima nuclear plant.**

Electricity usage (US)

- In 2014, the US used around 103 EJ of energy, of which around 41 EJ was used in the form of electricity.
- (Enerdata gives numbers of 81 & 14 EJ, perhaps due to different assumptions
- Almost 40% of this US electricity was generated using coal power. Natural gas has seen the largest rate of increase in recent years – an effect of fracking – reaching 27% by 2014. Around 14% of electricity came from renewable sources such as hydroelectric or wind power.
- For more information see *http://www.eia.doe.gov/*

US energy consumption, by type

Picture by RockyMtnGuy, Creative Commons License



7.2. ENERGY AND THE ENVIRONMENT

Fossil fuels

- Fossil fuels produce carbon dioxide, which is a greenhouse gas.
- Increasing levels of carbon dioxide are the major factor driving global warming.
- Coal also contains sulfur, which (when burnt) forms sulfur dioxide, which in turn causes acid rain.
- Natural gas has become cheaper due to “fracking” and it has a lower carbon content than oil or coal, but it does still release carbon dioxide when it burns

Oil and "fracking"

In the early 2000s many predicted "peak oil", and limits on supply, but higher prices and new technology have opened up new sources.

- **Increased prices for oil have made it viable to produce oil from tar sands, mainly found in Alberta, Canada**
- **Hydraulic fracturing, often known as "fracking", was recently developed in the US, and it has opened up vast reserves (much in the US) that were previously inaccessible. However, there are concerns that it can contaminate groundwater.**

Extraction of bitumen from tar sands has transformed Alberta's economy & environment. Picture Public Domain, from WM Commons

The effect of “fracking”

- **“Fracking” has opened up vast amounts of fossil fuel sources – oil and natural gas – to viable extraction.**
- **One result is that the US has rapidly gone from being a major importer of oil & gas to being almost self-sufficient – hence the growth in natural gas for electricity production.**
- **However, many have concerns about the environmental impact of fracking on the local area (even the CEO of Exxon Mobil!).**
- **The resultant growth in oil supply has put to rest the idea of “peak oil”. This boosts the economy, but raises concerns about fossil fuels causing catastrophic climate change.**

Picture by Joshua Doubek
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Nuclear power

- **Nuclear power uses uranium as an energy source, and although this is not renewable supplies of uranium are expected to last well into the future.**
- **Nuclear power causes very little emission of greenhouse gases, but nuclear waste is highly radioactive and must be contained for a long time to come.**
- **Nuclear fuels – uranium-235 and plutonium, are closely linked with nuclear weapons, and are therefore politically very sensitive. Recently India has developed technology to allow use of thorium which should be safer and less applicable for weapon production.**

Renewables

- **Renewables produce little or no greenhouse gases, and are generally seen as good for the environment.**
- **However, hydroelectric dams often have a serious environmental impact (flooded land, fish migration, etc.).**
- **Wind and solar power have little environmental impact, but large scale projects may be seen as eyesores, as with the Nantucket Sound wind farm, or with Donald Trump's golf course! Sometimes there are also concerns about bird deaths near wind turbines.**

7.2. ENERGY IN THE FUTURE

Energy usage by 2030 (US)

- **According to US government predictions, total energy usage in the US is expected to grow from around 103 EJ in 2015 to around 109 EJ in 2030.**
- **Some of this growth is predicted to be met by biomass and renewable energy, but fossil fuels are still expected to dominate in the US and maintain their % of total energy consumption. "Fracking" makes this likely, given that it frees the US from much of its dependence on foreign oil.**

Energy usage by 2020 (EU): "20 by 20"

- **The EU has set a target of meeting 20% of its supply from renewable sources by 2020 (it was 8.5% in 2005). It has already surpassed that having reached 30% by 2014.**
- **It also aims to cut energy usage by 20% by 2020 through conservation, etc.**
- **Energy policy in the EU is strongly linked to climate change policy, and planned reductions in greenhouse gas emissions of 20% by 2020 through emissions auctions/trading and conservation efforts.**

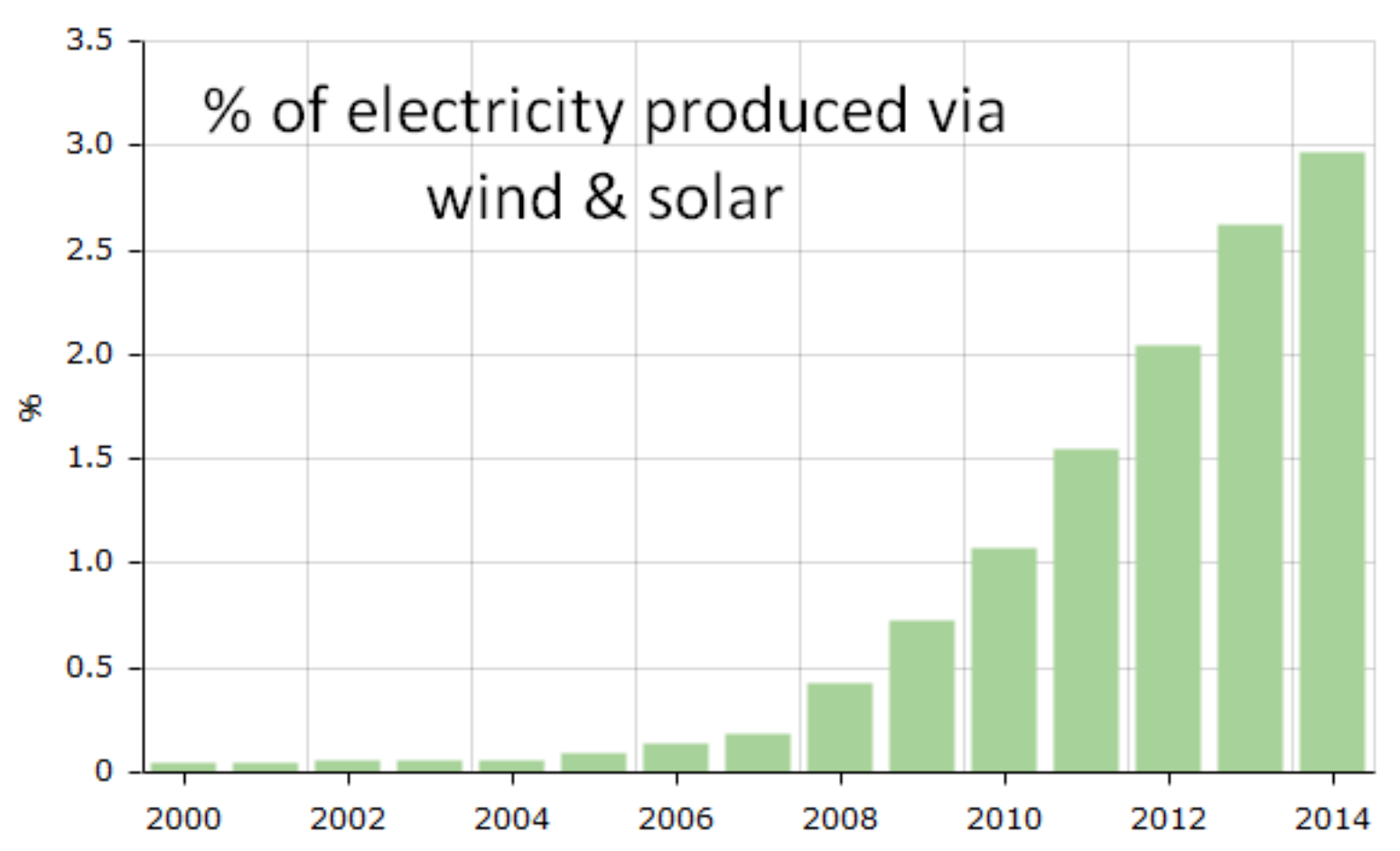
The UK: An example from the EU

- **Renewables supplied a mere 3.5% of energy in 2000, but this had risen to 12.3% by early 2013; by early 2015 it had reached 22.3%. Much of this growth has come from wind power, and the London Array (world's largest offshore wind farm) opened in Spring 2013. Biofuels such as biodiesel receive a 20p per litre tax incentive (~ $1.50 per US gallon).**

Energy usage: China

- Currently most of China's energy is used by industry.
- Most of this energy is supplied from coal, of which China has plentiful supplies. China is still building coal power stations.
- Plentiful hydro power means that renewables make up 23% of electricity, but wind & solar are now making an impact.
- China is the world's largest energy user, and also the largest producer of carbon dioxide.

China's wind & solar are making an impact



Source: Earthtrends

7.3. RENEWABLE ENERGY

Renewable energy

- Hydroelectric power- well established
- Wind power is becoming viable- now popular in Europe, esp. UK & Denmark
- Solar power also becoming viable- popular in Japan and Germany
- Geothermal power- used in Iceland, New Zealand.
- Biomass- still inefficient, competes with agriculture, but becoming more viable
- Wave & tidal power- useful only in certain locations

Renewable energy

- Currently 14% of US electricity (92 GW currently)
- 25% of the world's electricity
- Once built, it has zero carbon footprint

Limitations of renewable energy

- **Many newer renewable sources of electrical power (solar, wind, waves) are capital-intensive at present, requiring a higher level of investment (per MW) than fossil fuel plants. However, prices are rapidly falling (especially for solar) as technology improves and products become mass commodities.**
- **Many of these renewables also provide power only intermittently, which gives problems for reliability of supply (what if the wind isn't blowing when I want to run my washing machine?)**

Storage of renewable energy

- **Many of these renewables also provide power only intermittently, which gives problems for reliability of supply (what if the wind isn't blowing when I want to run my washing machine?). However, new battery technology such as the Tesla Powerwall is making battery storage much more viable for domestic & commercial use. This in turn makes local solar & wind much more viable.**

Picture by Tesla Motors, CC license

Hydroelectric power

- Currently about 7% of US electricity, and 16% of the world's electricity
- Still potential in Asia- big dams planned in China (20 GW Three Gorges already in place) & India
- Environmental impacts from flooding may hinder further development.

Three Gorges Dam – world's largest

Picture by Christoph Filnkößl, WM Commons, CC license.

Solar power

- **Photovoltaics- convert sunlight to electricity, most established method**
- **Solar/hot water- convert sunlight to heat**
- **Solar chimney- convert sunlight to heat to electricity**

Picture by Thomas Springer, Wikimedia Commons, CC License.

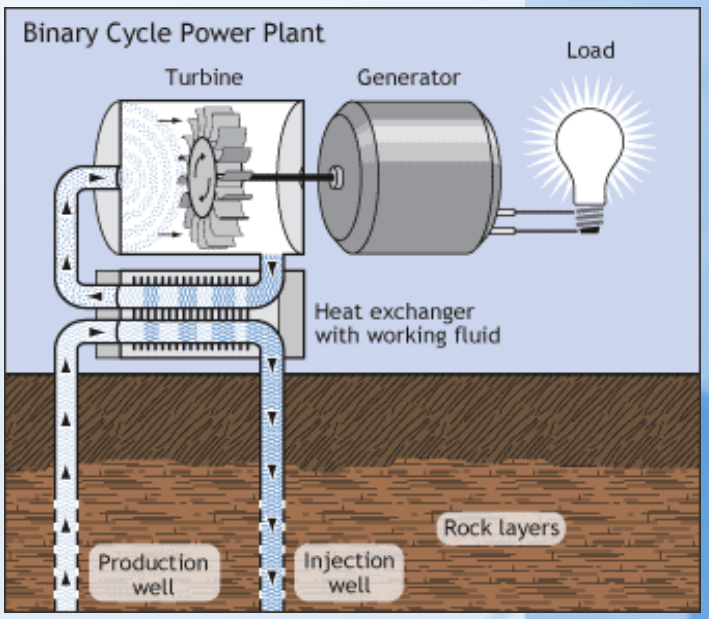
Wind power

- A turbine extracts energy from the wind and converts it to electrical energy.
- Most are horizontal axis (as in these slides), but some can be vertical axis. Three blades is common (for stability), but other numbers of blades are possible too.
- Wind power only works effectively in zones where high winds occur regularly.

- See the video of Prof. Visser, who is studying small turbine for home/farm use.

Other methods

- **Geothermal power:** "Hot rocks" under the earth- cold water is pumped underground, comes back up hot.
- **Tidal power** collects energy from tides; one French site has produced an average of 62MW for almost 50 years.
- **Wave power** captures energy from ocean waves. All are currently small, such as this scheme in Mutriku, Spain which produces 0.3 MW.

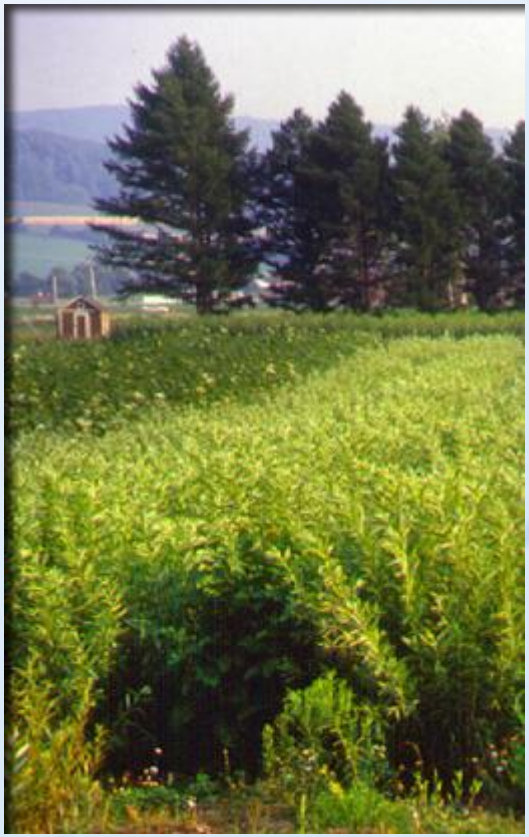


Picture by Sergio, CC license

Biomass: Mainly for fuel production

- **Plants burned, either directly or after conversion to fuels.**
- ***Waste* biomass is efficient to use, likely to become very important. Deliberately growing biomass to burn is less viable if it takes away useful arable land for food crops, but may contribute.**

- **See the video of Prof. Ewy.**



Biofuel from Willow
Research at SUNY-ESF

Useful resources

- The US Energy Information Administration
- World Energy Statistics by Enerdata