Lecture 16 – Bioenergy and Geothermal

Dr. Yu Zhang

ECE, UCSC

Outline

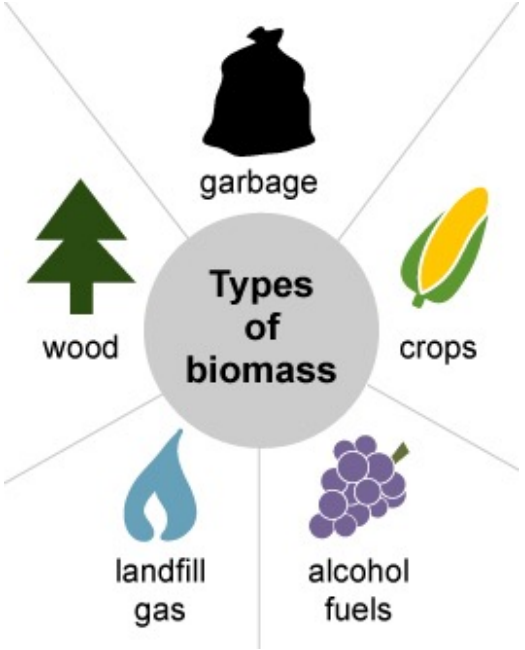
- Biomass Sources and Plants
- Biomass Conversion
- Biomass Statistics
- Geothermal Energy Source
- Geothermal Energy Technologies

- B3: Chap 5 and 10
- B1: Sec 8.7-8.8

Biomass

Biomass

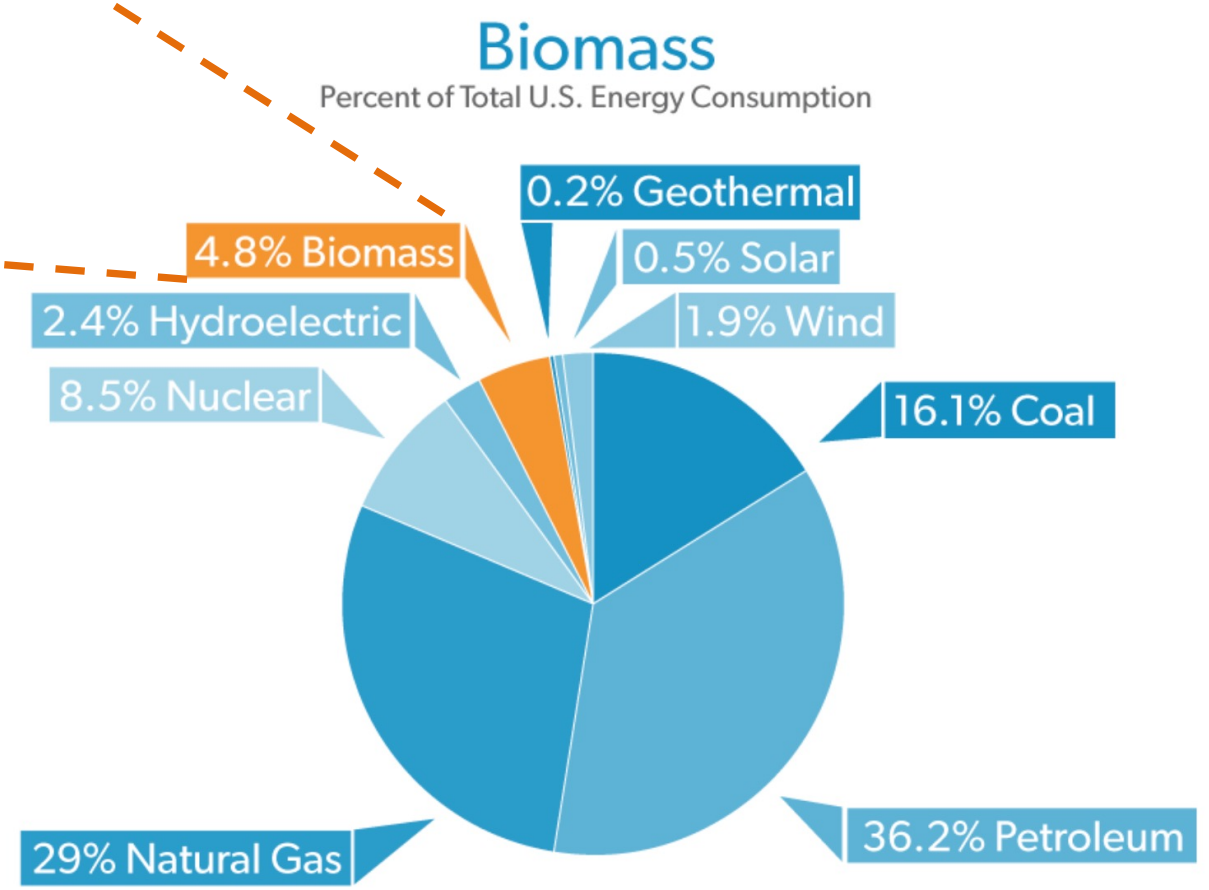
Biomass: Getting energy by burning wood and other organic matter



Biomass

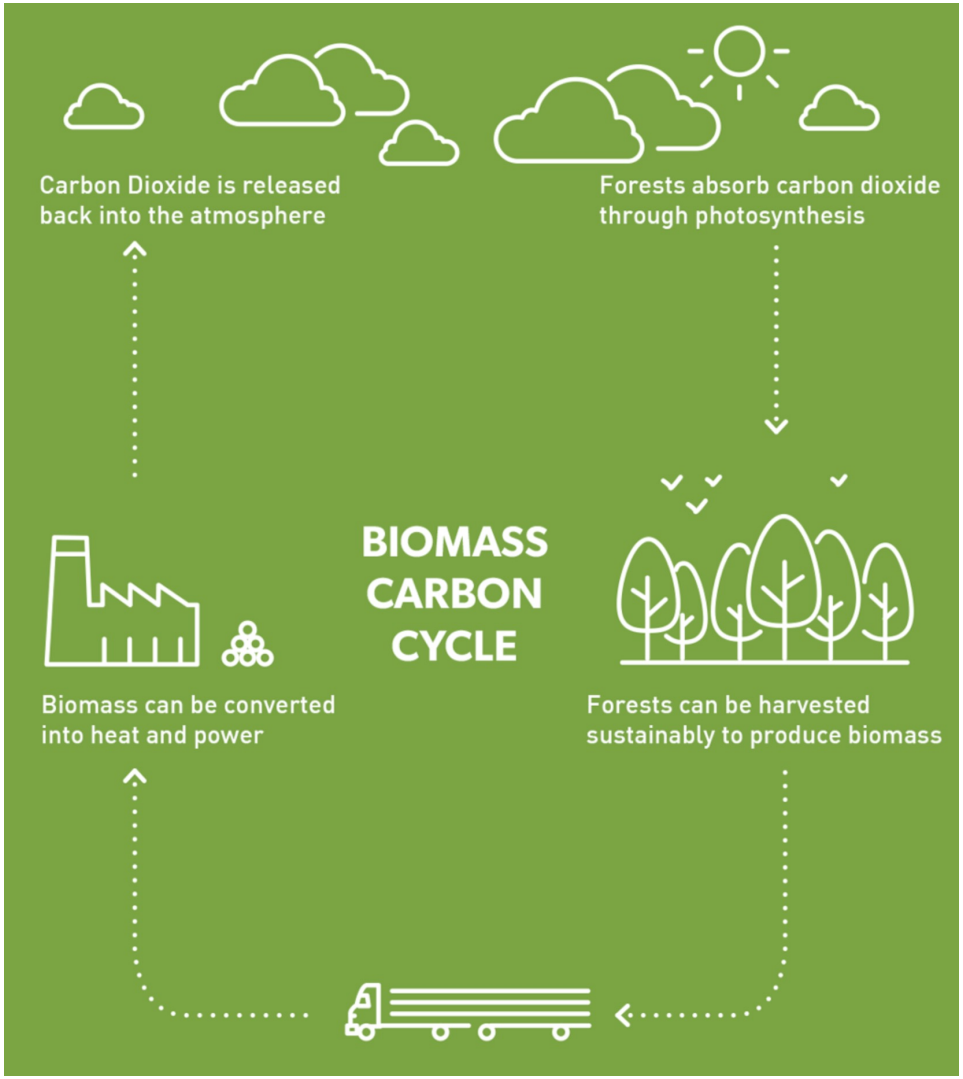
Biomass is based on wastes that must be disposed of anyway, biomass feedstocks for electricity production may have low/no/negative-cost advantages.

- 48% – biofuels (mostly ethanol)
- 41% – wood based biomass
- 11% – municipal waste

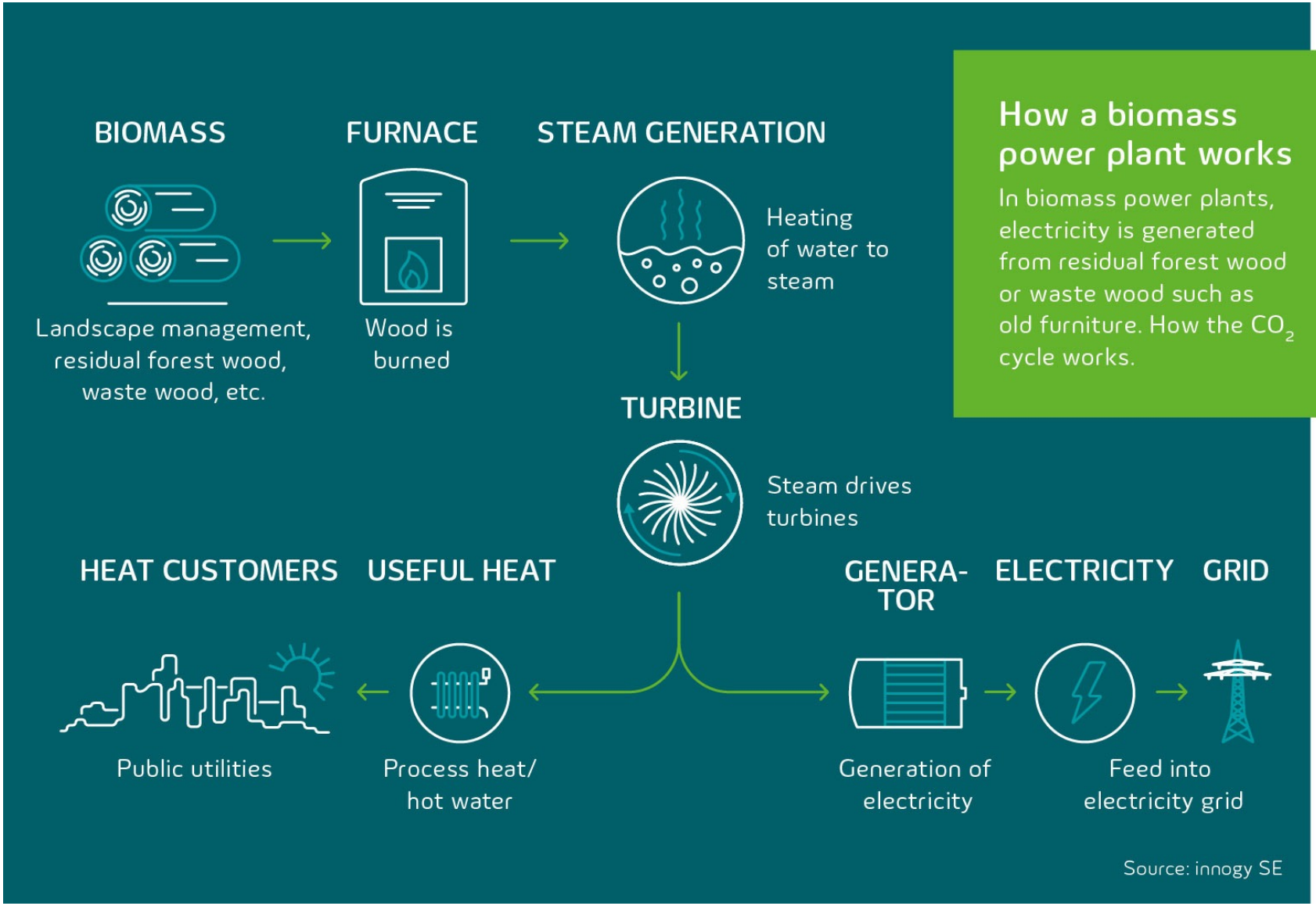


Biomass Carbon Cycle

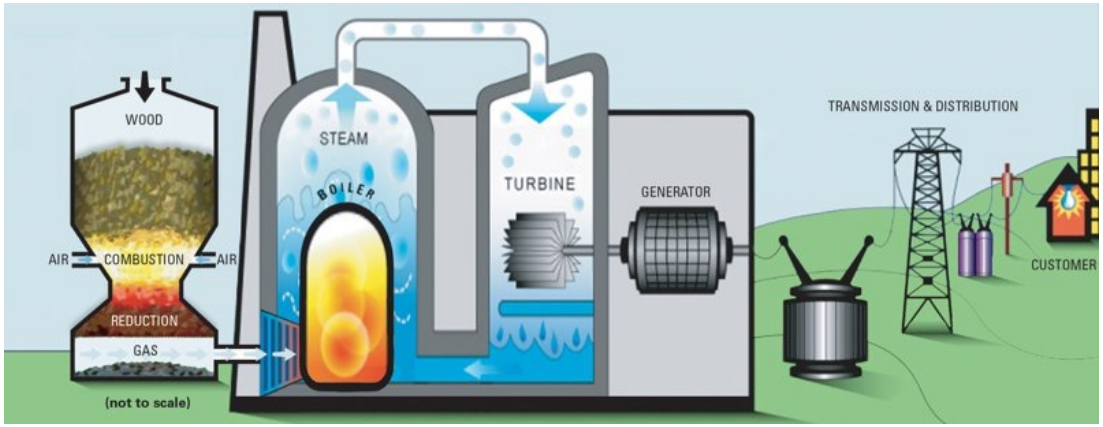
The biomass carbon cycle shows the roles of sunlight and photosynthesis and the resultant power generated by a biomass power plant



Biomass Power Plant



Biomass Power Plant (cont'd)



1) Moisture is first driven off.
2) At 400 ^{o}C, the biomass begins to break down
3) Yielding a product gas (syngas) & solid byproducts (char and ash).

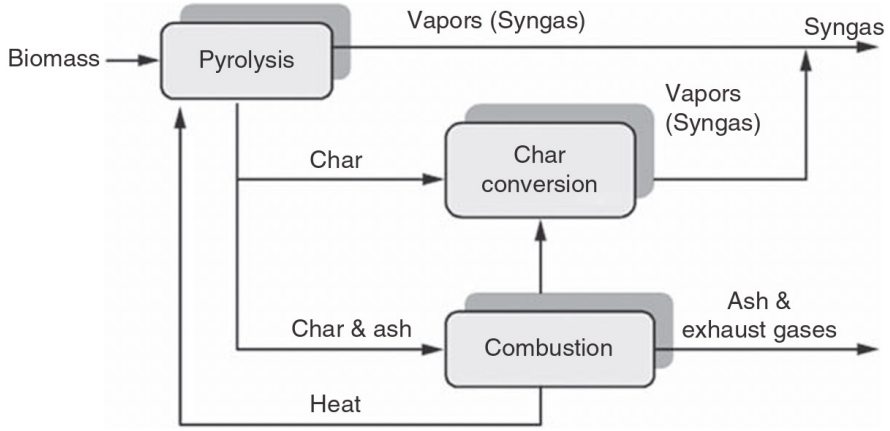


FIGURE 8.40 Biomass gasification process.

Syngas =
hydrogen (H_2) +
carbon monoxide (CO) +
methane (CH_4) +
carbon dioxide (CO_2) +
nitrogen (N_2) + tar

Biomass Conversion

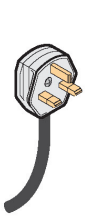
To produce a fuel that is more conveniently used, transported or stored, or to exploit some property of the process itself.

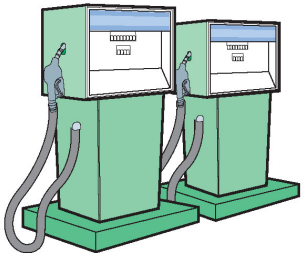
- wood / forestry / arboricultural residues
- crops / straw / other agricultural residues
- perennial energy crops
- organic fraction of 'wastes' (including food / marine / aquatic)

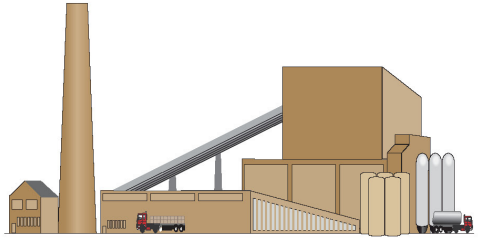
direct combustion

thermal processing

bio-processing







- Heat
- Electricity
- Hydrogen
- Other gases
- Ethanol / oils
- Chemicals
- Bio-based materials

Biomass Conversion (Cont'd)

Thermal conversion: Use heat to convert biomass into another chemical form

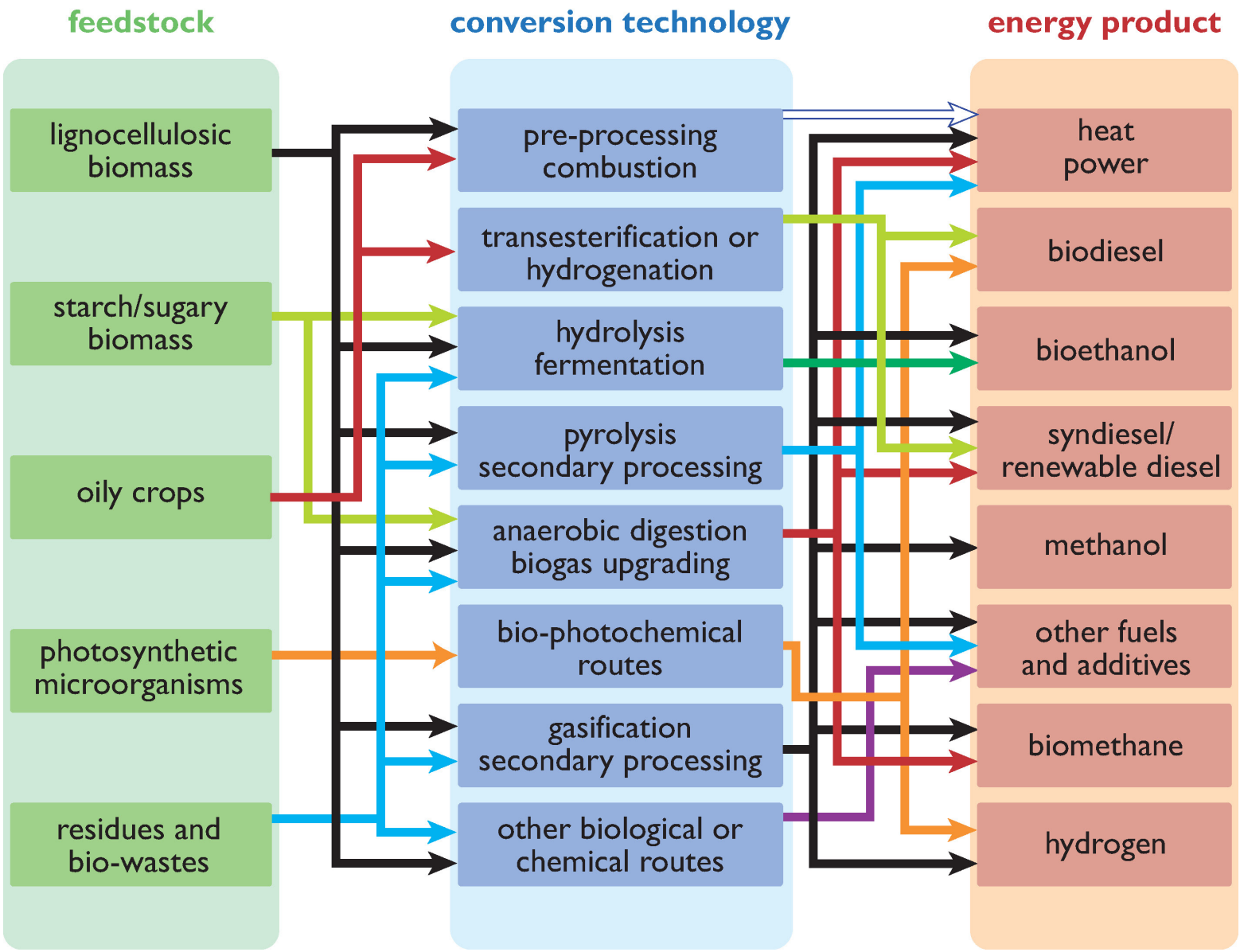
Chemical conversion: A range of chemical processes may be used to convert biomass into other forms

Biochemical conversion: Highly efficient biochemical processes have developed in nature to break down the molecules of which biomass is composed: *Anaerobic decomposition of organic materials by microorganisms to produce a biogas consisting primarily of methane and carbon dioxide.*

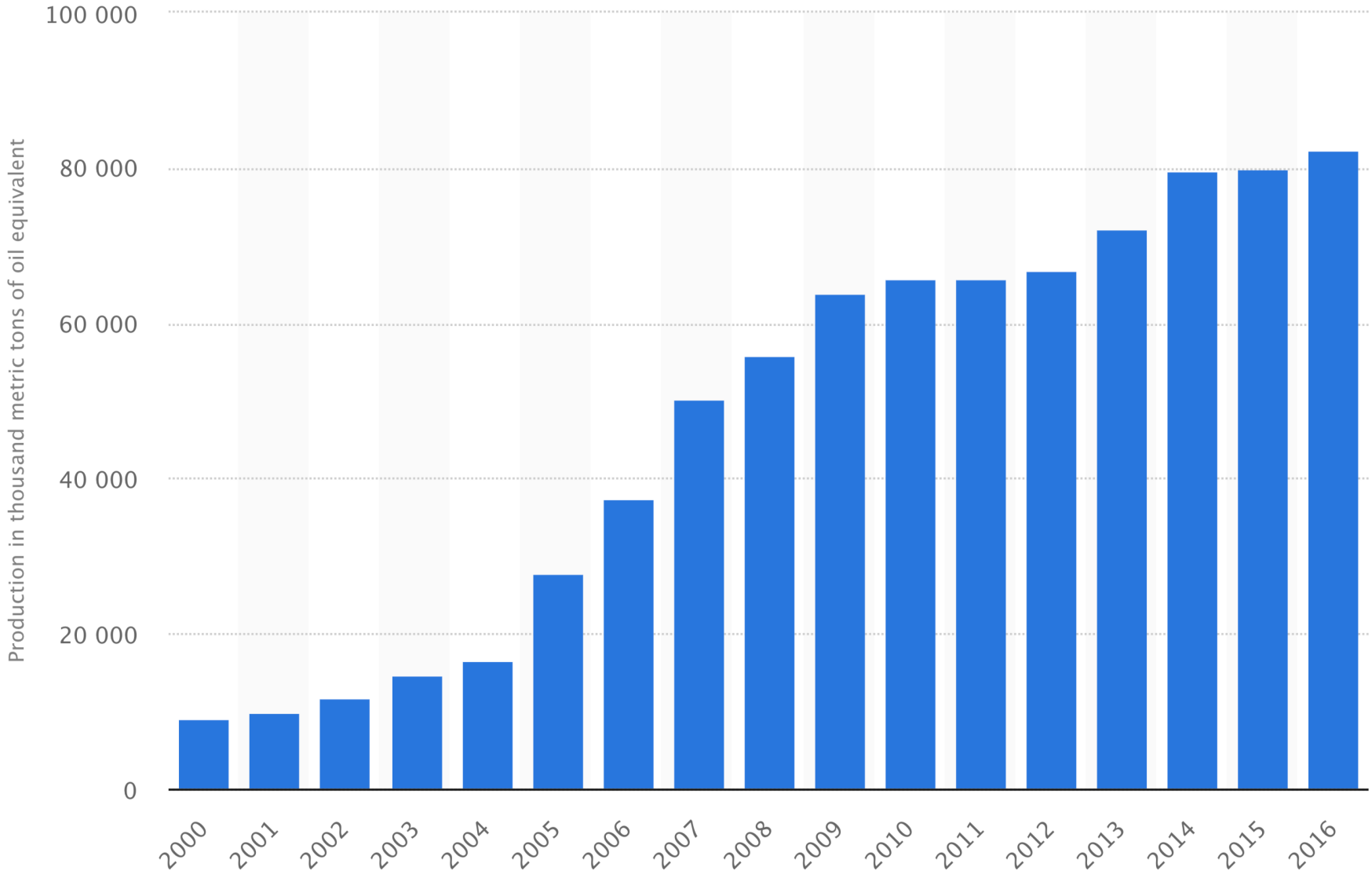
$$\underbrace{C_nH_aO_bN_cS_d}_{\text{Organic matter}} + H_2O + \text{bacteria} \rightarrow CH_4 + CO_2 + NH_3 + H_2S + \text{new cells}$$

Electrochemical conversion: In addition to combustion, biomass/biofuels can be directly converted to electrical energy via electrochemical (electrocatalytic) oxidation of the material.

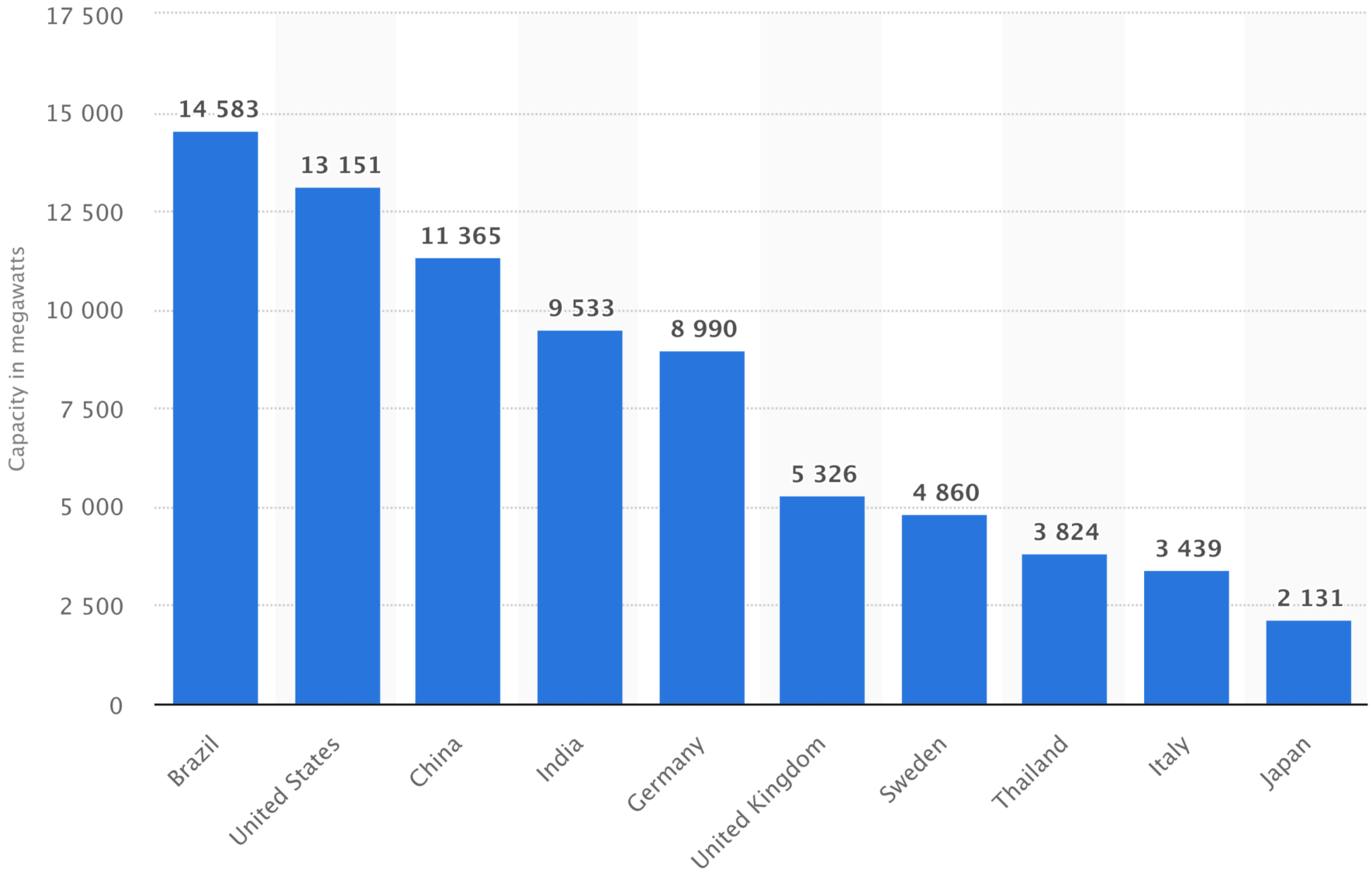
Biomass Conversion (Cont'd)



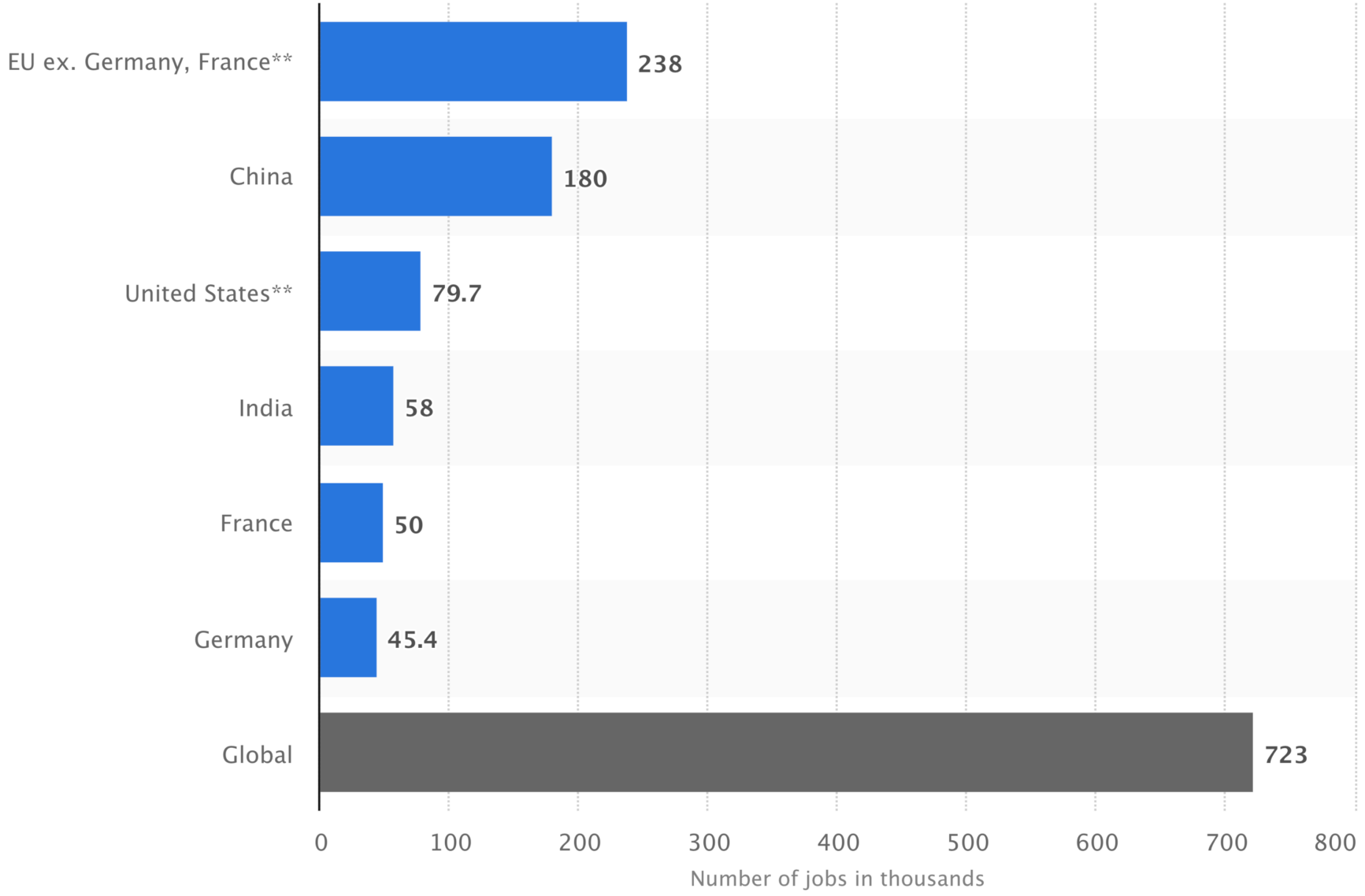
Global Biofuel Production



Leading Global Bioenergy Capacity in 2017



Number of Biomass Energy-related Jobs



Supply Chains

Supply chains play a key role in cost-effective delivery of bioenergy

Technical issues
- Inefficiencies of the conversion processes

Logistic issues
- Seasonal availability leading to storage challenges and/or seasonally idle facilities

Financial issues
- Lack of required transport infrastructure
- Limited flexibility or inflexibility to energy demand

Social issues
- Lack of participatory decision making
- Lack of public/community awareness

Policy and regulatory issues
- Lack of incentives to create competition among producers

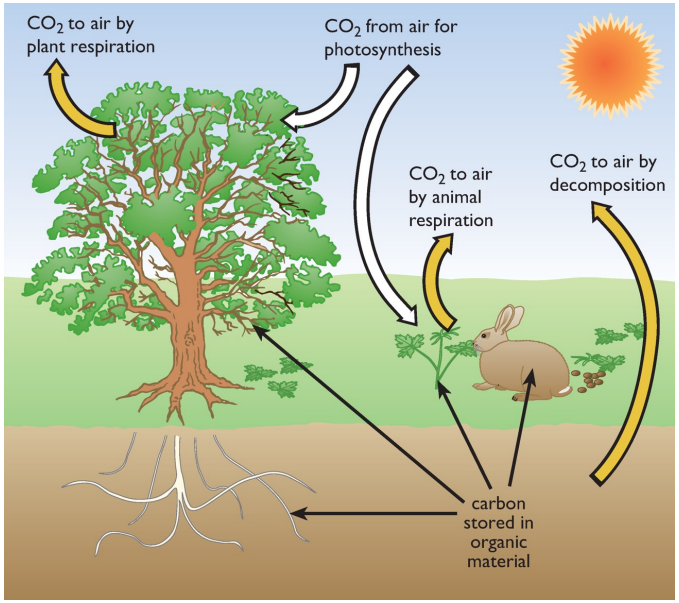
Institutional/organizational issues
- Lack of supply chain standards

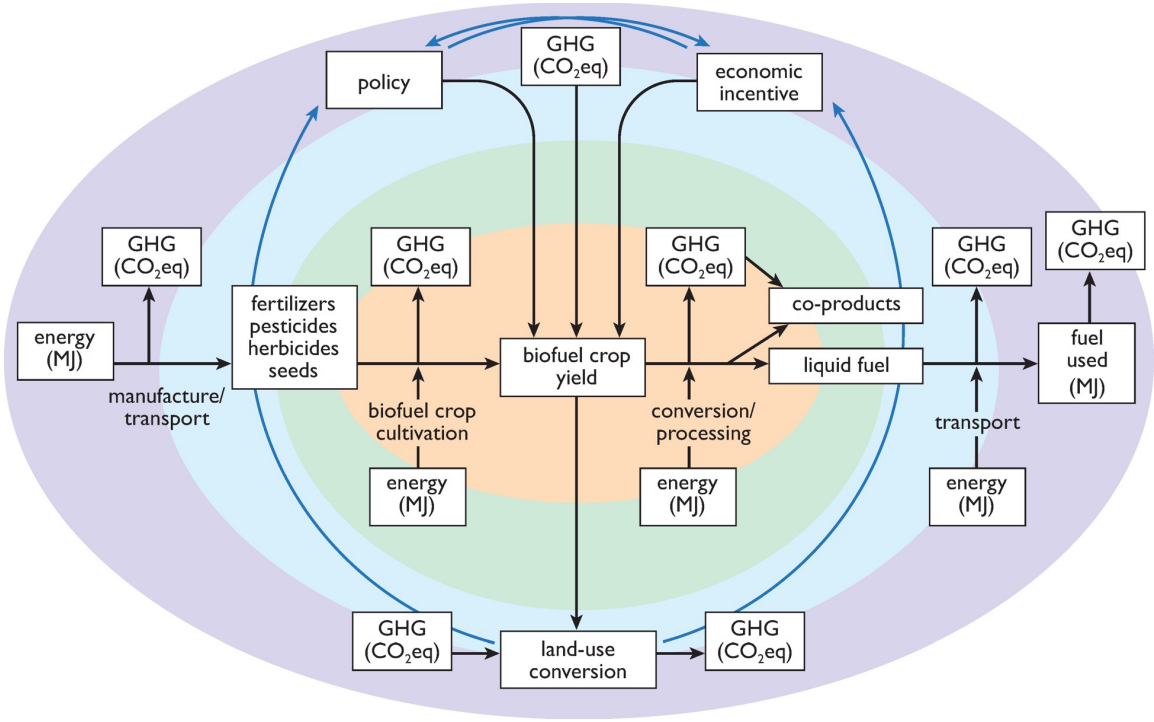
See details in https://en.wikipedia.org/wiki/Biomass

Environmental Impact

Using biomass produces air pollution in the form of

- Carbon monoxide and dioxide
- NOx (nitrogen oxides)
- VOCs (volatile organic compounds)
- Particulates and other pollutants





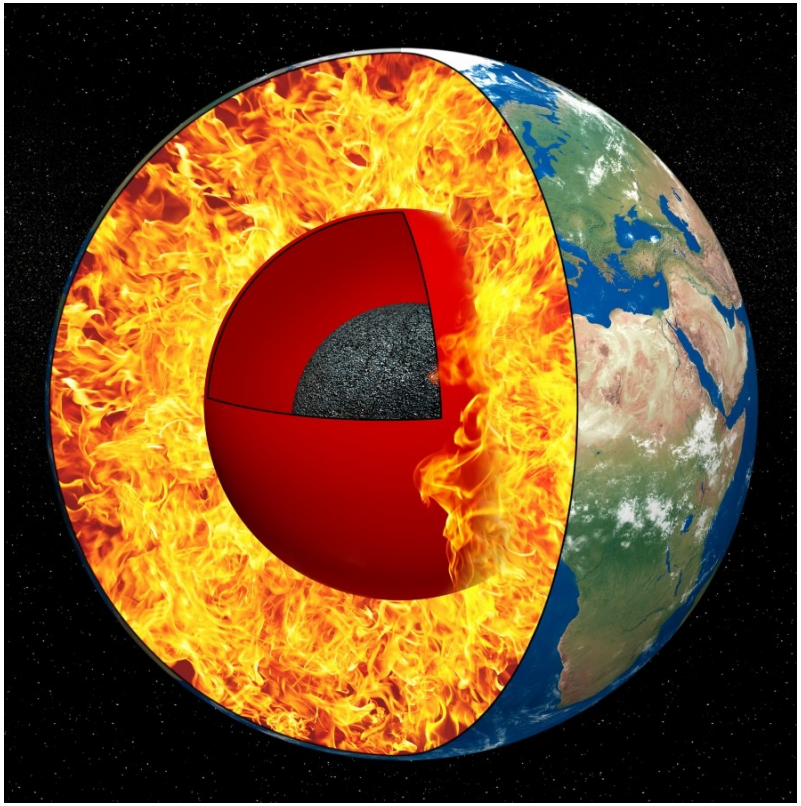
Different system boundaries for the life-cycle analysis of biomass energy systems

Geothermal Energy

Hawaii Volcano Eruptions

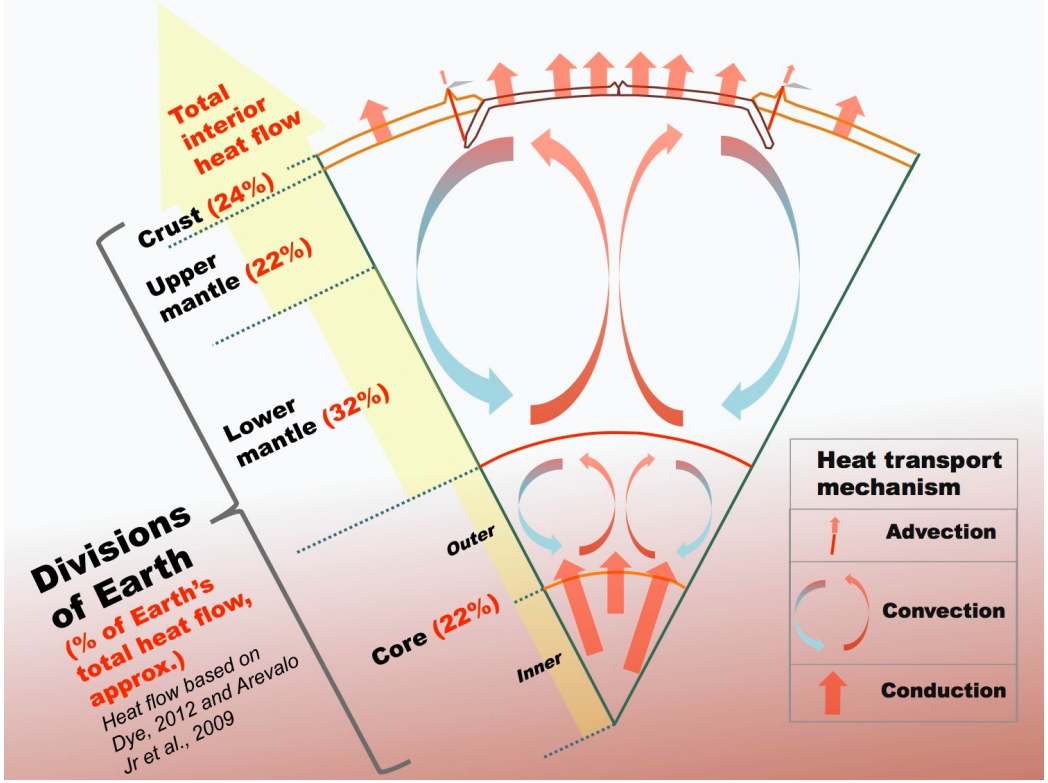
Geothermal Energy

Geothermal energy: Thermal energy generated and stored in the Earth



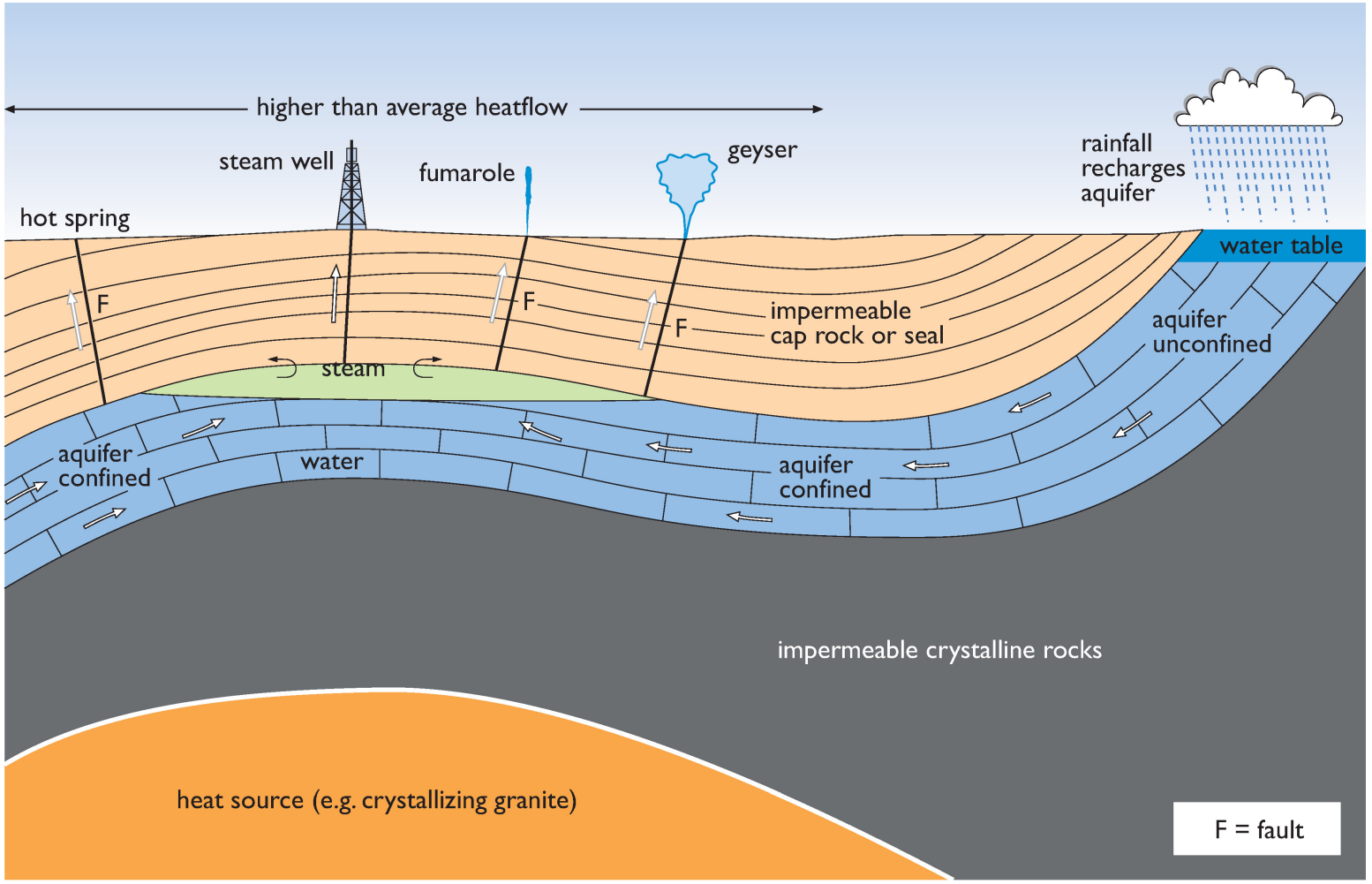
Earth Internal Heat

Earth's internal heat: Generated from radioactive decay and continual heat loss from Earth's formation



- Temperatures at the core–mantle boundary reach over 7,200°F (4000°C)
- The high temperature and pressure cause rock to melt and solid mantle to behave plastically
- Rock and water are heated in the crust, up to 700°F (370°C)

The Physics of Geothermal Resources



- An aquifer containing water that can be accessed by drilling
- A cap rock to retain the geothermal fluid
- A heat source

Volcano-related Heat Sources

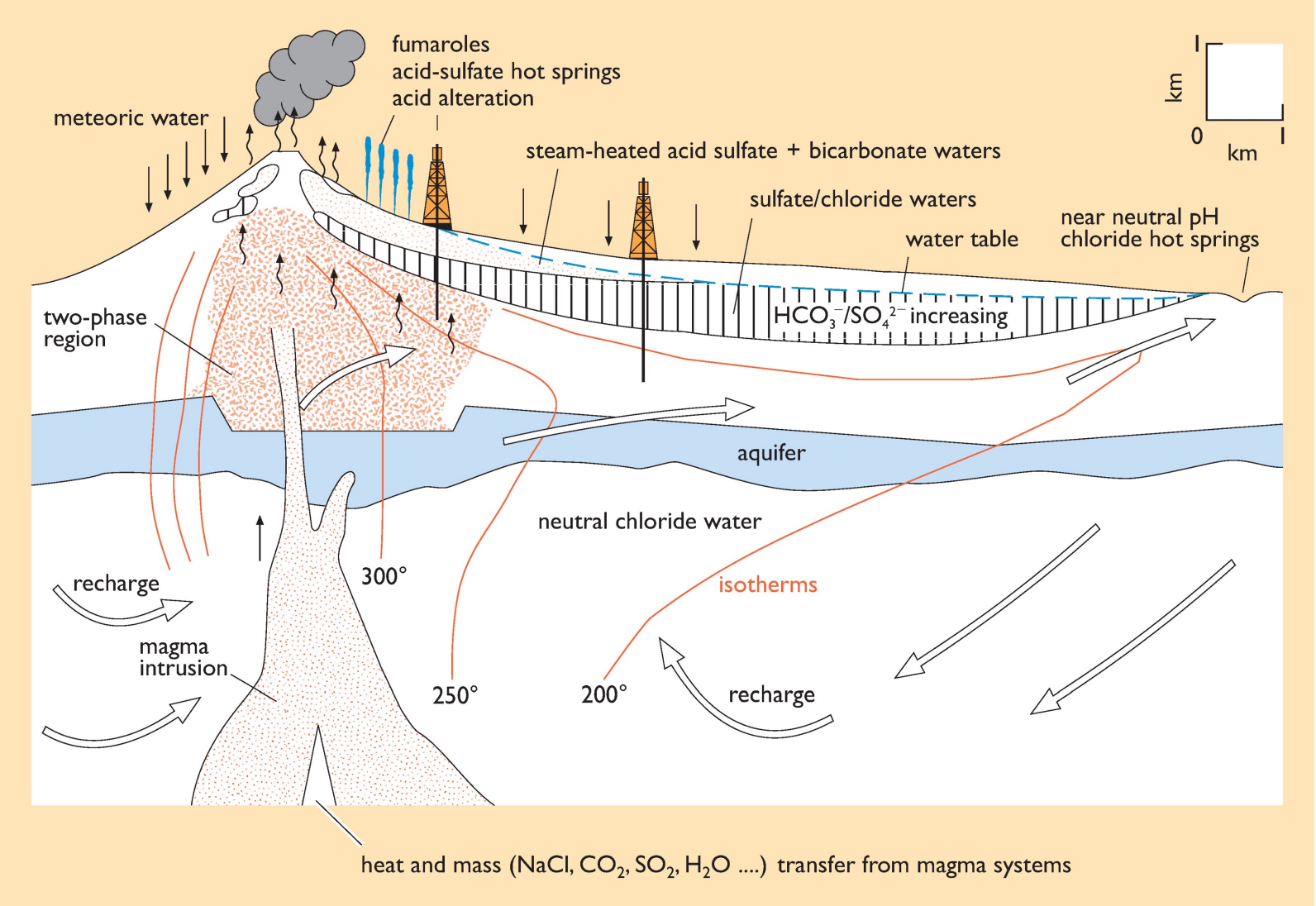
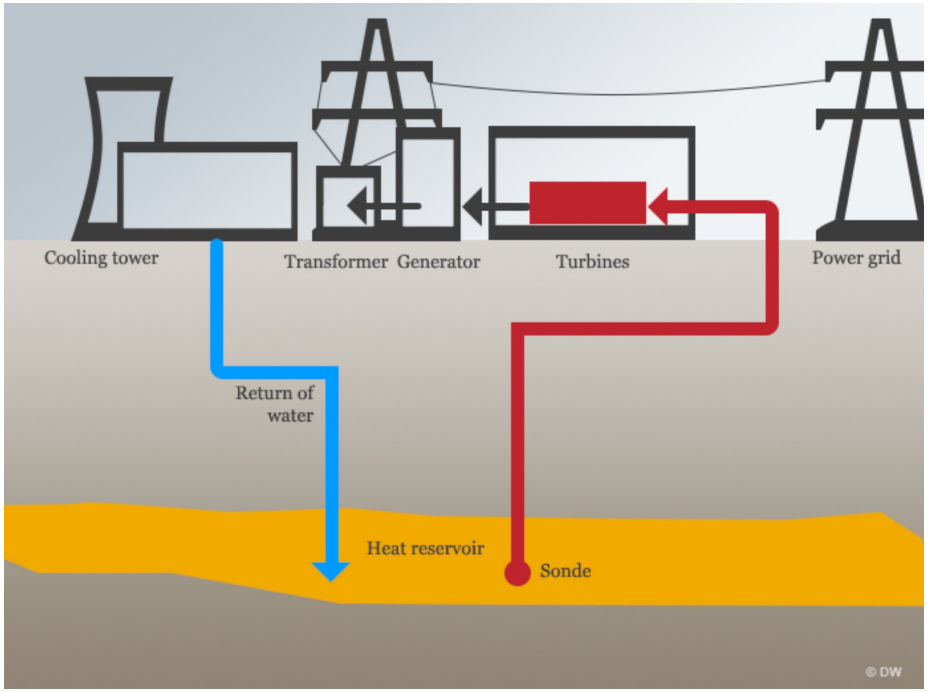


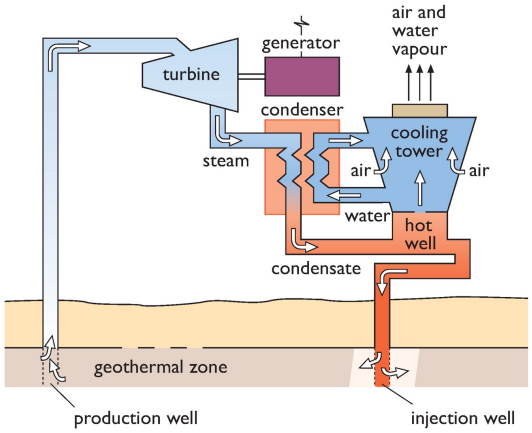
Fig: Conceptual model of a typical volcanic geothermal system

How Geothermal Energy Works

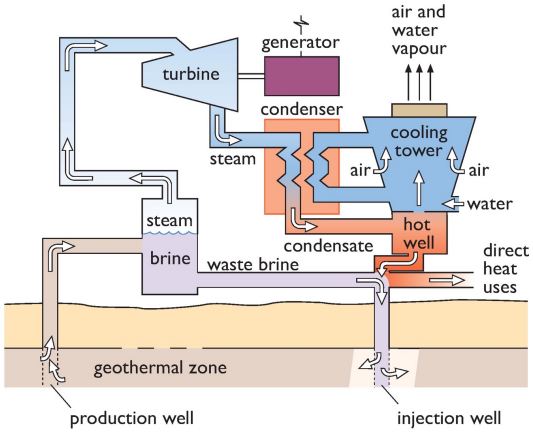


- Geothermal power plants tap into naturally existing hydrothermal reservoirs
- If that's not possible, water is pumped down an injection well, where it filters through cracks in hot rocks. The water then returns via a "recovery well," under pressure in the form of steam
- That steam is captured and used to drive electric generators or heat homes

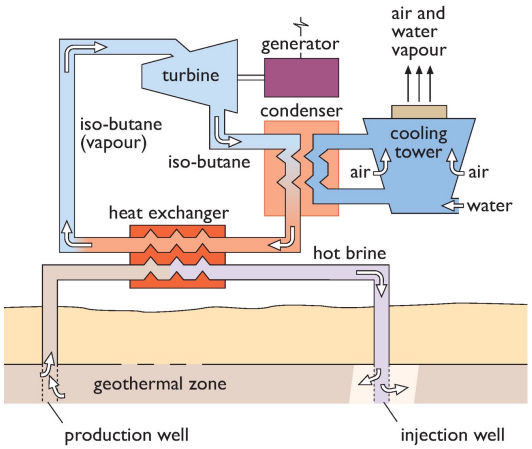
Geothermal Electrical Energy Production



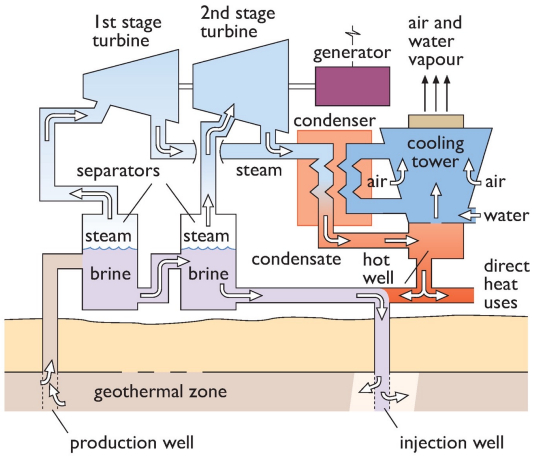
(a) dry steam power plant



(b) single flash steam power plant



(c) binary cycle / organic rankine cycle power plant

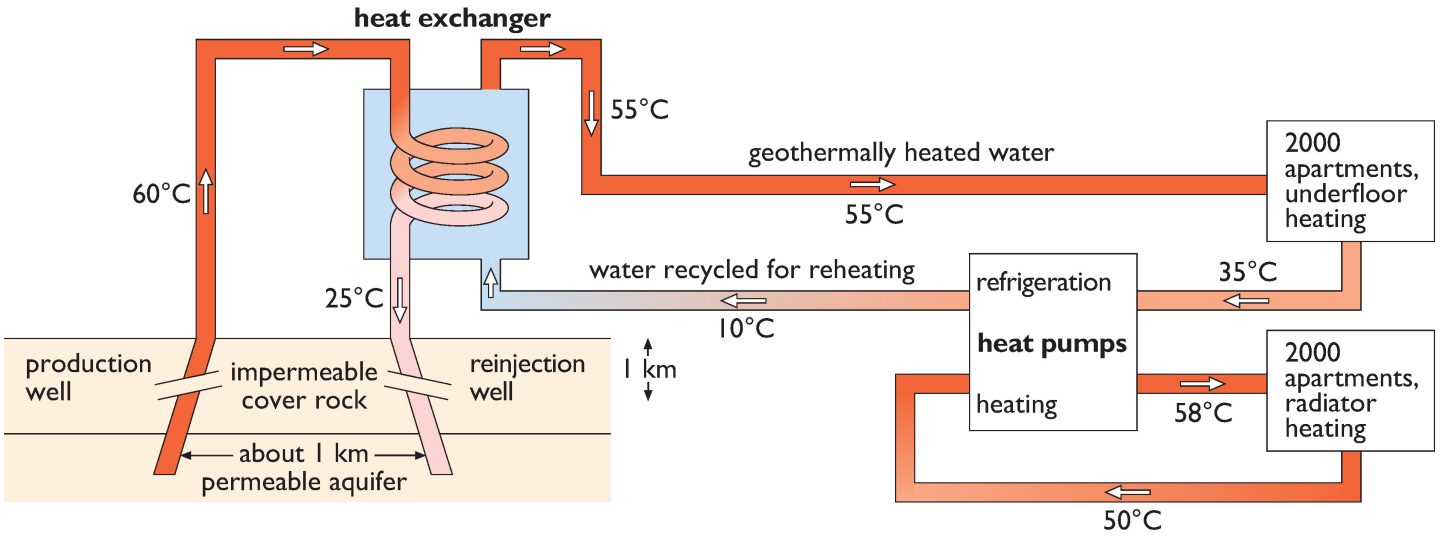


(d) double flash power plant

- A production well is drilled into a known geothermal reservoir. Typically, an injection well is also drilled to return used geothermal fluids to the geothermal reservoir. Hot geothermal fluids flow through pipes to a power plant for use in generating electricity.
- An injection well is drilled for the safe disposal of geothermal fluids, whose total dissolved solid concentrations in the state can reach 250,000 parts per million, about seven times higher than sea water.

Technologies for Direct Use of Geothermal

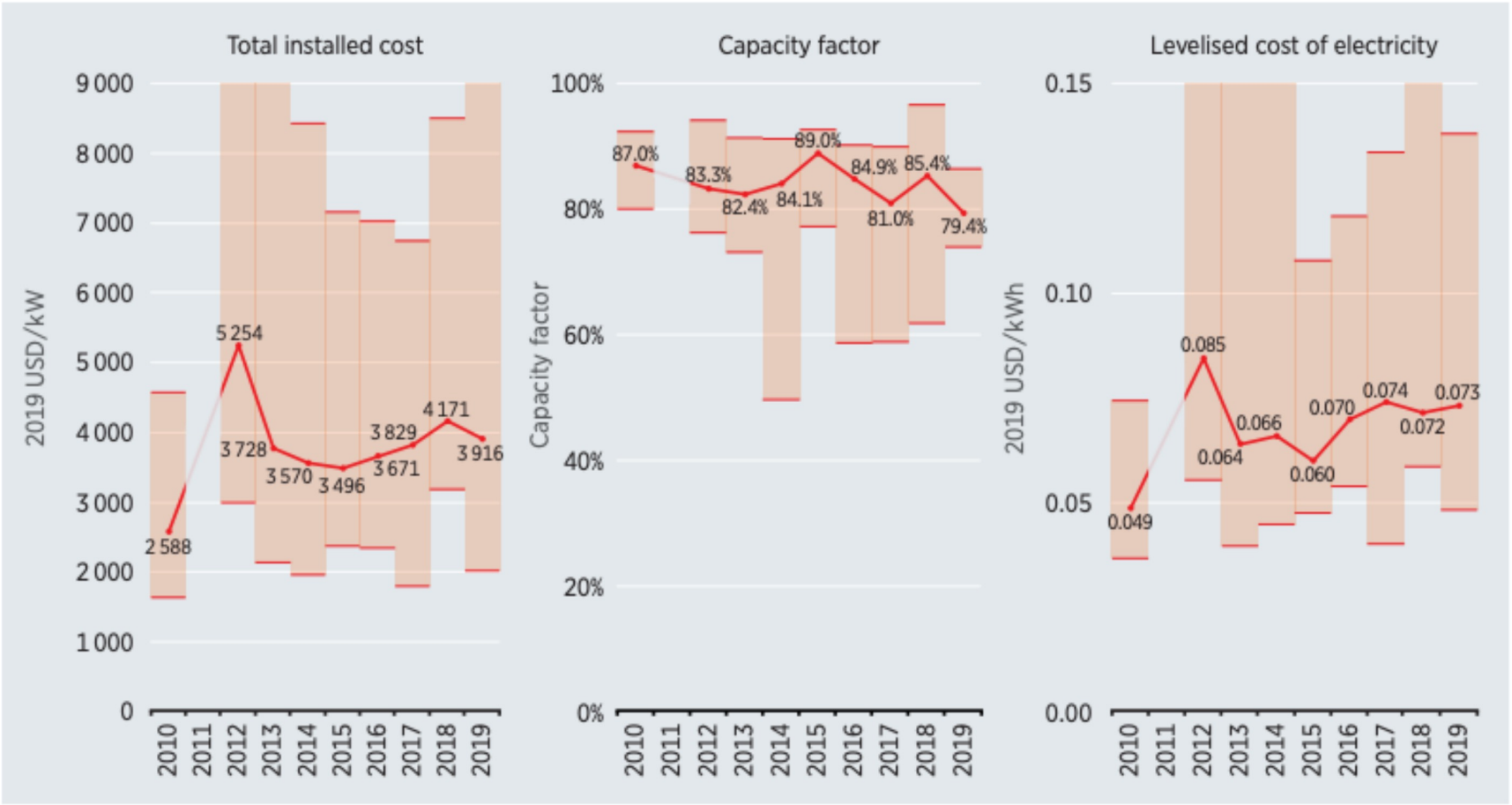
District heat systems



Enhanced geothermal systems

Costs of Geothermal

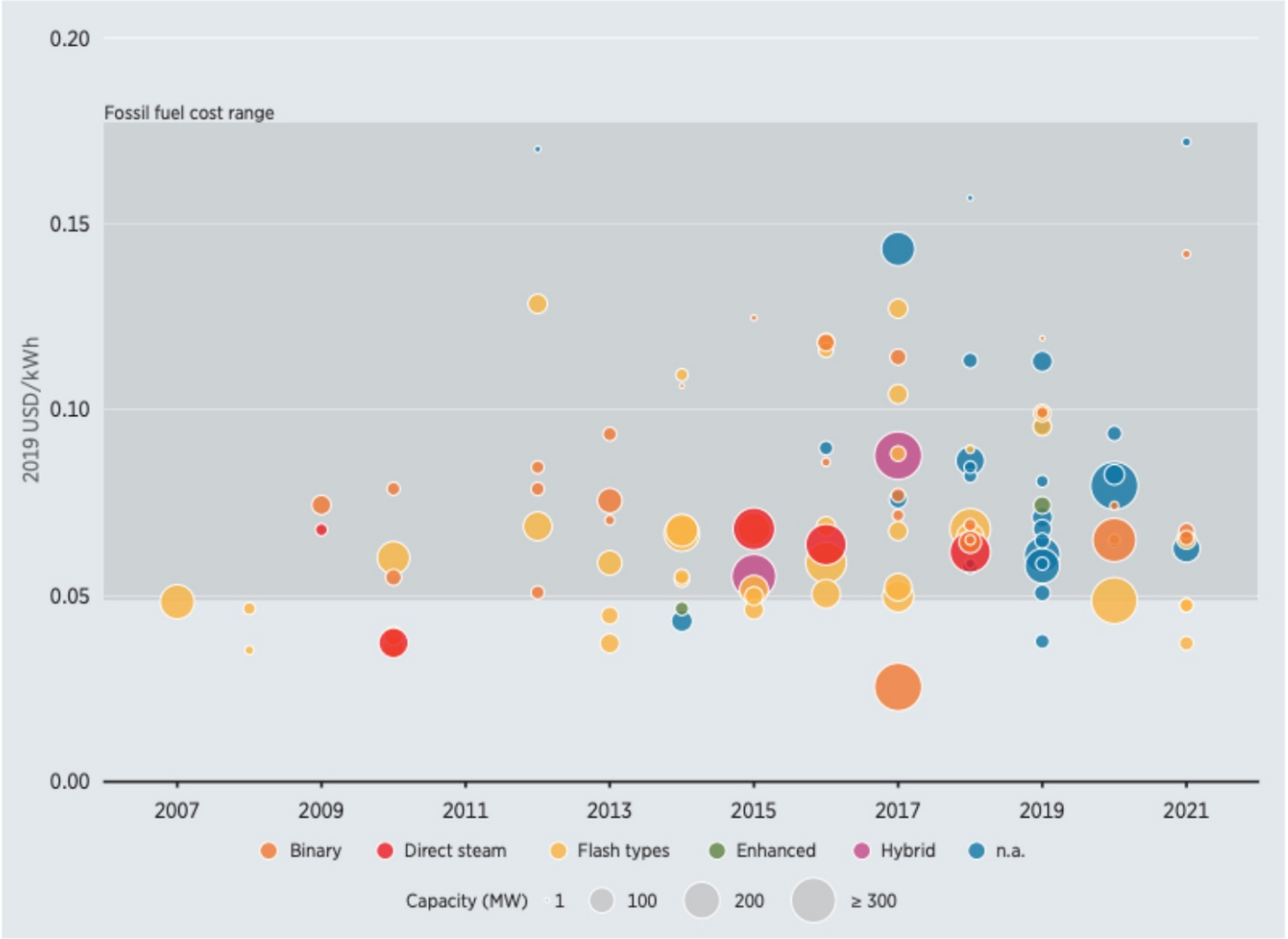
Global weighted average total installed costs, capacity factors and LCOE for geothermal, 2010-2019



Source: IRENA Renewable Cost Database.

LCOE of Geothermal Power

LCOE for geothermal power projects by technology and project size, 2007-2021



Source: IRENA Renewable Cost Database.

Outlook for the Geothermal Industry in 2016