Lecture 4
GEOS24705

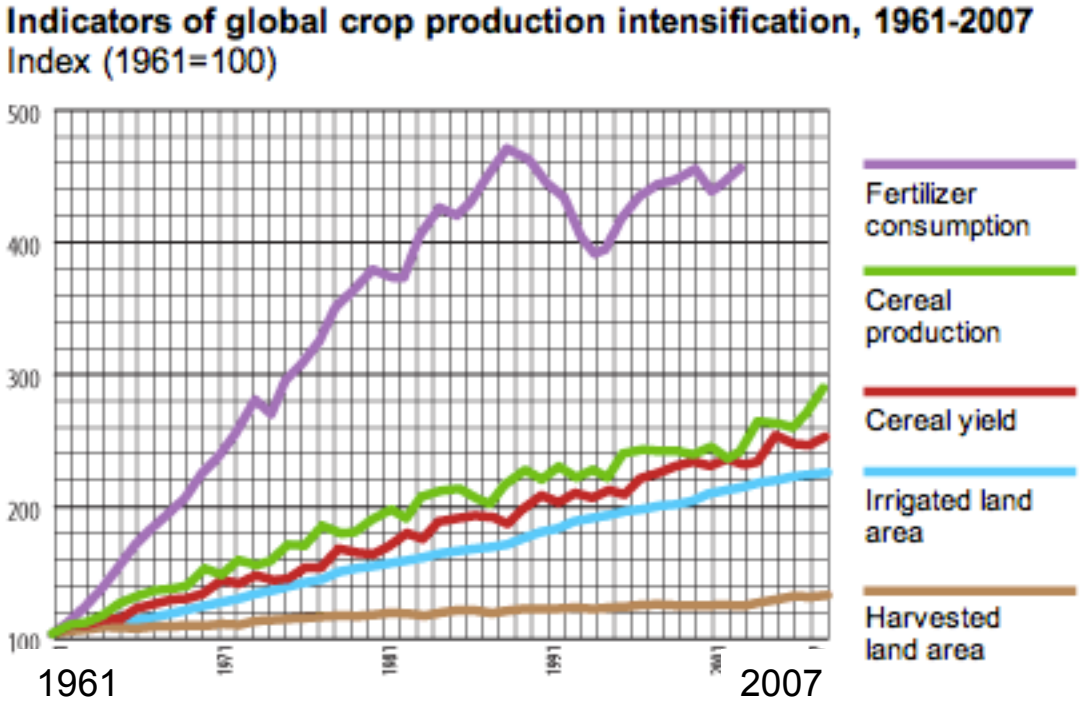
Agriculture, History of Energy Use I

Green Revolution: 3x yield increase

Prevented hunger, but at cost in $ and energy

Norman Borlaug, 1914-2009
born Iowa, college U. Minn.
Nobel Peace Prize 1970

Image: Associated Press, 1970



Yields go with fertilizer use and irrigation
world fertilizer use quadruples
during Green Revolution

Image: U.N. FAO

Green Revolution: 3x yield increase

Prevented hunger, but at cost in $ and energy

Norman Borlaug, 1914-2009
born Iowa, college U. Minn.
Nobel Peace Prize 1970

Image: Associated Press, 1970

Fertilizer plant
ammonia and urea production

Image: Hyosung Power & Industrial Systems

Green Revolution benefits not equally distributed

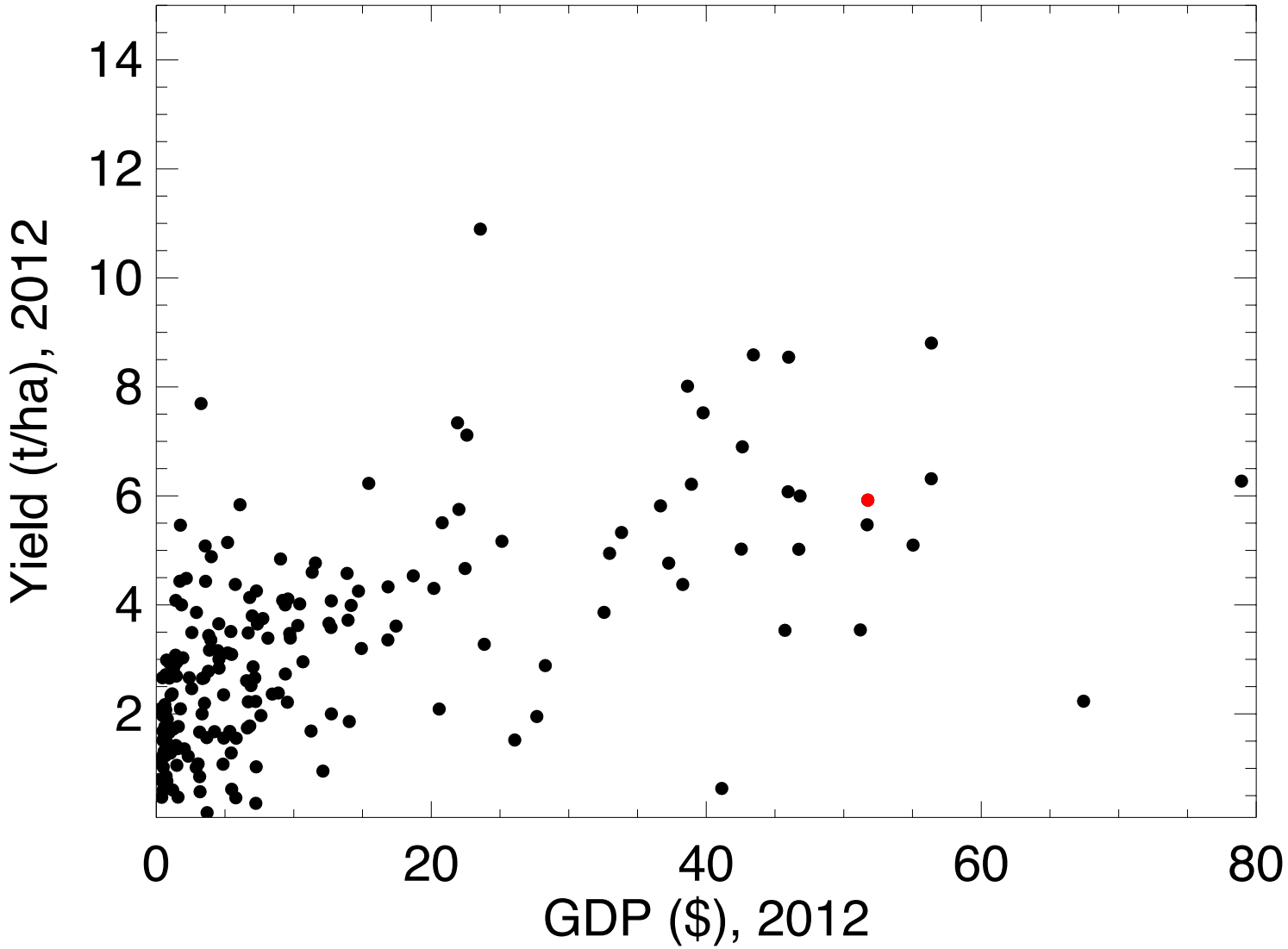
poorest countries have lowest yields

Poor infrastructure, high transport costs, limited investment in irrigation, and pricing and marketing policies that penalized farmers made the Green Revolution technologies too expensive or inappropriate for much of Africa.

P. Hazell,
Green Revolution: Curse or Blessing?
International Food Policy Research Institute, 2002

Green Revolution benefits not equally distributed

poorest countries have lowest yields



Data Source:
World Bank

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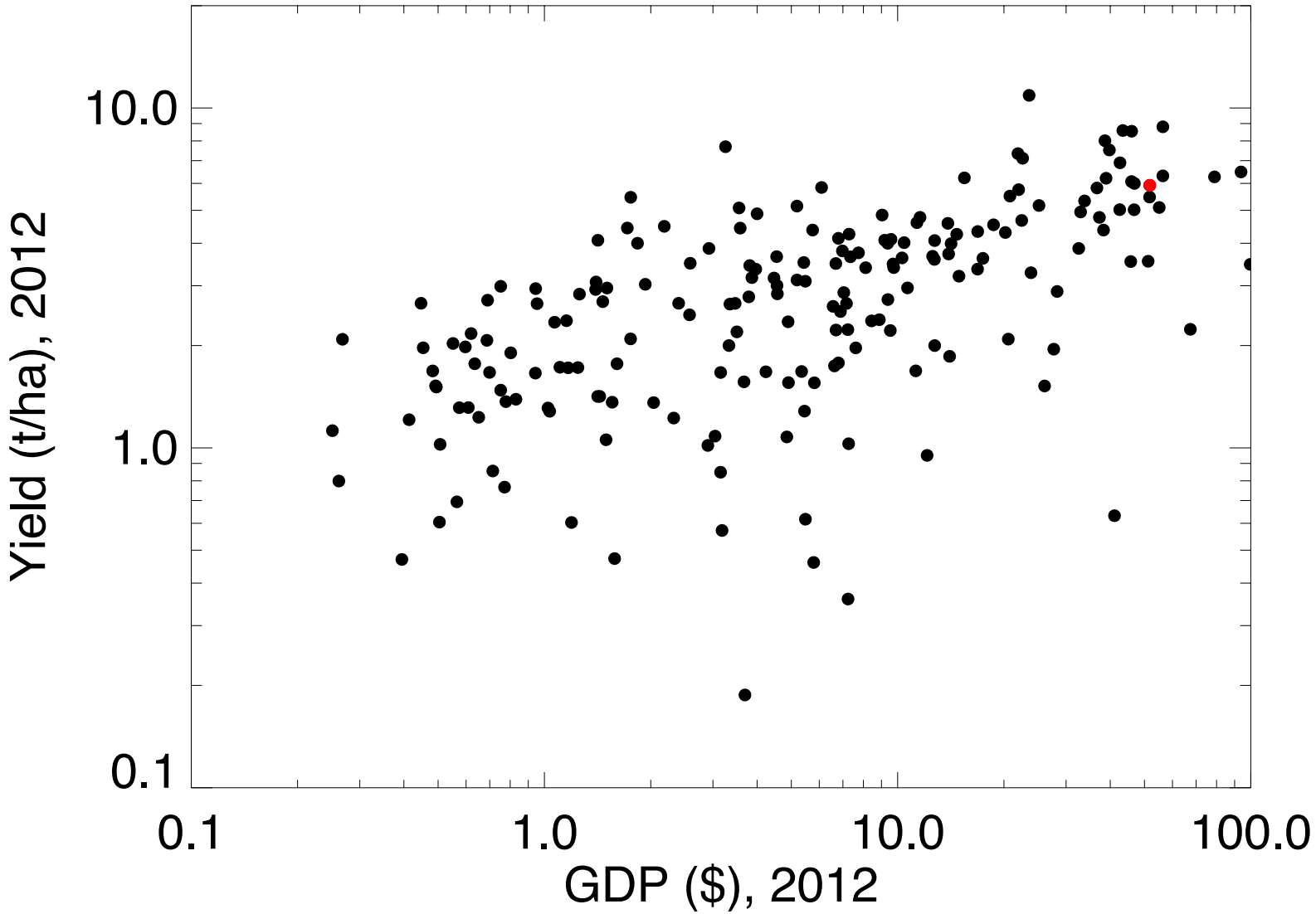


Data Source:
World Bank

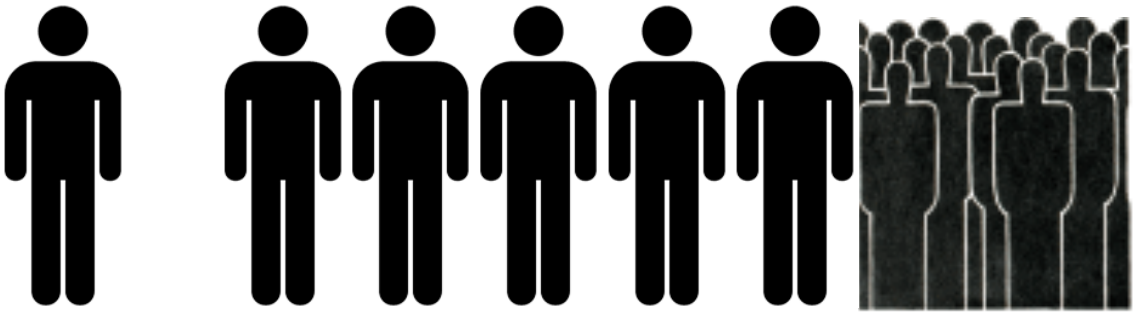
How did we build our energy system?

What technologies allowed us to increase primary energy use?

THEN

Hunter-gatherers – 100 W / person is food requirement

NOW



World average – 2,000 W / person (… 20 servants)

How did we go from 100 W to 10,000 W?

What technologies allowed us to increase primary energy use?

THEN

Hunter-gatherers – 100 W / person is food requirement

NOW

Americans – 10,000 W / person (…100 servants)

How did energy use change between Medieval times and present day?

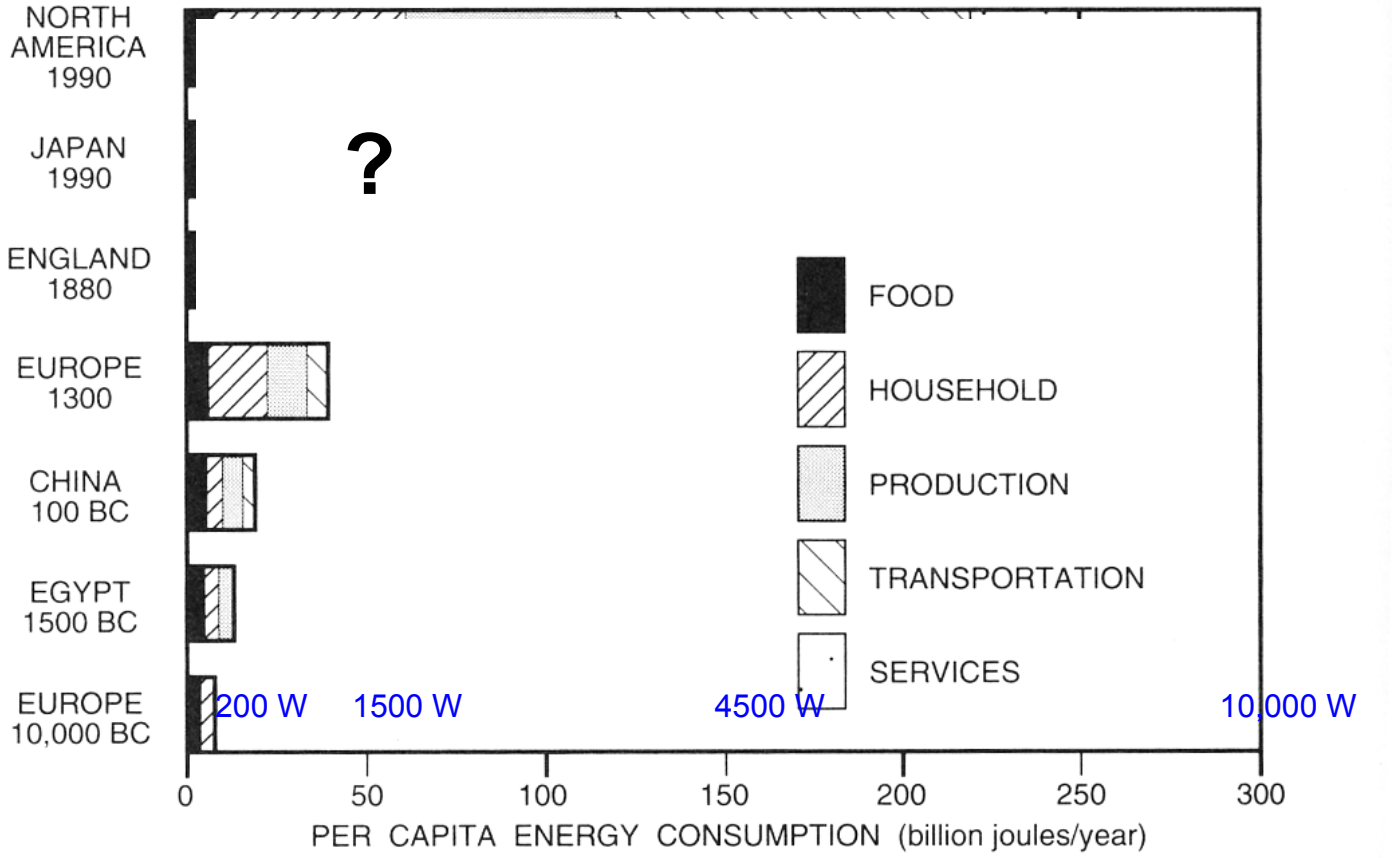
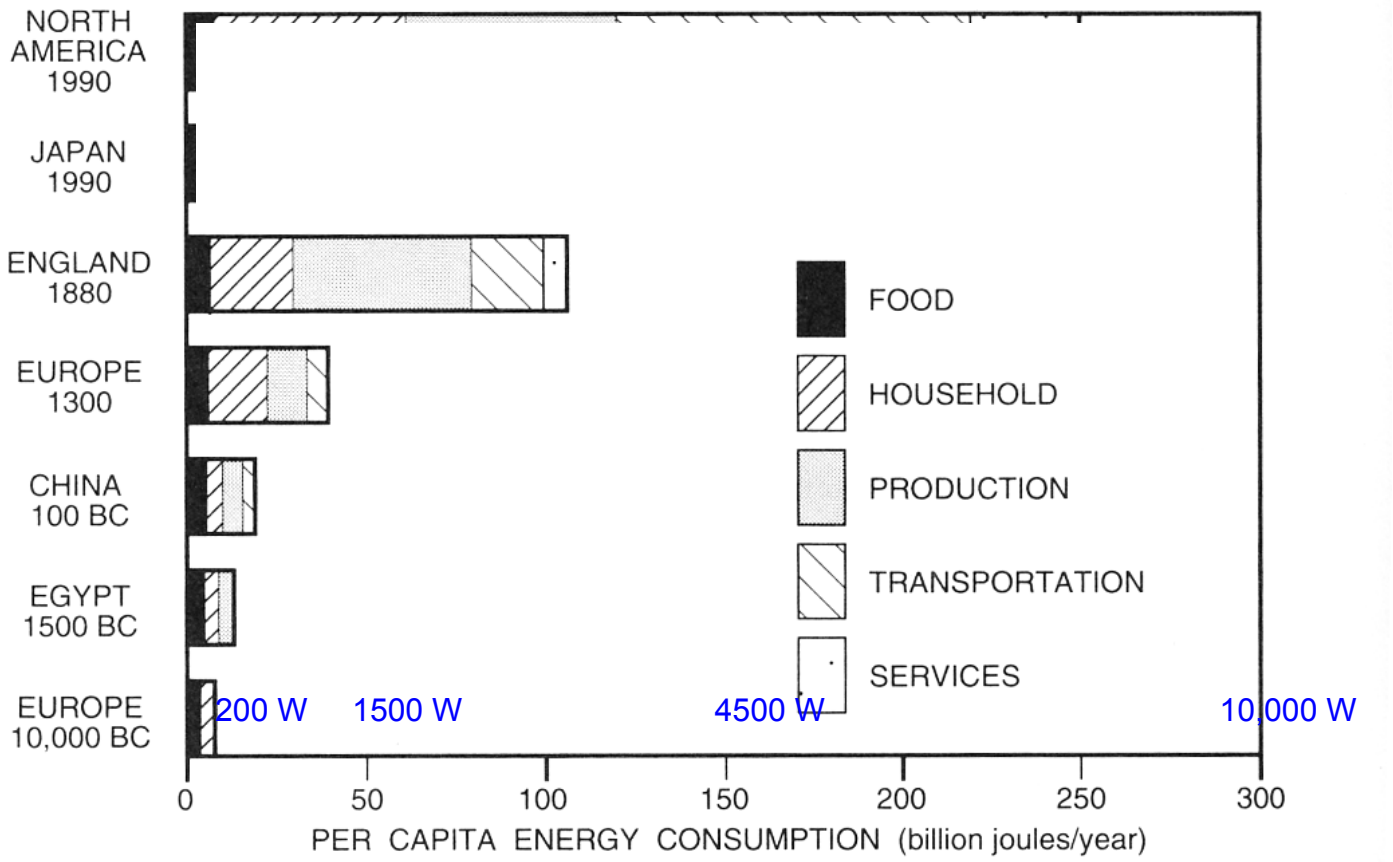


FIGURE 6.6 Comparisons of typical annual per capita consumption of energy during different stages of human evolution. As total consumption has increased, higher shares of energy have been used by households. Shares devoted to food production, manufacturing, service sector, and transportation have shown even higher relative increases. *Sources:* Pre-nineteenth-century values are only approximations; later figures are taken from various national statistical sources.

From V. Smil

Two radical jumps in energy use over history: rise in production (19th century)...



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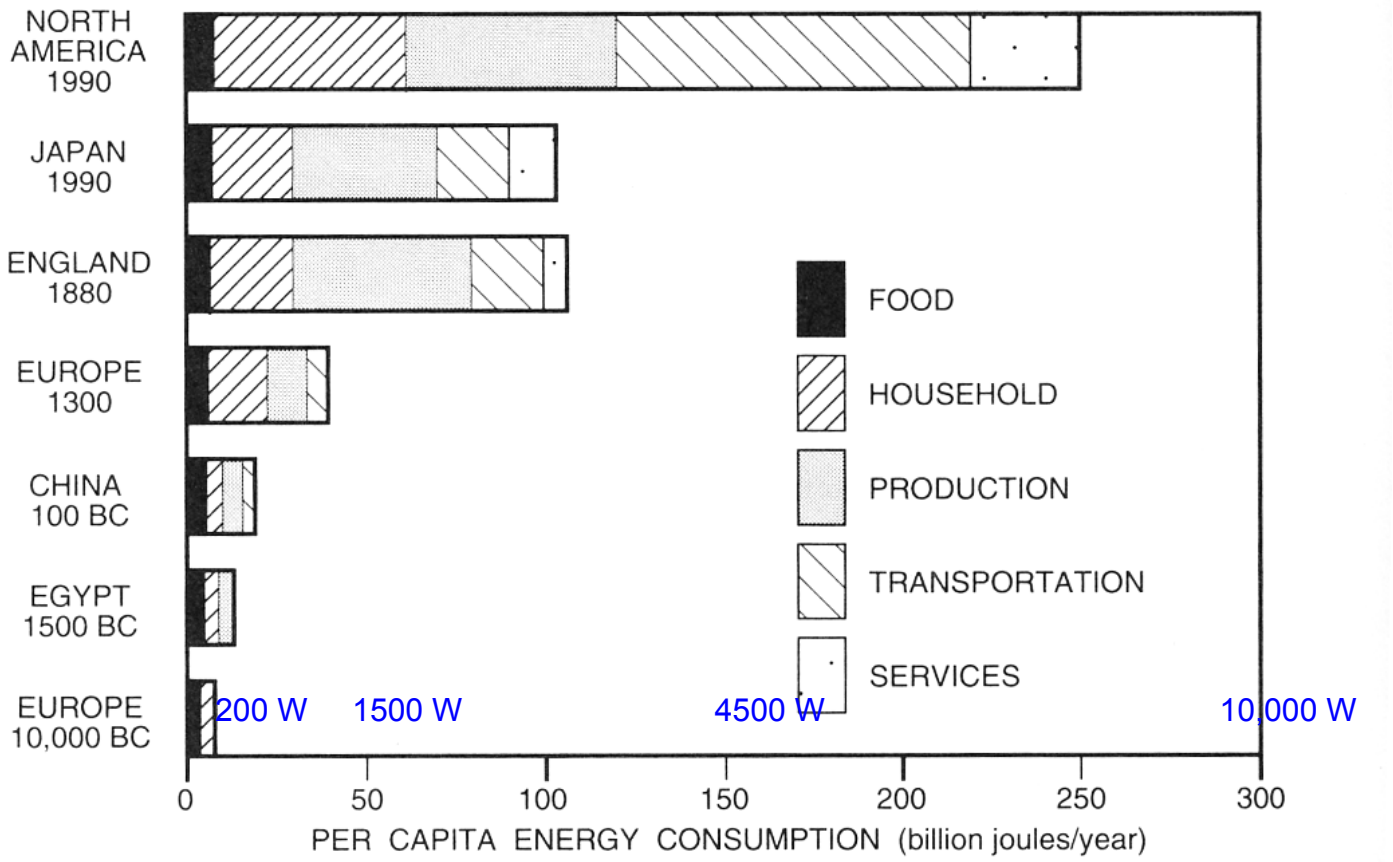
From V. Smil

Two radical jumps in energy use over history: ....and transportation (20th century)



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From V. Smil

In earliest human history the only “engines” were people

Maize farmer, somewhere
in Africa, 2007
Source: CIMMYT

In earliest human history the only “engines” were people

Ploughing by hand,
Uganda

In most of the world, people quickly adopted more powerful “bio-engines”

Diderot & d`Alembert eds, Encyclopédie méthodique. Paris 1763-1777 & 1783-87.

More “bio-engines” = increased power

W.H. Pyne, Microcosm or a pictoresque delineation of the arts, agriculture and manufactures of Great Britain … London 1806.

Horse-engine plough still used in Europe in 1940s

Horse drawn plough, northern France, likely 1940s. *G.W. Hales; Hutton Archives*

Harvesting by hand is tedious and slow

Wheat harvest, Hebei Province, China, 2007 *(source: www.powerhousemuseum.com)*

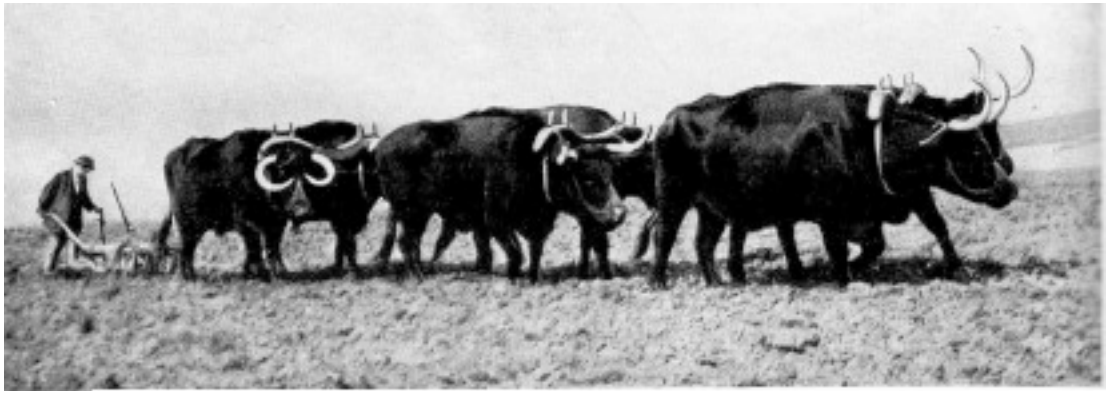
“Bio-engines” and some technology make harvesting much more efficient.

Horse drawn combine, likely 1910s-20s. *Source: FSK Agricultural Photographs*

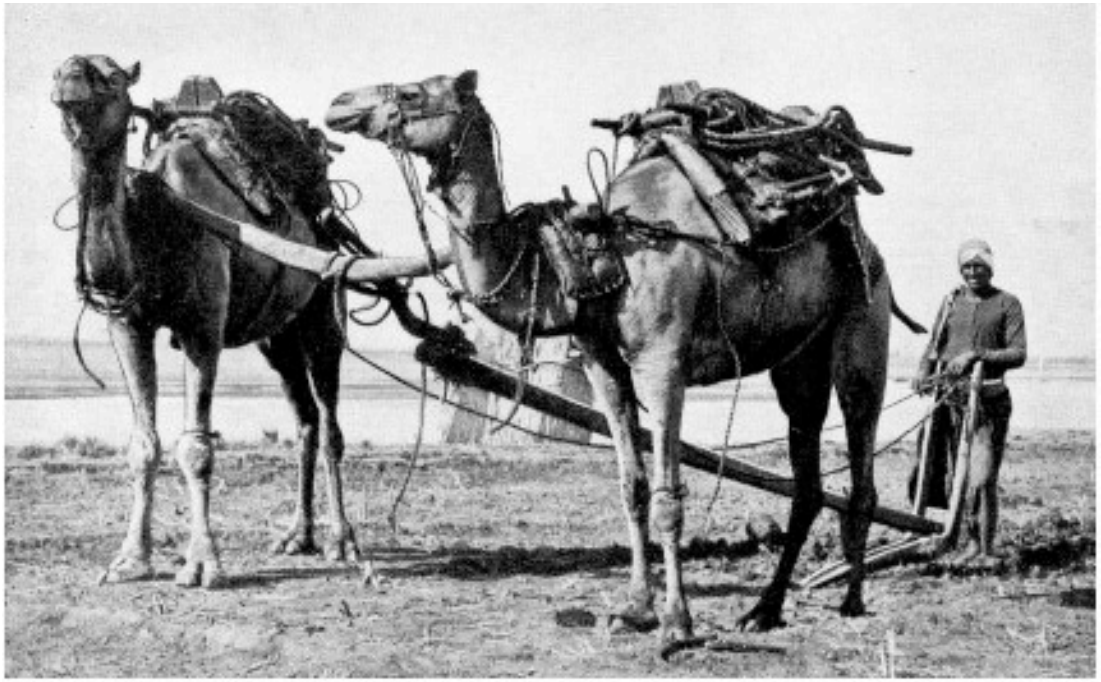
“Bio-engines” and some technology make harvesting much more efficient.

Horse-drawn combine, Almira, WA, 1911. *W.C. Alexander. Source: U. Wash. library*

“Bio-engines” must be suitable for location and task



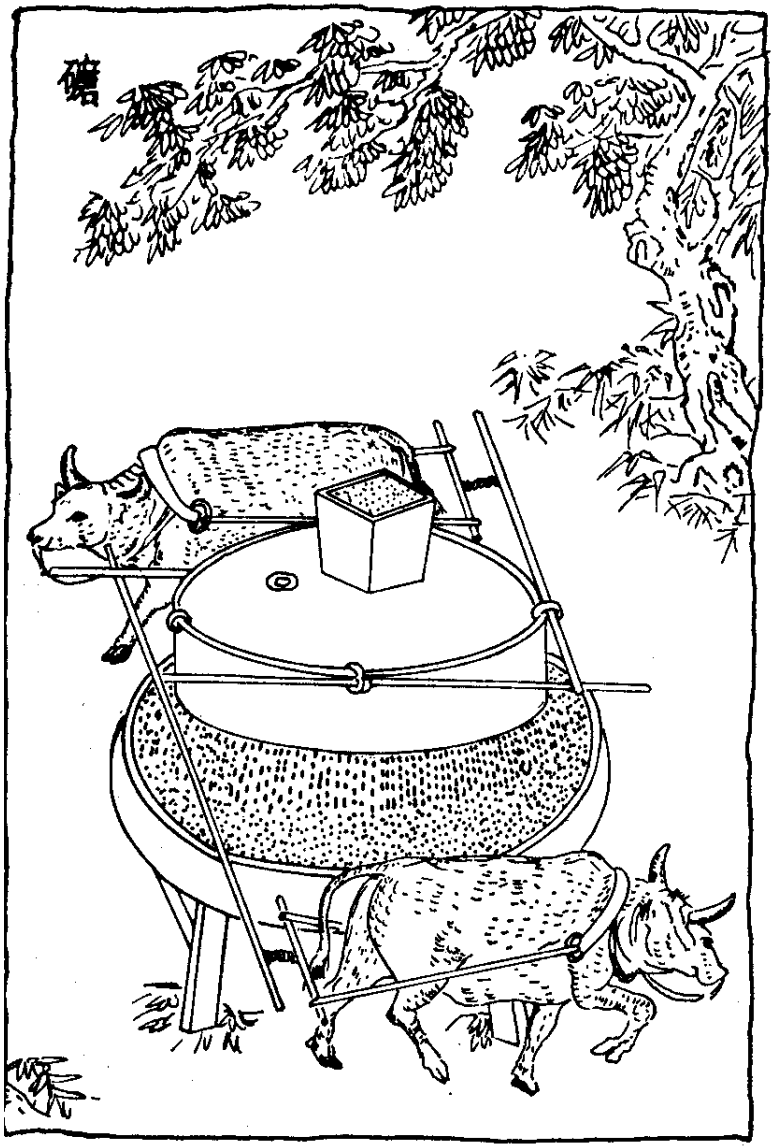
Ploughing with oxen, Sussex Downs, England, 1902. Oxen are preferred in heavy soil because they have more “pulling power” (what we’d now call “torque”)



Ploughing with camels, Egypt, early 1900s

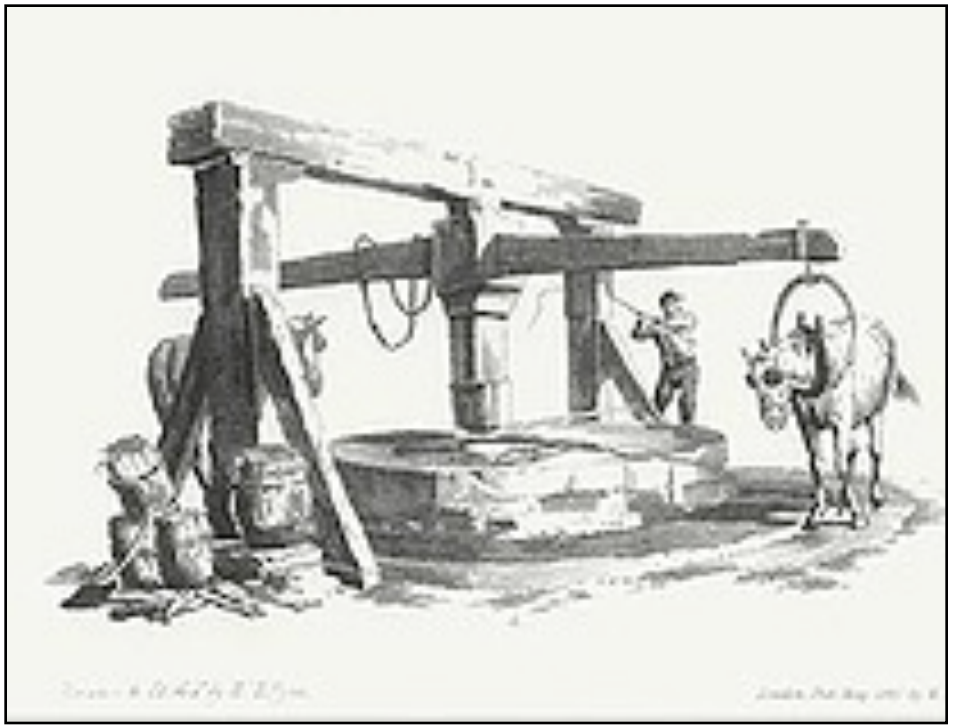
Both photos from “messybeast.com”, public domain

Rotation: animal powered wheels have a long history



Grindstone, China from the encyclopedia
“Tiangong Kaiwu”, by Song Yingxing (1637)

First use: grinding



Clay millers, W.H. Pyne, London (1806)

Human powered wheels persisted into the modern era

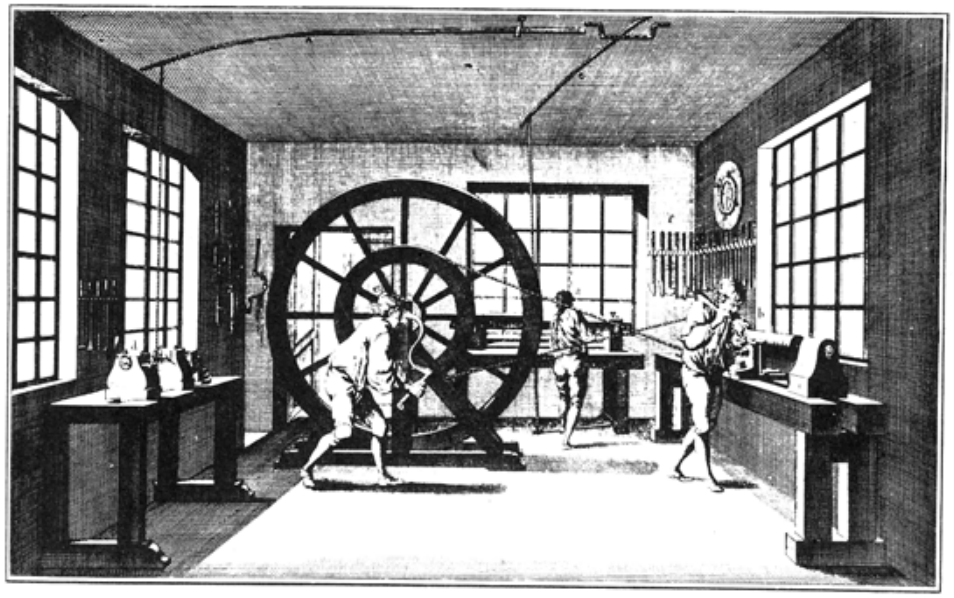


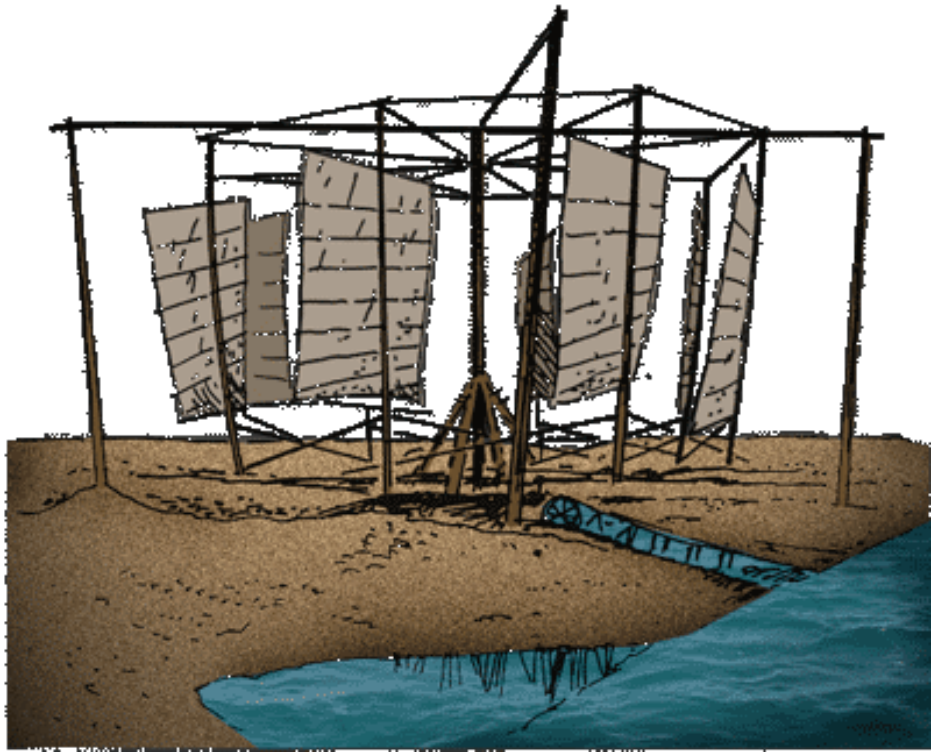
FIGURE 4.5 The great wheel powered by a crank in a mid-eighteenth-century French workshop to turn a metal-working lathe. The smaller wheel was used for working with larger diameters and vice versa. In the background of this picture a man works on a foot-powered lathe machining wood. *Source:* Reproduced from Diderot and D'Alembert (1769–1772).

Lathe, late 1700s

Japanese water pump, still used in 1950s

Rotational motion is a fundamental industrial need ….
Grinding is not the only use of rotational motion.

Other sources of rotational kinetic energy: wind and water



Vertical-axis Persian windmill,
7th century (634-644 AD) or later

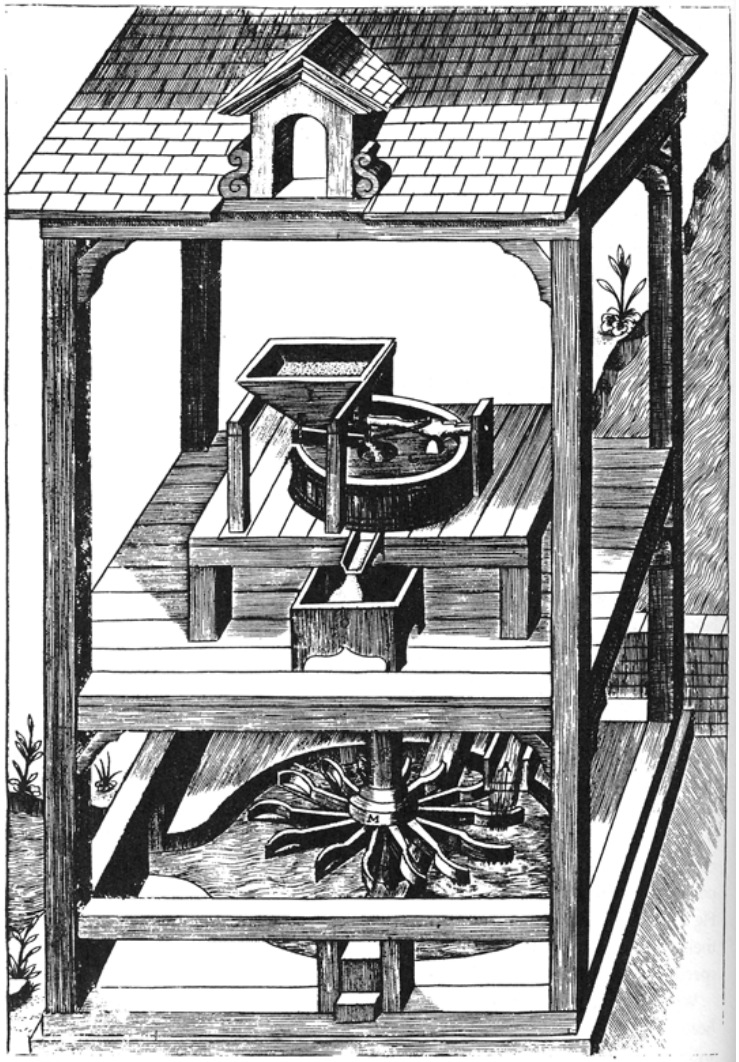
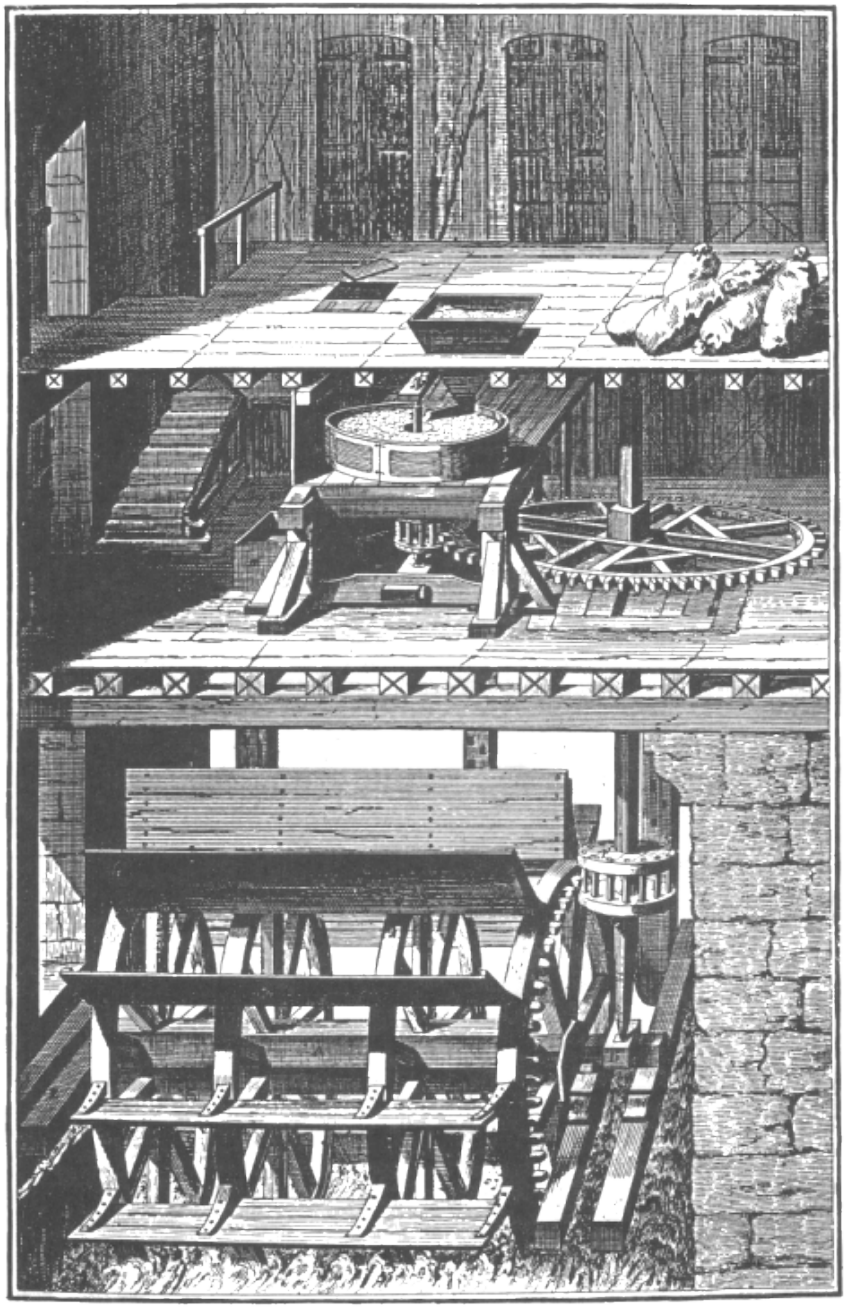


FIGURE 4.8 The horizontal waterwheel, also called a Greek or Norse wheel, was powered by the impact of running water and rotated the runner stone directly. *Source:* Reproduced from Ramelli (1588).

Vertical-axis waterwheel
1500s or earlier

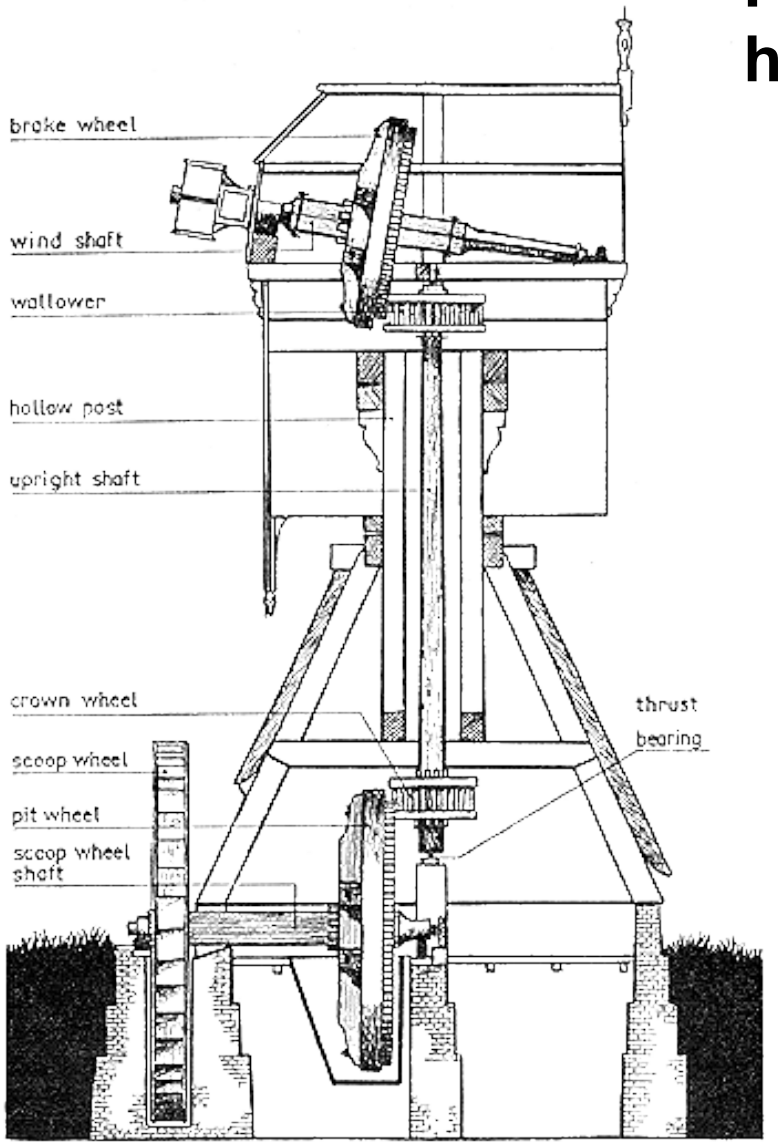
Very early a switch was made from vertical to horizontal axes

Pitstone windmill, believed to be the oldest in Britain.

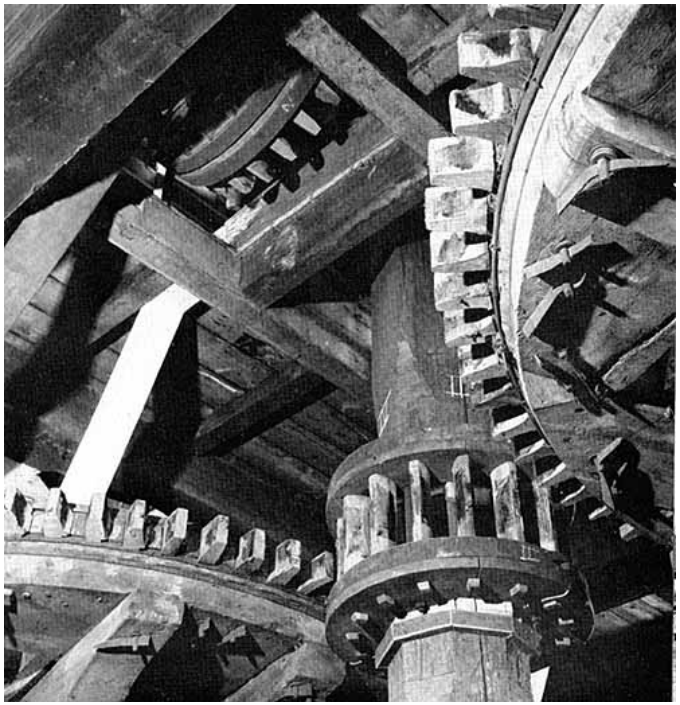


Horizontal-axis waterwheel

Pluses & minuses for horizontal axes



Post mill diagram, *from* ***The Dutch Windmill****, Frederick Stokhuyzen*

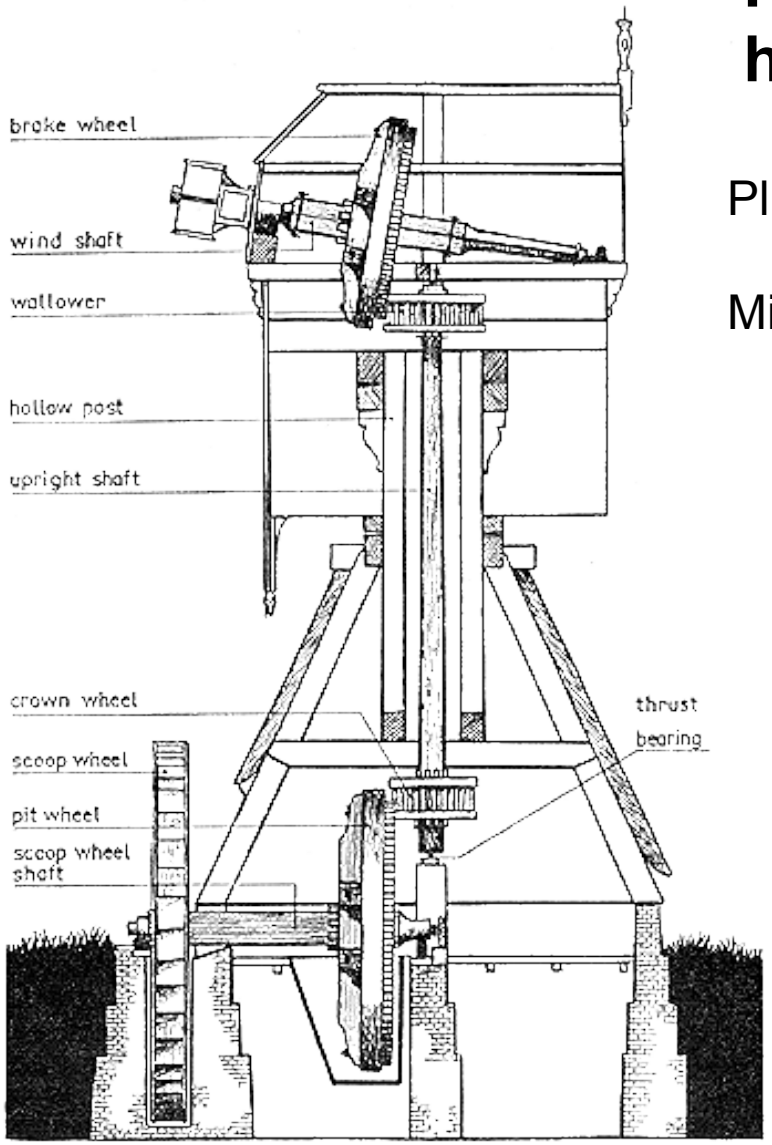


Industrial windmil cogs

Pluses & minuses for horizontal axes

Plus: * increased efficiency (both wind & water)

Minus: * complicated gearing to alter axes
* must rotate windmill to match wind dir.



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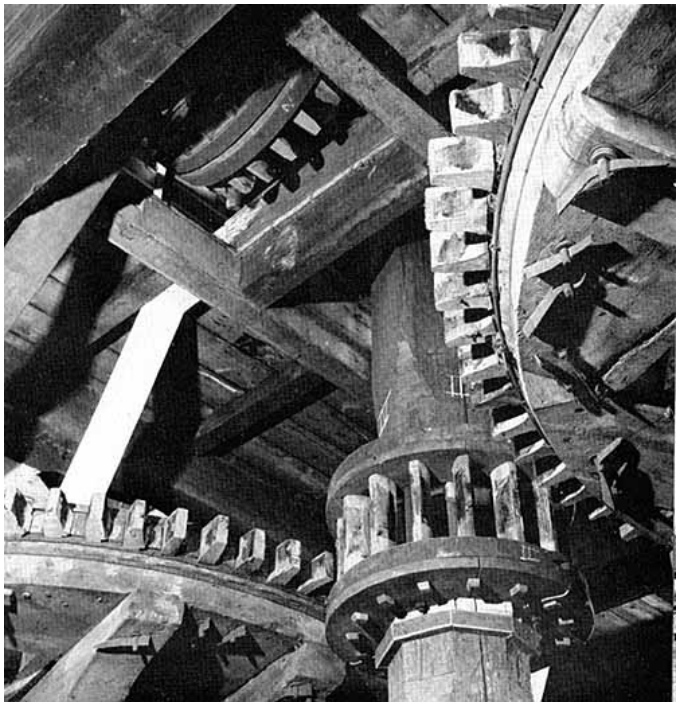


Industrial windmil cogs

What were the needs for mechanical work by mills?

anything besides grinding grain?

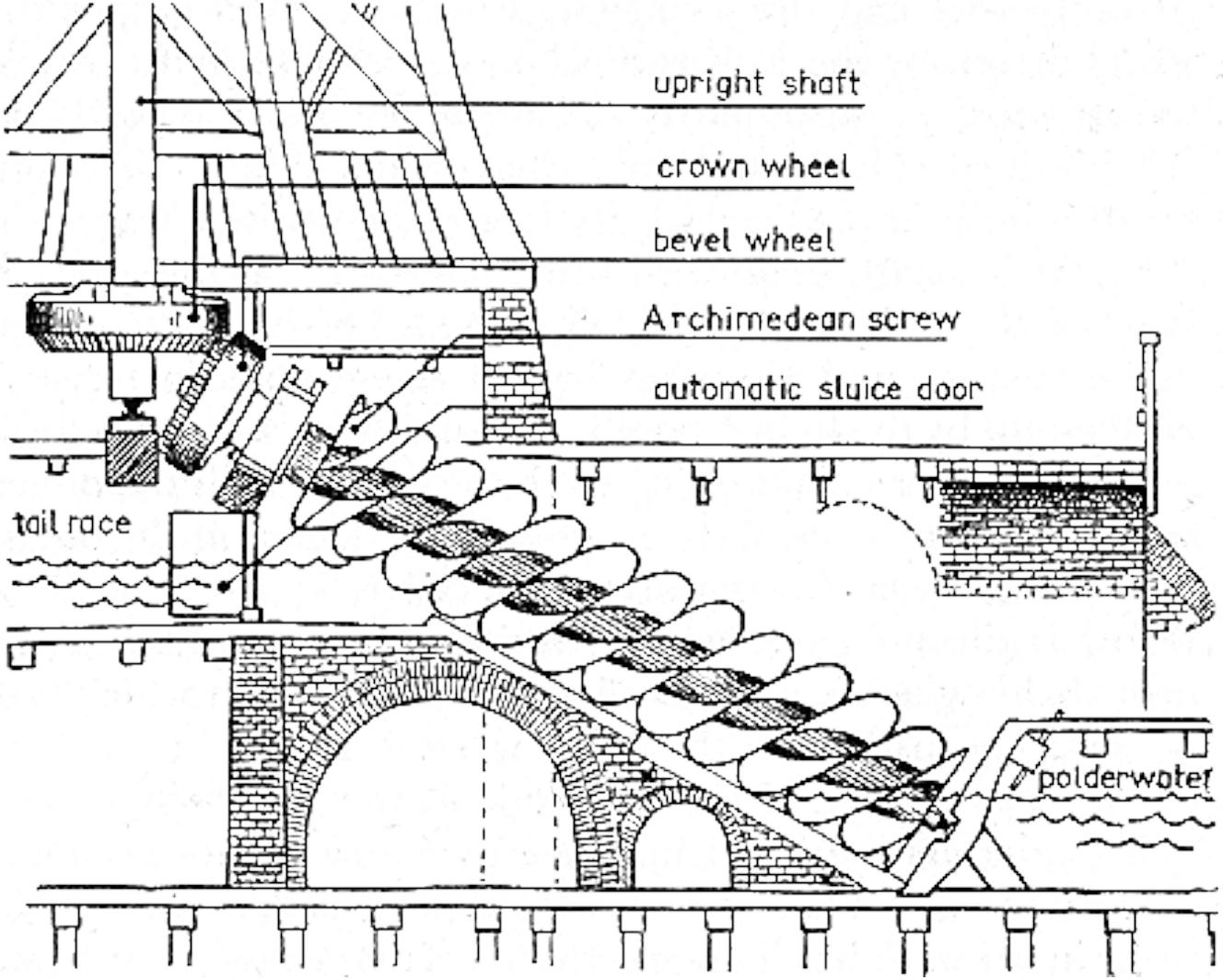
Why so many windmills along rivers?

.... to pump water from the fields

Source unknown

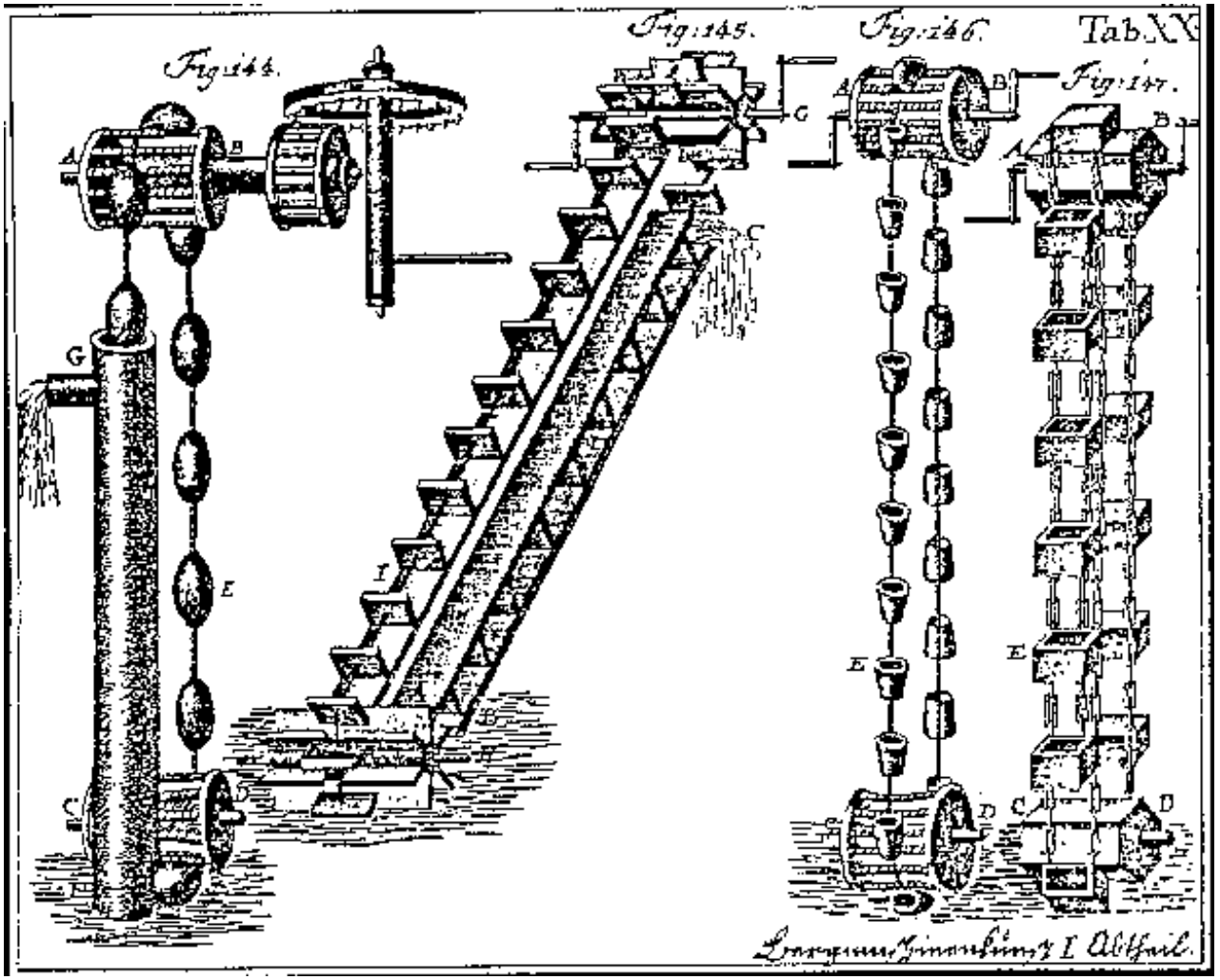
Luyken, 1694

Pumping can be done with rotational motion alone…



Dutch drainage mill using Archimedes' screw
*from **The Dutch Windmill**, Frederick Stokhuyzen*

Pumping can be done with rotational motion alone…



Bucket chain pumps are seen as early as 700 BC.

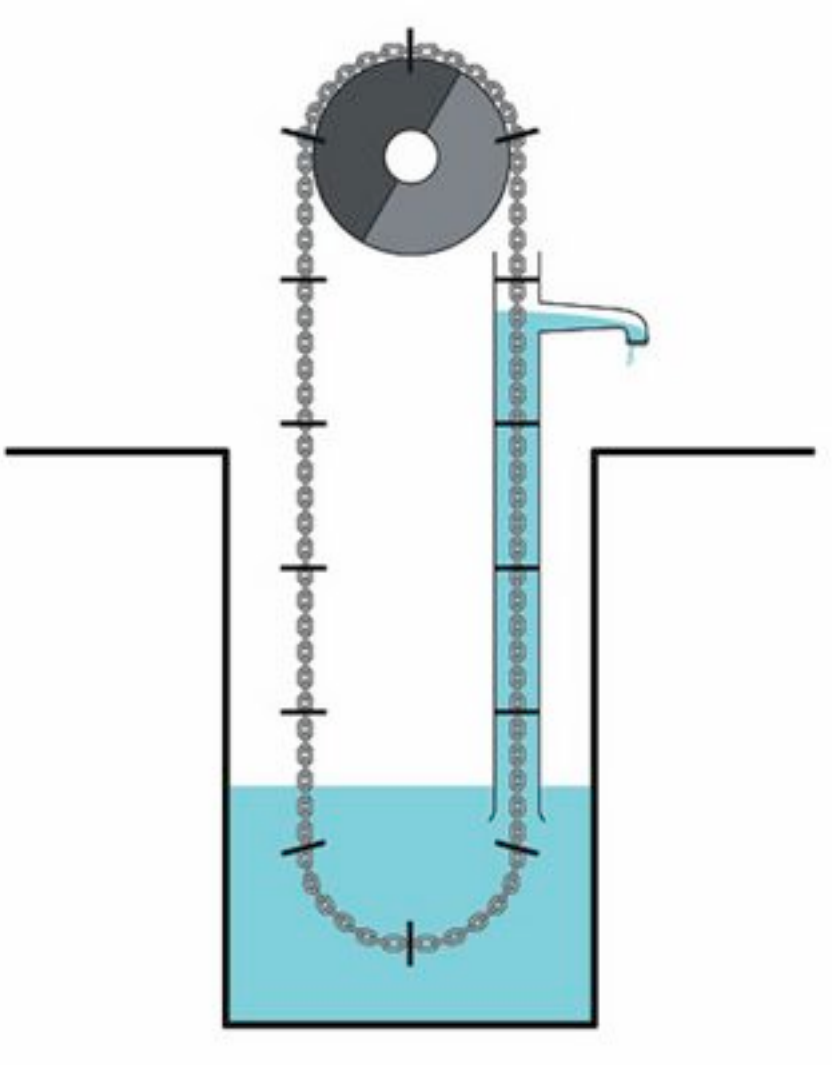
Common in ancient Egypt, Roman empire, China from 1st century AD, Medieval Muslim world, Renaissance Europe.

Chain pumps, including bucket chain pumps (R)

From Cancrinus, via Priester, Michael et al.

"Tools for Mining: Techniques and Processes for Small Scale Mining"

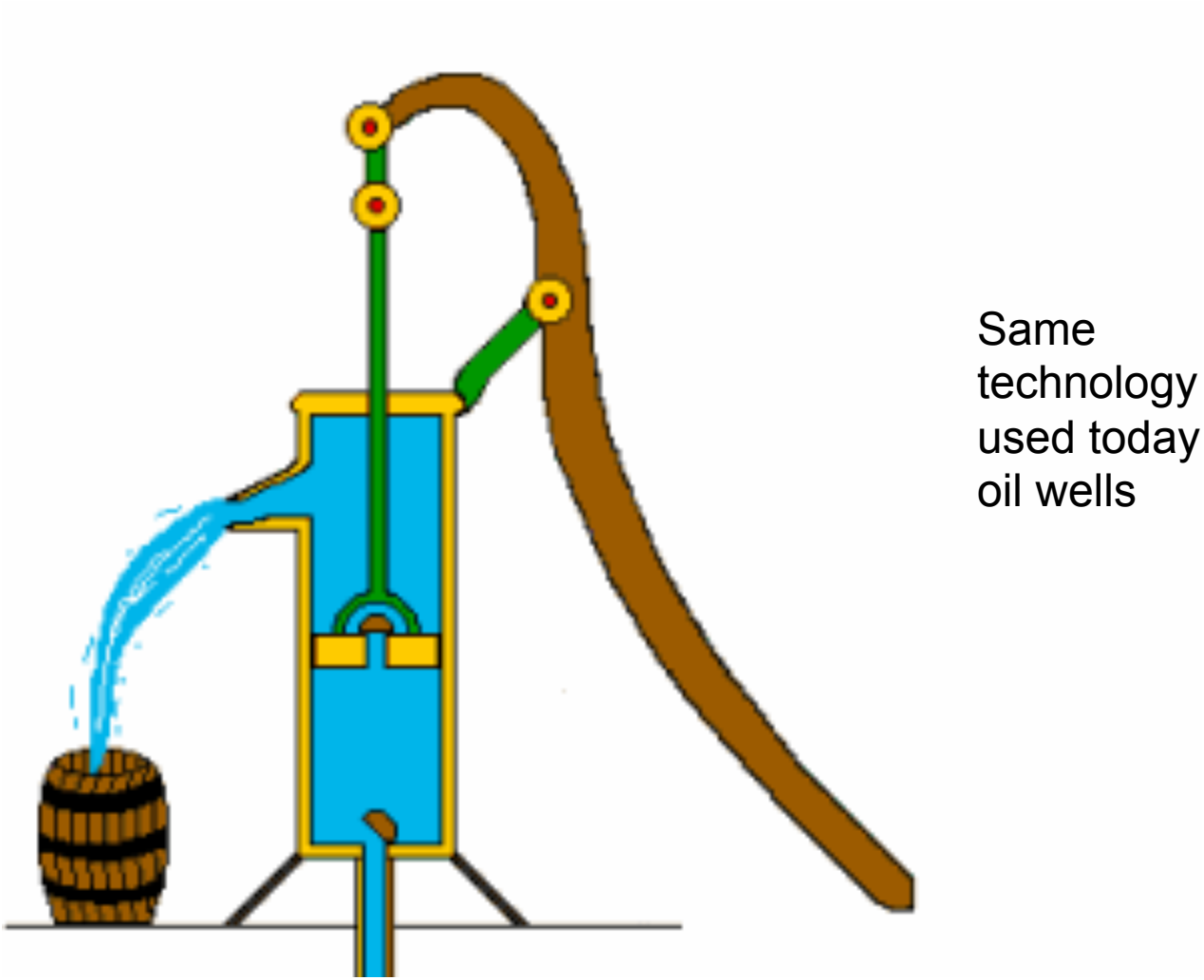
Chain pumps need not involve buckets



Chain pump cutaway

From Lehman's

…but linear motion allows more efficient pumping

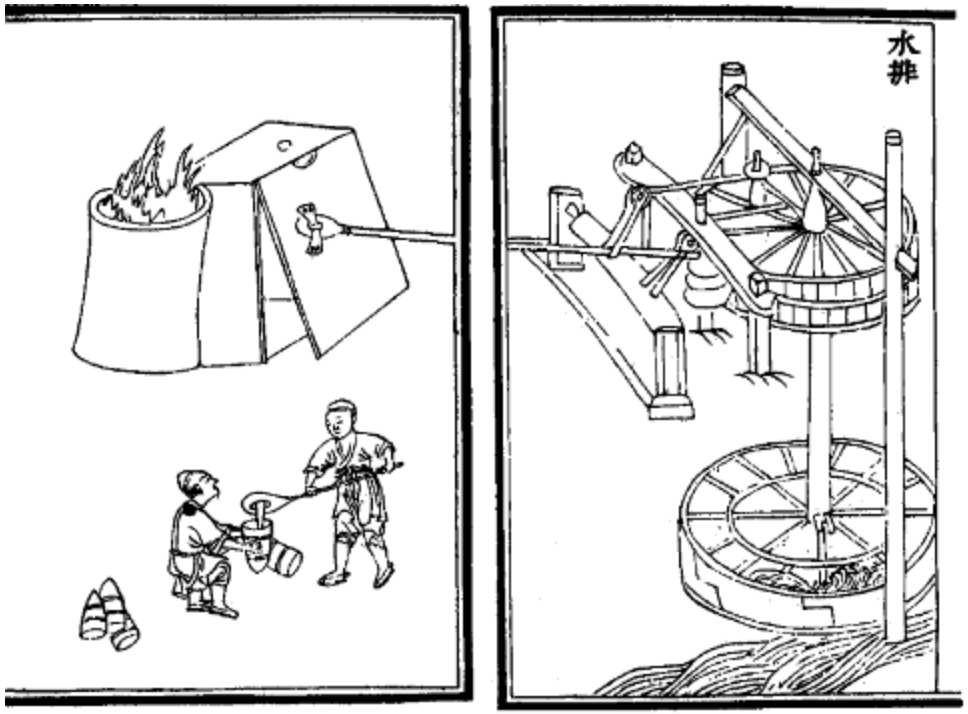


Same technology used today in oil wells

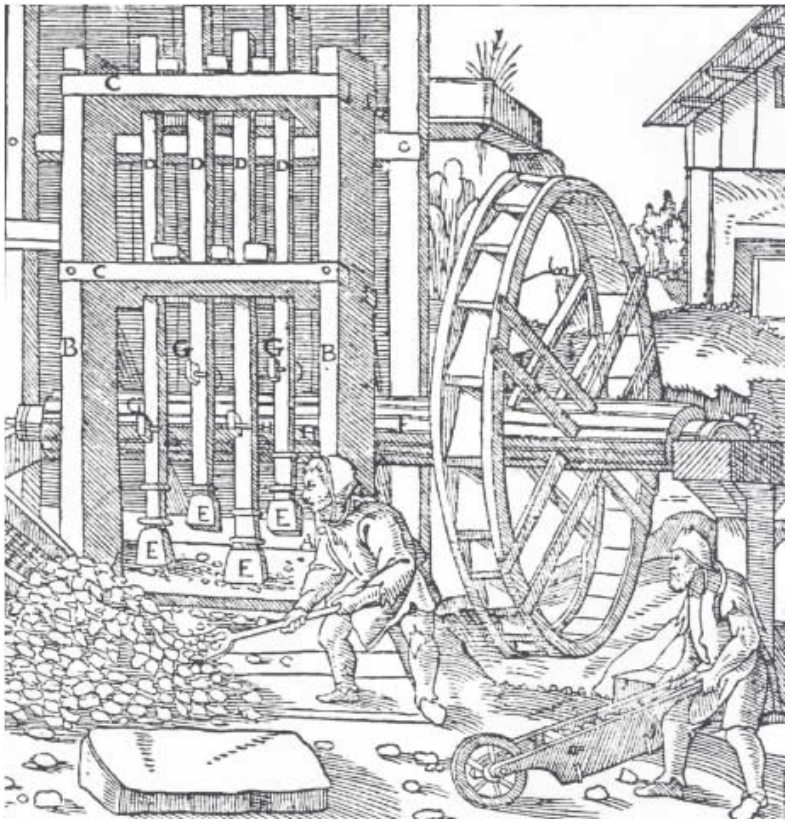
The lift pump

Animation from **Scuola Media di Calizzano**

Linear motions were needed very early in industrial history

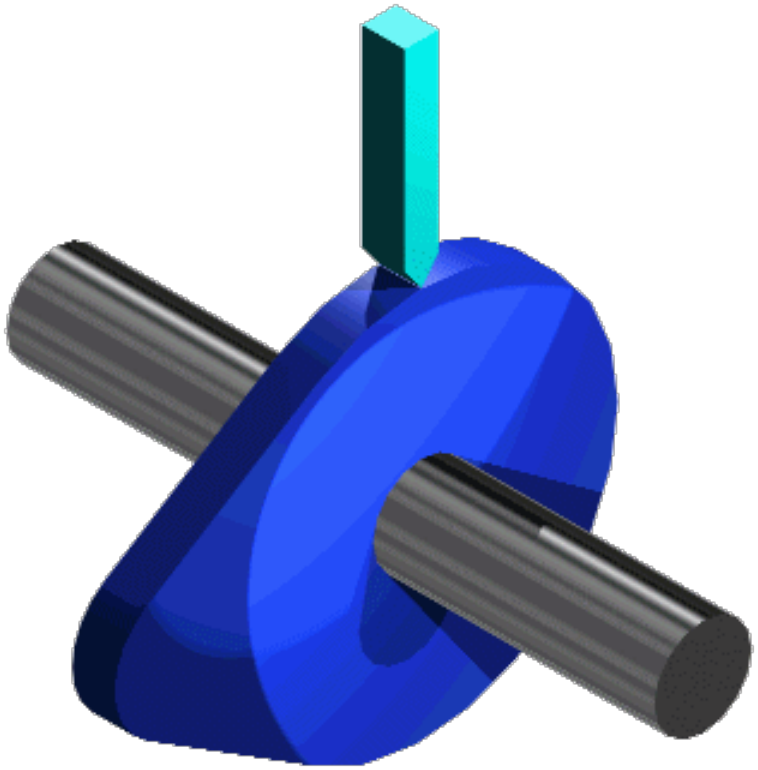


Chinese bellows, 1313 A.D.



European hammer mill w/ cam coupling, 1556 A.D.

The cam converts rotational to linear motion

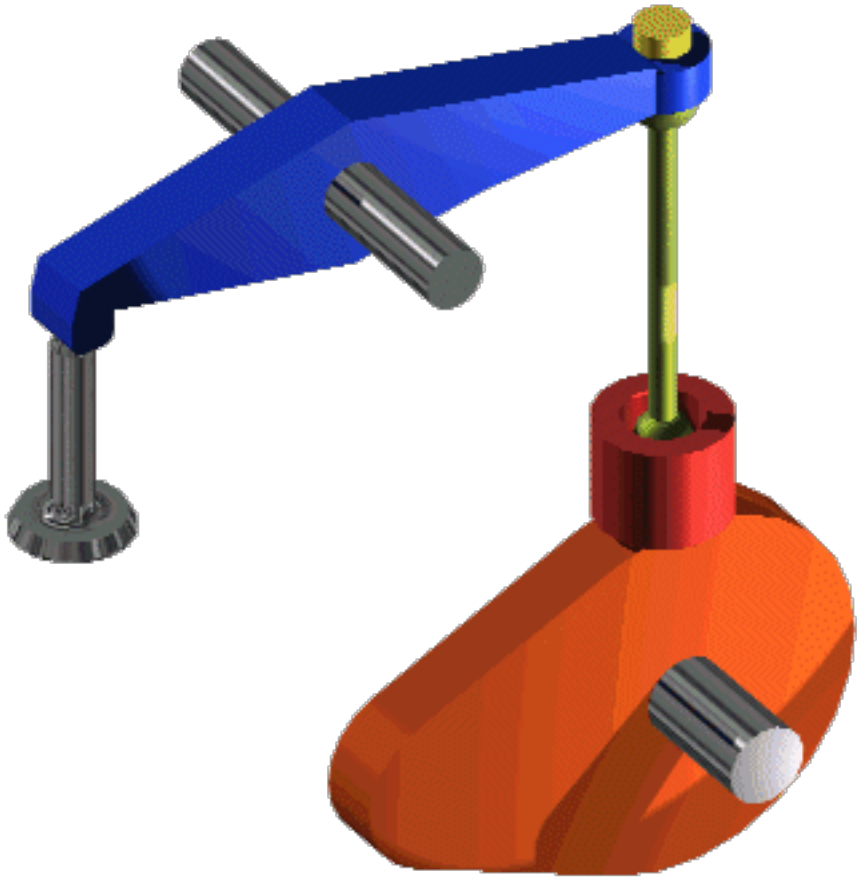


The noncircularity of the cam creates a push at only one part of the cycle

The knife-edge cam

Animation from **the University of Limerick**

The cam converts rotational to linear motion

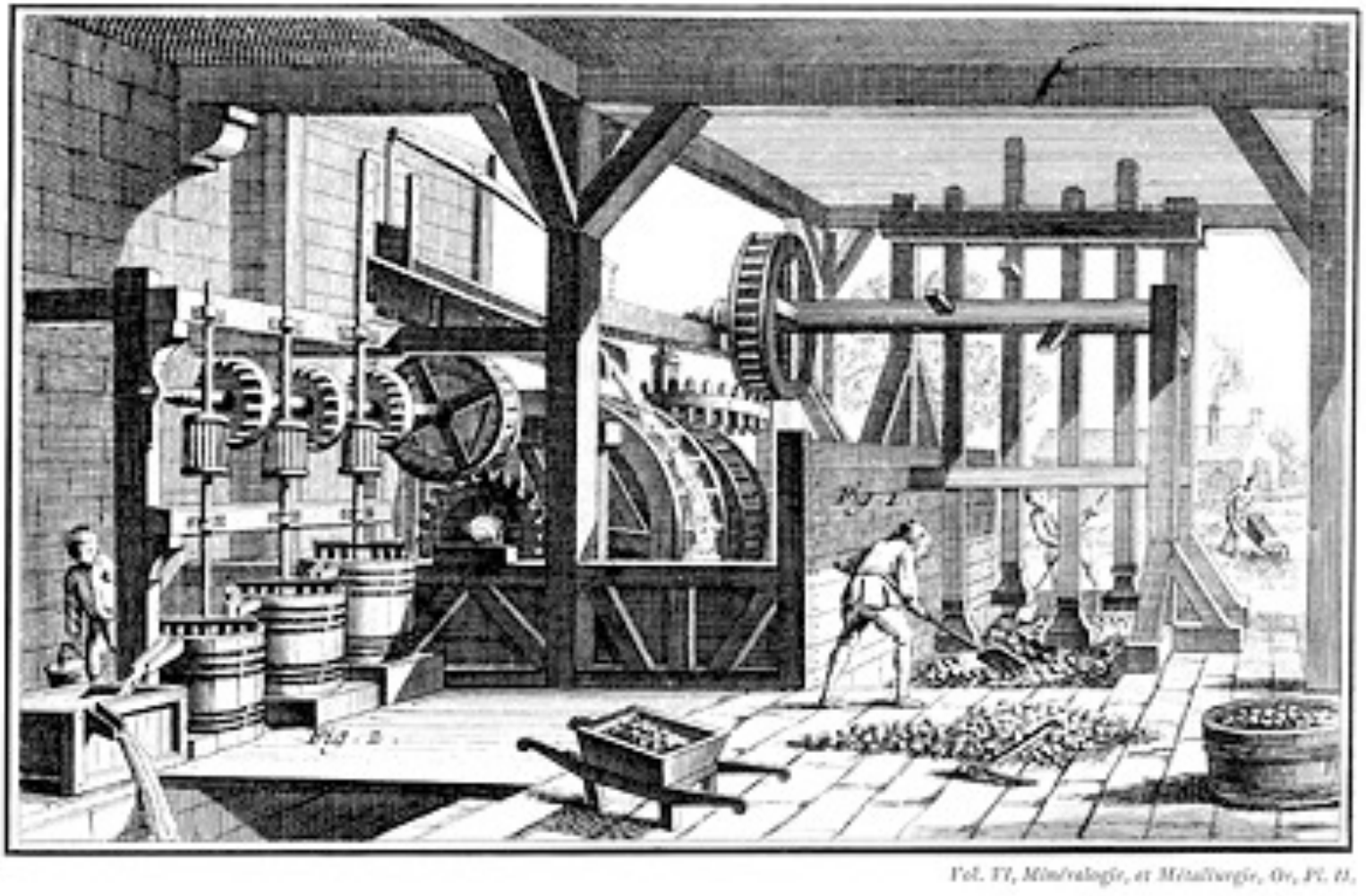


The noncircularity of the cam creates a push at only one part of the cycle

The rocker arm & camshaft

Animation from **the University of Limerick**

Gears and cams let one wheel drive multiple machines



Gold refining, France. *D. Diderot & J. Le Rond d`Alembert eds, Encyclopédie méthodique. Paris 1763-1777 & 1783-87.*

Machines powered by wind & water include:

Rotational

Linear (reciprocating)

Linear (non-reciprocating)

Machines powered by wind & water include:

Rotational

- Grindstones
- Pumps
- Winches
- Bucket lifts
- Spinning wheels
- Lathes, borers, drilling machines *(first use)*

Linear (reciprocating)

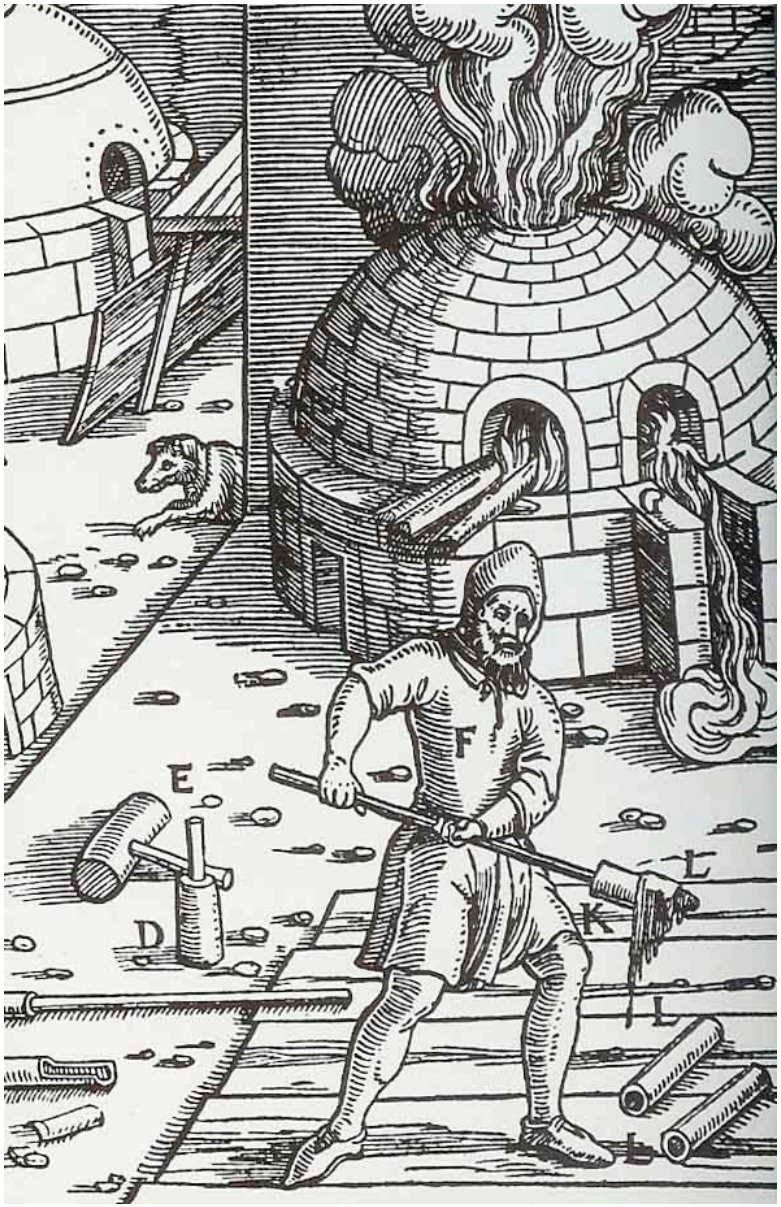
- Hammer-mills
- Beaters
- Bellows
- Saws
- Looms

Linear (non-reciprocating)

- Boats

Heating

Large-scale wood-burning to make heat for industrial use



Complex chemical transformations driven by heat were common in Medieval Europe.

Georg Acricola "De res metallica", Book XII (*"Manufacturing salt, soda, alum, vitriol, sulphur, bitumen, and glass"*), 1556.

Wood and coal fired technologies include

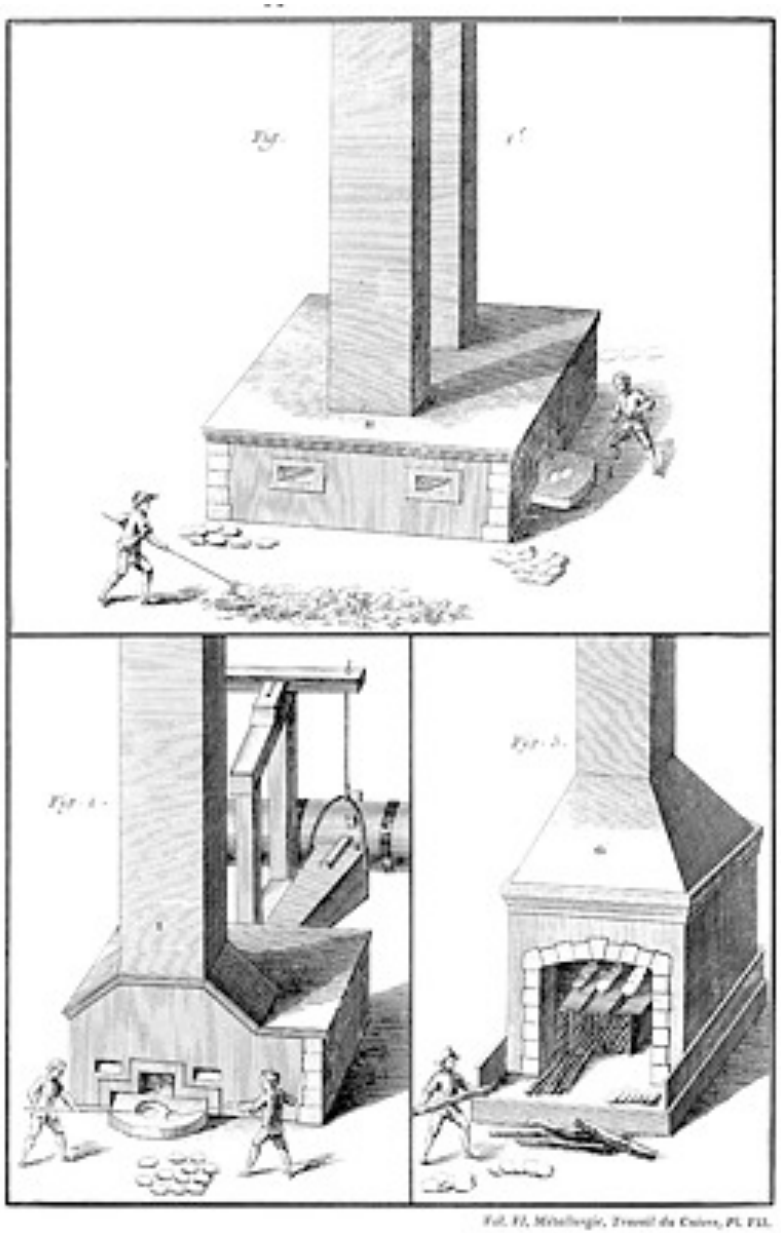
Fuel burnt for

Wood and coal fired technologies include

Fuel burnt for

- Heating
- Metallurgy
- Glass-making
- Brewing (drying the malt)
- Baking
- Brick-making
- Salt-making
- Tiles and ceramics
- Sugar refining

Heating: industrial furnaces grow larger and larger



Foundries are wood-fired in 1700s and much larger scale than 1500s

Copper foundry, France

D. Diderot & J. Le Rond d`Alembert eds, Encyclopédie méthodique. Paris 1763-1777 & 1783-87.

The energy crisis in Europe: lack of wood

1700s

"When the fuel situation became difficult in France in the eighteenth century, it was said that a single forge used as much wood as a town the size of Chalon-sur-Marne. Enraged villagers complained of the forges and foundries which devoured the trees of the forests, not even leaving enough for the bakers' ovens."

--- F. Braudel, *The Structures of Everyday Life, 1979.*

The energy crisis hit Britain first

1400s "Aeneas Sylvius (afterwards Pope Pius II), who visited Scotland… in the middle of the fifteenth century, mentions …that he saw the poor people who begged at churches going away quite pleased with stones given them for alms. 'This kind of stone … is burnt instead of wood, of which the country is destitute."

1600 "Within a few years after the commencement of the seventeenth century the change from wood fuel to coal, for domestic purposes, was general and complete."

--- R. Galloway, *A History of Coal Mining in Great Britain, 1882.*