The industrial revolution, the impact of heat engines on the U.S.
Industrial Revolution isn’t tied simply to heat engine evolution. Steam doesn’t overtake water power in British factories till ~1820s-30s. Why even then? Water power is cheaper AND wheels more powerful.

From V. Smil.
Mills had been mechanized & centralized since Medieval times

Grindstone, 1700s, U.S. from Hamilton, “The Village Mill in Early New England”

Yates gristmill, North Carolina U.S.
Larger wheels can provide power for mechanized factories

*Laxey water wheel, 72.5 ft dia.*

~ 200 hp (150 kW)

*Built 1854, for pumping mines*
Textiles were a home industry in the mid-1770s
*(only milling had been mechanized)*

but extremely repetitive motions are well suited to mechanization

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Jersey Spinning Wheel. *From: The Story of the Cotton Plant, Frederick Wilkinson, 1912, via Gutenberg.org*

Source: unknown
Spinning was mechanized first, happened quickly

Spinning jenny, 1764
James Hargreaves

power: human

“Water frame” 1769
John Kay, Richard Arkwright

power: horses, then water

Spinning mule, 1779
Samuel Crompton

Power: water
fully automated by 1830
Home weavers benefit from mechanization of spinning

from Radcliffe on weaving....

From the year 1770 to 1788 a complete change had gradually been effected in the spinning of yarns, - that of wool had disappeared altogether, and that of linen was also nearly gone, - cotton, cotton, cotton, was become the almost universal material for employment, the hand wheels, with the exception of one establishment were all thrown into lumber-rooms, the yarn was all spun on common jennies, the carding for all numbers...was done on carding engines.... In weaving no great alteration had taken place during these 18 years...

The next fifteen years, viz. from 1788 to 1803, which fifteen years I will call the golden age of this great trade, which has been ever since in a gradual decline.... new weavers' cottages with loom-shops rose up in every direction; all immediately filled, and when in full work the weekly circulation of money as the price of labour only rose to five times the amount ever before experienced in this sub-division, every family bringing home weekly 40, 60, 80, 100, or even 120 shillings per week! ! !

From William Radcliffe,
“Origin of the New System of Manufacture, Commonly Called Power Loom Weaving”, 1828
Weaving mechanization came next

Led to major social disruption…home weaving could no longer compete. Rural livelihoods were cut off, forcing migration.

Power loom, 1787
Edmund Cartwright

Power: water

by 1829 there are nearly 50,000 power looms in England

Power looms, 1844
Source: Getty Images
Cities grow rapidly as people move there

1696: 10% population urban / 1881: 70% urban

Cities become unhealthier as coal overtakes water power

Mechanization reduces labor needs, allows children to work

In 1785, the Rev. E. Cartwright invented a Loom to be worked by water or steam... A factory for Steam Looms was built in Manchester, in 1806. Soon afterwards two others were erected at Stockport, and about 1809, a fourth was completed in Westhoughton....

Before the invention of the Dressing Frame, one Weaver was required to each Steam Loom, at present a boy or girl, fourteen or fifteen years of age, can manage two Steam Looms, and with their help can weave three and a half times as much cloth as the best hand Weaver

*From Richard Guest, Compendious History of the Cotton Manufacture (Manchester 1823)*
Textile production in England changed social structure of labor.

Women and children left the home to work: women were cheap labor, small hands were valuable in operating machinery, and strength not required.

*Looms, England, early 1800s, source unknown*
Mechanization produces income disparity

from Radcliffe on weaving, 1828....

Although our family and some others in the neighbourhood during the latter half of the time, earned from three to four fold-wages to what the same families had heretofore done, yet, upon the whole, the district was not much benefited by the change; for what was gained by some families who had the advantage of machinery, might, in a great measure, be said to be lost to the others

....One of the formidable consequences of this change now began to make its appearance, the poor's rate, which previous to this change had only been known in a comparatively nominal way .. Relief to persons who could not get employment, or bastardy, were alike unknown on their books...

From William Radcliffe,  
“Origin of the New System of Manufacture, Commonly Called Power Loom Weaving”, 1828
The backlash against industrialization was strong

Ned Ludd breaks two knitting frames in 1779, becoming a folk hero

“Protection of Stocking Frames, etc. Act”, 1788
penalty: 7-14 years transportation to colonies

“Luddites” began organized acts of sabotage of industrial system, 1811-1812

“Frame-Breaking Act”, 1812
penalty: death

“Luddites” smashing a loom (“frame-breaking”), ca. 1812, source unknown
Much of mill labor was performed by children

Children were sent to the mills by their parents, perhaps caught in wage trap – child labor lowered wages, which meant children must labor...

Lewis Hine, children working in a textile factory in Cherryville
But soon **most** factory workers are children.

Source: "Report from Dr. James Mitchell to the Central Board of Commissioners, respecting the Returns made from the Factories, and the Results obtained from them." *British Parliamentary Papers*, 1834 (167) XIX. (from Burnette, Joyce, EH.net)
Note date: U.S. replicates British history 50-100 years later

Lewis Hine, 1912, Addie Card, 12 years, Spinner in N. Pownal Spinning Mill

Lewis Hine, 1911, Breaker boys working in Ewen Breaker of Pennsylvania Coal Co.
Labor conditions prompts the first child labor laws in U.K.

- **1802:** Health and Morals of Apprentices Act orders ventilation and cleanliness
- **1815:** Robert Owen suggests children under age 10 should not work in factories
- **1819:** Cotton Mills and Factories Act forbids employing children under 9, those 9-16 years old can work only 69 hour weeks: 12 hours/day + 9 hours on Saturday
- **1831:** Labor in Cotton Mills Act: limit to 12 hours/day extends to age 18, no night work for anyone under 21
- **1832:** Labor of Children... in Factories Act 1832 (Sadler’s Bill) extends protection to all textile factories, not just cotton. Limit reduced to 10 hours/day.
- ....this prompts backlash by employers, further legislation stalls for about a decade.
- **Only in late 1800s are protections extended to children in non-textile industries**

The “Ten Hour Movement” – should children work more than 10 hours/day?
In U.S., nearly a century behind...

- **1811**: Francis Cabot Lowell commits industrial espionage in Britain, steals plans
- **1814**: Lowell builds first U.S. textile mills in Massachusetts, hires local girls
  
  *By 1840s, striking workers are fired, hire immigrants, conditions worsen.*
- **1842**: first state labor law (Massachusetts children under 12 can’t work > 10 hrs)
  
  *by 1899, 28 states have some kind of child labor laws, 17 have none*

- **1900**: 18% of children between ages 10-15 are working
- **1908**: Lewis Hine becomes photographer for National Child Labor Committee
- **1924**: failed attempt to pass constitutional amendment banning child labor
- **1938**: Fair Labor Standards Act, 1st federal limits on child labor in some industries
  
  *max 12 hour days for all, children under 16 can’t work during school hours*
- **1944**: U.S. Supreme Court rules that government can regulate child labor
Several things to consider

1) What does mill layout tell you about the economics of industrial production?

2) What trends in political and economic thought conditions occurred in mid-1800s Britain?

3) Why are these two things related?
Several things to consider

1) What does mill layout tell you about the economics of industrial production?

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3) Why are these two things related?
1800s: Mechanization comes to other industries

German machine shop driven by single steam engine

(© Bildarchiv Preußischer Kulturbesitz)
1800s: Mechanization comes to other industries

Machine shop, likely late 1800s  
(source unknown)
Spinning mills retain same layout, get larger

Spinning mill

(Photo: Lewis Hine, lik. 1911)
Belts transport rotational motion over long distances.

Restored textile mill at Lowell, MA.
*Photo Paul Marotta / Getty Images*

Bill Mill No. 1 in Macon, GA, 1909
*Photo Lewis Hine*
Belt and chain drives in modern life
Belt and chain drives in modern life
Belt and chain drives in modern life
Belt and chain drives in modern life
What does this mean for economic organization in the 1800s?

• No hand-worker could compete with mechanization and use of industrial power. All production in factories.

• Because kinetic energy can’t be carried over long distances, every factory had to have its own power source

• *Therefore*: to be a producer you had to own your own power plant

• *Therefore*: capital required to start a business was extremely high. High labor productivity only possible with big capital investment.
Several things to consider

1) What does mill layout tell you about the economics of industrial production?

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3) Why are these two things related?
Writing about the working class in Britain

   written after 2-year stay in Manchester
Evolves to general theories of the working class

   written after 2-year stay in Manchester

2) Marx & Engels, “The Communist Manifesto”, 1848
   written jointly, Engels is in Manchester, Marx in Brussels
Marx and Engels in Britain

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   written jointly, Engels is in Manchester, Marx in Brussels

1850, Marx moves to London
   supported by Engels, visits Manchester
   writes for New York Daily Tribune

The former Red Dragon pub in Manchester where Marx and Engels hung out
Marx and Engels in Britain

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3) Marx, “Capital”, 1872-1894
   written in London
The two technological leaps of the Industrial Revolution that bring in the modern energy era \( (100 \text{ years separate}) \)

1. **“Heat to Work”**
   Chemical energy $\rightarrow$ mechanical work via mechanical device
   Use a temperature gradient to drive motion
   Allows use of stored energy in fossil fuels
   Allows expansion of industrial production, factories in cities
   **Late 1700’s**: commercial adoption of steam engine

2. **Efficient transport of energy: electrification**
   Mechanical work $\rightarrow$ electrical energy $\rightarrow$ mech. work
   Allows central generation of power
   **Late 1800’s**: rise of electrical companies
A generator and a motor provide a way to move kinetic energy from one location to another.

**Kinetic ------(generator)----------> Electrical -------(motor)----------> Kinetic**

Westinghouse generators, 1888

Tesla induction motor, 1888
Can electric motors reduce the terrible capital requirements of the 19th century?

Pre-electrification – must own power plant, all workers in one place. Power = power

Post-electrification – dispersed work possible, and workers now own the means of production (if utilities are public).

Main use of electricity is take rotational motion in one place and “move” it somewhere else
In U.S., electricity quickly (~50 years) becomes dominant means of delivering kinetic energy for factories and motors.

In U.S., steam doesn’t surpass water till 1870s

Steam peaks ~1900

Surpassed by electricity ~1920

Sources of Power for Mechanical Drives in the United States.


For most of 1800s, U.S. had little industry and abundant water-power

revolutionary impact of heat engines in U.S. history comes via transportation instead
Steam is important in 1810 North America

Boats before trains
First U.S. trial of steam boat 1787, Philadelphia (Fitch), patent 1791
Fulton begins submarine 1793 (in France)
Fulton’s first steamboat in U.S. 1807, traveled NYC → Albany
First steam boat on Mississippi 1811
Steam boats dominate rivers by 1830s
1830’s: U.S. transportation is by waterway

Rivers and canals dominate transportation

*Erie Canal (1825) connects Great Lakes to Hudson River*

*By 1830s, U.S. has complete water route from New York City to New Orleans*

.. and U.S. is world’s largest cotton producer
1830 map of railways in U.S.

Rivers and canals dominate transportation

Erie Canal (1825) connects Great Lakes to Hudson River

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.. and U.S. is world’s largest cotton producer
Rivers and canals dominate transportation
Railroads help get crops to water, steamboats are still key

Steamboats in popular imagination: Mark Twain’s “Tom Sawyer”, “Huckleberry Finn” set in 1840s
1840 map of railways in U.S.

California is Mexican territory, ~ 1 year by sail rt to New York, main industry cattle hides. Total population about 8,000 non-Indian, San Francisco < 200 people.
1850 map of railways in U.S.

1840-1850 states: add Texas + Florida, Iowa, Wisconsin. California still Mexican til 1846
1846: U.S. and Mexico go to war
CA declares independence from Mexico

1848: U.S. formally annexes Alta California, Santa Fe
< 3000 emigrants to CA + UT

1849: Gold discovered at Sutter’s Mill
> 26,000 emigrants to CA + UT

1850: > 50,000 emigrants to CA + UT
CA population risen to 120,000

Statistics from Hill, “The Oregon Trail, Yesterday and Today”
1850s: “frontier” actually middle of country: states in West and East, territories in between
1850 map of railways in U.S.

1850s: beginning of “Pioneer era”: walk 4-6 months
1860—This map shows the extent of railway development just prior to the Civil War. The decade 1850-1860 was a period of rapid railway expansion, characterized by the extension of many short, disjointed lines into important rail routes. This decade marked the beginning of railway development in the region about the Mississippi River. By 1860, the "Iron Horse" had penetrated westward to the Missouri River and was beginning to feel in Iowa, Arkansas, Texas, and California.

1860-61: Pony Express carries mail from St. Joseph MO to Sacramento CA, 7 days
1860 map of railways in U.S.

1860s: “cowboy era” of cattle drives begins: first meatpacking plant in Chicago, 1865
1870 — Although the War Between the States temporarily halted railway development, many projects were resumed or initiated soon after the close of that conflict. The nation’s network increased from 30,626 miles in 1860 to 52,922 miles in 1870. An outstanding development of the decade was the construction of the first railroad to the Pacific Ocean, making it possible for the first time to travel all the way across the country by rail. Railway development in the Mississippi and Missouri valleys was especially notable during this period.

1870s: cattle drives to Abilene & Dodge City KS, barbed wire introduced, range wars begin
1880 map of railways in U.S.

1880s: cowboy era is ending, first meatpacking plants W. of Chicago
1890—The period from 1880 to 1890 was one of rapid expansion. More than 70,300 miles of new lines were opened in that decade, bringing the total network up to 163,597 miles. By 1890, several trunk line railroads extended to the Pacific. In thirty years from 1860 to 1890, the total mileage of the region west of the Mississippi River increased from 2,175 to 72,383, and the population of that area increased fourfold.

1890: frontier is declared closed