



# EFFICIENCY, EMPIRE, AND ENERGY

CONTROLLING CHAOS IN A CLOCKWORK COSMOS

1700 - 1900

# What is “energy”?



Efficiency  
Empire  
Energy  
Control

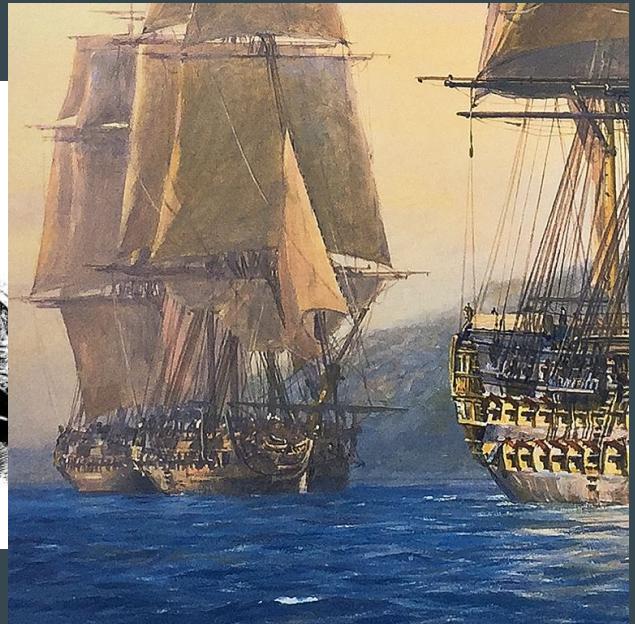
# EFFICIENCY



## First Industrial Revolution

- Began in England at the beginning of the 18th century (c. 1700).
- The English government wants more and better weapons.



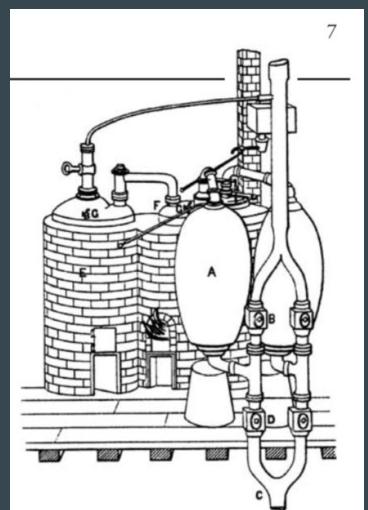
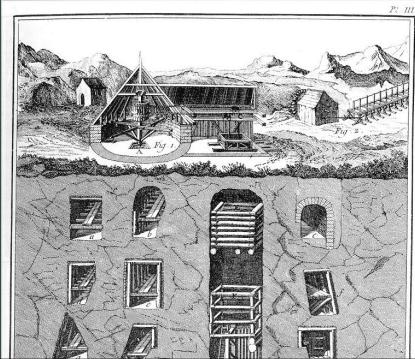


incomart indev



## Thomas Savery's Pump (c. 1700)

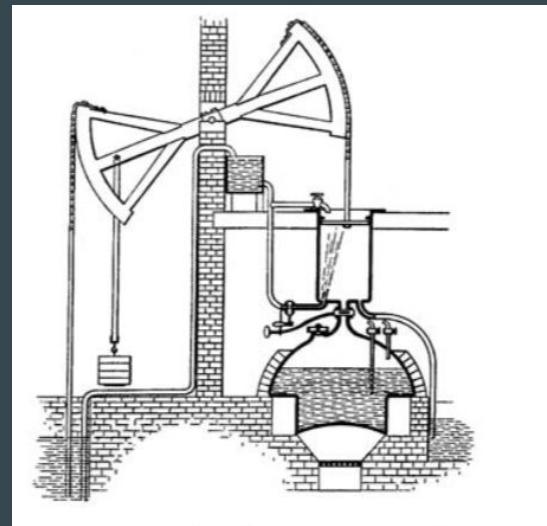
- The water table limits how much ore can be extracted from a mine.
- English mining speculator Thomas Savery invents a pump that uses a boiler to create a pressure differential and remove water from the shaft.



■ J. A. Ewing, *The Steam-Engine and Other Heat-Engines* (Cambridge: Cambridge University Press, 1894), p. 6.

## Thomas Newcomen's Engine (c. 1710)

- Boils water separately from the vacuum chamber--same suction but much safer.

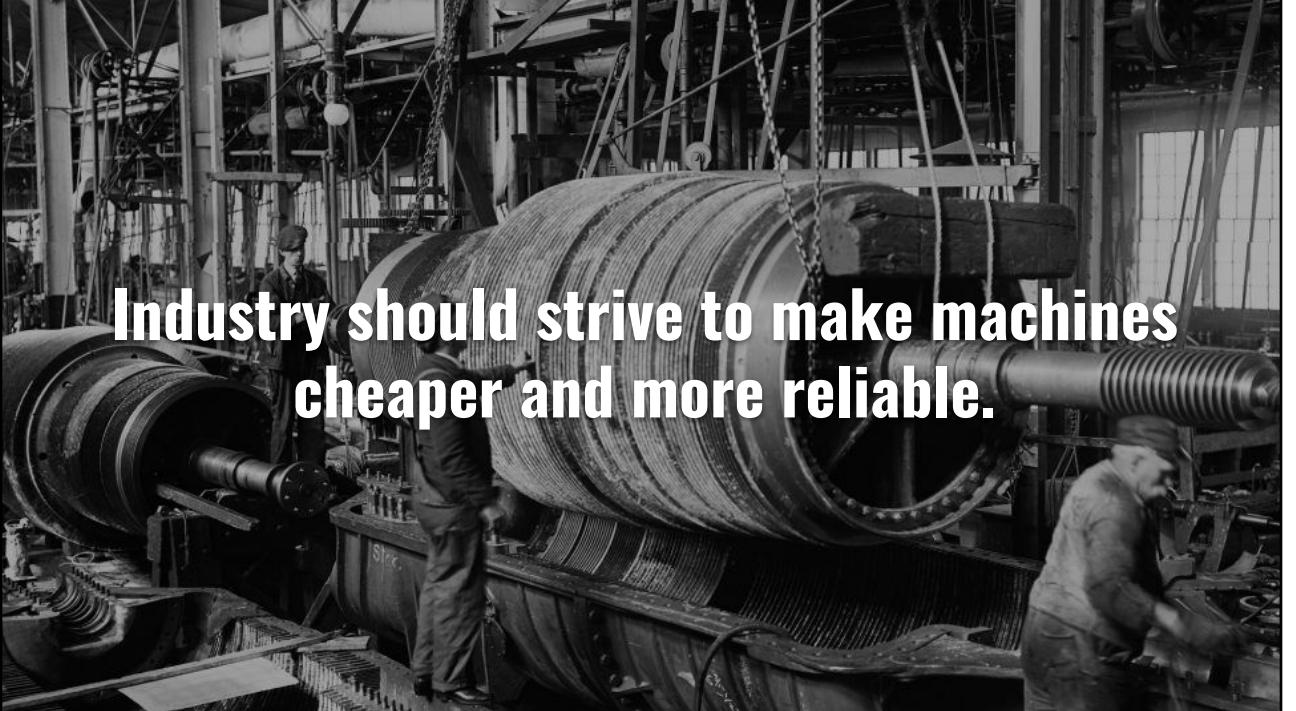


# But!

Both are expensive and dangerous.

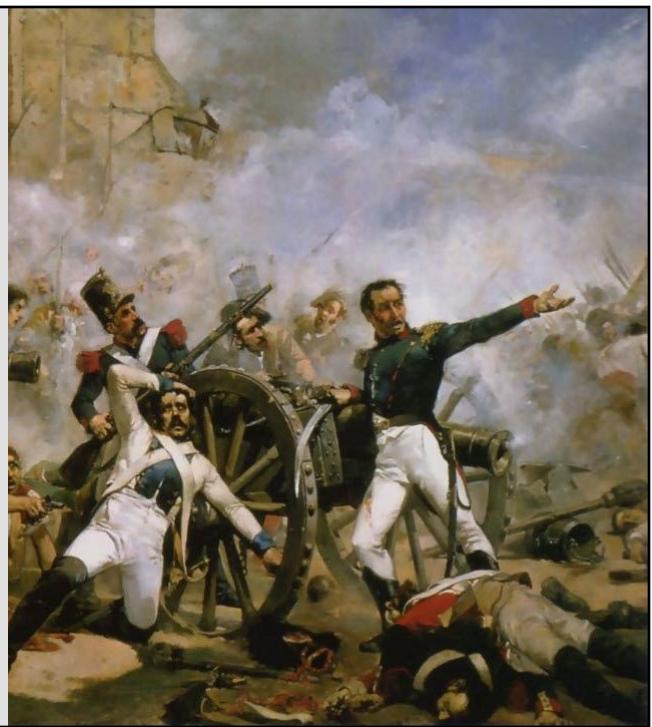
Neither works for a mineshaft deeper than ~20 feet.

Neither is a particularly sound investment.

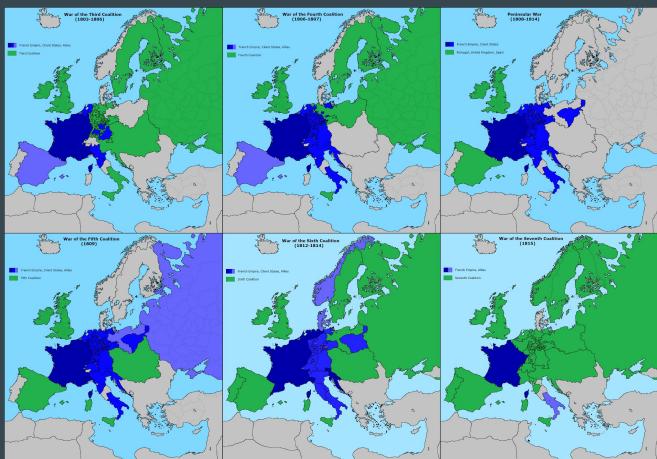


**Industry should strive to make machines  
cheaper and more reliable.**

# EMPIRE



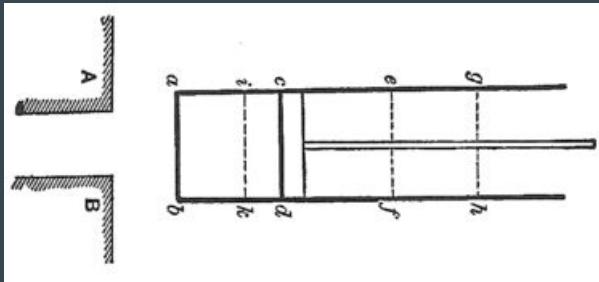
# French Revolutionary & Napoleonic Wars (1789-1815)

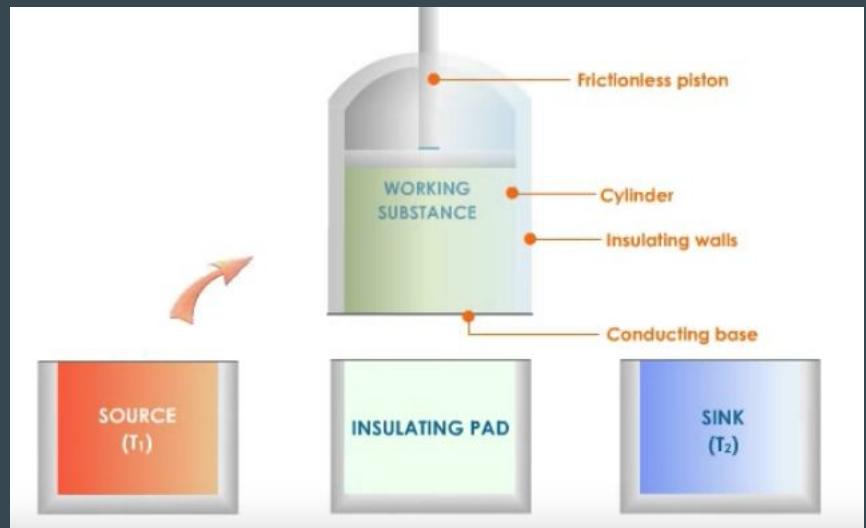


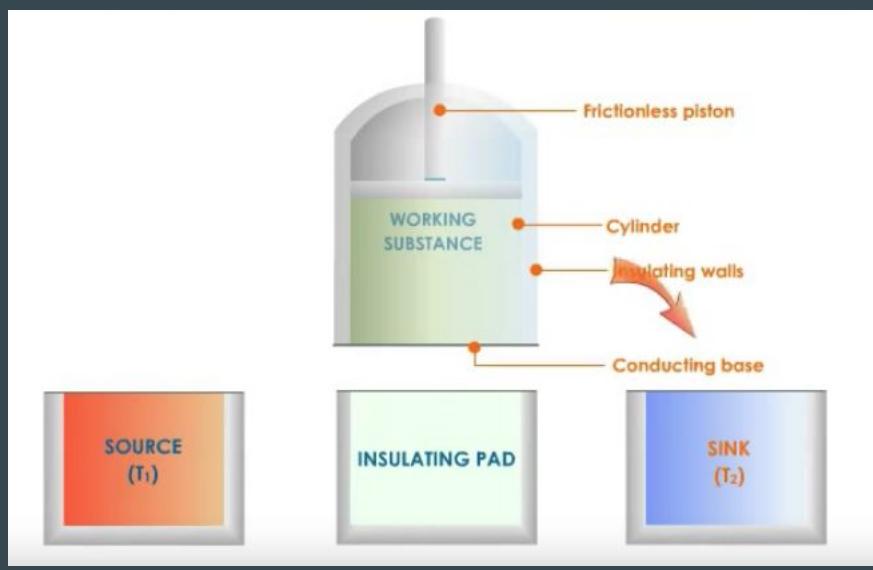
- The newly-formed French Republic against various European coalitions, usually headed by the newly-United Kingdom.
- One of the first “modern” wars:
  - “Total” in scale, involving every level of society.
  - Global in scope, reaching all over the planet.
- French military prowess: Napoleonic Valor, the Citizen’s Army.
- British conservatism: a traditional, professional army.
- The U.K. is victorious. **Why?**

## Sadi Carnot (c. 1820s)

- Military engineer educated in France in the aftermath of the Napoleonic Wars.
- Studies steam engines in the abstract: how to maximize their value and minimize their danger and expense?





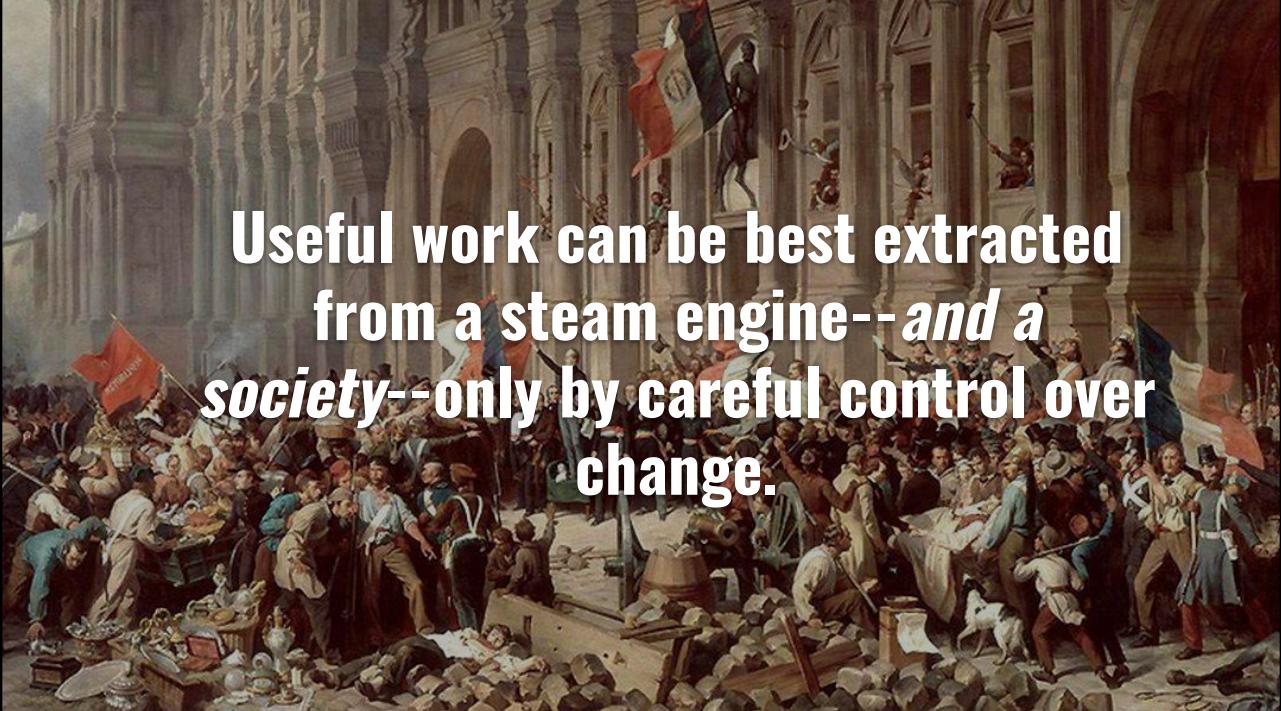


1. Energy cannot be created or destroyed, only transformed.
2. Entropy always increases in a closed system.
3. A closed system, no matter how perfect, will always have some residual entropy.

## Empire and Thermodynamics

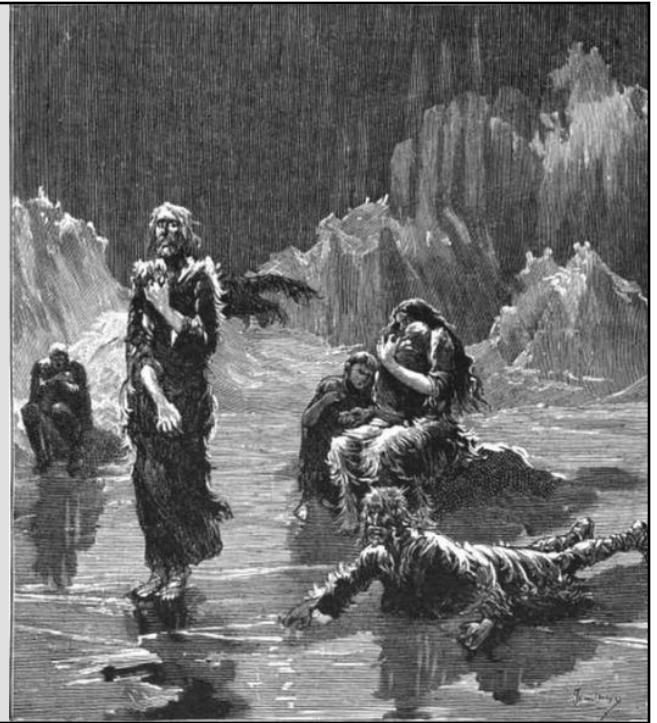


- Carnot associates British victory with *industry*. The victor of a modern war will be the one who produces the most and best machinery.
- Likewise, the best engine will be the one most closely associated with the traditionalist, conservative, British model.



**Useful work can be best extracted  
from a steam engine--*and a  
society*--only by careful control over  
change.**

# ENERGY

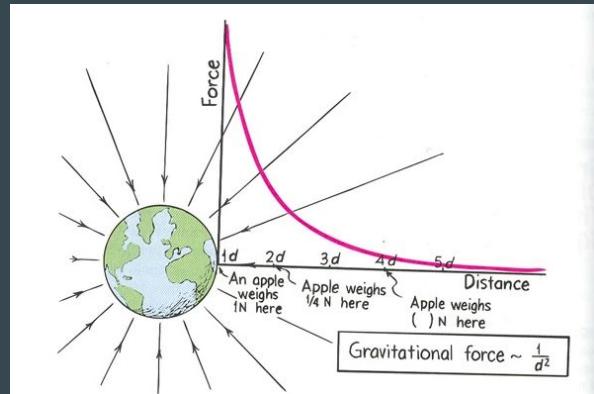


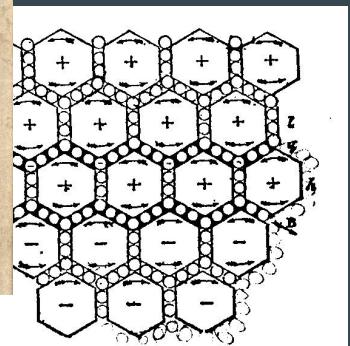
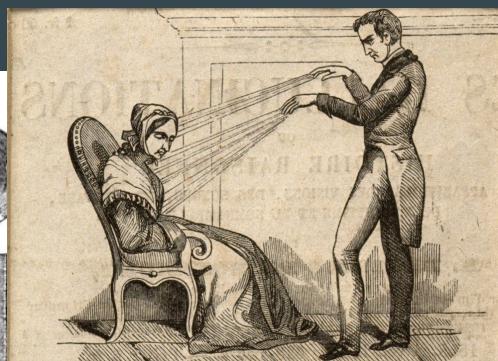
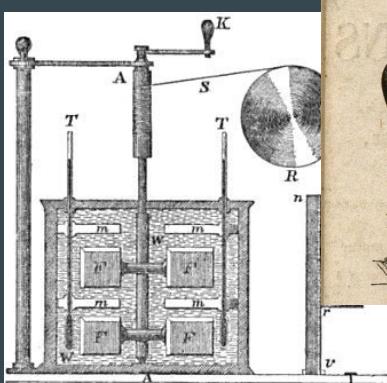
A Quick Detour

## Isaac Newton (c. 1700)

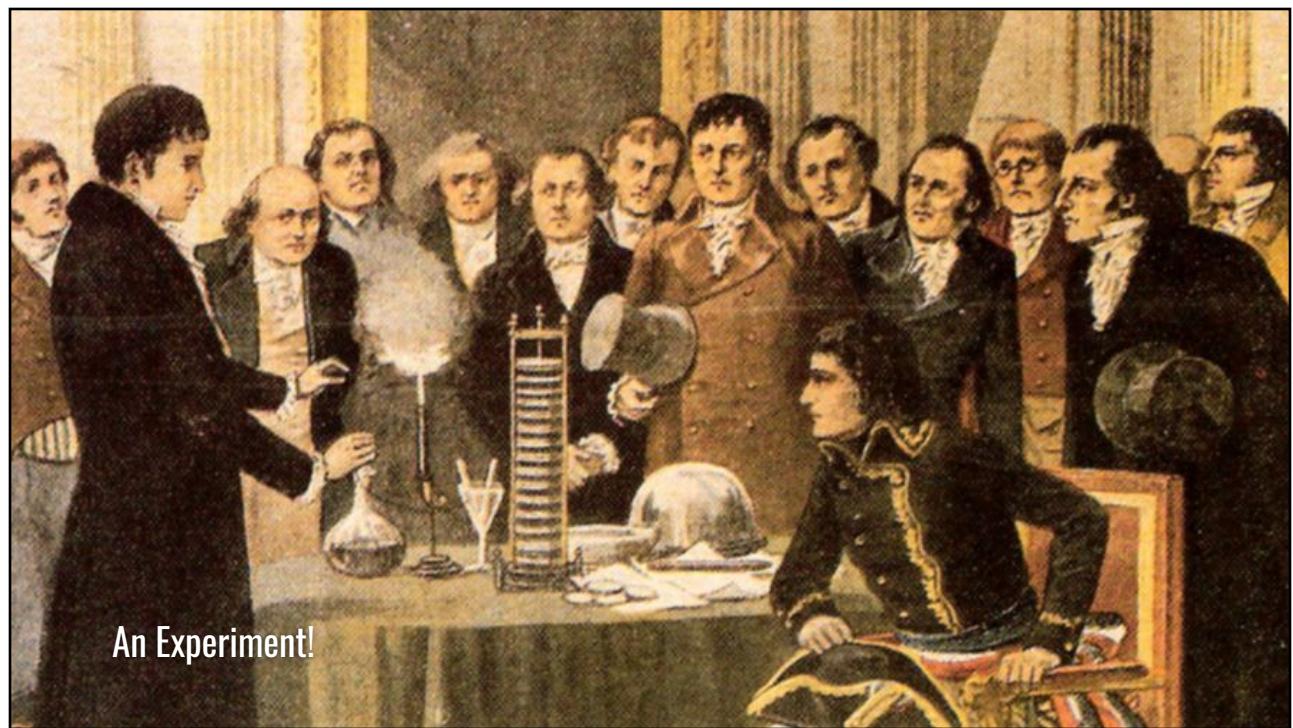
- Inverse Square Law of Gravitation
  - LAW is the key word here!
- Newton's law applied to any and every kind of force--heat, light, electricity, magnetism.

$$F = G \frac{m_1 m_2}{r^2}$$





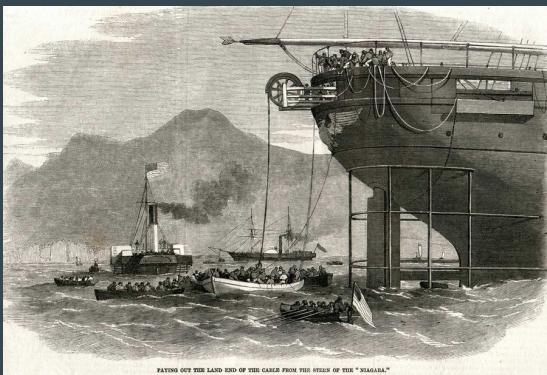
What is “energy”?



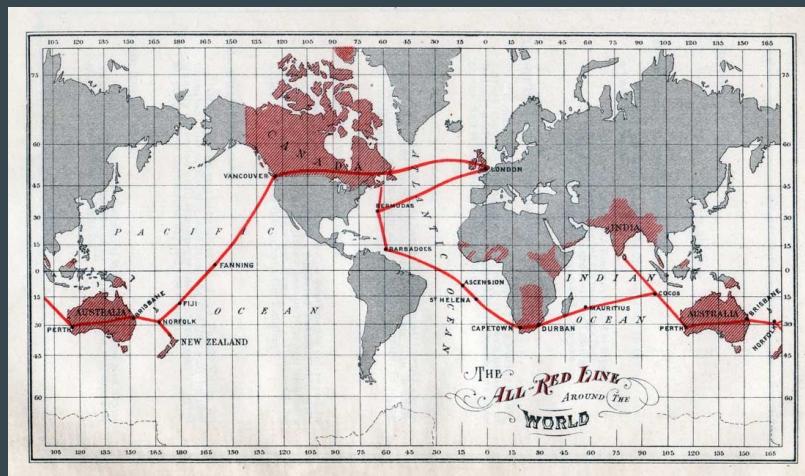
An Experiment!

## William Thomson, Lord Kelvin (c. 1840s-1900s)

- Designer of a multiplex telegraph, consulted for the British Government on construction of transatlantic telegraph cables.

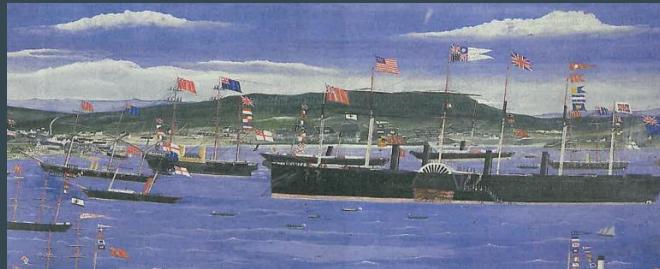


# Science, Industry, and Empire: “Lord Cable”



## Entropy, Telegraphy, and Politics

- Signals dissipate over time and distance.
- Calculating this dissipation leads Thomson to Carnot's ideas about efficiency.
- Thomson is Scottish, conservative, and agrees with Carnot's political analogy.
- For Thomson, Energy and Entropy are a philosophical "theory of everything."



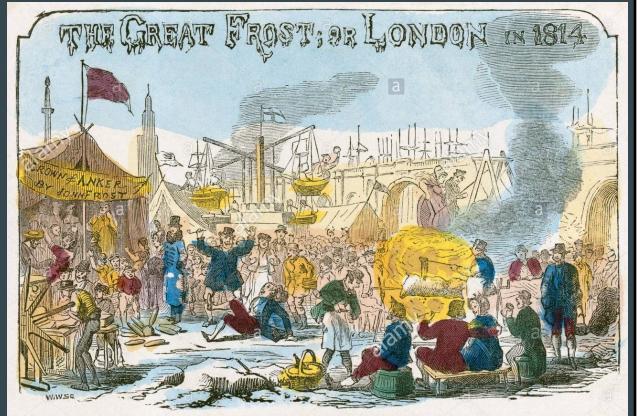


# THE HEAT DEATH OF THE UNIVERSE

"A FEW CITIES IN ASHES CANNOT ARREST THE HISTORY OF HUMANITY."

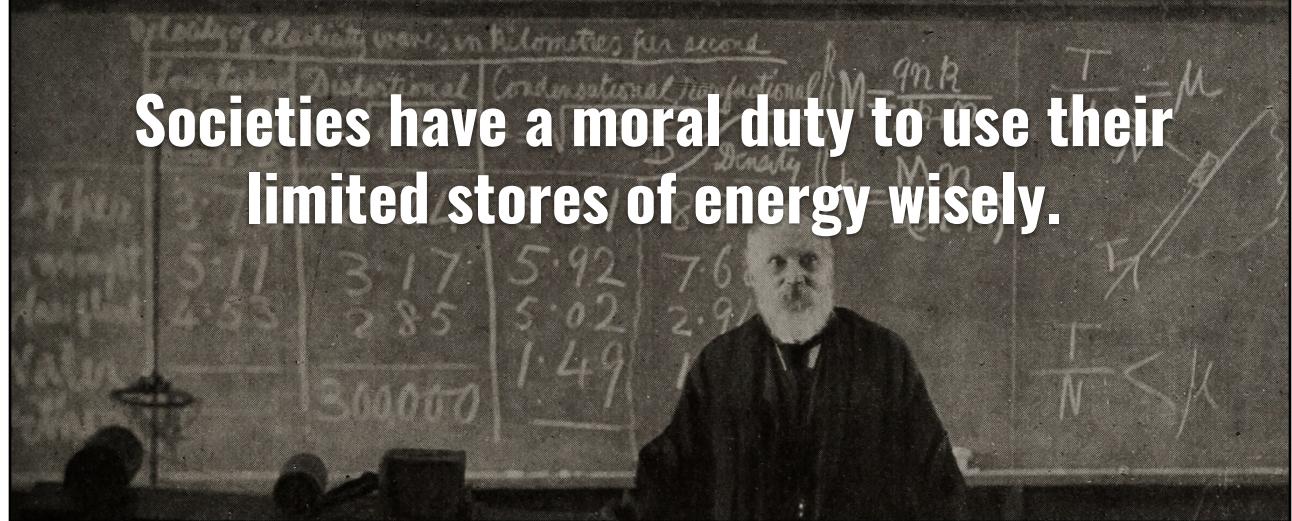
## Thomson's Predictions: A Frosty Future!

- Assuming the sun is a big, hot rock radiating heat out into space, how long will it last?
- Not long!
- At some point in the next few thousand years, nature will run out of steam.
- A grim urgency: “waste” is not only poor business, it’s sacreligious!



2.7 x 10		Zinc	955	Tors. G.	Torsional rigidity of couple per radian.
10.7 x 10		Gold	859.9	281.0	
4.7 x 10		Silver	758	270.0	
1.7 x 10		Cadmium	609		
3.5 x 10		Tin	401		Hence by 2.3) $\frac{S \cdot I^3}{T^2} = \frac{81 M^2}{T^2}$
		Lead	228		Flexural rigidity of a beam = Young's modulus $\times$ moment of inertia of cross section $\times$ proper diameter
		Flint glass	61.4	244.4	

Mileage of electricity were in Kilometres per second  
Electrical Distortion Corrosion Non functional M - gnt R  
~~Denisty~~ M M  
**Societies have a moral duty to use their limited stores of energy wisely.**



# CONTROL



# Coal as an Energy Source

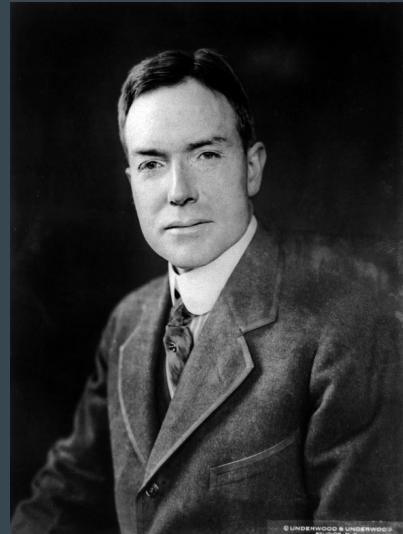


- Relatively portable compared to wind and water power.
- More energy-dense than wood and other carbon fuels.
- Fairly common throughout the British Isles, North-Western Europe, and the Eastern United States.

## Carbon Energy and Business

- Fierce competition over control of railways, canals, and other coal transportation networks.
- Separation between mining and consumption.
- As coal consumption increases and as societies become more invested in industrial production, energy monopoly means control over other economic factors.

John D. Rockefeller, Jr. (c. 1910s)  
Colorado Fuel & Iron Co.



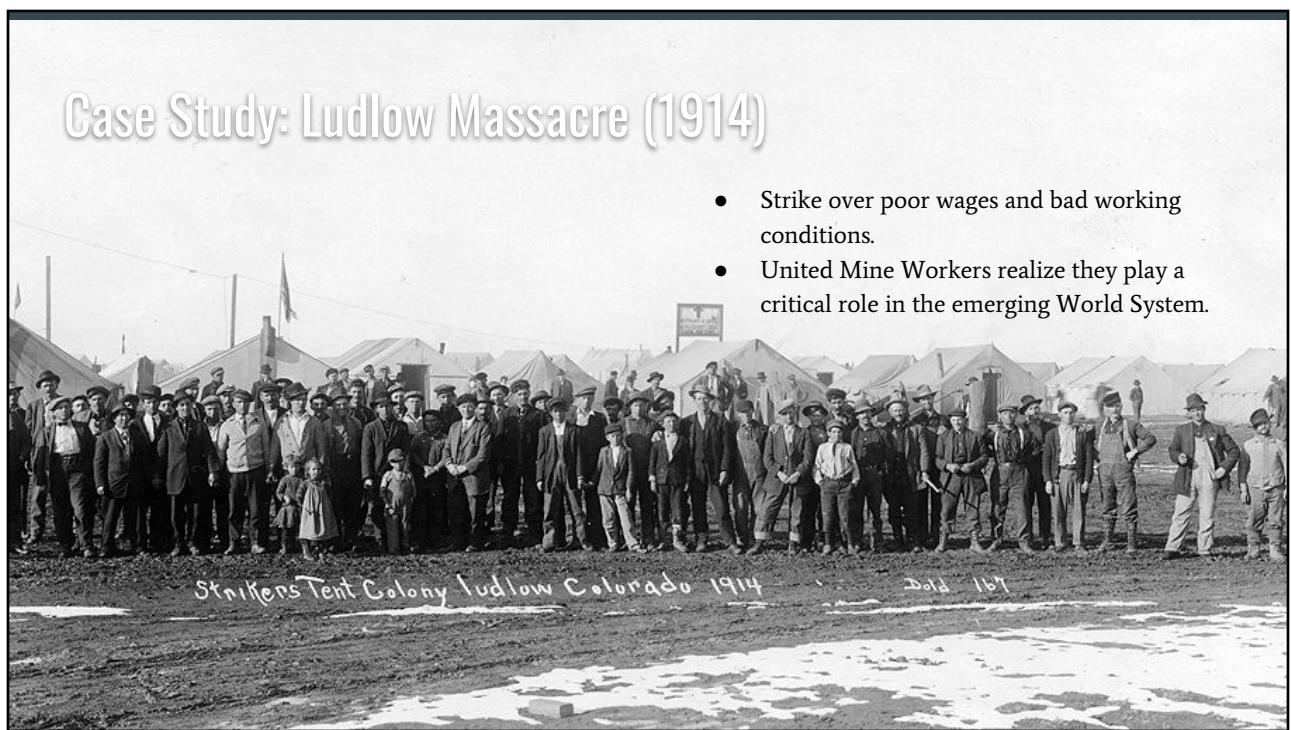
## Case Study: Ludlow Massacre (1914)

- Far from urban centers...
- But crucial to them!



## Case Study: Ludlow Massacre (1914)

- Strike over poor wages and bad working conditions.
- United Mine Workers realize they play a critical role in the emerging World System.



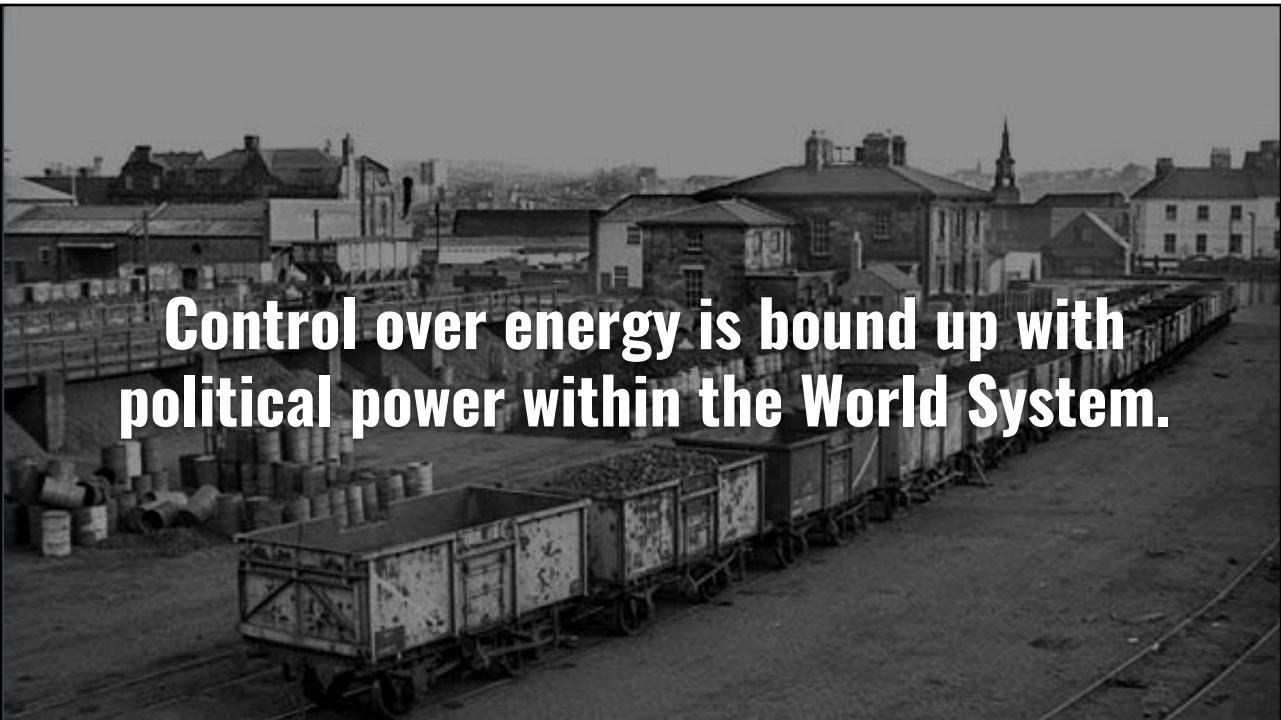
## Case Study: Ludlow Massacre (1914)

- Response: National Guard summoned, many killed.
- How can violence be prevented in the future and the flow of energy assured?



Looking ahead ~30 years...





**Control over energy is bound up with political power within the World System.**

So... WHAT IS “ENERGY”?

## What is “energy?”

- For states, energy is *military power*.
- For industrialists, energy is *time and money*.
- For politicians, energy is a powerful (but dangerous) *social resource*.
- For scientists, energy is a kind of fluid container for *force*.
- For laborers, energy is a way to make their voices heard... but for how long?

Efficiency  
Empire  
Energy  
Control

