Sean Hanley and G. Anthony Svatek

UNIT 4

Energy & 21st-century America

The role of energy in contemporary American life

Almost every aspect of life in the 21st century United States is shaped by energy systems, from where we live and how we get around, to what we eat and what we buy. But these systems, and their impacts, are frequently hidden from view. In this Unit, students gain awareness of how energy consumption underlies their daily lives and begin to think critically about how they, as informed consumers, can influence the environmental impacts of energy use.

The energy system that is so central to American life is most visible in the network called the Grid. At once a product of history and a feat of engineering, the Grid provides a framework for broader inquiry into the principles and pitfalls of infrastructure and system design. The Grid also gives a unique window into land use across the country and invites discussion of how the location of infrastructure impacts its functionality and effects. Through the case study of the 2021 Grid collapse in Texas during Winter Storm Uri, students examine the distribution of responsibilities, capacities, and vulnerabilities in a partially decentralized system of power supply.

But the Grid is not the whole story of energy consumption in the contemporary United States. As different sectors of consumption are closely intertwined with one another, the true energy cost — and environmental impacts — of our lifestyles can be hard to quantify. Frameworks including Embodied Energy, Carbon Footprint, and Lifecycle Energy Analysis anchor a discussion about how to measure consumption. Then, students confront these ambiguities head-on by adopting the perspectives of planning professionals who must use these frameworks to allocate land and resources towards sustainable housing development.

Finally, energy powers the defining feature of contemporary American life: the national and international circulation of goods and people. From the way the geography of the built environment centers cars, to the historical development of the consumer economy, to the expansion of global trade and e-commerce, the transportation and shipping sectors are the primary drivers of both energy consumption and greenhouse gas emissions. The potential decarbonization of transport is a case study in how science, economy, and politics intersect in efforts to shift lifestyles and lower energy consumption.

Throughout the Unit, students use primary data sources and interactive role-play activities to connect with energy use in their daily lives. Viewing energy at the scale of national systems allows students to begin to articulate a vision of a less energy-intensive future.

Objectives

Use primary data to analyze the role of different economic sectors and lifestyle factors in driving energy consumption and greenhouse gas emissions.

Reflect on how the constant availability of energy impacts daily life, especially in the realms of transportation and consumer goods.

Synthesize the historical development of energy infrastructure, the built environment, and transport networks, assessing how these histories contributed to contemporary energy consumption.

Explore how networks of energy supply are related to the geography of the natural environment in North America.

Analyze and evaluate complex scenarios involving multiple stakeholders with conflicting priorities in order to experience first-hand the challenges of creating energy system change.

Learning standards

The materials in this Unit correspond with the following New York State P-12 Science Learning Standards and elements of the New York State Grades 9-12 Social Studies Framework.

Science Learning Standards

ESS3-1 ESS3-2 ESS3-3 ESS3-4 ETS-1 ETS-2 ETS-3 ETS-4

Social Studies Framework

Practices | A1 A2 A5 A6 A7 B1 B2 B3 B4 B5 B7 C1 C2 C3 C4 C5 C6 D1 D2 D3 D4 D5 D6 E2 E4 E6 F2 F3 F4 F6 F8

Themes | ID GEO TECH MOV TCC SOC GOV CIV ECO

More information:

nysed.gov/curriculum-instruction/science-learning-standards

nysed.gov/curriculum-instruction/k-12-social-studies-framework

Key terms

The Grid

Alternating Current

Direct Current

Voltage

Power plants

Distribution lines

High-voltage transmission lines

Substation

Utility poles

Transformer

Resistance

Load

Blackout

“Peaker” power plant

Reserve margin

Electrification

Tennessee Valley Authority

Deregulation

Independent System Operator

Regional Transmission Organization

Grid-tied distributed solar generation

Anti-islanding

Smart Grid

Microgrid

End-use sector

Carbon Footprint

Consumer economy

Life Cycle Energy Analysis

Lifestyle

Operational Energy

Embodied Carbon

Embodied Energy

Waste-to-energy

Freight

“Just-in-time” shipping

“Last-mile” delivery

Diesel

Black carbon

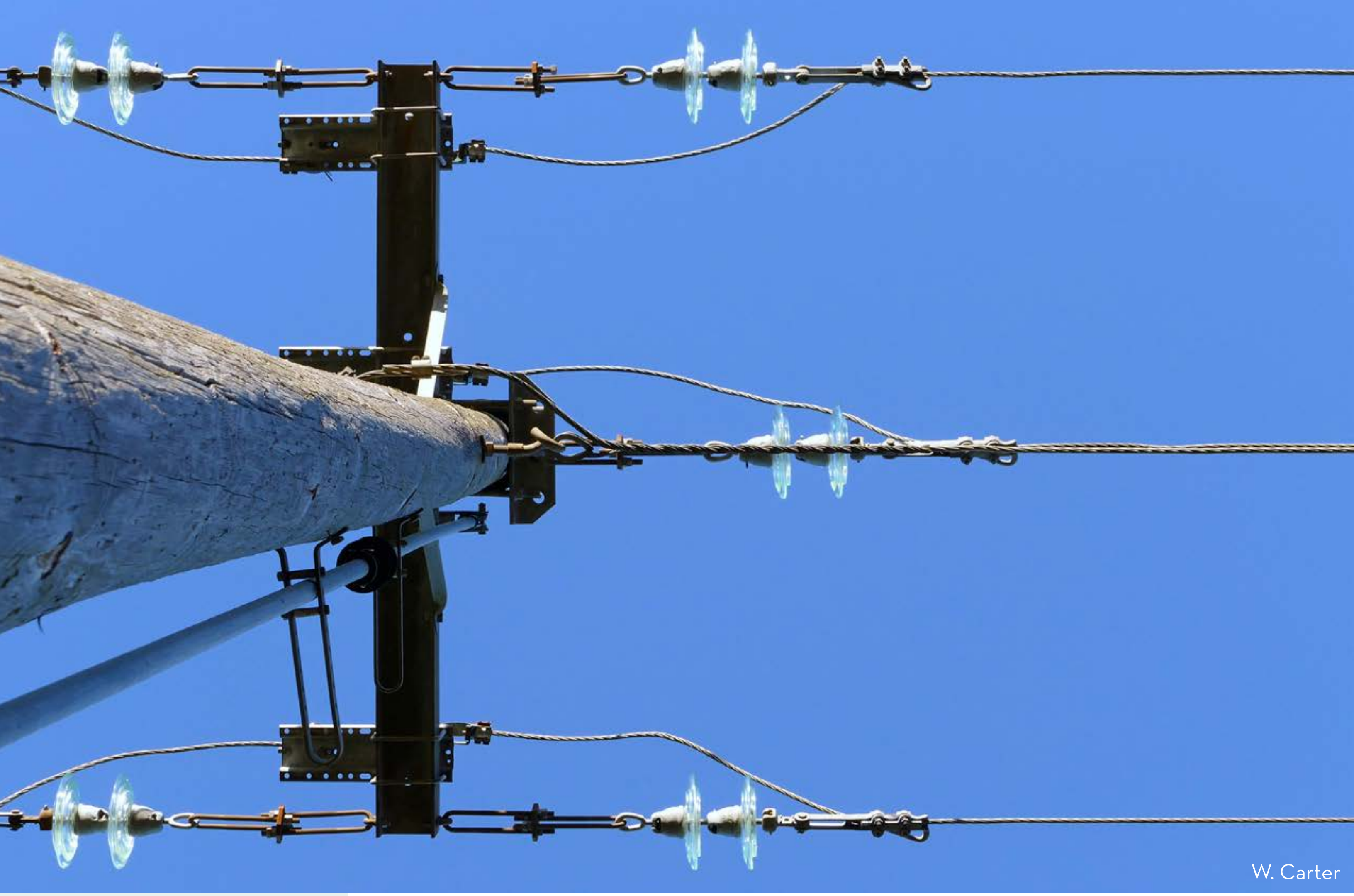
Bunker oil

CORE CONCEPT 1

Energy is supplied by the Grid

Contemporary energy consumption is made possible by a complex network of production and distribution that both impacts and is affected by the natural environment.

Lineworkers work to remove an osprey nest from a local utility pole
Courtesy of PSEG Long Island



W. Carter

The energy of connection

In this Core Concept, students explore the Grid: the network of distribution that enables contemporary US energy consumption. First students become acquainted with the different components of the Electrical Grid, and the evolution of the system, including the structure of the energy industry through utilities, regulatory bodies, and power-generating authorities. Interactive mapping tools published by the Energy Information Administration provide jumping-off points for discussion about the national geography of energy infrastructure, and the capacity, complexity, and responsiveness of this energy system. Emergent challenges due to climate change and aging infrastructure are introduced.

Next, in an interactive investigation, students learn about the causes and effects of power outages in the era of climate change through the lens of the February 2021 blackout in Texas. Students act as regulatory investigators seeking to establish responsibility for the events of that network failure, and make recommendations for how to hold those responsible accountable and prevent such a failure from reoccurring. Lastly, in a take-home activity, students learn about the history of public power in the US, and formulate a position in favor or against the establishment of utilities under full public ownership as part of the renewable energy transition.

What is a system?

What is a system? How do I know whether something is a system?

What are the characteristics of a well designed or strong system?

What are the characteristics of a poorly designed or vulnerable system?

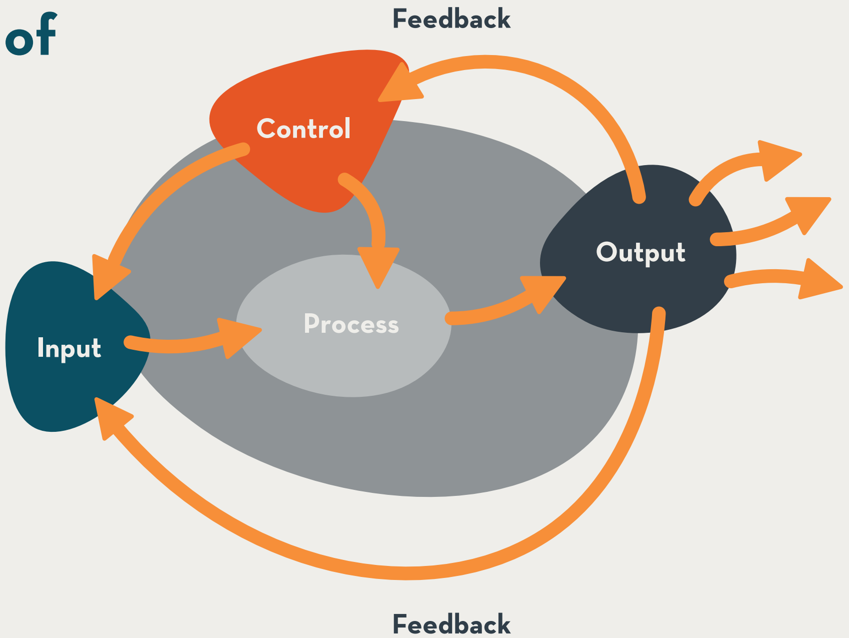
Try drawing your own map of the basic structure of a system, or consider the diagram below. A Process performs the work of the system using the Input (materials, information, or people) and with direction from the Control, which might be an individual person, a group of people, or some kind of automation. The Process then results in an Output: some result that the system is designed to achieve. Part of that Output may include materials or information that may be integrated by the system in the form of Feedback, while the remainder of the Output goes on to affect the environment.

Take an example of a school. Inputs might include the students, the teachers, and the school itself; all of these would be combined through a Process that would include a particular form of pedagogy. The whole school system would be overseen by an administrator. The Output might include feedback in the form of enthusiastic students who return as teachers, or evaluations from less enthusiastic students that can be used to change the pedagogical approach and hiring practices.

Do you think this accurately represents the basic structure of a system? What would you add, what would you take away? How would you elaborate on these concepts?

Based on what you already know, how would you map the Grid onto this structure? What are the strengths or vulnerabilities of each of these components in the case of the Grid?

Structure of systems



PRIMER

Give students a few minutes to respond, either alone or in small groups. Then move into the next activity by inviting students to share their answers.

AT THE CENTER

Groups working with the curriculum at the Jones Beach Energy & Nature Center can begin by viewing the Power of Seasons and Utility Pole exhibits in the West Gallery.

LEARN MORE

See 1.2 for discussion of the physics of electrical systems.

See 1.3 for discussion of energy source conversion processes and their environmental impacts.

DISCUSSION

The Grid today

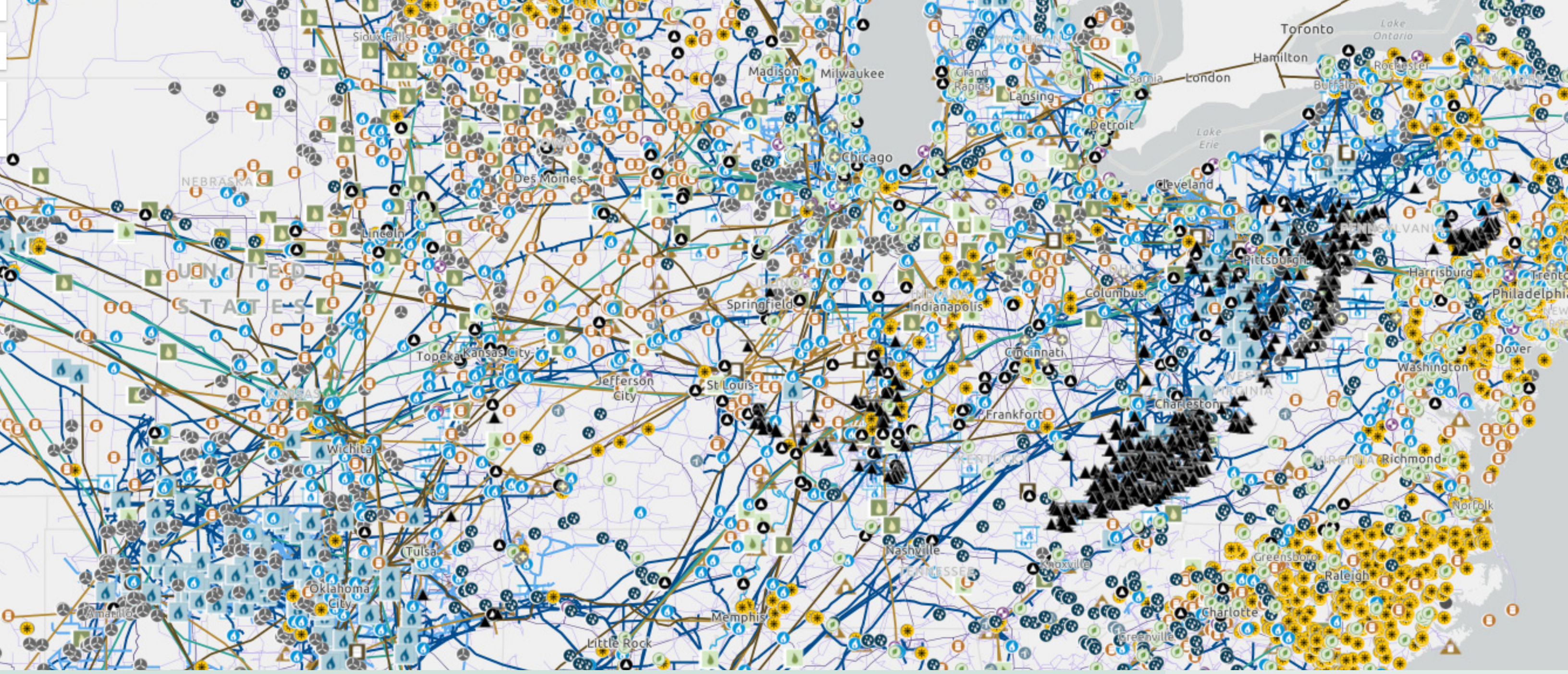
What is the Grid?

"The Grid" is the system that produces and transports power to points of consumption like homes, businesses, schools, factories, or elsewhere. Typically the term refers to the network of electricity generation and supply. The Electrical Grid, so defined, includes power generation plants, substations, transformers, long-distance transmission power lines, local distribution lines, and utility poles.

The Energy Grid can also be understood to include the system that mines and transports natural energy sources like coal, oil, and gas for conversion into electrical power, as well as that which mines, refines, and delivers energy sources like natural gas or oil for use in transportation, heating, or industrial processes. In that case, the Grid includes mines, processing plants and refineries, pipelines, and storage facilities.

Either way, the Grid is a vast and complex system that involves many different places, actors, and technologies in order to provide seamless access to power in our daily lives.

Map of Long Island Grid
Ruth Nervig



Map analysis

This interactive map shows the entire US energy grid, including power plants, transmission lines, transport, storage, pipelines, and refineries. You can use the layers function on the map to hide or highlight different parts of the Grid. Explore the map at the national level and discuss:

How does the layout of the Grid seem to relate to the geography of cities, towns, and neighborhoods, and the environment?

How are the networks of high-voltage (345V+) and lower-voltage electricity distribution lines related?

Identify the places with the greatest concentrations of:

- **Pipelines, waterways, refineries, and storage facilities for crude oil, natural gas, and petroleum products**
- **Coal mines**
- **Natural gas power plants**
- **Petroleum power plants**
- **Solar power plants**
- **Geothermal power plants**
- **Wind power plants**
- **Hydropower plants**
- **Nuclear power plants**

What might account for these distributions?

Then, zoom in on Long Island and New York State as a whole, and use the Long Island power map as a reference.

BREAK OUT

For full activity materials, see:

Unit 4 Appendix
Page 2

AT THE CENTER

Groups working with the curriculum at the Center can begin by viewing the Geography of Power exhibit in the South Gallery.

Investigate:

How do petroleum products and natural gas get to Long Island? Where do they come from? What refineries, pipelines, border crossings, and storage are involved in their journey?

What kind of power stations exist on Long Island? Where are they located relative to local landmarks and the natural landscape?

Compared to other parts of New York State, does Long Island have more or less of any kind of energy infrastructure? Why might that be?

Zoom in on the neighborhood of your school. Investigate:

Where does the transmission line that brings high-voltage power to your home neighborhood come from, and where does it terminate?

Source

Energy Information Administration | All energy infrastructure and resources

atlas.eia.gov/apps/all-energy-infrastructure-and-resources/explore

LEARN MORE

See 3.3 for further discussion of the development of the first centralized power station at Pearl Street in Lower Manhattan in the 1880s.

How did we get the Electrical Grid we have today?

The first centralized power station and "grid" of electrical distribution cables was established by Thomas Edison in Lower Manhattan in 1882. Edison got permission from the New York City government to dig up the streets and lay cables underground alongside preexisting gas lines.

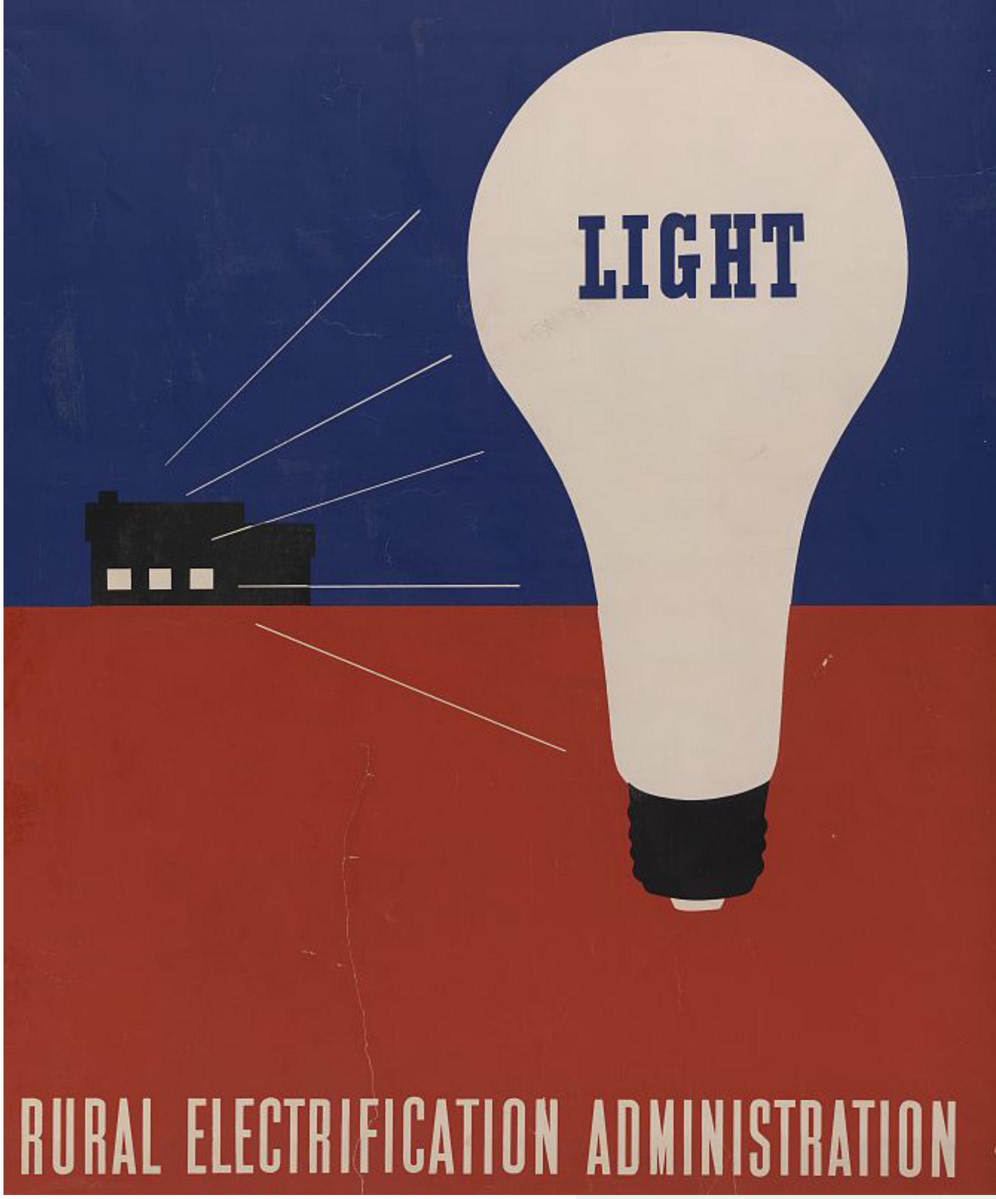
Edison's network supplied Direct Current (DC) electricity to a few hundred customers within a square mile of the Pearl Street Station. Edison's DC networks dominated the industry for a short time, but ultimately the Alternating Current (AC) electricity produced by his rivals would win out due to its ability to travel longer distances without energy loss.

For electricity traveling over a long distance, whether AC or DC, the higher the voltage of the current, the less energy is lost in transit. The difference between the two types of electricity lies in the ability of AC power to be converted to higher or lower voltages through the use of transformers. AC power can be converted to a high voltage ("stepped up") for travel, and transformed to a lower voltage ("stepped down") closer to the point of consumption, for easier and safer use in appliances, small motors, and home electrical circuits. It is harder to change the voltage of DC power, so its functional range is smaller. Some energy is still lost when high-voltage AC electricity travels long distances – about 5 percent, on average, in the US. These facts about the physics of electricity have fundamentally shaped the contemporary Grid.

The basic building blocks of the system are: power plants, where electrical current is generated; substations, where transformers increase the current's voltage for long-distance travel; high-voltage transmission lines, which for safety reasons must be kept apart from places where people live; regional substations, where the power is transformed again to a lower voltage; and distribution power lines that carry lower-voltage electricity from the regional substation to consumers along utility poles. Transformers on the poles then "drop" the electricity to an even lower voltage for use in households.

The dominance of AC electricity allowed utilities to build large networks across greater service areas, achieving "economies of scale" that translated increasing numbers of users into lower prices per unit of power. As demand for electricity grew, smaller networks were consolidated into large interstate utility companies. But the more they grew, the more unstable these organizations became, concentrating control in the hands of a few and putting customers at risk. Finally, the Great Depression, and the public-works-oriented presidency of Franklin Delano Roosevelt, provided an opening for oversight.

In 1935, following a years-long investigation of industry practices, two federal laws restricted the size and scope of the utility companies and subjected them to government regulation, as part of the New Deal. The first law, the Public Utility Holding Company Act of 1935, dictated that companies could not extend their service areas beyond state lines (making them easier to regulate through state law). The second, the Federal Power Act of 1935, established a federal regulatory commission with the authority to ensure the price of electricity was "reasonable, nondiscriminatory, and just."



The New Deal also established the Rural Electrification Administration, which through projects like the Tennessee Valley Authority expanded the Grid across the country. The New Deal also funded the construction of large power plants and the "electrification" of rural areas that previously had no power access. The result was a nationwide system of power supply administered by vertically-integrated utility companies and regulated by government agencies. For several decades, this system worked very well.

LEARN MORE

See 3.3 for further discussion of concepts of "natural monopoly" and "economy of scale."

In 1965, a massive regional blackout demonstrated that utilities as configured were vulnerable to crisis when there were technical issues in the transmission system, problems with the supply of fuel to power plants, or weather conditions driving high demand. The establishment of regional reliability commissions allowed utilities to respond to surging demand by drawing power from nearby systems. However, even this couldn't protect the system from failure. After the US experienced an energy crisis in the 1970s due to political conflict over the supply of oil, power companies began to construct more domestic coal- and nuclear-powered plants, which raised the baseline cost of power generation. Utilities raised prices to maintain their rate of profit, angering consumers.

Since the 1907s, some industry actors have have argued that deregulation would create more competition in the provision of electricity and make the industry more efficient, lowering costs. At their behest, lawmakers have gradually restructured the power system to separate the generation from distribution. Instead of the vertical integration of local power plants feeding into concentrated networks, independent commercial power generators send power to industrial customers hundreds of miles away, straining the long-distance distribution system.

Today, the contemporary US power Grid is a complex mix of private, investor-owned utility companies, publicly-owned or municipal utilities, independent power producers, and public benefit corporations. Nationwide, the Grid consists of more than 9,200 power generators, with more than 1 million megawatts of capacity, and more than 300,000 miles of transmission lines.

In mainland New York and New York City, the New York Power Authority (NYPA) owns the infrastructure of power distribution — the distribution lines, utility poles, and transformers. On Long Island and the Rockaways, the Long Island Power Authority (LIPA) fulfills this role. LIPA and NYPA are semi-private, public benefit corporations that are run by boards of trustees appointed by elected officials. NYPA contracts with Con Edison, while LIPA contracts with the Public Services Enterprise Group (PSEG Long Island), effectively leasing the distribution infrastructure to these investor-owned private corporations, which manage the delivery of electricity to consumers. NYPA, LIPA, PSEG Long Island, and Con Edison each own some of the power plants that supply energy to the Grid. There are also Independent Power Producers that sell electricity to the utility companies. Though they are private corporations, investor-owned utilities are regulated by state and federal commissions and must obtain permission from the government to raise prices or change policies. In New York, PSEG Long Island and Con Edison are regulated by the Public Service Commission, the members of which are appointed by the Governor.

Power companies are plugged into state- and regional-level networks that try to ensure consistent supply by managing the long-distance transmission network and monitoring demand. These Independent System Operators and Regional Transmission Organizations, established in the 1990s to manage the "wholesale market" of electrical power, broker deals between power generators and utility companies. In New York, the long-distance transmission infrastructure is managed by the New York Independent System Operator.

Discussion

What are the advantages and disadvantages of the Grid including so many entities at different levels?

What are the strengths and weaknesses of the modern Grid?

Today, the electricity brought to consumers by the Grid originates in an unprecedented diversity of energy sources. Fossil fuels, hydropower, solar power, wind power, nuclear power, and biomass all contribute to generating the electricity that powers our homes and businesses. This diversity can be an asset because when events impact one energy source or one part of the generation and transmission network, the entire system may not necessarily be affected. This is particularly true in areas overseen by regional transmission operators, which can compensate for lower production in one place by drawing from another. The US even draws from and sends energy to Canada and Mexico as needed.

However, the complexity of the modern Grid can also be a challenge. The Grid was never designed from the top-down to maximize efficiency as a single network. It emerged out of individual, privately-operated systems that were gradually consolidated and connected to one another. The technological, environmental, and social conditions that shaped those systems as they developed are very different from those of our world today.

A major challenge is the age of the infrastructure itself. The average transmission line in the US is more than 40 years old. Our energy system is a physical thing made of metal, wood, concrete, stone, and rubber. These materials break down over time, functioning less well as they age and requiring maintenance, which can be expensive.

Another challenge is that the original networks did not account for the diversity of energy sources available today or the changing patterns of production and consumption. Contemporary renewable energy sources physically generate power in very different ways than the plants that supported the original Grid. The earliest Grid was powered by relatively few, more centralized generators running on coal or hydropower. A fueled power plant can generate electricity as needed; a hydropower plant with dammed water can also run its generators in response to projected demand. But renewable energy sources like solar and wind depend on natural phenomena over which utility companies have no control. Renewable energy power plants also may have to be located further away from points of consumption. Wind contains more energy, for instance, in places where there are fewer buildings and other obstructions nearby; both wind and solar power plants require large amounts of open space in order to generate power at scale. Thus the contemporary Grid must adapt to integrate these more power sources.

BREAK OUT

Give students a few minutes to discuss, then come back together as a large group to share answers and continue the discussion.

Demand response is another challenge for the contemporary Grid. At present, electricity is mostly produced at the same time as it is consumed and production is closely coordinated with supply in order to keep the system running. This is because the Grid must maintain a certain frequency of current — 60 hertz — to function properly. If demand on the Grid, or "load," is lower than the volume in production, electricity may run through the Grid too quickly and cause a short-circuit. If the amount of power feeding into the system suddenly exceeds the rate of consumption, the network could also fail. For the most part, power supply is produced according to mathematical projections based on past consumption and scheduled one day ahead of time to allow power plants to ramp up their production capacity as necessary. Production has to be increased manually, which can take a long time, particularly for coal or nuclear plants.

For renewables like solar and wind, minute-by-minute generation capacity can be hard to predict, further complicating matters. In addition, as more and more consumers install renewable energy technologies at the point of consumption (like solar panels on the roofs of homes and businesses), the volume of power being fed into the Grid can be harder to track, making it more vulnerable to blackouts.

Better energy storage technologies are essential to help the Grid make best use of the power generated by renewable sources. Batteries allow energy that is produced at any time to be reserved for when it is needed most and fed into the Grid in a non-disruptive fashion. This is particularly important as anthropogenic (human-accelerated) climate change increases the frequency and intensity of extreme weather events, like heatwaves and storms, during which energy demand often peaks.

Long Island lineworker repairs downed lines after a storm in October, 2019
Courtesy PSEG Long Island

Peaker plant in Far Rockaway, Queens
Amy Howden Chapman

The present system is built around extra fail-safe capacity that is meant to mitigate the impact of these outlier weather events. Planned supply must include a "reserve margin" — a set amount of extra electrical generating power intended to account for potential errors in projection or unexpected power plant failures. But this capacity frequently goes to waste. "Peaker" power plants are left idle and on standby, waiting for the few times each year when demand exceeds the rest of the network's resources — like the hottest days of summer. Running those plants is very expensive, which leads to exorbitant "peak" rates at these times. Peaker plants are also among the most carbon-intensive power generators. But even this extra capacity can be overcome by intensifying weather patterns due to anthropogenic climate change.

Intensifying weather puts pressure on the infrastructure itself, as the volume of power a line can carry safely depends on environmental conditions. For instance, windy and icy conditions significantly lower the amount of power a line can carry. Meanwhile, more extreme weather events like heat waves and winter storms make peak demand periods more common, and generators struggle to keep up. Even the best planning cannot stretch the capacity of the modern Grid beyond its physical limitations. What happens when the weather becomes more and more unpredictable, the capacity of "peaker" plants is insufficient, and the reserve margin is not enough? Better energy storage can help the Grid cope in these events.

Battery at the Jones Beach Energy & Nature Center
Barry Sloan

SPOTLIGHT

Anti-islanding on Jones Beach Island

The 260 solar panels mounted on the roof of the Center generate electricity that feeds into the large battery outside. The battery in turn connects to the Grid, drawing electricity from the network in order to recharge or compensate for low solar generation, or sending solar electricity back into the system to meet the demands of consumers elsewhere. This is grid-tied distributed solar generation. It can be an asset when the Grid experiences unusually high demand and is part of a larger effort to replace fossil fuel-powered generation with renewable energy sources. But systems like this one can also make Grid maintenance complicated. Line workers can only safely operate on distribution lines when the power is cut; after blackouts, or when power lines and other infrastructure need to be repaired, utility companies will shut down the part of the network that line workers intend to operate on. Solar power generators that continue to feed electricity into the network can put these workers in danger. For this reason, solar power systems like the one at the Center must include an inverter with anti-islanding capabilities. This device senses when a power outage has occurred elsewhere in the network and automatically shuts down the local power generation system.

There are other important developments in the works as the contemporary Grid struggles to adapt to the changing climate. Microgrids are hyper-local networks of energy production and consumption that can more easily integrate renewable energy, linking solar panels on consumers' roofs to nearby wind power and battery storage. These networks may be more resilient in the face of extreme weather and more responsive to locally-monitored demand.

The "Smart Grid," meanwhile, describes the potential use of information technology to help tailor energy production to demand more closely, and detect and isolate problems before they become blackouts. Localized digital sensors would track rates of consumption throughout the network and feed information to a central computer system, which would automatically increase and decrease production as necessary or take parts of the network off-line in response to localize outages. At present, the Smart Grid is a vision rather than an existing system: to make it a reality would entail the construction and renovation of millions of pieces of the national energy infrastructure, from power lines to computers.


Installing a Smart Meter on the outside of a home
via Portland General Electric

What messed with Texas?

The majority of the time, the Grid functions properly and without incident. But extreme storms, heatwaves, and floods — more frequent and more damaging due to the changing climate — along with growing demand overall are putting increasing pressure on the system. Occasionally the Grid fails, resulting in a blackout that can have deadly consequences.

In February 2021, Winter Storm Uri swept across the middle of North America, bringing all-time record low temperatures. In Texas, the dangers of freezing temperatures were exacerbated when the Grid, unable to meet rising demand for electricity to power space heaters, began to fail. Consumers across the state lost electrical power; at least 210 people died, most of them from hypothermia, and more than 4.3 million households were left without power at the storm's peak. Long after the catastrophic event, Texans lacked clarity about what exactly happened, who was responsible, and how to prevent it from happening again.

In the US, almost every state is part of an interstate reliability network that is regulated by the federal government. Texas, however, is not. Texas has a (theoretically) completely internally self-sufficient Grid which, because it does not operate across state lines, is exempt from federal oversight. Instead, the Electricity Reliability Council of Texas, or ERCOT, oversees the Grid and has been widely blamed for the blackouts. To some commentators, the Texas Grid's failure is a cautionary tale about the dangers of deregulation; to others, it demonstrates the weaknesses of a Grid dependent on renewable energy sources.

Scenario

You are members of an independent regulatory committee charged with getting to the bottom of these events and making a recommendation to federal and state lawmakers about how to move forward. Is ERCOT responsible, and what should it have done differently? Was deregulation or renewable energy to blame? Is this an instance of climate change making the Grid less reliable? Or is this simply a freak occurrence?

Instructions

Investigate the Winter Strom Uri Blackout using the attached sources, using the Internet to supplement as necessary. Consider the following questions, and develop a short memo summarizing what occurred.

For full activity materials, see:

Unit 4 Appendix Pages 3-95

Describe the role of ERCOT in the Texas Grid. Who or what else are key players in the Texas Grid?

Describe the chain of events that transpired between February 13 and February 20, 2021.

What about the Texas Grid made it particularly vulnerable to these events?

How were wind turbines and natural gas pipelines impacted by the extreme weather event? How did these impacts contribute to the blackout?

How did the failure of the power grid lead to other system failures?

Who made the decision to execute rolling blackouts, or "load shedding," and what was their reason? Could this have been avoided?

Why was ERCOT not prepared to meet the demand of this event? Were the effects of the blackouts borne equally? Who was most impacted? How did impacts go beyond the loss of power itself?

Having established what happened, discuss the state's possible responses. Use the Public Utility Commission of Texas Commissioners' Report as a guide. Consider the following questions:

Who should be held responsible for these events? How should they be held responsible?

How should Texas — and the rest of the country — prepare for the future in order to ensure that this does not happen again?

What are the most important changes that Texas can make immediately? What changes can be made in the longer term?

Choose your top three recommendations from the Commissioners' Report, and present your choices to the rest of your class, making an argument about why you prioritized what you did.

Sources

"2 million Texas households without power as massive winter storm drives demand for electricity," Mitchell Ferman, Sami Sparber, and Elvia Limón, *Texas Tribune*, February 15, 2021.

"Texas largely relies on natural gas for power. It wasn't ready for the extreme cold." Erin Douglas, *Texas Tribune*, February 16, 2021.

Power outages in Houston, TX on February 16, 2021
Joshua Stevens via NASA Goddard Space Flight Center

"Texas leaders failed to heed warnings that left the state's power grid vulnerable to winter extremes, experts say," Erin Douglas, Kate McGee, and Jolie McCollough, *Texas Tribune*, February 17, 2021

"Catastrophic Texas power outages prompt finger pointing and blame shifting at legislative hearings," Reese Oxner, Mitchell Ferman, and Julián Aguilar, *Texas Tribune*, February 25, 2021

"Review of February 2021 Extreme Cold Weather Event – ERCOT Presentation", ERCOT Public, February 24, 2021

"Update to April 6, 2021 Preliminary Report on Causes of Generator Outages and Derates During the February 2021 Extreme Cold Weather Event," ERCOT Public, April 27, 2021

"ERCOT Winter Storm Uri Blackout Analysis (February, 2021)," Vibrant Clean Energy LLC, March 23, 2021 (Selection)

"Never Again: How to Prevent Another Major Texas Electricity Failure," Public Utility Commission of Texas Report, June 10, 2021

Bottled water provided by Federal Emergency Management Agency
in wake of water system failure caused by Winter Storm Uri
via the National Guard


Members of the Texas National Guard assist stranded motorists during Winter Storm Uri
via the National Guard


Blackouts in Austin, TX following Winter Storm Uri
Franklin Dmitryev via ***News and Letters***

Waste not

All parts of the Grid generate waste and impact the natural environment, including the air, ground, and water. Greenhouse gas emissions from burning fossil fuels are the most prevalent and best known, but there are many other kinds of pollution that result from the accumulation of energy sources, operation of power plants, and delivery of electrical power. The physical presence of the infrastructure itself impacts local ecosystems, and the construction of mines, power plants, and distribution systems generates solid waste that must be managed.

But what about a different relationship between waste and energy? "Waste-to-Energy" describes a power-generation process that uses Municipal Solid Waste to produce electricity and steam heat. Byproducts from the process are treated to prevent pollution. Harnessing the abundant waste materials in the US to produce electricity could be a way to kill two birds with one stone. But not everyone sees Waste-to-Energy as a silver bullet for the twin problems of waste management and electricity production. Some experts object to the cost and argue that the process does not prevent pollution as well as its proponents claim.

Instructions

For full activity materials, see:

Unit 4 Appendix Page 96

Research Waste-to-Energy and write a two-page analysis explaining how the process works, evaluating its pros and cons, and ultimately making an argument for or against prioritizing Waste to Energy as part of a renewable energy transition. Use at least five sources to support your analysis, and try to find data from case studies to illustrate your points. (Look at the EIA Energy Mapping System for population density and biomass availability data.)

What is the environmental impact of Waste-to-Energy, in both absolute and relative terms?

What is its absolute and relative cost?

How is waste geographically and socially distributed? How does this affect the environmental justice impacts of Waste-to-Energy?

CORE CONCEPT 2

Energy consumption shapes contemporary lifestyles

Energy shapes the way we live, and our lifestyles — including where we live — shape our energy consumption patterns.

The energy of consumption

In this Core Concept, students begin to think more deeply and critically about how energy consumption shapes lifestyles, and how lifestyles — including where people live — shape energy consumption patterns. Through this framework, they will also compare and evaluate different methods of measuring energy consumption and environmental impacts, with the intention of turning that lens on their own habits and those of their households.

First, students revisit data about US energy consumption and demographics introduced in previous Units, as well as new data about global energy consumption, GDP, and population growth. Students reflect on what these data tell us about contemporary US lifestyles — including consumerism, car ownership, and the geography of settlement in North America — in comparison to other countries. In the course of the discussion, students learn about and consider different methods of measuring energy use and environmental impact at the level of individuals, households, product manufacturing, built environment construction, and planning. Methods considered include in-home energy metering, Embodied Energy, Embodied Carbon, Life Cycle Assessments, and Carbon Footprints on the individual, household, and city level.

Then, in an interactive exercise, students adopt the role of planners to experience first-hand the challenge of minimizing energy footprint while maximizing housing affordability. Through the exercise, students come to intuitively grasp the relationship between density and efficiency, while understanding that material costs and lifestyle factors may make sustainable building practices more difficult. The activity ends with a group discussion about factors outside these calculations influencing the kinds and locations of housing that are built in the contemporary United States. Lastly, as a take-home exercise, students survey their own households to assess energy use and waste, ultimately recommending behavior changes that can help minimize their family's carbon footprint.

Lance Cheung via US Department of Agriculture

What's in a lifestyle?

What does "lifestyle" mean to me? What different things are included in a lifestyle? What's not included?

How would I describe my own lifestyle? Is there anything I would like to be different? Who has a lifestyle that I admire?

What role do energy and energy infrastructure play in my lifestyle?

Use Google Earth (in the "Clean" mode, without labels) to navigate to the following coordinates. Zoom in and out to explore the surrounding area.

- **38°36'60.0"N 90°33'22.7"W**
- **34°03'48.1"N 4°58'34.5"W**
- **42°47'45.8"N 69°11'35.1"E**
- **19°23'29.7"N 99°09'32.5"W**

What differences do you see in the geography of these places?

What do you think might account for these differences?

What can you extrapolate about the lifestyles of people who live in these places based on the built environment?

PRIMER

Give students a few minutes to respond, either alone or in small groups.

AT THE CENTER

Groups working with the curriculum on site can conduct the first portion of the discussion from the steps of the South Porch amphitheater, using the secondary dune ecosystem as a grounding example.

Groups working off site can use a nearby, familiar environment that includes plants and animals (like a lawn or a park) as their grounding example.

LEARN MORE

See 3.2 and 3.3 for discussion of how industrialization and suburbanization shaped the geography of the region surrounding Jones Beach.

Energy consumption in the context of daily life

What do we mean when we say "lifestyle" and how is it related to energy use?

"Lifestyle" describes all the variables that shape how we live. It can mean the food we eat; the objects we buy, make, and use; and the activities we do for enjoyment or survival. It can mean where we live and who we live with; how we move around in our communities, and where we go. Often, "lifestyle" is thought of as something we have total control over — the product of our choices. In fact, our lifestyles are often a product of our environments: where we can afford to live, where our school or work is located, what modes of transportation we have access to, how much free time we have, and what we have the option of doing with that free time.

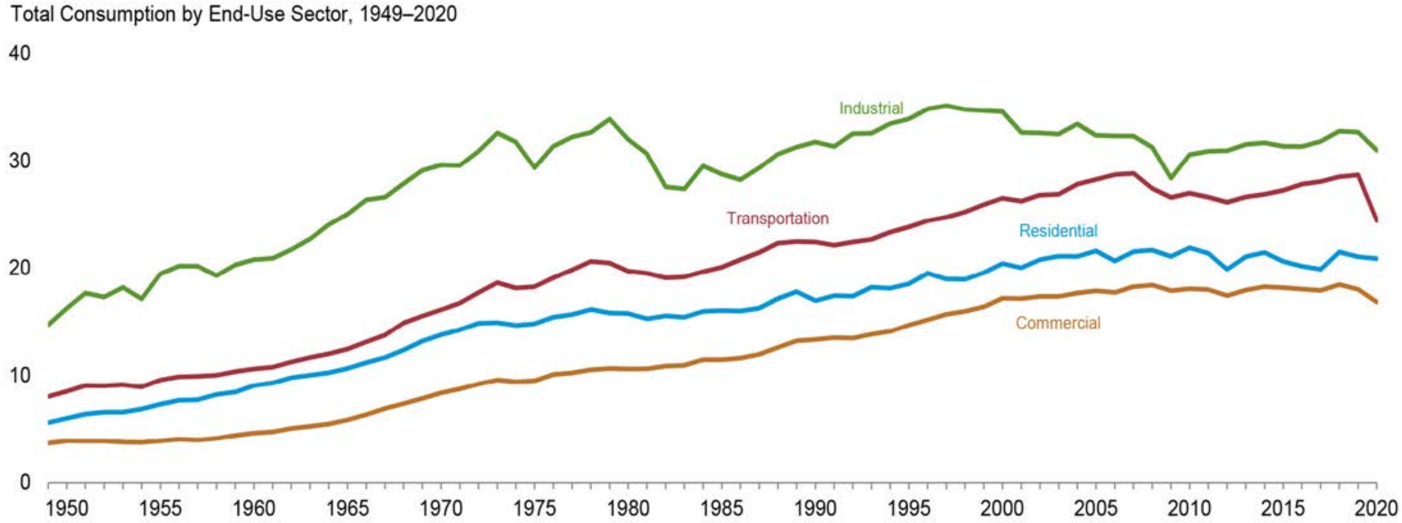
These environments — the spaces we live, work, and enjoy ourselves in — are produced and maintained using energy sources. The goods that we consume, from food to clothes to electronics, are also produced and transported to consumers using energy sources. Our habits — where we go, what we do, and how we get around — are enabled by fuels and electricity that power our modes of transportation and provide light, heat, and ventilation, making our spaces habitable.

Consider what kinds of essential resources and services — grocery stores and restaurants, green spaces, healthcare, entertainment venues — are available within walking distance of your school. For resources that are not accessible within walking distance, is public transportation available? Are cars required to get around? In the 20th century, the mass-production of the automobile and the development of suburbs and highway systems supported one another and the growth of a car-centric national culture. This culture profoundly shapes the geography of the contemporary United States, which in turn shapes our lifestyles.

Though the geography of the US is unique, trends toward industrialization, suburbanization, and a consumer economy have been replicated throughout the world as population increases have been associated with growing energy consumption and manufacturing productivity (measured in GDP) since the mid-20th century. These trends have irreversibly impacted the global landscape.

Figure 2.1 Energy Consumption by Sector

(Quadrillion Btu)



Data analysis

Examine the data set from the Energy Information Administration. Consider:

How has total US energy consumption changed over time?

How has the energy consumed by the residential and commercial sectors changed since 1950, versus the industrial or transportation sectors?

How have food consumption habits changed, in terms of how much people eat, what they eat, and how much they spend?

How did consumer spending in the US change over the course of the 20th century? How did the amount and distribution of spending change? Were there major moments of disruption?

How did the types and numbers of businesses change? How might this have impacted national energy consumption?

How did transportation and travel habits change?

How did manufacturing and production change?

In 2019, what percentage of natural gas went to the transportation, industrial, residential, and electricity production sectors?

In 2019, what percentage of coal went to electricity production?

How do lifestyle and productivity changes since 1950 account for changes in energy consumption by end-use sector?

Source

U. S. Energy Information Administration, "Monthly Energy Review October 2021: Chapter 2, Energy Consumption by Sector"

BREAK OUT

For full activity materials, see:

Unit 4 Appendix
Pages 97-112

BREAK OUT

For full activity materials, see:

Unit 4 Appendix Page 113

Data analysis

Examine the data sets from Our World in Data. Consider:

What do you observe about the historical trend of energy consumption and GDP per capita?

Based on these data, which countries would you expect to be most similar to the United States in terms of the average citizen's lifestyle, and which would be most different?

Choose one country that you expect to be similar and one that you expect to be different.

Note that the Gini Index measures the distribution of household income within a society. A higher Gini Index indicates greater inequality.

Based on these data, how does income inequality in these countries compare to that of the United States?

How might energy consumption relate to inequality?

What does this level of inequality suggest about the lifestyles of citizens of those countries?

What could change the relationship between income inequality and quality of life?

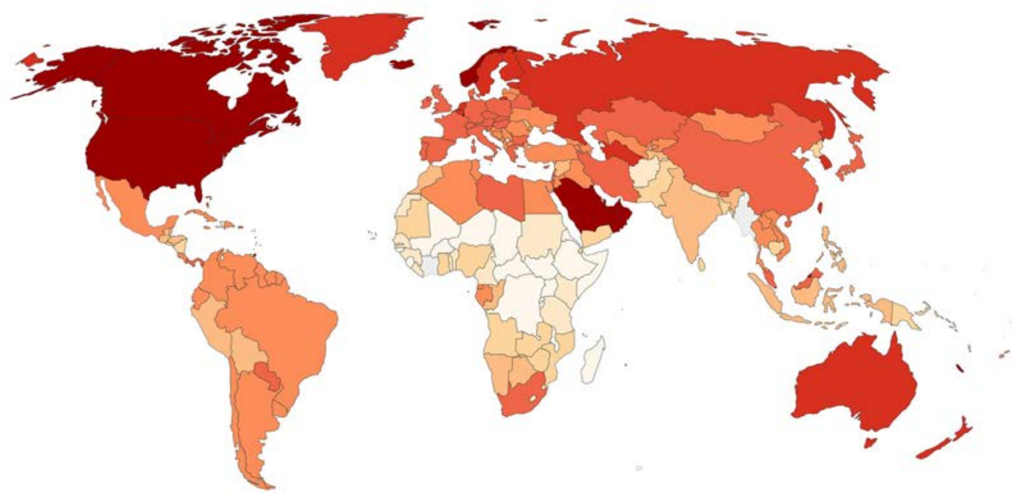
Sources

Our World in Data | Per capita energy use; GDP per capita; GDP per capita vs economic inequality

ourworldindata.org/grapher/per-capita-energy-use

ourworldindata.org/grapher/gdp-per-capita-maddison-2020

ourworldindata.org/grapher/gdp-per-capita-vs-economic-inequality



Rare earth minerals, like the ones mined at this site in Xinjiang, China are essential to the production of smartphones and other electronics
Peter Chou Kee Liu

How do our contemporary lifestyles rely on and drive energy consumption?

In the US, we consume fossil fuels directly in our daily lives in the form of gasoline for cars, buses, trains, and planes; and as natural gas and oil in the stoves or boilers that may heat our homes. But we are also significant secondary consumers of fossil fuels. In that case, fossil fuels are used to produce electricity or to manufacture commodities that we consume — including food, medicine, household items, and consumer technologies. Manufacturers may use fossil fuels directly, purchase electricity made using fossil fuels in order to power machines in their factories, or purchase raw materials that are harvested, transported, or processed using fuel or electrical energy.

Consider a smartphone. There are dozens of raw materials involved in the production of smartphones, including metals like copper, aluminum, and iron, and rare earth elements like Cerium or Praseodymium. Each of these materials must be mined from the earth or the sea floor using motorized drills and other mining equipment. They are then transported to a factory for processing into an intermediary material form, then to another factory for the production of the phone components, then to another factory for assembly into the phone itself, then to a distributor's storage facility, and finally to a point of sale or direct to a consumer. Each of these stages in the object's journey consumes energy in the form of motor oil or fuel for trains, trucks, airplanes, and ships. Meanwhile, in each farming, mining, factory, or warehouse setting, energy is used to gather, process, and combine materials into machine components, assemble components into finished products, and store and sort those products before sale. Energy has also been used to construct and maintain the spaces where these processes occur, and to provide light, heat, and ventilation for the workers who are performing the various tasks of processing and assembly. Thus, everything we use and consume has a long history with energy before it even reaches our hands. But when we talk about the "energy efficiency" of a device like a smartphone, too often we only account for the energy the phone itself consumes in the form of electricity during our use.

BREAK OUT

For full activity materials, see:

Unit 4 Appendix Page 114

Video analysis

These videos demonstrate a variety of manufacturing processes that consume energy directly or rely on spaces, objects, and materials produced using energy. Machines collect, sort, move, and transform components; vehicles move components and assembled products; and machines and factories are constructed with energy-consuming materials and methods.

Watch the videos and discuss:

How does manufacturing rely on energy?

What kinds of machinery seem most common in these processes? Why might that be?

Are there similarities in the kinds of work that the machines perform?

What kinds of work have not been automated? Why might that be?

Sources

Toilet paper

youtube.com/watch?v=Z74OfpUbeac

Aluminum

youtube.com/watch?v=yZMtBMBt_SU

Sugar

youtube.com/watch?v=-3lSWOuPEHk

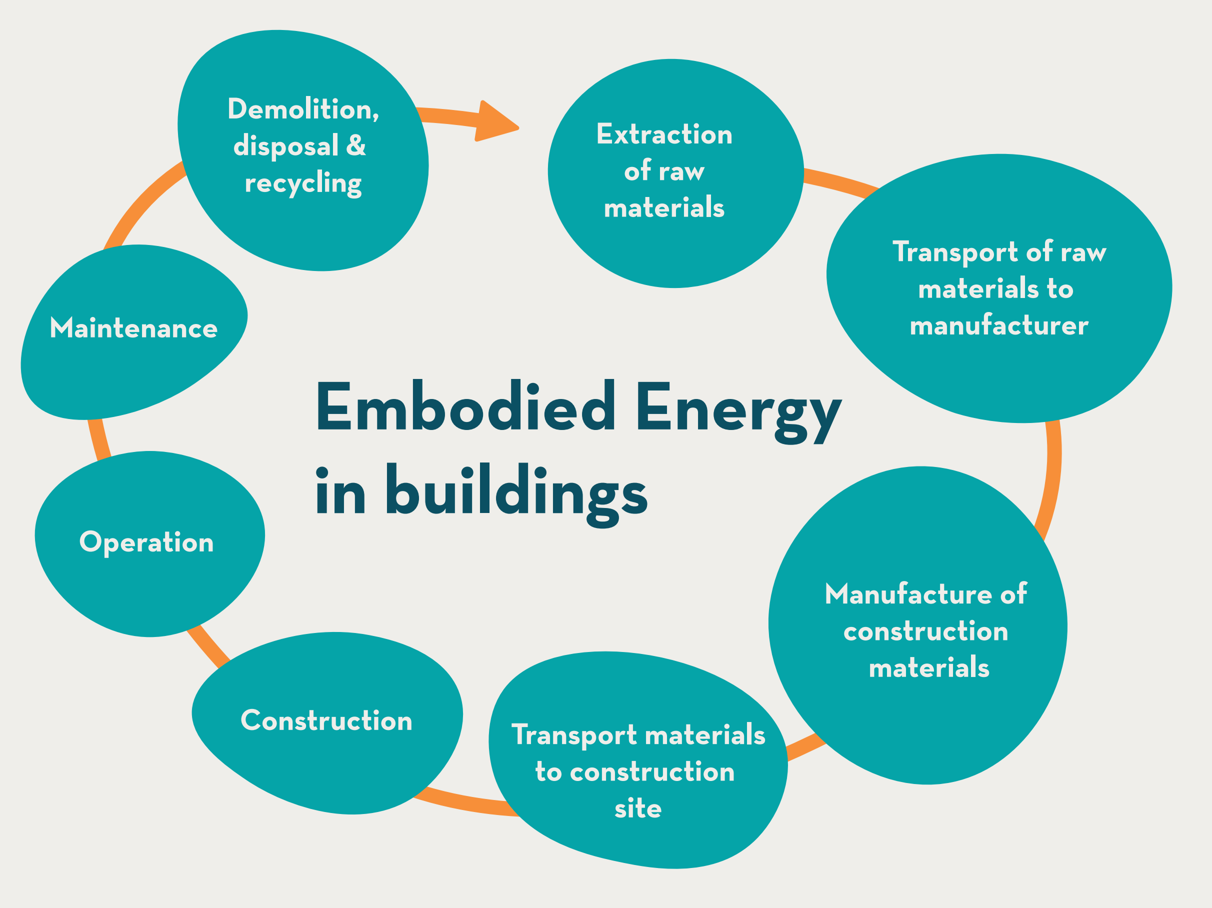
How do we measure total energy consumption and environmental costs?

The energy consumption that happens in the background of our lives can be easily overlooked and obscured. If we measure energy consumption only by how much electricity our devices use, how much gasoline our cars consume, or how much oil our heaters require, we may miss the largest impact of our lifestyles on the rate of our collective energy consumption and the environmental impacts of our energy use.

There are a few different ways of conceptualizing the total energy consumed by objects, structures, individuals, households, communities, and other entities.

"Embodied Energy" is a term borrowed from the architecture and design professions. It describes the overall energy consumption represented by an object, structure, or material based on the energy consumed at every step in its creation: mining, transport of raw materials, intermediate processing, final-product manufacturing, transport to a construction site, installation or assembly, and ultimately demolition and disposal of materials. (Non-recyclable materials have higher Embodied Energy than recyclable materials.)

Embodied Energy does not include the additional energy used to make a structure perform its intended purpose. For instance, the Embodied Energy of a school building might include the energy used to mine, manufacture, transport, and install the materials that the building is made out of, including steel, concrete, glass, wood, and plastic. But it would not include the energy used to power the building's light bulbs, computers, and ventilation system.




Boris Rumenov Balabanov via World Bank

The Embodied Energy framework can be used to evaluate the energy impact of any human-made structure or object, including commodities like electronics, paper goods, furniture, processed food, and so on. In the smartphone example, Embodied Energy could include all the energy used in the mining, transport, and processing of raw materials; the energy used to manufacture the phone components and assembly of components into the final product; the energy used to package and transport the final product to a warehouse; the energy used in the warehouses and shipping vehicles that convey the object to its point of sale; and the eventual recycling of the phone. But it wouldn't include the electricity used to charge the phone throughout its lifetime. The energy used to operate a structure or machine is called the Operational Energy.

Over time, as materials naturally degrade, a structure or machine may require more energy inputs to perform the same function. For example, a lithium battery in a smartphone breaks down and contains less charge over time; it will eventually need to be disposed of and replaced. Because of this, a Life Cycle Energy Analysis is useful to conceptualize how a product's maintenance requirements shape energy consumption and how durability influences performance over time. A battery that could be drained and recharged infinitely would have lower Life Cycle Energy consumption, even if it required more energy to manufacture in the first place.

All of these metrics represent the true energy cost of a given object or structure in different ways. But they do not represent total environmental impact, which depends on what kind of energy is used at each step. This impact can be partially represented through Embodied Carbon metrics, which quantify the greenhouse gases released during mining, manufacturing, construction, and so on. A high-Embodied-Energy material that is manufactured using renewable energy sources like wind or solar power could have lower Embodied Carbon than a material that requires less energy to produce but requires the consumption of fossil fuels. These metrics can also account for greenhouse gas impacts beyond energy consumption.

Buildings represent almost 40 percent of the world's total carbon dioxide emissions, so building materials can provide a useful window into how energy consumption may be seen differently from different angles. For instance, while wood as a building material consumes less energy than steel — which must be forged in a (usually coal-fired) furnace — the harvesting of timber destroys trees that otherwise would "sequester," or store, carbon absorbed during photosynthesis and converted into plant matter as they grow. (However, some in the building materials industry argue that the opportunity to re-grow harvested trees, and thus sequester additional carbon, lowers the embodied carbon of sustainably-harvested timber.

Concrete is another example. After water, concrete is the second-most widely used substance on the planet. As a result, though the Embodied Energy of concrete, by weight, is much less than that of steel, steel and concrete contribute roughly the same amount to global carbon emissions (about 8 percent each). The primary reason for concrete's large "Carbon Footprint" is the chemistry involved in making cement, a key component material in the manufacture of concrete. For each ton of concrete that is manufactured, about 800kg of carbon dioxide are emitted. Meanwhile, the process of decomposing calcium carbonate (limestone) into calcium oxide and carbon dioxide to make cement emits 530kg of CO_2 per ton produced.

The "Carbon Footprint" framework can be applied to evaluate an individual, family, or community's total contribution to greenhouse gas emissions. An individual that consumed more energy over-all, but supplied their energy needs through renewable sources like wind and solar power, would have a lower Carbon Footprint than someone with less overall consumption who depended on fossil fuels.

Discussion

What is the best, most precise, or most useful way to measure energy consumption and impact?

It is important to recognize that these metrics are imprecise. Much data is lacking about the energy consumption and effect of different materials and processes. These calculations are most useful for making internal comparisons: qualitatively comparing two energy consumers, suggesting how a consumer might be able to shrink their Carbon Footprint by making changes, or deciding between two options in favor of the one with a relatively smaller footprint.

BREAK OUT

INVESTIGATION

Planning lifestyles

Scenario

You are members of a regional planning commission tasked with planning and siting a new housing project.

You have been presented with three model housing structures, two available land parcels, and different construction material options for various elements that will impact the structure's overall price and Embodied Energy. You can buy up to two of each type of land parcel, and as many of each housing model as you can afford within the budget. You expect to have 100 units of funding at your disposal. Your task is to formulate the best possible proposal: one that will house the maximum number of people while minimizing Embodied Energy and construction costs, as well as advancing the region's fight against greenhouse gas emissions and climate change. It's also important that the plan account for the longevity of the construction; a cheaply made building will have to be replaced in a few years — a waste of public money!

Instructions

For full activity materials, see:

Unit 4 Appendix
Pages 115-121

Use the attached materials to discuss the pros and cons of the different housing types, land parcels, and construction materials. Then, develop a plan using the attached schedule of costs to calculate the construction and Embodied Energy coefficients of your intended construction. Outline an argument in support of your plan, trying to anticipate potential criticisms, and present your plan to the group.

Which Model will you build and how many?

Which Parcel will you build on?

What Materials will you use for the structure, insulation, exterior, and roofing? Will you include parking, and if so, how much?

How will the siting and density of your project impact the energy consumption of its inhabitants?

Materials

MODEL A

Structure

Building footprint: 1,100 sq. ft

Stories: 2

Minimum lot dimensions including setbacks: 55x100

Occupancy

Households: 1

Maximum total occupancy: 6

Projected total occupancy: 3-5

Base Construction Cost: 2 units

Base Embodied Energy: 10 EE

PARCEL 1

County: Kings

Required parking per unit: 0

Size: ~10 acres (396,000 sq ft)

New roads required: No

Dimensions: 2 blocks (2x330x600)

Total cost of land: 15 units

OPTION	Cost	Embodied Energy	Notes
FRAMING	x total	x half base EE	Percent of overall structure: 50%
Softwood timber framing	$24/sq ft	3.4 MJ/KG	A traditional framing material, suitable for small structures. Timber is renewable as trees can be replanted.
Concrete framing	$16/sq ft	2 MJ/KG	Concrete is the second most consumed substance on the planet, after water.
Steel framing	$18/sq ft	35 MJ/KG	The strength-to-weight ratio of steel is 9 times that of concrete; this means that a steel structure will weigh one-ninth of what an equivalently strong concrete structure weighs. Up to 100 percent of structural steel can be recycled and reused.
Glue-laminated timber framing	$30/sq ft	4.6 MJ/KG	"Glulam" is stronger by weight than steel. Use of glulam means that less material is needed for the structure over-all. Glulam is believed to be very durable but it is a relatively new material so information is limited.

Debrief

Did all groups come to the same conclusions? Why or why not?

What unknowns would complicate the planning process?

What type of housing is being built in your community? Is it different from the type of housing you planned to build? What might prevent the type you favored from being built?

Calculating a climate footprint

In order to lower greenhouse gas emissions and prevent the extreme effects of anthropogenic climate change, overall energy consumption must be decreased. When lifestyles strongly contribute to energy consumption throughout the US, each of us can play a role in reducing energy consumption by making changes in our behaviors, consumer choices, and expectations. But some changes are easier to make than others, and some things that appear to be choices are also conditioned by our environments, our backgrounds, and the needs of the people around us. In this activity, a Carbon Footprint calculator is a jumping-off point for discussions and reflections on how you and your household might be able to reduce your energy consumption and contribute to the fight against climate change.

Instructions

Begin by using the calculator interface to make a list of the different activities that impact the household's carbon footprint.

> **Write a brief explanation for how each of these habits is tied to energy consumption, using reliable internet sources to research as necessary.**
>
> **Then, gather data about your household's habits.**

Over the course of a week, keep a journal tracking these activities and behaviors. Interview whichever household member pays your utility bills to gather the necessary data.

Use the average of the data you gathered to calculate the household's carbon footprint.

> **What factors contribute the most to your household's carbon footprint?**
>
> **Consider whether there are other lifestyle factors not included in the calculator that might contribute to the household's carbon footprint. How much would these contribute?**

Discuss with the members of your household what shapes their consumption habits.

> **Is your individual and collective behavior shaped more by convenience, cost, time-intensiveness, habit, pleasure, or simply by the options available?**

For full activity materials, see:

Unit 4 Appendix
Pages 122-123

Which behaviors could the household feasibly change? Which ones feel out of reach? Why?

Choose one category from the calculator — travel, home, food, or shopping — and use the internet to research in more depth how they contribute to energy consumption in American society. Also research the accessibility of different options, both for your particular household and for American consumers in general.

Is access to alternatives equally or equitably distributed? Why or why not?

Are individuals, corporations, governments, or other entities most responsible for the impact of this consumption behavior on the US's carbon footprint?

Write a one-page reflection about your data collection, calculations, and household discussion. Consider:

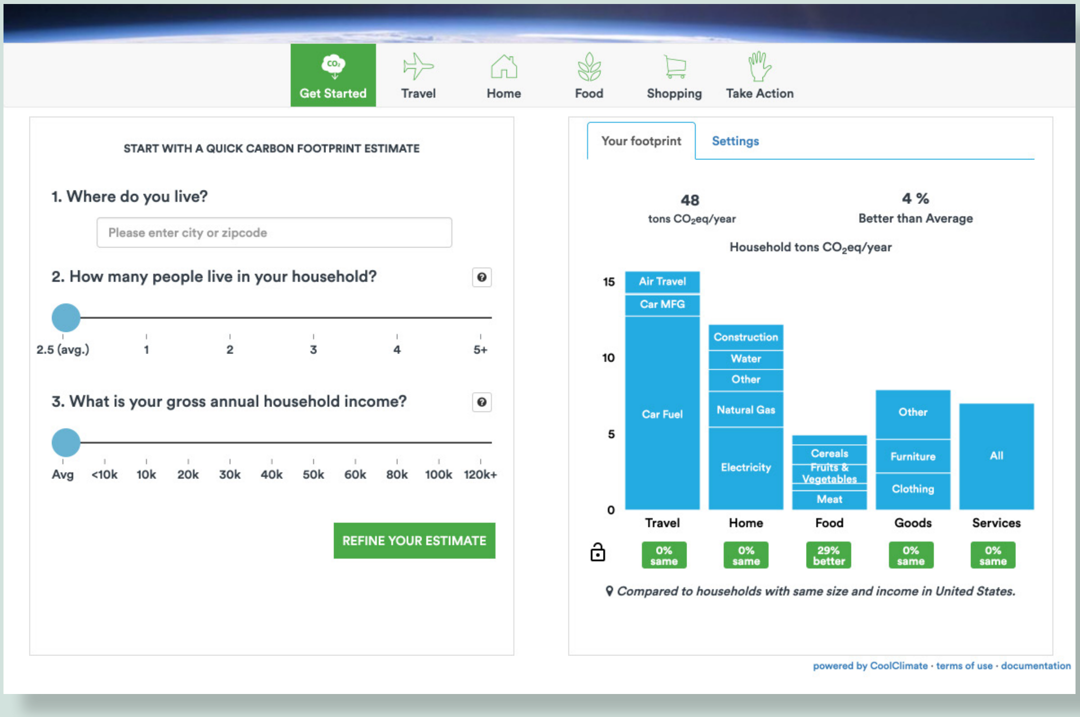
How would your household's day-to-day experience be different if you made these changes? Are there other changes you could make?

Do you feel empowered to make these changes? Do you believe that they can make a difference? Why or why not?

Source

UC Berkeley | CoolClimate footprint calculator

coolclimate.berkeley.edu/calculator



CORE CONCEPT 3

Energy allows goods and people to circulate

The transportation of goods and people is a primary driver of energy consumption and greenhouse gas emissions in modern life.

Container ship approaching Elizabeth-Port Authority Marine Terminal, June 2021
Brian Caraveo via Port Authority of New York and New Jersey

The energy of circulation

On a clear day, along the horizon, visitors to Jones Beach might spy the dark shapes of container ships far in the distance as they head for the Port Newark-Elizabeth Marine Terminal, the third-largest shipping port in the United States. These ships are an imposing reminder of one of energy's most important roles in 21st century American life. We spend our daily lives moving around in our local communities, going between home, school, work, parks, and the grocery store, but we are embedded in the networks of global circulation. Ships, trains, planes, and trucks criss-cross the globe, bearing the people, goods, and materials that construct and maintain our way of life. This circulation is only possible through the broad availability of energy, particularly fuel oil. In this Core Concept, students are encouraged to think critically about how circulation supports their own lives, often in invisible ways, even as greenhouse gas emissions from the transportation sector threaten the global future.

In the first activity, students analyze real data sets to identify the role of the transportation sector in driving energy consumption. Data first demonstrate the sector's overall energy consumption compared to other sectors, and then parse the relative contribution to greenhouse gas emissions of passenger cars, trucking, shipping, and aviation. A brief review of the history of national transportation infrastructure lays the groundwork for understanding the centrality of personal vehicle ownership in contemporary American life. The discussion then extends the narrative of the historical, geographical, and economic development of transportation in order to explain how a culture of personal consumption and consumer goods gave rise to the now behemoth global shipping industry. Global air travel is also explored as a driver of emissions. The discussion ultimately turns to the real reason — besides the sheer volume of goods and vehicles in circulation — that the transportation sector has such an enormous impact on emissions: fuel oil. Students become acquainted with the different grades of oil and their uses in different forms of transport, making the connection between the physical and material properties of a given sector's energy sources and its relative contribution to greenhouse gas emissions.

In the next activity, students analyze several proposals to "decarbonize" the shipping industry. Students evaluate and compare different proposals in a role-play context where they must represent competing special interests; ultimately they collaborate to reach a compromise and formulate an argument in favor of the interventions they find most promising. Finally, as a take-home activity, students examine data demonstrating a sharp drop in emissions at the beginning of the Covid-19 pandemic, largely due to the cessation of international air travel. Students then draw on this data and their personal experiences to reflect on the role of circulation in their own lives. What would it take to disentangle from these networks? Is that desirable? What is gained and what is lost by contracting to the local scale and reducing the energy consumption of circulation?

Long Island Expressway
Chris Gold

How do I move, and where do I go?

What is the role of transportation in my life?

Where do I go on a regular day, and how do I get there? Where do my family and community members travel, and how do they do it?

How do the things I consume reach me? Are they brought to me or do I go somewhere to acquire them? Where do they come from? How do they travel?

When I generate waste, where does it go?

PRIMER

Give students a few minutes to respond, either alone or in small groups. Then move into the next activity by inviting students to share their answers.

DISCUSSION

Transport, energy, fuel, and carbon

How are energy use and circulation linked in modern life?

In the past, energy has been a source of nutrients, fuel for industry, and infrastructure for societal expansion. In the 21st century, energy's foremost function is to enable the transportation of goods and people. Our lifestyles are made possible by a volume and speed of circulation, both nationally and globally, that is as unprecedented in human history as it is typical today.

There are more than 4.1 million miles of public road in the United States, traversed by more than 253 million passenger cars. These make 1.1 billion daily trips to cover over 11 billion miles, each day. There are almost 40 million miles of road criss-crossing the Earth's surface globally, on which travel around 1.4 billion cars and millions of other motor vehicles. The centrality of cars to daily life, throughout the world and especially in the 21st century United States, cannot be overstated. Likewise, the impact of this growing car culture on the national and global environment is impossible to ignore. Meanwhile, global commerce has crowded the seas with shipping vessels even as the number of trucks on the roads grows precipitously. As well as being a driving force in our daily lives, these networks of circulation are one of the primary drivers of greenhouse gas emissions worldwide.

BREAK OUT

For full activity materials, see:

Unit 4 Appendix Page 124

Data analysis

Examine the online data sets. Consider:

How does transportation contribute to overall energy consumption in the United States and globally?

How does transportation contribute to greenhouse gas emissions nationally and globally?

What kinds of transportation contribute the most?

Which countries contribute the most to the transportation sector's emissions?

Sources

Climate Watch | Historical emissions by sector and by country

climatewatchdata.org/data-explorer/

IEA | CO2 emissions by sector

iea.org/data-and-statistics?country=WORLD&fuel=CO2%20emissions&indicator=CO2BySector

Our World in Data | Cars, planes, trains: where do CO2 emissions from transport come from?

ourworldindata.org/co2-emissions-from-transport

World Resources Institute | Top GHG-emitting countries parsed by sector:

wri.org/insights/interactive-chart-shows-changes-worlds-top-10-emitters

Discussion

There are five main takeaways from this data:

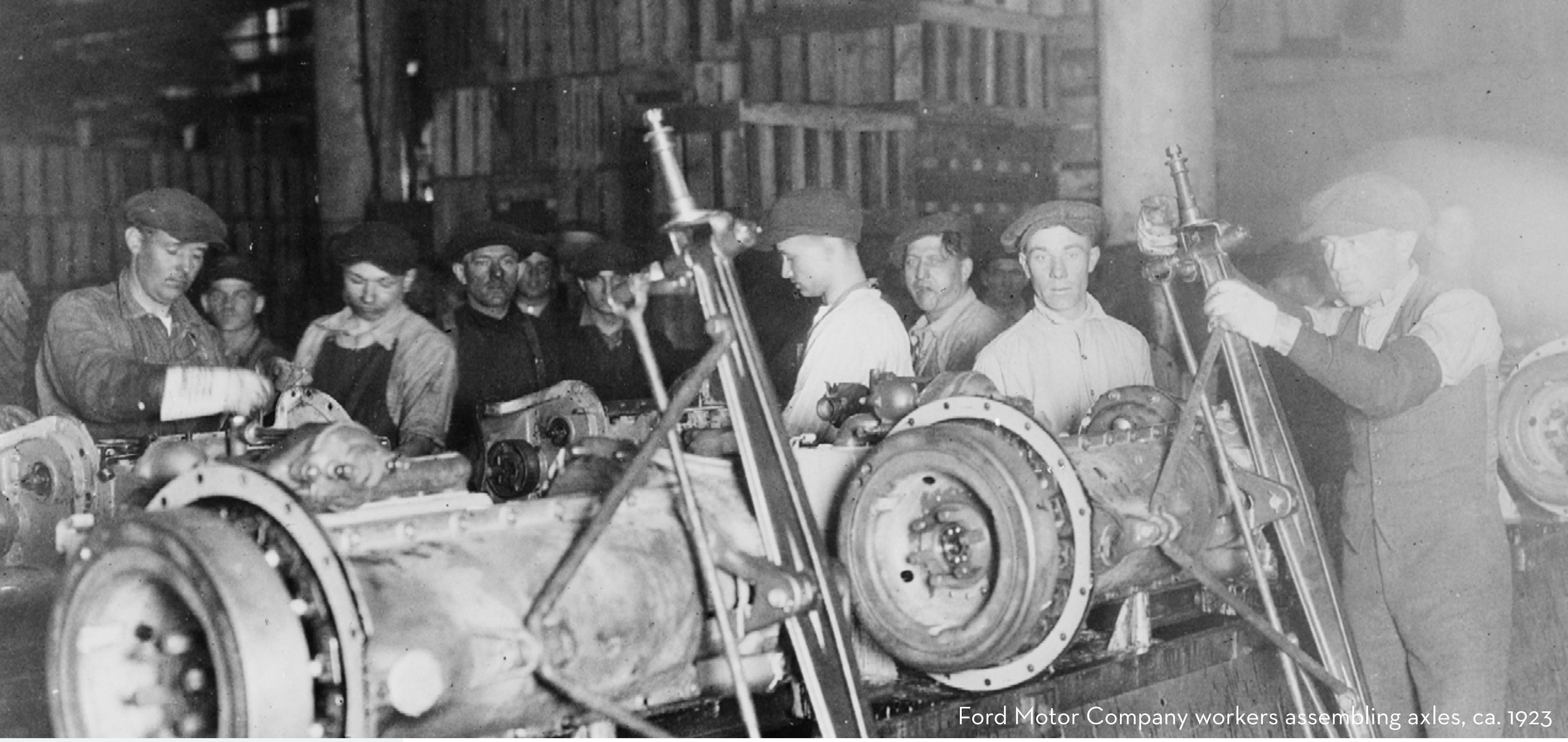
1. Transportation is responsible for about 30 percent of energy consumption in the US. Because the majority of greenhouse gas emissions from transport are in the form of carbon dioxide, a byproduct of hydrocarbon combustion, consumption of fuel energy and greenhouse gas emissions are closely correlated.

2. In the US, transportation accounts for 29 percent of greenhouse gas emissions. This is the largest share of any industry since transportation surpassed electricity generation in 2016.

3. Globally, transportation makes up about 24 percent of total greenhouse gas emissions.

4. Though in recent years China has been the largest contributor of greenhouse gases overall, the US is the largest contributor to transportation sector emissions by far.

5. Within the transportation sector, passenger car travel and trucking contribute the most greenhouse gases, with aviation and shipping contributing the next greatest share.



Ford Motor Company workers assembling axles, ca. 1923

LEARN MORE

See 3.2 and 3.3 for discussion of how transportation infrastructure came to shape so much of the American landscape in the 19th and 20th centuries.

How did transportation come to play such a large role in energy consumption and American life?

In the early and mid-20th century, a number of factors worked together to fix the centrality of the passenger car in modern American life. The development of assembly line production, alongside increased wages and rights for factory workers, created a new class of consumers for automobiles. The increasing population density of cities encouraged people with the means to do so (usually white middle class families) to move out of urban centers into burgeoning suburbs. And in the economic restructuring that following the Great Depression and World War II, multiple levels of government undertook large public works projects that helped boost the economy and employment figures, while creating the infrastructure – including highways – that would encourage the development of the American "car culture." The creation of Jones Beach State Park was one chapter in the story of Long Island's car-centric 20th century development.

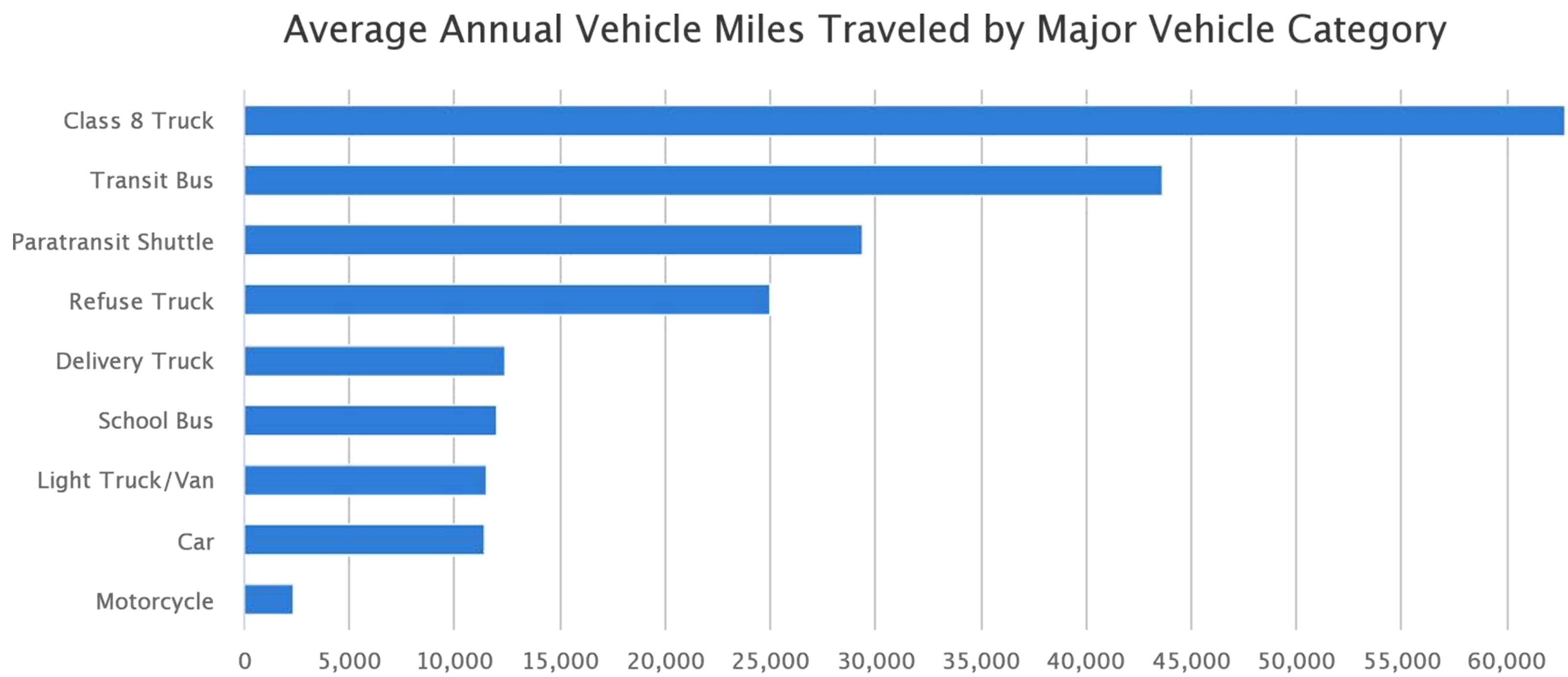
Today, the US far outstrips other countries in its number of vehicles per capita, especially compared to countries with similar total populations. Both proportionally and in absolute terms, there are a lot of cars in the United States: in 2019, 253.8 million. But car ownership is not the only factor driving greenhouse gas emissions in the US transportation sector. Cars and consumerism more broadly have historically gone hand-in-hand. The reasons for this are complex: cultural, economic, geographical, and political forces all play a role. At the same time that car ownership became central to American life at the end of World War II, government and business actors worked together to encourage the sale of consumer goods to individuals and families. Their aim was to maintain the manufacturing capacity developed during the war alongside the wartime economic recovery that followed two decades of struggle after the Great Depression. The ascendant advertising and media industries also played a role in communicating that consumerism was a core American value.

Meanwhile, the suburbanization that followed the growth of the car-owning middle class in the 1920s and '30s was ramped up in the 1950s, as government programs like the GI Bill sought to provide (some) returning soldiers with places to live and pathways to build wealth after the war. The geography of these suburbs promoted a way of life in which nuclear families were relatively isolated and autonomous and expected to have everything they needed within the confines of their homes. Appliances like refrigerators and washing machines would make domestic tasks easier; toys, televisions, and other media would make leisure time more entertaining. The impact on the national landscape was enormous. Food produced in large volume through industrial agricultural processes was transported many states away to residential areas for sale in supermarkets. Later, the rapid proliferation of shopping malls in suburban areas — at the exclusion of other public spaces — and the expansion of consumer credit would make shopping an even more central part of American life.

All together, these conditions set the stage for the expansion of commercial goods transportation. In subsequent decades, as companies began to move their manufacturing overseas in order to minimize labor costs and maximize profits, the consumer economy went global. Today, our local lifestyles are supplied by a circulation of goods, labor, and material that touches almost every corner of the globe.

On land, goods travel primarily by truck, which carry 72 percent of all freight in the US by weight; most of the rest is transported by freight train. Overseas, ships carry the majority of the freight that travels internationally — some freight travels by air, which is faster, but typically around five times more expensive than ocean freight. Cargo ships facilitate 80 to 90 percent of global trade by volume, and are responsible for about 3 percent of the world's greenhouse gas emissions. That might not sound like a lot, but consider this: If the shipping industry were a country, it would be the world's sixth largest emitter — ahead of Canada, Japan, and Brazil. Meanwhile, not only shopping is growing more global. Since the 1950s, international air travel has increased year by year at a steady rate. In 1950, there were 31 million air passengers globally, each traveling an average of 561 miles per flight. In 2019, there were 4.5 billion air passengers on 38.3 million flights, each traveling an average of 1,200 miles per trip.

JFK International Airport, New York
Eric Salard



BREAK OUT

Data analysis

How do trucks and passenger cars compare in their average miles traveled and their contributions to greenhouse gas emissions?

What does this data suggest about how US transportation behavior could be changed in order to reduce greenhouse gas emissions?

The graph from the Alternative Fuels Data Center shows the average miles traveled per vehicle of different classes of transport. Class-8 Trucks are 18-wheeler trucks, omnipresent on interstates and highways. These trucks travel long distances, meaning that each vehicle on the road logs, on average, more than 62,000 miles per year. Cars, meanwhile, average just short of 11,500 miles per vehicle per year. But their total contribution to the transportation sector's greenhouse gas emissions is much higher than trucking's contributions. Because the national rate of car ownership per capita is so high, cars are not being deployed efficiently: with fewer cars per capita, each vehicle might travel more miles, but, as a vehicle class, passenger cars could contribute less to emissions overall.

Sources

Department of Energy | Alternative Fuels Data Center

afdc.energy.gov/data/10309

While the total amount of energy consumed in the course of this global circulation is massive, it's not just the sheer volume of transport that is responsible for the transportation sector's environmental impact. It also comes down to the form of the energy itself. For the most part, passenger cars run on gasoline, a highly flammable liquid byproduct of petroleum refinement. Gasoline is useful for car engines — internal combustion engines — because its liquidity means it can vaporize at low temperatures. Though it is relatively less energy-dense than other forms of petroleum fuel, passenger cars are also relatively lightweight.

Freight trucks — the 18-wheelers often seen on interstate highways — mostly run on diesel fuel, which is less refined than gasoline and therefore less expensive. Diesel contains, at minimum, 13 percent more energy per gallon than gasoline, making it more efficient to move large, heavy trucks. But it also produces far more air pollution, including particulate matter called "black carbon," which is the ash that results from incompletely combusted hydrocarbon molecules. When deposited in the atmosphere, black carbon absorbs one million times as much thermal energy as carbon dioxide, and may be the second-largest contributor to climate change after CO_2. Container ships run on a fuel that mixes diesel with "bunker oil": a thick, sludgy oil that is the least refined byproduct of petroleum distillation. Bunker oil is even more polluting than diesel, releasing even greater quantities of black carbon into the atmosphere.

The jet fuel used to power airplanes is more energy-dense and less polluting than bunker oil. And because planes move more people further, along more direct paths, their efficiency, measured in miles transported per unit of energy, is greater than that of land or ocean vehicles. However, the pollutants that planes do release when they burn jet fuel are released directly into the upper atmosphere, where they may have a greater warming effect than emissions from the earth's surface. And air travel's energy efficiency depends on flights operating at maximum capacity, which is difficult to ensure within a fragmented, global system. Meanwhile, developing communication technologies make air travel for business purposes increasingly unnecessary. This means that greenhouse gas emissions from air travel could be cut with far less impact on daily life than emissions from trucking or passenger cars.


Port of Mumbai
Cyprien Hauser

Atlantic Right Whale close to shipping lane
Florida Fish and Wildlife Conservation Commission
Taken under NOAA research permit #15488

SPOTLIGHT

Shipping, speeding, noise pollution, and the ecosystem

Speeding and traffic noise aren't only problems for land-dwellers. Marine vehicles – including container ships, tankers, and smaller vessels like fishing boats and yachts – pose a significant threat to ecosystems in the waters around Jones Beach. Sonar, ship engines, and seismic air gun blasts used to explore the ocean floor can produce levels of noise that are hazardous to marine organisms. One study found that air guns, like those used to find fossil fuel deposits, can wipe out large numbers of zooplankton, including krill, which many larger marine animals depend on as a food source. Also at risk is the North Atlantic Right Whale, which migrates through the New York Bight to the south of Jones Beach – the same channel used by ships approaching the Port of Newark. Once on the brink of extinction due to overhunting by whalers, the North Atlantic Right Whale population has recovered somewhat, but the whales remain Endangered. Some estimates count fewer than 400 individuals. Whales and other marine organisms use clicks and other sounds to communicate in ocean waters; the noise produced by ships can confuse their efforts at echolocation, causing fatal collisions and interfering with migration and mating. Encounters with ships led to death or serious injury for Right Whales 86 times between 2000 and 2017. The noise may also stress the whales, leading to an increase in stress hormones in their bodies and affecting them biologically. One solution is to reduce the speed of container ships entering and leaving nearby ports. But a recent study found that 80 percent of ships in the New York Bight did not comply with existing speed limits. With noise from shipping projected to double between 2016 and 2030, this is a problem requiring urgent attention.

How else does the transportation sector's energy consumption affect the environment?

Besides the climate change that results from the transportation sector's greenhouse gas emissions, our high-circulation lifestyle has many direct environmental effects. Fuel-powered vehicles — especially diesel-powered vehicles like trucks — produce air pollution that causes lung disease. People who live near heavily trafficked trucking routes have much higher rates of asthma and lung cancer than average. Noise pollution from traffic also has negative health effects in humans, causing stress that increases the risk of cardiovascular disease. Both noise and chemical air pollution disrupt habitats for birds and other wildlife, which in turn impacts plant life by interfering with pollination or seed distribution. Road construction disrupts and destroys habitats and the installation of impermeable pavements can make remaining habitat more susceptible to flooding and toxic run-off. In international freight shipping, oil leaks and other chemical pollution can be toxic to fish and other sea-life.

Between 1990 and 2005, trucking became 12 percent less energy efficient as a mode of freight transport, largely due to the expansion of small shipments, idling in urban areas, and the number of "empty miles" traveled due to globalized trade. One study calculated that a speed reduction of 10 percent in the global container shipping industry would result in a 27 percent reduction in emissions. But the imperative to transport goods as quickly as possible has only intensified in recent years with the growth in the global e-commerce market.

The expansion of e-commerce has dovetailed with the normalization of "just-in-time" shipping — consumers' expectation that they will be able to receive goods ordered online within a few days at most. The emphasis on speed and convenience hugely amplifies freight industry's environmental impact. In urban centers, "last-mile" delivery — the movement of parcels from distribution centers to homes and businesses via parcel delivery services like UPS and FedEx — accounts for a significant proportion of the transportation sector's emissions, while more and more urban space is given over to warehouses and distribution centers. City streets are clogged with delivery trucks, leading to traffic jams. As they idle, vehicles burn fuel and fill the air with greenhouse gases and toxic particulates. And with more cars on the road in general, traffic and its negative effects have only gotten worse: commute times have increased from 20 to 35 percent in cities like Los Angeles, Beijing, and New York.

DEBATE

“Greening” the transportation industry

Scenario

In this activity, you must evaluate and debate different proposals for decarbonizing the transportation industry. As part of the federal government’s green energy transition plan, $60 billion has been allocated to develop new technologies to reduce the environmental impact of the transportation industry. In a series of congressional hearings, experts and stakeholders are due to testify in favor of their preferred funding proposals and/or against proposals they do not support.

Many of the people giving testimony represent constituents or companies that have historically organized against green energy policy. However, as climate change has given rise to more extreme weather events that threaten their industrial activities, the writing is on the wall. The energy of transportation must change. Some of these Stakeholder Representatives have come in front of Congress to advocate for a specific proposal that can help their communities or businesses move into a new phase; others have come to try to block proposals they see as particularly threatening to their constituencies or bottom line. Each group of two to four students is the "Staff" of one of these Stakeholder Representatives, tasked with advocating in favor of their agenda in a class-wide debate.

Instructions

For full activity materials, see:

Unit 4 Appendix
Pages 125-159

Start by analyzing the motivations and desires of the assigned profile, distill talking points from the provided data sets, and formulate a persuasive cultural argument for the proposed solution. Then, select one group member to represent the Stakeholder in the class-wide debate.

During the debate, consider each proposal one at a time, with Stakeholder Representatives invited to speak for or against any proposal.

Before the vote, all participants will have the opportunity to lobby and make deals with one another to advance their preferred outcome.

During voting, each participant may abstain from ranking once, or rank a proposal “with amendments” once.

If there is a tie, or sufficient support for amending the proposal, the group will have the opportunity to vote on and approve or disapprove your amendment; then the proposals will be ranked again.

Materials

Proposals

The Green Wheels Plan

Gasoline car buyback and retrofitting programs; research & development for electrified non-passenger vehicles (fork lifts, tractors, trucks, etc.); Consumer and industry tax incentives for electric passenger vehicles

The Fast Track Future Plan

Expansion of infrastructure; investment in maintenance of existing infrastructure; research & development for high-speed, low-emission passenger and freight rail

The Clean Packages Plan

Research & development and tax incentives for alternative fuels; regulate shipping pricing to reflect emissions cost [....]

Profiles

Representative from Michigan's 13th Congressional District

Your constituents have historically depended on the auto industry for employment. However, in recent decades, the vast majority of auto factories in Detroit have closed down and the city has been struggling. Some new industries, including arts and tech start-ups, have moved in but nothing has really taken the place of the auto industry as an economic driver.

You are in favor of the Green Wheels Plan, which you hope will revive the auto industry, and the Get Local Plan, which you hope will encourage development [...]

Sources

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"Greenhouse gas emissions from global shipping, 2013–2015," International Council on Clean Transportation, 2017

"The potential of liquid biofuels in reducing ship emissions," International Council on Clean Transportation, 2020

"Climate Emergency | Urban Opportunity," Coalition for Urban Transitions, 2019 – Chapter 2 (p. 28-60)

TAKE HOME: CREATIVE WRITING

Pandemic paradigm shift

In the Spring of 2020, environmental scientists observed a striking drop in greenhouse gas emissions. The impact of Covid-19 on lifestyles in the US and abroad at that point was unmistakable. Circulation was put on hold — global cities came under lockdown, and international flights were grounded. In the US, with offices, schools, and other institutions closed to the public, many Americans found themselves suddenly unemployed or working from home, spending much more time in their neighborhoods and localities. In the United States, energy-related emissions declined by 11 percent in 2020, with the majority the decrease coming from the transportation sector. Emissions from transportation dropped 15 percent, compared to a 6 percent and 8 percent drop from the residential and industrial energy use sectors, respectively. Globally, total emissions dropped 7 percent in 2020, the largest decrease in history.

Since the beginning of 2021, however, emissions returned to their regular level and continued to climb. Now, many scientists and other concerned observers of the global climate are wondering: if the low-emissions period was a brief demonstration of how the world will have to change in order to avert climate crisis, what would be necessary to make those changes a permanent reality? And what would be lost and gained by changing our lifestyles in this way?

For full activity materials, see:

Unit 4 Appendix Page 160

Instructions

In writing, reflect on your experience of the pandemic from the perspective of transportation, mobility, and circulation. Consider the following questions:

In the spring of 2020, what was difficult about being "locked down"? What did you like about it?

What did you have access to? What didn't you have access to? What forms of transportation did you rely on?

How did constrained movement change the way you related to your home? Did you feel more or less connected to your community?

What do you think is lost and gained by being so globally connected? What would be lost and gained by transitioning to a more locally-focused lifestyle?

How does the idea of a future with more limited circulation make you feel?

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