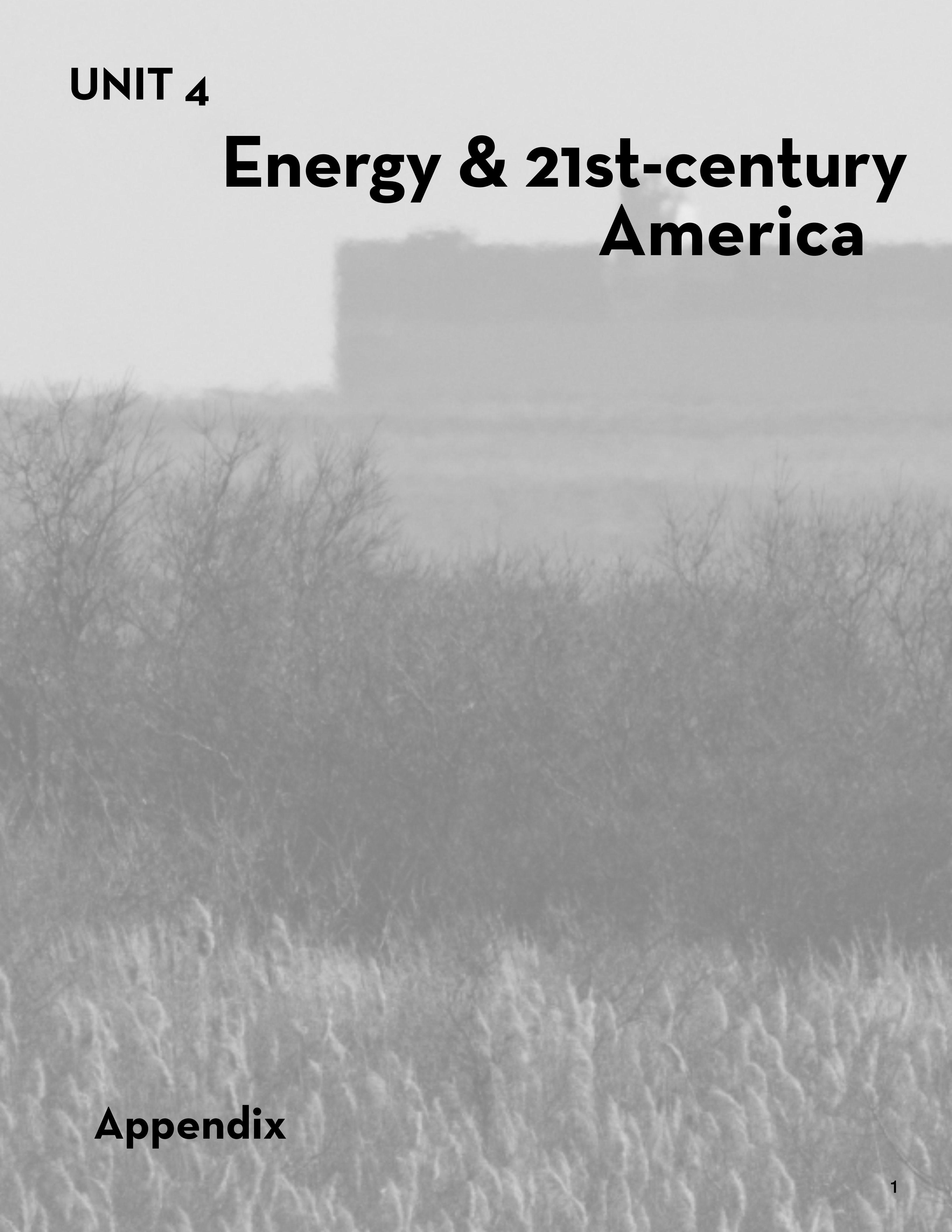

## UNIT 4

# Energy & 21st-century America

## Appendix

# Map analysis

**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. 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

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 57 people died, most of them from hypothermia, and one million people were without power for more than ten days after the storm. 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 events surrounding the Winter Strom Uri blackouts using the attached sources, using the Internet to supplement as necessary. Consider the following questions, and develop a short memo summarizing what occurred.

**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.

"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

"Never Again: How to Prevent Another Major Texas Electricity Failure," PUC of Texas Commissioners Report, June 10, 2021

WINTER STORM 2021

# 2 million Texas households without power as massive winter storm drives demand for electricity

> Some utility companies that deliver electricity to Texans are telling customers to expect power outages through Monday night and potentially into Tuesday.

BY **MITCHELL FERMAN**, **SAMI SPARBER** AND **ELVIA LIMÓN** FEB. 15, 2021
UPDATED: 7 PM CENTRAL

COPY LINK

Interstate 35 near Stassney Lane in Austin was blanketed with snow on the morning of Feb. 15. A major winter storm affected the entire state of Texas. Miguel Gutierrez Jr./The Texas Tribune

## Winter Storm 2021

*As Texas faced record-low temperatures this February and snow and ice made roads impassable, the state's electric grid operator lost control of the power supply, leaving millions without access to electricity. As the blackouts extended from hours to days, top state lawmakers called for investigations into the Electric Reliability Council of Texas, and Texans demanded accountability for the disaster. We have compiled a list of resources for Texans who are seeking help, or places to get warm. To get updates sent straight to your phone, text "hello" to 512-967-6919 or visit this page to sign up.* **MORE IN THIS SERIES ⟶**

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**Here's what you need to know:**

- 2 million Texas households are without power
- Dallas urges residents to reduce their electricity usage
- Houston mayor seeks answers on how outages were handled
- Texas cities open emergency shelters
- 100,000 Fort Worth residents receive boil water notice
- State sending extra resources to help across Texas

The state's electric grid operator lost control of the power supply Monday morning as 2 million Texas households didn't have heat or other electric appliances working at home while a massive winter storm delivered freezing temperatures across the state.

When the state's grid operator, the Electric Reliability Council of Texas, began implementing rolling blackouts at 1:25 a.m. Monday, the outages were intended to be implemented on a rolling basis — up to 45 minutes per affected area, according to the ERCOT.

Instead, some Texans in Austin, Houston and other cities were without power into Monday afternoon and all morning since even before ERCOT called for the rolling blackouts. And some companies that deliver electricity to households and businesses have told customers to expect to be without power through at least the end of the day as they work to restore power generating units that went offline during the storm.

“Unfortunately, if you are a customer who is currently experiencing an outage, you should be prepared to be without power for at least the rest of the day,” tweeted CenterPoint Energy. Houston Mayor Sylvester Turner said midday Monday that more than 1.1 million CenterPoint customers were without power.

Jackie Sargent, the general manager for Austin Energy, said Monday afternoon that based on information from ERCOT, the local power outages could extend into Tuesday afternoon.

“We are aware of where our system is at, and we are operating with the constraints and the direction of ERCOT,” she said. “ERCOT has said that based on what they are looking at that, this situation is likely to continue through the night and possibly into the afternoon tomorrow. So it depends on what we do as consumers in managing our load, our consumption of electricity.”

The electricity grid was designed to be in high demand during the summer, when Texans crank their air conditioning at home. But some of the energy sources that power the grid during the summer are offline during the winter. So when Texans stayed home during the storm on Sunday and demanded record amounts of electricity, the state’s energy system could not keep up.

Some of the energy sources powering the grid were knocked out by the inclement weather, most of which were facilities run by gas, coal or nuclear energy.

“Most of the plants that went offline during evening and morning today were fueled by one of those sources,” said Dan Woodfin, senior director of system operations at ERCOT.

Wind turbines, which provide a much smaller source of energy for the state’s power grid, were iced over and also out of commission.

The storm that hit Texas is rare for both its scope and its intensity. On Sunday, the National Weather Service issued a winter storm warning for all 254 counties. Cities like Dallas and Austin had temperatures in the single digits Monday morning. Close to the coast in places like Houston and Corpus Christi, the weather was in the teens.

ERCOT announced Sunday night that it had set a winter record for power demand, reaching 69,150 megawatts between 6 and 7 p.m. ERCOT said Monday morning that 30,000 megawatts of power generation had been forced off the system. The grid operator also said it would provide an update at 10:30 a.m. Central time Monday.

The storm has shut down much of the state. Numerous roads are iced over, many schools have closed and, at Gov. Greg Abbott's request, President Joe Biden declared a federal emergency declaration across the state. Despite Abbott's request, Turner, the Houston mayor, said the state needs to take responsibility for what happened.

“The state must own and explain the magnitude of these power outages across the State,” Turner tweeted Monday.

Abbott didn't publicly address the widespread outages until 1:29 p.m., more than 12 hours after hundreds of thousands of Texans began losing power.

“Many power generation companies' facilities froze overnight and shut down their ability to generate power,” Abbott tweeted. “They are working to get power back on line.”

— *Mitchell Ferman and Sami Sparber*

## “This is a very serious emergency”

In Dallas, County Judge Clay Jenkins declared a state of emergency and asked nonessential businesses to delay their opening or start times until 10 a.m. Tuesday. The order also asks manufacturing and industrial businesses that “use electricity in their operation or processes” to close on Tuesday.

Jenkins also strongly urged residents to set their thermostats to no more than 68 degrees Fahrenheit.

“This is a very serious emergency,” Jenkins said during a Monday night press conference. “My full focus is on this emergency and yours should be too.”

A spokesperson for the power company Oncor said most of the power outages in Dallas-Fort Worth have been due to excess demand. “That increased demand and that load has resulted in some of our transformers having equipment failures just because they’re having to run like it’s a 100-plus degree summer day,” the spokesperson, Kerri Dunn, said.

Dunn did not say when Dallas-area residents would get their power back, noting the overnight winter weather might complicate efforts. — *Elvia Limón*

### Houston mayor seeks answers on how outages were handled

In Houston, Mayor Sylvester Turner said that while the situation with this weekend’s winter storm was unprecedented, it should spark a debate on Texas’ electric resiliency.

“When this is all over, we will need to have a conversation — a serious conversation — about why we are where we are today,” Turner said Monday at a news conference. “These are not rolling blackouts. These are power outages at a huge unprecedented scale.”

According to CenterPoint Energy, around 1.2 million users in the Houston area are without power. Turner also said that the number of outages could increase as temperatures go down in the evening and that they could last even until tomorrow. By Monday afternoon, that number had gone down to 1 million.

On Monday afternoon, Harris County Judge Lina Hidalgo said about 70,000 of the outages in the area were because of weather damage and that CenterPoint was working to restore power to those homes.

“The bottom line is that neither CenterPoint nor I can give you an estimate on when the power will come back on,” she said. “As much as we wish it wasn’t so, things will likely get worse until they get better.”

Hidalgo also said a Harris County Health Department, where 8,400 of Moderna vaccines were being stored, had a power outage around 2 a.m. Monday and its background generator failed. County officials were able to distribute 5,410 of vaccines to several area hospitals, the county jail and Rice University before they could spoil, she said. The rest of the vaccines were stored again after receiving guidance from Moderna representatives, Hidalgo said. — *Elvia Limón*

## Texas cities open emergency shelters

Several cities across the state have opened emergency shelters for residents without homes. In Dallas, the Kay Bailey Hutchison Convention Center opened on Friday to 300 people and will remain open as long as temperatures are below freezing, reports NBC DFW.

On Monday, Fort Worth Mayor Betsy Price said residents could call 817-392-1234 to be directed to one of the city's warming centers. Residents can also find transportation help by calling that number.

The George R. Brown Convention Center and Lakewood Church in Houston opened as warming centers Sunday. Houston set up 500 beds inside the convention center and allowed pets. But on Sunday night, Houston Mayor Sylvester Turner said in a tweet that the center was nearing capacity. Turner said residents who need access to a warming center should call 311 or 211 to be directed to one of the several shelters in the city.

In Austin, a warming center opened on Saturday at Palmer Events Center. Austin officials said single adults in need of shelter should report to the Central Library and that families should go to the Downtown Salvation Army Shelter, reports KVUE. Several community organizations in San Antonio are stepping up to help unsheltered residents with a place to stay, food or supplies to keep warm. — *Elvia Limón*

## 100,000 Fort Worth residents receive boil water notice

Around 100,000 of Fort Worth residents are under a boil water order after a water treatment plant experiencing multiple power outages on Monday, reports WFAA. The Eagle Mountain Water Plant and raw water pump station has been without power for more than two hours. The boil order is expected to last until at least midday Wednesday. Even after water service returns, officials will need 24 hours to test the water.

Meanwhile, the city of Kyle in Central Texas is asking residents to stop all water use until further notice. According to the city's Twitter account, Kyle is close to "running out of water supply" after power outages at the Guadalupe-Blanco River Authority and locally. — *Elvia Limón*

## State sending extra resources to help across Texas

As Texans across the state grapple with a lack of power amid freezing temperatures, Gov. Greg Abbott on Monday said that he and the Texas Military Department have deployed National Guard troops across the state to help take people to one of the 135 local warming centers set up across Texas.

Other state agencies are also deploying resources and personnel to help local officials clear roadways and assist essential workers, including health care professionals and power grid workers.

Among the resource deployments Abbott announced:

- 3,300 troopers and 3,300 patrol vehicles from the Texas Department of Public Safety
- 90 personnel members and 28 high-mobility vehicles from the Texas Military Department
- 585 personnel members, 531 4x4 vehicles, one aircraft and nine K9 teams from Texas Parks and Wildlife
- 2,314 personnel, 695 snowplows and 757 4x4 vehicles from the Texas Department of Transportation.

## Drivers urged to stay home as road crews plan work

State transportation officials are urging Texas drivers to stay home as crews work to clear snow and ice from roads.

Low temperatures and snow accumulation resulted in freezing on roadway surfaces across the state, a spokesperson for the Texas Department of Transportation said in an email Monday afternoon.

“TxDOT crews have been treating roads across the state since early last week, and now we are plowing snow and once snow is removed, we can start to spot treat again,” Ryan LaFontaine said. “This weather event is expected to continue so we urge drivers to stay home and exercise patience as we try to clear roadways safely.” — *Sami Sparber*

**Here's how to help:**

- **Dallas:** Dallas Homeless Alliance President and CEO Carl Falconer said donations can be made to Our Calling, who is managing the city's shelter at the convention center.

- **Austin:** Chris Davis, communications manager for Austin's Ending Community Homelessness Coalition, or ECHO, said people can find a list of ways to help here. These donations range from sleeping bags to monetary donations for hygiene and snack kits.

- **San Antonio:** South Alamo Regional Alliance for the Homeless Executive Director Katie Vela said their biggest area of need is volunteers to work the overnight shifts, especially those living in the downtown area who might be able to walk to the shelters. Vela also said the shelters are also in need of hot meals beginning Tuesday. People can find the list of shelters here.

- **Houston:** Catherine B. Villarreal, the director of communications for the Coalition for the Homeless, said people can donate to any of the organizations in The Way Home listed here.

## Help us cover coronavirus in 2021

The Texas Tribune newsroom is reporting on how the new coronavirus is affecting Texans. From testing to health care interactions to economic impacts, we want to hear from you.

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**https://www.texastribune.org/about/tips/**

Are you one of these...

☐ Medical professional
☐ College student
☐ Parent
☐ Other

What immediate help do you need most?

Tell us about your experience: Where did you go to get it, how long did you wait, how long did it take you to find an available vaccine?

**WINTER STORM 2021**

# Texas leaders failed to heed warnings that left the state's power grid vulnerable to winter extremes, experts say

> Texas officials knew winter storms could leave the state’s power grid vulnerable, but they left the choice to prepare for harsh weather up to the power companies — many of which opted against the costly upgrades. That, plus a deregulated energy market largely isolated from the rest of the country’s power grid, left the state alone to deal with the crisis, experts said.

BY **ERIN DOUGLAS**, **KATE MCGEE** AND **JOLIE MCCULLOUGH** FEB. 17, 2021
UPDATED: FEB. 19, 2021

COPY LINK

Energy and policy experts said Texas' decision not to require equipment upgrades to better withstand extreme winter temperatures, and choice to operate mostly isolated from other grids in the U.S. left power system unprepared for the winter crisis. 📷 Jordan Vonderhaar for The Texas Tribune

## Winter Storm 2021

*As Texas faced record-low temperatures this February and snow and ice made roads impassable, the state's electric grid operator lost control of the power supply, leaving millions without access to electricity. As the blackouts extended from hours to days, top state lawmakers called for investigations into the Electric Reliability Council of Texas, and Texans demanded accountability for the disaster. We have compiled a list of resources for Texans who are seeking help, or places to get warm. To get updates sent straight to your phone, text "hello" to 512-967-6919 or visit this page to sign up.* **MORE IN THIS SERIES →**

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Millions of Texans have gone days without power or heat in subfreezing temperatures brought on by snow and ice storms. Limited regulations on companies that generate power and a history of isolating Texas from federal oversight help explain the crisis, energy and policy experts told The Texas Tribune.

While Texas Republicans were quick to pounce on renewable energy and to blame frozen wind turbines, the natural gas, nuclear and coal plants that provide most of the state's energy also struggled to operate during the storm. Officials with the Electric Reliability Council of Texas, the energy grid operator for most of the state, said that the state's power system was simply no match for the deep freeze.

"Nuclear units, gas units, wind turbines, even solar, in different ways — the very cold weather and snow has impacted every type of generator," said Dan Woodfin, a senior director at ERCOT.

Energy and policy experts said Texas' decision not to require equipment upgrades to better withstand extreme winter temperatures, and choice to operate mostly isolated from other grids in the U.S. left power system unprepared for the winter crisis.

## February Winter Storm 2021

**When will my water come back? How can I get water in the meantime?**

**Will I get a large energy bill?**

**How can I get updates?**

**I was without power for more than a day. Why are people calling these rolling outages?**

**Wait, we have our own power grid? Why?**

**I read online that wind turbines are the reason we lost power. Is that true?**

**How can I stay warm? How can I help others?**

SEE MORE COVERAGE

Policy observers blamed the power system failure on the legislators and state agencies who they say did not properly heed the warnings of previous storms or account for more extreme weather events warned of by climate scientists. Instead, Texas prioritized the free market.

“Clearly we need to change our regulatory focus to protect the people, not profits,” said Tom “Smitty” Smith, a now-retired former director of Public Citizen, an Austin-based consumer advocacy group who advocated for changes after in 2011 when Texas faced a similar energy crisis.

“Instead of taking any regulatory action, we ended up getting guidelines that were unenforceable and largely ignored in [power companies’] rush for profits,” he said.

It is possible to “winterize” natural gas power plants, natural gas production, wind turbines and other energy infrastructure, experts said, through practices like insulating pipelines. These upgrades help prevent major interruptions in other states with regularly cold weather.

## Lessons from 2011

In 2011, Texas faced a very similar storm that froze natural gas wells and affected coal plants and wind turbines, leading to power outages across the state. A decade later, Texas power generators have still not made all the investments necessary to prevent plants from tripping offline during extreme cold, experts said.

Woodfin, of ERCOT, acknowledged that there's no requirement to prepare power infrastructure for such extremely low temperatures. "Those are not mandatory, it's a voluntary guideline to decide to do those things," he said. "There are financial incentives to stay online, but there is no regulation at this point."

The North American Electric Reliability Corporation, which has some authority to regulate power generators in the U.S., is currently developing mandatory standards for "winterizing" energy infrastructure, a spokesperson said.

Texas politicians and regulators were warned after the 2011 storm that more "winterizing" of power infrastructure was necessary, a report by the Federal Energy Regulatory Commission and the North American Electric Reliability Corporation shows. The large number of units that tripped offline or couldn't start during that storm "demonstrates that the generators did not adequately anticipate the full impact of the extended cold weather and high winds," regulators wrote at the time. More thorough preparation for cold weather could have prevented the outages, the report said.

"This should have been addressed in 2011 by the Legislature after that market meltdown, but there was no substantial follow up," by state politicians or regulators, said Ed Hirs, an energy fellow and economics professor at the University of Houston. "They skipped on down the road with business as usual."

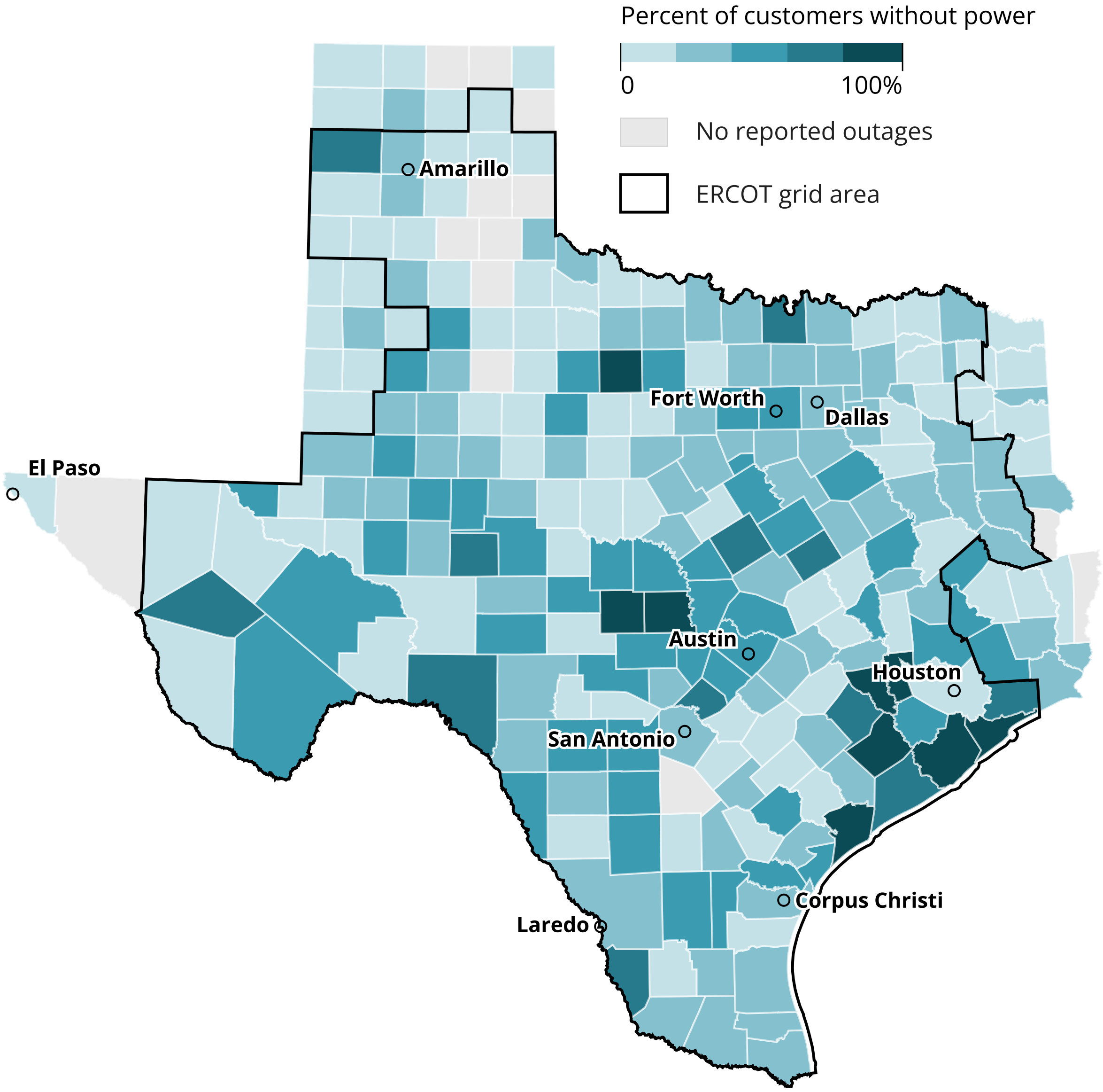
ERCOT officials said that some generators implemented new winter practices after the freeze a decade ago, and new voluntary "best practices" were adopted. Woodfin said that during subsequent storms, such as in 2018, it appeared that those efforts worked. But he said this storm was even more extreme than regulators anticipated based on models developed after the 2011 storm. He acknowledged that any changes made were "not sufficient to keep these generators online," during this storm.

After temperatures plummeted and snow covered large parts of the state Sunday night, ERCOT warned increased demand might lead to short-term, rolling blackouts. Instead, huge portions of the largest cities in Texas went dark and have remained without heat or power for days. On Tuesday, nearly 60% of

Houston households and businesses were without power. Of the total installed capacity to the electric grid, about 40% went offline during the storm, Woodfin said.

## On Feb. 16, at least 4.5 million customers in Texas were without power

The operator of Texas' power grid is under investigation after a massive winter storm caused millions of residents in the state to lose power for days. Here's where Texans were most impacted during the worst of the outages between 10 and 11 a.m. Feb. 16.



Note: PowerOutage.us gathers data from companies covering about 99% of utility customers in Texas. Data in some areas is incomplete, including the number of customers served.
Source: PowerOutage.us and the Electric Reliability Council of Texas
Credit: Chris Essig, The Texas Tribune, and Ren Larson, The Texas Tribune/ProPublica

## Climate wake-up call

Climate scientists in Texas agree with ERCOT leaders that this week's storm was unprecedented in some ways. They also say it's evidence that Texas is not prepared to handle an increasing number of more volatile and more extreme weather events.

"We cannot rely on our past to guide our future," said Dev Niyogi, a geosciences professor at the University of Texas at Austin who previously served as the state climatologist for Indiana. He noted that previous barometers are becoming less useful as states see more intense weather covering larger areas for prolonged periods of time. He said climate scientists want infrastructure design to consider a "much larger spectrum of possibilities" rather than treating these storms as a rarity, or a so-called "100-year event."

Katharine Hayhoe, a leading climate scientist at Texas Tech University, highlighted a 2018 study that showed how a warming Arctic is creating more severe polar vortex events. "It's a wake up call to say, 'What if these are getting more frequent?'" Hayhoe said. "Moving forward, that gives us even more reason to be more prepared in the future."

Hayhoe and Niyogi acknowledged there's uncertainty about the connection between climate change and cold air outbreaks from the Arctic. However, they emphasize there is higher certainty that other extreme weather events such as drought, flooding and heat waves are exacerbated by a warming climate.

Other Texas officials looked beyond ERCOT. Dallas County Judge Clay Jenkins argued that the Texas Railroad Commission, which regulates the oil and gas industry — a remit that includes natural gas wells and pipelines — prioritized commercial customers over residents by not requiring equipment to be better equipped for cold weather. The RRC did not immediately respond to a request for comment.

"Other states require you to have cold weather packages on your generation equipment and require you to use, either through depth or through materials, gas piping that is less likely to freeze," Jenkins said.

Texas' electricity market is also deregulated, meaning that no one company owns all the power plants, transmission lines and distribution networks. Instead, several different companies generate and transmit power, which they sell on the wholesale market to yet more players. Those power companies in turn are the ones that sell to homes and businesses. Policy experts disagree on whether a different structure would have helped Texas navigate these outages. “I don’t think deregulation itself is necessarily the thing to blame here,” said Josh Rhodes, a research associate at University of Texas at Austin’s Energy Institute.

## History of isolation

Texas’ grid is also mostly isolated from other areas of the country, a set up designed to avoid federal regulation. It has some connectivity to Mexico and to the Eastern U.S. grid, but those ties have limits on what they can transmit. The Eastern U.S. is also facing the same winter storm that is creating a surge in power demand. That means that Texas has been unable to get much help from other areas.

“If you’re going to say you can handle it by yourself, step up and do it,” said Hirs, the UH energy fellow, of the state’s pursuit of an independent grid with a deregulated market. “That’s the incredible failure.”

Rhodes, of UT Austin, said Texas policy makers should consider more connections to the rest of the country. That, he acknowledged, could come at a higher financial cost — and so will any improvements to the grid to prevent future disasters. There’s an open question as to whether Texas leadership will be willing to fund, or politically support, any of these options.

“We need to have a conversation about if we believe that we’re going to have more weather events like this,” Rhodes said. “On some level, it comes down to if you want a more resilient grid, we can build it, it will just cost more money. What are you willing to pay? We’re going to have to confront that.”

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☐ College student

WINTER STORM 2021

# Texas largely relies on natural gas for power. It wasn’t ready for the extreme cold.

Texas largely relies on natural gas — especially during times of high demand — to power the state. Experts say natural gas infrastructure, from pumping it out of the ground to the plants in city centers, was unprepared for the plunging temperatures brought by the winter storm.

BY **ERIN DOUGLAS** FEB. 16, 2021 5 PM CENTRAL

COPY LINK

The Blanco Vista neighborhood of San Marcos is blanketed with snow after a massive winter weather system caused power outages across Texas. The outages during this storm far exceeded what the Electric Reliability Council of Texas predicted for an extreme winter event. The forecast for peak demand was 67 gigawatts; peak usage during the storm was more than 69 gigawatts on Sunday. 📷 Jordan Vonderhaar for The Texas Tribune

## Winter Storm 2021

*As Texas faced record-low temperatures this February and snow and ice made roads impassable, the state's electric grid operator lost control of the power supply, leaving millions without access to electricity. As the blackouts extended from hours to days, top state lawmakers called for investigations into the Electric Reliability Council of Texas, and Texans demanded accountability for the disaster. We have compiled a list of resources for Texans who are seeking help, or places to get warm. To get updates sent straight to your phone, text "hello" to 512-967-6919 or visit this page to sign up.*

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Failures across Texas' natural gas operations and supply chains due to extreme temperatures are the most significant cause of the power crisis that has left millions of Texans without heat and electricity during the winter storm sweeping the U.S.

From frozen natural gas wells to frozen wind turbines, all sources of power generation have faced difficulties during the winter storm. But Texans largely rely on natural gas for power and heat generation, especially during peak usage, experts said.

Officials for the Electric Reliability Council of Texas, which manages most of Texas' grid, said the primary cause of the outages Tuesday appeared to be the state's natural gas providers. Many are not designed to withstand such low temperatures on equipment or during production.

## February Winter Storm 2021

**When will my water come back? How can I get water in the meantime?** ▸

**Will I get a large energy bill?** ▸

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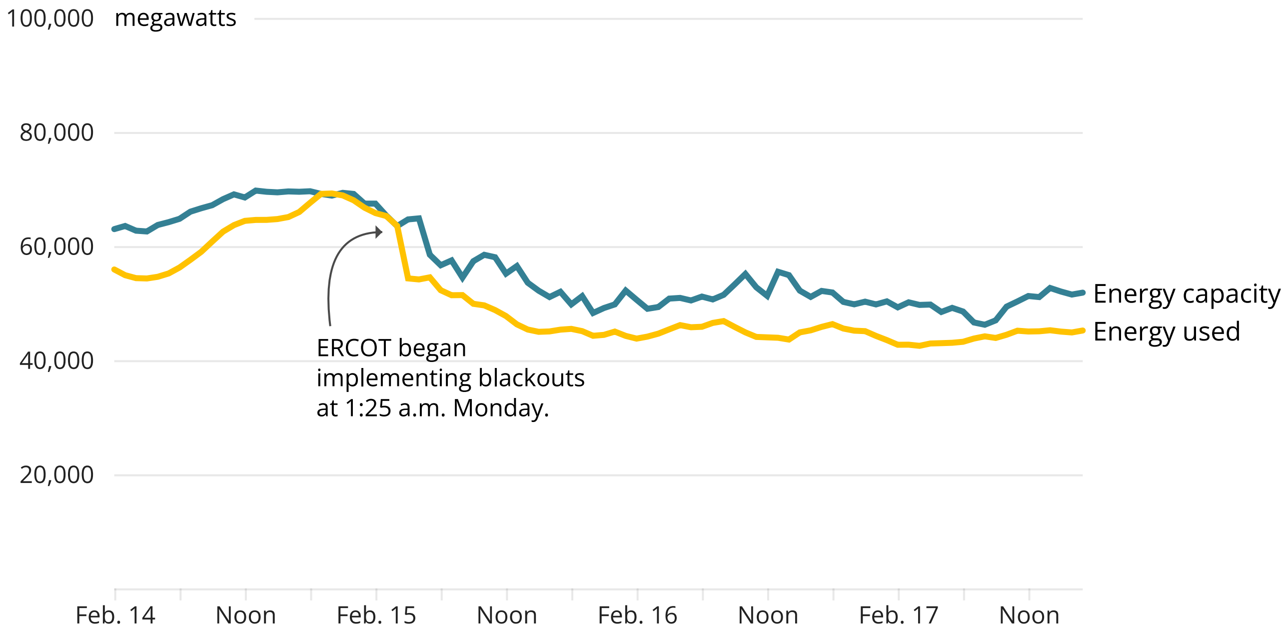
SEE MORE COVERAGE

By some estimates, nearly half of the state’s natural gas production has screeched to a halt due to the extremely low temperatures, while freezing components at natural gas-fired power plants have forced some operators to shut down.

“Texas is a gas state,” said Michael Webber, an energy resources professor at the University of Texas at Austin. While he said all of Texas’ energy sources share blame for the power crisis — at least one nuclear power plant has partially shut down, most notably — the natural gas industry is producing significantly less power than normal.

## ERCOT implemented blackouts on Monday as power plants went offline

Demand for electricity during the weekend cold front far exceeded what the Electric Reliability Council of Texas predicted for a winter storm. ERCOT implemented blackouts early Monday morning to reduce demand as low temperatures forced more power sources offline than expected.



Note: Energy capacity excludes offline power sources that could be brought online.
Source: Electric Reliability Council of Texas
Credit: Mandi Cai

“Gas is failing in the most spectacular fashion right now,” Webber said.

More than half of ERCOT’s winter generating capacity, largely powered by natural gas, was offline due to the storm, an estimated 45 gigawatts, according to Dan Woodfin, a senior director at ERCOT.

The outages during this storm far exceeded what ERCOT had predicted in November for an extreme winter event. The forecast for peak demand was 67 gigawatts; peak usage during the storm was more than 69 gigawatts Sunday.

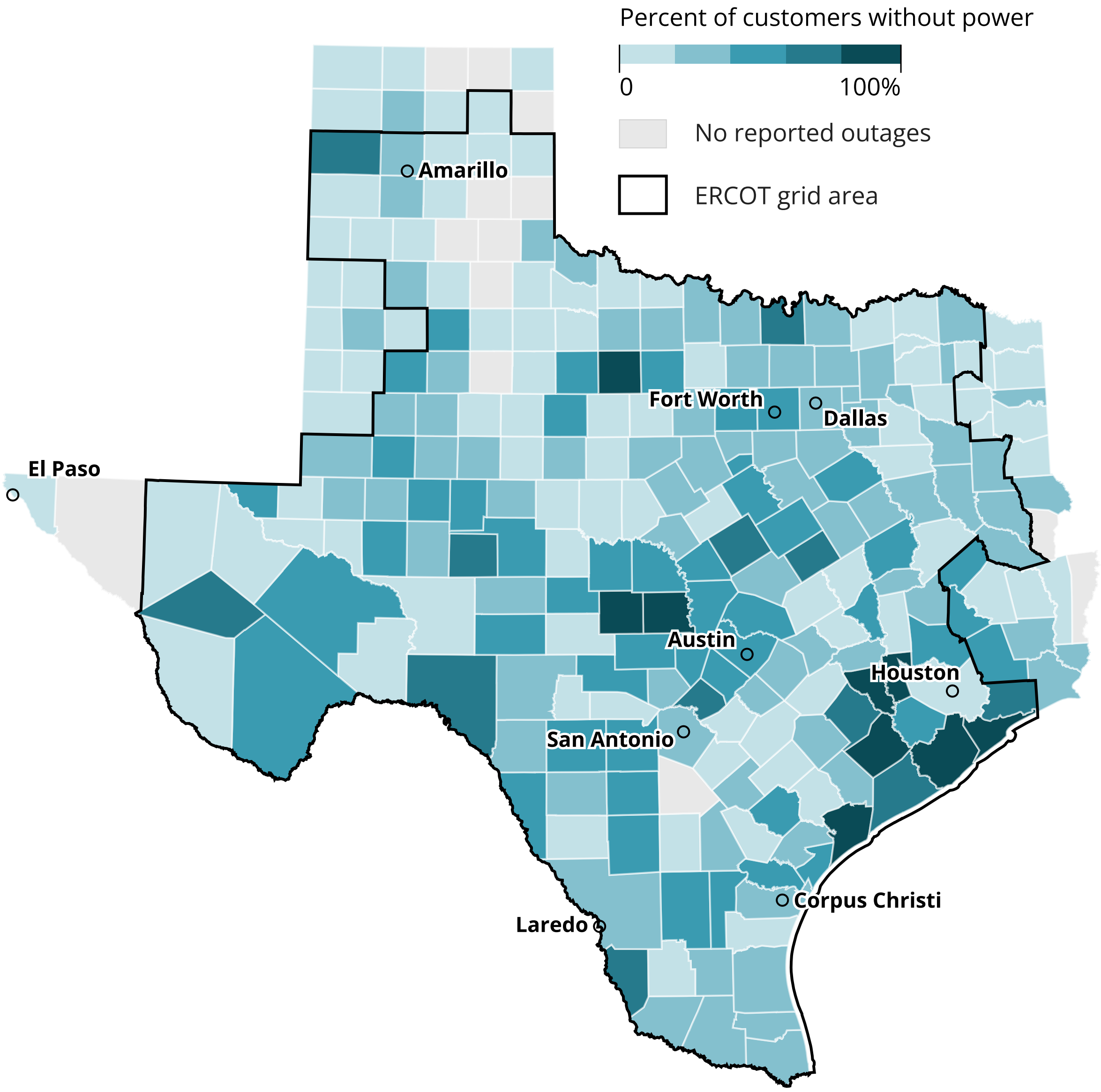
It’s estimated that about 80% of the grid’s capacity, or 67 gigawatts, could be generated by natural gas, coal and some nuclear power. Only 7% of ERCOT’s forecasted winter capacity, or 6 gigawatts, was expected to come from various wind power sources across the state.

Woodfin said Tuesday that 16 gigawatts of renewable energy generation, mostly wind generation, are offline and that 30 gigawatts of thermal sources, which include gas, coal and nuclear energy, are offline.

> “It appears that a lot of the generation that has gone offline today has been primarily due to issues on the natural gas system,” Woodfin said during a Tuesday call with reporters.

## On Feb. 16, at least 4.5 million customers in Texas were without power

The operator of Texas' power grid is under investigation after a massive winter storm caused millions of residents in the state to lose power for days. Here's where Texans were most impacted during the worst of the outages between 10 and 11 a.m. Feb. 16.



Note: PowerOutage.us gathers data from companies covering about 99% of utility customers in Texas. Data in some areas is incomplete, including the number of customers served.
Source: PowerOutage.us and the Electric Reliability Council of Texas
Credit: Chris Essig, The Texas Tribune, and Ren Larson, The Texas Tribune/ProPublica

Production of natural gas in the state has plunged, making it difficult for power plants to get the fuel necessary to run the plants. Natural gas power plants usually don't have very much fuel storage on site, experts said. Instead, the plants rely on the constant flow of natural gas from pipelines that run across the state from areas like the Permian Basin in West Texas to major demand centers like Houston and Dallas.

In early February, Texas operators were producing about 24 billion cubic feet per day, according to an estimate by S&P Global Platts. But on Monday, Texas production plummeted to a fraction of that: Operators in the state produced somewhere between 12 billion and 17 billion cubic feet per day.

The systems that get gas from the earth aren't properly built for cold weather. Operators in West Texas' Permian Basin, one of the most productive oil fields in the world, are particularly struggling to bring natural gas to the surface, analysts said, as cold weather and snow close wells or cause power outages that prevent pumping the fossil fuels from the ground.

"Gathering lines freeze, and the wells get so cold that they can't produce," said Parker Fawcett, a natural gas analyst for S&P Global Platts. "And pumps use electricity, so they're not even able to lift that gas and liquid, because there's no power to produce."

Texas does not have as much storage capacity as other states, experts said, because the resource-laden state can easily pull it from the ground when it's needed — usually.

Of the storage that the state does have, the resources are somewhat difficult to get to. Luke Jackson, another natural gas analyst for S&P Global Platts, said that physically withdrawing stored natural gas is slower than the immediate, ready supply of lines from production and is insufficient to make up for the dramatic declines in production.

Some power plants were already offline before the crisis began, adding to the problems, experts said. ERCOT anticipated 4 gigawatts of maintenance outages during the winter. Power plants in Texas usually do maintenance and updates to their plants during the typically mild winter months in preparation for the extreme electricity and power demand during the summer. That, too, is straining the grid's supply.

Another winter problem: heating homes and hospitals by burning natural gas.

"In the summer, you don't have as much direct burning of natural gas," said Daniel Cohan, an associate professor of civil and environmental engineering at Rice University, pointing out that during peak usage in the summer months, the demand is all for electricity.

The last time the state experienced a major freeze like this was a decade ago, in 2011. At that time, too, natural gas generation experienced difficulties — had ERCOT not reduced load through the rolling blackouts implemented during that storm, it would have resulted in widespread blackouts throughout the entire region, a federal report on the storm warned.

It is possible to "winterize" natural gas power plants, natural gas production and wind turbines, experts said, which prevents such major interruptions in other states with more regular extreme winter weather. But even after upgrades were made after the 2011 winter storm, many Texas power generators have still not made all the investments necessary to prevent these sorts of disruptions happening to the equipment, experts said.

ERCOT directors also said that the storm this week took a turn in the early morning hours of Monday, when extremely low temperatures forced many more generators offline than ERCOT had anticipated.

"It appeared that the winterization we were doing was working, but this weather was more extreme than [past storms]," Woodfin said. "The loss of generation during the morning of Monday, after midnight, was really the part that made this a more extreme event than we had planned."

Upgrading equipment to withstand extremely low temperatures and other changes, such as providing incentives for customers to conserve power or upgrade to smart appliances, could help avoid disasters like this one, said Le Xie, a professor of electrical and computer engineering at Texas A&M University and assistant director of energy digitization at A&M's Energy Institute.

"We used to not worry too much about such extreme cold weather in places like Texas, but we probably need to get ready for more in the future," Xie said. With climate change, he said, "We're going to have more extreme weather conditions throughout the country."

## Help us cover coronavirus in 2021

WINTER STORM 2021

# Catastrophic Texas power outages prompt finger pointing and blame shifting at legislative hearings

> Lawmakers grilled public regulators and energy grid officials about how power outages happened and why Texans weren't given more warnings about the danger.

BY **REESE OXNER**, **MITCHELL FERMAN** AND **JULIÁN AGUILAR** FEB. 25, 2021
UPDATED: FEB. 26, 2021

COPY LINK

Electrical workers repair a power line in Austin last week. Texas lawmakers on Thursday criticized and questioned the state's energy grid operator over this month's devastating power outages. 📷 Sergio Flores for The Texas Tribune

Texas lawmakers investigating this month's devastating power outages during a massive winter storm grilled power-grid officials Thursday and questioned whether state regulators did enough. Most of what they got during simultaneous public hearings in the Texas Senate and House was finger pointing.

"This is the largest train wreck in the history of deregulated electricity," said state Sen. Brandon Creighton, R-Conroe.

Officials with the Electric Reliability Council of Texas avoided taking full responsibility for the outages that left millions without power in subfreezing temperatures and disrupted water service for large swaths of the state. ERCOT officials, energy executives, utility company bosses and a meteorologist were among those questioned about the outages before committees in both chambers of the Texas Legislature.

After 11 p.m. Thursday, following more than 14 hours of testimony, state Rep. Todd Hunter, R-Corpus Christi, asked ERCOT CEO Bill Magness how much he earns, and where that money comes from. Magness answered that he made $803,000, which came from Texans paying their electric bills.

Earlier in the day, state Sen. John Whitmire, D-Houston, asked whether lawmakers should reexamine ERCOT's governance structure.

"Y'all made us," Magness said. "You should change us."

ERCOT last week ordered rotating power outages, but experts said many of Texas' power generators failed because they are not properly equipped to handle cold weather. Instead of half-hour increments, many Texans were left without power for hours or even days. Late Tuesday, Magness told Hunter ERCOT didn't accurately project how bad the situation was going to be.

Under an electricity system the Legislature shifted to two decades ago, power companies aren't required to produce enough electricity to get the state through crises like the one last week. In fact, they are incentivized to ramp up generation only when dwindling power supplies have driven up prices.

“Some of the blame belongs right here in this building,” State Rep. Charlie Geren, R-Fort Worth, said Thursday. “There’s blame out there for everybody.”

A Texas Tribune and ProPublica investigation found that over the last decade, lawmakers and regulators, including the Public Utility Commission and the industry-friendly Texas Railroad Commission, have repeatedly ignored, dismissed or watered down efforts to address weaknesses in the state’s sprawling electric grid. The PUC oversees ERCOT and the railroad commission regulates the oil and gas industry.

“If the Legislature fails to mandate weatherization of pipelines or power plants, there are limits to how far the regulatory agencies can go to step beyond where the Legislature has given them direction,” Alison Silverstein, an Austin-based energy consultant who has advised state and federal agencies, said Wednesday on a virtual conference with other energy experts.

The Senate Committee on Business & Commerce meeting and a joint hearing of the House’s State Affairs and Energy Resources committees lasted more than 12 hours. The committees were expected to continue the hearings Friday.

## Public Utility Commission's oversight criticized

Gov. Greg Abbott was mostly silent publicly ahead of the winter storm, and his office did not warn Texans that many of them would be without electricity and water for days during subfreezing temperatures. After widespread outages, he placed the blame firmly on ERCOT and made reforming the operator an emergency item for the Legislature.

State Rep. Rafael Anchía, D-Dallas, accused Abbott of ignoring the role that the PUC played in the crisis. Officials of the commission that regulates ERCOT are appointed by the governor.

“There's this very carefully curated discussion of blame by the governor that always speaks to ERCOT … and never mentioned the Public Utility Commission,” Anchía said. “The PUC bears responsibility here as well.”

The head of the PUC, DeAnn T. Walker, appeared before lawmakers on Thursday after Magness testified for roughly five hours. She deflected much of the responsibility for the power outages to ERCOT, downplaying the PUC's authority over the operator.

Later, in the House, Anchía quizzed Walker surrounding the PUC’s authority over ERCOT, concluding that the commission did have decision-making ability over the operator.

“It seems to me, comprehensive," Anchía said.

“We told you to report to us if you thought we were unprepared because we had promised our constituents, ‘This was not going to happen again,’ and we told PUC to take care of it," he said. "And we gave you power, we gave you rule-making authority to take care of it."

Anchía said the PUC was empowered to winterize with legislation passed in 2011, after frigid temperatures caused equipment failures and blackouts. He asked if the commission ever submitted a report as was it was authorized to in the bill. Walker answered no.

State Rep. Abel Herrero, D-Robstown, the vice chair of the energy resources committee, noted that Abbott had welcomed resignations from ERCOT members. He asked Walker if the governor had asked for hers.

“He has not,” she said.

## Energy companies and the Texas Railroad Commission

In the House’s joint hearing, representatives spent the first four hours grilling the CEOs of Vistra Corp and NRG, two of the largest energy providers in the state. The executives pointed to a number of problems — some internal but many external — that contributed to widespread outages and energy shortages in the state.

“Who’s at fault?” Hunter, the Corpus Christi Republican, asked the executives. “I want to hear who’s at fault. I want the public to know who screwed up.”

The executives agreed: The entire energy system in Texas saw widespread problems that ultimately led to supply failing to meet demand. Texans demanded an amount of electricity normally not seen in the winter months. The power grid was not prepared for that level of demand or equipment failure due to freezing temperatures.

“The entire energy sector failed Texans, we know we can do better,” NRG Energy CEO Mauricio Gutierrez said. “And we must do better to make sure that this never happens again.”

Vistra Corp. CEO Curt Morgan acknowledged that his company could have performed better, but said the biggest problem they faced was disruptions in the state’s natural gas supply system, which was not prepared for the winter weather. Morgan instructed his employees to buy gas at any price, but they couldn’t get it at the pressures necessary. He said that even if all equipment was winterized, it wouldn’t have prevented gas interruptions.

“We need to recognize the interdependencies and we need to come up with a protocol between gas and power,” he said. “There's nothing that I can do, if the gas companies cannot get pressurized gas to us.”

The Texas Railroad Commission is in charge of regulating natural gas. Commission Chair Christi Craddick told lawmakers that even though ERCOT is in charge of the grid, she had not communicated directly with the organization during the storm.

## Winterizing power generators and plants

After the outages began, Abbott asked state lawmakers to mandate the winterization of generators and power plants, a proposal previously floated but not implemented by state leaders in the aftermath of another winter storm in 2011. And Abbott requested that lawmakers provide power companies with funding to make the necessary changes.

Morgan told lawmakers that the state’s energy systems cannot operate much below 10 degrees.

”Let's be honest, they're not built for the winter,” he said.

Last week, the state average temperature dropped as low as 11.8 degrees and was even lower across large swaths of the state, according to the National Weather Service.

But retroactively equipping power plants to withstand cold temperatures is likely to be very difficult and costly, energy experts said. Building energy infrastructure to perform in winter conditions is easier and cheaper, they said.

Craddick, chair of the commission the oversees the natural gas industry, told lawmakers that wellheads, the component at the earth’s surface of an oil or gas well, can only be winterized with electricity.

## Communication failures

One way the state could have communicated the emergency better was through something similar to an amber alert, recommended state Sen. Angela Paxton, who left the state with her husband during the outages. Some of her colleagues agreed.

“ERCOT was pathetic. The PUC was non-existent,” said state Rep. Sam Harless, R-Spring, calling “across-the-board” communication from both state officials and energy providers inadequate. “We have to answer to our people, and they deserve to know what's going on. And they didn't.”

Several house representatives called for private companies to create better crisis communication plans for both customers and lawmakers.

Anchía questioned the PUC's Walker about why the public regulatory agency didn’t sound alarms sooner to warn the public that people could be stuck without power far beyond what rolling blackouts call for.

“That was a major failure,” Anchía said.

“I don’t disagree with you, sir,” Walker said.

Anchía asked Walker if she thought Texans deserved an apology from PUC.

She paused for a couple beats, and then he ended his questioning.

“The fact that you’re hesitating is astonishing," he said. "No further questions.”

## Communities of color

State Rep. Ron Reynolds, D-Missouri City, said hundreds of Texans have contacted his office since the storm, including Gary Bledsoe, the president of the Texas chapter of the NAACP. Reynolds said Bledsoe had concerns that poorer areas and neighborhoods of color were harder hit than more affluent areas and that people of color were possibly without resources longer than more affluent Texans once power was reconnected.

“Were neighborhoods that are densely populated by African Americans or people of color more likely to have sustained power outages?” he asked Kenny Mercado, executive vice president, electric utility for CenterPoint Energy. “There is the perception that there was some equitable issues, so could you give your perspective from CenterPoint’s standpoint in the Houston and Fort Bend areas?”

Mercado said he didn’t immediately have demographic information but said reconnections had nothing to do with ethnicity or race.

“I don’t have the answer that you’re asking [for] today, I need to really dig into the details and put that together,” he said. “The way that the circuits were rolling back on, it was first one out — whoever had been out the longest — was going to be the next one in. It had nothing to do with neighborhood or streets or race or color. However we can absolutely look through it and I would entertain the opportunity to make it better for the future.”

## Why were skylines lit during the outages?

Harless asked CenterPoint executive Mercado why Houston’s downtown was “lit up like Las Vegas” when the city’s residents were in the dark.

“Of course you saw the pictures and the optics were horrible,” he said. “I understand downtown Houston staying up, but shouldn’t we have had some sort of communication process in place, to tell them ‘Hey we can’t cut you off but at least turn the stuff down?’”

Mercado said that message was delivered after it should have and that some downtown customers had to be forced to power down.

“Yeah, I would argue it was probably at least a day late, in my opinion. Maybe two days late,” he said. “They did do it when they were demanded to do it and we talked to the mayor and got his help.”

## Loss of faith

Morgan, the Vistra CEO, said he’s lost confidence the state’s electrical grid could keep up with future demands, like greater numbers of electric vehicles on Texas roads.

“I was a big proponent of this market, and my faith has been shaken,” Morgan said.

Gutierrez of NRG agreed the state isn't prepared.

“We cannot afford to not have a system that is more resilient and reliable than the one we just saw," Gutierrez said.

Toward the end of the House committees' joint hearing, state Rep. Donna Howard, D-Austin, at times seemed to struggle to contain her frustration as testimony stretched past the 15-hour mark.

“Why are people not talking to each other? Why do we have this set up to where the PUC and ERCOT and the Railroad Commission and the Legislature and whoever else needs to be involved here, why are we not talking to each other?” she said. “I am dumbfounded by it. And I don’t want tonight to be the last thing we say about this.”

*Jolie McCullough contributed to this report.*

*Disclosure: CenterPoint Energy, NRG Energy and Rice University have been financial supporters of The Texas Tribune, a nonprofit, nonpartisan news organization that is funded in part by donations from members, foundations and corporate sponsors. Financial supporters play no role in the Tribune's journalism. Find a complete list of them here.*

# Review of February 2021 Extreme Cold Weather Event – ERCOT Presentation

*Bill Magness*
President & Chief Executive Officer
ERCOT

Texas Legislative Hearings:
Senate Business and Commerce Committee
House Joint Committee on State Affairs and Energy Resources

ERCOT Public
February 25, 2021

# Disclaimer

Information in this presentation is preliminary and represents the best available data at the time it was created.

# ERCOT Corporate Governance

- **Founded in 1970**
- **Texas non-profit corporation with members from seven market segments:**
  - Consumers (Commercial, Industrial, Residential)
  - Cooperatives
  - Independent Generators
  - Independent Power Marketers
  - Independent Retail Electric Providers
  - Investor-Owned Utilities
  - Municipals
- **The Texas Legislature enacted laws which govern all activities of ERCOT – See Public Utility Regulatory Act (PURA) Section 39.151.**
- **The Public Utility Commission of Texas (PUC) has complete authority over ERCOT's finances, budget and operations, with oversight by the Texas Legislature.**
  - Approves ERCOT Bylaws
- **16-member ERCOT Board composition is established by law:**
  - 5 Unaffiliated Directors (independent from ERCOT Market Participants); all must be approved by the PUC for three-year terms with a maximum of two renewals
  - 8 Directors each elected annually by different Market Segments
  - Office of Public Utility Counsel (represents Residential Consumer Market Segment)
  - ERCOT Chief Executive Officer
  - PUC Chairman (non-voting)

# ERCOT’s Role

- **Fulfills four responsibilities required by law as the independent organization certified by the PUC (PURA Section 39.151):**
  - Maintain electric system reliability
  - Facilitate a competitive wholesale market
  - Ensure open access to transmission
  - Facilitate a competitive retail market
- **Manages the flow of electric power over the bulk power system to approximately 26 million Texas end-use customers.**
  - About 90% of the state’s electric load
  - Over 680 generation units
  - Over 46,500 miles of transmission lines
- **Must, at all times (24/7/365), balance all consumer demand in the ERCOT region (load) and the power supplied by companies who generate electricity (generation) while maintaining system frequency of 60 Hz.**
- **Performs financial settlement for the competitive wholesale bulk power market and administers retail switching for nearly 8 million premises in competitive choice areas.**

# ERCOT's Role (continued)

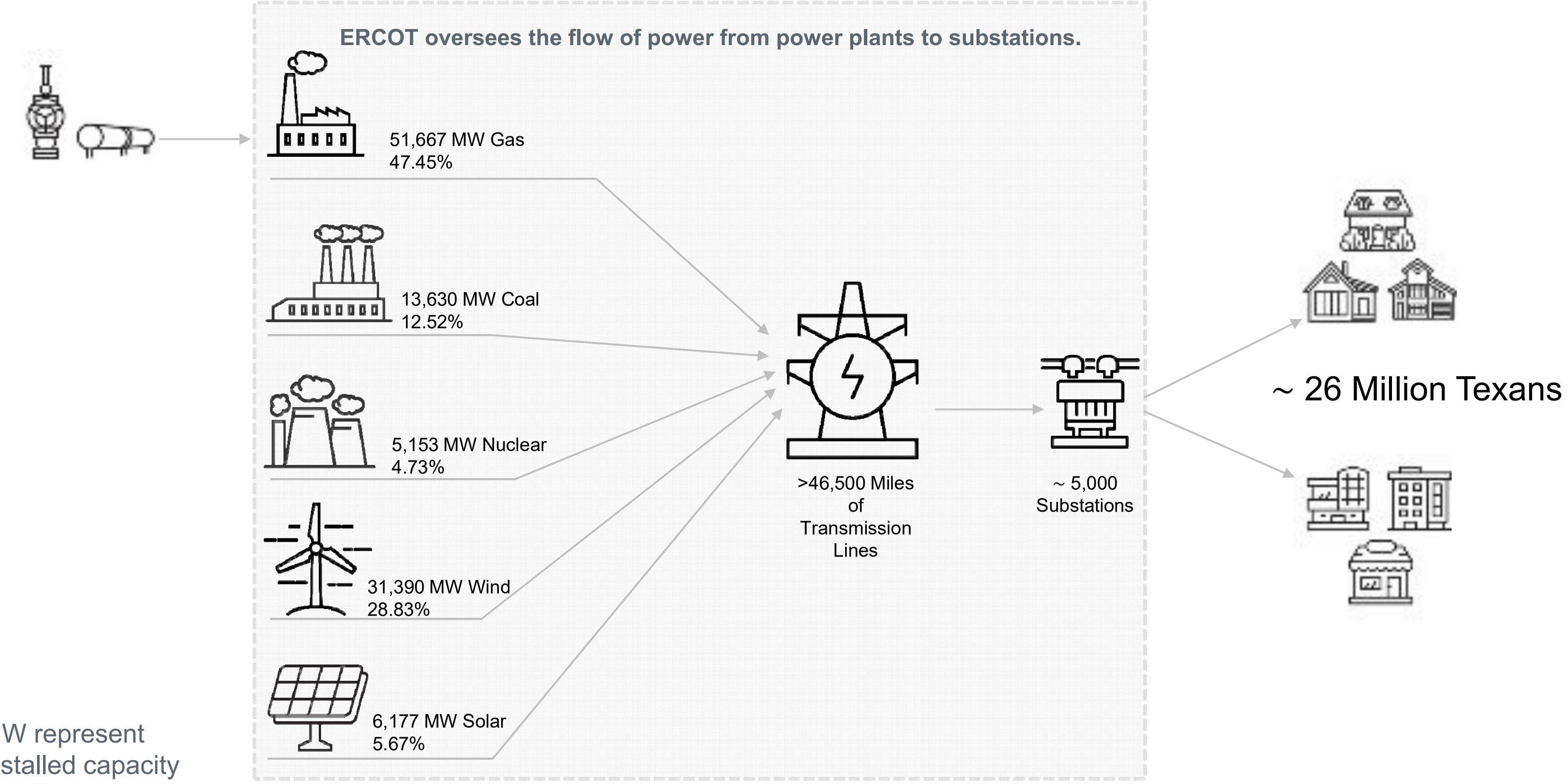
ERCOT does **not**:

- Own, operate or have any enforcement authority over any electric generation facilities or any electric transmission or distribution lines or substations.
- Sell or send bills for retail electricity to residences or businesses.
- Control or operate electric service to local areas, neighborhoods or individual premises.
- Establish pricing or rates for retail electric customers.
- Have any direct customer relationships with the public.

# ERCOT Budget & Funding

- **Budget is approved by the Board and the PUC biennially.**
- **Funded by a System Administration Fee to cover its system costs.**
  - Current fee is 55.5 cents per megawatt hour (MWh).
  - One megawatt of electricity can power about 200 Texas homes during periods of peak demand.
  - Average cost of $7/year (50-60 cents/month) for residential households.
- **ERCOT does not set consumer electric rates.**
  - Rates are either set by the PUC or companies that sell electricity at retail to end-use customers.
  - Additional transmission costs are proportionally passed on to customers.

# Electric Generation, Transmission & Distribution Overview



**ERCOT oversees the flow of power from power plants to substations.**

51,667 MW Gas
47.45%

13,630 MW Coal
12.52%

5,153 MW Nuclear
4.73%

31,390 MW Wind
28.83%

6,177 MW Solar
5.67%

>46,500 Miles
of
Transmission
Lines

~ 5,000
Substations

~ 26 Million Texans

MW represent
installed capacity

# Pre-Event Operational Preparation

- Canceled transmission maintenance outages affecting over 1,600 transmission devices and delayed other outages.
- Reviewed planned generation outages for potential early return to service.
- Noted potential for 11,100 MW of forced outages due to gas restrictions based on gas company communications – more units affected during this event compared to previous cold weather events.
- Began using maximum icing potential for wind forecasts.
- Waived COVID restrictions and brought additional support staff on-site.
- Prepared facilities for extended on-site staffing, activated additional remote engineering/support staff.
- Began regular calls with Chief System Operators (18 over 8 days).
- Requested TCEQ/DOE enforcement discretion for power plant emissions during anticipated event.
- Supported Railroad Commission of Texas review of natural gas priority.

All available generation was online on February 14.

# Pre-Event Communications

| | |
|---|---|
| November 5 | ERCOT meteorologist issues winter outlook for Market Participants and public noting the “very good” chance for an extreme cold weather event during winter 2020/2021. |
| February 3 | ERCOT meteorologist warns Market Participants and the public of coldest weather of the year. Weather updates continue. |
| February 8 | Operating Condition Notice issued for extreme cold weather event, posted on public website. |
| February 10 | Advisory issued for extreme cold weather event posted on public website. Issued grid conditions update for market media representatives. |
| February 11 | Watch issued for cold weather event (hotline calls made, notice to Market Participants, posted on public website). News release on extreme weather expected, social media outreach. |
| February 12 | Texas Energy Reliability Council meeting. |
| February 13 | State Operations Center news conference: forecast Conservation Alert.<br>Emergency notice issued for extreme cold weather event, posted on public website.<br>Texas Energy Reliability Council meeting. |
| February 14 | Issued conservation appeal by news release, performed social media outreach, held media briefing. |

# Overview of Cold Weather Event

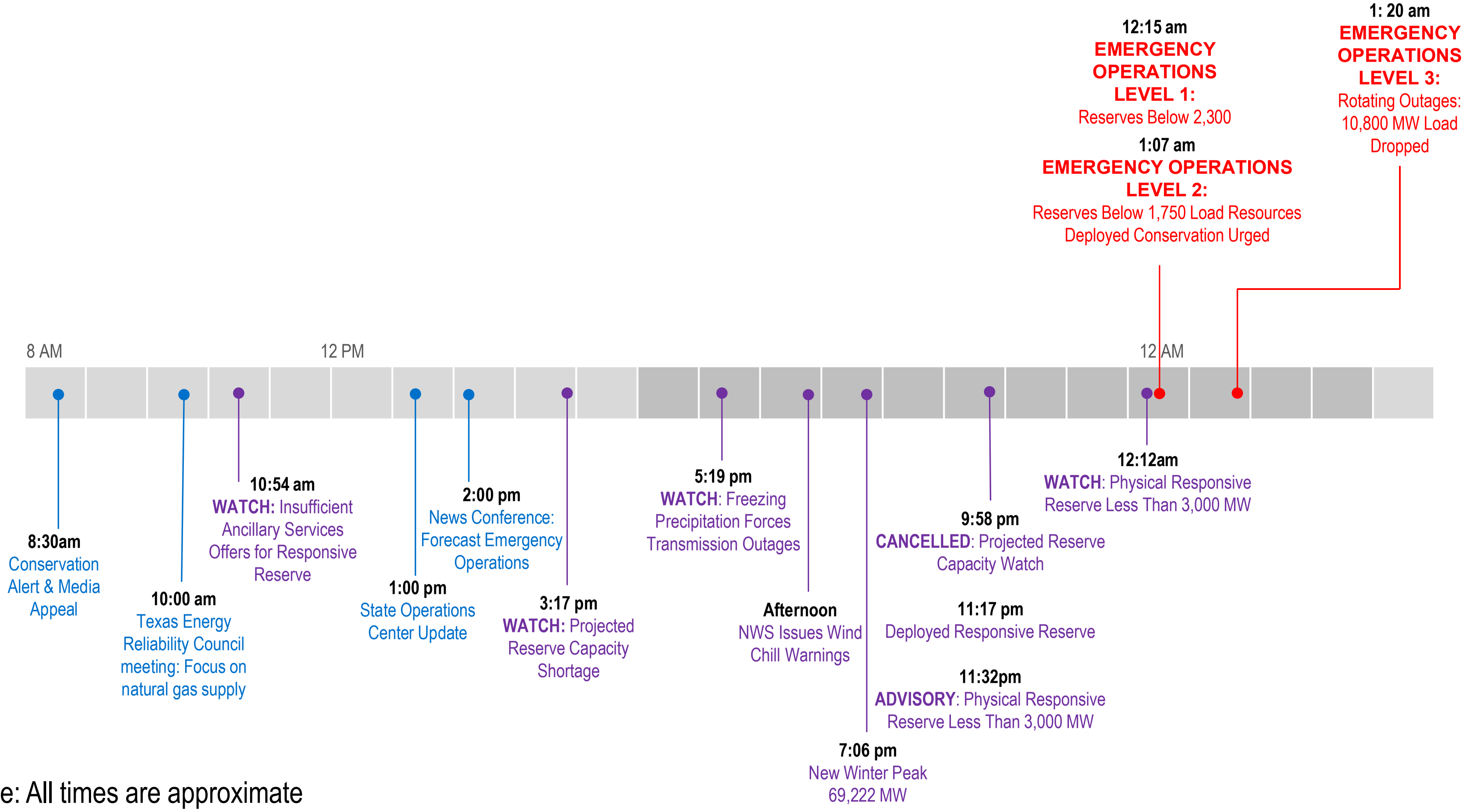
- Record-setting, sub-freezing temperatures and wind chills across the state.

- Approximately 48.6% of generation was forced out at the highest point due to the impacts of various extreme weather conditions.

- Controlled outages were implemented to prevent statewide blackout.
  - Electric demand had to be limited to available generation supply.

- Local utilities were limited in their ability to rotate outages due to the magnitude of generation unavailability and the number of circuits with critical load.

# Sunday, February 14 – Monday, February 15



**8:30am**
Conservation Alert & Media Appeal

**10:00 am**
Texas Energy Reliability Council meeting: Focus on natural gas supply

**10:54 am**
**WATCH:** Insufficient Ancillary Services Offers for Responsive Reserve

**1:00 pm**
State Operations Center Update

**2:00 pm**
News Conference: Forecast Emergency Operations

**3:17 pm**
**WATCH:** Projected Reserve Capacity Shortage

**5:19 pm**
**WATCH**: Freezing Precipitation Forces Transmission Outages

**Afternoon**
NWS Issues Wind Chill Warnings

**7:06 pm**
New Winter Peak 69,222 MW

**9:58 pm**
**CANCELLED**: Projected Reserve Capacity Watch

**11:17 pm**
Deployed Responsive Reserve

**11:32pm**
**ADVISORY**: Physical Responsive Reserve Less Than 3,000 MW

**12:12am**
**WATCH**: Physical Responsive Reserve Less Than 3,000 MW

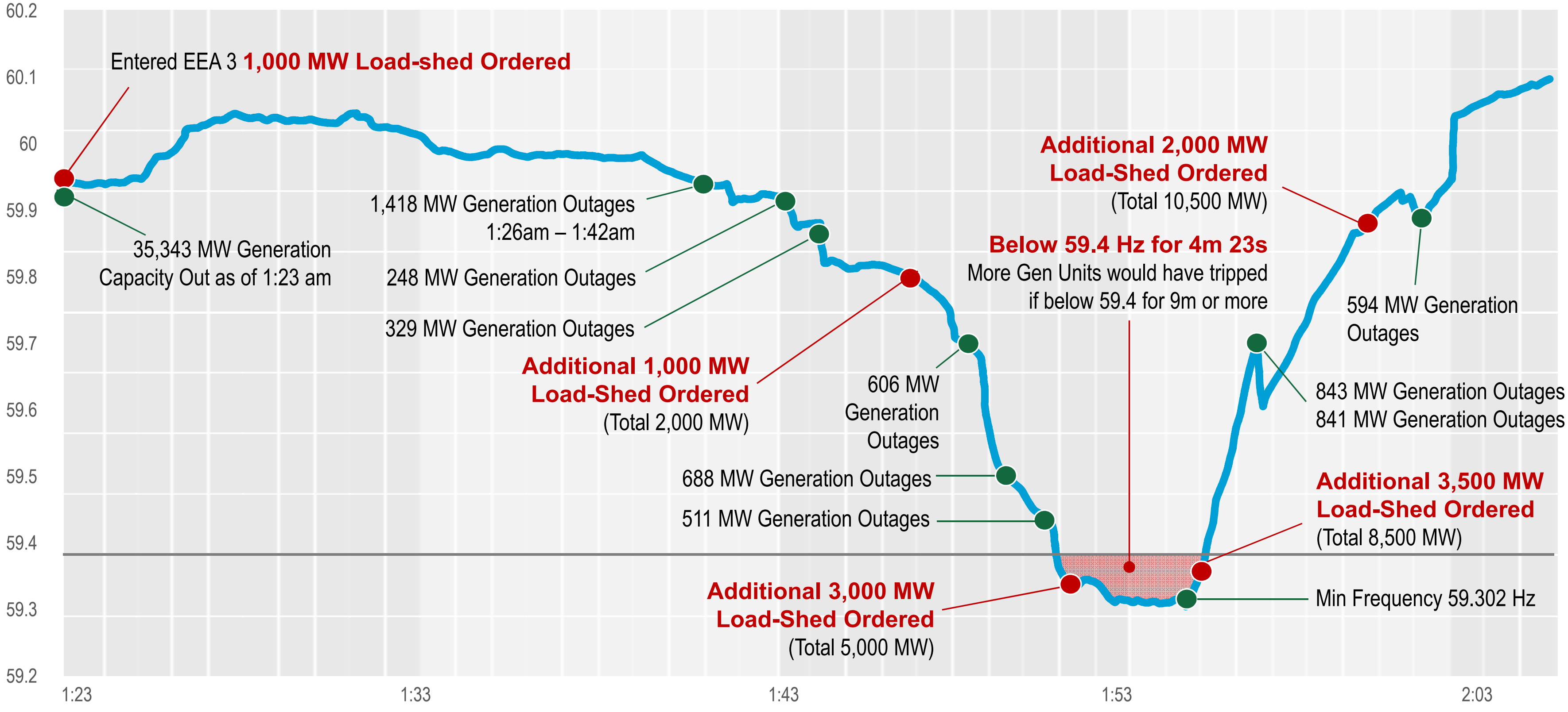
**12:15 am**
**EMERGENCY OPERATIONS LEVEL 1:**
Reserves Below 2,300

**1:07 am**
**EMERGENCY OPERATIONS LEVEL 2:**
Reserves Below 1,750 Load Resources Deployed Conservation Urged

**1: 20 am**
**EMERGENCY OPERATIONS LEVEL 3:**
Rotating Outages: 10,800 MW Load Dropped

Note: All times are approximate

# Rapid Decrease in Generation Causes Frequency Drop



Entered EEA 3 **1,000 MW Load-shed Ordered**

35,343 MW Generation Capacity Out as of 1:23 am

1,418 MW Generation Outages
1:26am – 1:42am

248 MW Generation Outages

329 MW Generation Outages

**Additional 1,000 MW Load-Shed Ordered**
(Total 2,000 MW)

606 MW Generation Outages

688 MW Generation Outages

511 MW Generation Outages

**Additional 3,000 MW Load-Shed Ordered**
(Total 5,000 MW)

**Additional 2,000 MW Load-Shed Ordered**
(Total 10,500 MW)

**Below 59.4 Hz for 4m 23s**
More Gen Units would have tripped if below 59.4 for 9m or more

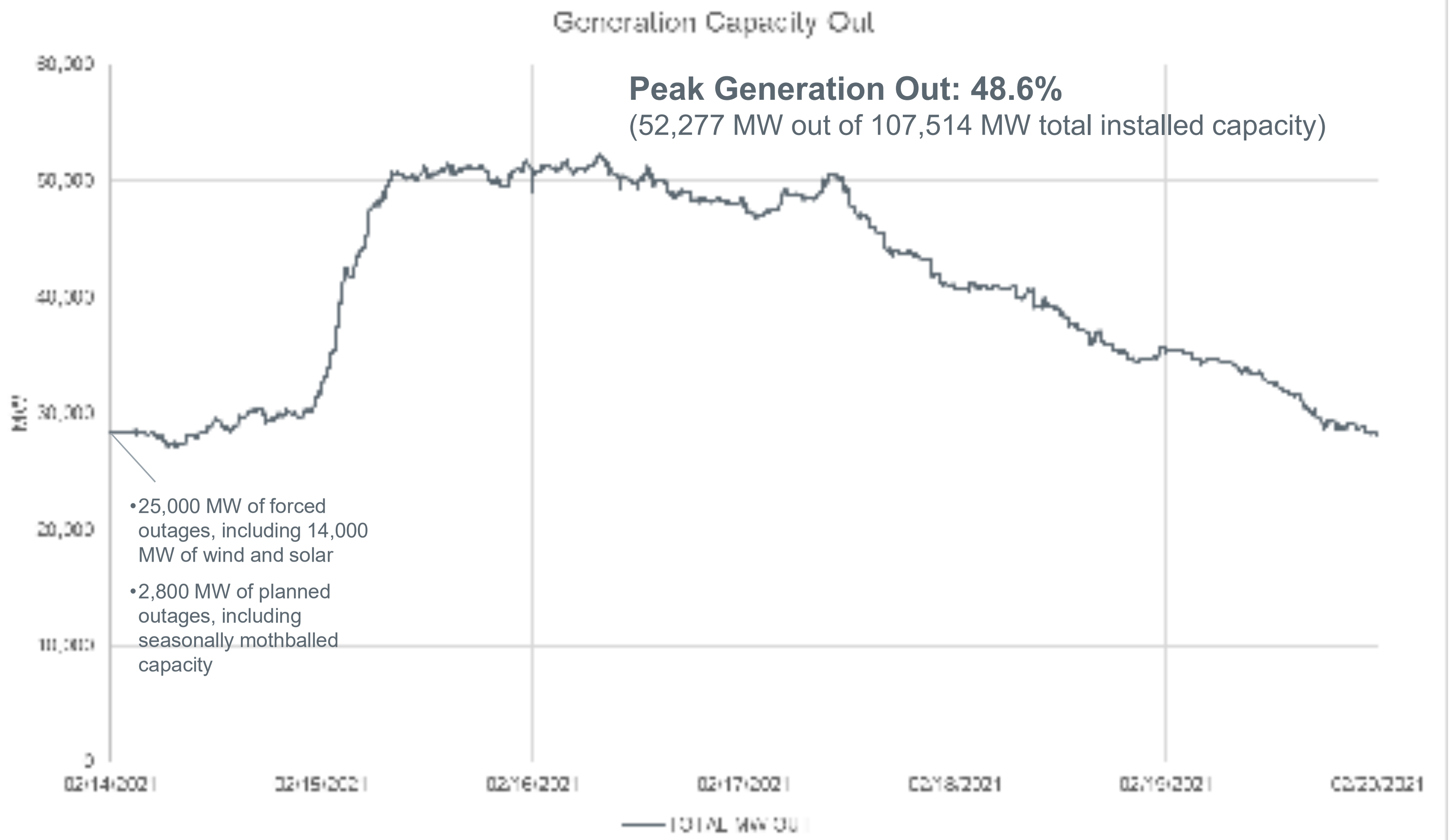
594 MW Generation Outages

843 MW Generation Outages
841 MW Generation Outages

**Additional 3,500 MW Load-Shed Ordered**
(Total 8,500 MW)

Min Frequency 59.302 Hz

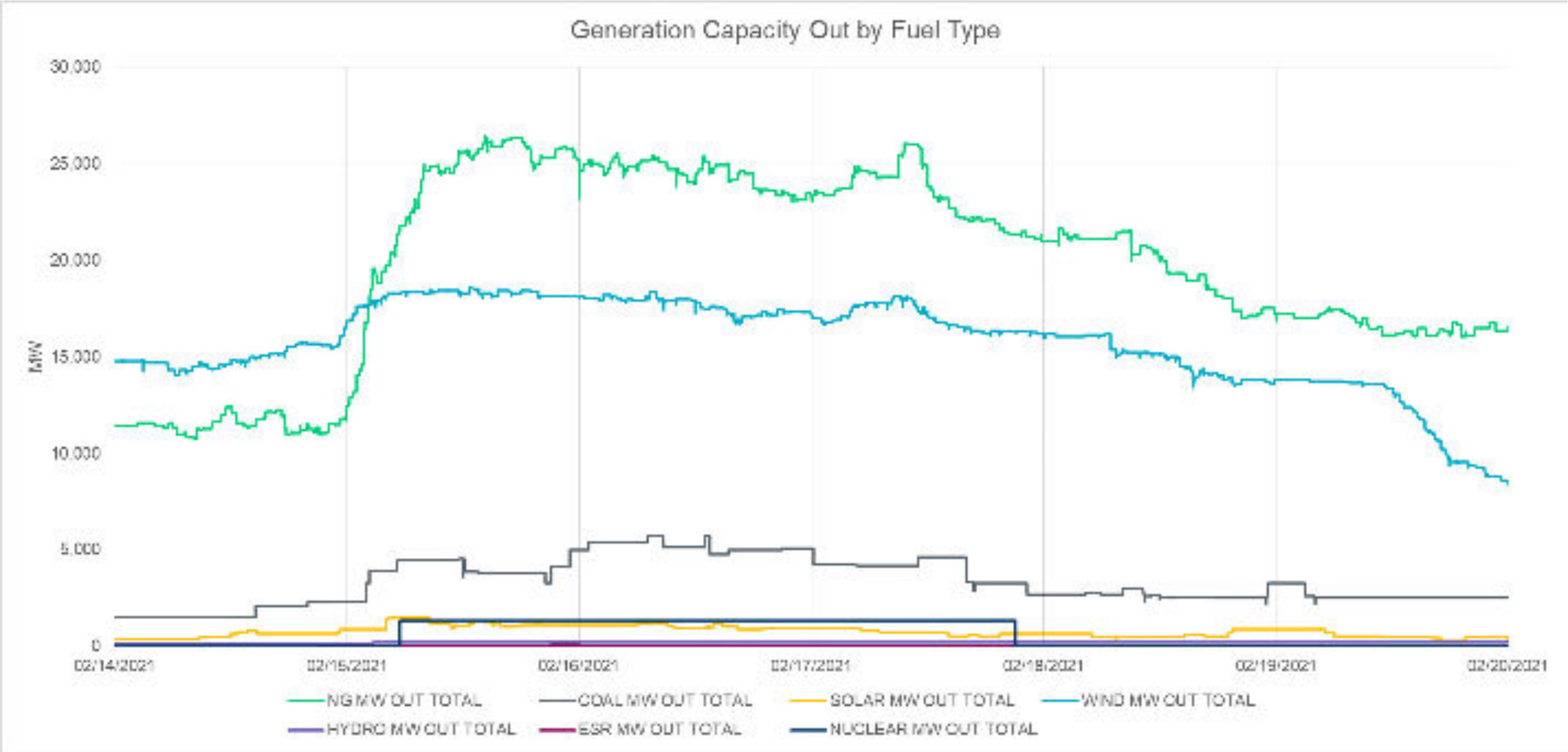
# Generation Capacity Out February 14 – 19, 2021



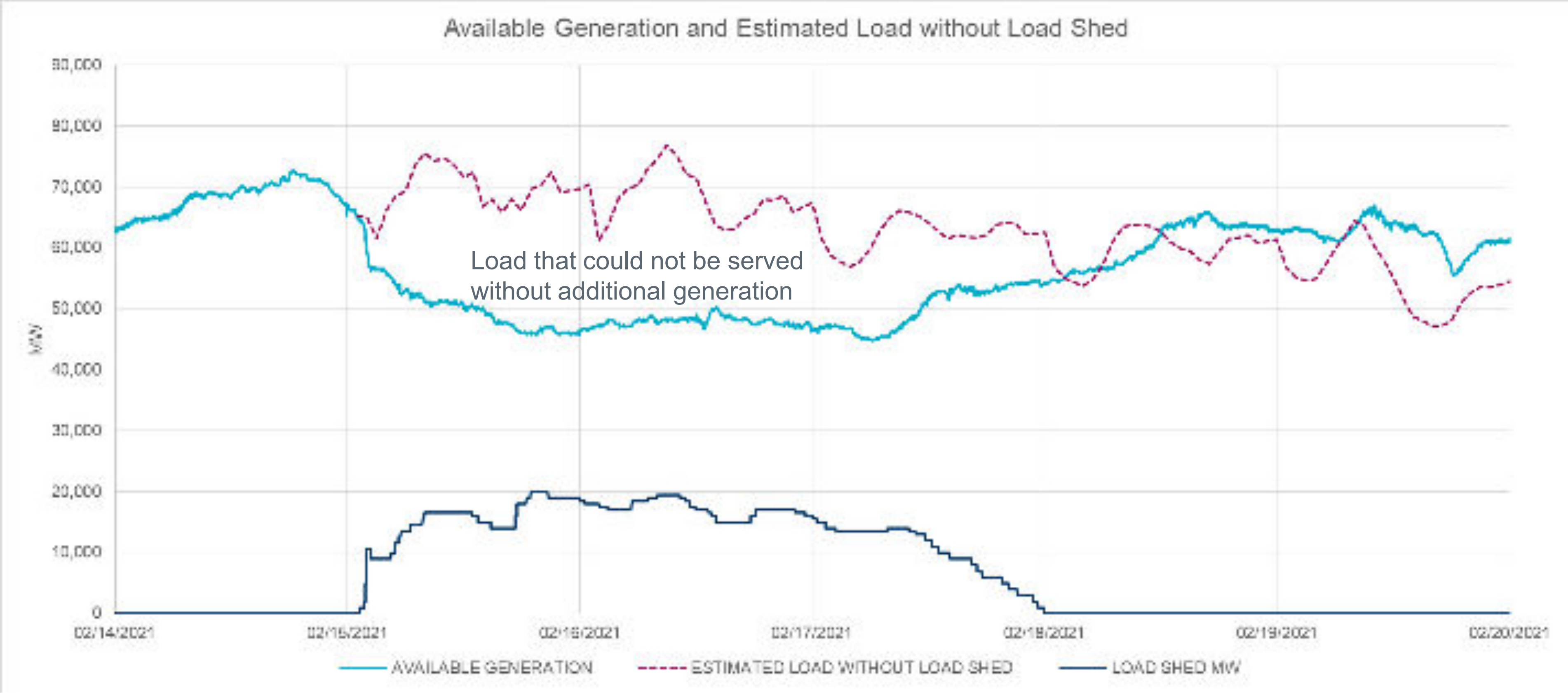
**Peak Generation Out: 48.6%**
(52,277 MW out of 107,514 MW total installed capacity)

- 25,000 MW of forced outages, including 14,000 MW of wind and solar
- 2,800 MW of planned outages, including seasonally mothballed capacity

# Generation Capacity Out by Fuel Type



# Available Generation and Estimated Load Without Load Shed



Load that could not be served without additional generation

Available Generation shown is the total HSL of Online Resources, including Quick Starts in OFFQS. The total uses the current MW for Resources in Start-up, Shut-Down, and ONTEST.

## Key Events (Monday, February 15 – Friday, February 19)

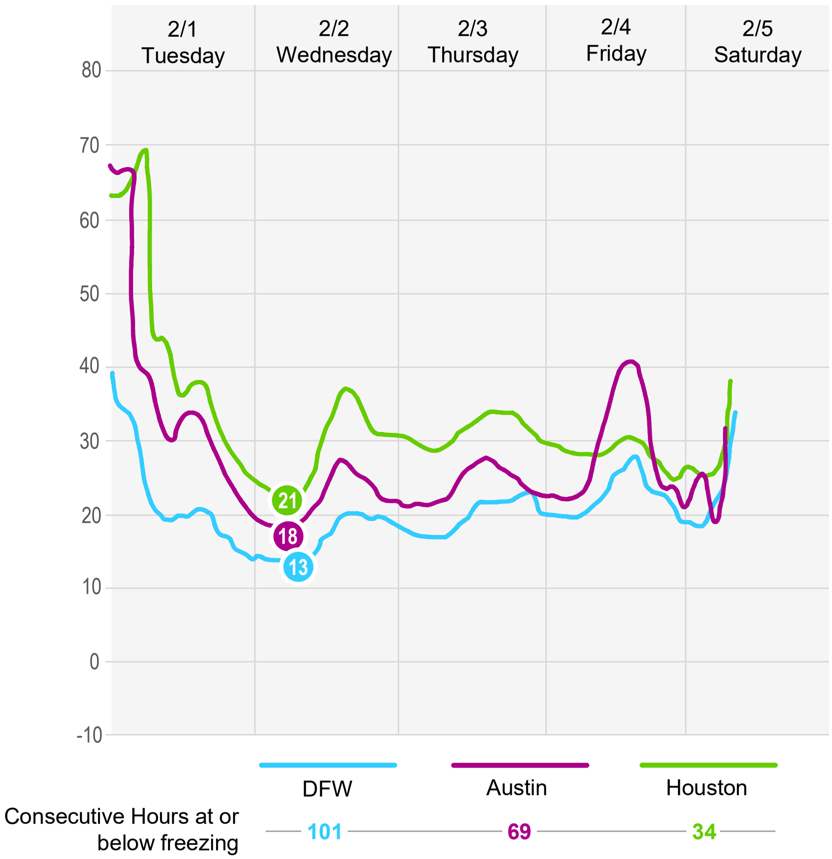
- More than 16,500 control room calls with generators and transmission owners (normal: ~5,000/week).
- Multiple daily coordinating calls between transmission owners and operations management.
- Monday, February 15
  - Up to an additional ~24,000 MW net generation unavailable due to extreme weather; loss of generation was 52,277 MW (approximately 48.6%) at the highest point.
  - 20,000 MW peak load shed.
  - Limited gas availability for gas-fired power plants.
  - Multiple DC-Tie constraints due to neighboring area emergencies.
  - Daily Texas Energy Reliability Council meetings.
- Tuesday, February 16
  - No net gain in generation as some generators were restored and others became unavailable.
  - Decreased volume of controlled outages during the day, increased for evening peak.
- Wednesday, February 17
  - Moderating temperatures allowed reduction in controlled outages, small net gain in generation.
- Thursday, February 18
  - Continued gain in generation.
  - 12:42 a.m. - Canceled last controlled outage orders - some outages remained due to ice storm damage; need for manual restoration and return of large industrial facilities.
- Friday, February 19 (all times approximate)
  - 9 a.m. - Returned to emergency operations level 2
  - 10 a.m. – Returned to emergency operations level 1
  - 10:35 a.m. – Returned to normal operations

# Generation Weatherization

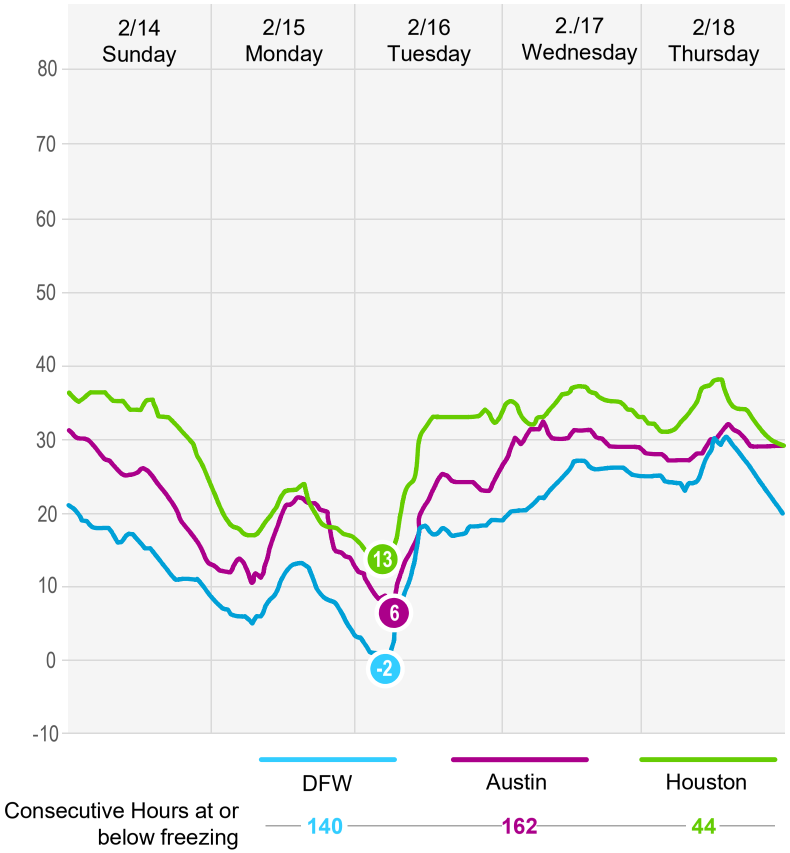
- ✓ Generation owners and operators are not required to implement any minimum weatherization standard or perform an exhaustive review of cold weather vulnerability. No entity, including the PUC or ERCOT, has rules to enforce compliance with weatherization plans or enforce minimum weatherization standards.
- ✓ In 2011, the PUC amended its rules to authorize ERCOT to conduct generator site visits to review compliance with weatherization plans. Spot checks include reviewing the weatherization plan, verifying that plant personnel are following the plan and providing recommendations based on PUC requirements, lessons learned or best practices.
- ✓ We currently perform spot checks at power plant units at the rate of about 80/year. Whenever possible, a Texas Reliability Entity (TRE) representative joins ERCOT for these spot checks.
- ✓ While we request and review detailed plant records, the only entity that can confirm that a plant is “weatherized” to any particular standard is the entity that owns or operates the plant.
- ✓ Each year, TRE and ERCOT host an annual workshop on weatherization with generation owners to review lessons learned and best practices.

# 2011 vs. 2021 Event Temperature Comparison

**February 2011**



**February 2021**



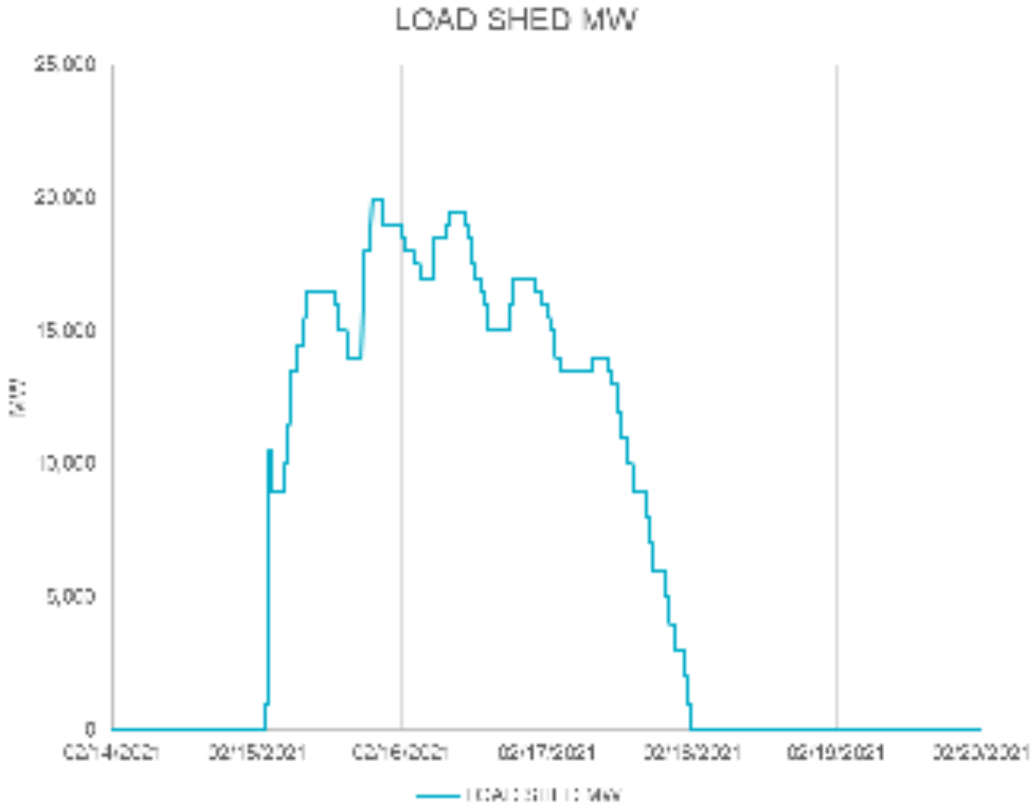
# 2011 vs. 2021 Event Comparison

| | 2011 | 2021 |
|---|---|---|
| Maximum generation capacity forced out at any given time (MW) | 14,702 | 52,277 |
| Generation forced out one hour before start of EEA3 (MW) | 1,182 | 2,489 |
| Cumulative generation capacity forced out throughout the event (MW) | 29,729 | 46,249* |
| Cumulative number of generators outaged throughout the event | 193 | 356 |
| Cumulative gas generation de-rated due to supply issues | 1,282 | 9,323 |
| Lowest frequency | 59.58 | 59.30 |
| Maximum load shed requested (MW) | 4,000 | 20,000 |
| Duration load shed request (hours) | 7.5 | 70.5 |
| Estimated peak load (without load shed) | 59,000 | 76,819 |

*Note: “Cumulative” values for 2021 were calculated using NERC 2011 report methodology.
Cumulative amount for 2021 starts at 00:01 on February 14, 2021

# Load Shed Ordered By Transmission Owner

| Transmission Operator | % of MW |
|---|---|
| AEP Texas Central Company | 8.7 |
| Brazos Electric Power Cooperative Inc. | 4.95 |
| Brownsville Public Utilities Board | 0.37 |
| Bryan Texas Utilities | 0.51 |
| CenterPoint Energy Houston Electric LLC | 24.83 |
| City of Austin DBA Austin Energy | 3.71 |
| City of College Station | 0.28 |
| City of Garland | 0.75 |
| CPS Energy (San Antonio) | 6.79 |
| Denton Municipal Electric | 0.48 |
| GEUS (Greenville) | 0.15 |
| Lamar County Electric Cooperative Inc* | 0.07 |
| LCRA Transmission Services Corporation | 5.96 |
| Oncor Electric Delivery Company LLC | 36.01 |
| Rayburn Country Electric Cooperative Inc. | 1.3 |
| South Texas Electric Cooperative Inc. | 2.52 |
| Texas-New Mexico Power Company | 2.62 |
| **ERCOT Total** | **100.00** |



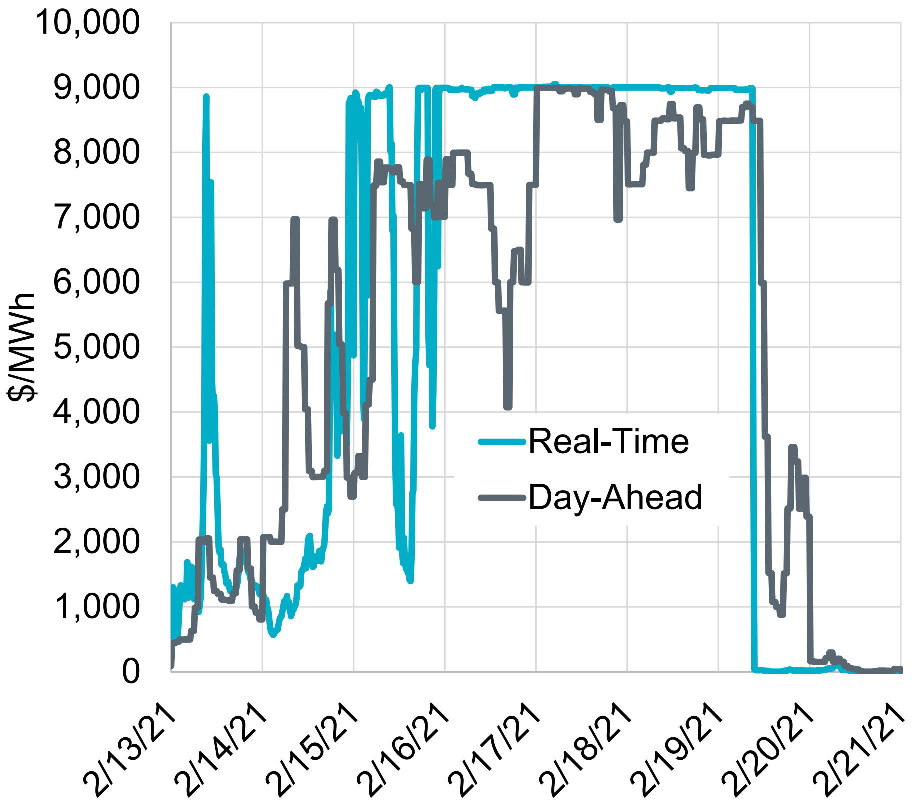
# Status of Recommendations After February 2011

A report published by the North American Electric Reliability Corporation following the February 2011 cold weather event contained several recommendations applicable to ERCOT. Over the past 10 years, ERCOT has made changes that support those recommendations.

Significant modifications include:

- Implemented the Seasonal Assessment of Resource Adequacy report that includes an analysis for extreme winter weather.
- Began a resource weatherization process that includes an annual workshop, review of resource weatherization plans and spot checks of facilities.
- Added additional staff (Shift Engineer and Resource Reliability Desk) in the control room.
- Modified the Ancillary Services procurement to allow additional procurement in anticipation of severe weather.
- Established the Gas Electric Working Group and created a notification procedure for QSEs to notify ERCOT if there are anticipated fuel restrictions.
- Modified the survey sent to natural gas generators that collects fuel switching capability for some resources in preparation for each winter season.
- Changed the rules and processes for withdrawing approval of resource outages in anticipation of severe weather.

# Real-Time and Day-Ahead System-Wide Pricing



Average system-wide pricing around the event relative to other historical periods (in $/MWh)

| Date Range | Real-Time | Day-Ahead |
|---|---|---|
| 2/14/21<br>2/19/21 | $6,579.59 | $6,612.23 |
| January '21 | $20.79 | $21.36 |
| February '20 | $18.27 | $17.74 |

This data is using the ERCOT Hub Average 345-kV Hub prices

# Hedging by Market Participants

- ERCOT has limited visibility into other methods of hedging that Market Participants may engage in, including but not limited to commodities exchanges and bilateral contracts.

- With the information available to ERCOT, the level of energy hedging by Load Serving Entities varied from fairly long to fairly short relative to their physical load. This could also vary by operating day for the same entity.

- These positions would have been affected by load reductions resulting from the instructed firm load shed and other losses of load, as well as loss of generation through de-ratings or outages that occurred during the event.

# 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

# Overview

**This report provides aggregated information about the causes of generator outages and derates during the February winter storm event based on information provided in response to ERCOT Requests for Information.**

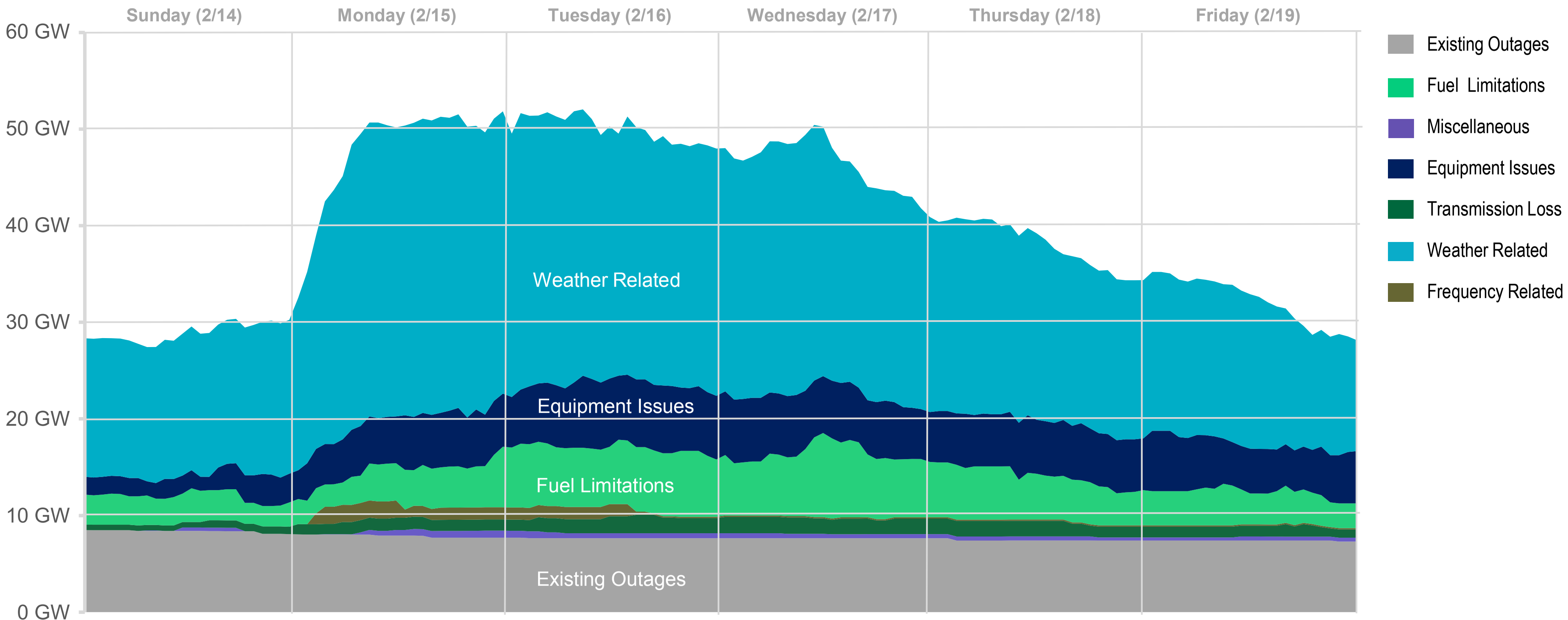
- On February 24, 2021, ERCOT sent Requests for Information (RFIs) to all Qualified Scheduling Entities (QSEs) that represent Generation Resources or Energy Storage Resources.
- The RFIs included questions about the causes of any generator outages and derates that occurred during the period of February 14-19, 2021, which were the days when the Energy Emergency Alert (EEA) was in effect.
- Using the RFI response information, ERCOT assigned each outage and derate to one of seven cause categories (*see slides 9-10 for a description of these categories*).
- The data in this report includes information about outages and derates entered by each QSE or Resource Entity into ERCOT's Outage Scheduler for the period February 14-19, 2021 as of 4 p.m. on March 4, 2021 (*Note: previously posted outage and derate data was based on entries as of February 20, 2021*).
- Following publication of the April 6, 2021 preliminary report, ERCOT requested that stakeholders provide written questions about the initial report. In response to the questions and comments received, ERCOT provides this updated version of the preliminary report with additional categorizations of the generation outage data. The supplemental analysis begins on slide 11.

# Important Notes

- The information in this document is preliminary and subject to change.
- Slides 4, 6, and 8 have been revised in this updated report to accurately reflect the seasonal capacities of each generator for the time of the event and to correct other minor categorization issues.
- For the purposes of this document, an “outage” is the complete unavailability of a generator’s capacity, and a “derate” is the partial unavailability of that capacity.
- All generator outage and derate values reflected in the graphs are based on generator nameplate capacity—i.e., the maximum possible MW output specified by the generator manufacturer. Because wind and solar output is typically much lower than the specified nameplate capacity, the outage and derate MW values used for those units to develop this report are generally much higher than the actual amount of power that would have been available in the absence of the outage or derate.
- ERCOT cannot disclose the unit-specific outage causes because they are Protected Information.

# Net Generator Outages and Derates by Cause (MW)

## February 14 – 19, 2021



*Version Date: 4/22/2021*

Net generator outages at the beginning of each hour on February 14-19, 2021, by cause category.

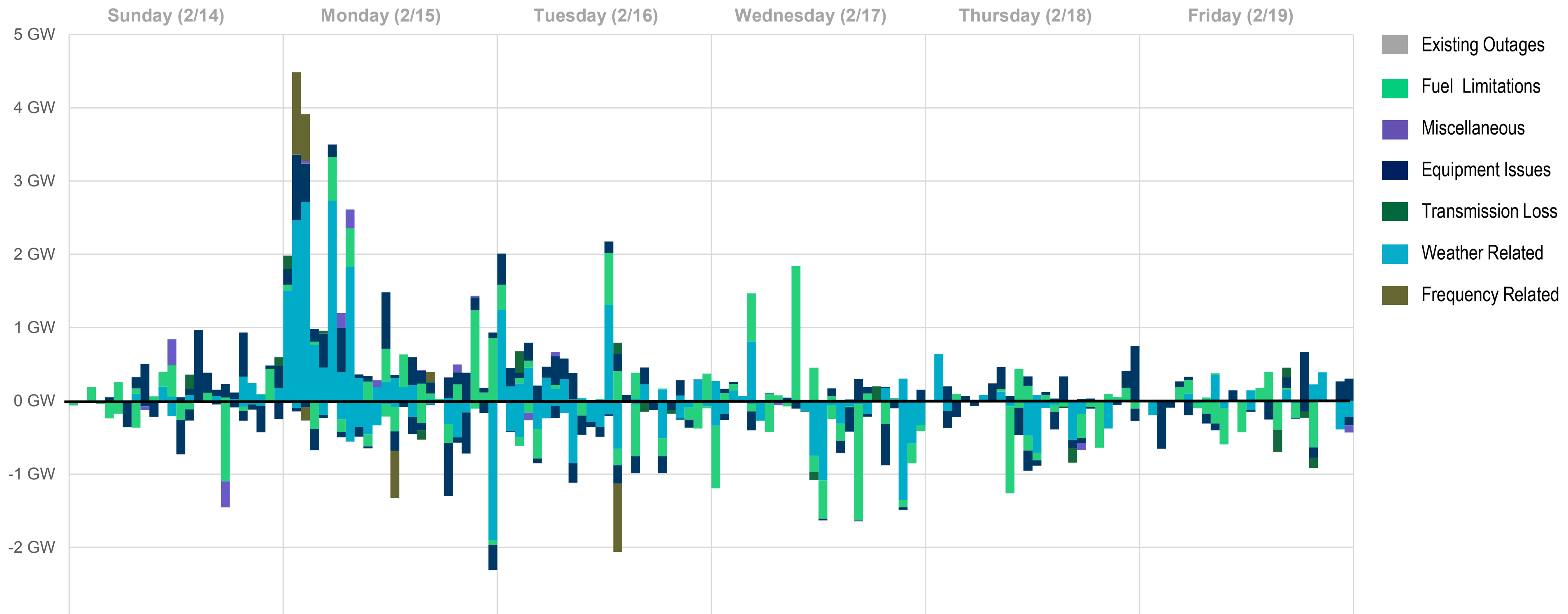
# Continued Volatility of Generation Supply During the Event

- The amount of outaged capacity shown on the previous slide (slide 4) increased sharply as the storm arrived on Sunday and stayed fairly constant from late morning on Monday to mid-day on Wednesday.

- However, as shown on the next slide (slide 6), the net level of outages masks the volatility in generation availability that continued throughout the week, with generators continuing to go out of service and come into service throughout the duration of the event.

- This volatility made it difficult to accurately forecast an end to emergency conditions.

# Incremental Generator Outage and Derates by Hour
## starting 00:00 on 2.14.21



*Version Date: 4/22/2021*

Outages and derates continued through the week at a high rate.

# Explanation: Incremental Generator Outage and Derates by Hour

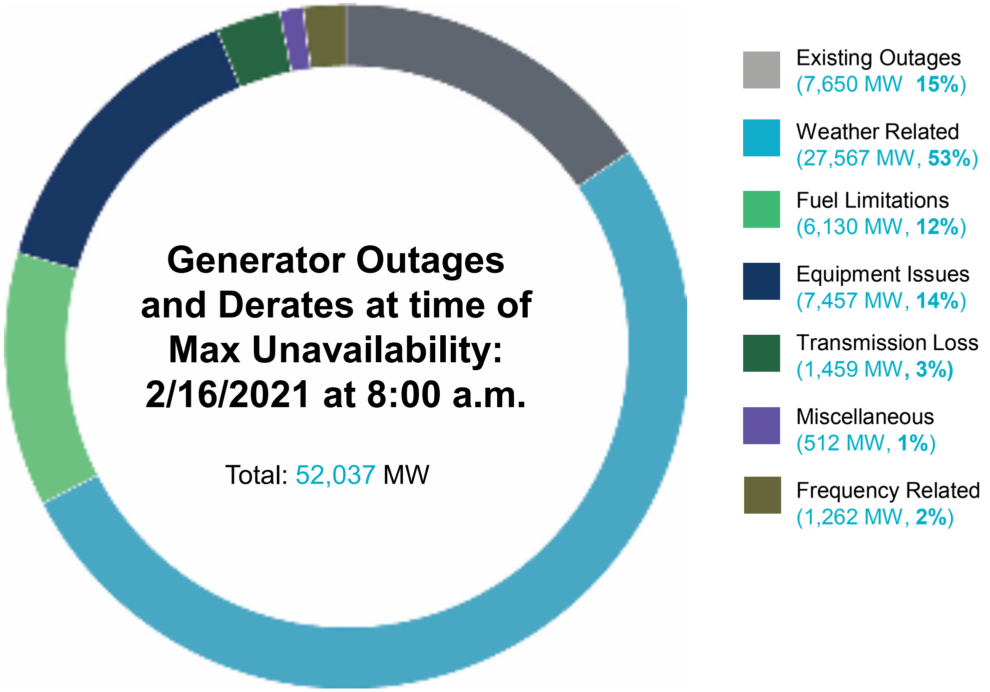
- The graph on the previous slide shows the generator outages and derates that started or ended in each hour on February 14-19, 2021, by cause category. The quantity of outages starting during a given hour are shown as positive values, and the quantity of outages ending during a given hour are shown as negative values.

- For example, if a 100 MW generator started an outage at 2 p.m. on February 14 due to a fuel limitation, and that outage ended at 5 p.m. on February 17, it would show as a positive 100 MW in the fuel limitation category for 2 p.m. on February 14 and a negative 100 MW in the fuel limitation category at 5 p.m. on February 17.

- This graph does not include the start of any outage or derate that occurred before February 14, but it does include the incremental reduction in outaged MW for any of those outages or derates that ended during the February 14-19 window.

# Generator Outage and Derates: Maximum Unavailability

- The highest amount of unavailable capacity during the period of February 14-19, 2021 occurred on February 16 at ~8:00 AM and was 52,037 MW.
- This chart shows the MW of the generator outages or derates that were occurring at that point in time by cause category.
- Note that the total outaged and derated capacity at this time is different than what was previously reported (52,277 MW) due to additional information received in response to the RFIs.



# Outage Cause Categories

**Existing Outages**:

Generator outages or derates that started before the issuance of the Operating Condition Notice on February 8, 2021; includes ongoing planned and forced outages as well as seasonally mothballed units. Some existing outages ended before or during the event, allowing the unit to return to service.

**Fuel Limitations**:

Generator outages or derates due to lack of fuel, contaminated fuel, fuel supply instability, low gas pressure, or less efficient alternative fuel supply.

**Weather Related**:

Generator outages or derates explicitly attributed to cold weather conditions in the RFI responses. This includes but is not limited to frozen equipment—including frozen sensing lines, frozen water lines, and frozen valves—ice accumulation on wind turbine blades, ice/snow cover on solar panels, exceedances of low temperature limits for wind turbines, and flooded equipment due to ice/snow melt.

# Outage Cause Categories *(continued)*

**Equipment Issues**:
Generator outages or derates due to facility equipment failures or malfunctions not explicitly attributed to cold weather in the RFI response. This includes trips and derates related to control system failures, excessive turbine vibrations, or other equipment problems.

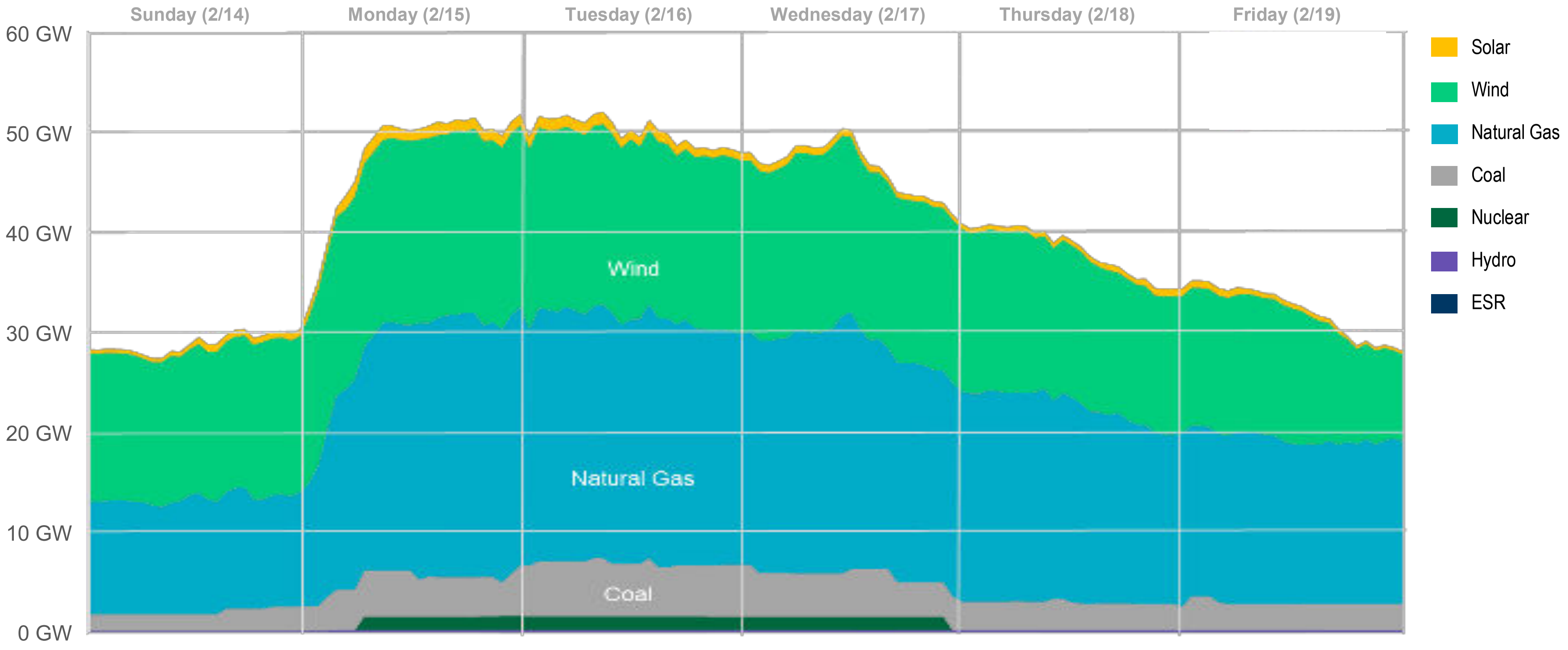
**Transmission Loss**:
Generator outage or derates due to forced outages on directly connected transmission facilities.

**Frequency Related**:
Generator outage or derates attributed to frequency deviations from 60Hz; includes automatic tripping due to under-frequency protection relays and any automatic or manual tripping attributed to plant control system issues related to frequency deviation.

**Miscellaneous**:
Other generator outages or derates not linked to one of the above causes, including outages for which a cause is yet unknown.

# Supplemental Analysis

# Net Generator Outages and Derates by Fuel Type (MW)



Version Date: 4/22/2021

Outage and derate MW for Wind in this graph are based on capacity.

# Actual Wind and Solar Production Lost Due to Outages and Derates

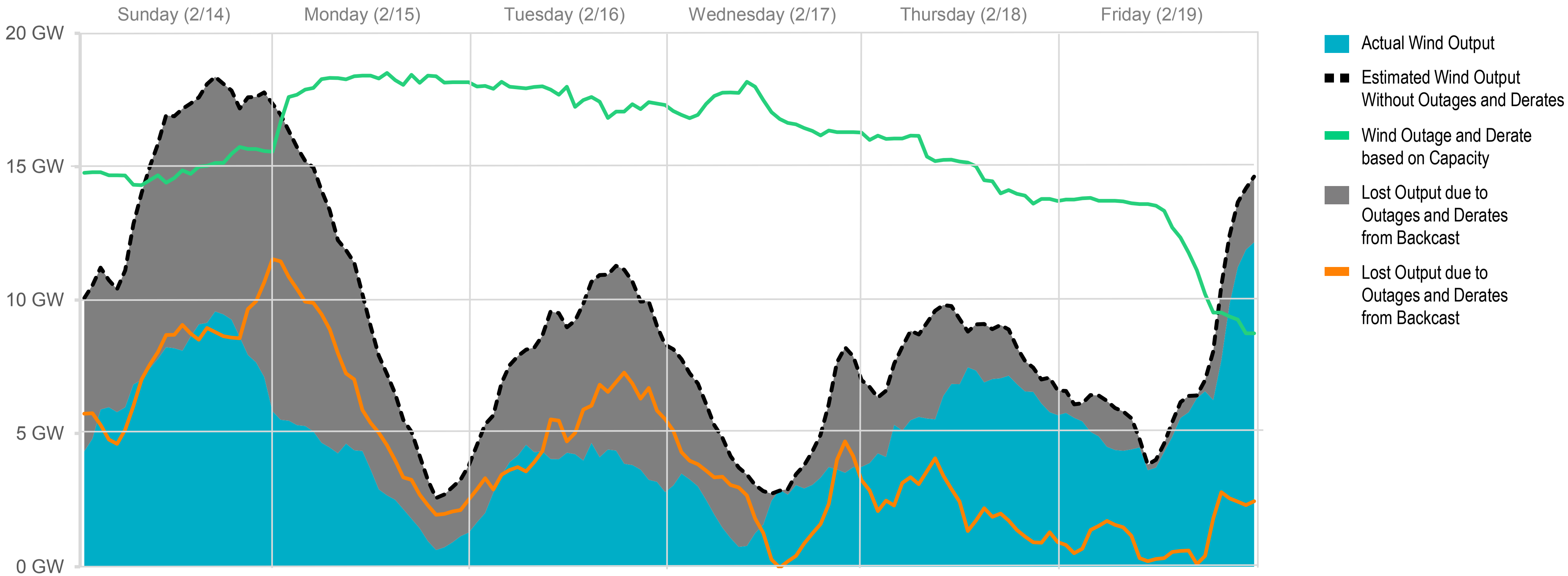
- The graphs in the April 6, 2021 version of this report (slides 4, 6, and 8) are based on the amount of capacity that was lost due to outages and derates, without regard to how much each generator would have otherwise produced during the period of the outage or derate.

- For wind and solar generators, using capacity values may not provide a complete picture of the actual energy production that was unavailable due to the outages; for example the outage of a solar generating unit at night would have no effect on the amount of generation that is available to serve consumers' demand.

- The graphs on the following two slides (slides 14 and 15) provide an estimate of the energy that would have been produced by wind and solar generation "but for" the reported outages and derates.
  - *For the wind generation estimate, ERCOT's wind forecast vendors produced a backcast of the systemwide MW that would have been produced by wind generators without outages or derates. The estimated lost output due to outages and derates is the difference between that systemwide backcasted value and the actual systemwide wind output.*
  - *For the solar generation estimate, ERCOT scaled the actual solar energy production up by the portion that reported an outage or derate of the total solar capacity.*

- These estimates were then used to reproduce the Net Generator Outages and Derates by Fuel Type graph on slide 16 based on the actual wind and solar production lost due to the outages or derates of solar and wind generation units.

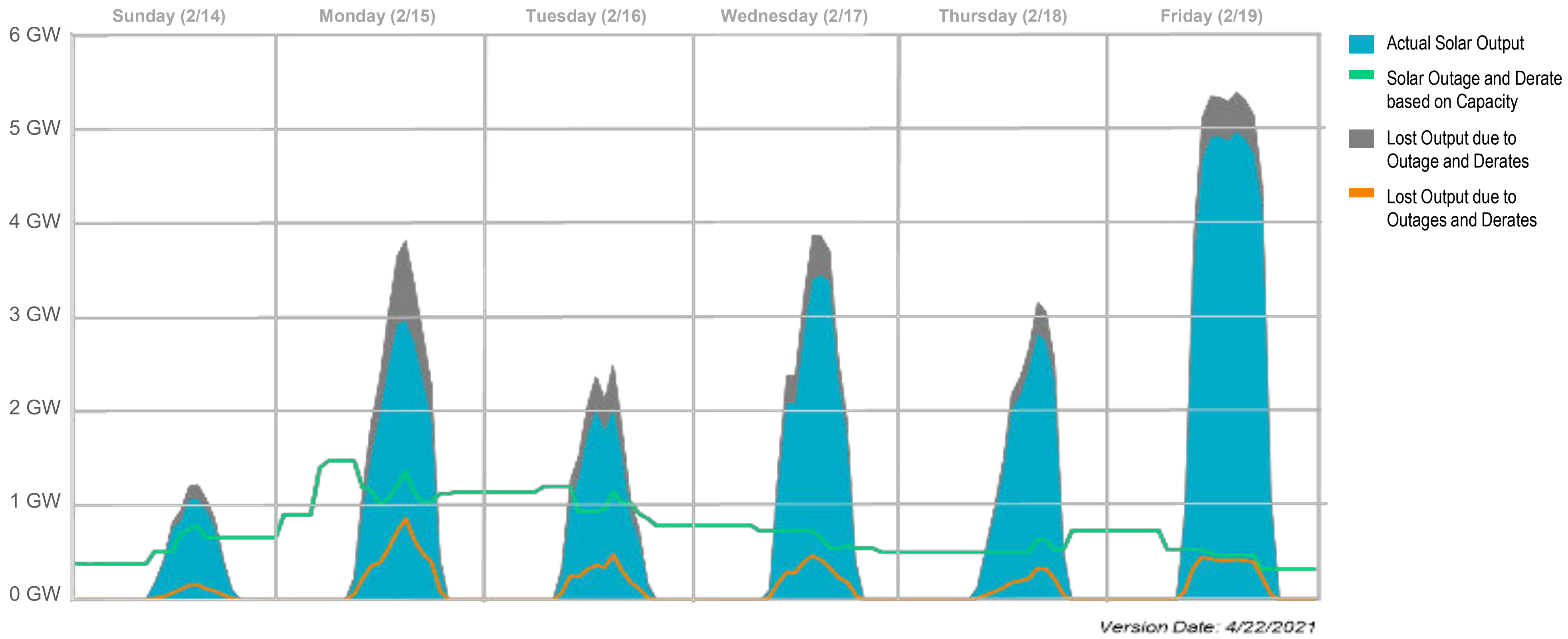
# Estimated Impacts of Outages and Derates on Wind Output



*Version Date: 4/22/2021*

Magnitude of orange line and gray area are both equal to the estimated impact of wind outages and derates.

# Estimated Impacts of Outages and Derates on Solar Output



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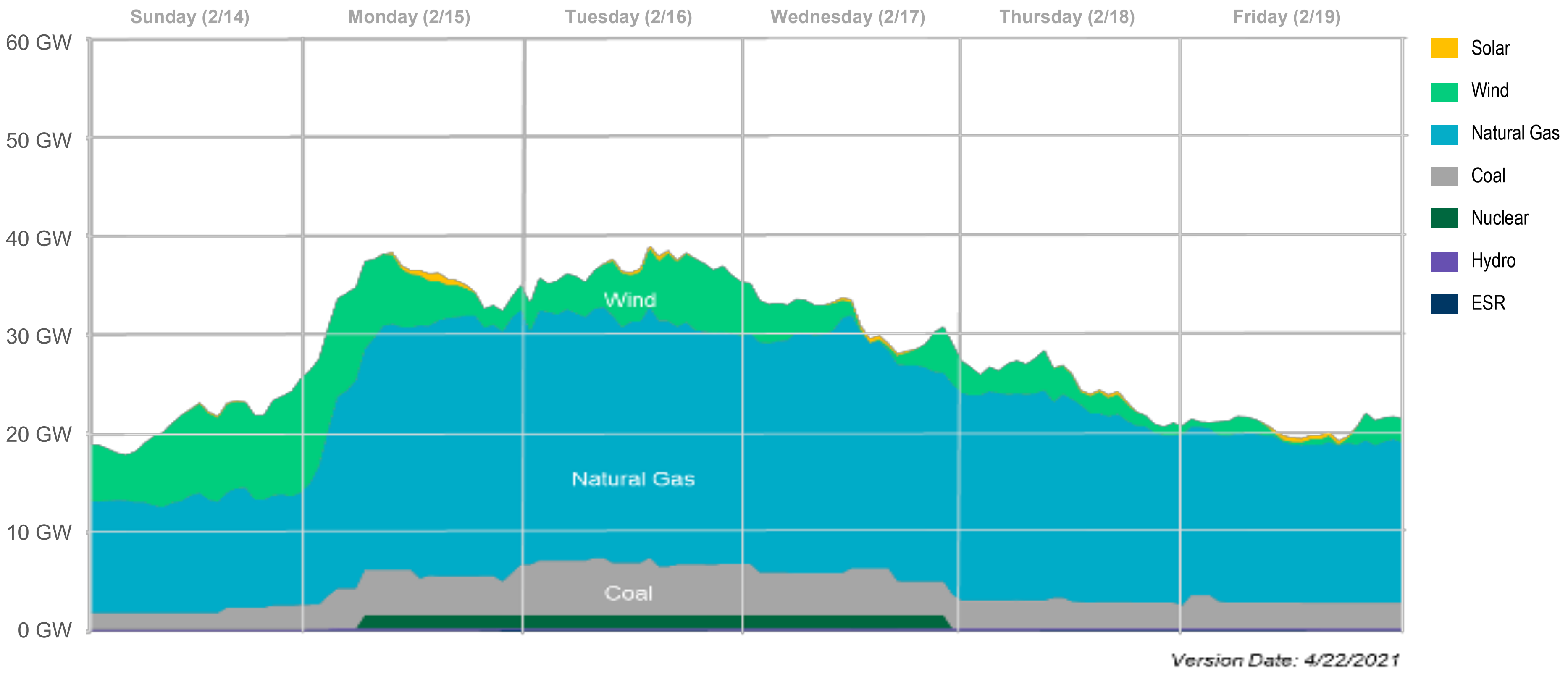
Magnitude of orange line and gray area are both equal to the estimated impact of wind outages and derates.

# Net Generator Outages and Derates by Fuel Type (MW)



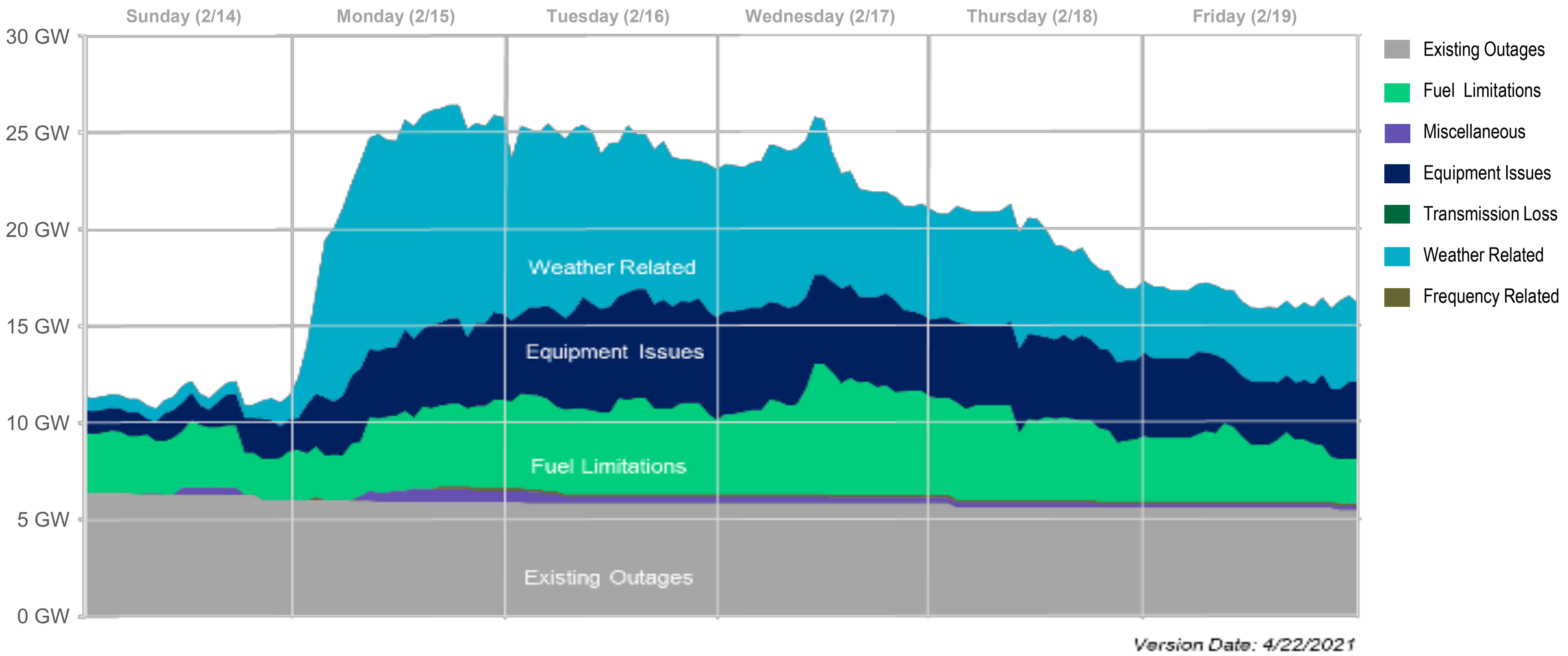
Wind and solar MW values based on estimated lost output due to outages and derates from slides 15 and 16.

# Outage and Derate Causes by Fuel Type

**The graphs on the following slides show the cause categories of the net outages or derates for each fuel type.**

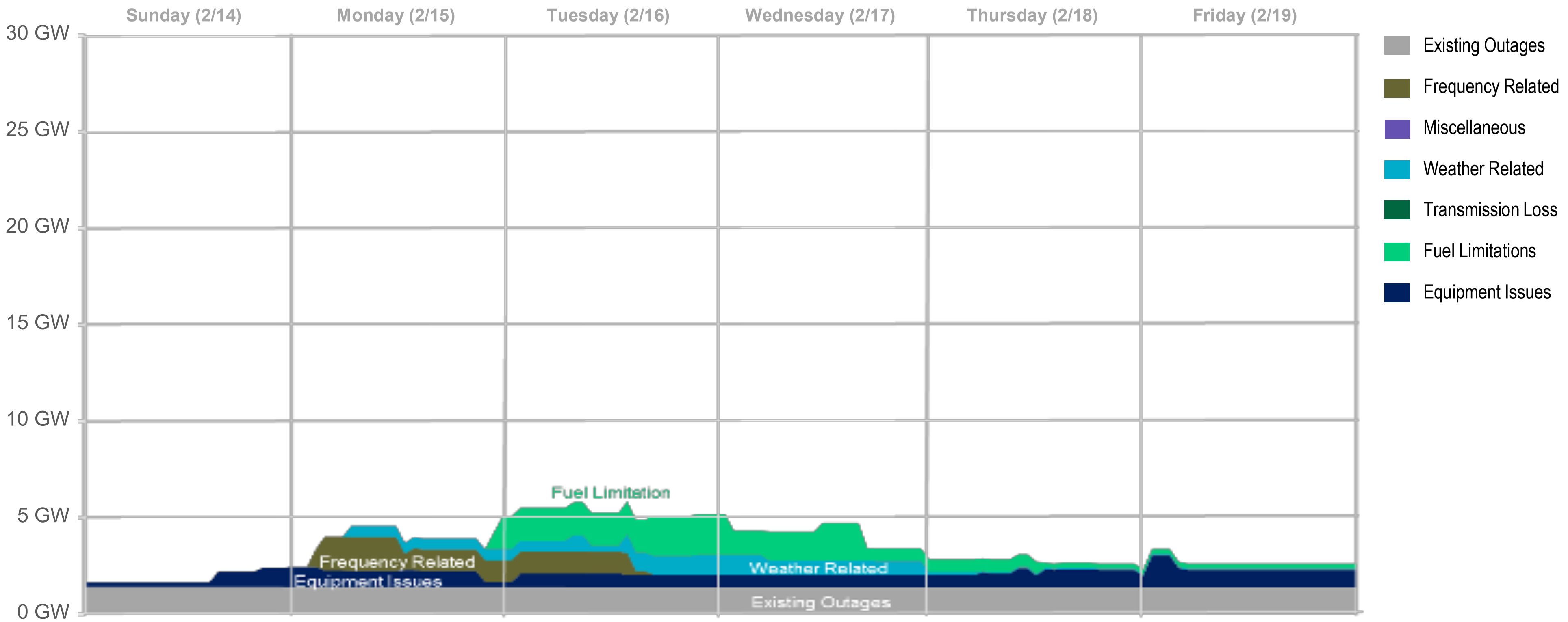
- Graphs are included for gas, coal, and wind generator outages and derates.
- For wind generators, the outages and derate values on slide 20 are based on capacity, and the values on slide 21 are based on estimated lost wind output. On slide 21, the allocation of the lost wind output to each cause code is based on the proportion of total outaged wind capacity assigned to each cause for each hour; this is an approximation, as the backcasted lost output is not available on a unit-by-unit basis.
- Graphs are not included for nuclear, hydro, solar and energy storage because the number of outages is small and it would be possible to identify individual generating unit outage causes.

# Net Generator Outages or Derates for Natural Gas Generators by Cause



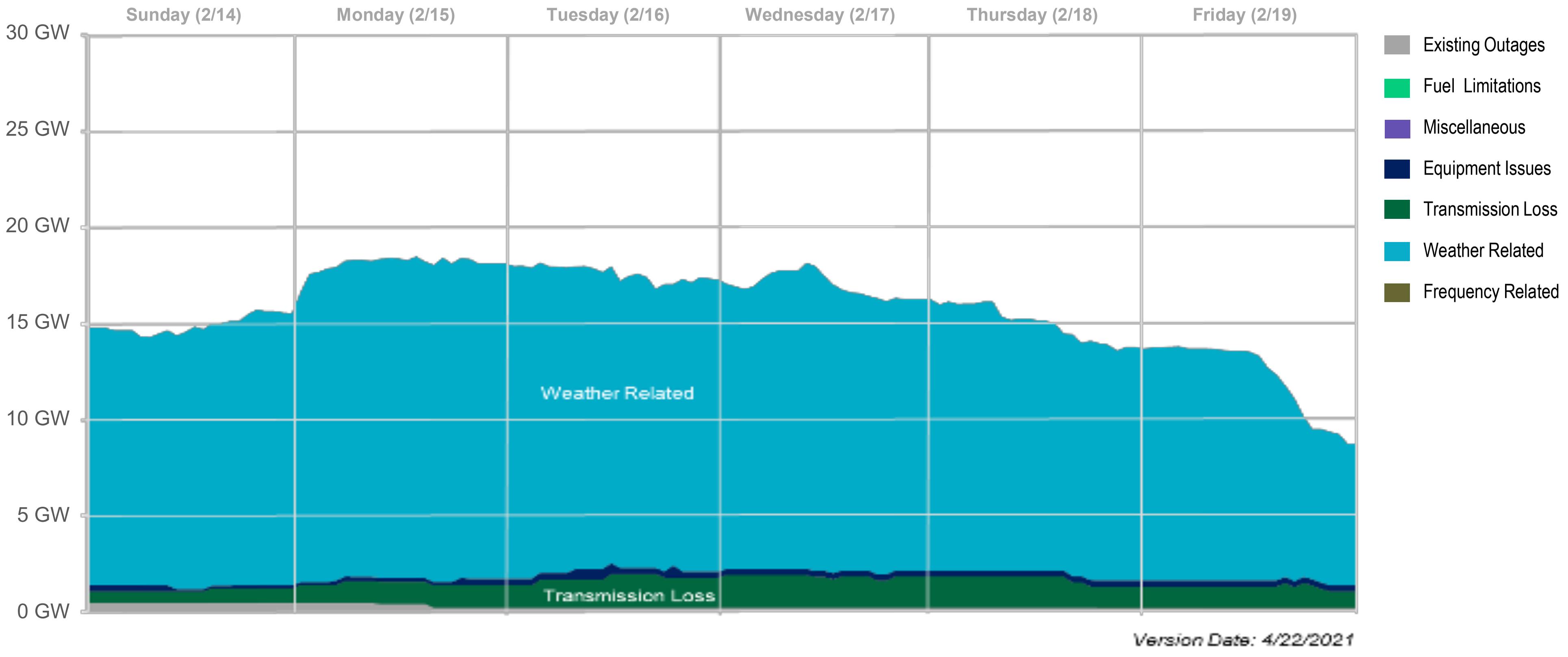
Version Date: 4/22/2021

# Net Generator Outages or Derates for Coal Generators by Cause



*Version Date: 4/22/2021*

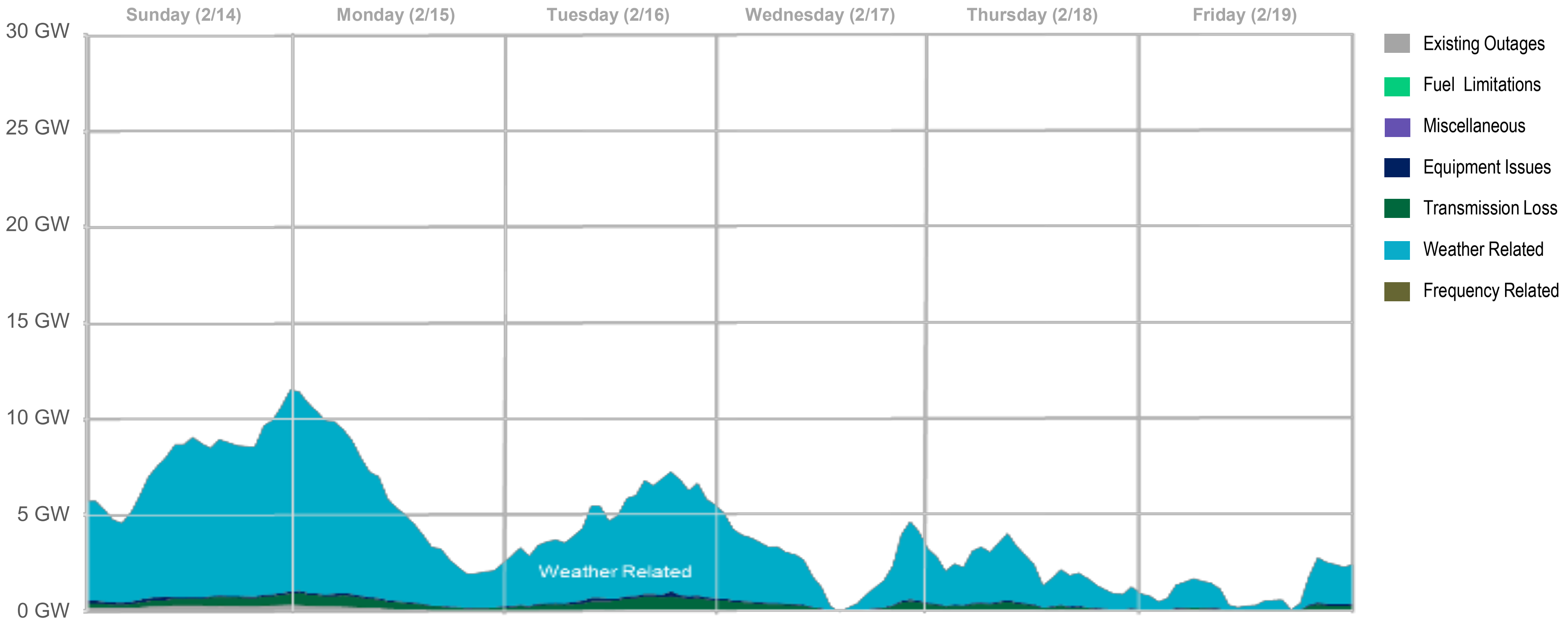
# Net Generator Outages or Derates for Wind Generators by Cause



*Version Date: 4/22/2021*

Outage and derate MW values are based on capacity.

# Net Generator Outages or Derates for Wind Generators by Cause



*Version Date: 4/22/2021*

Outage and derate MW values are estimated based on the proportion of total outaged wind capacity assigned to each cause for each hour.

# Outage and Derate Causes by Sub-causes

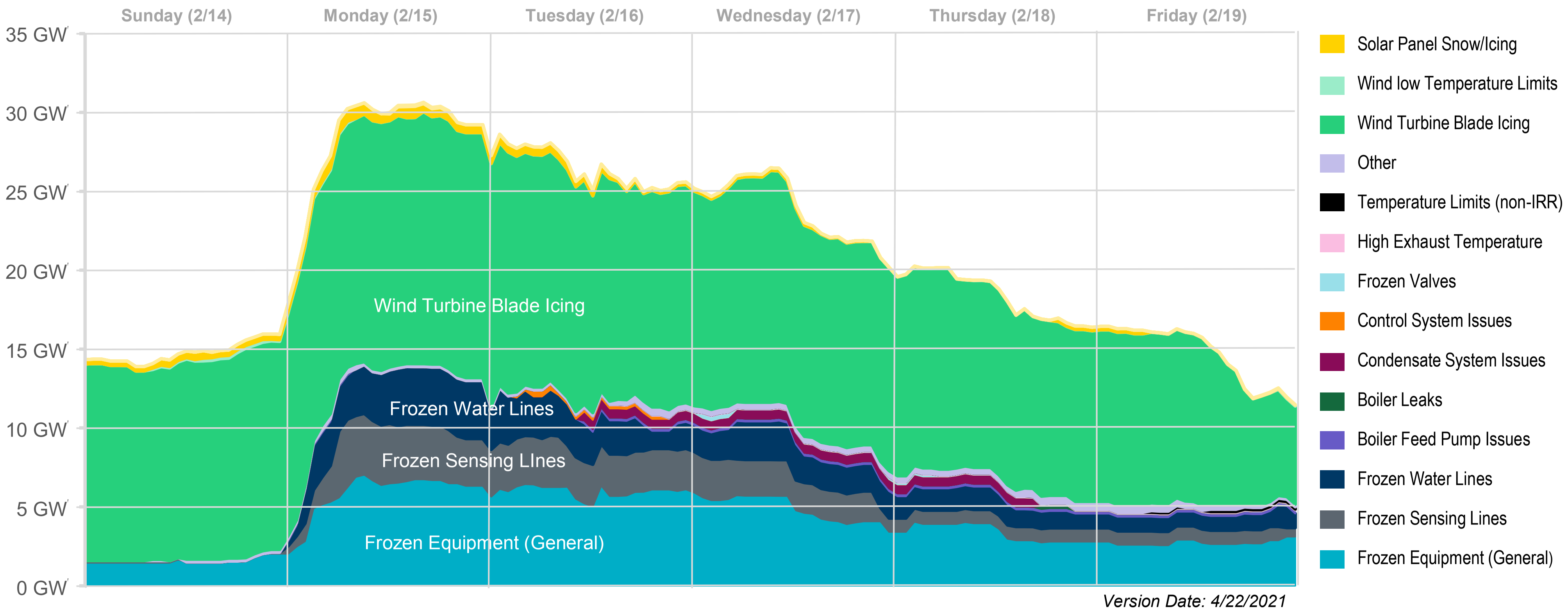
**ERCOT has further divided the Weather Related and Fuel Limitations cause categories into sub-categories of causes. These subcategories are as follows:**

- **Weather Related**
  - Boiler Feed Pump Issues
  - Boiler Leaks
  - Condensate System Issues
  - Control System Issues
  - Frozen Equipment (General)
  - Frozen Sensing Lines
  - Frozen Valves
  - Frozen Water Lines
  - High Exhaust Temperatures
  - Temperature Limits (non-IRR)
  - Solar Low Temperature Limits
  - Wind Low Temperature Limits
  - Solar Panel Snow/Icing
  - Wind Turbine Blade Icing
  - Other
- **Fuel Limitations**
  - Fuel Contamination
  - Fuel Equipment Issues
  - Fuel Impacted by Weather
  - Fuel Other
  - Fuel Pressure Issues
  - Fuel Switching
  - Lack of Fuel

**The following three graphs show the outages and derates by sub-cause for the Weather Related and Fuel Limitation outages and derates**

- *Slide 23 provides the sub-causes for the Weather Related outages using the capacity for wind outages. Slide 24 uses the estimated lost output due to outages and derates for wind outages based on the proportion of total outaged wind capacity assigned to each cause for each hour.*
- *Slide 25 provides the sub-causes for the Fuel Limitations outages.*

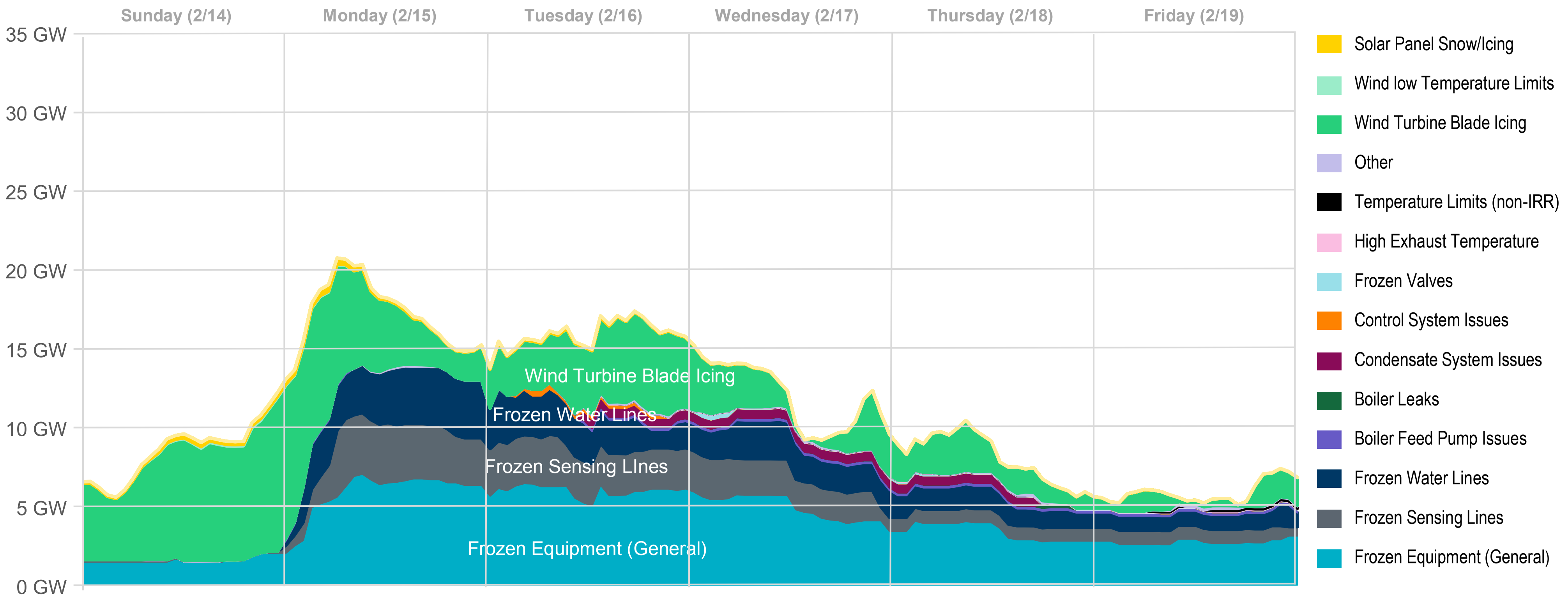
# Weather Related Generator Outages and Derates by Sub Cause



*Version Date: 4/22/2021*

Outage and derate MW for wind and solar are based on capacity.

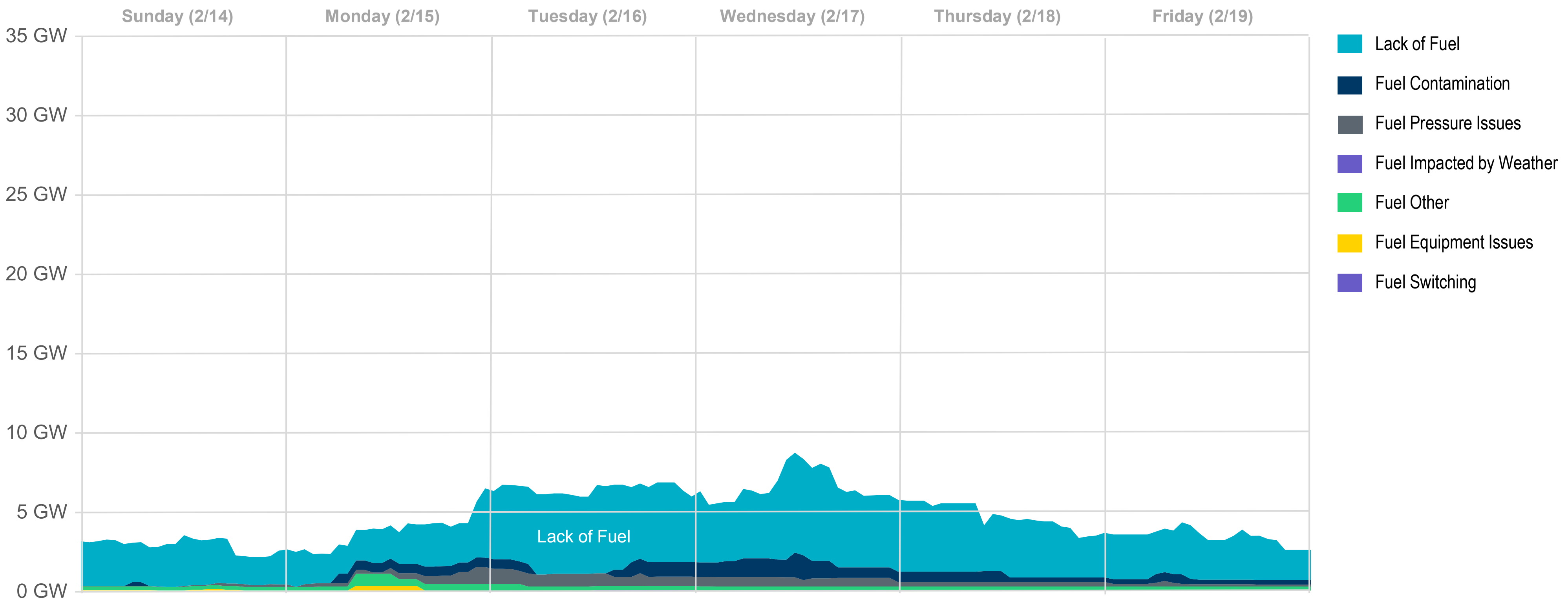
# Weather Related Generator Outages and Derates by Sub Cause



*Version Date: 4/22/2021*

Outage and derate MW for wind are estimated based on the proportion of total outaged wind capacity assigned to each cause for each hour.

# Fuel Limitations Generator Outages or Derates by Sub Cause



*Version Date: 4/22/2021*

# REPORT | NEVER AGAIN: HOW TO PREVENT ANOTHER MAJOR TEXAS ELECTRICITY FAILURE

**PUC of Texas Commissioners Report** | June 3, 2021

**Authors:**

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The historic weather system that hit the South Central United States in February 2021 led to the deaths of nearly 200 Texans[1] and caused over $100 billion in damages to Texans' homes and property.[2] Its impacts on power, natural gas, water, and transportation infrastructure were profound, leading the power grid operator, Electric Reliability Council of Texas (ERCOT), to order all local utilities to immediately decrease power demand early on February 15. This grid reliability order led to cuts in electric service to over four million premises, leaving millions of Texans out of power and in miserable conditions for up to four days.

The Texas Legislature has sent to Governor Abbott new statutes to address some of the problems that contributed to this disaster. But beyond these new laws, Texas has more work ahead to protect customers and ensure that our energy infrastructure works adequately. The February outages were triggered by an extreme weather event but were exacerbated by underlying problems that affected the entire energy system from the production of natural gas to the delivery of electricity to the customer.

These problems extend beyond the Electric Reliability Council of Texas (ERCOT) and the Public Utility Commission of Texas (PUCT) to include parts of the energy system regulated by the Texas Railroad Commission, the Texas Reliability Entity, and the North American Electric Reliability Corporation, all of which bear some responsibility for the reliability of our energy system. If Texas is to mitigate future energy system disasters and restore our state's reputation, we must do more than just tighten governance on ERCOT and the PUCT, weatherize power plants, patch the electric market, and reform some utility and retail practices.

As past PUCT Commissioners, the authors helped to design and implement many elements of ERCOT's electric system and market structure between 1995 and 2004. The mission of the PUCT is to protect customers, foster competition, and promote high-quality infrastructure. Until this February, the Texas electricity system had largely achieved that goal. We created a strong, competitive, reliable electricity system whose overall performance for more than 20 years lowered electric bills for all customer classes, created innovative options for electricity customers, attracted an unprecedented level of new natural gas and renewable generation, and kept the lights on as our state population grew by 40%.

While the February 2021 event was clearly unprecedented, prior outages should have provided a wake-up call to policymakers and regulators to address reliability issues. The events of February 2021 resulted from several policy failures as well as from operational and planning failures across our state's electric, natural gas and water systems. We must address the causes of this winter's weather challenge and prepare to deal with emerging economic, technology and extreme weather realities.

Texas is the world's ninth-largest economy. We owe it to our families and fellow citizens to learn from this event, plan for the future, and do the right thing for the good of Texas. We offer the following observations and 20 recommendations, which are organized based on the outage's contributing factors. Some of these require further legislative action; others can and should be implemented by the PUCT under existing authorities.

## Problem 1—Almost half of ERCOT's gas, coal and nuclear plants failed to produce when needed

ERCOT's publicly released data[3] and other analyses indicate that almost 9 GW (8%) of ERCOT's generation fleet was already out for maintenance on February 14 and another 22 GW (21%) of ERCOT's total generation fleet failed before 1am on February 15, when ERCOT was forced to initiate customer load-shedding. Natural gas generators represented the greatest loss of production (26 GW, including units out for maintenance). Most of those plants failed due to insufficient preparation for the intense winter storm and/or because fuel became unavailable (whether on-site, like coal plants, or due to lack of natural gas availability or delivery capability). Forty-six percent of ERCOT's total thermal generation capacity was unavailable or failed during the outage.[4]

SB3, the new reliability statute, requires the PUCT to adopt power plant winterization standards, informed by adverse weather forecasts, with compliance requirements and penalties for non-performance. This is a good start, particularly given that a recent analysis from the Federal Reserve Bank of Dallas suggests that the weatherization of Texas gas and wind power plants would be cost-effective.[5] The PUCT and ERCOT will have to ensure that these standards are appropriately rigorous and receive adequate enforcement.

SB3 directs the PUCT to examine ancillary services and incentives for dispatchable generation such as natural gas plants, and modify the design, procurement, and cost allocation of ancillary services to assure that appropriate services are available for weather emergencies. ERCOT and the PUCT are also directed to look at whether dual-fuel capability, fuel storage and different fuel procurement supply policies are appropriate solutions for extreme weather performance. The statute even calls for operation under drought conditions. These measures are a good start to assure that gas-fired power plants retain reliable fuel access.

### Recommendation 1-1—Mandatory weatherization to minimum standards for natural gas production and pipelines, with meaningful enforcement

Winterizing power plants will not help if power plant fuel supplies and delivery infrastructure (natural gas wells, production and processing facilities, storage, and pipelines) are not also winterized. Therefore, SB3 sets up a process to "map the state's electricity supply chain" to identify priority electricity service needs during extreme weather events, including natural gas production and delivery facilities. SB3 directs the PUCT and RRC to identify best practices for weatherizing these facilities, adopt a rule for natural gas facilities in the electricity supply chain to weatherize their facilities and prioritize electric service to those facilities.

It is not clear that SB3's new requirements will be sufficient to assure continuing delivery of natural gas at reasonable prices during future winter emergencies. SB3 places no compliance deadlines on the natural gas weatherization requirement, so the interdependence between natural gas supply and electric power generation could remain unaddressed for some time.

SB3 assumes that weatherization is only needed for identified supply chain facilities, which does not reflect the true interconnectedness of the entire natural gas delivery infrastructure. If only the natural gas facilities that directly serve electric generators are winterized, many others could fail, causing a shortage that drives natural gas prices across Texas and the entire Midwest. Therefore, the Legislature should clearly define "price gouging" for electric emergencies and set an appropriate limit on how high gas market participants can raise natural gas forward and real-time prices during emergency conditions.

## Problem 2—Electric demand skyrocketed 20% over forecast

In February, Texas and its neighboring states experienced a multi-day run of Arctic temperatures and winds that drove ERCOT electricity demand for heating to unprecedented levels. As much as 35 GW (over 40%) of the total Texas electric demand was for heating. Much of Texas' housing stock has little or no insulation and relies only on electric resistance heaters rather than gas heat, but at such low temperatures, uninsulated homes cannot be heated effectively. This drove ERCOT's winter electricity demand to unprecedented levels; had ERCOT not called rolling outages early in the morning on February 15th, we were on the way to an all-time system peak later that day.

Between leaky buildings, lack of electricity and poor public communications, over 100 Texans died of hypothermia or carbon monoxide poisoning during the February blackout.

Texas must fix this by improving the energy efficiency of our buildings. Over half of Texas homes were built before the state adopted building energy codes with insulation requirements in 2001. And over 60% of Texas homes are heated with electricity rather than gas. If these homes had energy-efficient building shells and heaters before February 14, that could have reduced electricity demand by at least 15 GW—enough to drop peak demand down to 62 GW and offset the loss of most of the generators that failed on February 14 and 15. Estimates developed for the U.S. Department of Energy indicate that Texas could use cost-effective energy efficiency measures to reduce 2030 residential electricity use by 18.5% and total electricity sales by 17%.[6]

### Recommendation 2-1—Update Texas building energy codes and require them to be automatically updated as international building codes are updated

Since Texas is the fastest-growing state in the nation, we have the opportunity to improve the quality of our housing stock with new builds, saving energy use and lowering energy bills for many residents and businesses. Texas energy efficiency requirements for new buildings were last updated in 2016 to comply with the 2015 International Energy Efficiency Code and 2015 International Residential Energy Code.[7] International building codes are updated every three years; the 2021 IECC and IRC code updates are now available. Texas should enact legislation to require automatic adoption and use of the latest international efficiency codes.[8] The U.S. Department of Energy estimates that new homes built to the IECC code would reduce energy use and bill savings by about 9% each.[9]

### Recommendation 2-2—Raise TDU energy efficiency program goals to increase both annual kWh savings and peak reduction

As part of Texas' electric restructuring bill enacted in 1999 (SB 7), the state required electric utilities to undertake limited energy efficiency programs beginning in 2002, giving each utility a minimum demand reduction goal – to reduce the growth in peak demand by 10% each year in programs delivered by retail electric providers. The PUCT increased this requirement in 2010 to reduce 30% of peak load growth plus an energy savings goal. Texas' energy efficiency programs have some of the lowest energy use reduction goals and per capita spending on energy efficiency compared to all other states.[10]

The PUCT should conduct a formal study to determine more appropriate energy efficiency goals and programs for Texas. Those programs should reflect the need to increase the efficiency of Texas' installed air conditioning and heating equipment in Texans' homes and businesses, in order to reduce both energy use and peak loads.[11] These should be assessed using broader cost-effectiveness tests that recognize residents' and owners' bill savings, grid operational reliability impacts, jobs benefits, health and equity benefits as well as energy savings. The study should be completed within nine months and the PUCT should adopt implementing rules six months later. The PUCT's new rules should increase utility energy efficiency program funding to levels that can support higher efficiency goals.

### Recommendation 2-3—Increase energy efficiency retrofits for low-income and multi-family housing across Texas

Over 4 million Texans (15.5%) live below the poverty line, and our state has a shortage of low-income housing with only 29 affordable homes for every 100 low-income renters. Low-income homes are less energy-efficient than other homes, and low-income citizens pay a much higher proportion of their incomes on housing and energy than other citizens. Making low-income homes, heaters, and air conditioners more energy efficient will reduce peak demand for all of ERCOT, reduce those customers' energy bills, and improve their health and comfort.

At present, fewer than 4,000 Texas low-income dwellings per year receive efficiency retrofits using federal DOE-WAP and HHS-LIHEAP-WAP funds; the utility-administered low-income weatherization programs weatherize fewer than 15,000 dwellings per year.

Therefore, the PUCT should require at least 40% of electric utility energy efficiency program savings to come from retrofits of low-income and multi-family housing. The Legislature should modify TDHCA's low-income programs to include weatherization, building repairs and replacement of inefficient heating and cooling appliances and systems. The TDHCA low-income program requirements should be modified and funded to serve a minimum of 100,000 households per year.

### Recommendation 2-4—Increase demand response for grid emergencies

All electric customers could modify their energy use in response to changes in the price of electricity or a call to conserve to protect grid reliability. But few customers practice this demand response capability, often because they don't have the information, tools or incentives to do so. Some of these tools include smart thermostats, automated building energy management systems, or remote-controlled equipment such as pool pump or water heater controls. Some retail electric providers and energy service companies and aggregators offer formal demand response programs that send price signals or control signals to customers' equipment, with payment for appropriate load reductions or increases as needed. If more of ERCOT's load could be managed through planned, deliberate, customer-consensual measures, we could minimize future involuntary load-shedding.

SB3 "allows" electric utilities to establish load management programs for use in the event of a grid emergency. It also tells them to seek voluntary load cuts from large customers before cutting residential loads. These measures are not enough.

Instead, all-electric utilities, municipal utilities, and cooperatives should offer customers compensated demand response options and procure demand response that can cut at least 10% of each entity's summer peak load and 10% of each entity's winter peak load through remote actuation. Design these and other measures to maximize and leverage customer-owned and distributed storage and distributed generation as well as customer load management for the provision of ancillary services, to facilitate the integration of intermittent generation and enhanced grid reliability around the clock. Coordinate these with Retail Electric Providers and adjust ERCOT and PUCT rules as needed to facilitate increases in price- and reliability-responsive demand response.

Every customer who enrolls to provide emergency demand response should be required to certify that it is not a critical load under the criteria the PUCT will develop pursuant to SB3. Each distribution utility should verify that no emergency demand response customer it serves is on its critical load registry.

## Problem 3—Distribution utilities didn't rotate outages, leaving two-thirds of Texans without electricity for up to 70 hours

SB3 requires the PUCT and utilities to update criteria and recognition of critical residential customers and critical facilities. It also requires the utilities to conduct annual load-shed exercises. These are valuable first steps. But if Texas identifies more critical customers yet cannot manage distribution outages more effectively, this measure may not help us better manage future outages.

Texas' electric utilities had to cut service to millions of customers because the critical facilities (those they knew of) are located on large circuits serving large numbers of customers and high electric loads on every circuit. Once those circuits were protected, there was no electricity left to serve the remaining circuits that don't serve critical facilities, so all the remaining circuits were cut. Although utilities aim to rotate small-scale outages across many circuits, in February there were so many circuits out relative to the available generation that there was no way for the utilities to rotate the outage burden among circuits and customers. Thus, many customers on circuits without critical facilities stayed out of power for several days in a row. The lack of outage rotation in February was the most customer-impacting part of this disaster—many homes reached freezing temperatures during multi-day outages, causing many deaths from hypothermia and carbon monoxide poisoning, and millions of frozen pipes and damaged property and possessions.

This outage management process must be overhauled. It is easier to manage outages and rotate outages fairly if circuits containing critical facilities are smaller and require less power, and if non-critical circuits are smaller so that outage burdens can be shared. Dividing the grid into smaller operational segments will enable the utilities to conduct smaller, more granular and targeted outages affecting fewer customers.

Texas customers have funded major utility investments in smart meters and other smart grid infrastructure. But the utilities have not yet leveraged these investments for better outage management. Extreme weather conditions are a perfect opportunity to deliver that functionality. Until it is clear that meter functionality and control capability can be used dependably for surgical outage management, other solutions are needed.

### Recommendation 3-1—Require TDUs to modify distribution circuits for more granular outage management

The PUCT should order utilities to modify their distribution systems using sectionalization devices wherever feasible to cut up each circuit into smaller sections, starting on those circuits hosting critical facilities so that a single hospital doesn't lock in service for a giant chunk of a city and leave others literally out in the cold.  Sectionalization around critical facilities and industrial customers will enable more granular outage management and outage rotation among customers.

### Recommendation 3-2—Require large industrial and commercial customers to be able to reduce load remotely

Require large industrial and commercial customers, including State of Texas facilities, to have the capability to reduce load remotely by at least 30% under emergency circumstances, and require these facilities to cut their loads before ERCOT orders residential customer load-shedding.

### Recommendation 3-3—Require all critical facilities to have two days' worth of backup power

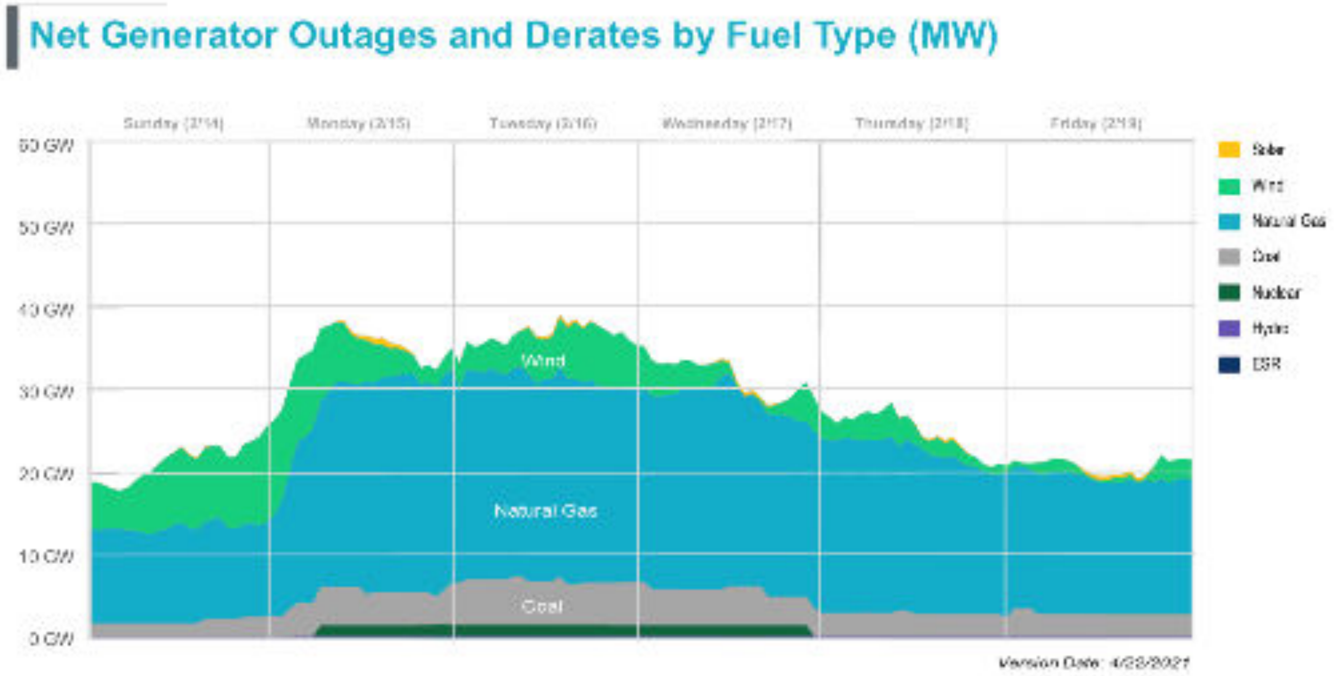
SB3 requires some water utilities to better prepare to maintain water provision to wholesale customers during emergencies.  The Legislature dropped provisions to offer matching funds to hospitals, nursing homes, water, and wastewater utilities to acquire backup power systems.

The Legislature should require most critical facilities to have two days' worth of backup power (combination of PV, battery, and low-emissions propane or diesel generation).  This offers two major benefits—it will improve community resilience in the face of diverse threats (such as extreme weather disasters or cyber-attack), and it will help each critical facility and its community ride through a brief grid outage or outage management failure.  While this would not be easy or inexpensive, the state can facilitate greater critical facility resilience through state Energy Star loans and energy efficiency improvements and leverage federal funding from FEMA, the Rural Utility Service, and other federal sources.

## Problem 4—Poor demand and supply forecasting and planning by ERCOT

The February winter storm was a historic event, but the role of scenario planning is to model just such extreme events.  ERCOT's season-ahead forecasts and scenarios have not created sufficiently broad, stressed scenarios for reliability and contingency planning purposes.  ERCOT's pre-winter Seasonal Assessment in November 2020 predicted winter peak demand under normal conditions to be 57.7 GW and an extreme season peak load of 67.2 GW.  This compares to the 77 GW ERCOT expected to hit later on February 15 if not for the load cuts, so ERCOT's planning scenario was at least 15% too low.  ERCOT has under-estimated peak load and peak net load in other summer and winter load events.

ERCOT's pre-season assessment[12] predicted about 8.5 GW of thermal generation on outage and 7 GW of wind capacity out of service.  In fact, actual outages were more than five times greater, as the ERCOT graphic below shows.[13]  Actual thermal generation during the freeze drastically under-performed ERCOT's winter assessment.  Meanwhile, ERCOT's assessment anticipated only 963 MW of planned winter-rated wind and solar capacity available, [14] when in fact generation from those resources actually exceeded those projections.



ERCOT's extreme case seasonal scenarios have assumed that adverse conditions occur individually (e.g., high demand with low renewables is a different scenario than high demand with low thermal generation) rather than assuming that multiple adverse events occur simultaneously (as often happens in real life, whether due to common modes of failure and/or Murphy's Law).  In the case of this event, ERCOT experienced the combination of a massive spike in cold weather demand with a massive failure of thermal generation, low renewable generation, and a spike in natural gas prices, all stretching over five days.  ERCOT's recent Summer 2021 assessment now reflects multiple adverse condition scenarios.[15]

**Recommendation 4-1—ERCOT should improve demand forecasting capabilities**

Load and net load (customer demand net of real-time wind and solar generation) affect how much and which generation is made available to meet load—i.e., daily and hourly operational reliability—and how much electricity will cost in each period (i.e., electricity price).  Consistently low forecasts or consistent misses during peak periods lead to lower generation availability, higher prices and more scarcity pricing events.

ERCOT, its market monitor, and the PUCT should all be scrutinizing ERCOT's past load forecasting and net load tools in much greater detail and sophistication. They need to identify significant biases and flaws in ERCOT's load forecasting tools and data, identify and implement better forecast tools, methods and data, and conduct on-going reassessment and improvement to assure on-going forecast accuracy with limited bias or error over time.

**Recommendation 4-2—ERCOT should broaden its use of scenario analysis with more aggressive worst-case outcomes**

ERCOT should design and explore multiple climate change and extreme weather forecasts and demand scenarios in combination with multiple compound failures per event, for planning, resource adequacy assessments, and stress-test analyses.  ERCOT's extreme stress scenarios should factor in potential communications and cyber-security failures as well as compound losses of transmission and/or generation.

**Recommendation 4-3—Acknowledge changing extreme weather threats**

The SB3 requirement that Texas agencies consider weather predictions from the State Climatologist is a good start, but the magnitude of climate threats requires us to do better. The Legislature should require the PUCT, RRC and utilities to use forward-looking 30-year climate and extreme weather projections in combination with the worst past extreme weather and grid disaster events over a 50-year history in all planning scenarios and electricity asset reasonableness and prudence evaluations.

## Problem 5—Power market operation was ineffective

During the five-day February power outages, it appears that errors in the design and implementation of ERCOT's market pricing software and industrial customer curtailments contributed to both dramatically high spot market prices and natural gas scarcity. The PUCT's decision to keep the $9,000/MWh scarcity price cap in effect for several days – even though the price cap clearly couldn't bring additional generation back online -- exacerbated the disaster.

The ERCOT energy markets are designed to operate when there are sufficient supplies to address demand and to raise prices under scarcity conditions. SB3 directs the PUCT to revise wholesale pricing mechanisms for emergency conditions, including a circuit breaker for use when higher prices cannot incent more electricity production. The statute allows the PUCT to give generators cost-of-service pricing if appropriate for some portion of the emergency event.

### Recommendation 5-1—Evaluate whether ERCOT needs different winter versus summer planning, operations and protocols

Summer heat and winter storms pose very different challenges for generation adequacy in Texas, and grid failures have different human and economic consequences in summer versus winter. To date, most resource adequacy efforts have focused on preparing to meet summer peaks rather than readying for winter weather operations, even though ERCOT's most stressful periods have historically occurred in January and February. Because so much of the state's dispatchable supply is fueled by natural gas, the winter demand for gas to heat homes and businesses (which doesn't exist in the summer) is a significant competing factor that does not complicate summer peaks. But this event reminded us that the consequences of a grid failure in winter can have much costlier human and economic consequences than a summer peak failure. Therefore, the PUCT and ERCOT should examine the distinctions between summer and winter resource needs carefully to determine whether different market products (e.g., winter-focused ancillary services) or operational protocols (e.g., limits on maintenance scheduling) are appropriate to different seasons.

SB3 directs the PUCT to study ancillary services to determine whether and how those services need to change going forward and to evaluate whether additional seasonal and other products are needed to enhance reliability. This will be important work.

### Recommendation 5-2—Reassess requirements and compensation for black-start capacity and test and drill twice/year

Grid operators use "black-start" capacity from stand-alone generators, batteries, or transmission to rebuild a power system, conducting a careful balancing act that powers one generator from another and adds customer load in sequence with generation additions. But in the February outages, it is not clear that all of ERCOT's designated black-start assets would have been available to restart our grid due to maintenance, frozen equipment, or lack of fuel. If ERCOT had actually lost the entire power system to a full blackout, these black-start units would not have been able to do the job we pay them to do. This is unacceptable.

ERCOT and the PUCT must reassess black-start performance requirements, compensation and penalties. After the February outage, ERCOT said that had the grid collapsed, a black start could have taken weeks or months to complete. This is also unacceptable. ERCOT must stress-test its assumptions and generators' claims about black-start unit availability and conduct regular drills to be sure that they can rebuild the system quickly after some future grid collapse, using whatever black-start resources are available. The benefits of this readiness go beyond weather-caused events to encompass preparation for and mitigation of impacts from cyber and physical attacks on the power system.

### Recommendation 5-3—Do not add an out-of-market "generation capacity reserve" scheme

The blackouts in February were not due to the lack of generation capacity within ERCOT, but rather to the failure of many generators to prepare their hardware and fuel supplies adequately for the Arctic weather; a capacity market would not have prevented this outcome. Similarly, adding emergency capacity through a fleet of additional generators funded without regulatory scrutiny through a non-market charge or tax will raise costs to every electricity customer and chill other new or existing investors' willingness to compete in the ERCOT market.

## Problem 6—Inadequate or inappropriate governance

Modern power systems are extraordinarily complex and costly. The extended power outages in February demonstrated the painful human and economic consequences of power system failure. Given these stakes, it is essential that our state assure that the regulatory, technical and management leaders who manage the institutions that run our grid have the expertise, experience, and independence to act in the best interests of our grid and our citizens.

### Recommendation 6-1—Strengthen Texas' Public Utility Commission

The Texas PUC is significantly under-resourced relative to its workload and to comparable state utility commissions. SB3 will add two more commissioners. The Legislature should increase PUCT funding and headcount to enable the Commission to hire more expert staff and consultants and improve the ongoing education of staff and commissioners about pressing market and oversight issues. Prize expertise in Commissioner and senior staff appointments.

### Recommendation 6-2—Give ERCOT an independent, expert Board of Directors

ERCOT now has a "hybrid" board of directors, with most members appointed from among the stakeholder communities and five unaffiliated directors. SB3 replaces ERCOT's "hybrid" board with eight voting expert members, but those experts will be selected by political appointees and subject to a Texas residency requirement. We recommend that future ERCOT board members be selected by ERCOT Board members without any external political screening, to avoid any actual or appearance of political interference with critical, complex Board decisions affecting the ERCOT power system. And ERCOT would be better served if the Board contains some non-Texans with valuable expertise and insight to complement and broaden the Texas perspective.

### Recommendation 6-3—Establish active reliability compliance oversight

The PUCT needs trusted, competent external entities to review and verify compliance with all weatherization and reliability requirements placed upon electric generators and utilities. Additionally, ERCOT and the PUCT need to actively review and act upon reliability review findings. SB3 points in this direction but it is unclear how this process will work in practice. Compliance with weatherization and reliability mandates is essential to move the likelihood of future supply-caused power outages toward zero.

### Recommendation 6-4—Study the potential benefits and costs of adding additional high-voltage transmission between ERCOT and its neighboring interconnections

ERCOT is unique among U.S. electric interconnections because it is not synchronously interconnected with other electrical regions. For that reason, Congress and federal electricity regulators have to date granted unusual deference to Texas regulators to set ERCOT's rules. Although additional transmission lines would not have been able to bring in enough additional energy to fill the deep shortfall ERCOT experienced on the morning of February 15, 2021, they could help to prevent or ameliorate future grid operational problems, particularly black-start energy that could be invaluable to rebuild the grid in the event of a future collapse. Last, given Texas' wealth of wind, solar and natural gas resources, the state could benefit from exporting generation. These issues and opportunities should be studied in a thorough and apolitical fashion.

An independent expert committee studied the question of transmission integration (called alternative current interconnection) with the Eastern Interconnection in 1995-6 pursuant to a 1995 Legislative directive. That study concluded that the costs exceeded the benefits of such interconnection. The new SB1 budget authorization directs the PUCT to again study the costs and benefits of interconnection with the Eastern and Western Interconnections and with Mexico. Such a study can address the questions above.

## Problem 7—We don't have full information on the contributing causes of the blackout and the sequence of events and actions by ERCOT, power plants, fuel suppliers, regulators, and customers before and during the event

There are investigations underway by ERCOT, the Public Utility Commission of Texas, the Texas Attorney General, and the Federal Energy Regulatory Commission with the North American Electric Reliability Corporation. The scopes and timetables for all of these investigations are unknown to the public.

The public and policymakers deserve to know what power plants failed, when they failed, the reasons they failed, when fuel deliveries became unavailable and why, where transmission constraints limited electricity deliveries from plant to customers, and whether each transmission and distribution utility cut all the load it was directed to cut and whether those load-shed allocations were appropriate. We should also confirm who profited from the $50 billion spent on power during the four-day-long outages—six times more than the cost of power in all of ERCOT in 2020.

It is not clear whether and when the results of these investigations will be made available for public understanding and policy development, even though responsible policy development depends on accurate information.

### Recommendation 7-1—Release all Texas investigative findings to the public

The governor should direct all Texas entities to release all investigation findings on the February outages, with no agency withholding privileges and minimal protection of private entities' commercial information.

### Recommendation 7-2—Routinely collect data on all grid and fuel supply failures and make it public

The public deserves to understand what happened when the institutions and infrastructure we rely on fail. Policy-makers need to know why it happened in order to prevent future failures. Understanding energy infrastructure problems requires that both private and public entities and individuals who possess relevant information share it, without excessive retreat behind claims of governmental or commercial privilege. The state should create formal mechanisms and entities to identify, collect and analyze relevant grid and related information for routine and extraordinary conditions (including fuel production and delivery status, power plant and transmission line status, and distribution utility outages and critical facility lists). A few elements of emergency event information may justify protection for the sake of grid security, but we should lean toward requiring all information to be shared analysis and improvement and minimize state agency or commercial barriers against information release.

## Conclusions

SB3 and other new statutes adopted by the Texas Legislature have provided a swift and focused response to the February disaster, but there is more work to be done to address all of the causes of the February 2021 Arctic outage and prepare for the challenges ahead.

This paper offers a broad set of recommendations; with multiple investigations under way, we hope to learn more to refine these and other solutions in the future. Although the Legislature has taken initial action, many of the recommendations above can be implemented by the PUCT, RRC and ERCOT under existing statutory authorities, as indicated in the table below.

## SUMMARY OF RECOMMENDATIONS

| RECOMMENDATION | PUCT existing authority | ERCOT existing authority | RRC existing authority | Legislative action needed |
|---|---|---|---|---|
| 1-1 weatherize natural gas production and pipelines | | | | More needed |
| 2-1 Update energy efficiency building codes | | | | Action needed |
| 2-2 Raise utility efficiency program goals and funding | Raise goals | | | Raise goals and funding |
| 2-3 Increase low-income energy-efficiency retrofits | | | | Needed |
| 2-4 Increase emergency demand response | Yes | Yes | | Raise funding |
| 3-1 Utilities to sectionalize distribution circuits | Yes | | | Helpful |
| 3-2 Large customers to reduce load remotely | Yes | | | Helpful |

| | | | | |
|---|---|---|---|---|
| 3-3 Critical facilities to have backup power | | | | More action needed |
| 4-1 ERCOT to improve demand forecasting | Yes | Yes | | |
| 4-2 ERCOT to use better scenario analysis | Yes | Yes | | |
| 4-3 Acknowledge changing extreme weather threats | Yes | Yes | | |
| 5-2 Evaluate summer v. winter protocols | Yes | Yes | | Done |
| 5-3 Reassess and toughen black-start | | | | Don’t act |
| 5-4 No “generation capacity reserve” | Yes | Yes | | Helpful |
| 6-1 Strengthen PUCT | | | | Needed |
| 6-2 Improve ERCOT Board of Directors | | | | Revise new statute |
| 6-3 Establish active compliance oversight | Yes | | | Helpful |
| 6-4 Study ERCOT interconnection to neighboring grids | Yes | Yes | | |
| 7-1 Release all Texas investigation findings to public | Yes | Yes | Not investigating | Governor should act |
| 7-2 Routinely collect electric and gas information | Yes | Yes | No | Needed |

The report was funded by a grant from Energy Foundation and the Cynthia and George Mitchell Foundation.

READ THE NEWS RELEASE >>

READ THE FACT SHEET >>

[1] *Buzzfeed estimates that at least 700 Texans died from the freeze and power outages*

[3] *ERCOT's publicly released information includes presentations to Texas House and Senate Committees on February 25, 2021 and the "Update to April 6, 2021 Preliminary Report on Causes of Generator Outages and Derates During the February 2021 Extreme Cold Weather Event" (April 27, 2021)*

[4] *ERCOT total thermal and hydro generation capacity from ERCOT "Winter 2020-21 Final Seasonal Assessment", November 5, 2021*

[5] *Golding, Kumar & Mertens, "Cost of Texas' 2021 Deep Freeze Justifies Weatherization" (April 15, 2021)*

[6] *Electric Power Research Institute, "State Level Electric Energy Efficiency Potential Estimates" (Technical Update, May 2017)*

[7] *American Council for an Energy Efficient Economy, State Efficiency Scorecard (2020)*

[8] *The Texas State Energy Conservation Office has the authority to update building codes every six years; this is insufficient*

[9] *https://www.energycodes.gov/regulatory/determinations/residential-determination*

[10] *ACEEE, "State Energy Efficiency Scorecard" (December 2020) and Texas data*

[11] *Air conditioning is the highest single energy use in ERCOT through the summer.  Energy efficiency improvements should include installation of high-efficiency air conditioners, which would reliably, consistently lower summer peak loads as Texas temperatures continue rising and heat waves last for more days each year.  The federal Energy Star program says a new Energy Star-certified central air conditioning unit is 30% more efficient than units 12 years or older, and new window air conditioners are 15-20% more efficient than 10-year old and older units.*

[12] *ERCOT Winter 2020-21 Final Seasonal Assessment (November 2020)*

[13] *ERCOT, Update to April 6, 2021 Preliminary Report on Causes of Generator Outages and Derates During the February 2021 Extreme Cold Weather Event (April 27, 2021)*

[14] *ERCOT, "Final 2020-21 Winter Seasonal Resource Assessment," (November 5, 2021)*

[15] *http://www.ercot.com/news/releases/show/227889*

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## 4.1 **Waste not |** Research and report

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 claim that the process does not prevent pollution as well as its proponents claim.

### Instructions

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?**

# Data analysis

## Instructions

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

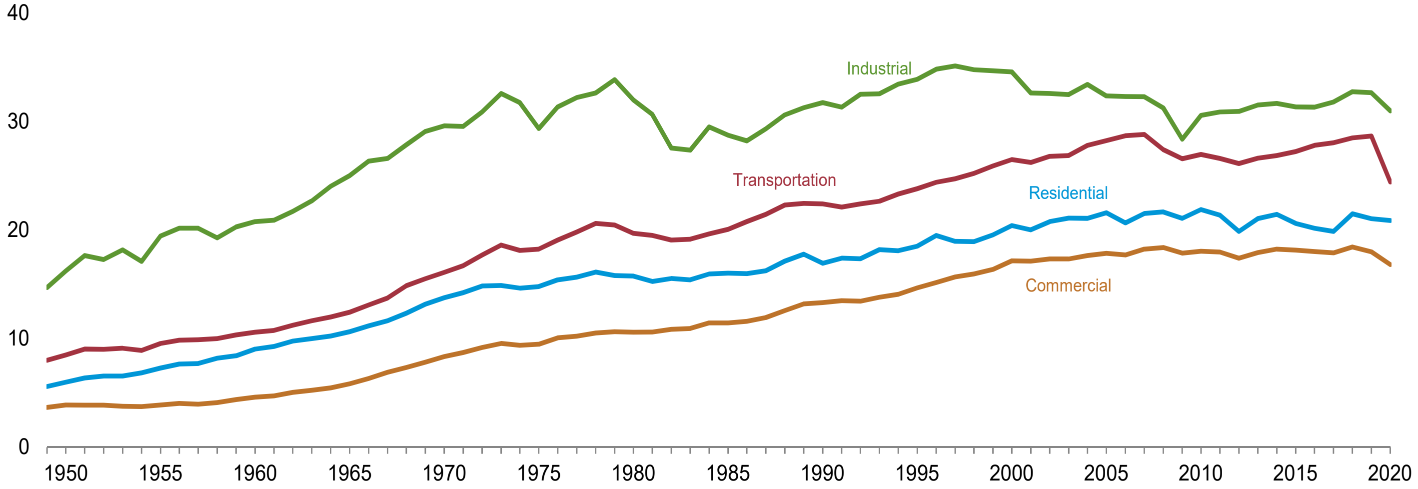
U. S. Energy Information Administration, “Monthly Energy Review October 2021: Chapter 2, Energy Consumption by Sector”

# 2. Energy Consumption By Sector

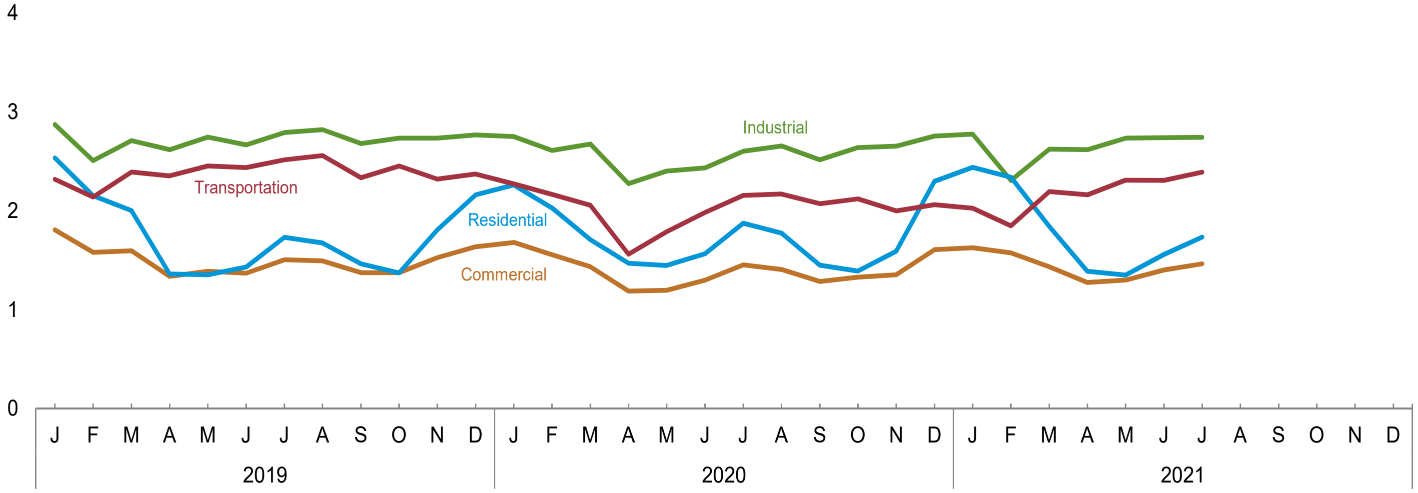
## Figure 2.1 Energy Consumption by Sector

(Quadrillion Btu)

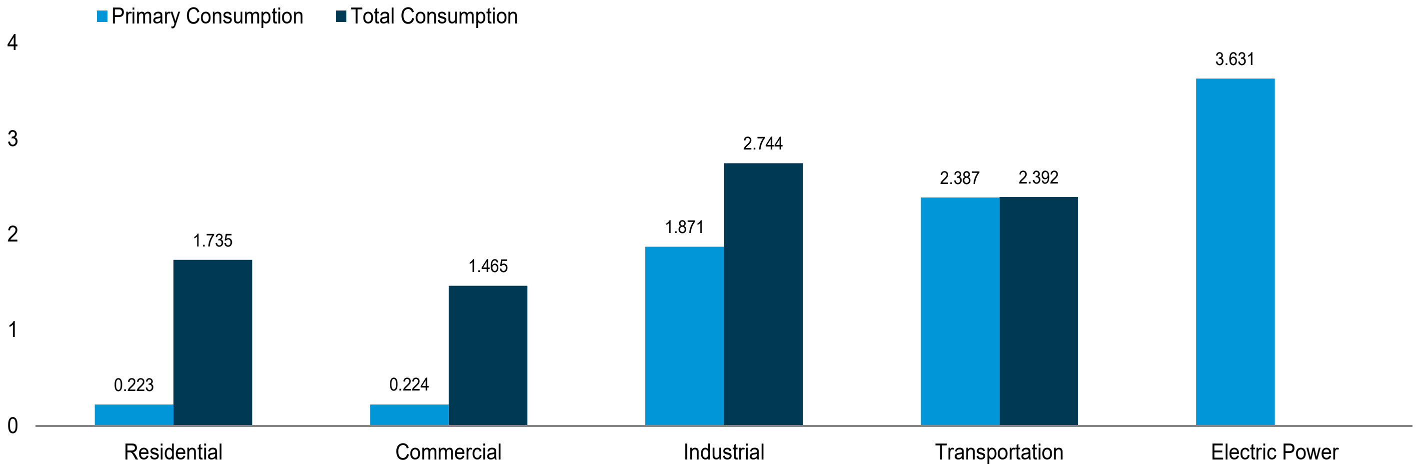
Total Consumption by End-Use Sector, 1949–2020



Total Consumption by End-Use Sector, Monthly



By Sector, July 2021



Web Page: http://www.eia.gov/totalenergy/data/monthly/#consumption.
Source: Table 2.1.

# Table 2.1 Energy Consumption by Sector

(Trillion Btu)

| | End-Use Sectors | | | | | | | | Electric Power Sector[c,d] | Balancing Item[g] | Primary Total[h] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Residential | | Commercial[a] | | Industrial[b] | | Transportation | | | | |
| | Primary[e] | Total[f] | Primary[e] | Total[f] | Primary[e] | Total[f] | Primary[e] | Total[f] | Primary[e] | | |
| **1950 Total** | **4,830** | **5,989** | **2,834** | **3,893** | **13,872** | **16,224** | **8,383** | **8,492** | **4,679** | **(s)** | **34,599** |
| **1955 Total** | **5,608** | **7,278** | **2,561** | **3,895** | **16,073** | **19,455** | **9,474** | **9,550** | **6,461** | **(s)** | **40,178** |
| **1960 Total** | **6,651** | **9,040** | **2,723** | **4,610** | **16,949** | **20,795** | **10,560** | **10,596** | **8,158** | **(s)** | **45,041** |
| **1965 Total** | **7,280** | **10,640** | **3,177** | **5,846** | **20,085** | **25,035** | **12,399** | **12,432** | **11,012** | **(s)** | **53,953** |
| **1970 Total** | **8,323** | **13,766** | **4,237** | **8,346** | **22,941** | **29,605** | **16,062** | **16,098** | **16,253** | **(s)** | **67,817** |
| **1975 Total** | **7,990** | **14,814** | **4,059** | **9,493** | **21,400** | **29,379** | **18,211** | **18,245** | **20,270** | **1** | **71,931** |
| **1980 Total** | **7,440** | **15,754** | **4,105** | **10,578** | **22,549** | **31,993** | **19,659** | **19,697** | **24,269** | **-1** | **78,021** |
| **1985 Total** | **7,149** | **16,042** | **3,732** | **11,451** | **19,384** | **28,757** | **20,042** | **20,088** | **26,032** | **-4** | **76,334** |
| **1990 Total** | **6,553** | **16,941** | **3,894** | **13,317** | **21,120** | **31,749** | **22,366** | **22,419** | [d] **30,495** | **7** | **84,433** |
| **1995 Total** | **6,935** | **18,517** | **4,101** | **14,690** | **22,657** | **33,908** | **23,757** | **23,812** | **33,479** | **3** | **90,931** |
| **2000 Total** | **7,156** | **20,422** | **4,278** | **17,175** | **22,748** | **34,587** | **26,456** | **26,515** | **38,062** | **2** | **98,702** |
| **2005 Total** | **6,901** | **21,613** | **4,052** | **17,854** | **21,343** | **32,374** | **28,179** | **28,261** | **39,626** | **(s)** | **100,102** |
| **2006 Total** | **6,155** | **20,671** | **3,748** | **17,707** | **21,455** | **32,317** | **28,618** | **28,697** | **39,417** | **(s)** | **99,392** |
| **2007 Total** | **6,589** | **21,520** | **3,923** | **18,253** | **21,284** | **32,306** | **28,727** | **28,815** | **40,371** | **-1** | **100,893** |
| **2008 Total** | **6,889** | **21,668** | **4,100** | **18,402** | **20,455** | **31,261** | **27,339** | **27,421** | **39,969** | **1** | **98,754** |
| **2009 Total** | **6,637** | **21,082** | **4,056** | **17,888** | **18,670** | **28,380** | **26,510** | **26,592** | **38,069** | **(s)** | **93,942** |
| **2010 Total** | **6,641** | **21,895** | **4,023** | **18,059** | **20,327** | **30,574** | **26,897** | **26,978** | **39,619** | **7** | **97,513** |
| **2011 Total** | **6,473** | **21,382** | **4,066** | **17,982** | **20,505** | **30,893** | R **26,526** | R **26,606** | **39,293** | **8** | R **96,870** |
| **2012 Total** | **5,684** | **19,870** | **3,725** | **17,422** | **20,781** | **30,954** | R **26,059** | R **26,135** | **38,131** | **2** | R **94,383** |
| **2013 Total** | **6,689** | **21,052** | **4,161** | **17,930** | **21,378** | **31,525** | R **26,542** | R **26,620** | **38,357** | **-1** | R **97,125** |
| **2014 Total** | **7,006** | **21,446** | **4,390** | **18,265** | **21,455** | **31,691** | R **26,801** | R **26,881** | **38,629** | **6** | R **98,288** |
| **2015 Total** | **6,465** | **20,618** | **4,441** | **18,157** | **21,417** | **31,361** | R **27,179** | R **27,256** | **37,890** | **1** | R **97,392** |
| **2016 Total** | **6,030** | **20,179** | **4,321** | **18,030** | **21,553** | **31,347** | R **27,737** | R **27,812** | **37,727** | **-4** | R **97,363** |
| **2017 Total** | **6,097** | **19,886** | **4,368** | **17,900** | **21,953** | **31,798** | R **27,974** | R **28,049** | **37,241** | **(s)** | R **97,634** |
| **2018 Total** | **6,982** | **21,509** | **4,776** | **18,440** | **22,861** | **32,756** | R **28,429** | R **28,505** | **38,163** | **-7** | R **101,203** |
| **2019** January | R 1,215 | R 2,537 | 700 | 1,810 | R 2,056 | R 2,875 | R 2,313 | R 2,320 | 3,258 | 2 | R 9,544 |
| February | R 1,035 | 2,156 | 600 | 1,581 | R 1,775 | R 2,510 | R 2,135 | R 2,141 | 2,844 | (s) | R 8,388 |
| March | 906 | R 2,003 | 551 | 1,598 | R 1,923 | R 2,713 | R 2,386 | R 2,393 | 2,940 | -2 | R 8,705 |
| April | R 486 | 1,362 | 346 | 1,339 | R 1,840 | R 2,620 | R 2,349 | R 2,355 | 2,655 | -4 | R 7,673 |
| May | 351 | 1,356 | 277 | 1,391 | R 1,900 | R 2,748 | R 2,450 | R 2,456 | 2,973 | -2 | R 7,949 |
| June | 249 | 1,434 | 229 | R 1,372 | R 1,829 | R 2,668 | R 2,434 | R 2,440 | 3,173 | 1 | R 7,915 |
| July | 231 | 1,734 | 227 | 1,507 | R 1,905 | R 2,793 | R 2,511 | R 2,518 | 3,677 | 7 | R 8,559 |
| August | 231 | 1,678 | 234 | 1,495 | R 1,944 | R 2,822 | R 2,555 | R 2,561 | 3,592 | 6 | R 8,562 |
| September | 223 | 1,466 | 223 | 1,376 | R 1,868 | R 2,682 | R 2,330 | R 2,337 | 3,216 | 3 | R 7,864 |
| October | 376 | R 1,375 | 310 | 1,376 | R 1,955 | R 2,735 | R 2,450 | R 2,455 | 2,849 | -2 | R 7,939 |
| November | 797 | 1,809 | 511 | R 1,527 | R 1,949 | R 2,735 | R 2,316 | R 2,322 | 2,819 | -1 | R 8,393 |
| December | R 989 | R 2,164 | 592 | 1,640 | R 1,993 | R 2,770 | R 2,367 | R 2,373 | 3,006 | -3 | R 8,944 |
| **Total** | R **7,088** | R **21,072** | R **4,800** | R **18,013** | R **22,940** | R **32,672** | R **28,597** | R **28,671** | **37,003** | **6** | R **100,434** |
| **2020** January | R 1,055 | R 2,264 | R 622 | R 1,681 | R 2,001 | R 2,753 | R 2,269 | R 2,275 | 3,025 | -3 | R 8,969 |
| February | R 945 | R 2,031 | R 568 | R 1,557 | R 1,879 | R 2,613 | R 2,162 | R 2,168 | 2,815 | -5 | R 8,364 |
| March | R 715 | R 1,709 | R 450 | R 1,435 | R 1,934 | R 2,676 | R 2,054 | R 2,059 | 2,727 | -5 | R 7,874 |
| April | R 546 | R 1,470 | R 332 | R 1,191 | R 1,617 | R 2,277 | R 1,559 | R 1,564 | 2,449 | -4 | R 6,498 |
| May | R 391 | R 1,451 | R 260 | R 1,199 | R 1,687 | R 2,403 | R 1,786 | R 1,791 | 2,720 | -1 | R 6,843 |
| June | 257 | R 1,568 | 216 | 1,302 | R 1,685 | R 2,436 | R 1,979 | R 1,984 | 3,152 | 2 | R 7,292 |
| July | R 230 | R 1,878 | R 209 | R 1,454 | R 1,802 | R 2,604 | R 2,154 | R 2,159 | 3,700 | 10 | R 8,105 |
| August | 218 | R 1,778 | R 210 | 1,409 | R 1,845 | R 2,659 | R 2,167 | R 2,172 | R 3,578 | R 9 | R 8,028 |
| September | R 246 | R 1,452 | R 228 | R 1,288 | R 1,786 | R 2,517 | R 2,070 | R 2,075 | 3,001 | 4 | R 7,336 |
| October | R 387 | R 1,394 | R 302 | R 1,331 | R 1,883 | R 2,641 | R 2,118 | R 2,123 | 2,799 | (s) | R 7,490 |
| November | R 608 | R 1,592 | R 394 | 1,355 | R 1,903 | R 2,654 | R 1,997 | R 2,002 | 2,702 | -1 | R 7,603 |
| December | R 1,021 | R 2,302 | R 575 | R 1,608 | R 2,002 | R 2,757 | R 2,057 | R 2,063 | 3,074 | 1 | R 8,731 |
| **Total** | R **6,617** | R **20,880** | R **4,368** | R **16,814** | R **22,025** | R **30,996** | R **24,373** | R **24,436** | **35,744** | R **8** | R **93,134** |
| **2021** January | R 1,102 | R 2,441 | R 612 | 1,629 | R 2,004 | R 2,777 | R 2,022 | R 2,028 | 3,133 | -1 | R 8,873 |
| February | R 1,089 | R 2,341 | R 611 | R 1,578 | R 1,586 | R 2,308 | R 1,845 | R 1,850 | 2,947 | 2 | R 8,079 |
| March | R 757 | R 1,843 | 466 | R 1,436 | R 1,903 | R 2,626 | R 2,192 | R 2,197 | 2,783 | -5 | R 8,097 |
| April | R 492 | R 1,390 | R 340 | R 1,277 | R 1,868 | R 2,619 | R 2,158 | R 2,163 | 2,592 | R -5 | R 7,445 |
| May | R 353 | R 1,352 | 273 | 1,301 | R 1,921 | R 2,736 | R 2,306 | R 2,311 | 2,846 | R -3 | R 7,697 |
| June | 244 | 1,561 | 226 | 1,405 | R 1,894 | R 2,742 | R 2,305 | R 2,310 | 3,349 | R 4 | R 8,021 |
| July | 223 | 1,735 | 224 | 1,465 | 1,871 | 2,744 | 2,387 | 2,392 | 3,631 | 8 | 8,345 |
| **7-Month Total** | **4,259** | **12,663** | **2,752** | **10,091** | **13,047** | **18,551** | **15,215** | **15,251** | **21,282** | **1** | **56,557** |
| **2020 7-Month Total** | **4,138** | **12,371** | **2,658** | **9,819** | **12,605** | **17,763** | **13,963** | **14,000** | **20,589** | **-6** | **53,947** |
| **2019 7-Month Total** | **4,472** | **12,582** | **2,930** | **10,598** | **13,229** | **18,927** | **16,579** | **16,623** | **21,520** | **2** | **58,732** |

[a] Commercial sector, including commercial combined-heat-and-power (CHP) and commercial electricity-only plants.

[b] Industrial sector, including industrial combined-heat-and-power (CHP) and industrial electricity-only plants.

[c] Electricity-only and combined-heat-and-power (CHP) plants within the NAICS 22 category whose primary business is to sell electricity, or electricity and heat, to the public.

[d] Through 1988, data are for electric utilities only. Beginning in 1989, data are for electric utilities and independent power producers.

[e] See "Primary Energy Consumption" in Glossary.

[f] Total energy consumption in the end-use sectors consists of primary energy consumption, electricity retail sales, and electrical system energy losses. See Note 1, "Electrical System Energy Losses," at end of section.

[g] A balancing item. The sum of primary consumption in the five energy-use sectors equals the sum of total consumption in the four end-use sectors. However, total energy consumption does not equal the sum of the sectoral components due to the use of sector-specific conversion factors for coal and natural gas.

[h] Primary energy consumption total. See Table 1.3.

R=Revised. (s)=Less than 0.5 trillion Btu and greater than -0.5 trillion Btu.

Notes: • Data are estimates, except for the electric power sector. • See Note 2, "Classification of Power Plants Into Energy-Use Sectors," at end of Section 7. • See Note 3, "Energy Consumption Data and Surveys," at end of section. • Totals may not equal sum of components due to independent rounding. • Geographic coverage is the 50 states and the District of Columbia.

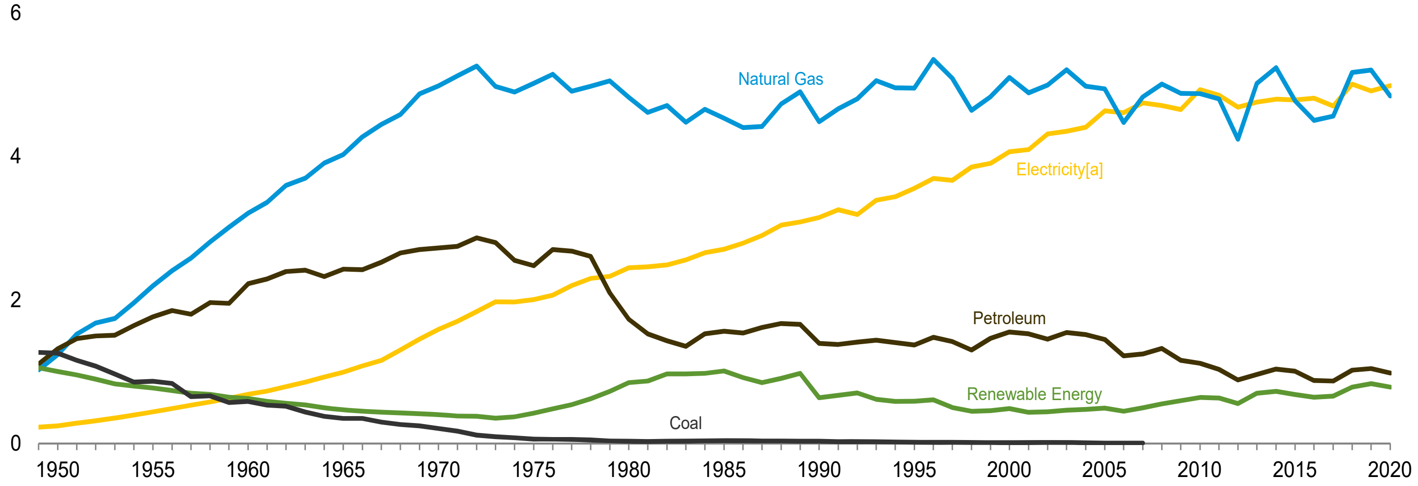
Web Page: See http://www.eia.gov/totalenergy/data/monthly/#consumption (Excel and CSV files) for all available annual data beginning in 1949 and monthly data beginning in 1973.

Sources: • **End-Use Sectors:** Tables 2.2–2.5. • **Electric Power Sector:** Table 2.6. • **Balancing Item:** Calculated as primary energy total consumption minus the sum of total energy consumption in the four end-use sectors. • **Primary Total:** Table 1.3.

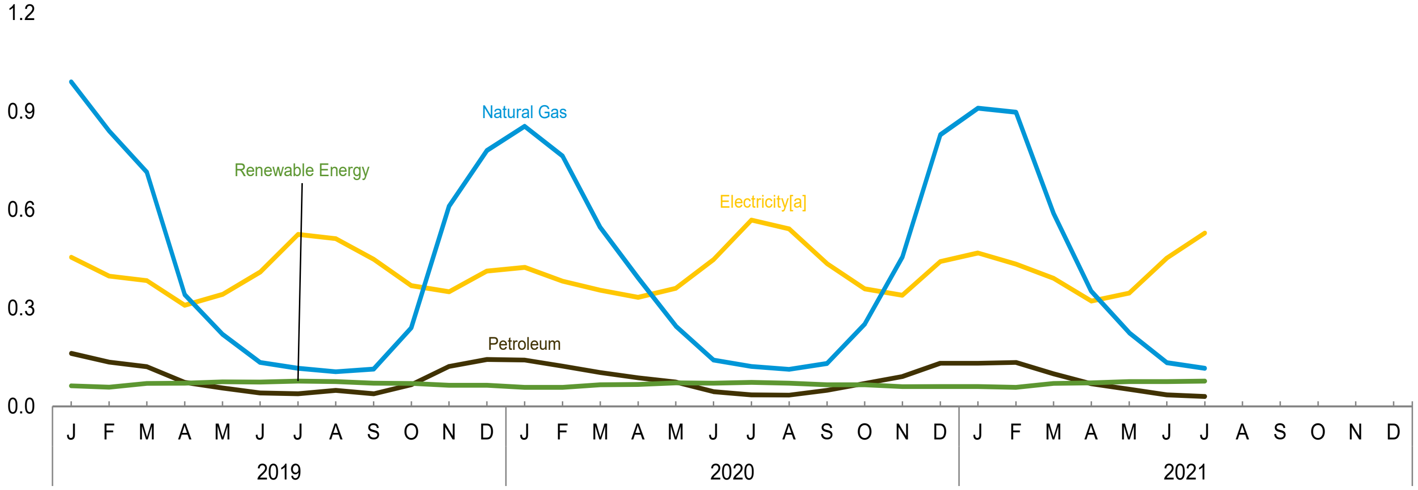
## Figure 2.2 Residential Sector Energy Consumption

(Quadrillion Btu)

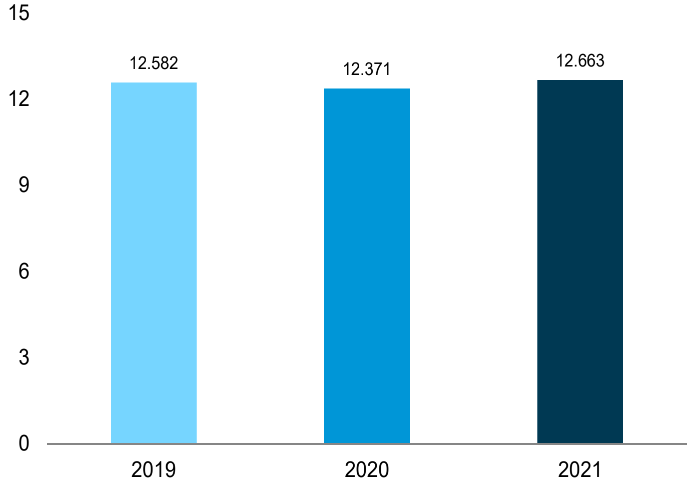
By Major Source, 1949–2020



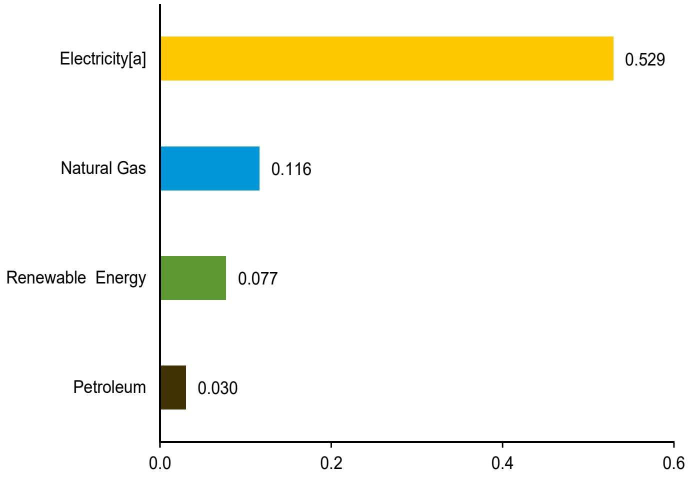
By Major Source, Monthly



Total, January–July



By Major Source, July 2021



[a] Electricity retail sales.
Web Page: http://www.eia.gov/totalenergy/data/monthly/#consumption.
Source: Table 2.2.

# Table 2.2 Residential Sector Energy Consumption

(Trillion Btu)

| | Primary Consumption[a] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fossil Fuels | | | | Renewable Energy[b] | | | | | | | |
| | Coal | Natural Gas[c] | Petroleum | Total | Geothermal | Solar[d] | Biomass | Total | Total Primary | Electricity Retail Sales[e] | Electrical System Energy Losses[f] | Total |
| **1950 Total** | 1,261 | 1,240 | 1,322 | 3,824 | NA | NA | 1,006 | 1,006 | 4,830 | 246 | 913 | 5,989 |
| **1955 Total** | 867 | 2,198 | 1,767 | 4,833 | NA | NA | 775 | 775 | 5,608 | 438 | 1,232 | 7,278 |
| **1960 Total** | 585 | 3,212 | 2,228 | 6,025 | NA | NA | 627 | 627 | 6,651 | 687 | 1,701 | 9,040 |
| **1965 Total** | 352 | 4,028 | 2,432 | 6,812 | NA | NA | 468 | 468 | 7,280 | 993 | 2,367 | 10,640 |
| **1970 Total** | 209 | 4,987 | 2,726 | 7,922 | NA | NA | 401 | 401 | 8,323 | 1,591 | 3,852 | 13,766 |
| **1975 Total** | 63 | 5,023 | 2,479 | 7,565 | NA | NA | 425 | 425 | 7,990 | 2,007 | 4,817 | 14,814 |
| **1980 Total** | 31 | 4,825 | 1,734 | 6,590 | NA | NA | 850 | 850 | 7,440 | 2,448 | 5,866 | 15,754 |
| **1985 Total** | 39 | 4,534 | 1,566 | 6,139 | NA | NA | 1,010 | 1,010 | 7,149 | 2,709 | 6,184 | 16,042 |
| **1990 Total** | 31 | 4,487 | 1,395 | 5,912 | 6 | 55 | 580 | 640 | 6,553 | 3,153 | 7,235 | 16,941 |
| **1995 Total** | 17 | 4,954 | 1,374 | 6,345 | 7 | 63 | 520 | 589 | 6,935 | 3,557 | 8,026 | 18,517 |
| **2000 Total** | 11 | 5,105 | 1,554 | 6,670 | 9 | 58 | 420 | 486 | 7,156 | 4,069 | 9,197 | 20,422 |
| **2005 Total** | 8 | 4,946 | 1,450 | 6,405 | 16 | 50 | 430 | 496 | 6,901 | 4,638 | 10,074 | 21,613 |
| **2006 Total** | 6 | 4,476 | 1,222 | 5,704 | 18 | 53 | 380 | 451 | 6,155 | 4,611 | 9,905 | 20,671 |
| **2007 Total** | 8 | 4,835 | 1,249 | 6,092 | 22 | 55 | 420 | 497 | 6,589 | 4,750 | 10,180 | 21,520 |
| **2008 Total** | NA | 5,010 | 1,325 | 6,335 | 26 | 58 | 470 | 555 | 6,889 | 4,711 | 10,068 | 21,668 |
| **2009 Total** | NA | 4,883 | 1,158 | 6,041 | 33 | 60 | 504 | 597 | 6,637 | 4,657 | 9,788 | 21,082 |
| **2010 Total** | NA | 4,878 | 1,120 | 5,999 | 37 | 65 | 541 | 642 | 6,641 | 4,933 | 10,321 | 21,895 |
| **2011 Total** | NA | 4,805 | 1,034 | 5,838 | 40 | 71 | 524 | 635 | 6,473 | 4,855 | 10,054 | 21,382 |
| **2012 Total** | NA | 4,242 | 886 | 5,128 | 40 | 79 | 438 | 557 | 5,684 | 4,690 | 9,496 | 19,870 |
| **2013 Total** | NA | 5,023 | 963 | 5,986 | 40 | 91 | 572 | 703 | 6,689 | 4,759 | 9,604 | 21,052 |
| **2014 Total** | NA | 5,242 | 1,036 | 6,279 | 40 | 109 | 579 | 728 | 7,006 | 4,801 | 9,638 | 21,446 |
| **2015 Total** | NA | 4,777 | 1,007 | 5,784 | 40 | 128 | 513 | 681 | 6,465 | 4,791 | 9,362 | 20,618 |
| **2016 Total** | NA | 4,506 | 878 | 5,384 | 40 | 162 | 445 | 646 | 6,030 | 4,815 | 9,334 | 20,179 |
| **2017 Total** | NA | 4,563 | 871 | 5,435 | 40 | 193 | 429 | 662 | 6,097 | 4,704 | 9,085 | 19,886 |
| **2018 Total** | NA | 5,174 | 1,022 | 6,197 | 40 | 221 | 524 | 785 | 6,982 | 5,013 | 9,515 | 21,509 |
| **2019** January | NA | 990 | 162 | R 1,152 | 3 | 13 | 46 | 63 | R 1,215 | 455 | 867 | R 2,537 |
| February | NA | 840 | 135 | R 976 | 3 | 15 | 42 | 59 | R 1,035 | 398 | 723 | 2,156 |
| March | NA | R 715 | 121 | R 836 | 3 | 21 | 46 | 70 | 906 | 384 | 712 | R 2,003 |
| April | NA | 341 | 73 | 414 | 3 | 23 | 45 | 71 | R 486 | 308 | 568 | 1,362 |
| May | NA | 220 | 56 | 276 | 3 | 26 | 46 | 75 | 351 | 342 | 663 | 1,356 |
| June | NA | 134 | 41 | 175 | 3 | 26 | 45 | 74 | 249 | 410 | 776 | 1,434 |
| July | NA | 116 | 38 | 154 | 3 | 27 | 46 | 77 | 231 | 525 | 979 | 1,734 |
| August | NA | 106 | 49 | 155 | 3 | 26 | 46 | 76 | 231 | 512 | 935 | 1,678 |
| September | NA | 114 | 38 | 152 | 3 | 23 | 45 | 71 | 223 | 449 | 794 | 1,466 |
| October | NA | 240 | 66 | R 307 | 3 | 20 | 46 | 70 | 376 | 368 | 630 | R 1,375 |
| November | NA | 611 | 122 | 733 | 3 | 16 | 45 | 64 | 797 | 350 | 662 | 1,809 |
| December | NA | 781 | 143 | R 925 | 3 | 15 | 46 | 64 | R 989 | 413 | 762 | R 2,164 |
| **Total** | NA | R 5,208 | 1,045 | R 6,253 | 40 | 251 | 544 | 835 | R 7,088 | 4,914 | 9,070 | R 21,072 |
| **2020** January | NA | R 855 | 141 | R 997 | 3 | 16 | 39 | 58 | R 1,055 | 424 | 785 | R 2,264 |
| February | NA | R 764 | 123 | R 887 | 3 | 18 | 36 | 58 | R 945 | 382 | 704 | R 2,031 |
| March | NA | R 546 | 103 | R 649 | 3 | 24 | 39 | 66 | R 715 | 355 | 640 | R 1,709 |
| April | NA | R 392 | 87 | R 478 | 3 | 26 | 38 | 67 | R 546 | 333 | 592 | R 1,470 |
| May | NA | R 245 | 74 | R 319 | 3 | 30 | 39 | 72 | R 391 | 360 | 700 | R 1,451 |
| June | NA | 141 | 45 | 186 | 3 | 30 | 38 | 71 | 257 | 448 | 863 | R 1,568 |
| July | NA | 122 | 35 | 157 | 3 | 31 | 39 | 73 | R 230 | 569 | 1,079 | R 1,878 |
| August | NA | 113 | 34 | 147 | 3 | 29 | 39 | 71 | 218 | 542 | R 1,018 | R 1,778 |
| September | NA | R 131 | 49 | R 180 | 3 | 26 | 38 | 66 | R 246 | 436 | 769 | R 1,452 |
| October | NA | R 251 | 70 | R 321 | 3 | 24 | 39 | 66 | R 387 | 359 | R 648 | R 1,394 |
| November | NA | R 456 | 91 | R 547 | 3 | 20 | 38 | 60 | R 608 | 339 | 645 | R 1,592 |
| December | NA | R 829 | 132 | R 961 | 3 | 18 | 39 | 60 | R 1,021 | 442 | 839 | R 2,302 |
| **Total** | NA | R 4,846 | 984 | R 5,829 | 40 | 291 | 458 | 788 | R 6,617 | 4,988 | 9,275 | R 20,880 |
| **2021** January | NA | R 910 | 132 | R 1,041 | 3 | 19 | 39 | 60 | R 1,102 | 468 | 871 | R 2,441 |
| February | NA | R 898 | 134 | R 1,031 | 3 | 20 | 35 | 58 | R 1,089 | 434 | 819 | R 2,341 |
| March | NA | R 589 | 99 | R 687 | 3 | 28 | 39 | 70 | R 757 | 391 | 695 | R 1,843 |
| April | NA | R 351 | 69 | R 420 | 3 | 31 | 37 | 72 | R 492 | 321 | 577 | R 1,390 |
| May | NA | R 225 | 52 | R 276 | 3 | 35 | 39 | 76 | R 353 | 346 | 653 | R 1,352 |
| June | NA | 133 | 35 | 168 | 3 | 35 | 37 | 76 | 244 | 453 | 864 | 1,561 |
| July | NA | 116 | 30 | 146 | 3 | 36 | 39 | 77 | 223 | 529 | 984 | 1,735 |
| **7-Month Total** | NA | 3,220 | 550 | 3,770 | 23 | 202 | 264 | 489 | 4,259 | 2,942 | 5,462 | 12,663 |
| **2020 7-Month Total** | NA | 3,066 | 608 | 3,674 | 23 | 175 | 266 | 464 | 4,138 | 2,871 | 5,362 | 12,371 |
| **2019 7-Month Total** | NA | 3,356 | 626 | 3,982 | 23 | 151 | 316 | 490 | 4,472 | 2,822 | 5,287 | 12,582 |

[a] See "Primary Energy Consumption" in Glossary.

[b] See Table 10.2a for notes on series components.

[c] Natural gas only; excludes the estimated portion of supplemental gaseous fuels. See Note 3, "Supplemental Gaseous Fuels," at end of Section 4.

[d] Distributed (small-scale) solar photovoltaic (PV) electricity generation in the residential sector and distributed solar thermal energy in the residential, commercial, and industrial sectors. See Tables 10.2a and 10.5.

[e] Electricity retail sales to ultimate customers reported by electric utilities and, beginning in 1996, other energy service providers.

[f] Total losses are calculated as the primary energy consumed by the electric power sector minus the energy content of electricity retail sales. Total losses are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See Note 1, "Electrical System Energy Losses," at end of section.

R=Revised. NA=Not available.

Notes: • Data are estimates, except for electricity retail sales. • See Note 2, "Oher Energy Losses," at end of section. • See Note 3, "Energy Consumption Data and Surveys," at end of section. • Totals may not equal sum of components due to independent rounding. • Geographic coverage is the 50 states and the District of Columbia.

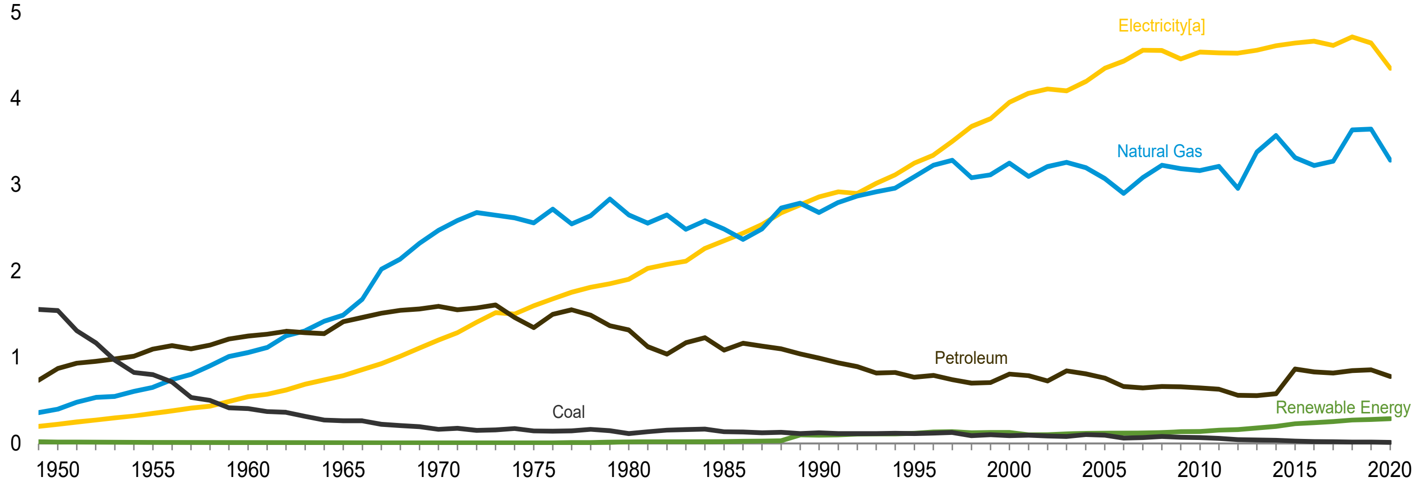
Web Page: See http://www.eia.gov/totalenergy/data/monthly/#consumption (Excel and CSV files) for all available annual data beginning in 1949 and monthly data beginning in 1973.

Sources: See end of section.

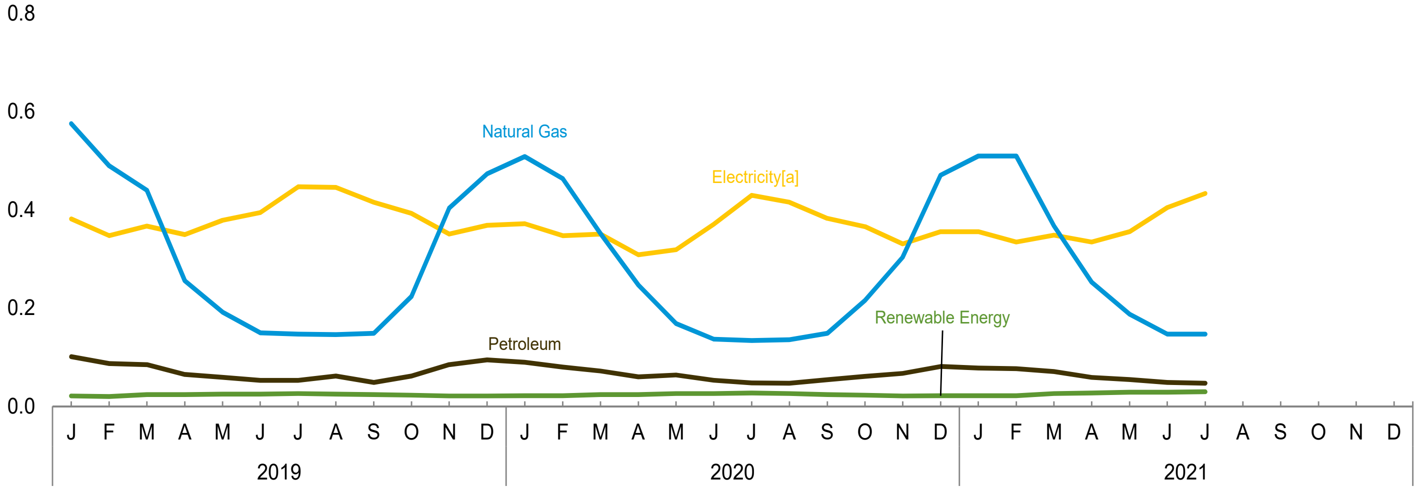
## Figure 2.3 Commercial Sector Energy Consumption

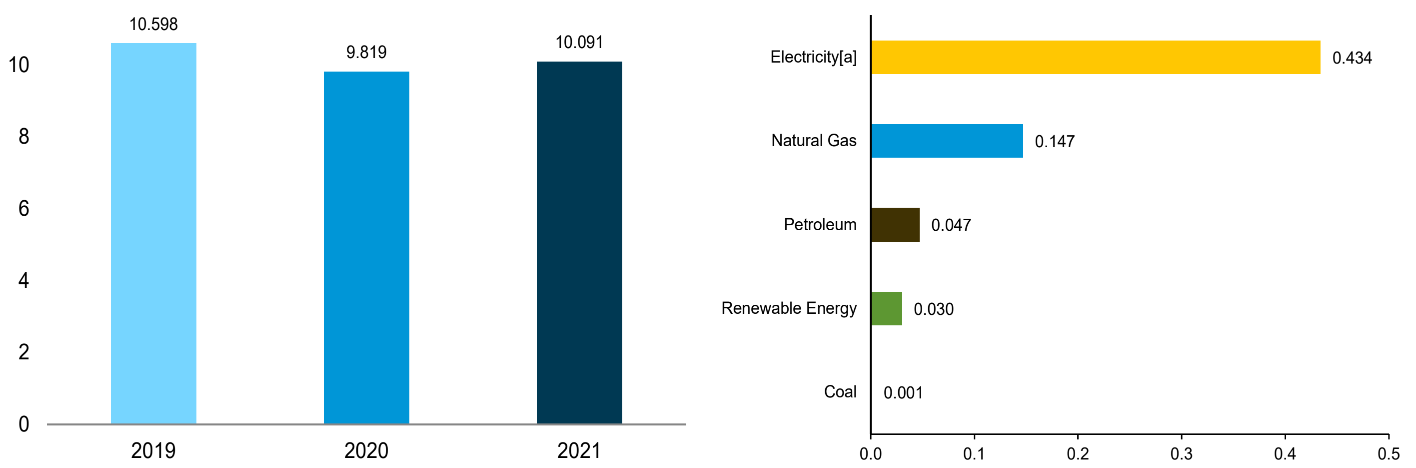
(Quadrillion Btu)

By Major Source, 1949–2020



By Major Source, Monthly





Total, January–July

By Major Source, July 2021

[a] Electricity retail sales.
Web Page: http://www.eia.gov/totalenergy/data/monthly/#consumption.
Source: Table 2.3.

# Table 2.3 Commercial Sector Energy Consumption

(Trillion Btu)

| | Primary Consumption[a] | | | | | | | | | | | Electricity Retail Sales[g] | Electrical System Energy Losses[h] | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fossil Fuels | | | | Renewable Energy[b] | | | | | | Total Primary | | | |
| | Coal | Natural Gas[c] | Petroleum[d] | Total | Hydroelectric Power[e] | Geothermal | Solar[f] | Wind | Biomass | Total | | | | |
| **1950 Total** | 1,542 | 401 | 872 | 2,815 | NA | NA | NA | NA | 19 | 19 | 2,834 | 225 | 834 | 3,893 |
| **1955 Total** | 801 | 651 | 1,095 | 2,547 | NA | NA | NA | NA | 15 | 15 | 2,561 | 350 | 984 | 3,895 |
| **1960 Total** | 407 | 1,056 | 1,248 | 2,711 | NA | NA | NA | NA | 12 | 12 | 2,723 | 543 | 1,344 | 4,610 |
| **1965 Total** | 265 | 1,490 | 1,413 | 3,168 | NA | NA | NA | NA | 9 | 9 | 3,177 | 789 | 1,880 | 5,846 |
| **1970 Total** | 165 | 2,473 | 1,592 | 4,229 | NA | NA | NA | NA | 8 | 8 | 4,237 | 1,201 | 2,908 | 8,346 |
| **1975 Total** | 147 | 2,558 | 1,346 | 4,051 | NA | NA | NA | NA | 8 | 8 | 4,059 | 1,598 | 3,835 | 9,493 |
| **1980 Total** | 115 | 2,651 | 1,318 | 4,084 | NA | NA | NA | NA | 21 | 21 | 4,105 | 1,906 | 4,567 | 10,578 |
| **1985 Total** | 137 | 2,488 | 1,083 | 3,708 | NA | NA | NA | NA | 24 | 24 | 3,732 | 2,351 | 5,368 | 11,451 |
| **1990 Total** | 124 | 2,680 | 991 | 3,795 | 1 | 3 | (s) | – | 94 | 98 | 3,894 | 2,860 | 6,564 | 13,317 |
| **1995 Total** | 117 | 3,096 | 769 | 3,982 | 1 | 5 | (s) | – | 113 | 119 | 4,101 | 3,252 | 7,337 | 14,690 |
| **2000 Total** | 92 | 3,252 | 807 | 4,150 | 1 | 8 | 1 | – | 119 | 128 | 4,278 | 3,956 | 8,942 | 17,175 |
| **2005 Total** | 97 | 3,073 | 761 | 3,931 | 1 | 14 | 2 | – | 105 | 121 | 4,052 | 4,351 | 9,451 | 17,854 |
| **2006 Total** | 65 | 2,902 | 661 | 3,627 | 1 | 14 | 3 | – | 103 | 120 | 3,748 | 4,435 | 9,525 | 17,707 |
| **2007 Total** | 70 | 3,085 | 646 | 3,801 | 1 | 14 | 4 | – | 103 | 122 | 3,923 | 4,560 | 9,771 | 18,253 |
| **2008 Total** | 81 | 3,228 | 660 | 3,970 | 1 | 15 | 6 | – | 109 | 131 | 4,100 | 4,559 | 9,743 | 18,402 |
| **2009 Total** | 73 | 3,187 | 659 | 3,919 | 1 | 17 | 8 | (s) | 112 | 137 | 4,056 | 4,459 | 9,373 | 17,888 |
| **2010 Total** | 70 | 3,165 | 647 | 3,881 | 1 | 19 | 12 | (s) | 111 | 142 | 4,023 | 4,539 | 9,497 | 18,059 |
| **2011 Total** | 62 | 3,216 | 632 | 3,910 | (s) | 20 | 20 | (s) | 115 | 155 | 4,066 | 4,531 | 9,385 | 17,982 |
| **2012 Total** | 44 | 2,960 | 560 | 3,563 | (s) | 20 | 33 | 1 | 108 | 162 | 3,725 | 4,528 | 9,168 | 17,422 |
| **2013 Total** | 41 | 3,380 | 558 | 3,979 | (s) | 20 | 41 | 1 | 120 | 182 | 4,161 | 4,562 | 9,206 | 17,930 |
| **2014 Total** | 40 | 3,572 | 578 | 4,190 | (s) | 20 | 52 | 1 | 127 | 200 | 4,390 | 4,614 | 9,261 | 18,265 |
| **2015 Total** | 31 | 3,316 | 864 | 4,211 | (s) | 20 | 57 | 1 | 152 | 230 | 4,441 | 4,643 | 9,073 | 18,157 |
| **2016 Total** | 24 | 3,224 | 832 | 4,079 | 2 | 20 | 62 | 1 | 158 | 242 | 4,321 | 4,665 | 9,044 | 18,030 |
| **2017 Total** | 21 | 3,273 | 820 | 4,113 | 2 | 20 | 76 | 1 | 156 | 255 | 4,368 | 4,616 | 8,916 | 17,900 |
| **2018 Total** | 19 | 3,638 | 845 | 4,502 | 2 | 20 | 94 | 2 | 156 | 274 | 4,776 | 4,715 | 8,949 | 18,440 |
| **2019** January | 2 | R 576 | 101 | R 679 | (s) | 2 | 6 | (s) | 13 | 21 | 700 | 382 | 728 | 1,810 |
| February | 2 | 490 | 87 | R 580 | (s) | 2 | 6 | (s) | 12 | 20 | 600 | 348 | 633 | 1,581 |
| March | 2 | 440 | 85 | 527 | (s) | 2 | 9 | (s) | 13 | 24 | 551 | 367 | 680 | 1,598 |
| April | 1 | 256 | 65 | 322 | (s) | 2 | 10 | (s) | 12 | 24 | 346 | 350 | 644 | 1,339 |
| May | 1 | 192 | 59 | 252 | (s) | 2 | 10 | (s) | 12 | 25 | 277 | 379 | 734 | 1,391 |
| June | 1 | 150 | 53 | 204 | (s) | 2 | 11 | (s) | 12 | 25 | 229 | 395 | 747 | R 1,372 |
| July | 1 | 147 | 53 | 201 | (s) | 2 | 11 | (s) | 13 | 26 | 227 | 447 | 834 | 1,507 |
| August | 1 | 146 | 62 | 209 | (s) | 2 | 11 | (s) | 13 | 25 | 234 | 446 | 815 | 1,495 |
| September | 1 | R 149 | 49 | 199 | (s) | 2 | 9 | (s) | 12 | 24 | 223 | 416 | 737 | 1,376 |
| October | 1 | 224 | 62 | 287 | (s) | 2 | 8 | (s) | 13 | 23 | 310 | 393 | 672 | 1,376 |
| November | 1 | R 404 | 85 | 490 | (s) | 2 | 6 | (s) | 12 | 21 | 511 | 351 | 664 | R 1,527 |
| December | 2 | 474 | 95 | 571 | (s) | 2 | 6 | (s) | 13 | 21 | 592 | 369 | 679 | 1,640 |
| **Total** | **17** | **R 3,647** | **857** | **R 4,521** | **2** | **24** | **103** | **2** | **149** | **279** | **R 4,800** | **4,643** | **8,570** | **R 18,013** |
| **2020** January | 2 | R 509 | 90 | R 601 | NM | 2 | 7 | (s) | 13 | 22 | R 622 | 372 | 687 | R 1,681 |
| February | 2 | R 464 | 80 | R 546 | NM | 2 | 8 | (s) | 12 | 22 | R 568 | 348 | 641 | R 1,557 |
| March | 2 | R 352 | 72 | R 426 | NM | 2 | 10 | (s) | 12 | 24 | R 450 | 351 | 633 | R 1,435 |
| April | 1 | R 247 | 60 | R 308 | NM | 2 | 11 | (s) | 11 | 24 | R 332 | 309 | R 551 | R 1,191 |
| May | 1 | R 169 | 64 | R 234 | NM | 2 | 12 | (s) | 12 | 26 | R 260 | 319 | 621 | R 1,199 |
| June | 1 | R 137 | 53 | 190 | NM | 2 | 12 | (s) | 12 | 26 | 216 | 371 | 715 | 1,302 |
| July | 1 | R 134 | 48 | R 182 | NM | 2 | 13 | (s) | 12 | 27 | R 209 | 430 | 814 | R 1,454 |
| August | 1 | 136 | 47 | 183 | NM | 2 | 12 | (s) | 12 | 26 | R 210 | 416 | 783 | 1,409 |
| September | 1 | R 149 | 54 | R 204 | (s) | 2 | 11 | (s) | 11 | 24 | R 228 | 383 | R 676 | R 1,288 |
| October | 1 | R 216 | 61 | R 279 | NM | 2 | 10 | (s) | 12 | 23 | R 302 | 366 | 662 | R 1,331 |
| November | 1 | 304 | 67 | 372 | NM | 2 | 8 | (s) | 12 | 21 | R 394 | 331 | 630 | 1,355 |
| December | 1 | R 471 | 81 | R 553 | NM | 2 | 7 | (s) | 12 | 22 | R 575 | 356 | 676 | R 1,608 |
| **Total** | **15** | **R 3,286** | **777** | **R 4,078** | **2** | **24** | **121** | **2** | **141** | **289** | **R 4,368** | **4,353** | **8,093** | **R 16,814** |
| **2021** January | 2 | 510 | 78 | 590 | NM | 2 | 8 | (s) | 12 | 22 | R 612 | 356 | 661 | 1,629 |
| February | 2 | R 510 | 77 | R 589 | NM | 2 | 9 | (s) | 11 | 22 | R 611 | 335 | 632 | R 1,578 |
| March | 1 | R 368 | 71 | 440 | NM | 2 | 12 | (s) | 12 | 26 | 466 | 349 | 620 | R 1,436 |
| April | 1 | R 253 | 59 | R 313 | NM | 2 | 13 | (s) | 11 | 27 | R 340 | 335 | 602 | R 1,277 |
| May | 1 | 188 | 55 | 244 | NM | 2 | 14 | (s) | 12 | 29 | 273 | 356 | 672 | 1,301 |
| June | 1 | 147 | 49 | 197 | NM | 2 | 14 | (s) | 12 | 29 | 226 | 405 | 774 | 1,405 |
| July | 1 | 147 | 47 | 195 | NM | 2 | 15 | (s) | 12 | 30 | 224 | 434 | 807 | 1,465 |
| **7-Month Total** | **9** | **2,123** | **436** | **2,568** | **1** | **14** | **86** | **1** | **82** | **184** | **2,752** | **2,570** | **4,768** | **10,091** |
| **2020 7-Month Total** | **9** | **2,010** | **467** | **2,486** | **1** | **14** | **73** | **1** | **82** | **172** | **2,658** | **2,499** | **4,661** | **9,819** |
| **2019 7-Month Total** | **10** | **2,251** | **503** | **2,765** | **1** | **14** | **63** | **1** | **87** | **165** | **2,930** | **2,668** | **5,000** | **10,598** |

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[a] See "Primary Energy Consumption" in Glossary.

[b] See Table 10.2a for notes on series components and estimation.

[c] Natural gas only; excludes the estimated portion of supplemental gaseous fuels. See Note 3, "Supplemental Gaseous Fuels," at end of Section 4.

[d] Does not include biofuels that have been blended with petroleum—biofuels are included in "Biomass."

[e] Conventional hydroelectric power.

[f] Solar photovoltaic (PV) electricity net generation in the commercial sector, both utility-scale and distributed (small-scale). See Tables 10.2a and 10.5.

[g] Electricity retail sales to ultimate customers reported by electric utilities and, beginning in 1996, other energy service providers.

[h] Total losses are calculated as the primary energy consumed by the electric power sector minus the energy content of electricity retail sales. Total losses are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See Note 1, "Electrical System Energy Losses," at end of section.

R=Revised. NA=Not available. NM=Not meaningful. – =No data reported. (s)=Less than 0.5 trillion Btu.

Notes: • Data are estimates, except for coal totals beginning in 2008; hydroelectric power; solar; wind; and electricity retail sales beginning in 1979. • The commercial sector includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants. See Note 2, "Classification of Power Plants Into Energy-Use Sectors," at end of Section 7. • See Note 2, "Oher Energy Losses," at end of section. • See Note 3, "Energy Consumption Data and Surveys," at end of section. • Totals may not equal sum of components due to independent rounding. • Geographic coverage is the 50 states and the District of Columbia.

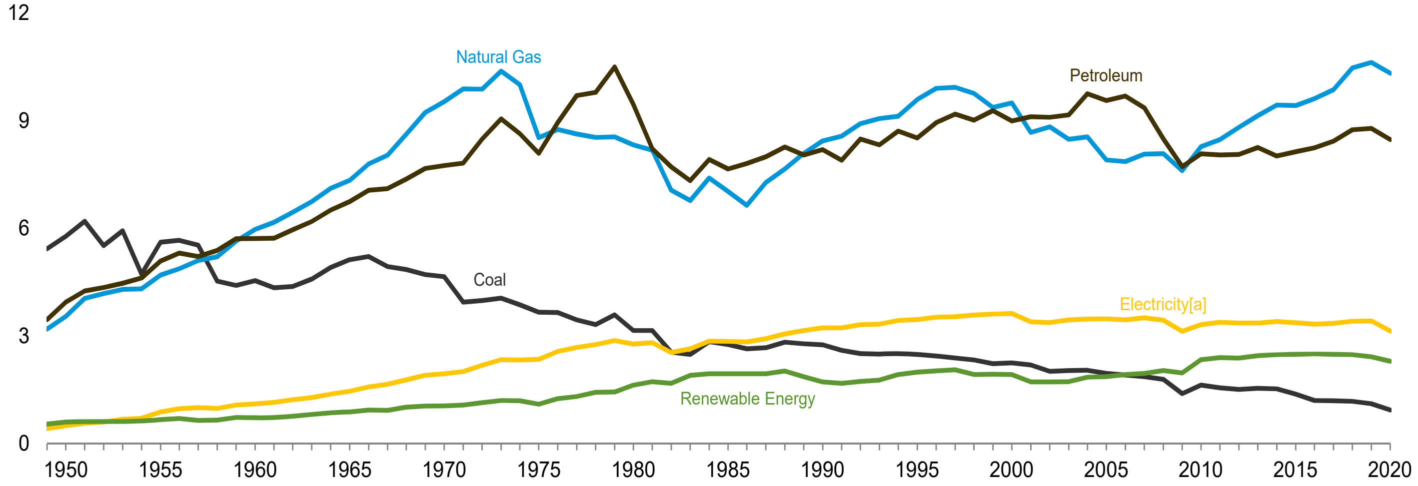
Web Page: See http://www.eia.gov/totalenergy/data/monthly/#consumption (Excel and CSV files) for all available annual data beginning in 1949 and monthly data beginning in 1973.

Sources: See end of section.

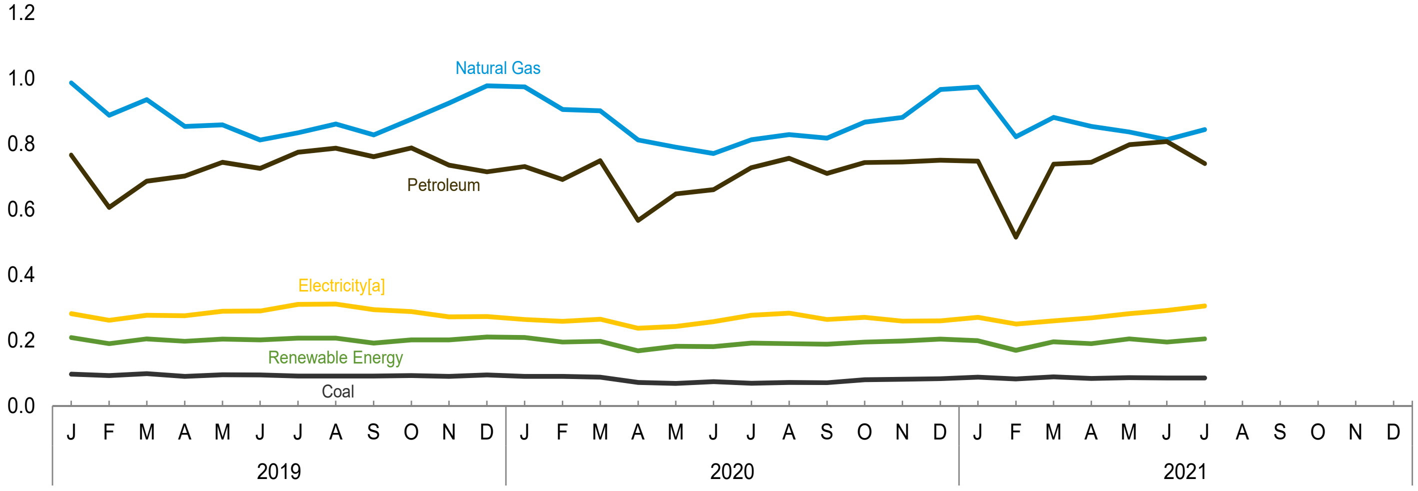
## Figure 2.4 Industrial Sector Energy Consumption

(Quadrillion Btu)

By Major Source, 1949–2020

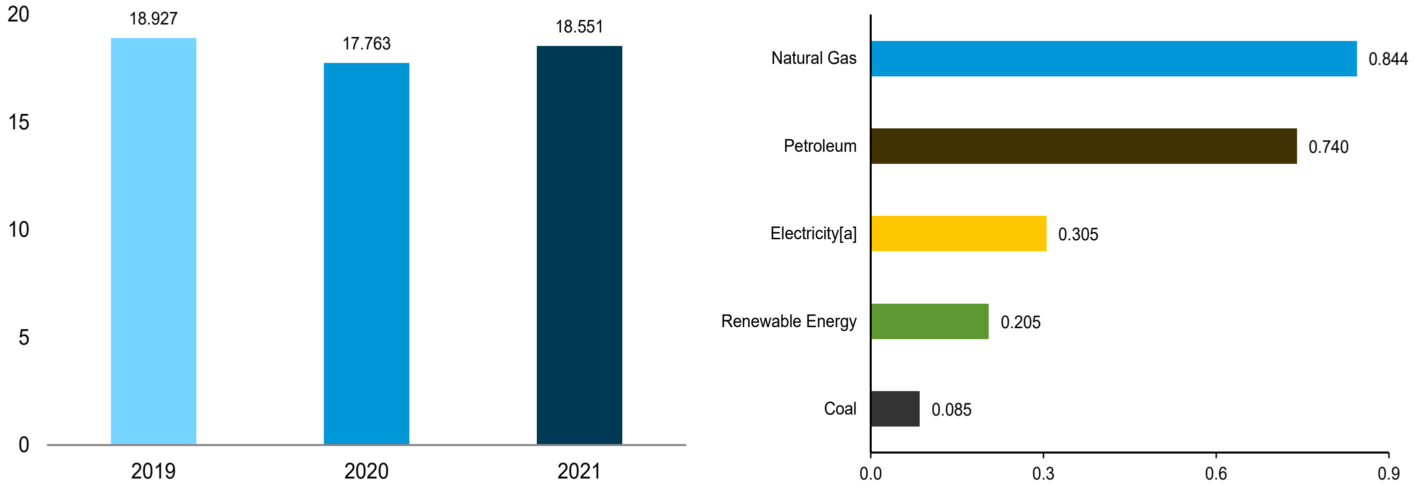


By Major Source, Monthly



Total, January–July

By Major Source, July 2021



[a] Electricity retail sales.

Web Page: http://www.eia.gov/totalenergy/data/monthly/#consumption.

Source: Table 2.4.

# Table 2.4 Industrial Sector Energy Consumption

(Trillion Btu)

| | Primary Consumption[a] | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fossil Fuels[b] | | | | Renewable Energy[c] | | | | | | | | | |
| | Coal | Natural Gas[d] | Petroleum[e] | Total[f] | Hydroelectric Power[g] | Geothermal | Solar[h] | Wind | Biomass | Total | Total Primary | Electricity Retail Sales[i] | Electrical System Energy Losses[j] | Total[f] |
| **1950 Total** | **5,781** | **3,546** | **3,943** | **13,271** | **69** | **NA** | **NA** | **NA** | **532** | **602** | **13,872** | **500** | **1,852** | **16,224** |
| **1955 Total** | **5,620** | **4,701** | **5,093** | **15,404** | **38** | **NA** | **NA** | **NA** | **631** | **669** | **16,073** | **887** | **2,495** | **19,455** |
| **1960 Total** | **4,543** | **5,973** | **5,720** | **16,231** | **39** | **NA** | **NA** | **NA** | **680** | **719** | **16,949** | **1,107** | **2,739** | **20,795** |
| **1965 Total** | **5,127** | **7,339** | **6,750** | **19,197** | **33** | **NA** | **NA** | **NA** | **855** | **888** | **20,085** | **1,463** | **3,487** | **25,035** |
| **1970 Total** | **4,656** | **9,536** | **7,754** | **21,888** | **34** | **NA** | **NA** | **NA** | **1,019** | **1,053** | **22,941** | **1,948** | **4,716** | **29,605** |
| **1975 Total** | **3,667** | **8,532** | **8,092** | **20,304** | **32** | **NA** | **NA** | **NA** | **1,063** | **1,096** | **21,400** | **2,346** | **5,632** | **29,379** |
| **1980 Total** | **3,155** | **8,333** | **9,463** | **20,916** | **33** | **NA** | **NA** | **NA** | **1,600** | **1,633** | **22,549** | **2,781** | **6,664** | **31,993** |
| **1985 Total** | **2,760** | **7,032** | **7,655** | **17,433** | **33** | **NA** | **NA** | **NA** | **1,918** | **1,951** | **19,384** | **2,855** | **6,518** | **28,757** |
| **1990 Total** | **2,756** | **8,443** | **8,199** | **19,402** | **31** | **2** | **(s)** | **–** | **1,684** | **1,717** | **21,120** | **3,226** | **7,404** | **31,749** |
| **1995 Total** | **2,488** | **9,592** | **8,524** | **20,665** | **55** | **3** | **(s)** | **–** | **1,934** | **1,992** | **22,657** | **3,455** | **7,796** | **33,908** |
| **2000 Total** | **2,256** | **9,500** | **8,998** | **20,820** | **42** | **4** | **(s)** | **–** | **1,881** | **1,928** | **22,748** | **3,631** | **8,208** | **34,587** |
| **2005 Total** | **1,954** | **7,907** | **9,567** | **19,472** | **32** | **4** | **(s)** | **–** | **1,834** | **1,871** | **21,343** | **3,477** | **7,554** | **32,374** |
| **2006 Total** | **1,914** | **7,861** | **9,693** | **19,529** | **29** | **4** | **1** | **–** | **1,892** | **1,926** | **21,455** | **3,451** | **7,411** | **32,317** |
| **2007 Total** | **1,865** | **8,074** | **9,363** | **19,326** | **16** | **5** | **1** | **–** | **1,937** | **1,958** | **21,284** | **3,507** | **7,515** | **32,306** |
| **2008 Total** | **1,793** | **8,083** | **8,502** | **18,420** | **17** | **5** | **1** | **–** | **2,012** | **2,035** | **20,455** | **3,444** | **7,362** | **31,261** |
| **2009 Total** | **1,392** | **7,609** | **7,720** | **16,698** | **18** | **4** | **2** | **–** | **1,948** | **1,972** | **18,670** | **3,130** | **6,580** | **28,380** |
| **2010 Total** | **1,631** | **8,278** | **8,080** | **17,983** | **16** | **4** | **3** | **–** | **2,320** | **2,343** | **20,327** | **3,314** | **6,934** | **30,574** |
| **2011 Total** | **1,561** | **8,481** | **8,052** | **18,105** | **17** | **4** | **4** | **(s)** | **2,375** | **2,401** | **20,505** | **3,382** | **7,005** | **30,893** |
| **2012 Total** | **1,513** | **8,819** | **8,063** | **18,399** | **22** | **4** | **7** | **(s)** | **2,349** | **2,383** | **20,781** | **3,363** | **6,810** | **30,954** |
| **2013 Total** | **1,546** | **9,140** | **8,259** | **18,929** | **33** | **4** | **9** | **(s)** | **2,403** | **2,449** | **21,378** | **3,362** | **6,785** | **31,525** |
| **2014 Total** | **1,530** | **9,441** | **8,021** | **18,971** | **12** | **4** | **11** | **1** | **2,456** | **2,484** | **21,455** | **3,404** | **6,832** | **31,691** |
| **2015 Total** | **1,380** | **9,426** | **8,138** | **18,925** | **13** | **4** | **14** | **(s)** | **2,460** | **2,491** | **21,417** | **3,366** | **6,578** | **31,361** |
| **2016 Total** | **1,205** | **9,617** | **8,247** | **19,050** | **12** | **4** | **19** | **1** | **2,467** | **2,503** | **21,553** | **3,333** | **6,461** | **31,347** |
| **2017 Total** | **1,195** | **9,864** | **8,433** | **19,463** | **13** | **4** | **22** | **1** | **2,450** | **2,490** | **21,953** | **3,358** | **6,487** | **31,798** |
| **2018 Total** | **1,180** | **10,474** | **8,753** | **20,381** | **10** | **4** | **24** | **1** | **2,440** | **2,480** | **22,861** | **3,414** | **6,481** | **32,756** |
| **2019** January | 97 | R 986 | 766 | R 1,847 | 1 | (s) | 2 | (s) | 206 | 209 | R 2,056 | 282 | 537 | R 2,875 |
| February | 93 | R 887 | 606 | R 1,585 | 1 | (s) | 2 | (s) | 187 | 190 | R 1,775 | 261 | 474 | R 2,510 |
| March | 98 | R 935 | 686 | R 1,719 | 1 | (s) | 2 | (s) | 201 | 205 | R 1,923 | 277 | 513 | R 2,713 |
| April | 90 | R 853 | 702 | R 1,644 | 1 | (s) | 3 | (s) | 193 | 197 | R 1,840 | 275 | 506 | R 2,620 |
| May | 95 | R 858 | 744 | R 1,696 | 1 | (s) | 3 | (s) | 199 | 204 | R 1,900 | 289 | 559 | R 2,748 |
| June | 94 | R 812 | 725 | R 1,629 | 1 | (s) | 3 | (s) | 196 | 201 | R 1,829 | 290 | 549 | R 2,668 |
| July | 91 | R 834 | 775 | R 1,698 | 1 | (s) | 3 | (s) | 204 | 207 | R 1,905 | 310 | 578 | R 2,793 |
| August | 91 | R 861 | 787 | R 1,738 | 1 | (s) | 3 | (s) | 203 | 207 | R 1,944 | 311 | 567 | R 2,822 |
| September | 91 | R 827 | 761 | R 1,676 | (s) | (s) | 3 | (s) | 189 | 192 | R 1,868 | 294 | 520 | R 2,682 |
| October | 93 | R 875 | 788 | R 1,754 | 1 | (s) | 2 | (s) | 198 | 201 | R 1,955 | 288 | 492 | R 2,735 |
| November | 90 | R 925 | 735 | R 1,748 | 1 | (s) | 2 | (s) | 198 | 201 | R 1,949 | 272 | 514 | R 2,735 |
| December | 94 | R 977 | 715 | R 1,783 | 1 | (s) | 2 | (s) | 207 | 210 | R 1,993 | 273 | 504 | R 2,770 |
| **Total** | **1,117** | R **10,630** | **8,790** | R **20,517** | **9** | **4** | **28** | **1** | **2,381** | **2,423** | R **22,940** | **3,420** | **6,312** | R **32,672** |
| **2020** January | 90 | R 974 | 731 | R 1,793 | 1 | (s) | 2 | (s) | 206 | 209 | R 2,001 | 264 | 488 | R 2,753 |
| February | R 90 | R 905 | 691 | R 1,684 | 1 | (s) | 2 | (s) | 192 | 195 | R 1,879 | 258 | 476 | R 2,613 |
| March | 88 | R 901 | 749 | R 1,736 | 1 | (s) | 3 | (s) | 193 | 197 | R 1,934 | 265 | 478 | R 2,676 |
| April | 72 | R 812 | 566 | R 1,449 | 1 | (s) | 3 | (s) | 163 | 168 | R 1,617 | 237 | 423 | R 2,277 |
| May | 68 | R 790 | 647 | R 1,506 | 1 | (s) | 3 | (s) | 177 | 182 | R 1,687 | 243 | 473 | R 2,403 |
| June | 74 | R 771 | 660 | R 1,504 | 1 | (s) | 3 | 1 | 176 | 181 | R 1,685 | 257 | 495 | R 2,436 |
| July | 69 | R 813 | 728 | R 1,610 | 1 | (s) | 3 | 1 | 187 | 192 | R 1,802 | 277 | 525 | R 2,604 |
| August | 72 | R 828 | 756 | R 1,655 | 1 | (s) | 3 | 1 | 185 | 190 | R 1,845 | 283 | R 531 | R 2,659 |
| September | 71 | R 818 | 710 | R 1,598 | 1 | (s) | 3 | 1 | 183 | 188 | R 1,786 | 264 | 467 | R 2,517 |
| October | 80 | R 866 | 743 | R 1,688 | 1 | (s) | 3 | 1 | 191 | 195 | R 1,883 | 270 | 488 | R 2,641 |
| November | 81 | R 881 | 745 | R 1,706 | 1 | (s) | 2 | 1 | 194 | 198 | R 1,903 | 259 | 492 | R 2,654 |
| December | 83 | R 966 | 750 | R 1,798 | 1 | (s) | 2 | 1 | 200 | 204 | R 2,002 | 260 | 494 | R 2,757 |
| **Total** | R **938** | R **10,324** | **8,477** | R **19,726** | **9** | **4** | **32** | **6** | **2,247** | **2,298** | R **22,025** | **3,137** | **5,834** | R **30,996** |
| **2021** January | 88 | R 973 | 747 | R 1,805 | 1 | (s) | 2 | 1 | 195 | 199 | R 2,004 | 270 | 502 | R 2,777 |
| February | 82 | R 822 | 515 | R 1,416 | 1 | (s) | 2 | 1 | 166 | 170 | R 1,586 | 250 | 472 | R 2,308 |
| March | 89 | R 881 | 738 | R 1,707 | 1 | (s) | 3 | 1 | 191 | 196 | R 1,903 | 260 | 463 | R 2,626 |
| April | R 84 | R 853 | 744 | R 1,677 | 1 | (s) | 3 | 1 | 185 | 190 | R 1,868 | 269 | 483 | R 2,619 |
| May | R 86 | R 836 | 797 | R 1,716 | 1 | (s) | 4 | 1 | 200 | 205 | R 1,921 | 282 | 532 | R 2,736 |
| June | R 85 | R 813 | 807 | R 1,699 | 1 | (s) | 4 | 1 | 190 | 195 | R 1,894 | 291 | 556 | R 2,742 |
| July | 85 | 844 | 740 | 1,667 | 1 | (s) | 4 | (s) | 199 | 205 | 1,871 | 305 | 568 | 2,744 |
| **7-Month Total** | **599** | **6,023** | **5,087** | **11,687** | **5** | **2** | **21** | **5** | **1,327** | **1,361** | **13,047** | **1,928** | **3,576** | **18,551** |
| **2020 7-Month Total** | **551** | **5,965** | **4,772** | **11,281** | **6** | **2** | **19** | **2** | **1,294** | **1,323** | **12,605** | **1,801** | **3,357** | **17,763** |
| **2019 7-Month Total** | **658** | **6,165** | **5,005** | **11,817** | **6** | **2** | **17** | **1** | **1,386** | **1,412** | **13,229** | **1,982** | **3,716** | **18,927** |

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[a] See "Primary Energy Consumption" in Glossary.

[b] Includes non-combustion use of fossil fuels.

[c] See Table 10.2b for notes on series components and estimation.

[d] Natural gas only; excludes the estimated portion of supplemental gaseous fuels. See Note 3, "Supplemental Gaseous Fuels," at end of Section 4.

[e] Does not include biofuels that have been blended with petroleum—biofuels are included in "Biomass."

[f] Includes coal coke net imports, which are not separately displayed. See Tables 1.4a and 1.4b.

[g] Conventional hydroelectric power.

[h] Solar photovoltaic (PV) electricity net generation in the industrial sector, both utility-scale and distributed (small-scale). See Tables 10.2b and 10.5.

[i] Electricity retail sales to ultimate customers reported by electric utilities and, beginning in 1996, other energy service providers.

[j] Total losses are calculated as the primary energy consumed by the electric power sector minus the energy content of electricity retail sales. Total losses are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See Note 1, "Electrical System Energy Losses," at end of section.

R=Revised. NA=Not available. – =No data reported. (s)=Less than 0.5 trillion Btu.

Notes: • Data are estimates, except for coal totals; hydroelectric power in 1949–1978 and 1989 forward; solar; wind; and electricity retail sales. • The industrial sector includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants. See Note 2, "Classification of Power Plants Into Energy-Use Sectors," at end of Section 7. • See Note 2, "Oher Energy Losses," at end of section. • See Note 3, "Energy Consumption Data and Surveys," at end of section. • Totals may not equal sum of components due to independent rounding. • Geographic coverage is the 50 states and the District of Columbia.

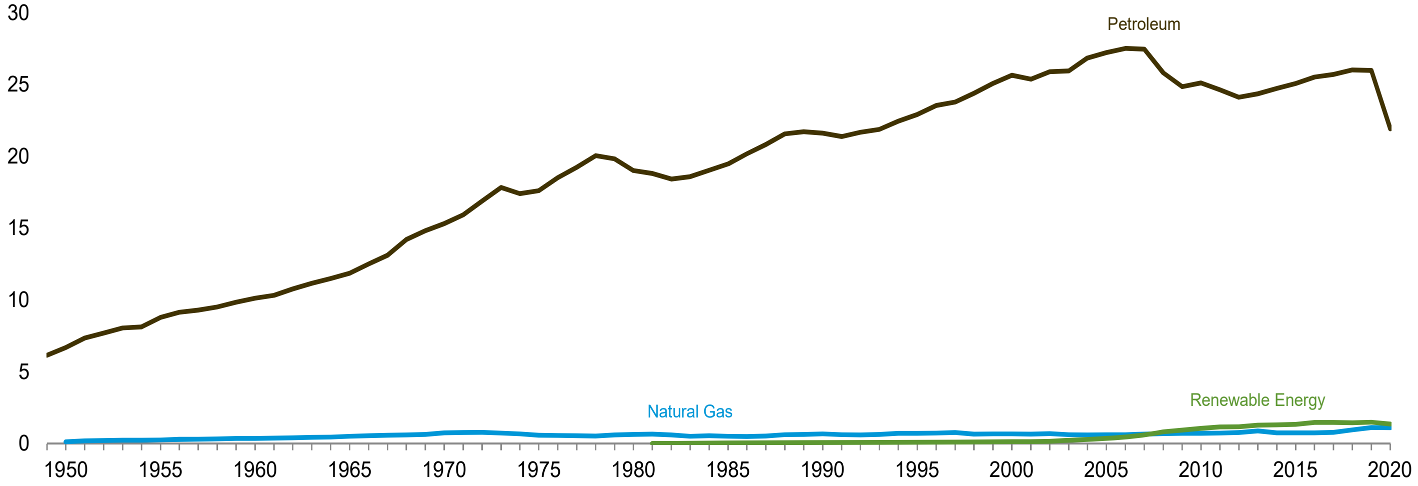
Web Page: See http://www.eia.gov/totalenergy/data/monthly/#consumption (Excel and CSV files) for all available annual data beginning in 1949 and monthly data beginning in 1973.

Sources: See end of section.

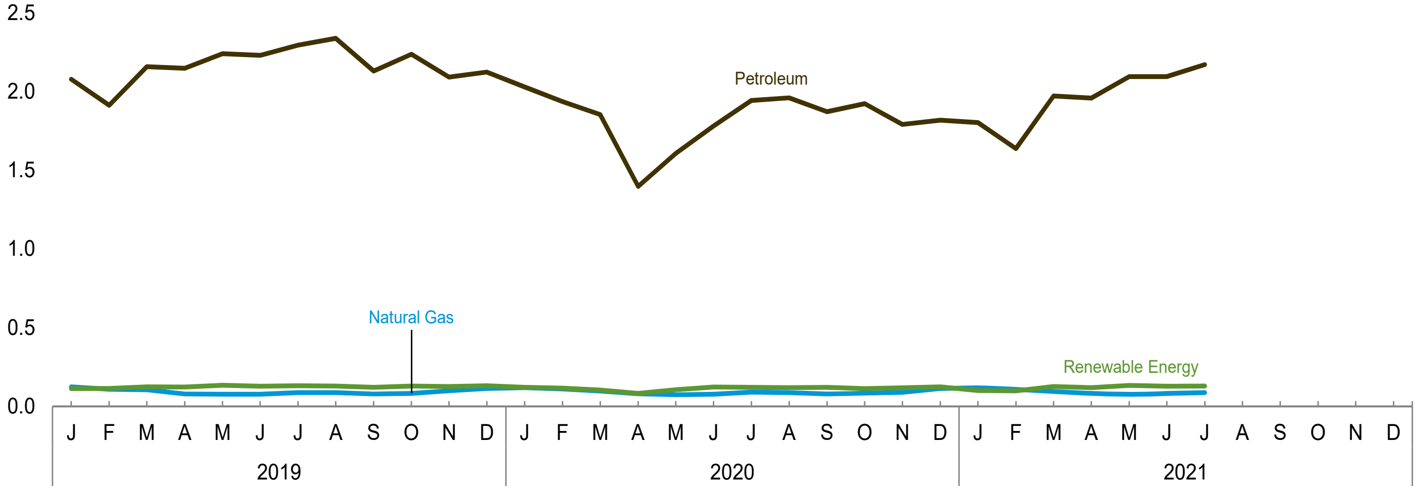
## Figure 2.5 Transportation Sector Energy Consumption

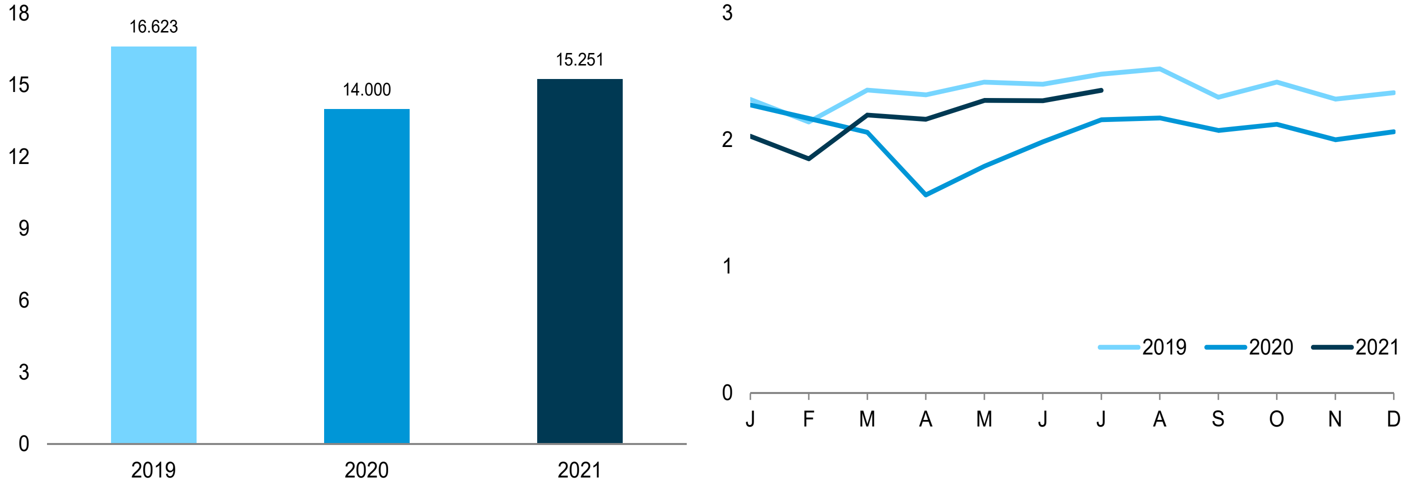
(Quadrillion Btu)

By Major Source, 1949–2020



By Major Source, Monthly





Total, January–July

Total, Monthly

Web Page: http://www.eia.gov/totalenergy/data/monthly/#consumption.
Source: Table 2.5.

# Table 2.5 Transportation Sector Energy Consumption

(Trillion Btu)

| | Primary Consumption[a] | | | | | | Electricity Retail Sales[e] | Electrical System Energy Losses[f] | Total |
|---|---|---|---|---|---|---|---|---|---|
| | Fossil Fuels | | | | Renewable Energy[b] | Total Primary | | | |
| | Coal | Natural Gas[c] | Petroleum[d] | Total | Biomass | | | | |
| **1950 Total** | **1,564** | **130** | **6,690** | **8,383** | **NA** | **8,383** | **23** | **86** | **8,492** |
| **1955 Total** | **421** | **254** | **8,799** | **9,474** | **NA** | **9,474** | **20** | **56** | **9,550** |
| **1960 Total** | **75** | **359** | **10,125** | **10,560** | **NA** | **10,560** | **10** | **26** | **10,596** |
| **1965 Total** | **16** | **517** | **11,866** | **12,399** | **NA** | **12,399** | **10** | **24** | **12,432** |
| **1970 Total** | **7** | **745** | **15,311** | **16,062** | **NA** | **16,062** | **11** | **26** | **16,098** |
| **1975 Total** | **1** | **595** | **17,615** | **18,211** | **NA** | **18,211** | **10** | **24** | **18,245** |
| **1980 Total** | **(g)** | **650** | **19,009** | **19,659** | **NA** | **19,659** | **11** | **27** | **19,697** |
| **1985 Total** | **(g)** | **519** | **19,472** | **19,992** | **50** | **20,042** | **14** | **32** | **20,088** |
| **1990 Total** | **(g)** | **679** | **21,626** | **22,305** | **60** | **22,366** | **16** | **37** | **22,419** |
| **1995 Total** | **(g)** | **724** | **22,920** | **23,644** | **112** | **23,757** | **17** | **38** | **23,812** |
| **2000 Total** | **(g)** | **672** | **25,649** | **26,321** | **135** | **26,456** | **18** | **42** | **26,515** |
| **2005 Total** | **(g)** | **624** | **27,217** | **27,840** | **339** | **28,179** | **26** | **56** | **28,261** |
| **2006 Total** | **(g)** | **625** | **27,518** | **28,143** | **475** | **28,618** | **25** | **54** | **28,697** |
| **2007 Total** | **(g)** | **663** | **27,462** | **28,126** | **602** | **28,727** | **28** | **60** | **28,815** |
| **2008 Total** | **(g)** | **692** | **25,823** | **26,515** | **825** | **27,339** | **26** | **56** | **27,421** |
| **2009 Total** | **(g)** | **715** | **24,860** | **25,575** | **935** | **26,510** | **27** | **56** | **26,592** |
| **2010 Total** | **(g)** | **719** | **25,103** | **25,822** | **1,075** | **26,897** | **26** | **55** | **26,978** |
| **2011 Total** | **(g)** | **734** | **24,626** | **25,360** | R **1,166** | R **26,526** | **26** | **54** | R **26,606** |
| **2012 Total** | **(g)** | **780** | **24,111** | **24,890** | R **1,169** | R **26,059** | **25** | **51** | R **26,135** |
| **2013 Total** | **(g)** | **887** | **24,362** | **25,249** | R **1,292** | R **26,542** | **26** | **53** | R **26,620** |
| **2014 Total** | **(g)** | **760** | **24,727** | **25,487** | R **1,314** | R **26,801** | **26** | **53** | R **26,881** |
| **2015 Total** | **(g)** | **745** | **25,083** | **25,828** | R **1,351** | R **27,179** | **26** | **51** | R **27,256** |
| **2016 Total** | **(g)** | **757** | **25,511** | **26,268** | R **1,469** | R **27,737** | **26** | **50** | R **27,812** |
| **2017 Total** | **(g)** | **799** | **25,702** | **26,500** | R **1,474** | R **27,974** | **26** | **50** | R **28,049** |
| **2018 Total** | **(g)** | **962** | **26,011** | **26,974** | R **1,456** | R **28,429** | **26** | **50** | R **28,505** |
| **2019** January | (g) | R 123 | 2,078 | R 2,201 | R 112 | R 2,313 | 2 | 4 | R 2,320 |
| February | (g) | R 108 | 1,913 | R 2,022 | R 113 | R 2,135 | 2 | 4 | R 2,141 |
| March | (g) | R 105 | 2,158 | R 2,263 | R 123 | R 2,386 | 2 | 4 | R 2,393 |
| April | (g) | R 79 | 2,148 | R 2,228 | R 122 | R 2,349 | 2 | 4 | R 2,355 |
| May | (g) | R 76 | 2,240 | R 2,316 | R 134 | R 2,450 | 2 | 4 | R 2,456 |
| June | (g) | R 76 | 2,230 | R 2,306 | R 128 | R 2,434 | 2 | 4 | R 2,440 |
| July | (g) | R 86 | 2,294 | R 2,380 | R 131 | R 2,511 | 2 | 4 | R 2,518 |
| August | (g) | R 87 | 2,339 | R 2,426 | R 129 | R 2,555 | 2 | 4 | R 2,561 |
| September | (g) | R 79 | 2,131 | R 2,210 | R 120 | R 2,330 | 2 | 4 | R 2,337 |
| October | (g) | R 82 | 2,238 | R 2,320 | R 129 | R 2,450 | 2 | 3 | R 2,455 |
| November | (g) | R 99 | 2,092 | R 2,191 | R 125 | R 2,316 | 2 | 4 | R 2,322 |
| December | (g) | R 113 | 2,124 | R 2,237 | R 130 | R 2,367 | 2 | 4 | R 2,373 |
| **Total** | **(g)** | R **1,114** | **25,986** | R **27,100** | R **1,497** | R **28,597** | **26** | **48** | R **28,671** |
| **2020** January | (g) | R 119 | 2,029 | R 2,148 | R 120 | R 2,269 | 2 | 4 | R 2,275 |
| February | (g) | R 110 | 1,937 | R 2,046 | R 115 | R 2,162 | 2 | 4 | R 2,168 |
| March | (g) | R 97 | 1,853 | R 1,950 | R 104 | R 2,054 | 2 | 4 | R 2,059 |
| April | (g) | R 80 | 1,397 | R 1,478 | R 82 | R 1,559 | 2 | 3 | R 1,564 |
| May | (g) | R 74 | 1,607 | R 1,681 | R 105 | R 1,786 | 2 | 3 | R 1,791 |
| June | (g) | R 77 | 1,781 | R 1,857 | R 122 | R 1,979 | 2 | 3 | R 1,984 |
| July | (g) | R 90 | 1,943 | R 2,032 | R 121 | R 2,154 | 2 | 4 | R 2,159 |
| August | (g) | R 86 | 1,961 | R 2,048 | R 119 | R 2,167 | 2 | 3 | R 2,172 |
| September | (g) | R 78 | 1,872 | R 1,950 | R 120 | R 2,070 | 2 | 3 | R 2,075 |
| October | (g) | R 84 | 1,923 | R 2,006 | R 112 | R 2,118 | 2 | 3 | R 2,123 |
| November | (g) | R 88 | 1,792 | R 1,879 | R 117 | R 1,997 | 2 | 3 | R 2,002 |
| December | (g) | R 114 | 1,819 | R 1,933 | R 124 | R 2,057 | 2 | 4 | R 2,063 |
| **Total** | **(g)** | R **1,097** | **21,913** | R **23,011** | R **1,362** | R **24,373** | **22** | **41** | R **24,436** |
| **2021** January | (g) | R 117 | 1,803 | R 1,921 | 101 | R 2,022 | 2 | 4 | R 2,028 |
| February | (g) | R 109 | 1,638 | R 1,746 | 98 | R 1,845 | 2 | 4 | R 1,850 |
| March | (g) | R 94 | 1,972 | R 2,066 | 126 | R 2,192 | 2 | 3 | R 2,197 |
| April | (g) | R 81 | 1,959 | R 2,040 | 118 | R 2,158 | 2 | 3 | R 2,163 |
| May | (g) | R 77 | 2,096 | R 2,173 | 133 | R 2,306 | 2 | 3 | R 2,311 |
| June | (g) | R 81 | 2,096 | R 2,177 | 128 | R 2,305 | 2 | 3 | R 2,310 |
| July | (g) | 86 | 2,172 | 2,258 | 129 | 2,387 | 2 | 3 | 2,392 |
| **7-Month Total** | **(g)** | **645** | **13,736** | **14,381** | **834** | **15,215** | **13** | **23** | **15,251** |
| **2020 7-Month Total** | **(g)** | **647** | **12,547** | **13,194** | **769** | **13,963** | **13** | **24** | **14,000** |
| **2019 7-Month Total** | **(g)** | **653** | **15,062** | **15,715** | **864** | **16,579** | **15** | **29** | **16,623** |

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[a] See "Primary Energy Consumption" in Glossary.

[b] See Table 10.2b for notes on series components.

[c] Natural gas only; does not include supplemental gaseous fuels—see Note 3, "Supplemental Gaseous Fuels," at end of Section 4. Data are for natural gas consumed in the operation of pipelines (primarily in compressors) and small amounts consumed as vehicle fuel—see Table 4.3.

[d] Does not include biofuels. Biofuels are included in "Biomass." Includes non-combustion use of lubricants.

[e] Electricity retail sales to ultimate customers reported by electric utilities and, beginning in 1996, other energy service providers.

[f] Total losses are calculated as the primary energy consumed by the electric power sector minus the energy content of electricity retail sales. Total losses are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See Note 1, "Electrical System Energy Losses," at end of section.

[g] Beginning in 1978, the small amounts of coal consumed for transportation are reported as industrial sector consumption.

R=Revised. NA=Not available.

Notes: • Data are estimates, except for coal totals through 1977; and electricity retail sales beginning in 1979. • See Note 2, "Oher Energy Losses," at end of section. • See Note 3, "Energy Consumption Data and Surveys," at end of section. • Totals may not equal sum of components due to independent rounding. • Geographic coverage is the 50 states and the District of Columbia.

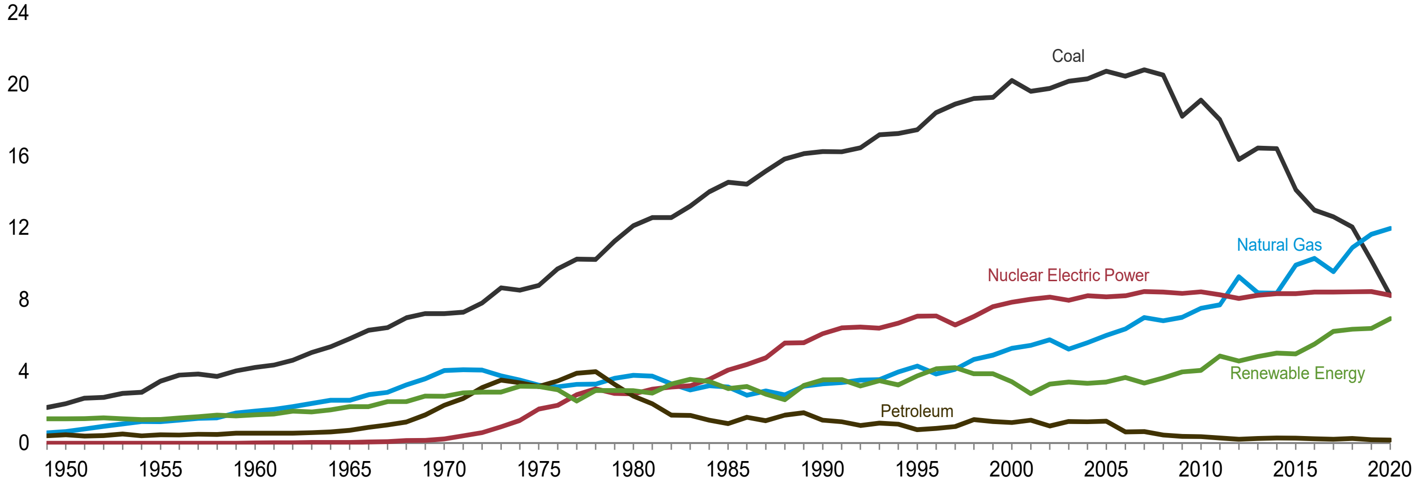
Web Page: See http://www.eia.gov/totalenergy/data/monthly/#consumption (Excel and CSV files) for all available annual data beginning in 1949 and monthly data beginning in 1973.

Sources: See end of section.

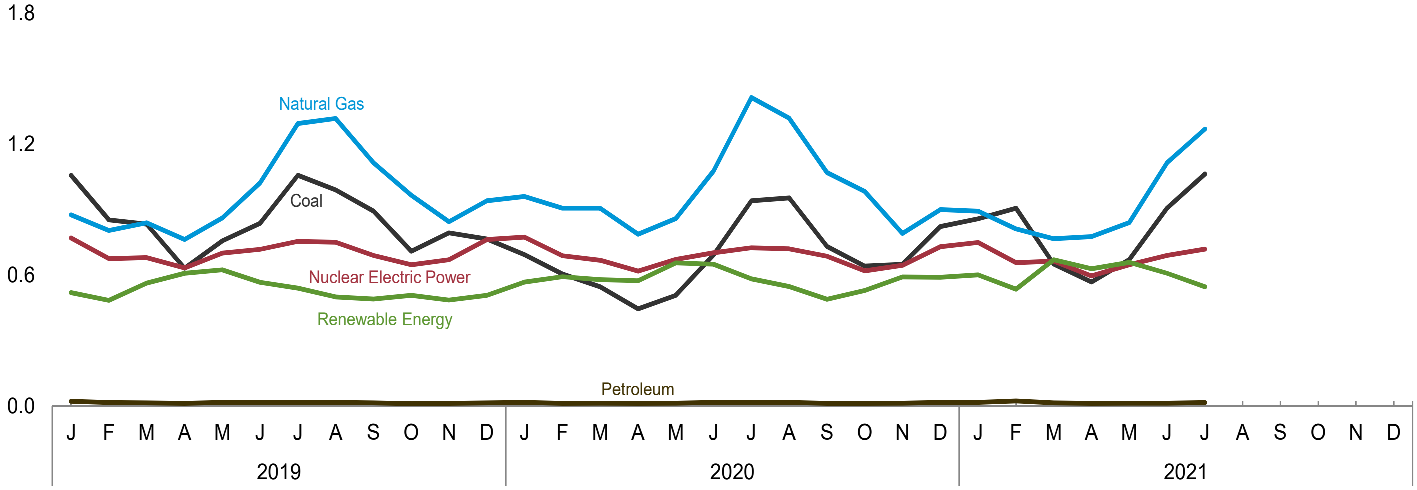
## **Figure 2.6 Electric Power Sector Energy Consumption**

(Quadrillion Btu)

By Major Source, 1949–2020

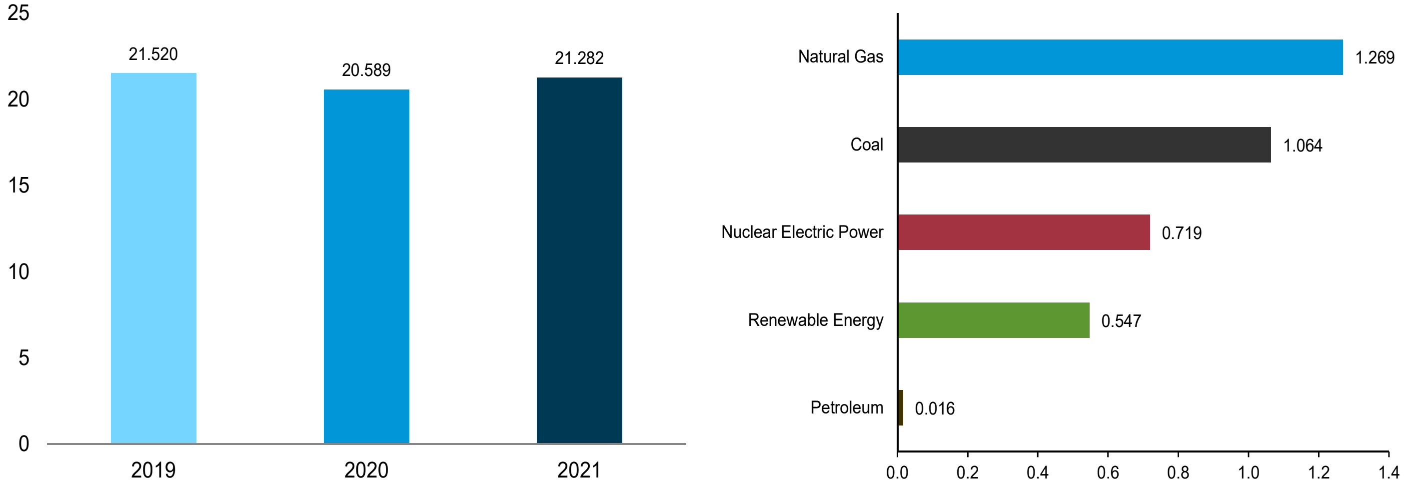


By Major Source, Monthly



Total, January–July

By Major Source, July 2021



Web Page: http://www.eia.gov/totalenergy/data/monthly/#consumption.
Source: Table 2.6.

# Table 2.6 Electric Power Sector Energy Consumption

(Trillion Btu)

| | Primary Consumption[a] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fossil Fuels | | | | Nuclear Electric Power | Renewable Energy[b] | | | | | | Electricity Net Imports[f] | Total Primary |
| | Coal | Natural Gas[c] | Petroleum | Total | | Hydroelectric Power[d] | Geothermal | Solar[e] | Wind | Biomass | Total | | |
| **1950 Total** | 2,199 | 651 | 472 | 3,322 | 0 | 1,346 | NA | NA | NA | 5 | 1,351 | 6 | 4,679 |
| **1955 Total** | 3,458 | 1,194 | 471 | 5,123 | 0 | 1,322 | NA | NA | NA | 3 | 1,325 | 14 | 6,461 |
| **1960 Total** | 4,228 | 1,785 | 553 | 6,565 | 6 | 1,569 | (s) | NA | NA | 2 | 1,571 | 15 | 8,158 |
| **1965 Total** | 5,821 | 2,395 | 722 | 8,938 | 43 | 2,026 | 2 | NA | NA | 3 | 2,031 | (s) | 11,012 |
| **1970 Total** | 7,227 | 4,054 | 2,117 | 13,399 | 239 | 2,600 | 6 | NA | NA | 4 | 2,609 | 7 | 16,253 |
| **1975 Total** | 8,786 | 3,240 | 3,166 | 15,191 | 1,900 | 3,122 | 34 | NA | NA | 2 | 3,158 | 21 | 20,270 |
| **1980 Total** | 12,123 | 3,778 | 2,634 | 18,534 | 2,739 | 2,867 | 53 | NA | NA | 4 | 2,925 | 71 | 24,269 |
| **1985 Total** | 14,542 | 3,135 | 1,090 | 18,767 | 4,076 | 2,937 | 97 | (s) | (s) | 14 | 3,049 | 140 | 26,032 |
| **1990 Total** | 16,261 | 3,309 | 1,289 | 20,859 | 6,104 | 3,014 | 161 | 4 | 29 | 317 | 3,524 | 8 | [g]30,495 |
| **1995 Total** | 17,466 | 4,302 | 755 | 22,523 | 7,075 | 3,149 | 138 | 5 | 33 | 422 | 3,747 | 134 | 33,479 |
| **2000 Total** | 20,220 | 5,293 | 1,144 | 26,658 | 7,862 | 2,768 | 144 | 5 | 57 | 453 | 3,427 | 115 | 38,062 |
| **2005 Total** | 20,737 | 6,015 | 1,222 | 27,974 | 8,161 | 2,670 | 147 | 6 | 178 | 406 | 3,406 | 85 | 39,626 |
| **2006 Total** | 20,462 | 6,375 | 637 | 27,474 | 8,215 | 2,839 | 145 | 5 | 264 | 412 | 3,665 | 63 | 39,417 |
| **2007 Total** | 20,808 | 7,005 | 648 | 28,461 | 8,459 | 2,430 | 145 | 6 | 341 | 423 | 3,345 | 107 | 40,371 |
| **2008 Total** | 20,513 | 6,829 | 459 | 27,801 | 8,426 | 2,494 | 146 | 9 | 546 | 435 | 3,630 | 112 | 39,969 |
| **2009 Total** | 18,225 | 7,022 | 382 | 25,630 | 8,355 | 2,650 | 146 | 9 | 721 | 441 | 3,967 | 116 | 38,069 |
| **2010 Total** | 19,133 | 7,528 | 370 | 27,031 | 8,434 | 2,521 | 148 | 12 | 923 | 459 | 4,064 | 89 | 39,619 |
| **2011 Total** | 18,035 | 7,712 | 295 | 26,042 | 8,269 | 3,085 | 149 | 17 | 1,167 | 437 | 4,855 | 127 | 39,293 |
| **2012 Total** | 15,821 | 9,287 | 214 | 25,322 | 8,062 | 2,606 | 148 | 40 | 1,339 | 453 | 4,586 | 161 | 38,131 |
| **2013 Total** | 16,451 | 8,376 | 255 | 25,082 | 8,244 | 2,529 | 151 | 83 | 1,600 | 470 | 4,833 | 197 | 38,357 |
| **2014 Total** | 16,427 | 8,362 | 295 | 25,085 | 8,338 | 2,454 | 151 | 165 | 1,726 | 530 | 5,026 | 182 | 38,629 |
| **2015 Total** | 14,138 | 9,926 | 276 | 24,341 | 8,337 | 2,308 | 148 | 228 | 1,776 | 525 | 4,985 | 227 | 37,890 |
| **2016 Total** | 12,996 | 10,301 | 244 | 23,542 | 8,427 | 2,459 | 146 | 328 | 2,094 | 505 | 5,531 | 227 | 37,727 |
| **2017 Total** | 12,622 | 9,555 | 218 | 22,395 | 8,419 | 2,752 | 147 | 486 | 2,341 | 510 | 6,235 | 192 | 37,241 |
| **2018 Total** | 12,053 | 10,912 | 260 | 23,225 | 8,438 | 2,651 | 145 | 576 | 2,480 | 496 | 6,348 | 152 | 38,163 |
| **2019** January | 1,058 | 876 | 22 | 1,956 | 770 | 220 | 12 | 32 | 216 | 41 | 520 | 11 | 3,258 |
| February | 853 | 804 | 16 | 1,673 | 676 | 203 | 11 | 34 | 201 | 36 | 485 | 11 | 2,844 |
| March | 834 | 840 | 15 | 1,688 | 680 | 233 | 12 | 52 | 229 | 37 | 564 | 8 | 2,940 |
| April | 632 | 763 | 12 | 1,407 | 633 | 247 | 11 | 60 | 257 | 34 | 608 | 8 | 2,655 |
| May | 757 | 862 | 18 | 1,637 | 701 | 284 | 12 | 63 | 229 | 37 | 624 | 10 | 2,973 |
| June | 837 | 1,022 | 16 | R 1,875 | 718 | 249 | 12 | 70 | 200 | 37 | 567 | 12 | 3,173 |
| July | 1,057 | 1,294 | 18 | 2,370 | 754 | 221 | 12 | 72 | 197 | 40 | 541 | 13 | 3,677 |
| August | 991 | 1,318 | 18 | 2,327 | 751 | 200 | 12 | 69 | 178 | 40 | 500 | 14 | 3,592 |
| September | 893 | 1,115 | 15 | 2,023 | 690 | 164 | 12 | 60 | 218 | 37 | 491 | 12 | 3,216 |
| October | 709 | 966 | 11 | R 1,687 | 648 | 162 | 10 | 54 | 246 | 35 | 507 | 7 | 2,849 |
| November | 793 | 845 | 13 | 1,651 | 670 | 179 | 8 | 38 | 224 | 36 | 486 | 12 | 2,819 |
| December | 766 | 941 | 15 | 1,722 | 763 | 190 | 10 | 30 | 237 | 39 | 507 | 14 | 3,006 |
| **Total** | 10,181 | R 11,647 | 189 | R 22,017 | 8,452 | 2,553 | 134 | 635 | 2,632 | 448 | 6,402 | 133 | 37,003 |
| **2020** January | 694 | 960 | 17 | 1,671 | 774 | 225 | 11 | 41 | 254 | 38 | 569 | 11 | 3,025 |
| February | 605 | 906 | 13 | 1,524 | 689 | 234 | 11 | 50 | 262 | 36 | 593 | 10 | 2,815 |
| March | 546 | 906 | 14 | 1,467 | 668 | 209 | 13 | 57 | 263 | 37 | 579 | 13 | 2,727 |
| April | 445 | 787 | 13 | 1,245 | 618 | 196 | 13 | 72 | 262 | 33 | 575 | 11 | 2,449 |
| May | 507 | 859 | 14 | 1,379 | 672 | 270 | 13 | 86 | 252 | 35 | 656 | 12 | 2,720 |
| June | 693 | 1,077 | 17 | 1,787 | 702 | 258 | 12 | 85 | 262 | 33 | 650 | 13 | 3,152 |
| July | 941 | 1,414 | 18 | 2,374 | 725 | 246 | 13 | 92 | 198 | 35 | 583 | 19 | 3,700 |
| August | 954 | R 1,319 | 17 | R 2,290 | 720 | 214 | 12 | 84 | 199 | 39 | 548 | 20 | R 3,578 |
| September | 731 | R 1,069 | 12 | 1,813 | 686 | 170 | 12 | 70 | 205 | 33 | 489 | 13 | 3,001 |
| October | 641 | 983 | 13 | 1,637 | 620 | 162 | 12 | 65 | 256 | 33 | 529 | 13 | 2,799 |
| November | 650 | 791 | 14 | 1,455 | 645 | 194 | 13 | 52 | 299 | 34 | 591 | 12 | 2,702 |
| December | 823 | 900 | 17 | 1,740 | 730 | 205 | 13 | 48 | 288 | 37 | 590 | 15 | 3,074 |
| **Total** | 8,231 | 11,972 | 180 | R 20,383 | 8,248 | 2,581 | 147 | 802 | 2,998 | 424 | 6,952 | 161 | 35,744 |
| **2021** January | 858 | 893 | 17 | 1,768 | 750 | 232 | 12 | 51 | 270 | 36 | 601 | 14 | 3,133 |
| February | 907 | 812 | 24 | 1,743 | 657 | 196 | 11 | 57 | 237 | 35 | 536 | 10 | 2,947 |
| March | 651 | 767 | 15 | 1,433 | 665 | 189 | 11 | 83 | 351 | 37 | 671 | 13 | 2,783 |
| April | 568 | 776 | 12 | 1,356 | 596 | 171 | 11 | 97 | 319 | 32 | 629 | 11 | 2,592 |
| May | 672 | 841 | 14 | 1,526 | 648 | 208 | 12 | 110 | 295 | 35 | 659 | 13 | 2,846 |
| June | 906 | 1,115 | 14 | 2,035 | 690 | 221 | 12 | 107 | 234 | 35 | 609 | 15 | 3,349 |
| July | 1,064 | 1,269 | 16 | 2,349 | 719 | 200 | 12 | 106 | 190 | 38 | 547 | 17 | 3,631 |
| **7-Month Total** | 5,626 | 6,474 | 110 | 12,210 | 4,725 | 1,417 | 82 | 610 | 1,896 | 248 | 4,253 | 93 | 21,282 |
| **2020 7-Month Total** | 4,432 | 6,910 | 106 | 11,448 | 4,847 | 1,637 | 85 | 484 | 1,751 | 248 | 4,205 | 89 | 20,589 |
| **2019 7-Month Total** | 6,028 | 6,461 | 116 | 12,605 | 4,931 | 1,656 | 81 | 382 | 1,530 | 261 | 3,910 | 74 | 21,520 |

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[a] See "Primary Energy Consumption" in Glossary.

[b] See Table 10.2c for notes on series components.

[c] Natural gas only; excludes the estimated portion of supplemental gaseous fuels. See Note 3, "Supplemental Gaseous Fuels," at end of Section 4.

[d] Conventional hydroelectric power.

[e] Solar photovoltaic (PV) and solar thermal electricity net generation in the electric power sector. See Tables 10.2c and 10.5.

[f] Net imports equal imports minus exports.

[g] Through 1988, data are for electric utilities only. Beginning in 1989, data are for electric utilities and independent power producers.

R=Revised. NA=Not available. (s)=Less than 0.5 trillion Btu.

Notes: • Data are for fuels consumed to produce electricity and useful thermal output. • The electric power sector comprises electricity-only and combined-heat-and-power (CHP) plants within the NAICS 22 category whose primary business is to sell electricity, or electricity and heat, to the public. • See Note 3, "Energy Consumption Data and Surveys," at end of section. • Totals may not equal sum of components due to independent rounding. • Geographic coverage is the 50 states and the District of Columbia.

Web Page: See http://www.eia.gov/totalenergy/data/monthly/#consumption (Excel and CSV files) for all available annual data beginning in 1949 and monthly data beginning in 1973.

Sources: See end of section.

# Table 2.7 U.S. Government Energy Consumption by Agency, Fiscal Years

(Trillion Btu)

| Fiscal Year[a] | Agri-culture | Defense | DHS[b] | Energy | GSA[c] | HHS[d] | Interior | Justice | NASA[e] | Postal Service | Trans-portation | Veterans Affairs | Other[f] | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 .......... | 9.5 | 1,360.2 | – – | 50.4 | 22.3 | 6.5 | 9.4 | 5.9 | 13.4 | 30.5 | 19.3 | 27.1 | 10.5 | 1,565.0 |
| 1976 .......... | 9.3 | 1,183.3 | – – | 50.3 | 20.6 | 6.7 | 9.4 | 5.7 | 12.4 | 30.0 | 19.5 | 25.0 | 11.2 | 1,383.4 |
| 1977 .......... | 8.9 | 1,192.3 | – – | 51.6 | 20.4 | 6.9 | 9.5 | 5.9 | 12.0 | 32.7 | 20.4 | 25.9 | 11.9 | 1,398.5 |
| 1978 .......... | 9.1 | 1,157.8 | – – | 50.1 | 20.4 | 6.5 | 9.2 | 5.9 | 11.2 | 30.9 | 20.6 | 26.8 | 12.4 | 1,360.9 |
| 1979 .......... | 9.2 | 1,175.8 | – – | 49.6 | 19.6 | 6.4 | 10.4 | 6.4 | 11.1 | 29.3 | 19.6 | 25.7 | 12.3 | 1,375.4 |
| 1980 .......... | 8.6 | 1,183.1 | – – | 47.4 | 18.1 | 6.0 | 8.5 | 5.7 | 10.4 | 27.2 | 19.2 | 24.8 | 12.3 | 1,371.2 |
| 1981 .......... | 7.9 | 1,239.5 | – – | 47.3 | 18.0 | 6.7 | 7.6 | 5.4 | 10.0 | 27.9 | 18.8 | 24.0 | 11.1 | 1,424.2 |
| 1982 .......... | 7.6 | 1,264.5 | – – | 49.0 | 18.1 | 6.4 | 7.4 | 5.8 | 10.1 | 27.5 | 19.1 | 24.2 | 11.6 | 1,451.4 |
| 1983 .......... | 7.4 | 1,248.3 | – – | 49.5 | 16.1 | 6.2 | 7.7 | 5.5 | 10.3 | 26.5 | 19.4 | 24.1 | 10.8 | 1,431.8 |
| 1984 .......... | 7.9 | 1,292.1 | – – | 51.6 | 16.2 | 6.4 | 8.4 | 6.4 | 10.6 | 27.7 | 19.8 | 24.6 | 10.7 | 1,482.5 |
| 1985 .......... | 8.4 | 1,250.6 | – – | 52.2 | 20.7 | 6.0 | 7.8 | 8.2 | 10.9 | 27.8 | 19.6 | 25.1 | 13.1 | 1,450.3 |
| 1986 .......... | 6.8 | 1,222.8 | – – | 46.9 | 14.0 | 6.2 | 6.9 | 8.6 | 11.2 | 28.0 | 19.4 | 25.0 | 10.8 | 1,406.7 |
| 1987 .......... | 7.3 | 1,280.5 | – – | 48.5 | 13.1 | 6.6 | 6.6 | 8.1 | 11.3 | 28.5 | 19.0 | 24.9 | 11.9 | 1,466.3 |
| 1988 .......... | 7.8 | 1,165.8 | – – | 49.9 | 12.4 | 6.4 | 7.0 | 9.4 | 11.3 | 29.6 | 18.7 | 26.3 | 15.8 | 1,360.3 |
| 1989 .......... | 8.7 | 1,274.4 | – – | 44.2 | 12.7 | 6.7 | 7.1 | 7.7 | 12.4 | 30.3 | 18.5 | 26.2 | 15.6 | 1,464.7 |
| 1990 .......... | 9.6 | 1,241.7 | – – | 43.5 | 17.5 | 7.1 | 7.4 | 7.0 | 12.4 | 30.6 | 19.0 | 24.9 | 17.5 | 1,438.0 |
| 1991 .......... | 9.6 | 1,269.3 | – – | 42.1 | 14.0 | 6.2 | 7.1 | 8.0 | 12.5 | 30.8 | 19.0 | 25.1 | 18.1 | 1,461.7 |
| 1992 .......... | 9.1 | 1,104.0 | – – | 44.3 | 13.8 | 6.8 | 7.0 | 7.5 | 12.6 | 31.7 | 17.0 | 25.3 | 15.7 | 1,294.8 |
| 1993 .......... | 9.3 | 1,048.8 | – – | 43.4 | 14.1 | 7.2 | 7.5 | 9.1 | 12.4 | 33.7 | 19.4 | 25.7 | 16.2 | 1,246.8 |
| 1994 .......... | 9.4 | 977.0 | – – | 42.1 | 14.0 | 7.5 | 7.9 | 10.3 | 12.6 | 35.0 | 19.8 | 25.6 | 17.1 | 1,178.2 |
| 1995 .......... | 9.0 | 926.0 | – – | 47.3 | 13.7 | 6.1 | 6.4 | 10.2 | 12.4 | 36.2 | 18.7 | 25.4 | 17.1 | 1,128.5 |
| 1996 .......... | 9.1 | 904.5 | – – | 44.6 | 14.5 | 6.6 | 4.3 | 12.1 | 11.5 | 36.4 | 19.6 | 26.8 | 17.7 | 1,107.7 |
| 1997 .......... | 7.4 | 880.0 | – – | 43.1 | 14.4 | 7.9 | 6.6 | 12.0 | 12.0 | 40.8 | 19.1 | 27.3 | 20.8 | 1,091.2 |
| 1998 .......... | 7.9 | 837.1 | – – | 31.5 | 14.1 | 7.4 | 6.4 | 15.8 | 11.7 | 39.5 | 18.5 | 27.6 | 19.5 | 1,037.1 |
| 1999 .......... | 7.8 | 810.7 | – – | 27.0 | 14.4 | 7.1 | 7.5 | 15.4 | 11.4 | 39.8 | 22.6 | 27.5 | 19.8 | 1,010.9 |
| 2000 .......... | 7.4 | 779.1 | – – | 30.5 | 17.6 | 8.0 | 7.8 | 19.7 | 11.1 | 43.3 | 21.2 | 27.0 | 20.3 | 993.1 |
| 2001 .......... | 7.4 | 787.2 | – – | 31.1 | 18.4 | 8.5 | 9.5 | 19.7 | 10.9 | 43.4 | 17.8 | 27.7 | 20.7 | 1,002.3 |
| 2002 .......... | 7.2 | 837.5 | – – | 30.7 | 17.5 | 8.0 | 8.2 | 17.7 | 10.7 | 41.6 | 18.3 | 27.7 | 18.4 | 1,043.4 |
| 2003 .......... | 7.7 | 895.1 | 18.3 | 31.9 | 18.5 | 10.1 | 7.3 | 22.7 | 10.8 | 50.9 | 5.5 | 30.6 | 22.7 | 1,132.3 |
| 2004 .......... | 7.0 | 960.7 | 23.5 | 31.4 | 18.3 | 8.8 | 8.7 | 17.5 | 9.9 | 50.5 | 5.2 | 29.9 | 20.4 | 1,191.7 |
| 2005 .......... | 7.5 | 933.2 | 18.9 | 29.6 | 18.4 | 9.6 | 8.6 | 18.8 | 10.3 | 53.5 | 5.0 | 30.0 | 23.2 | 1,166.4 |
| 2006 .......... | 6.8 | 843.7 | 17.1 | 32.9 | 18.2 | 9.3 | 8.1 | 23.5 | 10.2 | 51.8 | 4.6 | 29.3 | 20.9 | 1,076.4 |
| 2007 .......... | 6.8 | 864.6 | 17.1 | 31.5 | 19.1 | 9.9 | 7.5 | 20.7 | 10.6 | 45.8 | 5.6 | 30.0 | 21.0 | 1,090.2 |
| 2008 .......... | 6.5 | 910.8 | 21.7 | 32.1 | 18.8 | 10.3 | 7.1 | 19.0 | 10.8 | 47.1 | 7.7 | 29.0 | 22.4 | 1,143.2 |
| 2009 .......... | 6.6 | 874.3 | 18.6 | 31.1 | 18.6 | 10.8 | 7.9 | 16.5 | 10.2 | 44.2 | 4.3 | 29.9 | 21.8 | 1,094.8 |
| 2010 .......... | 6.8 | 889.9 | 21.2 | 31.7 | 18.8 | 10.4 | 7.3 | 15.7 | 10.1 | 43.3 | 5.7 | 30.2 | 21.8 | 1,112.7 |
| 2011 .......... | 8.3 | 890.3 | 20.3 | 33.1 | 18.5 | 10.5 | 7.3 | 13.9 | 10.1 | 43.0 | 6.7 | 30.6 | 21.4 | 1,114.1 |
| 2012 .......... | 6.7 | 828.5 | 20.1 | 30.3 | 16.3 | 10.0 | 6.7 | 15.1 | 8.9 | 40.8 | 5.6 | 29.7 | 20.5 | 1,039.3 |
| 2013 .......... | 7.3 | 749.5 | 18.9 | 28.9 | 16.4 | 10.5 | 6.2 | 15.3 | 8.7 | 41.9 | 5.3 | 29.9 | 20.4 | 959.3 |
| 2014 .......... | 6.3 | 730.6 | 18.5 | 29.4 | 17.0 | 9.5 | 6.2 | 15.6 | 8.3 | 43.0 | 5.2 | 31.4 | 20.6 | 941.5 |
| 2015 .......... | 6.2 | 734.5 | 17.9 | 30.1 | 16.3 | 9.0 | 6.8 | 16.2 | 8.4 | 44.0 | 6.0 | 30.7 | 19.8 | 945.8 |
| 2016 .......... | 6.2 | 709.2 | 18.1 | 28.9 | 15.8 | 8.7 | 6.4 | 15.6 | 8.5 | 43.9 | 6.0 | 30.3 | 19.5 | 917.2 |
| 2017 .......... | 6.3 | 707.9 | 19.2 | 28.8 | 15.0 | 8.8 | 5.9 | 15.5 | 8.6 | 43.7 | 6.6 | 29.1 | 19.7 | 915.1 |
| 2018 .......... | 6.1 | 690.6 | 16.8 | 27.3 | 15.6 | 10.0 | 6.1 | 16.2 | 8.4 | 45.5 | 5.8 | 29.7 | 18.8 | 897.0 |
| 2019 .......... | 5.9 | 682.1 | 16.2 | 27.2 | 15.4 | 9.8 | 6.2 | 15.8 | 8.5 | 46.0 | 5.9 | 31.9 | 19.1 | 890.0 |
| 2020 .......... | 5.4 | 648.8 | 17.1 | 26.4 | 14.4 | 9.5 | 5.5 | 14.6 | 8.1 | 46.1 | 5.5 | 30.6 | 17.0 | 849.0 |

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[a] For 1975 and 1976, the U.S. Government's fiscal year was July 1 through June 30. Beginning in 1977, the U.S. Government's fiscal year is October 1 through September 30 (for example, fiscal year 2014 is October 2013 through September 2014).

[b] U.S. Department of Homeland Security.

[c] General Services Administration.

[d] U.S. Department of Health and Human Services.

[e] National Aeronautics and Space Administration.

[f] Includes all U.S. government agencies not separately displayed. See http://ctsedwweb.ee.doe.gov/Annual/Report/AgencyReference.aspx for agency list.

– – =Not applicable.

Notes: • Data in this table are developed using conversion factors that often differ from those in Tables A1–A6. • Data include energy consumed at foreign installations and in foreign operations, including aviation and ocean bunkering, primarily by the U.S. Department of Defense. U.S. Government energy use for electricity generation and uranium enrichment is excluded. • Totals may not equal sum of components due to independent rounding.

Web Page: See http://www.eia.gov/totalenergy/data/monthly/#consumption (Excel and CSV files) for all annual data beginning in 1975.

Sources: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program. See http://ctsedwweb.ee.doe.gov/Annual/Report/Report.aspx, "A-1 Total Site-Delivered Energy Use in All End-Use Sectors, by Federal Agency (Billion Btu)".

# Table 2.8 U.S. Government Energy Consumption by Source, Fiscal Years

(Trillion Btu)

| Fiscal Year[a] | Coal | Natural Gas[b] | Petroleum | | | | | | Other Mobility Fuels[f] | Electricity | Purchased Steam and Other[g] | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Aviation Gasoline | Fuel Oil[c] | Jet Fuel | LPG[d] | Motor Gasoline[e] | Total | | | | |
| 1975 | 77.9 | 166.2 | 22.0 | 376.0 | 707.4 | 5.6 | 63.2 | 1,174.2 | 0.0 | 141.5 | 5.1 | 1,565.0 |
| 1976 | 71.3 | 151.8 | 11.6 | 329.7 | 610.0 | 4.7 | 60.4 | 1,016.4 | .0 | 139.3 | 4.6 | 1,383.4 |
| 1977 | 68.4 | 141.2 | 8.8 | 348.5 | 619.2 | 4.1 | 61.4 | 1,042.1 | .0 | 141.1 | 5.7 | 1,398.5 |
| 1978 | 66.0 | 144.7 | 6.2 | 332.3 | 601.1 | 3.0 | 60.1 | 1,002.9 | .0 | 141.0 | 6.4 | 1,360.9 |
| 1979 | 65.1 | 148.9 | 4.7 | 327.1 | 618.6 | 3.7 | 59.1 | 1,013.1 | .0 | 141.2 | 7.1 | 1,375.4 |
| 1980 | 63.5 | 147.3 | 4.9 | 307.7 | 638.7 | 3.8 | 56.5 | 1,011.6 | .2 | 141.9 | 6.8 | 1,371.2 |
| 1981 | 65.1 | 142.2 | 4.6 | 351.3 | 653.3 | 3.5 | 53.2 | 1,066.0 | .2 | 144.5 | 6.2 | 1,424.2 |
| 1982 | 68.6 | 146.2 | 3.6 | 349.4 | 672.7 | 3.7 | 53.1 | 1,082.5 | .2 | 147.5 | 6.2 | 1,451.4 |
| 1983 | 62.4 | 147.8 | 2.6 | 329.5 | 673.4 | 3.8 | 51.6 | 1,060.8 | .2 | 151.5 | 9.0 | 1,431.8 |
| 1984 | 65.3 | 157.4 | 1.9 | 342.9 | 693.7 | 3.9 | 51.2 | 1,093.6 | .2 | 155.9 | 10.1 | 1,482.5 |
| 1985 | 64.8 | 149.9 | 1.9 | 292.6 | 705.7 | 3.8 | 50.4 | 1,054.3 | .2 | 167.2 | 13.9 | 1,450.3 |
| 1986 | 63.8 | 140.9 | 1.4 | 271.6 | 710.2 | 3.6 | 45.3 | 1,032.1 | .3 | 155.8 | 13.7 | 1,406.7 |
| 1987 | 67.0 | 145.6 | 1.0 | 319.5 | 702.3 | 3.6 | 43.1 | 1,069.5 | .4 | 169.9 | 13.9 | 1,466.3 |
| 1988 | 60.2 | 144.6 | 6.0 | 284.8 | 617.2 | 2.7 | 41.2 | 951.9 | .4 | 171.2 | 32.0 | 1,360.3 |
| 1989 | 48.7 | 152.4 | .8 | 245.3 | 761.7 | 3.5 | 41.1 | 1,052.4 | 2.2 | 188.6 | 20.6 | 1,464.7 |
| 1990 | 44.3 | 159.4 | .5 | 245.2 | 732.4 | 3.8 | 37.2 | 1,019.1 | 2.6 | 193.6 | 19.1 | 1,438.0 |
| 1991 | 45.9 | 154.1 | .4 | 232.6 | 774.5 | 3.0 | 34.1 | 1,044.7 | 6.0 | 192.7 | 18.3 | 1,461.7 |
| 1992 | 51.7 | 151.2 | 1.0 | 200.6 | 628.2 | 3.0 | 35.6 | 868.4 | 8.4 | 192.5 | 22.5 | 1,294.8 |
| 1993 | 38.3 | 152.9 | .7 | 187.0 | 612.4 | 3.5 | 34.5 | 838.1 | 5.8 | 193.1 | 18.6 | 1,246.8 |
| 1994 | 35.0 | 143.9 | .6 | 198.5 | 550.7 | 3.2 | 29.5 | 782.6 | 7.7 | 190.9 | 18.2 | 1,178.2 |
| 1995 | 31.7 | 149.4 | .3 | 178.4 | 522.3 | 3.0 | 31.9 | 735.9 | 8.4 | 184.8 | 18.2 | 1,128.5 |
| 1996 | 23.3 | 147.3 | .2 | 170.5 | 513.0 | 3.1 | 27.6 | 714.4 | 18.7 | 184.0 | 20.1 | 1,107.7 |
| 1997 | 22.5 | 153.8 | .3 | 180.0 | 475.7 | 2.6 | 39.0 | 697.6 | 14.5 | 183.6 | 19.2 | 1,091.2 |
| 1998 | 23.9 | 140.4 | .2 | 174.5 | 445.5 | 3.5 | 43.0 | 666.8 | 5.9 | 181.4 | 18.8 | 1,037.1 |
| 1999 | 21.2 | 137.4 | .1 | 162.1 | 444.7 | 2.4 | 41.1 | 650.4 | .4 | 180.0 | 21.5 | 1,010.9 |
| 2000 | 22.7 | 133.8 | .2 | 171.3 | 403.1 | 2.5 | 43.9 | 621.0 | 1.8 | 193.6 | 20.2 | 993.1 |
| 2001 | 18.8 | 133.7 | .2 | 176.9 | 415.2 | 3.1 | 42.5 | 638.0 | 4.8 | 188.4 | 18.6 | 1,002.3 |
| 2002 | 16.9 | 133.7 | .2 | 165.6 | 472.9 | 2.8 | 41.3 | 682.8 | 3.2 | 188.3 | 18.5 | 1,043.4 |
| 2003 | 18.1 | 135.5 | .3 | 190.8 | 517.9 | 3.2 | 46.3 | 758.4 | 3.3 | 193.8 | 23.2 | 1,132.3 |
| 2004 | 17.4 | 135.3 | .2 | 261.4 | 508.2 | 2.9 | 44.1 | 816.9 | 3.1 | 197.1 | 22.0 | 1,191.7 |
| 2005 | 17.1 | 135.7 | .4 | 241.4 | 492.2 | 3.4 | 48.8 | 786.1 | 5.6 | 197.6 | 24.3 | 1,166.4 |
| 2006 | 23.5 | 132.6 | .6 | 209.3 | 442.6 | 2.7 | 48.3 | 703.6 | 2.1 | 196.7 | 18.2 | 1,076.4 |
| 2007 | 20.4 | 131.5 | .4 | 212.9 | 461.1 | 2.7 | 46.5 | 723.7 | 2.9 | 194.9 | 16.7 | 1,090.2 |
| 2008 | 20.8 | 129.6 | .4 | 198.4 | 525.4 | 2.3 | 49.0 | 775.4 | 3.6 | 196.1 | 17.7 | 1,143.2 |
| 2009 | 20.3 | 131.7 | .3 | 166.4 | 505.7 | 3.2 | 48.3 | 723.9 | 10.1 | 191.3 | 17.7 | 1,094.8 |
| 2010 | 20.0 | 130.1 | .4 | 157.8 | 535.8 | 2.5 | 51.3 | 747.7 | 3.0 | 193.7 | 18.2 | 1,112.7 |
| 2011 | 18.5 | 124.7 | .9 | 166.5 | 533.6 | 2.0 | 52.7 | 755.8 | 2.7 | 193.2 | 19.1 | 1,114.1 |
| 2012 | 15.9 | 116.2 | .4 | 148.6 | 493.5 | 1.7 | 50.1 | 694.4 | 3.1 | 187.2 | 22.5 | 1,039.3 |
| 2013 | 14.3 | 122.5 | .7 | 140.0 | 424.0 | 1.9 | 46.6 | 613.2 | 2.8 | 184.7 | 21.8 | 959.3 |
| 2014 | 13.5 | 125.6 | .3 | 133.5 | 414.3 | 1.8 | 44.9 | 594.8 | 3.6 | 182.1 | 21.9 | 941.5 |
| 2015 | 12.6 | 122.2 | .3 | 134.4 | 418.9 | 1.8 | 46.8 | 602.2 | 3.7 | 184.3 | 20.9 | 945.8 |
| 2016 | 10.2 | 115.4 | .3 | 129.7 | 403.9 | 1.7 | 46.5 | 582.2 | 3.6 | 184.5 | 21.4 | 917.2 |
| 2017 | 9.1 | 115.1 | .3 | 135.1 | 400.1 | 1.5 | 46.4 | 583.5 | 2.7 | 181.7 | 23.0 | 915.1 |
| 2018 | 6.2 | 125.8 | .3 | 127.8 | 383.2 | 1.7 | 45.5 | 558.5 | 3.0 | 180.0 | 23.6 | 897.0 |
| 2019 | 5.0 | 131.7 | .3 | 125.4 | 376.8 | 1.9 | 46.6 | 551.0 | 2.7 | 178.2 | 21.5 | 890.0 |
| 2020 | 5.2 | 128.3 | .2 | 129.6 | 345.0 | 1.7 | 43.3 | 520.0 | 1.6 | 173.8 | 20.3 | 849.0 |

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[a] For 1975 and 1976, the U.S. Government's fiscal year was July 1 through June 30. Beginning in 1977, the U.S. Government's fiscal year is October 1 through September 30 (for example, fiscal year 2014 is October 2013 through September 2014).

[b] Natural gas, plus a small amount of supplemental gaseous fuels.

[c] Distillate fuel oil, including diesel fuel; and residual fuel oil, including Navy Special.

[d] Liquefied petroleum gases, primarily propane.

[e] Includes E10 (a mixture of 10% ethanol and 90% motor gasoline) and E15 (a mixture of 15% ethanol and 85% motor gasoline).

[f] Other types of fuel used in vehicles and equipment. Primarily includes alternative fuels such as compressed natural gas (CNG); liquefied natural gas (LNG); E85 (a mixture of 85% ethanol and 15% motor gasoline); B20 (a mixture of 20% biodiesel and 80% diesel fuel); B100 (100% biodiesel); hydrogen; and methanol.

[g] Other types of energy used in facilities. Primarily includes chilled water, but also includes small amounts of renewable energy such as wood and solar thermal.

Notes: • Data in this table are developed using conversion factors that often differ from those in Tables A1–A6. • Data include energy consumed at foreign installations and in foreign operations, including aviation and ocean bunkering, primarily by the U.S. Department of Defense. U.S. Government energy use for electricity generation and uranium enrichment is excluded. • Totals may not equal sum of components due to independent rounding.

Web Page: See http://www.eia.gov/totalenergy/data/monthly/#consumption (Excel and CSV files) for all annual data beginning in 1975.

Sources: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program. See http://ctsedwweb.ee.doe.gov/Annual/Report/Report.aspx, "A-5 Historical Federal Energy Consumption and Cost Data by Agency and Energy Type (FY 1975 to Present)".

# Data analysis

### Instructions

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**

# 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.

## Instructions

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**

## 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, or about $5 billion. 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

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.

**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?**

Outline an argument in support of your plan, trying to anticipate potential criticisms, and present your plan to the group.

## Additional resources:

Portland State University | Embodied Energy and carbon calculators for structural systems

**web.pdx.edu/~cgriffin/eecc/**

CoolClimate Network | Average US household carbon footprints

**coolclimate.org/maps**

## MODEL A

**Structure**

Building footprint: 1,100 sq. ft

Stories: 2

Minimum lot dimensions including setbacks: 55x100

**Occupancy**

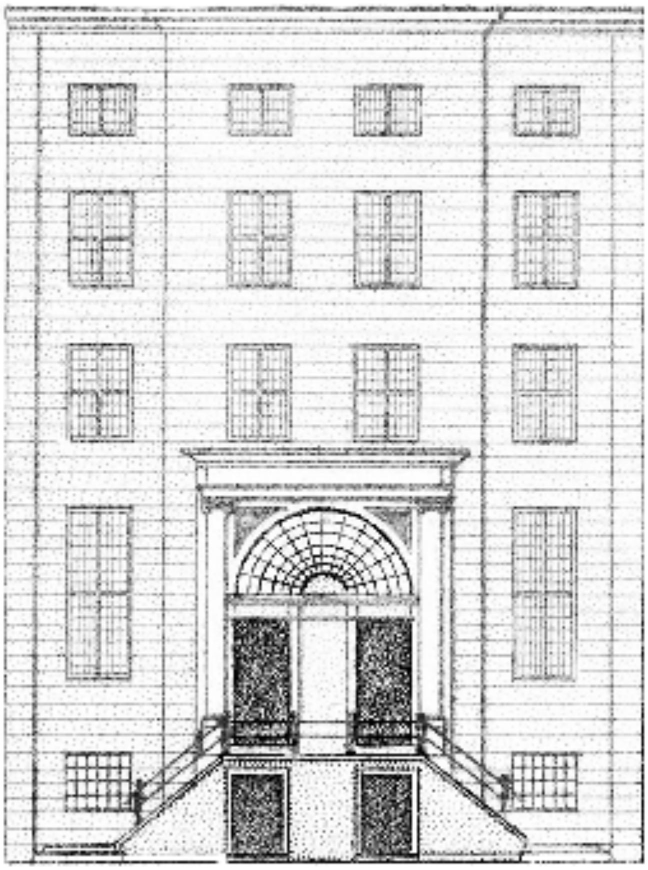
Households: 1

Maximum total occupancy: 6

Projected total occupancy: 3-5

Base Construction Cost: 2 units

Base Embodied Energy: 10 EE



## MODEL B

**Structure**

Building footprint: 2,200 sq. ft

Stories: 4

Minimum lot dimensions including setbacks: 40x130

**Occupancy**

Households: 8

Maximum total occupancy: 40

Projected total occupancy: 24-32

Base Construction Cost: 4 units

Base Embodied Energy: 40 EE

## MODEL C

**Structure**

Building footprint: 7,00 sq. ft

Stories: 5

Minimum lot dimensions including setbacks: 120x70

**Occupancy**

Households:

Maximum total occupancy: 86

Projected total occupancy: 50-60

Base Construction Cost: 10 units

Base Embodied Energy: 100 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

## PARCEL 1

**County:** Suffolk

**Required parking per unit:** 2 cars (300 sq ft)

**Size:** ~60 acres (2,600,000 sq ft)

**New roads required:** Yes (24 ft wide)

**Dimensions:** 6 x 10 acres

**Total cost of land:** 20 units

Note: the quantitative values assigned in these materials are not exact, and should only be used for the purposes of comparison within each category. Bear in mind the different densities and weight-to-strength ratios of different materials.

| 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. |
| INSULATION | x total | | Percent of overall structure: 15% |
| Cellulose | $2/sq ft | 3.3 MJ/KG | Made of recycled paper and wood materials. Lasts longer than fiberglass. |
| Fiberglass | $1.48/sq ft | 30.3 MJ/KG | The most common insulation material, made up of sand and recycled material. May cause health problems. |
| Polystyrene | $2.30/sq ft | 117 MJ/KG | A type of thermoplastic foam most often sold in planks and sheets. |
| EXTERIOR | x total | | Percent of overall structure: 20% |
| Fiber cement board | $4/sq ft | 23 MJ/KG | Made of cement reinforced with cellulose fibers. Lasts more than 100 years. |
| Vinyl | $3/sq ft | 28 MJ/KG | Least durable material, lasting up to 60 years. |
| Engineered wood | $2/sq ft | 38 MJ/KG | Manufactured wood composite. Lasts more than 100 years when installed correctly. |
| Brick | $6/sq ft | 62 MJ/KG | Can last 200 years or more when properly maintained. |
| ROOFING | x footprint | | Percent of overall structure: 15% |
| Clay tile | $10/sq ft | 2 MJ/KG | Lasts 100 years or more. Good insulation. Recyclable. |
| Asphalt | $1/sq ft | 3.4 MJ/KG | Available as shingles for pitched roofs or sheets for flat roofs. Lasts about 25 years on average; poor insulation; retains heat from sun. |
| Synthetic rubber | $0.80/sq ft | 110 MJ/KG | One of the most common roofing materials, especially for large buildings with flat roofs. Poor insulation; retains heat from sun. |
| MISCELLANEOUS | | | |
| Parking - asphalt | $1/sq ft | 3.4 MJ/KG | Lasts about 25 years on average. |
| Labor | $15/sq ft | | |

|  | Number of housing units (million) | Total site energy consumption (trillion Btu) |  |  |  |  |  | Average site energy consumption (million Btu per household using the end use) |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Total US | Total | Space heating | Water heating | AC | Refrig. | Other | Total | Space heating | Water heating | AC | Refrig. | Other |
| **Census urban/rural classification** |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Urban | 94.7 | 7,181 | 3,119 | 1,399 | 588 | 235 | 1,840 | 75.8 | 34.8 | 14.8 | 7.1 | 2.5 | 19.4 |
| Urbanized Area | 82.2 | 6,239 | 2,686 | 1,221 | 523 | 204 | 1,605 | 75.9 | 34.8 | 14.9 | 7.3 | 2.5 | 19.5 |
| Urban cluster | 12.5 | 942 | 434 | 178 | 64 | 31 | 235 | 75.2 | 35.2 | 14.2 | 5.9 | 2.5 | 18.8 |
| Rural | 23.5 | 1,933 | 826 | 347 | 143 | 67 | 550 | 82.4 | 37.2 | 14.8 | 7.2 | 2.9 | 23.4 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Housing unit type** |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Single-family detached | 73.9 | 6,991 | 3,201 | 1,185 | 586 | 221 | 1,798 | 94.6 | 44.9 | 16.1 | 8.9 | 3 | 24.3 |
| Single-family attached | 7 | 491 | 228 | 95 | 33 | 16 | 119 | 70 | 34.1 | 13.5 | 5.4 | 2.3 | 17 |
| Apartments in buildings with 2-4 units | 9.4 | 503 | 197 | 136 | 25 | 17 | 129 | 53.5 | 22.2 | 14.5 | 3.3 | 1.8 | 13.7 |
| Apartments in buildings with 5 or more units | 21.1 | 724 | 183 | 234 | 51 | 35 | 220 | 34.2 | 9.7 | 11.1 | 2.9 | 1.7 | 10.4 |
| Mobile homes | 6.8 | 406 | 136 | 96 | 36 | 14 | 124 | 59.8 | 22.1 | 14.1 | 6.2 | 2.2 | 18.3 |

| County | Pop. | Electricity (kWh) | Nat. Gas (cu. ft.) | Fuel oil (gallons) | Vehicle miles traveled | Transport (t CO2e/yr) | Housing (t CO2e/yr) | Food (t CO2e/yr) | Goods (t CO2e/yr) | Services | Total Household Carbon Footprint (t CO2e/yr) | Households | Total County Carbon Footprint (t CO2e/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALBANY | 274135 | 7,253 | 60,046 | 127 | 18,261 | 13.1 | 10.4 | 6.9 | 5.3 | 6 | 41.7 | 152972 | 6,376,491 |
| ALLEGANY | 48380 | 7,815 | 56,151 | 85 | 18,613 | 12.7 | 9.8 | 7.5 | 4.5 | 4.9 | 39.4 | 23852 | 939,148 |
| BRONX | 1327690 | 5,245 | 35,475 | 280 | 8,680 | 6.4 | 9.9 | 8.4 | 4.4 | 4.6 | 33.6 | 493639 | 16,582,895 |
| BROOME | 205205 | 7,375 | 59,080 | 129 | 18,635 | 12.9 | 10.5 | 7.2 | 4.8 | 5.3 | 40.6 | 90763 | 3,684,425 |
| CATTARAUGUS | 85977 | 7,673 | 56,750 | 92 | 19,622 | 13.4 | 9.9 | 7.6 | 4.6 | 5 | 40.6 | 40230 | 1,633,184 |
| CAYUGA | 79609 | 7,618 | 50,916 | 179 | 20,057 | 13.8 | 10.6 | 7.6 | 4.9 | 5.4 | 42.4 | 34229 | 1,450,351 |
| CHAUTAUQUA | 141547 | 7,898 | 65,505 | 33 | 18,474 | 12.7 | 9.8 | 7.4 | 4.6 | 5 | 39.5 | 65878 | 2,605,094 |
| CHEMUNG | 89263 | 7,799 | 69,471 | 61 | 19,464 | 13.4 | 10.4 | 7.3 | 4.8 | 5.3 | 41.3 | 37044 | 1,528,995 |
| CHENANGO | 53794 | 6,800 | 23,524 | 381 | 21,274 | 14.4 | 11 | 7.6 | 4.6 | 5 | 42.7 | 24997 | 1,066,856 |
| CLINTON | 83232 | 6,270 | 14,406 | 432 | 20,758 | 14.2 | 10.8 | 7.5 | 4.8 | 5.3 | 42.7 | 34992 | 1,495,438 |
| COLUMBIA | 61168 | 6,870 | 19,356 | 475 | 20,940 | 14.6 | 12 | 7.3 | 5.1 | 5.8 | 44.7 | 29288 | 1,309,763 |
| CORTLAND | 48785 | 7,357 | 49,713 | 180 | 19,970 | 13.6 | 10.5 | 7.5 | 4.6 | 5 | 41.3 | 20278 | 836,780 |
| DELAWARE | 43562 | 6,653 | 18,416 | 436 | 18,243 | 12.6 | 11.3 | 7.2 | 4.6 | 5 | 40.6 | 26380 | 1,071,305 |
| DUTCHESS | 282461 | 7,147 | 25,481 | 467 | 23,991 | 16.9 | 12.4 | 7.9 | 6 | 6.8 | 50 | 107071 | 5,350,174 |
| ERIE | 947862 | 8,186 | 77,359 | 16 | 18,243 | 12.9 | 10.5 | 7.3 | 5.1 | 5.7 | 41.4 | 414820 | 17,184,090 |
| ESSEX | 34102 | 6,279 | 12,825 | 466 | 18,098 | 12.5 | 11.2 | 7.2 | 4.6 | 5.1 | 40.6 | 20573 | 835,505 |
| FRANKLIN | 53104 | 5,908 | 12,165 | 510 | 18,504 | 12.6 | 11.5 | 7.4 | 4.5 | 4.9 | 40.9 | 25113 | 1,027,611 |
| FULTON | 49833 | 6,995 | 44,627 | 269 | 18,356 | 12.6 | 11.1 | 7.2 | 4.6 | 5 | 40.6 | 26118 | 1,059,848 |
| GENESEE | 61638 | 8,295 | 54,308 | 150 | 23,687 | 16.2 | 10.7 | 7.8 | 5.1 | 5.7 | 45.6 | 24643 | 1,122,868 |
| GREENE | 48884 | 6,521 | 15,311 | 501 | 19,862 | 13.7 | 11.9 | 7.3 | 4.8 | 5.3 | 43 | 26555 | 1,141,651 |
| HAMILTON | 4784 | 6,158 | 14,384 | 395 | 14,565 | 10.3 | 10.2 | 6.6 | 4.4 | 4.8 | 36.4 | 7429 | 270,171 |
| HERKIMER | 61870 | 7,094 | 45,203 | 277 | 19,960 | 13.6 | 11.3 | 7.4 | 4.6 | 5 | 41.9 | 30457 | 1,275,175 |
| JEFFERSON | 113221 | 6,932 | 42,466 | 200 | 18,465 | 12.7 | 10 | 7.9 | 4.8 | 5.2 | 40.5 | 54953 | 2,228,138 |
| KINGS | 2465326 | 5,892 | 46,574 | 199 | 9,029 | 6.8 | 9.9 | 8.4 | 4.7 | 5 | 34.7 | 930866 | 32,327,808 |
| LEWIS | 25484 | 6,766 | 16,207 | 412 | 20,018 | 13.6 | 10.9 | 8 | 4.7 | 5.1 | 42.4 | 14305 | 606,165 |
| LIVINGSTON | 67959 | 8,053 | 47,598 | 150 | 24,237 | 16.6 | 10.2 | 7.8 | 5.2 | 5.8 | 45.7 | 24930 | 1,138,210 |
| MADISON | 65705 | 7,482 | 42,599 | 265 | 21,817 | 15 | 11.2 | 7.7 | 5.1 | 5.7 | 44.6 | 27104 | 1,209,815 |
| MONROE | 736201 | 8,337 | 70,310 | 33 | 19,811 | 14.1 | 10.3 | 7.5 | 5.5 | 6.2 | 43.6 | 304759 | 13,293,214 |
| MONTGOMERY | 57918 | 6,968 | 42,271 | 306 | 20,075 | 13.7 | 11.4 | 7.4 | 4.6 | 5 | 42.1 | 26009 | 1,095,687 |
| NASSAU | 1344933 | 8,677 | 36,119 | 442 | 23,419 | 17.3 | 17.4 | 8.9 | 7.4 | 8.5 | 59.5 | 463600 | 27,566,505 |
| NEW YORK | 1529317 | 4,683 | 30,520 | 261 | 6,101 | 5.8 | - | 6.3 | 5.4 | 6.2 | 32.6 | #N/A | #N/A |
| NIAGARA | 219534 | 7,952 | 65,429 | 79 | 19,573 | 13.6 | 10.4 | 7.4 | 5 | 5.5 | 41.9 | 95603 | 4,000,989 |
| ONEIDA | 237046 | 7,308 | 54,672 | 192 | 19,058 | 13.2 | 10.9 | 7.3 | 4.8 | 5.3 | 41.5 | 104056 | 4,318,282 |

| County | Pop. | Electricity (kWh) | Nat. Gas (cu. ft.) | Fuel oil (gallons) | Vehicle miles traveled | Transport (t CO2e/yr) | Housing (t CO2e/yr) | Food (t CO2e/yr) | Goods (t CO2e/yr) | Services | Total Household Carbon Footprint (t CO2e/yr) | Households | Total County Carbon Footprint (t CO2e/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ONONDAGA | 463210 | 7,910 | 69,951 | 49 | 19,230 | 13.5 | 10.4 | 7.4 | 5.2 | 5.8 | 42.3 | 198932 | 8,423,295 |
| ONTARIO | 97496 | 8,160 | 54,515 | 110 | 22,426 | 15.5 | 10.2 | 7.6 | 5.3 | 5.9 | 44.6 | 41575 | 1,852,792 |
| ORANGE | 343611 | 7,935 | 42,073 | 306 | 23,537 | 16.5 | 11.7 | 8.7 | 6 | 6.8 | 49.6 | 123304 | 6,121,983 |
| ORLEANS | 43568 | 7,755 | 44,805 | 214 | 22,675 | 15.4 | 10.7 | 8 | 5 | 5.5 | 44.5 | 17090 | 760,913 |
| OSWEGO | 124742 | 7,618 | 43,469 | 172 | 20,858 | 14.3 | 10 | 7.8 | 4.9 | 5.3 | 42.3 | 53963 | 2,280,818 |
| OTSEGO | 61596 | 6,765 | 24,647 | 391 | 19,690 | 13.5 | 11.3 | 7.2 | 4.6 | 5 | 41.6 | 28580 | 1,189,756 |
| PUTNAM | 96181 | 7,612 | 14,351 | 521 | 29,398 | 20.9 | 12.6 | 8.6 | 7.3 | 8.5 | 57.9 | 35228 | 2,038,743 |
| QUEENS | 2237335 | 6,451 | 46,210 | 212 | 11,955 | 9 | 10.3 | 8.6 | 5.4 | 5.9 | 39.2 | 824598 | 32,290,559 |
| RENSSELAER | 154891 | 7,111 | 42,792 | 279 | 20,684 | 14.5 | 11.2 | 7.4 | 5.2 | 5.9 | 44.2 | 68283 | 3,014,846 |
| RICHMOND | 443728 | 8,475 | 60,347 | 102 | 17,830 | 13.1 | 11 | 8.4 | 6.1 | 6.9 | 45.4 | 163993 | 7,437,771 |
| ROCKLAND | 286757 | 9,810 | 75,412 | 24 | 24,473 | 17.6 | 11 | 9.2 | 7 | 8 | 53 | 94974 | 5,029,870 |
| SAINT LAWRENCE | 110126 | 6,863 | 36,939 | 317 | 19,301 | 13.2 | 11.1 | 7.5 | 4.6 | 5 | 41.3 | 48324 | 1,994,531 |
| SARATOGA | 196275 | 7,852 | 48,438 | 195 | 22,830 | 16.1 | 10.7 | 7.6 | 5.7 | 6.5 | 46.6 | 84169 | 3,918,433 |
| SCHENECTADY | 166188 | 7,819 | 68,006 | 111 | 19,944 | 14.1 | 11 | 7.2 | 5.3 | 6 | 43.7 | 71975 | 3,147,826 |
| SCHOHARIE | 29336 | 6,767 | 13,940 | 469 | 21,301 | 14.5 | 11.5 | 7.4 | 4.8 | 5.3 | 43.5 | 14807 | 644,199 |
| SCHUYLER | 18886 | 7,270 | 34,083 | 239 | 22,222 | 15.1 | 10.1 | 7.6 | 4.8 | 5.3 | 42.9 | 8712 | 374,137 |
| SENECA | 30924 | 7,499 | 48,456 | 160 | 20,900 | 14.3 | 10.2 | 7.5 | 4.8 | 5.3 | 42.2 | 13621 | 574,844 |
| STEUBEN | 97252 | 7,716 | 53,830 | 105 | 20,465 | 14 | 9.9 | 7.5 | 4.7 | 5.2 | 41.4 | 45474 | 1,880,752 |
| SUFFOLK | 1413291 | 8,374 | 29,168 | 488 | 25,371 | 18.1 | 17.3 | 9 | 6.9 | 7.9 | 59.3 | 520464 | 30,840,665 |
| SULLIVAN | 75583 | 6,414 | 13,398 | 475 | 17,624 | 12.3 | 11.3 | 7.5 | 4.8 | 5.3 | 41.3 | 46471 | 1,917,341 |
| TIOGA | 51556 | 7,386 | 31,342 | 324 | 23,972 | 16.3 | 11.1 | 7.8 | 5 | 5.6 | 45.8 | 21412 | 980,842 |
| TOMPKINS | 97235 | 6,809 | 47,917 | 113 | 17,095 | 12 | 9.2 | 7 | 4.7 | 5.3 | 38.2 | 38961 | 1,489,190 |
| ULSTER | 174523 | 6,613 | 21,999 | 459 | 21,502 | 15 | 11.8 | 7.4 | 5.2 | 5.9 | 45.3 | 76259 | 3,456,520 |
| WARREN | 63465 | 7,035 | 41,167 | 257 | 18,572 | 13 | 10.7 | 7.3 | 5 | 5.5 | 41.5 | 35150 | 1,458,478 |
| WASHINGTON | 61625 | 7,045 | 26,615 | 380 | 21,670 | 14.8 | 11.3 | 7.7 | 4.9 | 5.4 | 44.2 | 26795 | 1,185,285 |
| WAYNE | 96521 | 8,458 | 50,210 | 164 | 24,222 | 16.6 | 10.7 | 7.9 | 5.4 | 6 | 46.7 | 39841 | 1,858,620 |
| WESTCHESTER | 922135 | 7,381 | 37,503 | 357 | 20,310 | 15.3 | 12.2 | 8.1 | 7.1 | 8.3 | 50.9 | 348961 | 17,773,207 |
| WYOMING | 41336 | 8,008 | 53,866 | 123 | 23,238 | 15.8 | 10.3 | 7.9 | 5.1 | 5.6 | 44.6 | 16940 | 756,117 |
| YATES | 25737 | 7,386 | 37,470 | 183 | 19,084 | 13.1 | 9.7 | 7.8 | 4.7 | 5.2 | 40.4 | 13055 | 527,877 |

## Scenario

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?**
>
> **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**

# Data analysis

## Instructions

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 | $CO_2$ emissions by sector

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

Our World in Data | Cars, planes, trains: where do $CO_2$ 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

# 4.3 “Greening” the transportation industry | Debate

## 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

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.

## Sources

“The Future of Rail: Opportunities for energy and the environment,” International Energy Agency, 2019

“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

**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 and development funding and tax incentives for alternative fuels; regulate shipping pricing to reflect emissions cost; end subsidies for diesel and bunker oil production

### The Local Cities Plan

Congestion taxes and gasoline car buybacks; grants for small local businesses; corporate tax incentives for dense, multi-use green development in metro areas; tax breaks for bike and public transit commuters; carbon taxes on interstate and international shipping; increased regulation of in-city truck activities

**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.

**Representative from New York's 18th Congressional District**

You represent a region due north of the country's largest metropolitan center, which includes a number of small cities including Poughkeepsie, Newburgh, and Beacon. These communities were established around industry that exploited the power of the Hudson River, but in recent decades, industrial production has mostly left town. One exception is a large computer factory in Poughkeepsie. The city is now home to large numbers of immigrants and about 25 percent of the population lives below the poverty line. You are in favor of the Fast Track Future Plan, which you hope will encourage people from New York City to move to these cities as commuters and establish them as tech industry hubs, and the Get Local Plan, which you hope will encourage development.

**Representative from California's 44th Congressional District**

Your district includes the Port of Los Angeles on San Pedro Bay, the busiest container shipping port in the Americas. It is also includes southern Los Angeles County neighborhoods like Watts, Compton, and Carson, which are majority-Black and -Latino, working-class communities that have long struggled with unemployment and lack of public investment. You are in favor of the Clean Packages Plan, as you expect it will encourage the long-term survival of the shipping industry which provides many jobs for your constituents. While the investment portions of the Get Local Plan could also be positive for your poorer constituents, you are concerned about the effect of congestion taxes on those who rely on their cars for work, such as ride-share and delivery drivers. You are in favor of incentives for electric passenger vehicles and alternative fuels, as air pollution from diesel and gasoline vehicles causes significant health problems for your constituents.

**Representative from Texas's 36th Congressional District**

You represent the third-largest city in Texas, which is also the center of the American fossil fuel industry. You are not very happy about any of the proposals but you are particularly concerned about the Green Wheels Plan, the Clean Packages Plan, and the Get Local Plan, which you anticipate will dramatically impact the market for gasoline- and diesel-powered vehicles and, therefore, your industrial constituents. You mostly hope to argue against these plans but when pressed can support the Fast Track Future Plan and parts of the Get Local Plan that seem least likely to impact fossil fuel consumption at a system-wide level.

**Representative from the International Brotherhood of Teamsters**

You represent the largest union of transportation and shipping workers in the United States. Your membership includes long-distance truckers, warehouse workers, freight workers, delivery workers, railway engineers, and others. In the past, your union has mobilized against environmental causes, but recently the Union's position has been to accept the necessity of adaptation and change in the face of climate crisis. You are in favor of the portions of the Green Wheels, Clean Packages, and Fast Track Future Plans that technologies and fuels to reduce emissions, but you are opposed to the portions of the Get Local Plan that disincentivize travel and interstate or international shipping. You are also concerned that any measures that increase the cost of shipping will result in your members being laid off or pressured to increase productivity to make up the difference.

**Representative from United Parcel Service (UPS)**

You represent the largest package delivery company in the world, with 11.5 million pick-up and delivery customers, 495,000 employees, 1,800 operating facilities, 125,000 delivery vehicles, and more than 5.5 billion packages delivered per year. The company operates in 220 nations and territories but is headquartered in Sandy Springs, Georgia. You are strongly opposed to any proposal that threatens the business, and are concerned about the Get Local Plan in particular, as you expect the tax on congestion pricing and interstate and international shipping to hurt your bottom line, and the Green Packages Plan, which in making fast shipping more expensive may disincentivize online commerce.

**Representative from Youth Climate Action**

You are not satisfied with any of the proposals under consideration. Given the rate of reduction in greenhouse gas emission that is necessary to avoid exceeding 1.5°C of global atmospheric warming, you consider these plans to be insufficiently aggressive and overly dependent on the whims of the private sector. (1.5°C is the threshold beyond which parts of the country's coastal cities will be inundated by sea level rise and large portions of the southern and western United States will become uninhabitable due to heat and fire risk.) Of the proposals, you are least opposed to the Clean Packages Plan, as eliminating subsidies for fossil fuel companies and ending the extraction of oil and gas are among your top priorities.

**Representative from Energy Information Administration**

Your role is to make a factual and objective report to Congress about the projected impact of each of the proposals. You have no position on any of the proposals except insofar as you believe they will or will not make the necessary difference in the effort to prevent catastrophic climate crisis.

# 2. A pathway to inclusive, zero-carbon cities

To avoid a global temperature increase of more than 1.5°C with limited or no overshoot, science shows cities worldwide must reach net-zero $CO_2$ emissions by mid-century.[50] This chapter shows how to achieve that and explores how this urban transition could raise living standards for all.

Though no zero-carbon cities exist yet, most necessary elements are already available, and there are many success stories that can inspire decision-makers as they craft their own climate action plans. *Section 2.1* demonstrates how a wide array of proven abatement options, implemented together, could move cities towards net-zero emissions.

A rapid transition to zero-carbon cities is challenging, but it is both feasible and attractive. In all countries, deep decarbonisation will require overcoming vested interests and managing difficult trade-offs. It is thus crucial for decision-makers to understand and be able to communicate the many benefits of climate mitigation. *Section 2.2* explores how the bundle of abatement options required to reach net-zero emissions can help create cities with a high quality of life, particularly if the measures are implemented in ways that reduce inequality and vulnerability. These gains could in turn help build and sustain public appetite for further climate action.[51] Copenhagen, Indore, Medellín, Seoul and Windhoek offer potent examples of how quickly cities can be transformed for the better when different tiers and sectors of government work together towards a shared vision.

Without a zero-carbon urban transition, countries risk being left behind economically as global policies and markets evolve. This would leave workers and assets stranded. Moreover, as global climate change accelerates, cities will be hotspots of vulnerability, with dire repercussions for the whole country. Even with immediate action to reduce emissions, cities will need to adapt to significantly greater climate risk. *Section 2.3* examines the consequences for cities and countries if there is no swift action to limit warming to 1.5°C, and underscores the importance of enhancing climate resilience.

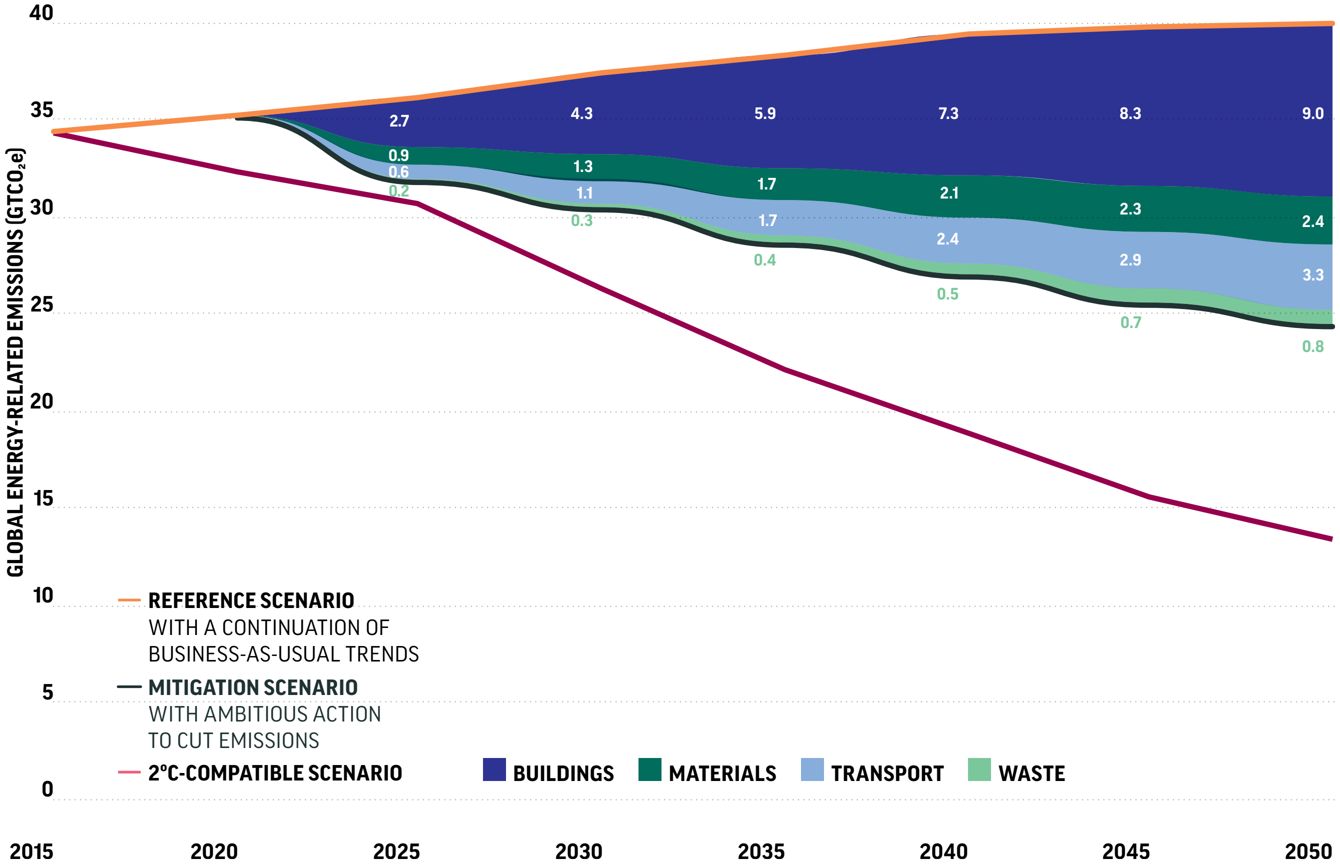
**Currently available, technically feasible measures can reduce greenhouse gas emissions from urban buildings, transport, materials and waste by almost 90% in 2050. This would contribute over half of the global energy-related emission reductions needed to keep global warming below 2°C.**

## 2.1 What is the pathway to zero-carbon cities?

The IPCC special report makes it clear that cities need to reach net-zero emissions by mid-century.[52] An analysis by the Stockholm Environment Institute for this report finds that, without further action to tackle climate change, greenhouse gas emissions attributable to urban buildings, transport and waste could reach 17.3 billion tonnes of carbon dioxide equivalent ($tCO_2$-e) in 2050 – 24% higher than in 2015, when the Paris Agreement was signed. Urban emissions would be even higher if industry and other sectors were included. This projection assumes that current trends in economic activity and energy use will continue, but takes into account recently adopted national policies and commitments, including Nationally Determined Contributions (NDCs) under the Paris Agreement.

The new analysis identifies a range of abatement options that are already widely deployed in cities, and evaluates their mitigation potential if deployed at scale. It finds that it is possible to reduce emissions from urban buildings, materials, transport and waste from the projected level of 17.3 billion $tCO_2$-e to 1.8 billion in 2050, using technically feasible measures that, for the most part, are already commercially available. This is a reduction of almost 90% relative to business-as-usual levels. In absolute terms, it is more than the 2014 energy-related emissions of the China and the US combined.[53] Altogether, this analysis suggests that these abatement measures in cities could avoid the equivalent of 39% of projected energy-related emissions in 2050. This amounts to 58% of the global energy-related emission reductions needed to be on the International Energy Agency's 2°C pathway (see *Figure 1*).[54]

**FIGURE 1. POTENTIAL CONTRIBUTION OF CITIES TO GLOBAL ENERGY-RELATED GREENHOUSE GAS EMISSION REDUCTIONS USING TECHNICALLY FEASIBLE, COMMERCIALLY AVAILABLE ABATEMENT OPTIONS.**



*Source: Stockholm Environment Institute for the Coalition for Urban Transitions. For the full methodology, see Annex 1.*

The emission reductions available in cities are distributed across different sectors: 58% would come from commercial and residential buildings, 21% from transport, 16% from materials and 5% from solid waste management (see *Figure 2*). Fully half of the abatement potential identified in this analysis comes from decarbonising urban electricity, primarily by generating electricity from non-emitting technologies such as solar, wind, hydro, nuclear, biomass and geothermal power – as well as carbon capture and storage technologies.[55] Other significant sources of abatement in cities include:

- Improved cement production processes;
- A shift from using private cars to public transport, cycling and walking;
- More efficient cooking and water heating in residential buildings;
- More efficient space heating and cooling in all buildings;
- More efficient and electric vehicles;
- Reduced use of materials in building construction; and
- Waste prevention.

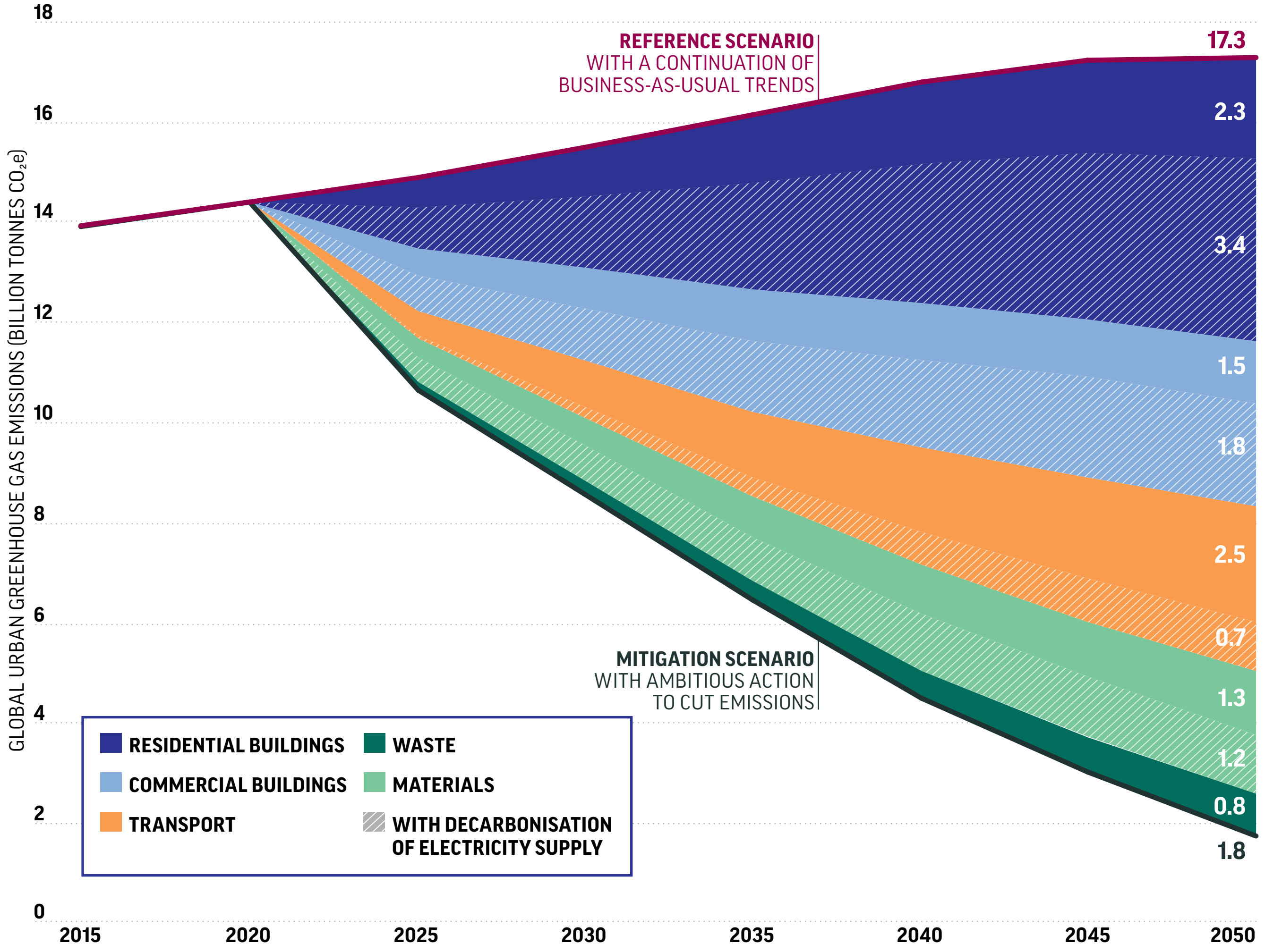
The decarbonisation of energy must go hand-in-hand with a massive expansion in the supply of energy, since successful urbanisation in developing countries – linked as it is to structural economic change and rising per capita incomes – will drive an enormous increase in energy demand. In sub-Saharan Africa, a staggering tenfold expansion of generation capacity is required by 2040 to provide universal access to energy and support economic activity.[56] In all countries, electrification of cooking, heating, transport and other end uses will shift demand from fossil fuels towards electricity, demanding further investment in generation infrastructure. Crucially, this bundle of abatement measures will deliver very substantial energy savings, reducing total energy use in cities by around 1,075 megatonnes of oil equivalent (Mtoe) in 2030 and 2,134 Mtoe in 2050 (see *Table 1*). The savings would significantly offset the total investments needed to expand the electricity supply.

Still, moving towards zero-carbon cities while supporting human development and industrial activity will require massive new investments in electricity generation infrastructure, while simultaneously directing that investment towards renewable options. Many renewable technologies offer significant advantages over fossil fuel options: for instance, they produce little or no air pollution, and some can be deployed quickly and even off-grid. Renewable technologies are also increasingly economically attractive: the levelised cost of electricity generated from solar photovoltaics and offshore wind, for example, is now often competitive with fossil power, and capital costs are projected to fall by a further 25–40% between 2018 and 2023.[57] These factors help to explain why new renewable generation capacity has grown so rapidly, with annual new capacity expanding eightfold between 2001 and 2014, from 20GW to over 160GW.[58] Renewables now account for 33% of global generation capacity, up from 22% in 2001.[59]

Renewable technologies do also pose challenges. Their capital costs are higher, even if the levelised cost of electricity is competitive over the lifespan of the investment. Geothermal and hydropower are only available at scale in a limited number of countries. The intermittent nature of solar and wind energy requires upgrades to grid infrastructure and management. Still, while a zero-carbon energy transition is complex, it is certainly possible,[60] and this analysis makes it clear that it is an essential precondition for a zero-carbon urban transition.

> **Moving towards zero-carbon cities while supporting human development and industrial activity will require massive new investments in electricity generation infrastructure, while simultaneously directing that investment towards renewable options.**

**FIGURE 2. TECHNICALLY FEASIBLE POTENTIAL TO REDUCE GREENHOUSE GAS EMISSIONS FROM CITIES BY 2050, BY SECTOR.**



*Note: The striped wedges reflect the mitigation potential through decarbonisation of energy.*
*Source: Stockholm Environment Institute for the Coalition for Urban Transitions. For the full methodology, see Annex 1.*

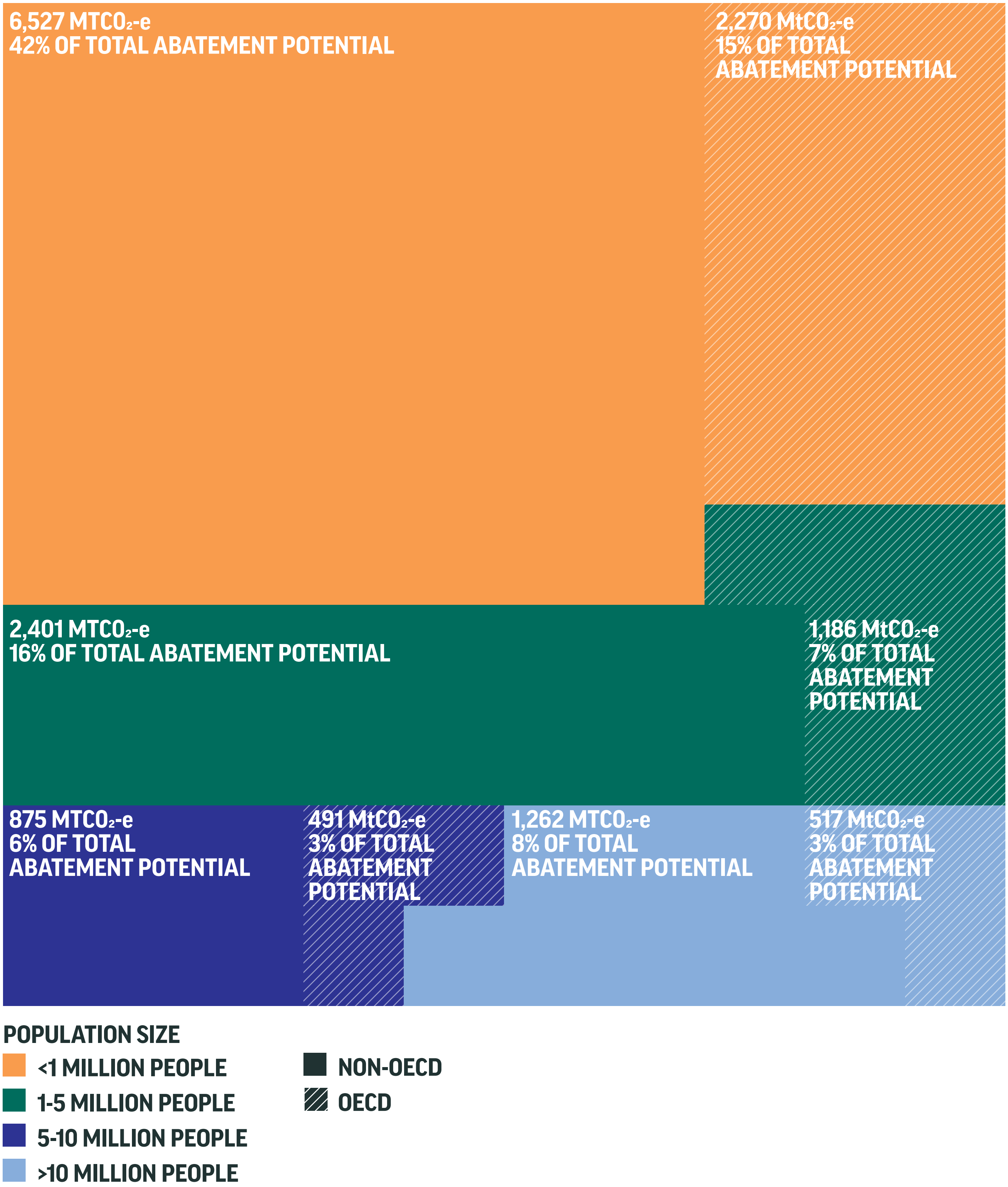
## TABLE 1. ENERGY SAVINGS AND EMISSION REDUCTIONS ASSOCIATED WITH AMBITIOUS DEPLOYMENT IN CITIES OF A RANGE OF TECHNICALLY FEASIBLE LOW-CARBON MEASURES.

| | Energy savings (Mtoe) | | Emission reductions (GtCO$_2$-e) | | Share of abatement (%) | |
|---|---|---|---|---|---|---|
| | 2030 | 2050 | 2030 | 2050 | 2030 | 2050 |
| **Buildings** | 545.83 | 956.59 | 4.26 | 8.95 | 61.40% | 57.70% |
| **Residential** | 317.35 | 580.04 | 2.41 | 5.66 | 34.70% | 36.50% |
| Decarbonisation of electricity | - | - | 1.25 | 3.38 | 18.10% | 21.80% |
| Distributed solar photovoltaics (PV) | - | - | 0.03 | 0.29 | 0.50% | 1.80% |
| Fuel switching to low-carbon options | - | - | 0.17 | 0.25 | 2.40% | 1.60% |
| Cooking and water heating efficiency | 100.67 | 237.33 | 0.24 | 0.61 | 3.40% | 3.90% |
| Appliance and lighting efficiency | 25.14 | 70.40 | 0.10 | 0.25 | 1.40% | 1.60% |
| Heating and cooling efficiency | 191.54 | 272.31 | 0.62 | 0.89 | 8.90% | 5.70% |
| **Commercial** | 228.48 | 376.55 | 1.85 | 3.29 | 26.70% | 21.20% |
| Decarbonisation of electricity | - | - | 0.92 | 1.84 | 13.20% | 11.80% |
| Distributed solar photovoltaics (PV) | - | - | 0.01 | 0.08 | 0.10% | 0.50% |
| Fuel switching to electricity and biomass | - | - | 0.14 | 0.21 | 2.00% | 1.40% |
| Cooking and water heating efficiency | 21.54 | 44.58 | 0.06 | 0.12 | 0.80% | 0.80% |
| Appliance and lighting efficiency | 62.23 | 141.16 | 0.24 | 0.49 | 3.50% | 3.20% |
| Heating and cooling efficiency | 144.71 | 190.81 | 0.49 | 0.55 | 7.00% | 3.60% |
| **Transport** | 249.31 | 652.37 | 1.13 | 3.29 | 16.40% | 21.20% |
| **Passenger** | 216.01 | 567.71 | 0.97 | 2.71 | 14.00% | 17.40% |
| Decarbonisation of electricity | - | - | 0.11 | 0.55 | 1.60% | 3.60% |
| Fuel switching to advanced biofuels | - | - | 0.07 | 0.16 | 1.00% | 1.00% |
| Vehicle efficiency and electrification | 92.70 | 210.18 | 0.32 | 0.71 | 4.60% | 4.60% |
| Motorised mode shift | 62.94 | 199.93 | 0.24 | 0.73 | 3.50% | 4.70% |
| Reduced motorised travel demand | 60.37 | 157.61 | 0.23 | 0.56 | 3.30% | 3.60% |
| **Freight** | 33.30 | 84.66 | 0.17 | 0.58 | 2.40% | 3.70% |
| Decarbonisation of electricity | - | - | 0.01 | 0.19 | 0.10% | 1.30% |
| Fuel switching to advanced biofuels | - | - | 0.03 | 0.06 | 0.40% | 0.40% |
| Vehicle efficiency and electrification | 24.15 | 62.02 | 0.09 | 0.23 | 1.30% | 1.50% |
| Logistics improvements | 9.15 | 22.63 | 0.04 | 0.09 | 0.50% | 0.60% |
| **Infrastructure** | 220.42 | 423.59 | 1.26 | 2.45 | 18.20% | 15.80% |
| Decarbonisation of electricity | - | - | 0.70 | 1.16 | 10.10% | 7.50% |
| Reduced cement process emissions | - | - | 0.21 | 0.48 | 3.00% | 3.10% |
| Reduced materials – vehicles | 19.32 | 36.55 | 0.02 | 0.05 | 0.30% | 0.30% |
| Reduced materials – road and rail | 18.91 | 37.43 | 0.02 | 0.02 | 0.30% | 0.10% |
| Reduced materials – buildings | 182.19 | 349.61 | 0.31 | 0.73 | 4.40% | 4.70% |
| **Waste** | 64.22 | 134.36 | 0.28 | 0.84 | 4.10% | 5.40% |
| Recycling | 18.81 | 30.46 | 0.10 | 0.15 | 1.40% | 1.00% |
| Landfill methane capture and utilisation | - | - | 0.04 | 0.30 | 0.60% | 2.00% |
| Waste prevention | 45.42 | 103.89 | 0.15 | 0.39 | 2.10% | 2.50% |
| **TOTAL** | 1,075.18 | 2,133.81 | 6.93 | 15.53 | 100.00% | 100.00% |

*Source: Stockholm Environment Institute for the Coalition for Urban Transitions. For the full methodology, see Annex 1.*

**FIGURE 3. TECHNICALLY FEASIBLE MITIGATION POTENTIAL IN CITIES IN 2050, BY REGION AND CITY SIZE.**

*Annual average abatement (million tonnes CO2-e) in 2050.*
*Source: Stockholm Environment Institute for the Coalition for Urban Transitions. For the full methodology, see Annex 1.*



The urban abatement potential is dispersed across cities of different sizes and in different regions (see *Figure 3*). Megacities – those with over 10 million inhabitants – make an outsized contribution to global emissions and also have the largest scope for climate mitigation: the world's 29 megacities in 2015 account for 12% of the identified urban abatement potential in 2050. Including cities with over 5 million inhabitants brings the share to over a fifth of the world's urban abatement potential. These larger cities often have relatively well-resourced and capable city governments, so local leadership and action will be particularly significant in these contexts.

However, over half of all urban abatement potential is in cities with populations of less than 750,000 (as of 2015). These cities often lack the financial and technical resources of their larger counterparts. And even for cities with sufficient capacity, taking aggressive unilateral efforts to reduce emissions may be untenable if their economic peers fail to act. It is for these cities that national support and standards are most important.

Nearly three quarters (71%) of urban abatement potential identified in this analysis is in countries outside the Organisation for Economic Co-operation and Development (OECD). Cities in China account for 22% and cities in India account for 12% of the identified emission reductions. In OECD countries, meanwhile, over half of the urban abatement potential is in US cities, which account for 15% of the global potential identified. National and state governments in China, India and the US thus have particularly important roles to play in supporting a zero-carbon urban transition.

Crucially, the bundle of measures identified in this report would not be quite enough to reach net-zero emissions in the selected urban sectors by 2050. They could reduce emissions by 96% from commercial and residential buildings, 76% from materials use, 86% from passenger and freight transport, and over 99% from solid waste management. But reaching net-zero emissions by mid-century would require still more aggressive deployment of existing measures or additional innovations. Moreover, this analysis focuses mainly on emissions from energy use within city boundaries, electricity production, materials use and municipal waste. Reaching net-zero emissions worldwide will demand much greater attention to emissions from consumption,[61] including air travel, meat and dairy products, and goods manufactured and disposed of beyond city boundaries.[62] Because of cities' economic heft, a small subset of urban residents have especially high levels of consumption and particularly strong influence over global supply chains. The nearly 100 cities that are members of the C40 Cities Climate Leadership Group alone represent 10% of global greenhouse gas emissions when using consumption-based accounting.[63] A suite of additional climate actions will be required to engage citizens around this issue and cut emissions from unsustainable levels of consumption.[64]

> **Over half of all urban abatement potential is in cities with populations of less than 750,000 (as of 2015).**

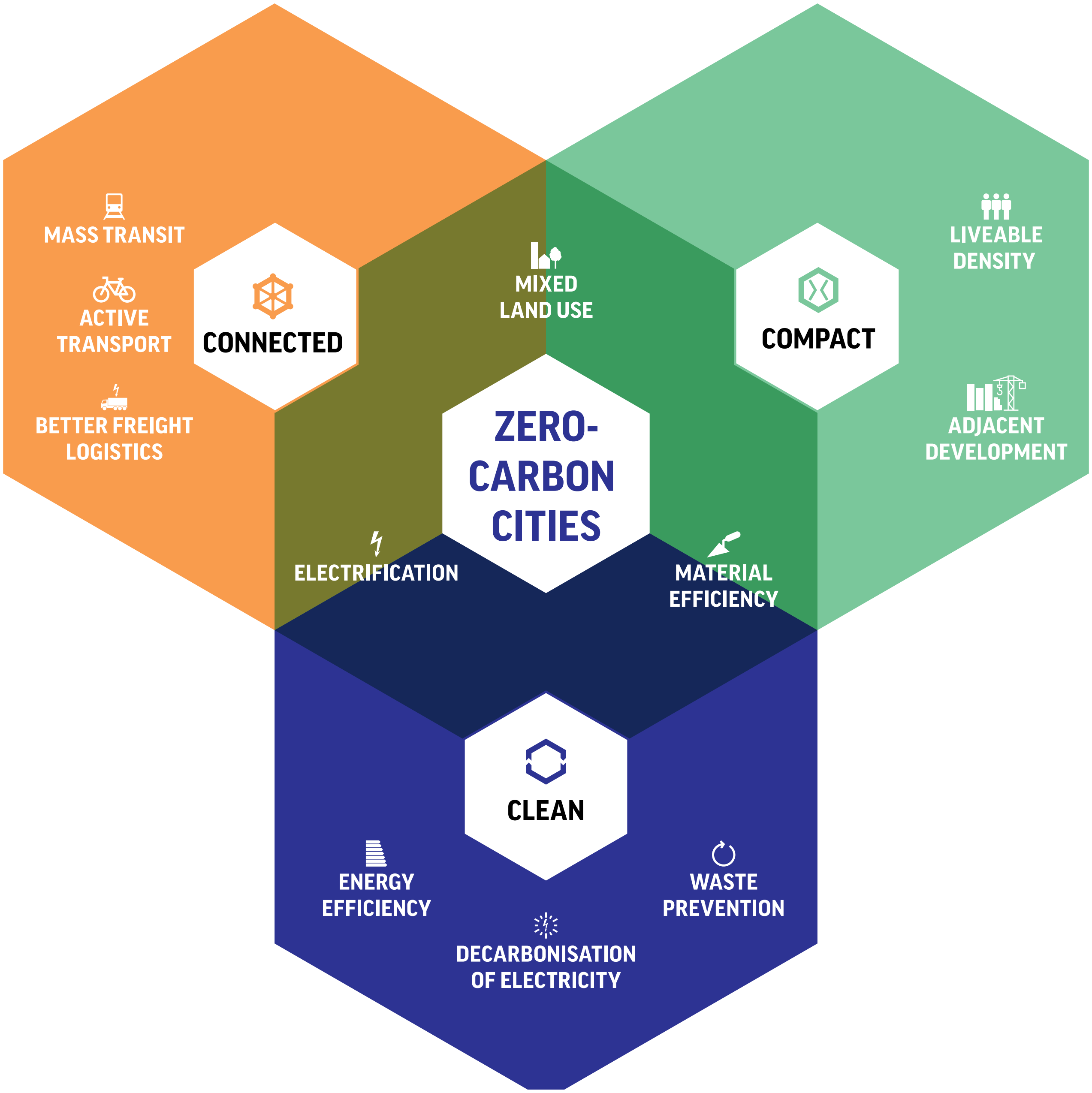
## 2.2 What might life be like in zero-carbon cities?

The bundle of measures identified above could rapidly improve quality of life by making cities at all levels of development more compact, connected and clean (see *Figure 4*). These three aspects are closely interrelated and complementary. Good connectivity – with safe sidewalks, cycling lanes and mass transit – facilitates compactness by reducing dependence on space-hungry private cars. More compact cities are more resource-efficient, because they use less space per resident and provide more opportunities for mass transit, active travel and district heating and cooling systems.[65] This section spells out the characteristics of compact, connected and clean cities, and explores what life in such cities might look and feel like. It highlights the wide range of social and environmental benefits of an urban transition (*Chapter 3* examines the economic benefits), then considers the wider societal and technological forces that can be harnessed to realise these benefits.

This bundle of low-carbon measures could raise living standards and improve urban environments, but complementary actions are needed to realise their full potential. For instance, effective rule of law is crucial to improving public safety and the ease of doing business; strong labour standards are needed to ensure working people have decent jobs that pay a living wage; and careful macroeconomic policies are crucial to reducing investment risk. Additional measures will also be needed to achieve the Sustainable Development Goals (SDGs) and make cities truly resilient to climate change impacts. Governments need to pursue an inclusive urban transition that ensures that markets are regulated, services are provided and space is used in ways that meet the needs of disadvantaged groups, such as the poor, women, the elderly, children, people with disabilities, migrants and minorities. Exclusionary urban development can lead to informality, fragility and insecurity that are hard to redress in the longer term.[66] While the poor bear the most severe consequences, everyone suffers if a city is less productive and more violent. Climate change will only deepen poverty and inequality. Policies must therefore be designed to address the social and economic drivers of vulnerability, as well as physical exposure to hazards.[67] Meeting the needs and building the adaptive capacity of the urban poor is a precondition for creating resilient cities with flourishing economies, healthy communities and clean environments[68] – and sustaining public appetite for a zero-carbon urban transition.

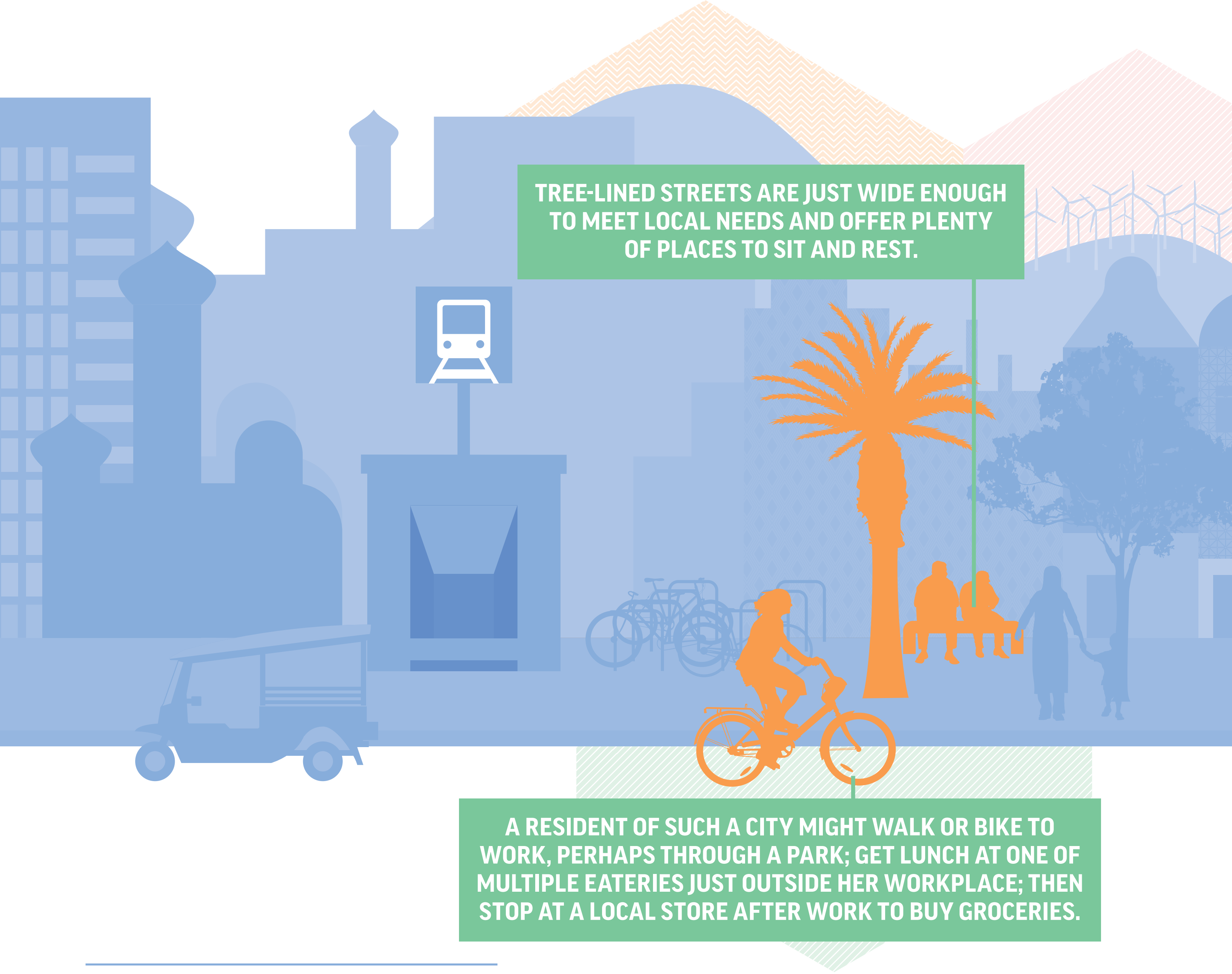
> **More compact cities are more resource-efficient because they use less space per resident and provide more opportunities for mass transit, active travel and district heating and cooling systems.**

**FIGURE 4. KEY LOW-CARBON MEASURES ASSOCIATED WITH COMPACT, CONNECTED AND CLEAN CITIES.**



## The benefits of compact cities

Envision a city that truly makes the most of its land. Countless cities like this already exist, especially in places settled well before cars became common. But they are not the norm.



TREE-LINED STREETS ARE JUST WIDE ENOUGH TO MEET LOCAL NEEDS AND OFFER PLENTY OF PLACES TO SIT AND REST.

A RESIDENT OF SUCH A CITY MIGHT WALK OR BIKE TO WORK, PERHAPS THROUGH A PARK; GET LUNCH AT ONE OF MULTIPLE EATERIES JUST OUTSIDE HER WORKPLACE; THEN STOP AT A LOCAL STORE AFTER WORK TO BUY GROCERIES.

The shape and layout of cities greatly affects their economic, social and environmental performance. Compact cities have three key characteristics:[69]

- Economic density, with a high concentration of people living, doing business and working in a given area;
- Morphological density, making the most efficient use of available land and built space to meet people's needs; and
- Mixed land use, putting residential, employment, retail, and leisure opportunities close to one another.

The average population density of cities is falling in every region of the world.[70] This is largely because greenfield land around the urban periphery tends to be cheaper (at least from the perspective of property developers and households), and building there is easier than redeveloping and/or densifying existing urban areas.[71] Many subnational governments also generate revenues from land sales, so they are incentivised to favour sprawl rather than densification: in China, local land revenues now fund nearly a quarter of local fiscal expenditure.[72] Policies at all levels of government typically mean that residents in outlying areas do not bear the full costs of sprawl, which are outlined in *Section 3.1*. Cultural preferences for larger homes, private gardens and car-based transport may reinforce those economic factors.

**HOMES ARE MODEST BUT COMFORTABLE, IN MULTI-STOREY BUILDINGS THAT ARE CLUSTERED CLOSELY TOGETHER.**

**EFFICIENT LAND USE MAKES IT EASIER TO CARVE OUT GREEN SPACES WHERE PEOPLE CAN RELAX AND DIVERSE SPECIES THRIVE.**

**WITH STEADY FOOT TRAFFIC, LOCAL RETAILERS AND EATERIES THRIVE, SO RESIDENTS ENJOY PLENTY OF EMPLOYMENT, SHOPPING AND LEISURE OPPORTUNITIES CLOSE BY.**

Reversing this trend by pursuing more compact urban development could deliver better living standards and more vibrant cities. People could enjoy easier access to jobs, services and amenities.[73] Public services could be cheaper, as they could be delivered more efficiently.[74] More time in shared spaces could help to connect people across class and cultural lines.[75] Higher densities could support a greater variety of shops, restaurants and public spaces within neighbourhoods. By safeguarding farmland and natural habitats around the city, compact urban growth could conserve biodiversity and maintain ecosystem services that enhance climate resilience.[76] Compactness is not a panacea – in particular, increasing the density of people living and working in cities can drive up housing prices significantly, with the burden borne disproportionately by the poor and the young.[77] But if this risk is carefully managed, the potential economic, social and environmental benefits of compactness are substantial.

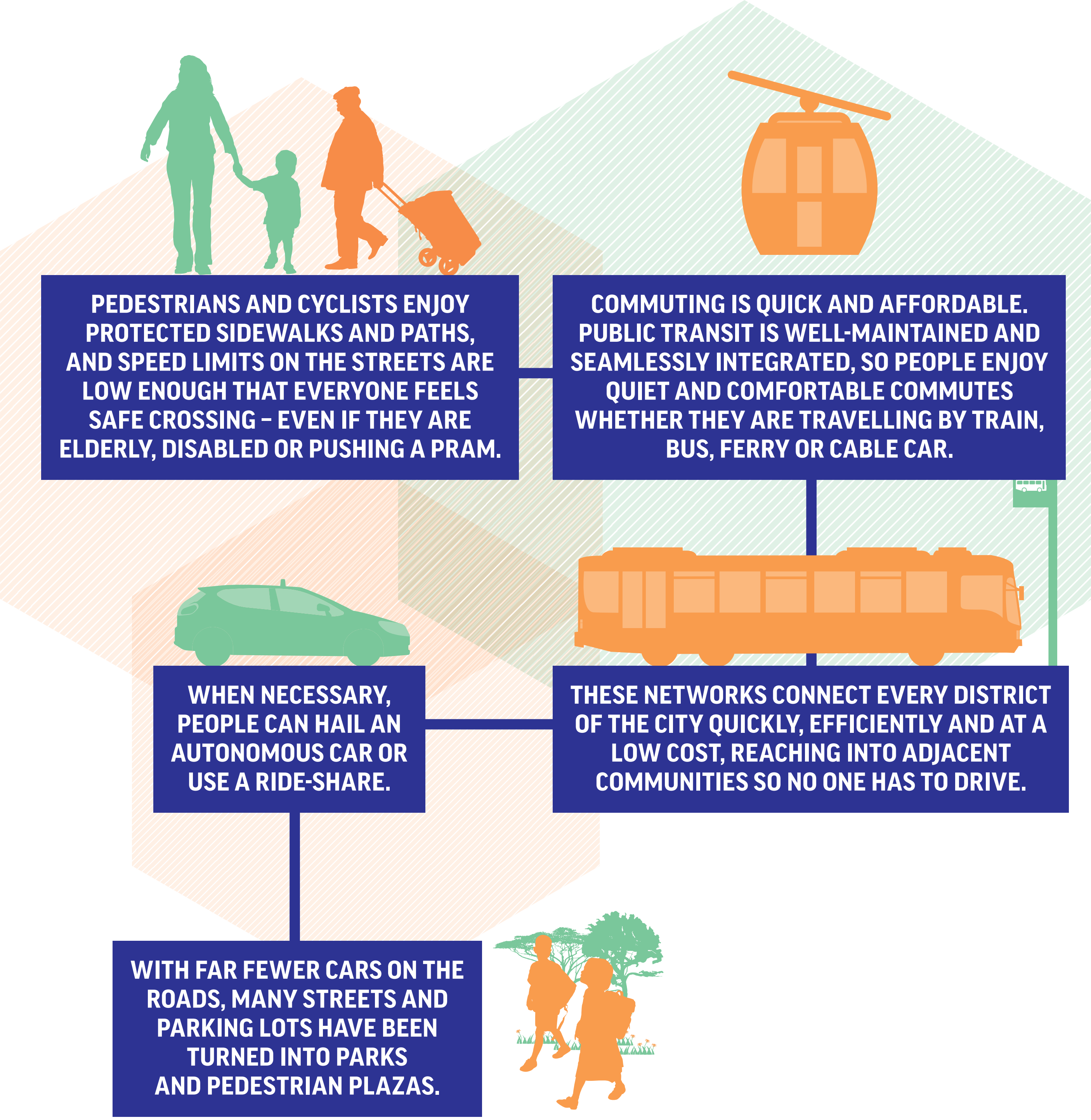
*Figure 5* compares the spatial footprint of two cities: Stockholm (Sweden) and Pittsburgh (US). These cities have roughly the same population, but Pittsburgh occupies five times as much land area. This means that people need to travel farther, at greater personal and environmental expense, excluding many of them from economic and social opportunities. Meanwhile, Stockholm is widely recognised as having a very high quality of life and a thriving, inclusive economy thanks in part to its compact, connected form.

Demographic change, cultural change and urbanisation offer a window of opportunity to achieve more compact urban forms. Many cities in high-income countries have ageing populations and smaller households than they did historically. These trends are complemented by an increasing preference for city life over suburbia. The result is falling demand for larger homes around the urban periphery and growing demand for smaller homes with better access to the city centre. These changes in the housing market offer a chance to encourage densification around transport hubs. Seoul in South Korea demonstrates how a relatively established city can align land use, transport and housing strategies to create dense, vibrant, mixed-use neighbourhoods (see *Box 2*).

By comparison, many cities in developing Africa and Asia have rapidly expanding populations with large youth bulges and severe infrastructure deficits. Governments need to proactively prepare for this growth, recognising that people at all income levels have a right to the city and that meeting their needs is crucial to long-term economic, social and environmental success.[78] The urban poor need special attention to ensure that competition for well-located land does not lead to eviction or gentrification. Windhoek, Namibia, for example, made small plots of competitively priced and serviced land available to poor residents, reducing the heavy health burden associated with informal settlement and making it cheaper to upgrade housing and services over time (see *Box 3*).

**The benefits of connected cities**

Let's go back to that city we visited earlier. It's not just compact; it's also very easy to move around. The air is much cleaner. And with commuting times sharply reduced, people have much more free time, which they spend enjoying the city with their loved ones.



PEDESTRIANS AND CYCLISTS ENJOY PROTECTED SIDEWALKS AND PATHS, AND SPEED LIMITS ON THE STREETS ARE LOW ENOUGH THAT EVERYONE FEELS SAFE CROSSING – EVEN IF THEY ARE ELDERLY, DISABLED OR PUSHING A PRAM.

COMMUTING IS QUICK AND AFFORDABLE. PUBLIC TRANSIT IS WELL-MAINTAINED AND SEAMLESSLY INTEGRATED, SO PEOPLE ENJOY QUIET AND COMFORTABLE COMMUTES WHETHER THEY ARE TRAVELLING BY TRAIN, BUS, FERRY OR CABLE CAR.

THESE NETWORKS CONNECT EVERY DISTRICT OF THE CITY QUICKLY, EFFICIENTLY AND AT A LOW COST, REACHING INTO ADJACENT COMMUNITIES SO NO ONE HAS TO DRIVE.

WHEN NECESSARY, PEOPLE CAN HAIL AN AUTONOMOUS CAR OR USE A RIDE-SHARE.

WITH FAR FEWER CARS ON THE ROADS, MANY STREETS AND PARKING LOTS HAVE BEEN TURNED INTO PARKS AND PEDESTRIAN PLAZAS.

People are drawn to cities for economic and social opportunities – but access to those opportunities depends on the time, cost and convenience of moving around. Good connectivity helps maximise and share the benefits of agglomeration, while reducing greenhouse gas emissions. Connected cities have transport systems that link people's homes to areas with employment opportunities and services such as schools, hospitals and parks. Connectivity may be achieved through compact, mixed-use neighbourhoods with safe sidewalks and cycle lanes that allow people to live, work, shop, study and meet one another without long trips. Meanwhile, high-capacity transport systems can seamlessly connect people with jobs, services and amenities all across the city.[107] Options include railways, metro lines, trams, buses, cable cars and ferries, complemented by ride-sharing and e-hailing services to fill any gaps in transport services.

**Cars in cities contribute to:**

- **Up to 70% of air pollution.**
- **1.3 million deaths globally every year.**
- **78.2 million traffic injuries warranting medical care.**
- **Inefficient and expensive urban sprawl.**
- **23% of carbon emissions from final energy use (up to 40% in urban areas).**

Through most of the 20th century, urban transport planning has focused on moving cars efficiently. The result has been chronic congestion, toxic air pollution, and unacceptable traffic fatalities. Many people assume these are inherent features of cities, but they are not. In cities of the global South, up to 70% of air pollution can be attributed to cars.[108] Road crashes account for 1.3 million deaths globally every year, and 78.2 million traffic injuries warranting medical care.[109] Cars also require huge amounts of land, exacerbating urban sprawl. Moreover, the transport sector globally accounts for 23% of carbon emissions from final energy use, with up to 40% of that energy use in urban areas.[110] Simply electrifying established transport systems will not solve these issues. The next generation of urban transport planning must focus primarily on moving people, not cars.[111]

Urbanisation, technological innovation and public concerns about air quality and congestion can be harnessed to create more connected cities. Rapid population growth offers an opportunity for transit-oriented development, in which attractive residential and commercial neighbourhoods are built up around high-capacity transit stations. Once "the murder capital of the world",[112] Medellín in Colombia exemplifies how creative transport solutions – complemented by better service delivery and iconic cultural projects – can reduce commuting times and improve social inclusion (see *Box 4*). Meanwhile, advances in cashless payments, data collection and analytics, mobile communications and machine learning have led to the proliferation of new mobility services. Car- and bike-sharing systems, mobile trip-planning apps and ride-hailing networks are now common, while self-driving cars may soon be a common sight in cities.[113] Governments can influence the development and uptake of these innovations so that they not only improve convenience for passengers, but also tackle pollution, congestion and greenhouse gas emissions. Transport planning and policy must bring urban residents along on the journey – or follow their lead. Copenhagen in Denmark is arguably the world's cycling capital, a legacy of its visionary citizenry, who protested against highways and petitioned for better cycle lanes. National and local governments embraced their demand, and today nearly half of Copenhagen's population cycles to work (see *Box 5*).[114]

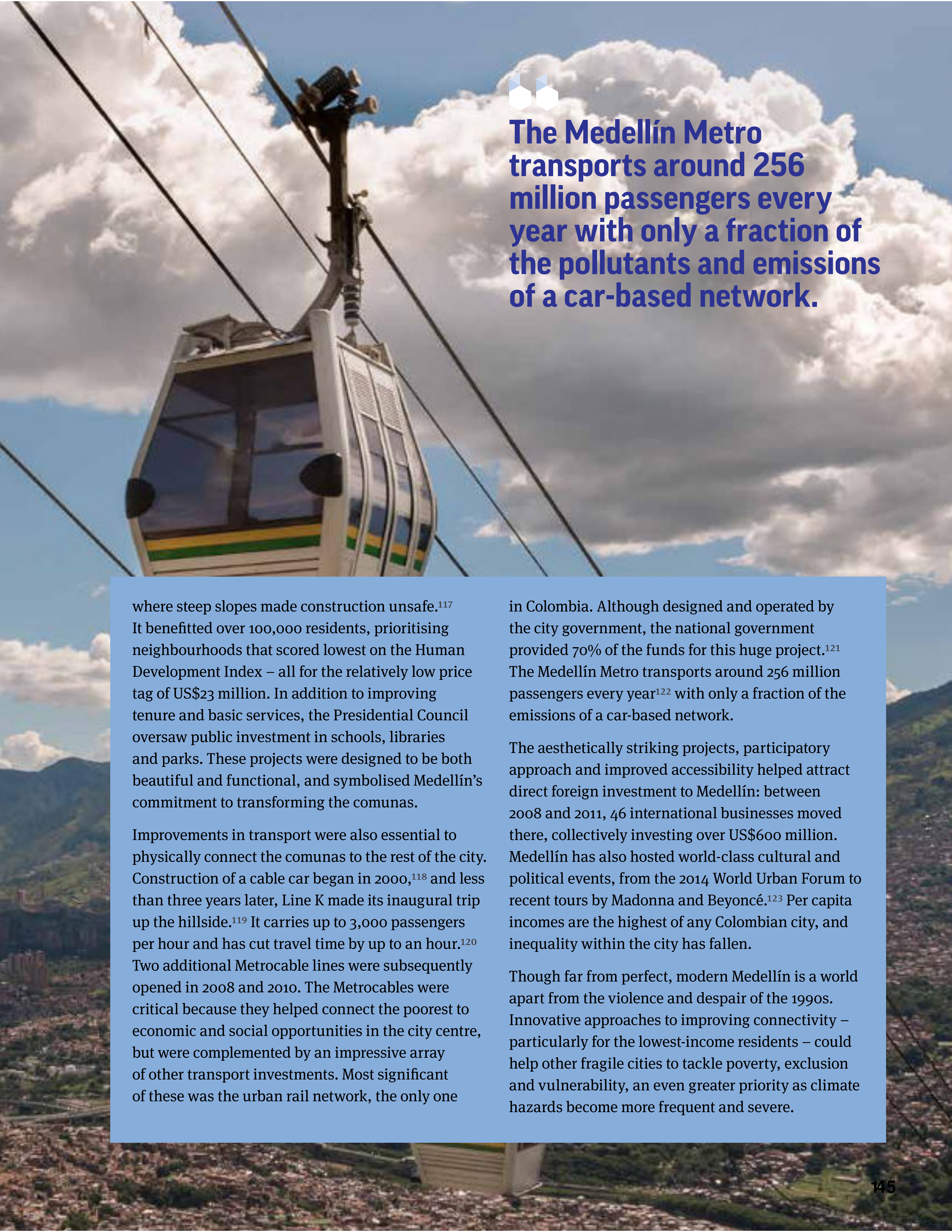
# Box 4. Medellín: How connecting informal settlements helped transform an embattled city

Medellín is Colombia's second-largest city, with a population of nearly 4 million people.[115] Since the early 1990s, it has transformed from a violent and poverty-stricken city to a safe, vibrant centre studded with striking parks and buildings. Thanks to a combination of transport investments, upgrades to informal settlements, and iconic architectural projects in the most deprived neighbourhoods, its residents now enjoy higher living standards and a sense of civic pride. Medellín's experience shows how bold, creative interventions to connect people to opportunities can revitalise a city.

Medellín originally prospered thanks to railways, coffee exports, and a robust manufacturing sector. In the 1960s and '70s, the city's economy stagnated even as its population grew, with many Colombians fleeing guerrilla violence in the countryside and settling in comunas. These informal settlements lacked basic services such as water and sanitation, and often sat precariously on the steep hills around Medellín, making it difficult to reach the city centre. With a shrinking formal economy, Medellín's residents resorted to selling goods such as black-market whiskey, appliances, marijuana – and eventually cocaine. This thrust Medellín into the epicentre of Colombia's burgeoning drug trade. As drug cartels and local militias clashed with the national government, Medellín became the world's deadliest city, with a murder rate of 4 per 1,000 in 1992.

In 1991, Colombia approved a new constitution that granted more power and resources to city governments. It required them to create municipal development plans, promised significant fiscal transfers, and strengthened accountability and transparency.[116] In 1993, a Presidential Council was convened specifically to address poverty and violence in Medellín, bringing together the national and local government, private businesses, community-based organisations and academics.

Thus emerged PRIMED (Programa Integral de Mejoramiento de Barrios Subnormales en Medellín), a programme to integrate the comunas into the rest of Medellín. PRIMED granted over 2,100 households legal tenure, improved over 3,500 houses, built and improved vital infrastructure, and relocated or stabilised almost 70% of the neighbourhoods



**The Medellín Metro transports around 256 million passengers every year with only a fraction of the pollutants and emissions of a car-based network.**

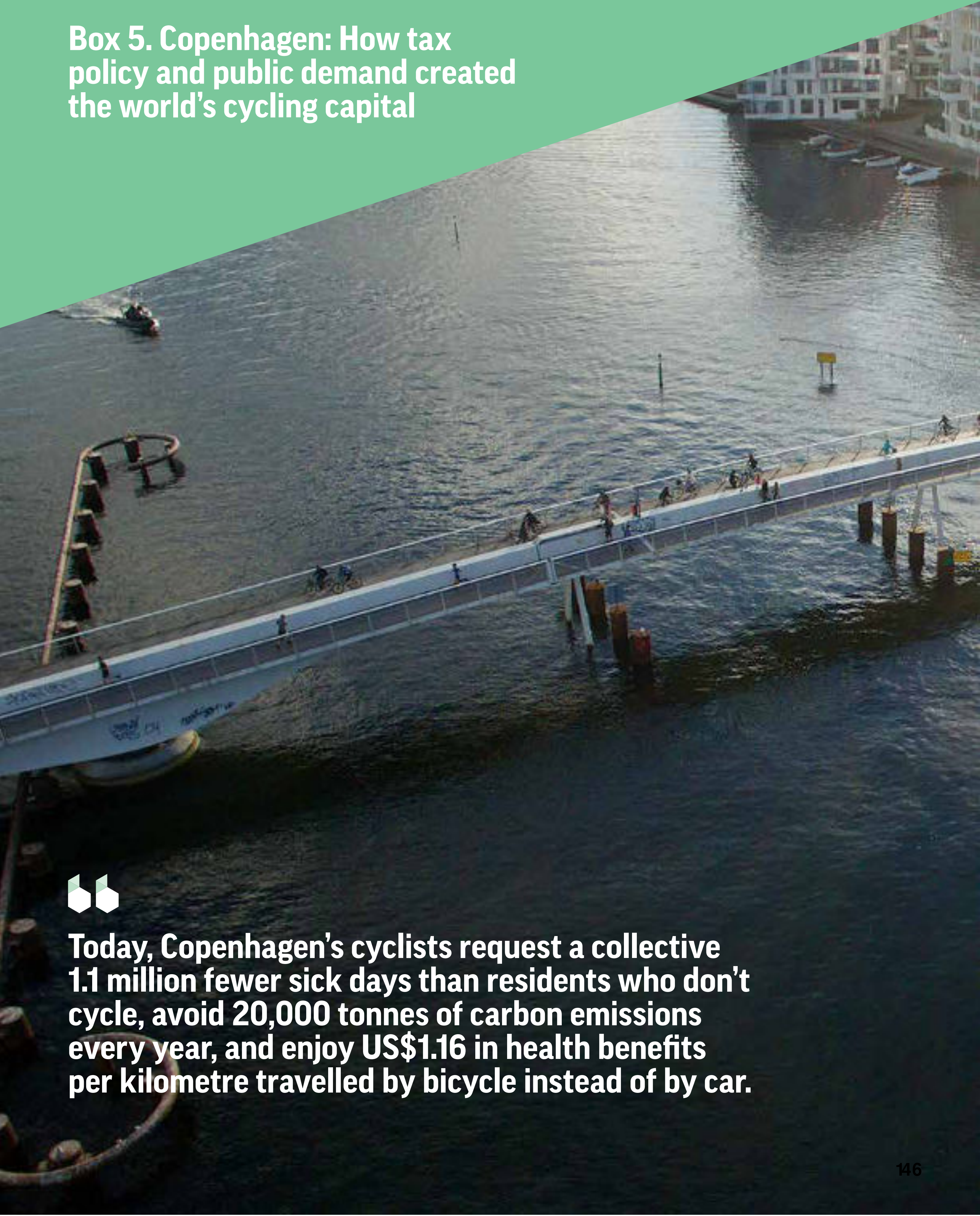
where steep slopes made construction unsafe.[117] It benefitted over 100,000 residents, prioritising neighbourhoods that scored lowest on the Human Development Index – all for the relatively low price tag of US$23 million. In addition to improving tenure and basic services, the Presidential Council oversaw public investment in schools, libraries and parks. These projects were designed to be both beautiful and functional, and symbolised Medellín's commitment to transforming the comunas.

Improvements in transport were also essential to physically connect the comunas to the rest of the city. Construction of a cable car began in 2000,[118] and less than three years later, Line K made its inaugural trip up the hillside.[119] It carries up to 3,000 passengers per hour and has cut travel time by up to an hour.[120] Two additional Metrocable lines were subsequently opened in 2008 and 2010. The Metrocables were critical because they helped connect the poorest to economic and social opportunities in the city centre, but were complemented by an impressive array of other transport investments. Most significant of these was the urban rail network, the only one in Colombia. Although designed and operated by the city government, the national government provided 70% of the funds for this huge project.[121] The Medellín Metro transports around 256 million passengers every year[122] with only a fraction of the emissions of a car-based network.

The aesthetically striking projects, participatory approach and improved accessibility helped attract direct foreign investment to Medellín: between 2008 and 2011, 46 international businesses moved there, collectively investing over US$600 million. Medellín has also hosted world-class cultural and political events, from the 2014 World Urban Forum to recent tours by Madonna and Beyoncé.[123] Per capita incomes are the highest of any Colombian city, and inequality within the city has fallen.

Though far from perfect, modern Medellín is a world apart from the violence and despair of the 1990s. Innovative approaches to improving connectivity – particularly for the lowest-income residents – could help other fragile cities to tackle poverty, exclusion and vulnerability, an even greater priority as climate hazards become more frequent and severe.

# Box 5. Copenhagen: How tax policy and public demand created the world's cycling capital



> **Today, Copenhagen's cyclists request a collective 1.1 million fewer sick days than residents who don't cycle, avoid 20,000 tonnes of carbon emissions every year, and enjoy US$1.16 in health benefits per kilometre travelled by bicycle instead of by car.**

Copenhagen is known for its beautiful public spaces, the colourful houses that line its waterways, and its cycling culture. Danish bike culture goes back at least 100 years.[124] However, as the city grew more prosperous in the wake of World War II, people started to switch to mopeds and cars.[125] In 1948, Copenhagen's urban planners put forward the "Finger Plan", which concentrated urban development along five arteries extending from the city centre to nodes of high-rise housing and development on the periphery.[126] Through the 1950s and 1960s, Copenhagen's tram and cycling infrastructure was incrementally replaced by highways.

However, in the late 1960s and early 1970s, Copenhagen's finances floundered. Rising oil prices hit Denmark hard, forcing Copenhagen to shut off every other streetlight and implement car-free Sundays.[127] Public opposition to highways grew more vocal, with petitions and protests proliferating.[128] Lacking both funding and support for the "Finger Plan", the national government established Greater Copenhagen's Capital Regional Authority to facilitate integrated transport planning.[129] Over decades, this local agency has steadily expanded the cycle track network[130] and converted planned highways to parks and housing.[131] As of 2017, 43% of Copenhagen's commutes to work or school are by bicycle,[132] which residents rate as most convenient.[133] Copenhagen today has 375 kilometres of dedicated lanes, and there are further plans for a network of 45 "cycle superhighways", about 746 kilometres, to connect the entire capital region.[134] Today, Copenhagen's cyclists request a collective 1.1 million fewer sick days than residents who don't cycle, avoid 20,000 tonnes of carbon emissions every year, and enjoy US$1.16 in health benefits per kilometre travelled by bicycle instead of by car.[135]

Cycling is the most visible part of Copenhagen's transport networks, but the city also benefits from an excellent mass transit system. The Ørestad Development Corporation, a joint venture between the national and local government, was established in 1992 with the mandate to build and operate a metro.[136] The first line opened in 2002,[137] and in the following year, car trips in the harbour corridor decreased by 2.9% on average workdays.[138] A new Circle Line is slated to open shortly, and is expected to bring 100,000 more passengers on to public transit every day.[139]

Cycling has flourished in Copenhagen not only because of the "pull" of good local infrastructure, but also national policies to "push" people away from car use.[140] The national government introduced a two-tier vehicle ownership tax in 1977, incentivising smaller and more fuel-efficient cars.[141] These national efforts have been complemented by city-scale initiatives, including a steady reduction in downtown parking and the creation of pedestrian-only zones. Car owners also pay a petrol tax and high fees for vehicle registration, insurance, parking and disposal.[142] As a result, in 2012, Copenhagen had 360 cars per 1,000 inhabitants, while Rome had 641 and Melbourne had 593.[143]

Copenhagen nearly became another congested city carved up by highways and choked with air pollution. Instead, the Government of Denmark and City of Copenhagen worked closely together to build a safe, easy and clean transport network. Today, many fast-growing cities face the same choice: invest in cars or invest in connectivity. They can look to Copenhagen for inspiration, with its vibrant streetscapes and healthy residents.

presented in *Section 2.1* would support the equivalent of 87 million jobs in 2030 and 45 million jobs in 2050. In 2030, most of these jobs would be from deep building efficiency improvements. In 2050, most of these jobs would be in the transport sector. These employment estimates usefully illustrate the magnitude of the impacts expected, but have not been modelled to reflect specific supply chains or labour market dynamics. They therefore provide a short-term picture which may not account for the skills profile or absorptive capacity of an urban area, or other regional differences.

These findings are conservative estimates of the economic returns from low-carbon investment in cities. The returns and payback periods associated with these abatement options are sensitive to energy prices, interest rates and technological learning rates (i.e. price and performance improvements as technologies are more widely deployed). The findings presented in *Table 3* are based on a central scenario

**TABLE 3. THE ECONOMICS OF SELECTED LOW-CARBON INVESTMENTS IN CITIES BETWEEN 2020 AND 2050.**

| | Total incremental investment (US$ trillions) | Annual returns (US$ billions) | | Net present value (US$ trillions) | Average payback (years) | Jobs supported (millions) | |
|---|---|---|---|---|---|---|---|
| Measure | | 2030 | 2050 | | | 2030 | 2050 |
| **BUILDINGS –RESIDENTIAL** | | | | | | | |
| Deep building efficiency | 25.42 | 338.63 | 945.30 | -12.99 | N/A | 59.4 | - |
| Efficient lighting | 0.07 | 23.65 | 39.89 | 0.42 | 1 | <0.1 | 0.1 |
| Efficient appliances | 2.13 | 24.42 | 185.07 | -0.22 | N/A | 0.8 | 2.5 |
| Efficient cooking | - | 36.17 | 133.66 | 0.90 | 9 | n/a | n/a |
| Rooftop solar PV | 0.42 | 8.11 | 87.79 | 0.16 | 12 | 0.3 | 1.3 |
| **BUILDINGS –COMMERCIAL AND PUBLIC** | | | | | | | |
| Deep building efficiency | 13.09 | 294.02 | 722.77 | -4.09 | N/A | 18.1 | - |
| Efficient lighting | 0.04 | 27.08 | 234.56 | 1.51 | 1 | <0.1 | <0.1 |
| Efficient appliances | 0.04 | -16.55 | 51.67 | -0.05 | N/A | <0.1 | 0.1 |
| Rooftop solar PV | 0.12 | 2.44 | 23.87 | 0.05 | 11 | 0.1 | 0.3 |
| **MATERIALS EFFICIENCY** | | | | | | | |
| More efficient material use (cement and steel) | - | 87.96 | 359.30 | 2.15 | - | n/a | n/a |
| **TRANSPORT – PASSENGER** | | | | | | | |
| More efficient and electric vehicles | 8.61 | 320.42 | 1,095.59 | 3.66 | 8 | 3.6 | 20.4 |
| Mode shift to mass transit | 4.01 | 1,024.96 | 660.46 | 19.62 | 1 | 2.6 | 11.8 |
| Reduced motorised travel demand | 0.58 | 513.12 | 1,762.66 | 10.25 | 1 | 1.1 | 3.8 |
| **TRANSPORT – FREIGHT** | | | | | | | |
| More efficient and electric vehicles | 0.59 | 79.85 | 529.20 | 2.29 | 1 | 0.1 | 2.4 |
| Improved logistics | 1.59 | 36.69 | 143.93 | 0.18 | 1 | 0.6 | 2.7 |
| **WASTE** | | | | | | | |
| Landfill gas utilisation | 0.01 | 1.02 | 8.53 | 0.03 | 5 | <0.1 | <0.1 |

*Note: These figures assume a discount rate of 3.5%, annual energy prices increases of 2.5% and low technological learning rates.*
*Source: Vivid Economics for the Coalition for Urban Transitions. For the full methodology, see Annex 7.*

# Box 7: China: Driving an electric transport revolution

> **China is home to 40% of the world's electric passenger cars and over 99% of the world's electric buses and electric two-wheelers.**

It is difficult to overstate China's dominance of the global electric vehicle (EV) landscape. As of 2017, China was home to 40% of the world's electric passenger cars, with 1.2 million battery or plug-in hybrid EVs.[223] China also accounts for over 99% of the 370,000 electric buses and the 250 million electric two-wheelers in the world.[224] China's sustained commitment to EVs is grounded in their potential to improve air quality and energy security. China's air pollution is among the world's most extreme, leading to 1.37 million premature deaths every year,[225] and the country depends heavily on oil imports.[226] EVs, especially when powered by renewable electricity, can address both these pressing issues.

China's dominance in this market can be largely attributed to the national New Energy Vehicles (NEV) programme, which, since its launch in 2001, has systematically dismantled both supply- and demand-side barriers to large-scale deployment. The NEV programme initially focused on research and development (R&D) in three key technologies: powertrain control systems, motor control systems, and battery management systems. In the last few years, the Government of China has primarily channelled its R&D towards integrating NEVs into cities, particularly by improving and expanding charging infrastructure.[227] Innovations have not just been technological: the city government of Shenzhen, for instance, has developed new business models such as leasing rather than purchasing electric buses, and has coordinated utilities and bus operators to optimise EV charging. In 2018, Shenzhen became the first city in the world to electrify its entire public bus fleet.[228]

Complementing these efforts, the national government partnered with 10 pioneering city governments to increase demand for EVs. The 10

city governments received subsidies and technical support for public procurement of EVs and installation of public EV chargers. This strategy helped manufacturers to achieve the economies of scale and technological breakthroughs that eventually made EV production cost-competitive with internal combustion engine vehicles. Public procurement policies were accompanied by policies to incentivise the private purchase of EVs. In 2006, the national government reduced consumer tax on NEVs[229] and in 2010, it extended purchase subsidies from the public sector to support private purchases of battery EVs.[230] The NEV programme was subsequently expanded to a further 39 cities.[231] The country's fleet is accordingly expanding rapidly: over half of all electric cars sold worldwide in 2017 were sold in China.[232]

As EVs became more cost-competitive, the national government has been able to deploy a different set of policy instruments. First, it has steadily rolled back EV subsidies and replaced them with a cap-and-trade system to reduce the pressure on government budgets.[233] Second, the national government now mandates that any company manufacturing vehicles in China has to produce at least 10% NEVs. The quota will increase incrementally to 20% by 2025. Companies that fail to meet the target can buy NEV credits from manufacturers who exceeded the target, or else face federal fines.

China's NEV programme has built domestic and international capacity to cost-effectively produce EVs,[234] paving the way for a more rapid global uptake. By crafting regulation, providing incentives and offering technical support, China's national government turned its cities into test beds for innovation and public procurement. This has ensured that cities such as Beijing and Shenzhen are at the forefront of emerging technologies.

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

### SUMMARY

This study explores the potential contribution from different biofuel pathways in achieving the emissions reduction targets set by the International Maritime Organization’s (IMO) initial greenhouse gas (GHG) strategy. We screen a variety of potential liquid alternative fuels based on qualitative criteria, assess the potential GHG and air-pollution benefits of key candidates compared with distillate bunker fuel, and then discuss the compatibility of these fuels with marine engines. We also consider other barriers to their use, including feedstock availability, cost, and competition with other sectors.

Of the fuels and feedstocks assessed, we identified five liquid biofuels with the potential to reduce shipping GHG emissions on a well-to-wake, life-cycle basis relative to conventional, distillate marine fuels:

1. Fatty acid methyl ester (FAME) biodiesel produced from waste fats, oils, and greases (FOGs)

2. Hydrotreated renewable diesel produced from waste FOGs

3. Fischer-Tropsch (FT) diesel produced from lignocellulosic biomass

4. Dimethyl ether (DME) generated by gasifying lignocellulosic feedstocks followed by catalytic synthesis

5. Methanol generated by gasifying lignocellulosic feedstocks followed by catalytic synthesis

Overall, we find that feedstock is more important than conversion technology in determining a fuel pathway’s GHG reductions. Additionally, regardless of feedstock, all fuels investigated will reduce particulate air pollution, and this is primarily due to their low sulfur content relative to conventional marine fuels. Based on a holistic assessment of various criteria and the feedstock limitations for several pathways, we identified several trends.

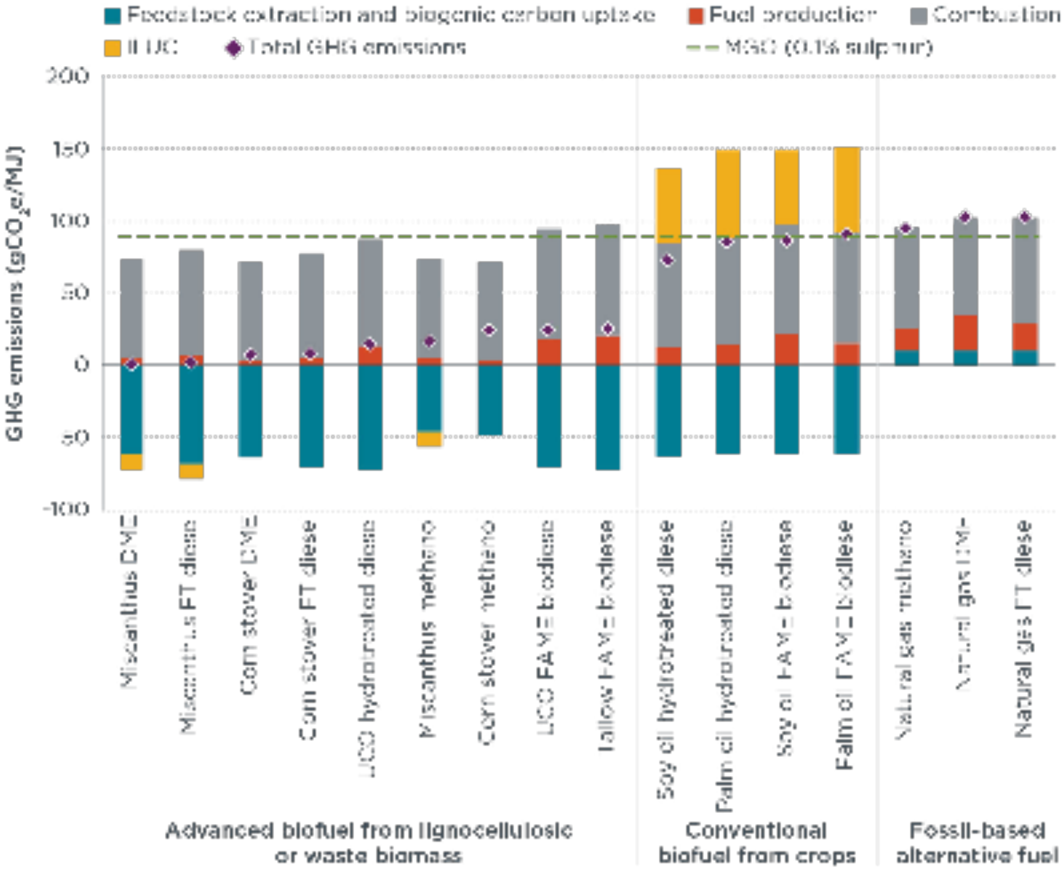
The technical and cost barriers for the use of FAME biodiesel in marine engines are low, but only FAME biodiesels produced from waste FOGs are likely to generate substantial life-cycle GHG reductions compared with distillate fuel. After taking into account indirect effects like indirect land-use change (ILUC), FAME biodiesel produced from food crops is likely to undermine any emissions savings compared with conventional distillatefuels. Furthermore, if it is to be used in existing marine engines, FAME biodiesel must be blended with conventional marine fuels up to a certain limit; this blending constraint reduces the overall, sector-wide potential of emission reductions from FAME biodiesel.

Hydrotreated renewable diesel produced from FOGs is more expensive than FAME biodiesel but is the cheapest, most commercially ready drop-in biofuel that is compatible with a wide range of engines. Like FAME biodiesel, however, hydrotreated renewable diesel produced from virgin vegetable oils has life-cycle GHG emissions comparable to distillate marine fuels. Within this pathway, only waste FOG-derived hydrotreated renewable diesel is likely to offer any GHG savings. Moreover, given that waste FOGs are a limited resource, increased demand for their use in the marine sector would create competition with other sectors, like road and aviation fuels, where waste FOGs are already being utilized for biofuels.

FT diesel is at a lower level of technological readiness than hydrotreated renewable diesel but has significant long-term potential. The renewable FT diesel pathway utilizes non-food feedstocks that are available in greater quantities and produces lower-carbon fuels with no or even negative ILUC emissions. Furthermore, this pathway produces drop-in fuels that can be used "neat" or at high blends without compatibility issues. The use of fossil feedstocks such as natural gas for FT diesel would generate fuels without any emissions savings and is thus not aligned with IMO's GHG reduction goals.

DME or methanol would require specialized, dedicated engines to be used neat. We estimate that DME or methanol generated from natural gas would have higher life-cycle emissions than distillate marine fuels. Only DME or methanol produced from lignocellulosic feedstocks would generate GHG reductions relative to distillate fuel. On average, all of the fuels investigated are expected to be higher cost than fossil bunker fuel, ranging from 10% more (fossil-derived DME) to almost three times (lignocellulosic FT diesel) the price of marine gas oil (MGO) in 2019.

The results imply three lessons for policymakers. First, to promote only those fuels that offer significant life-cycle GHG benefits, governments should adopt rigorous life-cycle assessment methodologies that include land-use change emissions. Second, because pathways with the highest potential to deliver deep GHG reductions are also the most technologically complex and currently have the highest costs, policies should focus on addressing the barriers to these sustainable, second-generation pathways. Third, because engine compatibility issues might limit the applicability of certain fuels in existing engines, policies to promote alternative fuels should take into account that many fuels will need to be blended with conventional fossil fuels, and that they can only reduce life-cycle emissions relative to their blending ratio.



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

## EXECUTIVE SUMMARY

In this report, we describe trends in global ship activity and emissions for the years 2013 to 2015. Specifically, we estimate fuel consumption, carbon dioxide (CO2), other GHGs, operational efficiency, energy use, installed power, cargo carrying capacity, operating hours, distance traveled, and operating speed. We found that emissions generally increased over this period, with efficiency improvements more than offset by increases in activity. Key findings are highlighted below.

## FUEL CONSUMPTION IS INCREASING

Total shipping fuel consumption increased from 291 million tonnes to 298 million tonnes (+2.4%) from 2013 to 2015, compared to a 7% increase in transport supply (dwt- nm). Like the Third IMO GHG Study (Smith et al., 2015), our bottom-up (activity-based) fuel consumption estimates are systematically higher than the International Energy Agency’s (IEA’s) top-down fuel consumption estimates (Figure ES-1). However, the gap between our bottom-up estimates and IEA’s top-down findings is smaller than IMO’s. This is likely a result of improving AIS data coverage over time, which reduces the uncertainty in bottom-up estimates. Overall, bottom-up emissions remain below the 2008 peak estimated in the Third IMO GHG Study, although there are minor differences in methodologies across the bottom-up ICCT and IMO studies.

## CO2 AND OTHER CLIMATE POLLUTANT EMISSIONS ARE INCREASING

Total shipping CO2 emissions increased from 910 million tonnes to 932 million tonnes (+2.4%) from 2013 to 2015 (Table ES-1). International shipping emissions increased by 1.4%; domestic shipping emissions increased by 6.8%; and fishing emissions increased by 17%. In 2015, total shipping emissions were responsible for 2.6% of global CO2 emissions from fossil fuel use and industrial processes. International shipping contributed the most, representing about 87% of total CO2 emissions from ships each year. If treated as a country, international shipping would have been the sixth largest emitter of energy-related CO2 in 2015, just above Germany (Olivier, Janssens- Maenhout, Muntean, & Peters, 2016).

Ship CO2-eq emissions also increased from 2013–2015, increasing by 2.5% over that period. On a 100-year timescale, ship CO2-eq emissions increased from 1,000 million tonnes to 1,025 million tonnes. Similarly, on a 20-year timescale, CO2-eq emissions increased from 1,189 million tonnes to 1,222 million tonnes.

[...]

## BLACK CARBON IS A MAJOR CONTRIBUTOR TO SHIPPING’S CLIMATE IMPACTS

After CO2, black carbon (BC) contributes the most to the climate impact of shipping, representing 7% of total shipping CO2-eq emissions on a 100-year timescale and 21% of CO2-eq emissions on a 20-year time scale (Figure ES-3). Because BC is a short-lived climate pollutant, reducing BC emissions from ships would immediately reduce shipping’s climate impacts. Until now, BC has been largely ignored as a climate pollutant from ships. In this study, we report the “missing inventory” of BC emissions that ought to be considered when evaluating the climate impacts of shipping.

## INCREASES IN EFFICIENCY HAVE NOT REDUCED ABSOLUTE CO2 EMISSIONS FROM SHIPS

Although the CO2 intensity of many major ship classes decreased (i.e., they became more efficient) from 2013 to 2015, total CO2 emissions from ships increased. Even in some cases where a ship class became much more efficient, their CO2 emissions increased. For example, although the CO2 intensity of general cargo ships (measured as emissions per unit of transport supply) decreased by 5%, CO2 emissions increased by 9% (Figure ES-4). Thus, increases in distance traveled due to a greater demand for shipping more than offset gains in operational efficiency during the period studied.

As an example, the CO2 intensities of bulk carriers and container ships decreased (improved) by 6% and 9%, respectively, from 2013 to 2015, but their total CO2 emissions dropped less than 1%. That is because the overall transport supply (dwt- nm) for shipping increased by about 6% for container ships and 9% for oil tankers. Only refrigerated bulk carriers managed to reduce their CO2 emissions by a greater percentage than they reduced their CO2 intensity, owing to a 5% drop in overall supply for these ships from 2013 to 2015. The disconnect between CO2 intensity and total emissions suggests that business as usual improvements in energy efficiency are unlikely to yield substantial reductions in CO2 emissions from ships.

## THE BIGGEST SHIPS ARE SPEEDING UP AND POLLUTING MORE

Whereas average ship cruising speeds remained largely unchanged between 2013 and 2015, the largest oil tankers (>200,000 dwt) and the largest container ships (>14,500 TEU) sped up. In fact, the largest oil tankers increased their cruising speed over ground (SOG) by nearly 4%, and the largest container ships increased their cruising SOG by more than 11% (Figure ES-5). As these ships speed up, they cover greater distances in a shorter amount of time. They also consume more fuel and emit more CO2. In fact, while the carbon intensity of oil tankers and container ships as a class decreased (became more efficient), the carbon intensity of the largest oil tankers and container ships increased (became less efficient) from 2013 to 2015, with >200,000 dwt oil tankers emitting 1% more CO2/dwt-nm in 2015 and >14,500 TEU container ships emitting 18% more CO2/dwt-nm in 2015. From an emissions perspective, this is worrisome because if more ships follow suit and speed up, the CO2 efficiency of the maritime transport sector will degrade. We already see a statistically significant increase in ship speeds for the next largest oil tankers: +2.3% for 120,000–199,999 dwt and +1.4% for 80,000–119,999 dwt.

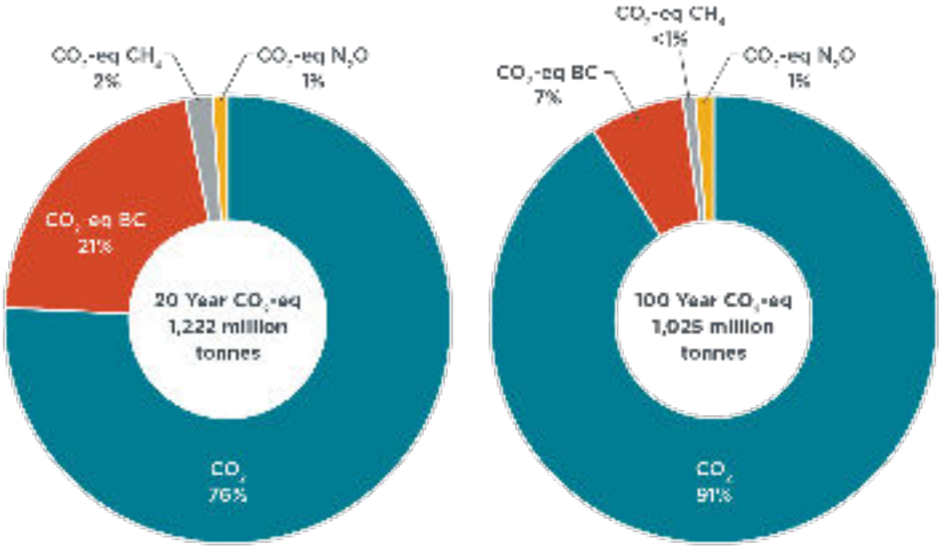


**Figure ES-3.** Total shipping $CO_2$-eq emissions, 20-year and 100-year GWP, 2015

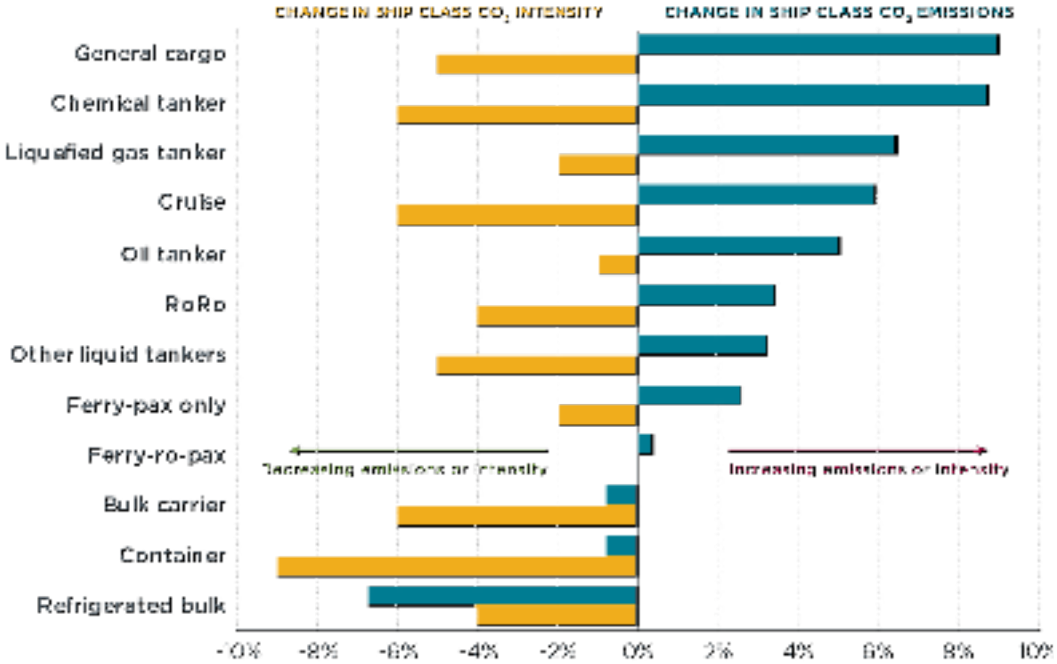


**Figure ES-4.** Change in $CO_2$ emissions and $CO_2$ intensity for key ship classes

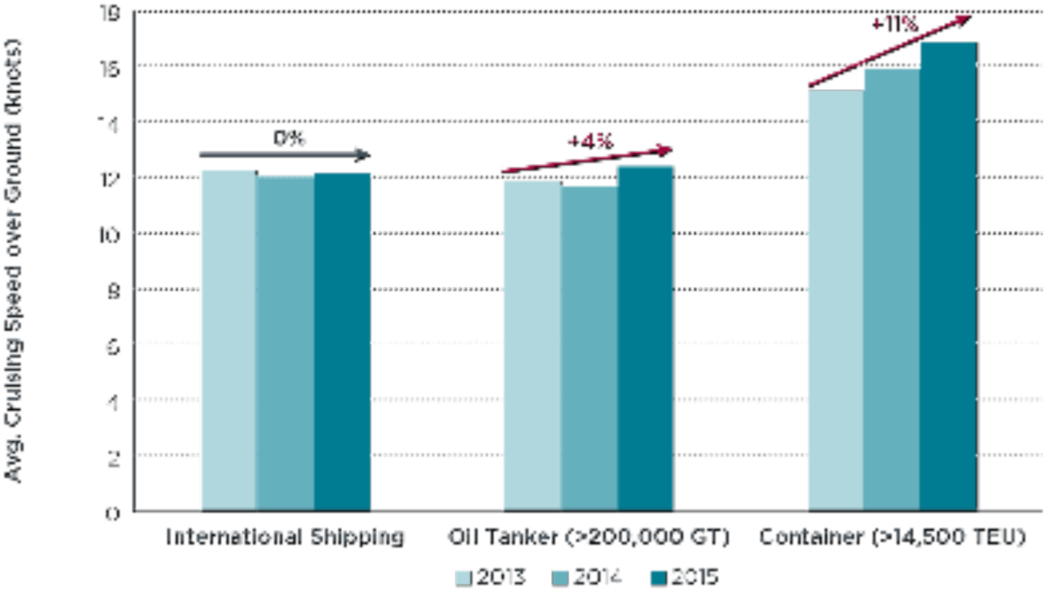


**Figure ES-5.** Changes in speed over ground for the largest oil tankers and container ships vs the international shipping average, 2013–2015

**“The Future of Rail: Opportunities for energy and the environment,” International Energy Agency, 2019 (All rights reserved)**

EXECUTIVE SUMMARY

Rail has a long-standing position as one of the pillars of passenger mobility and freight transport. Today, conventional rail provides nearly one-sixth of the world’s long-distance passenger travel around and between cities. High-speed rail provides a high quality substitute to short-distance intracontinental flights. In cities, metros and light rail offer reliable, affordable and fast alternatives to road travel, reducing congestion and carbon dioxide (CO2) emissions and local pollution. Freight rail enables high capacity goods movements over very long distances, allowing access to trade for resources that otherwise would likely be stranded and facilitating operation of major industrial clusters.

Rail is among the most efficient and lowest emitting modes of transport. With a strong reliance on electricity, it is also the most energy diverse. Rail networks carry 8% of the world’s motorised passenger movements and 7% of freight transport, but account for only 2% of energy use in the transport sector. Rail services consume less than 0.6 million barrels per day (mb/d) of oil (about 0.6% of global oil use) and around 290 terawatt-hours (TWh) of electricity (more than 1% of global electricity use). They are responsible for about 0.3% of direct CO2 emissions from fossil fuel combustion and the same share (0.3%) of energy-related emissions of fine particulate matter (PM2.5). The high efficiency of train operations means that rail saves more oil than it consumes and more emissions than it generates. If all services currently performed by railways were carried by road vehicles, such as cars and trucks, then the world’s transport-related oil consumption would be 8 mb/d (15%) higher and transport-related greenhouse gas (GHG) emissions would increase by 1.2 gigatonnes (Gt) CO2-equivalent (CO2-eq) on a well-to-wheel basis.

Most rail networks today are located in India, the People’s Republic of China, Japan, Europe, North America and the Russian Federation, while metro and light rail networks operate in most of the world’s major cities. About 90% of global passenger movements on conventional rail take place in these countries and regions, with India leading at 39%, followed by the People’s Republic of China (“China”) (27%), Japan (11%) and the European Union (9%). Globally, about three-quarters of conventional passenger rail activity use electricity, and the remaining quarter relies on diesel. Significant investments have been made in high-speed rail and metros, most notably in China, which has overtaken all other countries in terms of network length of both types within a single decade. Today China accounts for about two-thirds of high-speed rail activity, having overtaken both Japan (17%) and the European Union (12%). The regional distribution of urban rail activity is more even; China, European Union and Japan each have around one-fifth of urban passenger rail activity. Both high-speed and urban rail are entirely powered by electricity. Freight movements are concentrated in China and the United States, each of which accounts for about one-quarter of global rail freight activity, and the Russian Federation (“Russia”), which accounts for one-fifth. Despite the fact that electrification of freight rail faces greater challenges than other rail types, half of global freight movements rely on electricity.

The future of rail will be determined by how it responds to both rising transport demand and rising pressure from competing transport modes. Rising incomes and populations in developing and emerging economies lead to strong demand for mobility, but social considerations and the need for speed and flexibility tend to favour car ownership and air travel. Rising incomes also drive demand growth in freight, where higher incomes, together with digital technologies, have sharply increased demand for rapid delivery of higher value and lighter goods. The rail sector has important advantages to exploit in competing for business, but this will require additional strategic investments in rail infrastructure, further efforts to improve its commercial competitiveness and technological innovation.

In the Base Scenario, annual investment in rail infrastructure increases to USD 315 billion (United States dollars) in 2050, on the basis of projects currently in various stages of construction and planning. In this scenario, which assumes no significant new emphasis on rail in policy making, the pace of infrastructure build is fastest in urban rail. The length of metro lines under construction or slated for construction over the coming five years is twice the length of those built over any five-year period between 1970 and 2015. The result is unprecedented growth in passenger movements on urban rail; global activity in 2050 is 2.7 times higher than current levels. Growth is strongest in India and Southeast Asia, which see more than a sevenfold growth in passenger movements on urban rail, albeit from a low baseline. In the three countries with the highest urban rail activity today, activity increases by more than threefold in China, 25% in Japan and 45% in the European Union.

The Base Scenario also sees strong growth in high-speed rail networks, particularly over the coming decade. As has been the case over the past decade, China accounts for a large share of high-speed rail developments; nearly half of those projects undertaken between now and 2050 are in China. The result is strong activity growth on high-speed rail: passenger movements in China increase more than threefold, while those in Japan increase by 85% and by 66% in the European Union. Construction of non-urban rail infrastructure in India is particularly notable, supporting volumes of passenger activity that, by 2050, are unparalleled anywhere in the world. However, despite impressive global growth, rail does no more worldwide than maintain its current share in activity relative to personal cars and passenger air travel by 2050. Global freight activity across all categories nearly triples in 2050 from 2017 levels.

Strong growth of rail activity in the Base Scenario brings up rail energy demand: by 2050 rail electricity use reaches nearly 700 TWh. By 2050, 97% of passenger rail movements and two-thirds of freight take place on electrified rail, meaning that rail remains far and away the most electrified of all transport modes. Rail's energy use, however, pales in comparison with the energy it saves by diverting traffic from other modes. In 2050, if all rail services were performed by cars and trucks, oil demand would be 9.5 mb/d higher (or 16%) higher than in the Base Scenario. GHG emissions from transport would increase by 1.8 Gt CO2-eq (or 13%) above the Base Scenario in 2050. Fine particulate matter (PM2.5) emissions would rise by 340 kilotonnes (kt).

The High Rail Scenario explores how these benefits might be further capitalised. The scenario rests on three pillars: Minimising costs per passenger-kilometre or tonne-kilometre moved by ensuring maximum rail network usage, removing technical barriers and integrating rail services seamlessly into the portfolio of available mobility options. Maximising revenues from rail systems, such as through "land value capture", i.e. capitalising on the "aggregation" capacity of railway stations whereby commercial and residential properties in their proximity increase in value due to improved mobility options and greater activity, and using this value to finance rail systems. And implementing policies that ensure that all forms of transport pay adequately for the impacts they generate. Traditionally this has been accomplished through fuel taxes, but road pricing, and especially congestion charging, may be effective going forward.

In the High Rail Scenario, global passenger activity on rail grows to a level that is 60% higher than in the Base Scenario in 2050, and freight activity is 14% higher. Urban rail has the greatest potential for additional growth: activity on metros and light rail in 2050 is 2.6 times higher than in the Base Scenario, concentrated in densely populated cities in China, India and Southeast Asia. The High Rail Scenario also captures the potential for high-speed rail to provide a reliable, convenient and price competitive alternative to short-distance intracontinental passenger air services. Activity on high-speed rail in the High Rail Scenario is 85% higher than in the Base Scenario, reflecting strategic investments in this mode.

Aggressive, strategic deployment of rail can lead CO2 emissions in global transport to peak in the late 2030s. By 2050, oil use in the High Rail Scenario is more than 10 mb/d lower than in the Base Scenario. GHG emissions are 0.6 Gt CO2-eq lower and PM2.5 emissions are reduced by about 220 kt, the latter primarily as a result of diminished aggregate vehicle kilometres by cars and trucks. Primarily as a result of increased urban and high-speed rail operations, electricity use by rail in 2050 is 360 TWh higher than in the Base Scenario, 50% more than in the Base Scenario, an increase that is roughly equal to the current total electricity consumption of Thailand and Viet Nam combined.

Annual average investment in the High Rail Scenario in trains and rail infrastructure combined is USD 770 billion, a 60% increase over investment in the Base Scenario. The biggest part of the increased investment goes to infrastructure for urban rail (nearly USD 190 billion) and high-speed rail (USD 70 billion); the additional costs of the trains are small in comparison. As a result of these investments, in 2050 fuel expenditures are reduced by around USD 450 billion, relative to the Base Scenario. India could save as much as USD 64 billion on fuel expenditures by mid-century.

Rail activity in India – a special focus in this report – is set to grow more than any other country, with passenger movements in India reaching 40% of global activity. Activity in India is already among the highest in the world, being second only to China for passenger movements and fourth for freight movements. Rail remains the primary transport mode in India connecting numerous cities and regions. Indian Railways is also the country's largest employer. As a result, the railway network in India is sometimes referred to as the lifeline of the nation. Guaranteeing affordable passenger mobility by rail to the entire population has always been a priority in India. Today rail passengers in India travel 1.2 trillion kilometres, more than the distance travelled by cars; and about one-third of total surface freight volumes are transported by rail, a very high share by global standards. By far, coal is the predominant commodity carried on freight trains today in India.

Indian Railways is spearheading a wide range of ambitious undertakings. Construction has started on the first high-speed rail line. The total length of metro lines is planned to more than triple in the next few years. Two dedicated freight corridors are planned to enter operation in 2020. The country is set to double, or possibly even triple, existing capacity on the most utilised rail routes, and it aims to electrify the entire broad gauge network by 2022. With these and other measures realised in the Base Scenario, rail passenger movements almost triple and freight movements more than double over current levels by 2050. Electricity consumption from rail operations increases by nearly a factor of six, reaching almost 100 TWh. Electrification of highly utilised corridors leads to reductions in oil use by rail to less than 10% of current levels, reaching 3 000 barrels per day in 2050. As in other countries, rail in India saves more energy and emissions than it consumes: in the Base Scenario, rail activity in 2050 reduces oil demand by 1.6 mb/d, GHG emissions by 270 Mt CO2-eq and PM2.5 emissions by 8 kt.

Going beyond the targets captured in the Base Scenario, India has the potential to serve as an example to other emerging economies. In the High Rail Scenario, India further increases investment in railways, commissioning high-speed rail lines to connect every major city along the “Golden Quadrilateral”, achieves the target of doubling the share of rail in urban areas by 2050 and constructs dedicated freight corridors to connect all the largest freight hubs. Shifts in transport activity from road modes and aviation lead to additional savings in oil consumption of 1.5 mb/d, compared to the Base Scenario, and to an additional reduction in GHG emissions of 315 Mt CO2-eq and 6 kt of PM2.5.

Two categories – urban and high-speed rail – hold major promise to unlock substantial benefits both in India and throughout the world. In an era of rapid urbanisation, urban rail systems can provide a reliable, affordable, attractive and fast alternative to travel by road: metro and light rail can reduce congestion, increase throughput on the most heavily trafficked corridors and reduce local pollutant and GHG emissions. With co-ordinated planning, urban rail systems increase the attractiveness of high-density districts and boost their overall economic output, equality, safety, resilience and vitality of metropolises. High-speed rail can provide a high quality substitute for short-distance intracontinental flights. As incomes rise, demand for passenger aviation, a mode of transport that is extremely difficult and expensive to decarbonise, will continue to grow rapidly. If designed with comfort and reliability as key performance criteria, high- speed rail can provide an attractive, low-emissions substitute to flying.

# 4.3 Pandemic paradigm shift | Creative writing

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?

## 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?**