



SKYSCRAPERS

HANDBOOK

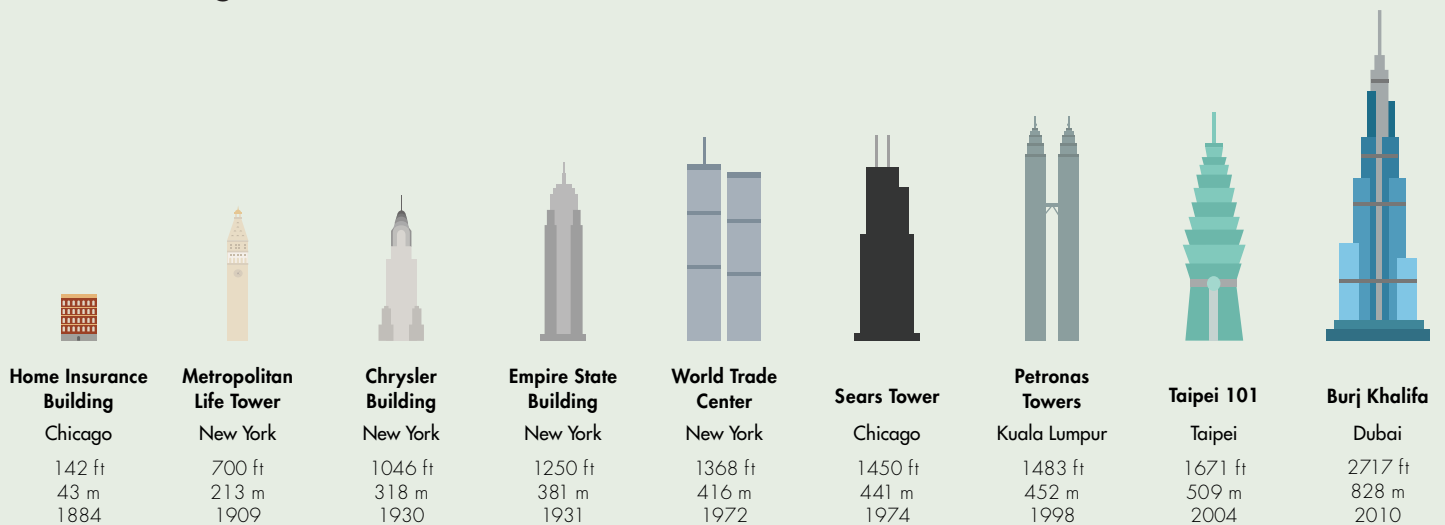




Skyscrapers are super tall buildings. They are so tall—at least 500 feet or 150 meters tall—they look like they could touch or scrape the sky. Skyscrapers tower around us in cities across the world, making space in crowded places for people to live and work.

The first skyscrapers were built in the U.S., in Chicago, Illinois, in the 1880s. The city and its businesses were growing so quickly that the city—bordered by a river and a lake—quickly ran out of space. The only option was to build up, as high and as fast as possible. Today, cities continue to grow upwards to accommodate more and more people.

Tallest buildings in the world over time



Skyscrapers are created by architects and engineers. Architects design how the building looks inside and out. They have to think about how a skyscraper will fit in with the other buildings in a city and what the people using the building will want and need. Engineers decide how to construct the building an architect has designed. They must consider how the building will stand given the soil under it and how other forces, like wind and earthquakes, will act on it. They also have to figure out how people, water, and electricity will travel through it.

In the *Skyscrapers* app, we'll explore how skyscrapers look, how they are built, and how people, water, and electricity move in them.



Skyline

View, rearrange, or change your buildings



Form: height, floors, façade & top

Investigate and design how a building looks



Structure: steel frames & foundations

Explore and test the strength of a building



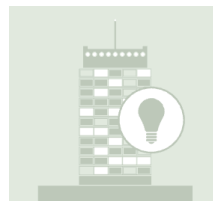
Elevators & stairs

Discover how people travel in a skyscraper



Water

Investigate how water travels in a skyscraper



Electricity

Investigate how electricity travels in a skyscraper



IN THE APP

We encourage open play and close observation. Use the toolbar on the left to navigate through your skyline, form, structure, elevators and stairs, water, and electricity.

DIG IN

Tap the gear in the toolbar to turn interactive text labels on or off.



Close-ups are marked by a round pin. Tap them to open and explore more.

Panels will appear on the right in some scenes. Drag items from the panels into the building and see what happens.



Observe how people act and react to what is going on in the building. Tap people to make them move and use the elevators, the bathrooms, and different parts of the building.

DISCUSSION QUESTIONS

What do you think people do inside of skyscrapers? What do you think those people need?

Imagine that you are in charge of building a skyscraper. Who will you need to hire? What skills will you need? What types of workers would you find on a skyscraper construction site?

Can you think of any inventions that might make a skyscraper more comfortable to live or work in? What about ones that would make skyscrapers more environmentally friendly?



Skylines

Skyscrapers are so big that they become an important part of a city's culture and appearance. The most iconic skyscrapers in the world have silhouettes that people recognize just as they would the peak of a beloved mountain or the face of a friend. Architects think about how a skyscraper will look on its own, as well as how it looks next to, behind, or in front of the buildings around it. All of the structures together create the **skyline** of a city. Just like all the buildings that make it up, skylines are unique to their cities.

Skyscrapers often reflect the culture and values of the people who live in the cities they're built in. For example, the Makkah Royal Clock Tower in Mecca, Saudi Arabia, has a giant clock, making the time—a significant element to Muslims—visible to people within the city and to those approaching from a road. Taipei 101, in Taipei, Taiwan, was designed in eight sections because eight is a Chinese lucky number; the word for eight in Chinese sounds similar to the word for prosperity.



IN THE APP

Tap the + to add a new building to your skyline.

Drag buildings to arrange your skyline. Observe what happens to their foundations.

Tap a building to enter and edit it.

Drag a building up to the recycling bin to delete it.

DISCUSSION QUESTIONS

Are there skyscrapers in your city or town? What do they look like?

Why do you think they look that way?

If you were designing a skyscraper for your town or city, what would you design for the top? Why?



Form:

HOW SKYSCRAPERS LOOK

HEIGHTS & FLOORS

Skyscrapers are at least 500 feet or 150 meters tall and are made up of at least 30 levels, or floors. Early skyscrapers were built just for people to work in, but now most include floors for people to live in, too. Some skyscrapers are basically little cities with floors that include everything people might need, including supermarkets, restaurants, and parks.

Living spaces, hotels or apartments, are usually on the upper floors of skyscrapers so people can enjoy the view. You can often see your whole city from the top of a skyscraper! Offices, spaces for people to work in, are usually on the lower floors. **Mechanical floors**, levels for storing all the equipment needed to operate and maintain the building's plumbing, electricity, heating, cooling, and communications equipment, are layered in between. And sometimes, businesses like restaurants and supermarkets are on the ground floors of skyscrapers.

There's more to a skyscraper than what you can see above ground. Like the roots of a tree, skyscrapers have layers of concrete below ground, called the **foundation**, that holds them up and keeps them strong and stable. Without a foundation, skyscrapers would collapse or sink. The taller a skyscraper is, the deeper the foundation must go into the ground.



IN THE APP

Drag floors into your building. What types of floors can you add?

Observe what happens to the foundation as you add floors.

(Please note: the app is scaled down on a 3:1 ratio. Each floor added to a building in the app represents three floors of a real building. So, a small skyscraper made up of 10 floors in the app represents 30 floors in a real building. A large skyscraper of 50 floors in the app represents 150 floors in a real building.)

DISCUSSION QUESTIONS

Why do you think skyscrapers are built above ground and not below the ground?

What are some things that people want and need in buildings that would not be possible underground?

FAÇADE & TOP

As they design skyscrapers, architects think about how both the inside and the outside of the building will look and be used by people. The exterior of a building, the façade and the top, can be both decorative and functional.

The outside or “skin” of a building is called the **façade**. The façade of a skyscraper is called the **curtain wall**. The curtain wall keeps air inside a skyscraper and prevents outside air and water from getting in so people stay comfortable, not too hot or too cool, and of course, dry. The curtain wall includes **windows** and the spaces in between them, called **spandrels**. The curtain wall isn’t otherwise structural. It only supports its own weight so the architect can choose a material—stone, glass, concrete, or steel—depending on how they want the building to look.

The tops of skyscrapers can have clocks (like the Makkah Royal Clock Tower), radio and television towers, or decorative spires. Decorative lights, viewing decks, and gardens on the tops of buildings can make skyscrapers nice places for people to visit. The tops of skyscrapers might also have spires just to make them taller. As long as people have been building skyscrapers, people have been trying to build the world’s tallest. Spires and unoccupied floors are cheap and easy ways to make a building taller.

While New York’s Chrysler Building was under construction, from 1928 to 1930, its sparkling spire was hidden inside. At the last minute, the builders put up the spire, winning the title of the tallest building in the world from the Bank of Manhattan Trust Building which had been the tallest (but only for a month!). The Chrysler Building also lost the tallest building title quickly when the Empire State Building was completed within a year. Now in 2016, the Burj Khalifa is the tallest building in the world; the top 29% of it is unoccupied space.



IN THE APP

Swipe to change the curtain wall and top of your skyscraper.

Tap the top of your building and see what happens.

Tap the palette to change the color of your building.

DISCUSSION QUESTIONS

Some cities have restrictions on how tall a building can be.

Why do you think people would keep buildings shorter?

Why would they want to build higher?

Imagine you are designing a building for your city.

What would the top look like? Why?



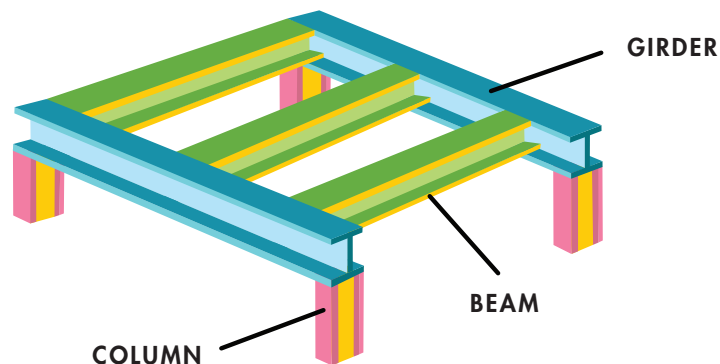
Structure:

HOW SKYSCRAPERS ARE BUILT

STEEL FRAMES & FOUNDATION

Things you see every day can lead to great discoveries. In 1884, William Le Baron Jenney saw his wife rest a heavy book on top of a steel birdcage. He quickly realized that steel structures could support much heavier loads and steel frames could be used to make tall buildings. Before Jenney's discovery, tall buildings were supported by their walls. The higher a building, the thicker the walls needed to be. But, thick walls take up space; they can only be so thick before a building doesn't have much usable space inside, which limits how tall a building can be.

Now engineers design **steel frames** to support a building the way your bones support the rest of your body. In the steel frames of a skyscraper, vertical steel columns are bolted firmly to horizontal **beams** and **girders**. Beams connect girders to other girders. Girders connect columns to other columns. Columns connect to the **foundation**, which distributes the building's weight over and down into the ground.



The soil and ground under a skyscraper influence the engineering of the building. Different types of soil offer different amounts of support. Soft clay soil is less stable than soil with lots of gravel in it. Hard bedrock is the most stable. Engineers study the soil and rocks beneath a building site to see what their foundation needs to do to compensate.

The stiffness of the steel frame combined with grounding from the foundation helps skyscrapers hold both a dead load and a live load. The **dead load** is the weight of the building. The **live load** is the weight of people, furniture, and everything else in the building, as well as wind, earthquakes, and other forces that act on a building. While the dead load of the building won't change, the live load can as people enter and leave a building, or in the middle of a big storm. Engineers have to prepare their buildings to hold up to the dead load as well as any changes in the live load.

To withstand high winds and earthquakes, skyscrapers sway and move with the forces acting on them. This isn't dangerous but it can make the people in them feel sea sick. So, engineers place giant counterweights in the top of buildings called **tuned mass dampers**. Tuned mass dampers swing as the building moves, applying an opposite force to balance the wind's effects and to keep the building steady. Think of tuned mass dampers when you're on a swing. To swing higher and faster, you pump your legs and move with the swing. But if you move your legs and body in the opposite direction, you slow down and can stop swinging. Tuned mass dampers work the same way. In some buildings, like Taipei 101, seeing the tuned mass damper is reason enough to visit!

To protect it from lightning, skyscrapers have **lightning rods**. Lightning usually hits the tallest thing in its path as it travels down from the sky—a skyscraper might be hit two to eight times during a single storm! Instead of hitting the building directly, lightning will strike the rod, travel down the side of the building through a wire, and down into the ground through a **grounding rod**. The building

doesn't get any electricity from this, but the rods protect the building and the people in it.



IN THE APP

Tap to create wind and lightning. Tap or shake to create an earthquake. What protects people in the building from these things?

If your building has a tuned mass damper (hint: it must have 18 floors or more), observe what it does in a windstorm or earthquake.



In the close-up, drag and add elephants, dinosaurs, and other objects into your building. What happens? Then swipe the ground beneath the building to change it. How does each ground type affect the way your skyscraper reacts to weight?

DISCUSSION QUESTIONS

Steel is a relatively lightweight material. The steel frames of skyscrapers support weight much greater than their own. Can you think of or find any other examples of a light frame supporting something heavy in your house? Look around your bedroom, kitchen, and backyard.



Elevators & stairs

Building up in a skyscraper gives us more useable space—but only if we can get to it. Being able to move up and down in a building can limit or expand our ability to build taller and taller skyscrapers. In early tall buildings, people had to walk up and down stairs. Elevators were eventually installed in the lobbies of luxury hotels, in the 1860s, to save guests from the work of climbing stairs. Called “moveable rooms,” these elevators were lavishly furnished with carpets, chandeliers, and benches. By the 1870s elevators were being used in office buildings. Now, more than seven billion elevator journeys are taken in tall buildings all over the world.

While more people in a building require more elevators, having more elevators doesn’t necessarily make a building better. Like wide walls used to, elevators take up space. If you fill your entire building with elevators, there’s not much room left for people to live and work. There must be a balance between elevators, space, and the number of people a building will have.

Elevators are often in the **core** of a building, a central area for mechanical equipment. Elevators move up and down in **elevator shafts** which are grouped in banks of about eight elevators. One bank of elevators can serve 15-20 floors, two banks up to 35 floors. Three banks are needed for 40-45 floors and so on. A really tall skyscraper with more than 60 floors might have local elevators that travel to every floor and express elevators that skip to higher floors.

A bank of elevators might have different rules for each — the ones on the left side of a bank serve floors 1-30, the ones on the right serve 30-60, for example, or some may only serve residential or commercial floors.

While elevators are useful, skyscrapers still have stairs. There are usually at least two staircases on opposite sides of a building. People can take the stairs to avoid waiting for an elevator, when elevators aren't working — especially in an emergency — if the power goes out, or when fires make elevators unsafe. In an emergency, it takes about one minute per floor to evacuate people by stairs. It could take up to two hours to fully evacuate a super tall building but it's still the safest way to go.

IN THE APP



Tap people to put them in elevators. Drag to move the elevators up and down. Does every elevator stop at every floor? Why not?

In the close-up: tap people to put them in elevators. Drag to move the elevators up and down. Observe how people react.

DISCUSSION QUESTIONS

Imagine you are an engineer. Would you design an elevator to stop at every floor? Why or why not? What information would you need to decide how many elevators a building needs?

Would you want to live in a skyscraper without stairs? Without elevators? Why or why not?



Water

People on every floor of a skyscraper need water to drink, to flush toilets, to wash their hands, and for lots of other things. They also need water in sprinklers throughout the building to protect them in case there's a fire. But water is heavy and has to travel a long ways up in a skyscraper.

Getting water to all of a skyscraper's floors is a huge engineering feat. City water supplies only have enough pressure to reach the first few floors of a tall building. So, engineers include **pumps**, powered by electricity, to push water up to all the floors in a skyscraper. As water is pumped up, it fills **tanks** that sit on the mechanical floors. The tanks are backup sources of water, in case the power goes out and the pumps can't move water for a period of time. The tanks also allow the high water pressure that it took to move the water up to lower so the water can flow more slowly out to faucets and toilets.

But, what goes up, must come down. The toilets, sinks, and tubs from each floor connect to **drain pipes** that drain waste and wastewater down toward the sewer. The pipes also vent up out of the roof to let gas and smelly air rise and escape. Drain pipes move water out of the building and into the municipal sewage treatment system — in most cases. The Burj Khalifa is not connected to a municipal sewage system, so waste has to be carried out by trucks!

Sprinklers also send water down, when there's a fire in a skyscraper. Sprinkler heads contain a liquid that expands under heat and causes the glass surrounding them to break (normally at temperature above 150° F or 64° C). Once the glass breaks, water pressure sends water out and down through a room.

IN THE APP



Tap water pipes to see where and how water travels.

Drag the wrench to fix a water pump when it breaks.

Drag flames to start a fire. What happens?

In the close-up, drag toilet paper or a rubber duck to the toilet. What happens?

DISCUSSION QUESTIONS

What would happen if a pump broke in the building? A pipe?

Why would toilets be in the same place on each floor of a building?



Electricity

The people living and working in a skyscraper need electricity, just like you do at home, to run heating and cooling systems, lights, equipment, and appliances. But buildings this big need and use a lot more power than we do at home.

Electricity travels into a building with a great force, or a high voltage, through a **transformer**. Transformers decrease the voltage of electricity so it is safe to use in each of the spaces throughout a building.

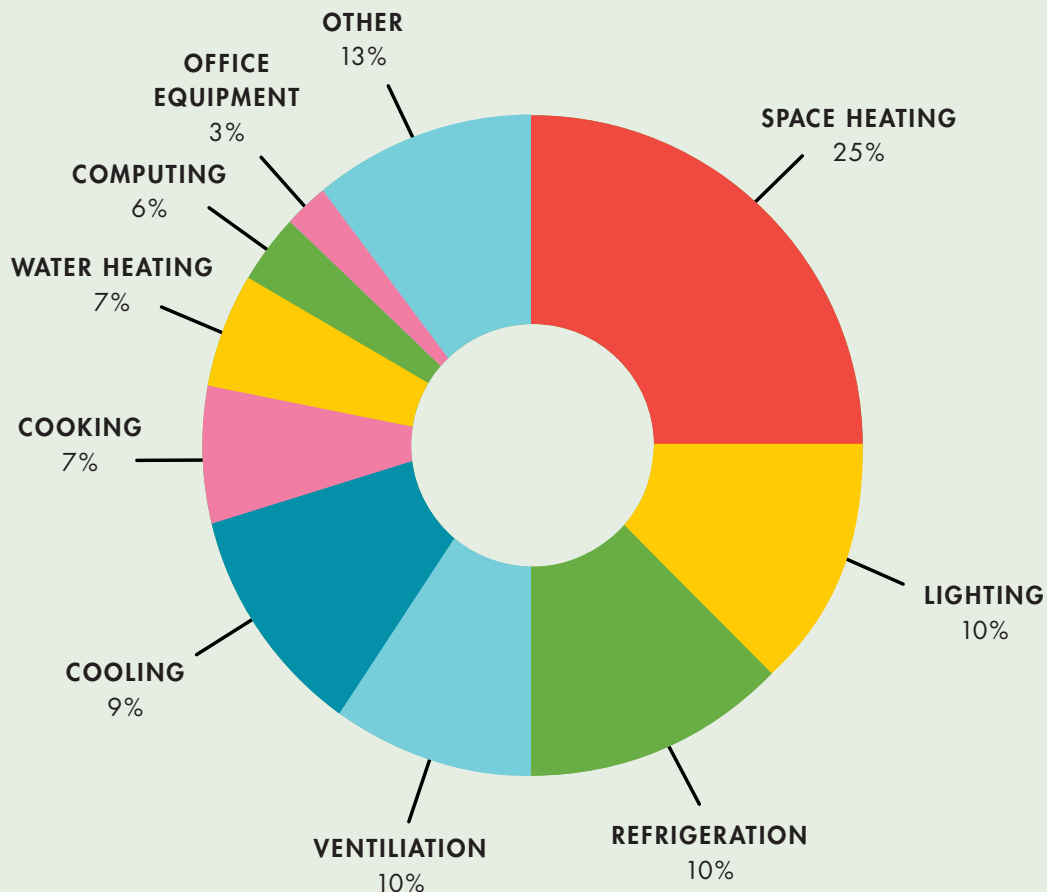
Next, electricity travels to a **switchgear**. The switchgear sends electricity safely and efficiently to mechanical floors throughout the building. Mechanical floors house safety features, including **breaker boxes**, which are filled with small switches called **circuit breakers** that can control a whole floor of a building or a small system, like ones you might have in your home that control just a room. Circuit breakers allow people to stop the flow of power if there's an emergency or electrical work needs to be done.

A switchgear and breaker boxes will automatically stop the flow of power if too much is being used in one place. Too much power can be dangerous; it can cause overheating, melting, and sometimes, a fire.

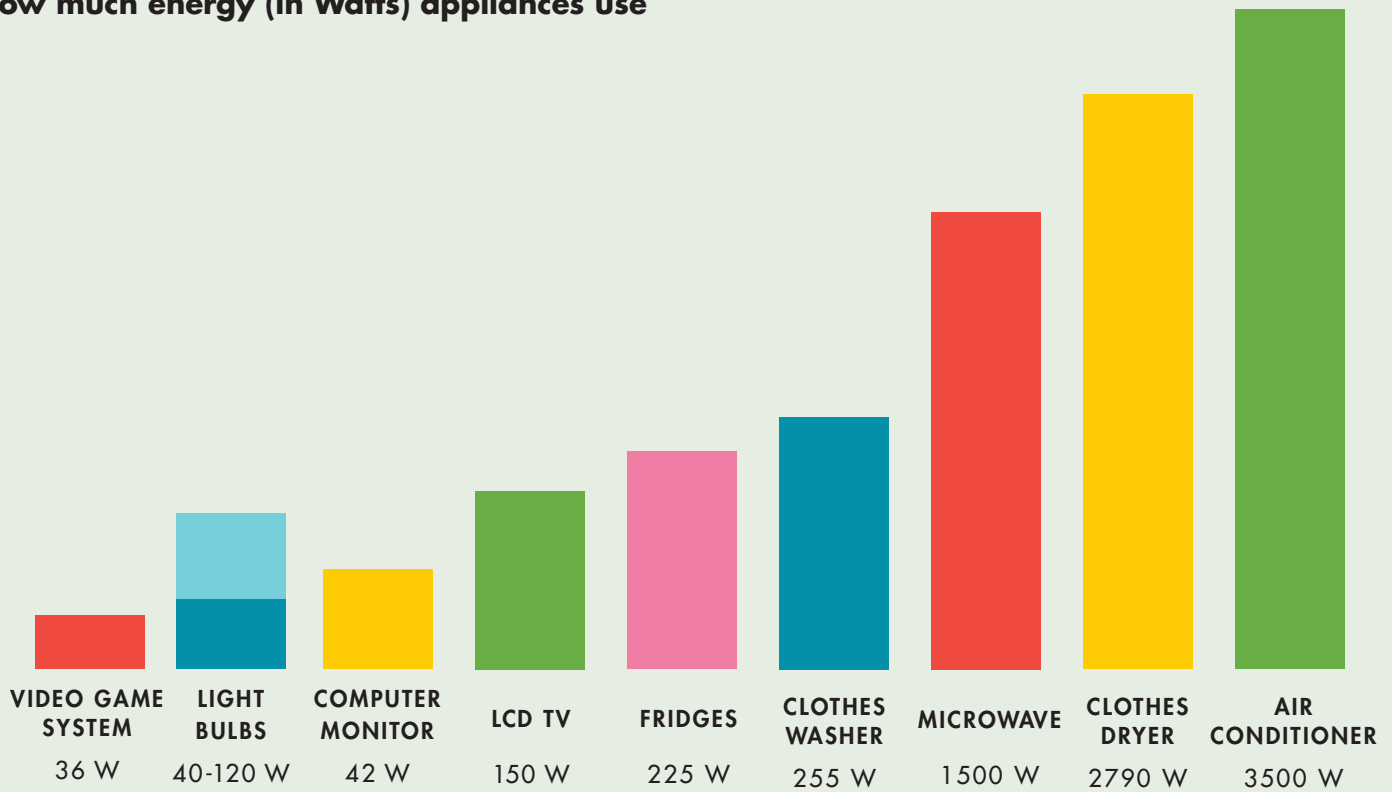
As electricity enters a building, it's measured by a **meter**. Sometimes just one meter measures how much electricity an entire building uses. Other times several meters measure how much each floor, office, or apartment in a building uses. Electricity costs money; the more electricity a floor, office, or building takes and uses, the higher the electricity bill.

Different systems and appliances use different amounts of electricity at different times. A microwave, for example, uses a lot of electricity for a very short period of time. Lights use less electricity but they are on for a longer period of time. Any appliance that is plugged in uses some power, even if it is not being used. You can save electricity by plugging devices and appliances into a power strip and turning it off when it is not in use.

Average energy usage of a commercial building over the course of a year



How much energy (in Watts) appliances use



IN THE APP

Tap to turn lights on in the building. Turn on as many as you can. What happens?

In the close-up: tap lights, computers, and appliances to turn them on and off. What happens to the meter at the top?

DISCUSSION QUESTIONS

How could you reduce the use of electricity in a building?

What are some other types of power that can be used to generate electricity (solar, wind, geothermal)? How could you integrate these into a skyscraper?

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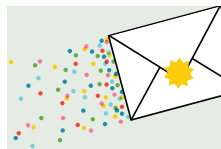
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