# Today I Learned About Materials

"As technology has become amazing and advanced, we increasingly make things more complicated, meaning more elements ... which makes it more difficult to manage at end of [the product's] life. We sometimes make the joke that you carry the periodic table in your pocket."
*Professor Elsa Olivetti, MIT Department of Materials Science & Engineering*
*TILclimate podcast: Today I Learned About Materials*

## The Periodic Table in Your Pocket

The average smartphone contains more than 30 separate chemical elements (more than a quarter of the periodic table) in many combinations.[1] While this makes the device the technological wonder that it is, it also makes it difficult to separate those elements for recycling after a user upgrades to a new phone. US *e-waste* (cell phones, computers, wearables, etc.) is often sent overseas to be recycled. There are many materials in e-waste that then affect human and environmental health in these countries.

What if we could better separate and handle the materials in our e-waste? According to the United Nations (UN), "industrial and consumer products containing [chemical elements] have often been regarded as waste material rather than as 'surface mines' waiting to be exploited. This is a nearsighted and unfortunate view... [W]e limit our technological future by using these resources once and then discarding them through neglect, poor product design, or poor planning."[2]

## What is Recyclable, What is Recycled?

On the next page, find infographics that describe some of the elements that go into a smartphone, and the average recycling rates for those elements worldwide.

1. What do you notice? Does anything surprise you?
2. We often focus on recycling as an eco-friendly action and forget that 'reduce' and 'reuse' come before 'recycle.' In the case of the materials in electronic devices, what would 'reduce' and 'reuse' look like?
3. What did the UN report mean that products containing these elements could be seen as 'surface mines'? Research programs or organizations that are working to increase the safe harvesting of e-waste materials.
4. Engineers and designers are working to develop electronic devices that are more fully recyclable, so that their materials can be reused again and again. Research one of these projects – how are they thinking about materials use?

1 The Chemical Elements of a Smartphone https://www.compoundchem.com/2014/02/19/the-chemical-elements-of-a-smartphone/
2 United Nations Environment Programme, Recycling Rates of Metals, 2011
https://wedocs.unep.org/bitstream/handle/20.500.11822/8702/Recycling_Metals.pdf

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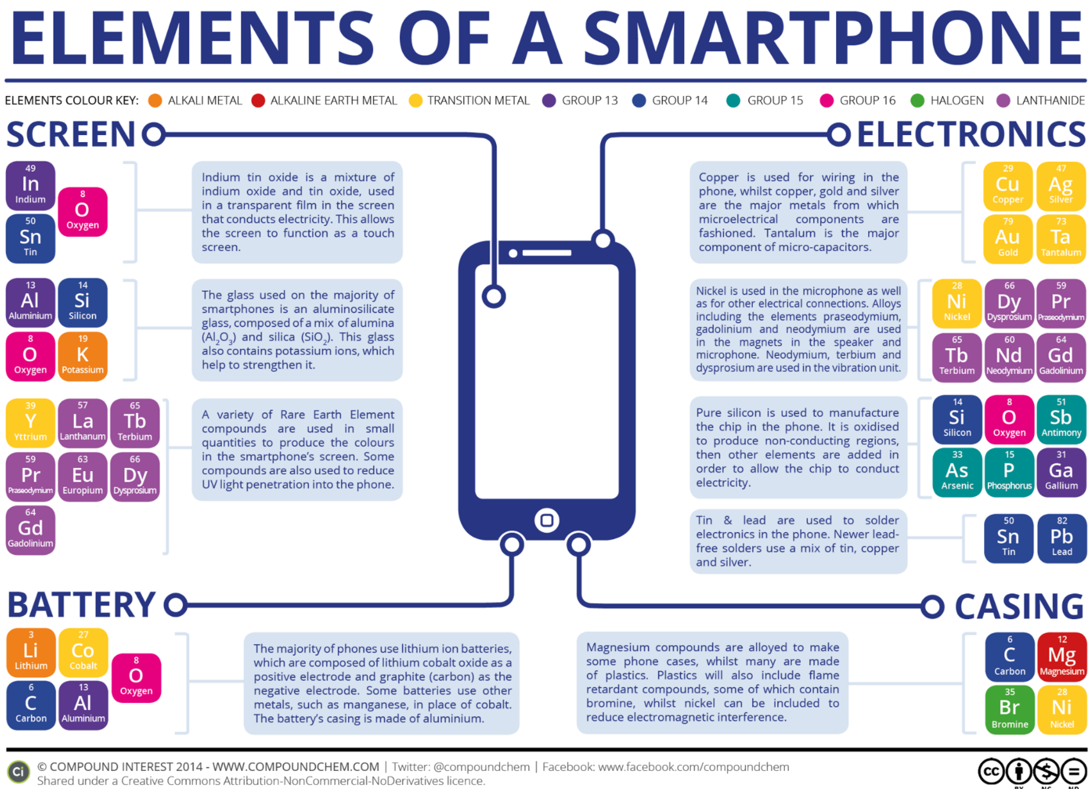


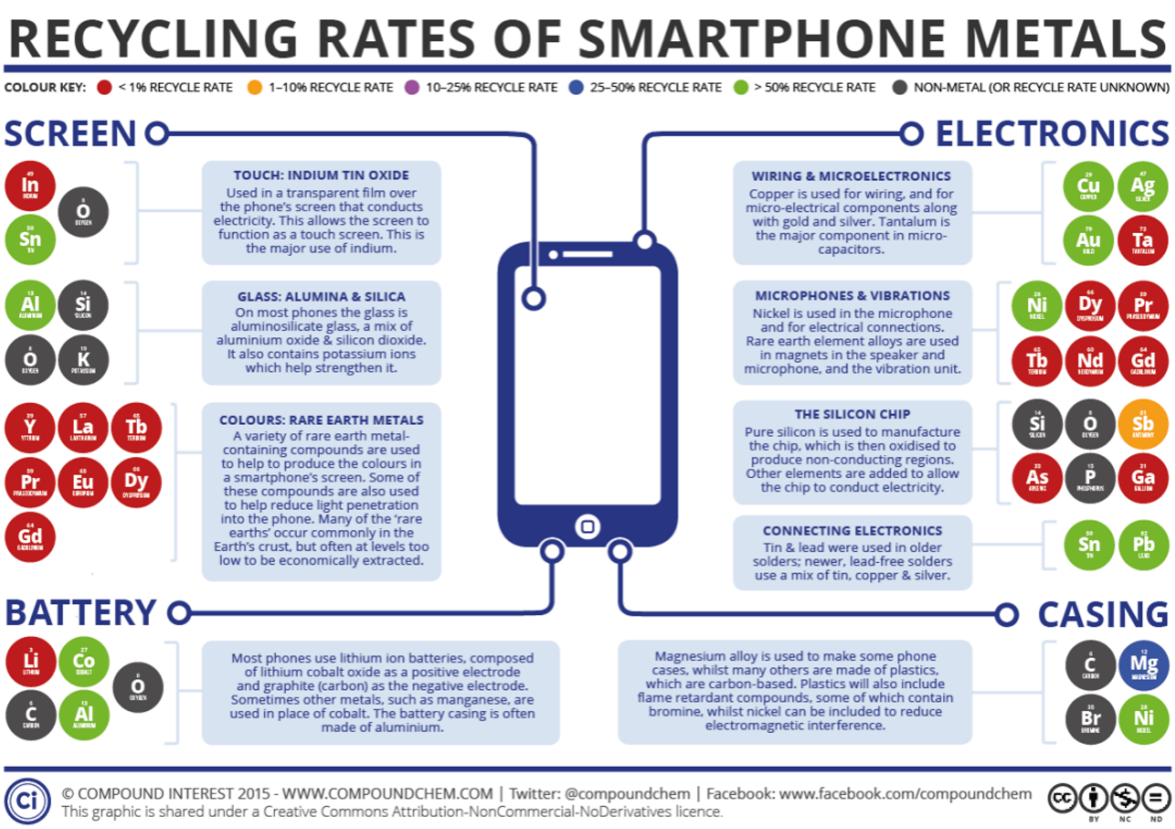

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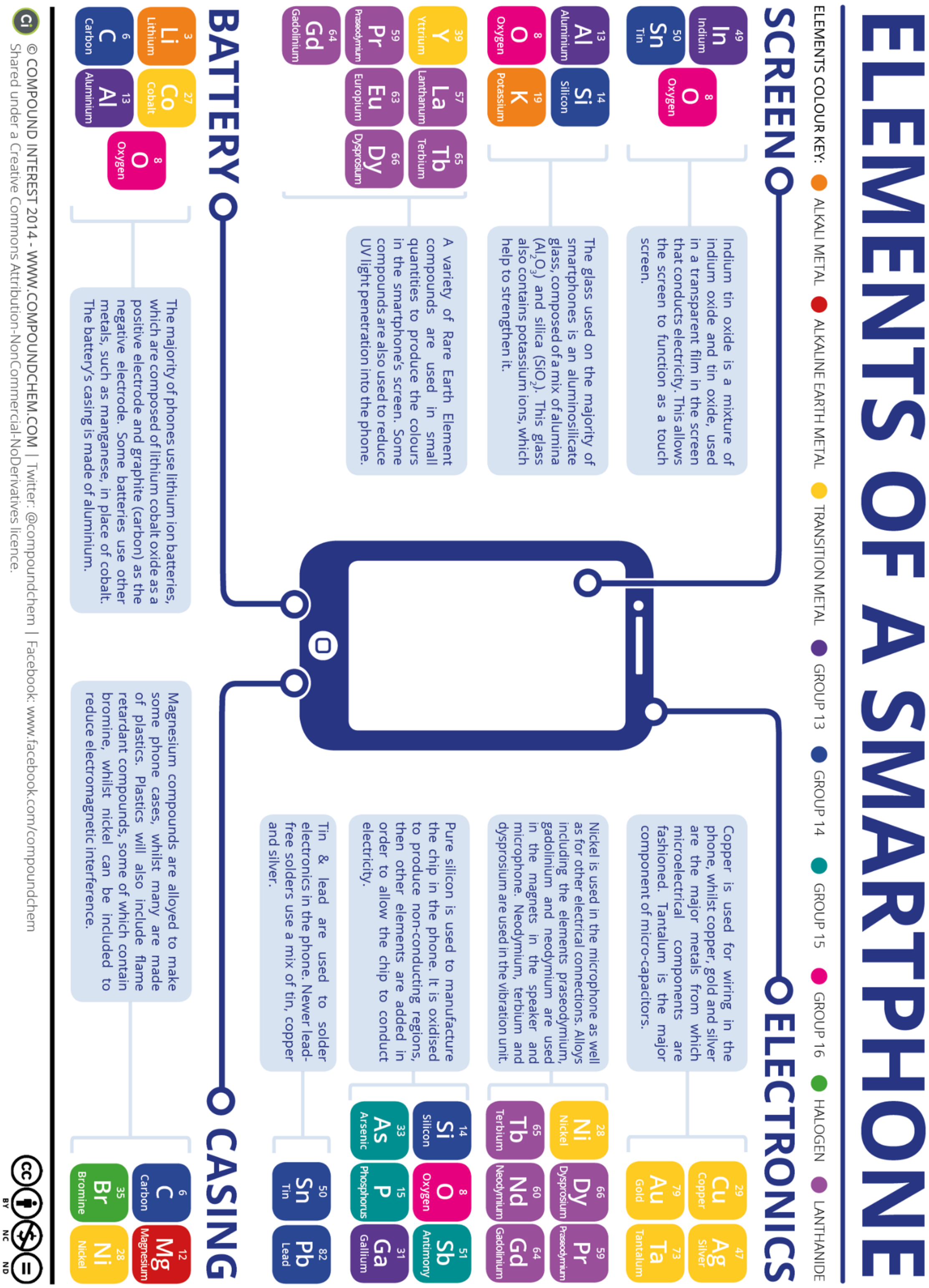

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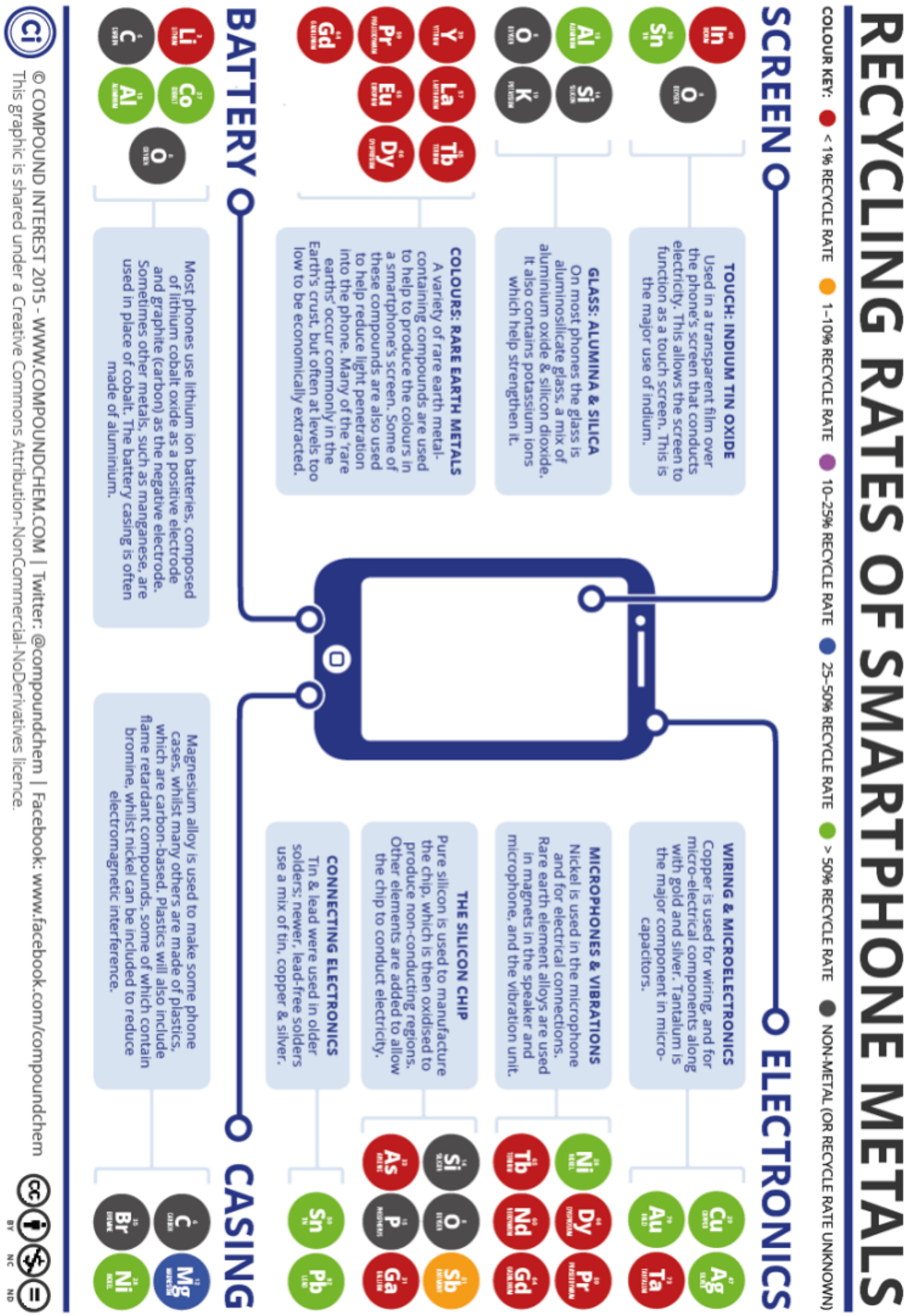

# Today I Learned About Materials

"The majority of [$CO_2$ emissions from materials and manufacturing] is steel and cement. Aluminum and paper and plastic are all about five to ten percent... Focusing on innovations in steel and cement are always useful."

*Professor Elsa Olivetti, MIT Department of Materials Science & Engineering*

*TILclimate podcast: Today I Learned About Materials*

## Steel

If a new building is going up in your neighborhood (especially a very tall one) chances are the structure is made of steel. Steel is used in cars, bridges, and buildings all over the world. Steel is iron with other added elements to improve its strength and flexibility.

Steel begins its life as iron ore, mined out of the ground. From there, it is processed, melted, mixed, and reformed into the many shapes and types of steel needed. Almost every step of the steel process requires large amounts of heat. Most steel plants use coal or other fossil fuels as their primary heat source. Burning fossil fuels releases carbon dioxide ($CO_2$).

## Cement and Concrete

Walk down a sidewalk. Look at the foundation (basement) of a building. Concrete is all around us – it is the second-most used material on the planet, after water.[1] We rarely think about how it is made, or what it is made of.

As Prof. Olivetti mentioned in the podcast episode, concrete is made of a mixture of water, sand and gravel, chemical additives, and cement. Cement is the glue that holds the other materials together and gives the concrete its strength. Cement is like the flour, while concrete is like the bread that is made with the flour.

Most cement is made from heated limestone and is a major source of $CO_2$ around the world. Its production emits $CO_2$ in two main ways: As *clinker* forms in a heated kiln, $CO_2$ is released directly from the chemical reaction. To heat the kiln to the necessary 2600˚F, most cement factories burn fossil fuels, which also release $CO_2$.

## A Warming Planet

In the atmosphere, $CO_2$ acts like a blanket, trapping heat. This trapped heat is warming our Earth, ocean, and air and causing dramatic changes to weather and climate patterns all over the world.

Globally, cement accounts for around 7% of all heat-trapping gas emissions[1] while steel emits another 7% or more[2].

1 MIT Explainer: Concrete https://climate-dev.mit.edu/explainers/concrete
2 IEA (2020), Iron and Steel Technology Roadmap, IEA, Paris https://www.iea.org/reports/iron-and-steel-technology-roadmap
Images from Pixabay

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## Each One, Teach One

Each member of your group will choose one of the following articles about an innovation that is reducing the $CO_2$ emissions of steel or concrete.

**As you read:**

1. In your own words, summarize the innovation – is a new manufacturing process, material, method of construction, energy source, something else?
2. What do you find the most interesting about this innovation?
3. How does this innovation reduce $CO_2$ emissions?

**After you read:**

1. Each member of the group teaches the others about their article.
2. Discuss similarities and differences among these innovations.
3. Imagine your group was in charge of building a new youth center in your community. One key goal is for the building to meet your community's needs while emitting as little $CO_2$ as possible in its materials, construction, and use. Which of these new innovations might you use in constructing the building? What other methods, materials, or ideas have you heard about that could decrease the $CO_2$ emissions of the building?
4. Some innovations are 'multisolving' – that is, they solve more than one challenge. How do some of the solutions you learned about solve multiple problems at once?

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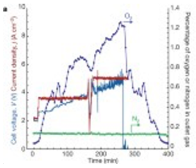
## Innovations: Steel

Reducing industrial carbon emissions https://news.mit.edu/2021/reducing-emissions-decarbonizing-industry-0721

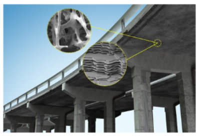


One order of steel; hold the greenhouse gases https://news.mit.edu/2013/steel-without-greenhouse-gas-emissions-0508

Taking the carbon out of construction with engineered wood https://news.mit.edu/2019/taking-carbon-out-construction-with-engineered-wood-1211

## Innovations: Cement

New approach suggests path to emissions-free cement https://news.mit.edu/2019/carbon-dioxide-emissions-free-cement-0916



Finding a new formula for concrete https://news.mit.edu/2016/finding-new-formula-for-concrete-0526

How to make stronger, “greener” cement https://news.mit.edu/2014/stronger-greener-cement-0925

# Today I Learned About Materials

"[W]hat's tricky about any of these conversations around $CO_2$ or materials use is that the numbers are huge. [H]ow do you relate them to anything that feels more concrete to us?"
*Professor Elsa Olivetti, MIT Department of Materials Science & Engineering*
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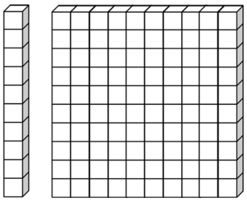
## Numbers are Hard: Science Communication



The human brain finds very large numbers difficult to comprehend. We can easily imagine 10 of something and can probably roughly estimate that we are looking at 100 of something. Once numbers get much larger than that, however, they start to be difficult to imagine, compare, and understand.

In the modern world, we are often faced with extremely large numbers: trillions of dollars in government budgets, billions of dollars owned by single individuals, millions of people in one city. When discussing climate change, we hear about millions of metric tons of carbon dioxide emissions – but what is a metric ton, and what is a million?

People who make big numbers make sense in an everyday context often use some of the following techniques:

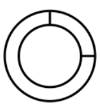
## Data Communication Tips

**Make it Smaller:** For example, if a building is going to cost $10 million to build, and will take two years to build, that is $416,666 per month. While this is still a large number, it is closer to the average cost of a house in the US.

**Change the Unit:** The Mariana Trench (the deepest known part of the ocean) is over 36,000 feet deep. Most people cannot imagine this. Convert it to 6.8 miles and it becomes more understandable.

**Divide it Up:** It may be too much to imagine one million people – but how many times would you need to fill your local football stadium to fit one million? It may be easier to imagine 15 football stadiums of people.

**Convert to Time:** Another way to imagine one million people is in interactions. If you spoke to each person for one minute, eight hours a day, every day, it would take 5.7 years to meet each person.



**Visualize It:** Numbers are often easier to compare if they are represented in a graph, chart, graphics, or video. However, it is important that your graphics are accurate in terms of area or length.

Base ten images from Pixabay.
All other images from The Noun Project by Bhima, Vladimir Belochkin, Tezar Tantular, Alice-vector, and Made by Made

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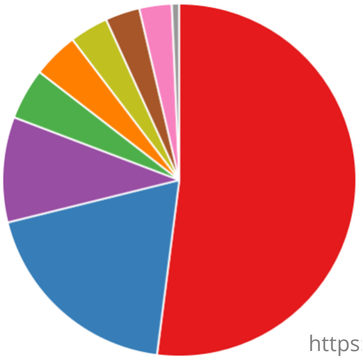

**US Heat-Trapping Gas Emissions from Industry, 2019**

- Fossil fuel combustion: 52%
- Natural gas & petroleum systems: 19.1%
- Other industrial categories: 9.7%
- Chemical production & use: 4.7%
- Mineral products: 4.2%
- Coal mining: 3.5%
- Production & use of fluorinated gases: 3.1%
- Metal production: 3%

https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

## Data Communication Practice

Take one or more of the following data points from the US Environmental Protection Agency (EPA.) Reframe it to make more sense to the general public, using one or more of the tips on the previous page. All data points are US measurements from 2019, listed in million metric tons (mmt) of carbon dioxide equivalents ($CO_2$e – a method of combining data for all heat-trapping gases.)

Total: 6,588mmt

Total industrial use: 1,504.83mmt

Industrial fossil fuel use: 782.82mmt

Iron and steel production: 41.32mmt

Cement production: 40.90mmt

Lime production: 12.11mmt

For more data points, or data from other years, visit https://cfpub.epa.gov/ghgdata/inventoryexplorer/index.html

To convert metric tons of $CO_2$ to passenger cars, homes, smartphones, and more, visit https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

## Questions

1. Why do you think it is so hard to talk about very large numbers?
2. Many science communicators focus on talking about impacts and solutions instead of showing graphs, figures, and numbers. How could you reframe the fact(s) you chose above to remove the numbers altogether? What is your goal in sharing this information?
3. Have you seen scientific data presented in a way that resonated with you? What did you like about how the communicator(s) chose to present the material?

All data from EPA "Greenhouse Gas Inventory Data Explorer" https://cfpub.epa.gov/ghgdata/inventoryexplorer/index.html