A set of US reference images – methodology

The purpose of the images

Action on greenhouse gas emissions would be easier if we could see what we were talking about. Not only is carbon dioxide invisible, it is measured in units of mass. Intuitively we make sense of mass in terms of weight and because gases are buoyant this gives us another level of abstraction to deal with.

The simple expedient of illustrating quantities of gas in terms of the space they occupy gives viewers a direct and concrete way to make emissions, savings and targets meaningful to themselves. When viewed this way, audiences who would switch off as soon as soon as numbers get mentioned can engage intelligently quantitative arguments.

When the audience is already engaged with the numbers (e.g. an audience made up of professionals tracking emissions and aiming for targets) then regular charts and tables will be more direct. For other audiences however, physical representations can be a 'way in'. In short, if the audience is coming to the data to answer their own questions, go for regular charts and tables. Conversely, if you are taking the data to the audience and asking them to engage with it then physical representations like these are more effective.

In summary, the purpose of these images is to:

- Make carbon dioxide 'real' (physical) and not just a number
- Provide a physical sense of scale
- Allow people without strong numeracy to engage with quantitative arguments

Ethos

'Regular' data visualization practice is ingenuous, parsimonious and dense. Disingenuous practices are frowned upon (e.g. using design to exaggerate the difference between two values). Data visualizers also eschew 'chart junk', which is anything in a data visualization that isn't directly representing data. In addition, regular data visualization is 'dense' in the sense that the aim is to communicate the most data with the least ink (or fewest pixels). 'Concrete' visualization such as these images of carbon dioxide gas adopts a similar ethos with some necessary modifications.

The goal is to support quantitative analysis by helping viewers to relate physically to the numbers. For this reason, viewers must be able to place themselves in the image and relate the scale to their own experience. This means that things that would be considered 'chart junk' in regular (abstract) data visualization are necessary in concrete visualization. For instance, in this set of images there are silhouettes of people and a representation of a typical house. Concrete visualization coopts the world itself as a visualization medium. Nevertheless, the principle of parsimony applies. Elements of the image that are not direct representations of the data are there to help viewers make sense of the scale of the data. Extraneous elements are avoided, particularly if they are distracting.

The main difference between the ethos of abstract visualization and that of concrete visualization concerns density. Often, the goal of concrete visualization is a better understanding of a single value (e.g. 1 metric ton of carbon dioxide) which wouldn't warrant illustration at all in abstract visualization – it would just remain as a number. Thus in concrete visualization, much ink and many pixels are sometimes devoted to little data.

Concrete visualization has the same requirement as regular visualization to be honest and ingenuous. Because concrete visualization makes quantities 'real' there is more scope for misrepresenting data. The images by themselves should not have any moral message – it is not the picture's job to say 'US emissions are too big' even if it is the conclusion a viewer will come to on their own or the conclusion drawn in accompanying text. The picture just says, 'this is the case'. An article that includes the picture can say, 'this is too much', but the picture itself just shows the comparison. The integrity of concrete visualization depends on a commitment to neutrality.

FAQs

Is it fair to give the impression that the gas actually takes up that much space, seemingly displacing what's around it?

Yes it's fair. The point of showing the gas this way is that it is physically meaningful. The gas we add to the air *does* take up that space. It is true that it gets mixed into the air, but the total volume of air increases. In this way it behaves just as liquid. If you have a pint of water and you add a pint of beer to it, you end up with 2 pints of watery beer. If you pour a pint of beer into the ocean, then the volume of the ocean increases by 1 pint. It's the same with gases and the atmosphere. (Note, if you add gas to a sealed room the volume won't increase because it can't. Instead the pressure increases and the CO_2 molecules fit into the space between the other molecules, but when you open the door the volume will increase then.)

Doesn't CO_2 freely mix with other gases in the atmosphere and fill in some of the empty space between molecules?

No. The spacing between molecules is determined by temperature and pressure. CO_2 mixes freely, but the total volume of gas increases (just like beer and water). It is not like pouring water into a sponge.

Why is it relevant to isolate the gas in this way? Doesn't it travel, outside the box – thus affecting the planet as a whole?

The reason we isolate the gas is because that is how we know how much there is. It is the *only* way of showing how much there is when we are talking about everyday emissions and savings, rather than global quantities.

Think of it like water pollution. Sometimes it communicates more to say, 'this factory adds 1,000 gallons of pollutants to the river every day' than 'this factory increases the concentration of pollutants in the river by 1 microgram per cubic meter'. It depends on the context whether absolute or relative quantities are relevant and appropriate.

It is Carbon Visuals goal is to connect individual emissions and the global situation. The Carbon Quilt is an attempt to do that – it places even small emissions into a global context: http://www.carbonvisuals.com/work/the-carbon-quilt-a-global-engagement-tool But the Carbon Quilt is not always the easiest or most direct way to give people a way to understand emissions, savings and targets quantifiably.

Doesn't the idea of putting the gas into a box or sphere distract from the way it has impact?

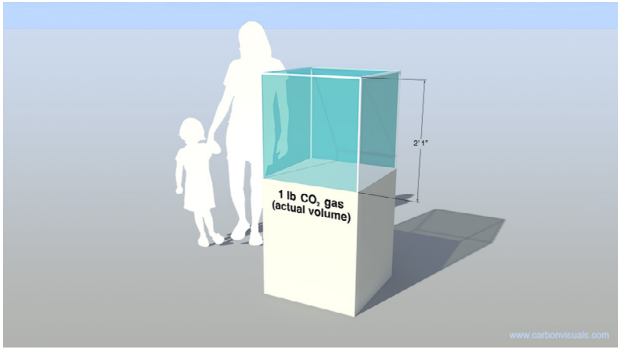
It may do in some ways, but at Carbon Visuals we have noticed very powerful numerical misconception that prevents many people understanding the impact we have on the atmosphere. Bringing the gas together into a single volume effectively deals with this misconception and so far from detracting from the way carbon dioxide has impact, it makes it apparent.

The misconception is this: CO_2 makes up less than half of one tenth of one percent of the gases in the atmosphere. Expressed like this, the number sounds tiny. Many people (including many senators and congressmen who should know better) believe something so dilute can have little impact. This is a wrong conclusion for many reasons, but the reason it sounds plausible at all is because people are not good at relating to small concentrations. If we talk about absolute quantities instead of concentrations, carbon dioxide no longer seems insignificant, and one way to do that is to (conceptually) extract it from the air and show the actual volume it would take up as concentrated gas.

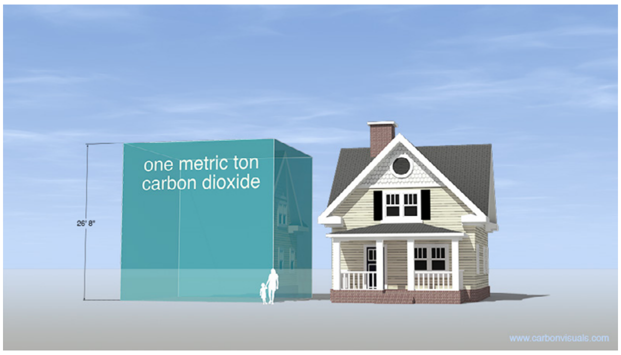
Take a typical room 20 feet x 20 feet x 9 feet. Only 400 parts per million of the air in the room is carbon dioxide, which doesn't sound like a lot. However, that is nearly 11 US gallons of carbon dioxide, which sounds a lot more significant. 3.2 US gallons of that came from burning fossil fuels. If you show people that in every small room there is 3 US gallons of greenhouse gas that we have put there if begins to seem like a big deal.

The idea is that you show a container of gas so you can see how much will be emptied into the air. Otherwise all you know is that 'some' greenhouse gas is in the air.

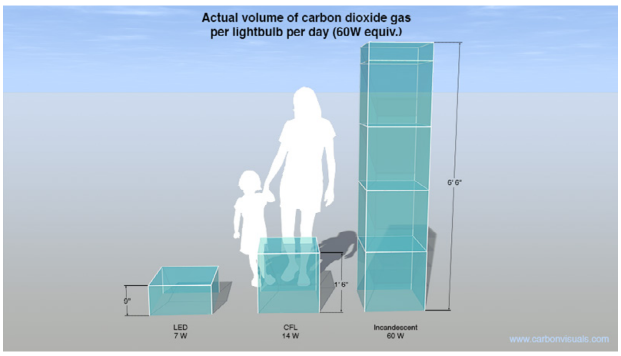
Images data and sources



At standard pressure and 15 °C (59 °F) the density of carbon dioxide gas is 1.87 kg/m^3 (0.1167 lb/ft^3). One pound (454 grams) of carbon dioxide gas occupies 0.2426 m^3 (8.566 ft^3, 64 US gallons, 243 liters). It would fill a cube 62.4 cm high (24.6”) or a sphere 77.4 cm across (30.5”).



At standard pressure and 15 °C (59 °F) the density of carbon dioxide gas is 1.87 kg/m^3 (0.1167 lb/ft^3). One metric ton (2,205 lb) of carbon dioxide gas occupies 534.8 m^3 (18, 885 ft^3, 117,631 US gallons). It would fill a cube 8.12 meters high (26’ 8”) or a sphere 10.07 meters across (33’)



Comparison of the actual volume of carbon dioxide gas emitted as the result of illuminating a 60 W incandescent bulb, an equivalent compact fluorescent bulb (14 W) and an equivalent light emitting diode bulb (7 W) for 24 hours using US grid electricity. The volume representing the compact fluorescent bulb is a cube 1” 6” high. The other volumes have the same base area.

Incandescent bulb: 60 W x 24 hours = 1.44 kWh = 0.798 kg CO_2(e)
Compact fluorescent bulb: 14 W x 24 hours = 0.336 kWh = 0.186 kg CO_2(e)
LED bulb: 7W x 24 hours = 0.168 kWh = 0.093 kg CO_2(e)

The conversion coefficient used is 0.554 kg.CO_2(e)/kWh which is a weighted average of the coefficients reported for each eGRID subregion for 2009 (weighted by total energy output and emissions).

Source: October 2012, 'eGRID2012 Version 1.0 with Year 2009 Data Released' http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2012_year09_TechnicalSupportDocument.pdf

The calculation assumes that power delivered to a compact fluorescent bulb is equivalent to that delivered to incandescent bulbs and LED bulbs. In fact there is a subtle difference, which means the emissions from the compact fluorescent bulbs is an underestimate. Because compact fluorescent bulbs have a power factor that is less than 1, more current flows along the transmission wires (see: http://en.wikipedia.org/wiki/Power_factor). This means that the transmission losses (energy lost as electricity is delivered to homes) are greater for a14 Watt energy saving bulb than they would be for a 14 Watt incandescent bulb or LED bulb, and so a bit more carbon dioxide will be emitted. However, the transmission losses are a small percentage of the total load so the difference is small.

The combustion of one US gallon of gasoline in a passenger car results in emissions of 8.872 kg CO_2(e). At standard pressure and 15 °C (59 °F) the density of carbon dioxide gas is 1.87 kg/m^3. 8.872 kg occupies a volume of 4.744 m^3 (167.6 ft^3) which would fill a cube 5' 6" high or a sphere 6' 10" across.

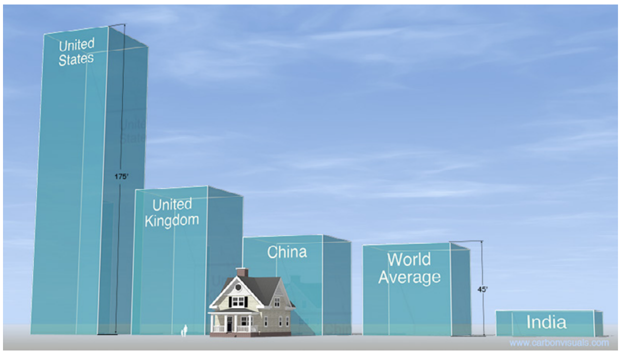
Source: Greenhouse Gas Protocol (http://www.ghgprotocol.org/calculation-tools/all-tools) accessed via AMEE: http://discover.amee.com/categories/US_road_transport_by_Greenhouse_Gas_Protocol/data/passenger%20car/gasoline/2005-present/result/none/1.0/1;gal?usage=byFuelOnly

Daily per-capita emissions in 2008:

United States: 51 kg CO_2(e)
United Kingdom: 23 kg CO_2(e)
China: 15 kg CO_2(e)
World Average: 13 kg CO_2(e) (Source: CDIAC)
India: 4 kg CO_2(e)

Source: Climate Analysis Indicators Tool: http://cait.wri.org

CDIAC (for world average figure): Boden, T.A., G. Marland, and R.J. Andres. 2012. *Global, Regional, and National Fossil-Fuel CO_2 Emissions*. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2012



Annual per-capita emissions in 2008:

United States: 18.6 metric tons CO_2(e)
United Kingdom: 8.4 metric tons CO_2(e)
China: 5.4 metric tons CO_2(e)
World Average: 4.8 metric tons CO_2(e) (Source: CDIAC)
India: 1.3 metric tons CO_2(e)

Source: Climate Analysis Indicators Tool, World Resources Institute: http://cait.wri.org

CDIAC (for world average figure): Boden, T.A., G. Marland, and R.J. Andres. 2012. *Global, Regional, and National Fossil-Fuel CO_2 Emissions*. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V201