ACTIVITIES BY

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ACTIVITIES

1. Where is carbon?

You are on the shore of Lake Victoria.
Where can you find carbon?

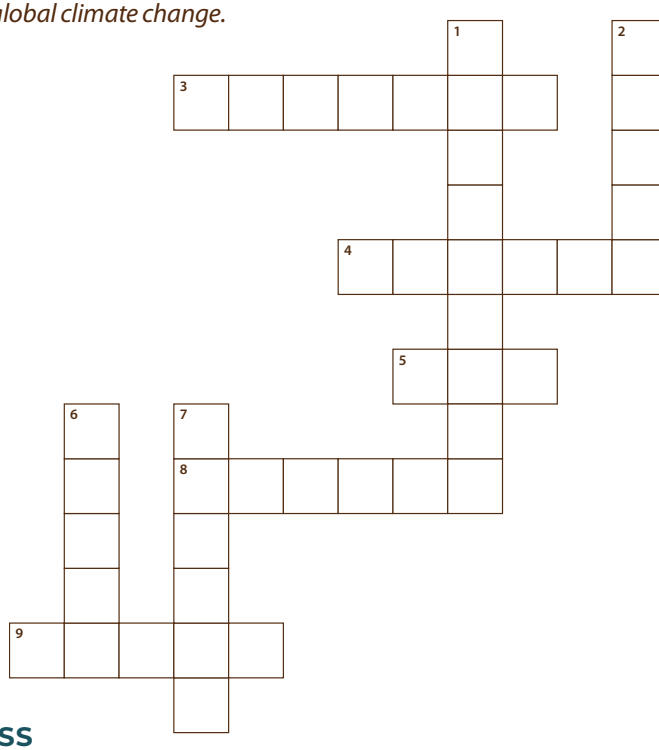
Guess where the most carbon is stored: air, water, plants, soil or deep inside the Earth?

Solution on page 25

2. Who is responsible?

Solution on page 26

Carbon dioxide stays in the atmosphere for several generations, so human-caused emissions from the 20th and even 19th centuries are still causing climate change. ***Solve the crossword*** to find the top ten carbon-polluting countries. *One country you definitely won't find on that list is Uganda — historically it contributed relatively little to global climate change.*



ACROSS

3. The *sixth-highest polluter* is the country that printed the first bible **(7 letters)**.

4. The *tenth-highest polluting country* has the longest coastline in the world **(6 letters)**.

5. The *highest polluter* is the only country that encompasses all five major climate zones: tropical, dry, temperate, continental, and polar **(3 letters)**.

8. This *third-highest polluting country* is the largest in the world **(6 letters)**.

9. In 2060, the *seventh-highest polluter* will be the country with the most people **(5 letters)**.

DOWN

1. The *tenth-highest polluting* country is home of the giant padma— the largest flower in the world **(9 letters)**.

2. The *second-highest polluting country* is the home of giant pandas **(5 letters)**.

6. In the *ninth-highest polluting country* origami was invented **(5 letters)**.

7. The *fourth-highest polluting country* is home of the largest carnival in the world **(6 letters)**.

3. Trace emissions

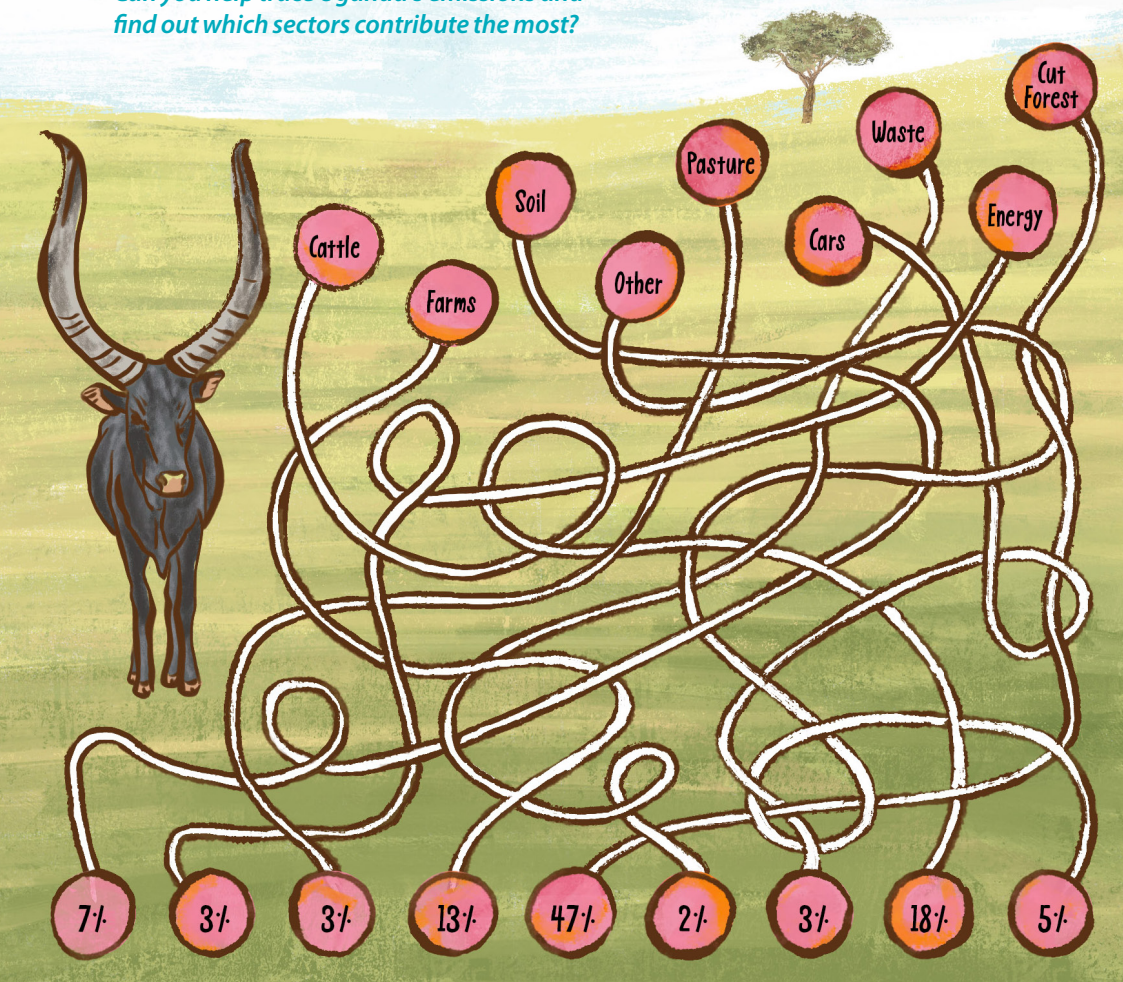
Solution on page 28

In the decade since 2010, human-caused emissions amounted to 40–50 Gt of CO_2 per year. However, the goal for the world is to reach net zero emissions around 2050. This will require both drastically cutting emissions and taking emissions out of the atmosphere.

Uganda emits only 0.2% of the global total while accounting for 0.6% of the population. To improve the well-being of people in Uganda, a lot of infrastructure still needs to be built. Under international agreements, Uganda can increase its emissions in the next few decades, while richer countries are cutting theirs.

However, Uganda needs to manage this rise in emissions and is committed to increasing its emissions by less than would have occurred in a 'business-as-usual' scenario. To manage its emissions, the country needs to count carbon emissions from various sources.

Can you help trace Uganda's emissions and find out which sectors contribute the most?



Solution on page 29

4. How much money?

Climate change is also about money: spending, investing, making money, paying debts, or cancelling debts. The countries that made money while spewing carbon into the atmosphere and causing climate change are now poised to also make money from new climate-friendly technologies. The countries that contributed little to climate change, like Uganda, but have suffered from the consequences (disruption to rains, extreme weather events) have a right to compensation. Adapting to climate change is costly and globally these costs should be shared.

Solve this 'SEND + MORE = MONEY' math puzzle to find out how much climate finance is needed by 2050:

```
     S E N D
+    M O R E
= M O N E Y   (in billion US dollars)
```

CLUE:

Each letter {S, E, N, D, M, O, R, N, Y}
stands for one of the digits {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}.

Figure out which digit is encoded in each letter.

5. Uncertainty

Solution on page 30

It is very difficult to predict the future. Most of our knowledge is assembled from looking backwards in time, and then creating a narrative about a sequence of events. However, if one thing caused something in the past, in many complex chaotic systems (such as society or climate) we cannot extrapolate. The same cause might have a different effect.

What does this fragment of a poem 'If I could Tell You' by W. H. Auden tell us about the limits of understanding nature, and our ability to foresee the future? Could nature have its own will to be and grow? Do our imaginations or visions have a capacity to affect change?

Discuss the various aspects of uncertainty in scientific knowledge that are captured in this poem. You can keep your answers vague and ambiguous, in keeping with the theme.

The winds must come from somewhere when they blow,
There must be reasons why the leaves decay;
Time will say nothing but I told you so.

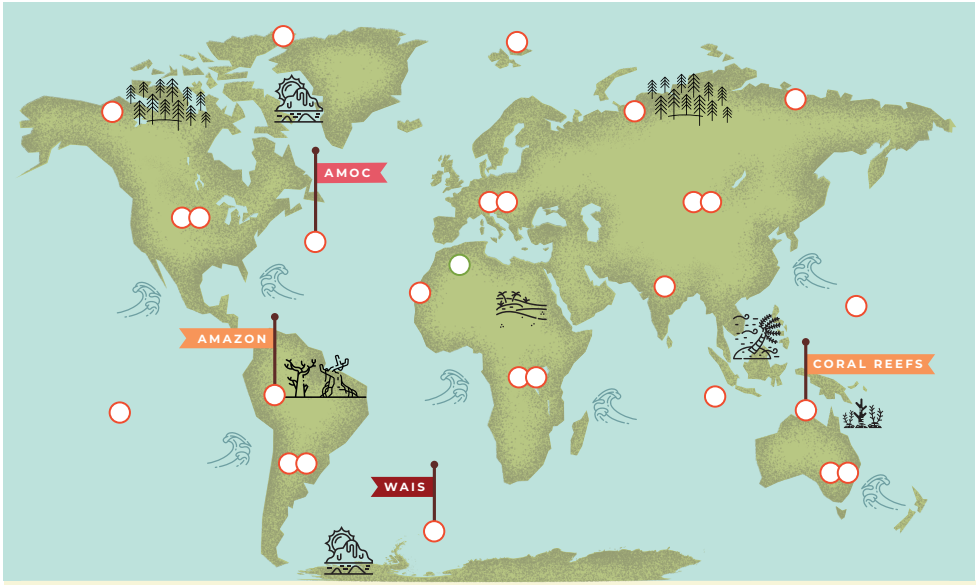
Perhaps the roses really want to grow,
The vision seriously intends to stay;
If I could tell you I would let you know.

6. Tipping points

Solution on page 32

Some of the least predictable impacts of human-caused carbon emissions are possible climate tipping points. Climate has existed in various different states in the deep past. The Sahara desert was a rainforest thousands of years ago, but covered in glaciers during some of the ice ages. There might be triggers that push climate from one state to another. These processes are not well understood and abrupt climate change is considered unlikely—the predicted climate change, of around 2 degrees Celsius warmer, by the end of the century, is dangerous enough. But the less we disturb the carbon balance, the less likely we are to trigger any of the interconnected tipping points and unleash a cascade of rapid changes over the next few centuries.

Scientists have identified 12 potential tipping points below. Can you help them locate these on the map? Some might affect more than one place.



1. **Collapse of Ice Sheets and/or major ice formations**
   → *much higher sea levels.*
2. **Permafrost thaw releases methane**
   → *acceleration of global warming.*
3. **Massive loss of forests**
   → *loss of biodiversity & release of greenhouse gases → acceleration of global warming.*
4. **Rapid climate change**
   → *mass extinctions of animals, plants, other life forms.*
5. **Shutdown of Atlantic Meridional Overturning Circulation (AMOC)**
   → *Cooling of Northern Hemisphere*
   (AMOC conveys heat from the tropics).
6. **Increase in El Niño–Southern Oscillation (ENSO)**
   → *drought in South East Asia.*
7. **West African Monsoon**
   → *droughts across Mauritania, Senegal, Burkina Faso, Mali, and Niger.*
8. **Greening of the Sahara**
   → *greater local biodiversity.*
9. **Indian Monsoon shift**
   → *droughts on the Indian subcontinent.*
10. **Tipping points at regional level**
    → *severe local impacts on all continents.*
11. **Changed marine ecosystems**
    → *abrupt West Tropical Indian Oceanic Bloom*
    (Sudden increase in deep water upwelling brings nutrients to the upper layers of ocean, leading to gains in productivity from microorganisms to fisheries).
12. **Disappearance of coral reefs**
    → *loss of biodiversity, habitats, coastal erosion, cultural and economic losses.*

7. Misinformation

Solution on page 33

Misinformation and false beliefs about climate change are everywhere: on social media, websites, and even in the news. For example, widely circulating beliefs such as "climate change is caused by the hole in the ozone layer", "Ugandans cutting trees caused the local climate to change", or "climate change is caused by local car pollution" are all incorrect. Uganda and the ozone hole bear relatively minor responsibility for global change. Local impacts such as rain patterns in Uganda are the results of global changes, and are determined by what happens in faraway oceans and the global atmosphere.

Practice telling true statements from false ones.
Which of the ten statements below is true?

- ❒ **Exactly 1** of these statements is false.
- ❒ **Exactly 2** of these statements are false.
- ❒ **Exactly 3** of these statements are false.
- ❒ **Exactly 4** of these statements are false.
- ❒ **Exactly 5** of these statements are false.
- ❒ **Exactly 6** of these statements are false.
- ❒ **Exactly 7** of these statements are false.
- ❒ **Exactly 8** of these statements are false.
- ❒ **Exactly 9** of these statements are false.
- ❒ **Exactly 10** of these statements are false.

8. Find solutions

Solution on page 34

We can reduce how much carbon we emit by shifting energy production to **solar** and **wind** (and other renewables), to certain types of **hydrogen**, and (more controversially) to **nuclear** and by **electrification** of transport, heating and industry. We can take away carbon from the atmosphere with nascent greenhouse gas removal such as enhanced weathering, **biochar**, **BECCS** (bioenergy with carbon capture and storage) and **CCUS** (carbon capture utilisation and storage), as well as nature-based solutions such as restoring **wetlands** and **forests**. This will need to be paid for by climate **finance**. The global economy will need to be rebalanced through processes such as **degrowth** and **bioeconomy**, especially for agriculture. For **justice**, these changes will need to be supported by **education**, **activism**, and economic reforms such as **UBI** (universal basic income).

Solutions exist; can you find a few of them below, and better yet create your own? Words can go in any direction, including backwards and diagonal.

WORDSEARCH

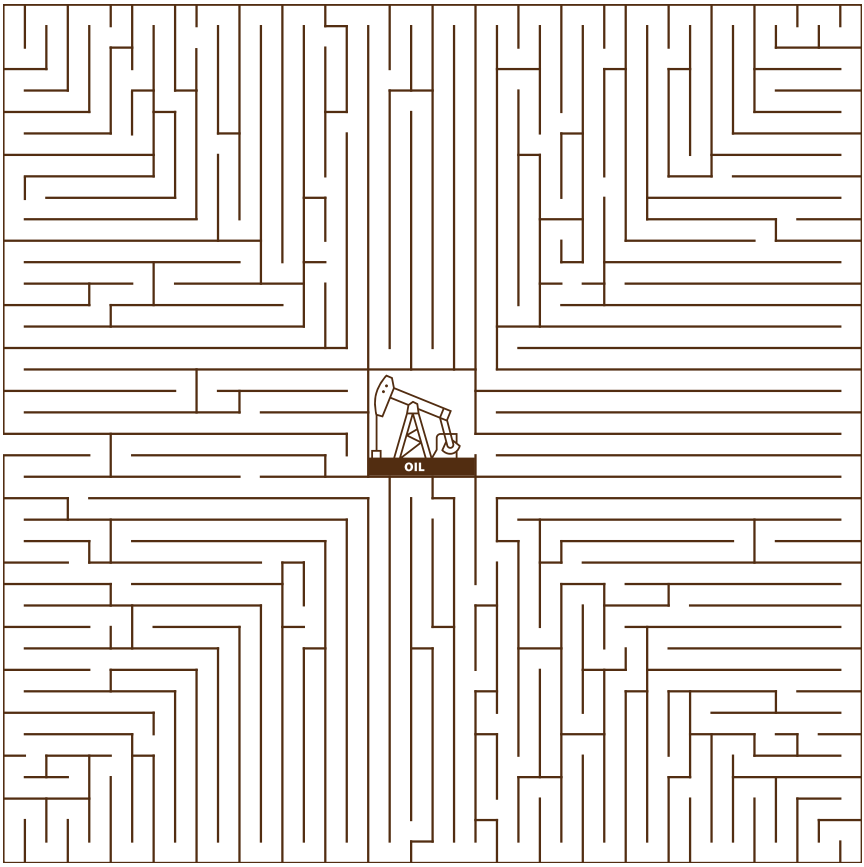
N	H	V	J	R	B	I	O	C	H	A	R	I	K	D
F	B	Y	A	U	T	H	C	F	Y	B	B	X	E	O
M	I	L	M	P	S	Z	B	N	O	U	E	G	T	P
U	O	Y	S	R	K	T	U	A	N	R	R	C	R	H
S	E	U	I	F	H	B	I	T	G	O	E	F	C	I
Q	C	P	V	I	Y	X	F	C	W	G	Y	S	N	S
F	O	I	I	R	U	K	H	T	E	P	F	S	T	M
G	N	C	T	H	A	Y	H	U	L	C	I	Y	Q	S
Z	O	C	C	J	D	E	P	I	I	G	N	M	K	Z
A	M	U	A	R	K	Q	L	J	V	E	A	Q	J	O
J	Y	S	O	D	N	I	W	C	I	X	N	L	J	B
E	K	G	N	Y	H	O	P	B	U	D	C	C	T	S
Y	E	W	E	T	L	A	N	D	S	N	E	R	T	M
N	N	O	I	T	A	C	U	D	E	O	W	T	P	Z
E	L	E	C	T	R	I	F	I	C	A	T	I	O	N

9. Stranded assets

Solution on page 35

There is a possibility that various regulatory measures to limit climate change (or markets on their own) will turn the value of various assets such as oil fields and related infrastructure into liabilities, with dire implications for the finances of some countries that are heavily invested in the carbon economy. There is a great deal of uncertainty about which fossil fuel assets might become stranded and which might escape the predicament, a lot depends on location and geology, but other factors like laws, taxes, and future costs of (carbon capture) technology will play a major role.

Can you help this oil rig find a way out to a sustainable use?



10. Elders and eiders

Solution on page 36

Science and technology are crucial to tackling the climate crisis, but **traditional knowledge** is essential for successful adaptation. Rain harvesting, agroforestry, biological pest control, community risk sharing, and traditional methods for fire management can all increase resilience as climate change makes extreme events more common.

Many other solutions to climate change depend on figuring out **all intermediate steps**. For example, energy transition depends on vast extraction of metals needed in construction of solar panels, wind turbins and batteries, on new infrastructure such as charging stations for electric vehicles or upgraded electricity grids, on regulatory approvals and social acceptance, on ability to finance all these activities and to support people negatively affected by them.

Turn climate CHAOS into ORDER with the help of an ELDER (and an EIDER that is a type of duck).

The rules are you can only change one letter at a time, each new word in a chain must exist, and transposing letters is not allowed (e.g. CATS can become RATS but not a CAST). For example, this is how you can change DEFY to WARS: **DEFY** – DEFT – DAFT – DART – WART – **WARS**.

HINT: Eider is arguably the weakest link here—it is one word in the chain that few people know.

11. Does it add up?

Solution on page 37

Net zero means all emissions must add up to zero. The positive emissions are offset with carbon-negative technologies such as tree planting or BECCS. Counting emissions is difficult, and double counting is an issue, especially, for offsets. For example, is the Mabira Forest part of the natural ecosystem or is it part of a managed resource that can be claimed as a carbon offset? Some efforts to cut emissions in one place can increase emissions elsewhere—this is known as leakage. For example, protecting one forest can result in deforestation elsewhere.

Ensuring net zero is a bit like completing a magic square—everything needs to add up no matter how you look at it, or from which direction you start to count.

Complete a magic square below where all rows and columns and both diagonals add up to 100%.

30	18	16	36
10			
		20	
	26		

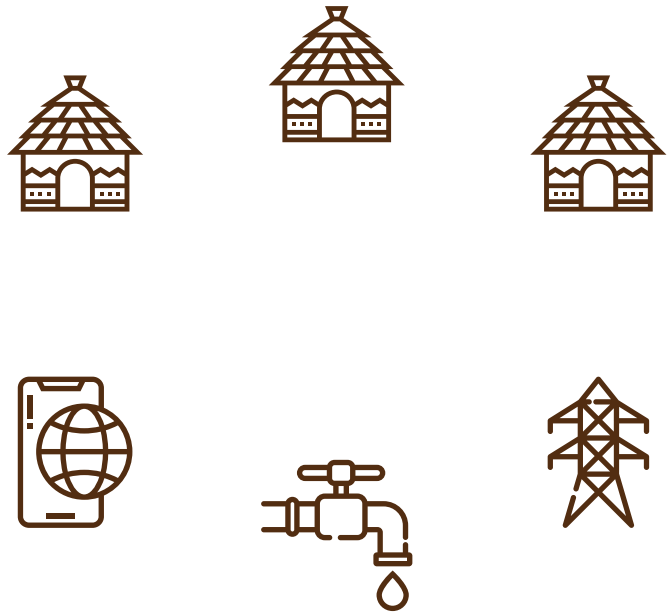
Solution on page 38

12. Perpetual growth?

The mainstream economic theory is built on the idea of perpetual growth, although limitless growth may neither be possible nor desirable. Degrowth proponents argue that once we ensure everyone in the world has the basics, we can reimagine what it means to have a good life—there must be alternatives other than ever-expanding consumption built on extractivism.

Let's say a good standard of living involves a house that has internet, water, and electricity.

Connect each of the three houses, in a homestead below, to all three utilities. To reduce the risk of accidents, you need to connect them so that the lines don't cross (or overlap) on the map. Can you do this?



13. Just Transition

Solution on page 40

Let's imagine a future on the other shore of the time river where the climate is stable, and all people are safe and free. Crossing over requires tricky decisions. For example, development requires resources (natural, material, social and financial) that compete or trade-off with reducing carbon emissions. Transitioning to a net zero economy means electrification that relies on mining metals such as cobalt and lithium, extracting which have justice implications for people who live near the mines and who will suffer the impacts, such as displacement and pollution. Climate goals trade-offs with Justice; Development goals trade-off with Climate.

Let's represent *Development* by **grass**, *Climate* by a **goat**, and *Justice* by a **lion**. You are standing on one shore keeping an eye on all three and you want to cross to that other lush side of the river, without losing anyone. The only problem is that your boat is small and can only fit you and one other. You cannot leave the goat and the grass unattended while you cross the river, because the goat will eat the grass. And you cannot leave the lion and the goat on a shore while you sail because the lion will eat the goat.

Can you get them safely across?
Cross the river as many times as you need.

14. On the road to net zero

Solution on page 41

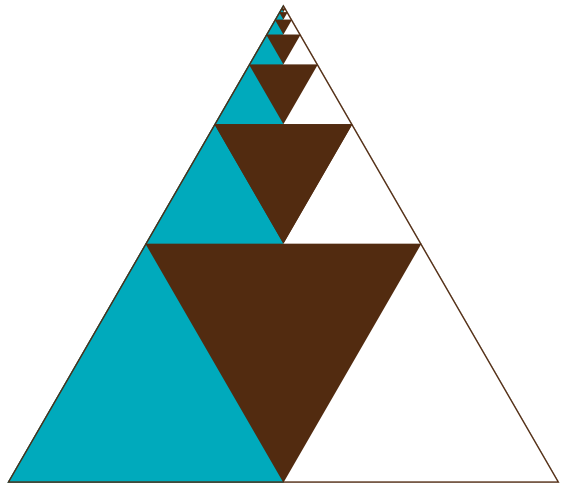
Uganda is committed to reducing emissions by one quarter compared to business-as-usual projections for 2030, if it receives promised financial support. The business-as-usual scenario is a modelling exercise that predicts that emissions would grow because the population in Uganda is growing and standards of living are increasing. Uganda's 2022 NDC (nationally determined contribution) to global climate goals means it is promising to keep emissions as they are now (estimated to be 125 million tons of CO_2 per year). Uganda needs to build roads, schools, hospitals, and houses; grow more food; make sure everyone has access to electricity, running water, and waste collection—all of which will increase its carbon emissions. The main route to offset these emissions needed for development will be through forestry, better farming methods, and bio-economy.

Imagine a small-holder farm.

It can reduce emissions by planting trees, improving soils, minimising harvest losses, etc. Suppose, a farmer reduces her carbon emissions by ¼ by using alternative fertiliser. She sells ¼ of the produce and manages to reduce emissions during transport by a ¼ by teaming up with a company that uses electric trucks. A shop buys ¼ of the products delivered by the truck and manages to reduce emissions by ¼ installing solar panels and keeping produce cool and fresh. I buy the food from the shop and reduce my 'business-as-usual' emissions from food waste again by ¼ by feeding the scraps to a community biogas processor.

What is the total CO_2 reduction?

HINT:



15. Biodiversity and food security

Solution on page 41

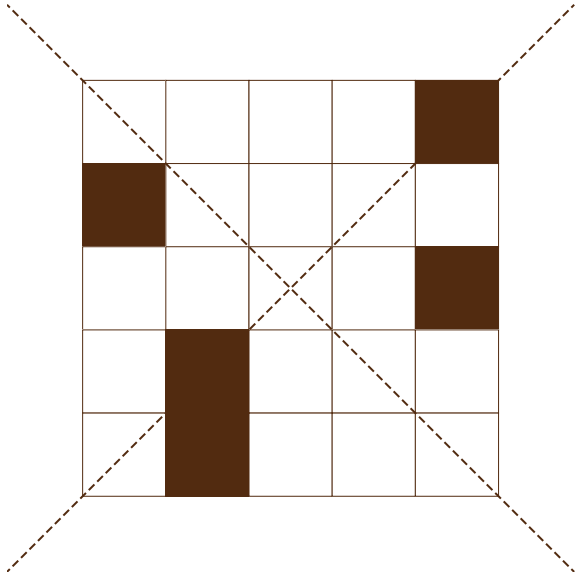
About 40% of the land surface globally is used to grow food. About ⅓ of agricultural land is for crops and the other ⅔ are for grazing cattle. Expanding agriculture is destroying habitats, leading to species extinction. Agriculture is also responsible for ¼ of global CO_2 emissions, through deforestation and soil depletion. However, scientists are certain that instead of adding to the total CO_2 in the atmosphere every year, the farmers can help us subtract it by adopting new methods, ranging from agroforestry to soil improvements. They can help us reduce the total amount of CO_2 while growing more food and supporting biodiversity.

The total amount people have added since the mid-eighteenth century is 1500 Gt (or 1.5 trillion tones of CO_2). Net zero is the point where we are no longer adding to the total, this will hopefully happen within your lifetime (probably by the time you have grandchildren). After we reach net zero, people might need to subtract CO_2 from the total for a number of decades—agriculture and forestry will be key.

Balancing food production and biodiversity is tricky. Let the square represent the total available land, let the filled squares represent the land for human use and unfilled squares the habitats reserved for other species.

Fill in the minimum number of squares so that the picture is symmetric with respect to both lines of symmetry, 'food security' and 'biodiversity'.

How many squares are left unshaded? What proportion of land should be protected from destructive human impacts?



16. Social tipping points

Solution on page 42

Social tipping points work a bit like exponential growth. Suppose you convince your 9 friends to do something about climate change, and they convince their 9 friends to do something, and they convince their 9 friends to do something—this is 9^3, or 729 people! Scientists believe that social tipping points are key to transformative action which might prevent the worst impacts of climate change.

Let the number of friends be DD where D is one of the digits (0, 1, 2 , …, 9) and the friendship chain is E connections deep. If the total number of people convinced to act is DEED.

What are D and E?

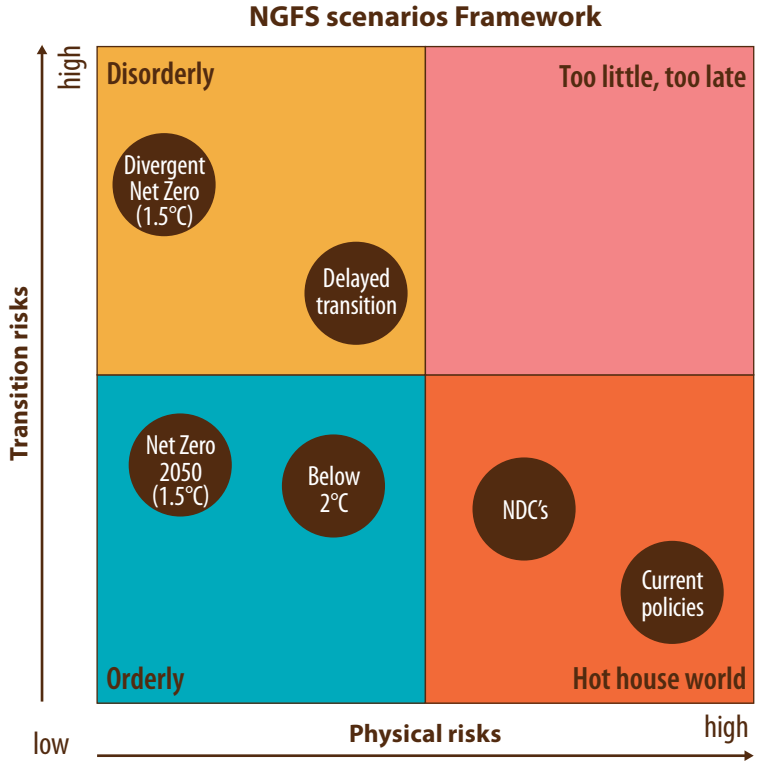
$(DD)^E = DEED$

HINT: For example, the solution to the puzzle **USSR + USA = PEACE** is U = 9, S = 3, R = 8, A = 2, P = 1, E = 0, and C = 7; or 9338 + 932 = **10270.**

17. The colour of the future

Solution on page 42

The banks like to divide the map of the future into 4 regions: Orderly, Disorderly, 'Too little, too late' and 'Hot house world'. This two-dimensional guide to the future has two axes, one to do with the physical world (temperature, rain) and one to do with social changes (inflation, unemployment). They picture the future like this:

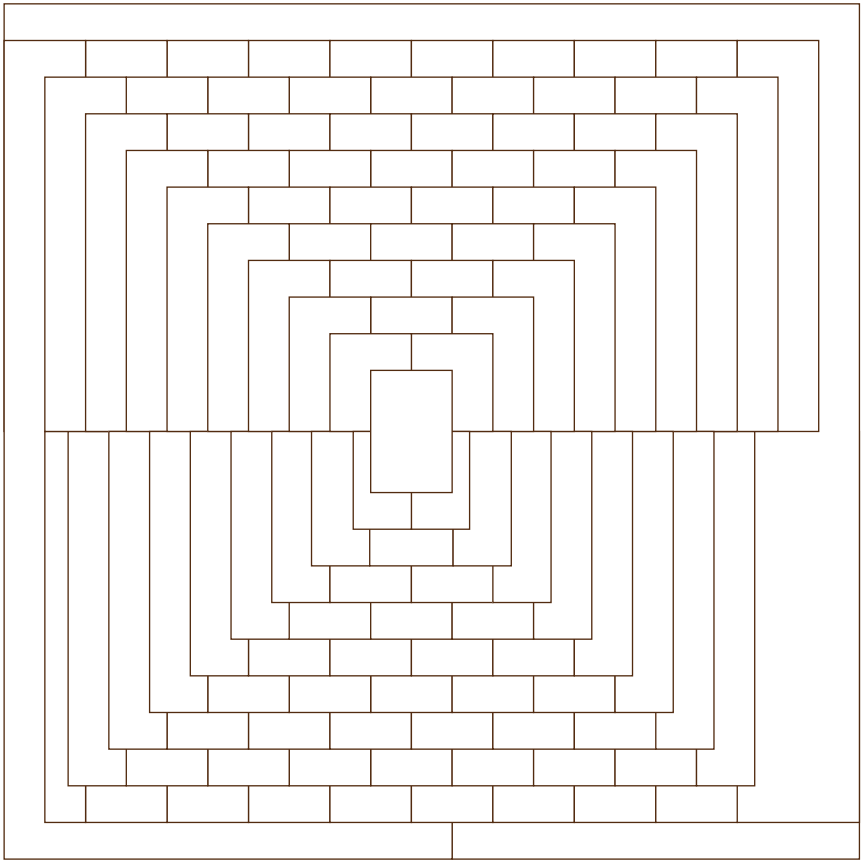


Surely, the map of the future must look more complicated than that?

No matter how complicated the map of the future is, there is a theorem that says it can be coloured with **only four colours** in such a way that no two regions that share a border are the same colour. By simplifying the map however, banks and governments are underestimating the risks and not preparing as well as they could.

(continued on next page)

Let's say the future looks more like this. Can you use only four colours and colour it so that regions that share a border are different colours:



yellow | pink | blue | orange

18. Global stocktaking

Solution on page 43

The Global Stocktaking is one of the key aims of COP28 in 2023. It is the first of regular accounting exercises that will repeat every 5 years; the second stocktaking is scheduled for 2028. Lots of things are being counted: who emits what and where, who and how can carbon emissions be reduced, how can money to pay for these reductions be channelled to projects that need them, how can compensation for existing damage be calculated and paid.

These calculations will be used to update nationally determined contributions (NDC) or targets for greenhouse gas emissions that each country agrees to do. The next set of targets is due in 2025. Countries will be able to trade carbon emissions, buying and selling offsets.

Numbers, numbers, numbers.

All of these numbers will involve a certain amount of guesswork. While we can count how many CO_2 molecules there are in a sample of air, figuring out where they came from is difficult.

Sometimes, guessing numbers can be almost magically precise, especially if you know how the numbers were processed. For example, pick or ask someone to pick a random 3-digit number where all digits are different. Now, follow this recipe:

Step 1. Reverse the number.
(For example, if you picked '123' the reverse will be '321'.)

Step 2. Subtract the smaller of the two from the larger.
(In our example, 321-123=198.)

Step 3. Reverse the answer.
(In our example, 891).

Step 4. Add the number from Step 3 to the number in Step 2.
(In our example, 891+198)

No matter what the original number was, the outcome is always 1089.

Can you think of reasons why we can be sure of the answer?
Can you think of reasons why guessing how much carbon a country emits will be easier or harder?

Notes