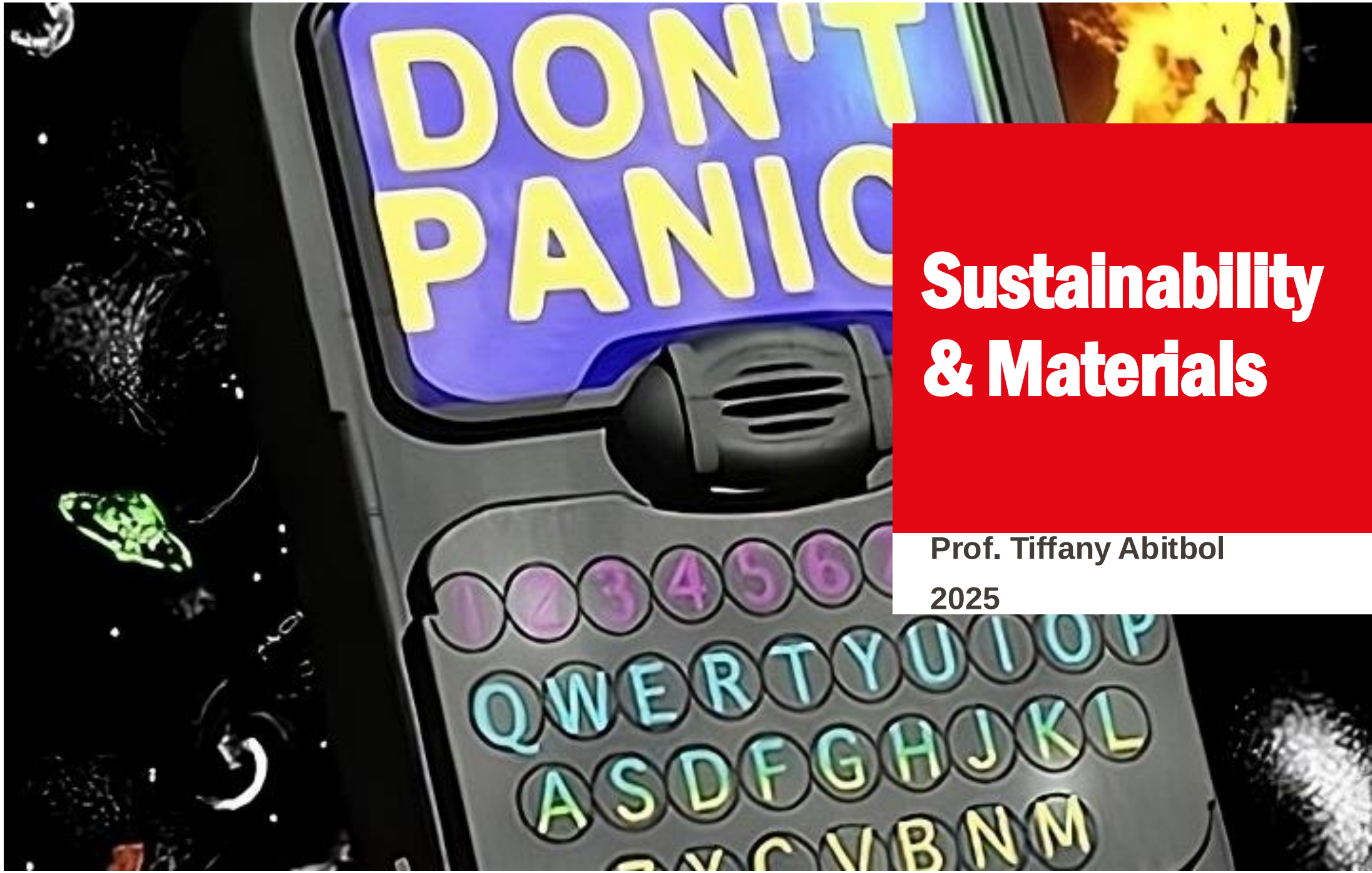


Sustainability & Materials

Prof. Tiffany Abitbol

2025

Revisit Green Chemistry

- Green Chemistry – a first formulation of sustainability & material production (today - we will touch on this a little more)

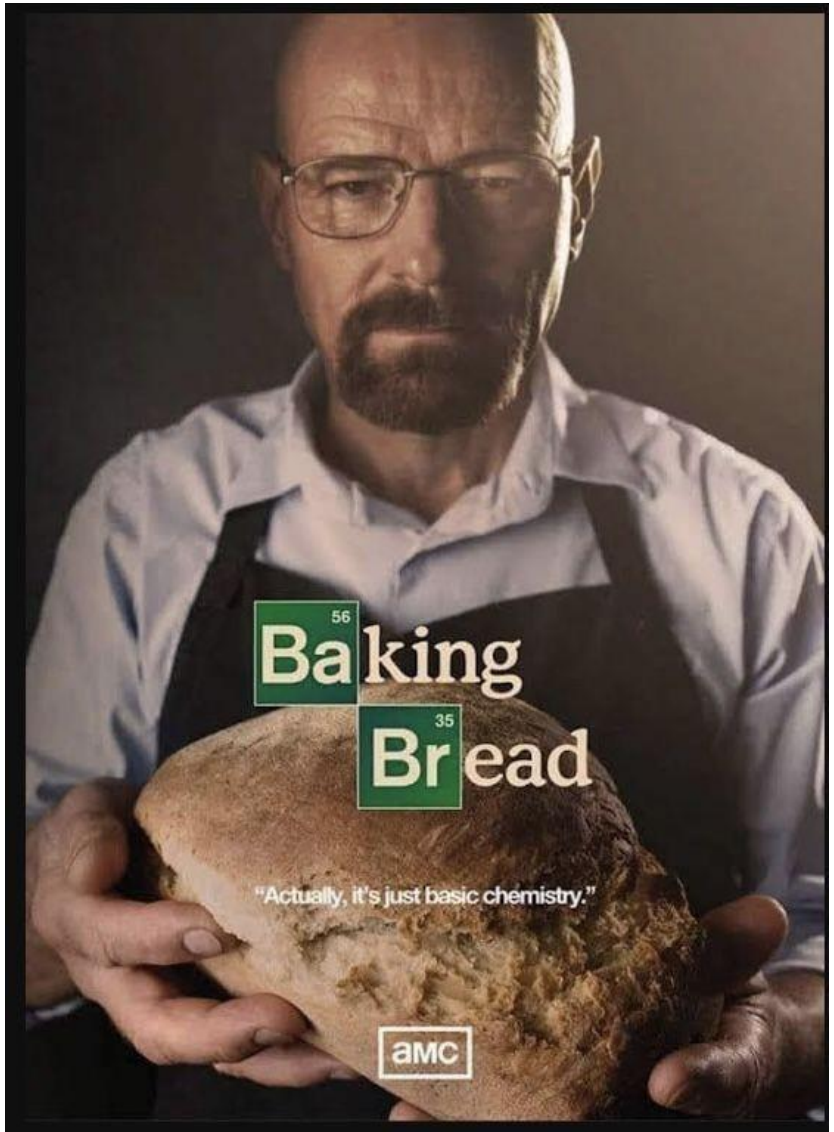
1. **Prevention**. It is better to prevent waste than to treat or clean up waste after it is formed.
2. **Atom Economy**. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. **Less Hazardous Chemical Synthesis**. Whenever practicable, synthetic methodologies should be designed to use and generate substances that pose little or no toxicity to human health and the environment.
4. **Designing Safer Chemicals**. Chemical products should be designed to preserve efficacy of the function while reducing toxicity.
5. **Safer Solvents and Auxiliaries**. The use of auxiliary substances (e.g. solvents, separation agents, etc.) should be made unnecessary whenever possible and, when used, innocuous.
6. **Design for Energy Efficiency**. Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.
7. **Use of Renewable Feedstocks**. A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
8. **Reduce Derivatives**. Unnecessary derivatization (use of blocking groups, protection/ deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.
9. **Catalysis**. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. **Design for Degradation**. Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.
11. **Real-Time Analysis for Pollution Prevention**. Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. **Inherently Safer Chemistry for Accident Prevention**. Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

What is synthetic chemistry?

$$A + B \rightarrow AB$$

Reactants Product

- “**Synthetic chemistry** is the branch of chemical science involved with developing means of **making new chemicals** and **developing improved ways of synthesizing existing chemicals**. A key aspect of green chemistry is the involvement of synthetic chemists in the practice of environmental chemistry. ”



Synthetic and green chemistry

Revisiting the E-factor

E-factor *(environmental impact factor)* – *mass of total waste divided by mass of total product*

Cake recipe (please don't try)

Ingredients (reagents):

- 2 eggs
- 2 cups flour
- 1/2 cup oil
- 1/2 cup milk
- 1 cup sugar
- 1 tsp baking powder
- 1 tsp baking soda
- ½ tsp salt
- 1 tsp vanilla

Method

- Fry your eggs into an omelet
- In one bowl: mix oil, milk, sugar, and vanilla (*wet ingredients*)
- In a second bowl: Mix flour, baking powder, baking soda. Baking powders, and salt (*dry ingredients*)
- Add dry ingredients to wet ingredients
- Pour mixture into mold and bake until you have a cake!

What's my E-factor?

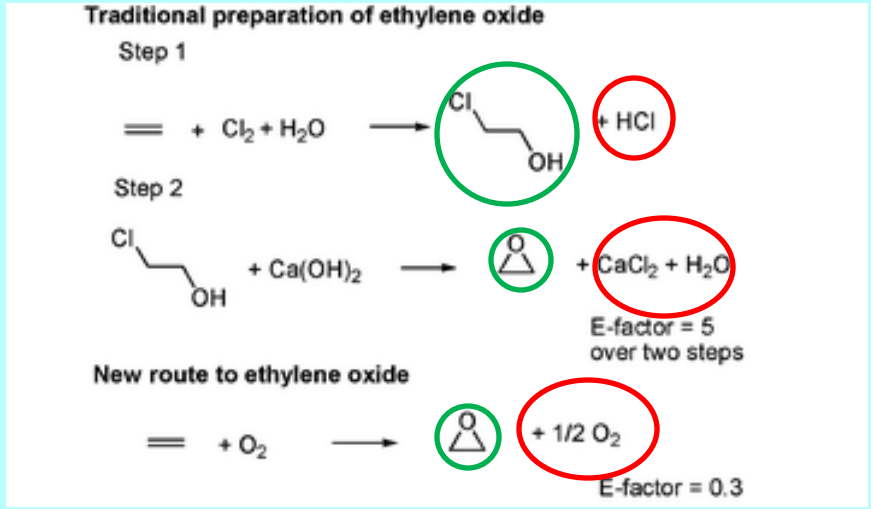
Mass of omelet/mass of cake > 0, because I generated waste

If I added the eggs to my actual cake (can make sense):

E-factor = 0, since all my ingredients end up in my actual cake! (Best scenario)

Example from last week

Principle 1 – Waste prevention



E-factor *(environmental impact factor)* – *mass of total waste divided by mass of total product*

Traditional reaction mass balance:

Products in red circle; waste in green circle; **E-factor is mass of red divided by mass of green**

- E-factor step 1: 80.5135 g/mol / 36.46 g/mol = 2.21
- E-factor in step 2: 110.98 g/mol + 18.015 g/mol / 44.05 g/mol = 2.93

E factor over two steps ≈ 5

New route is better: 16 g/mol /44.05 g/mol= 0.36

- DOI: 10.1039/B918763B (Critical Review) *Chem. Soc. Rev.*, 2010, **39**, 301-312
- https://www.pnas.org/doi/epdf/10.1073/pnas.0804348105

Revisiting atom economy vs. yield

AE = MW useful product/MW of reagents * 100%; measures efficiency of reaction

%Yield = actual mass of product/theoretical mass of product * 100%; doesn't say anything about efficiency, more about how effective your reaction is

Cake recipe (please don't try)

Ingredients (reagents):

- 2 cups flour
- 2 eggs
- 1/2 cup oil
- 1/2 cup milk
- 1 cup sugar
- 1 tsp baking powder
- 1 tsp baking soda
- ½ tsp salt
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Method

- Fry your eggs into an omelet
- In one bowl: mix oil, milk, sugar, and vanilla (*wet ingredients*)
- In a second bowl: Mix flour, baking powder, baking soda. Baking powders, and salt (*dry ingredients*)
- Add dry ingredients to wet ingredients
- Pour mixture into mold and bake until you have a cake!

What's my yield?

Mass of cake/theoretical mass of cake = 100%

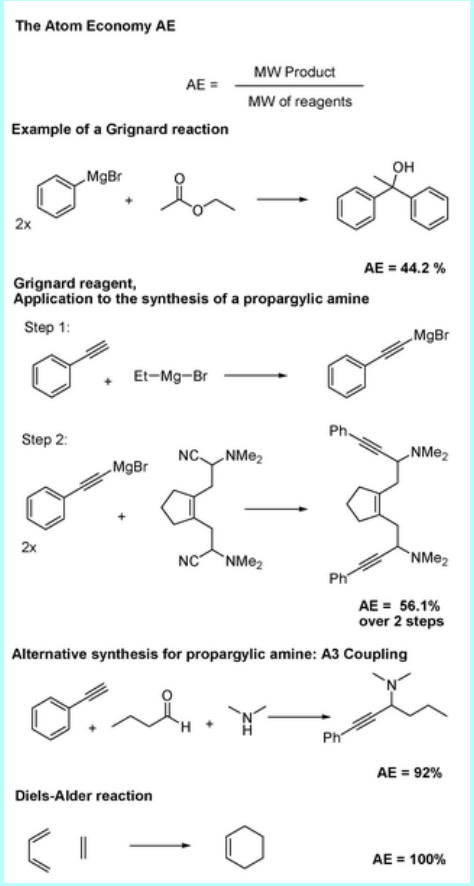
But what about the eggs I turned into an omelet while making my cake?

What's my AE?

Mass of cake/mass of all ingredients < 100% because omelet waste

Examples of Green Chemistry in Action

Principle 2 – Atom economy/Atom efficiency



Comparing atom economy to % yield:

AE = MW useful product/MW of reagents * 100%; measures efficiency of reaction

%Yield = actual mass of product/theoretical mass of product * 100%; doesn't say anything about efficiency, more about how effective your reaction is

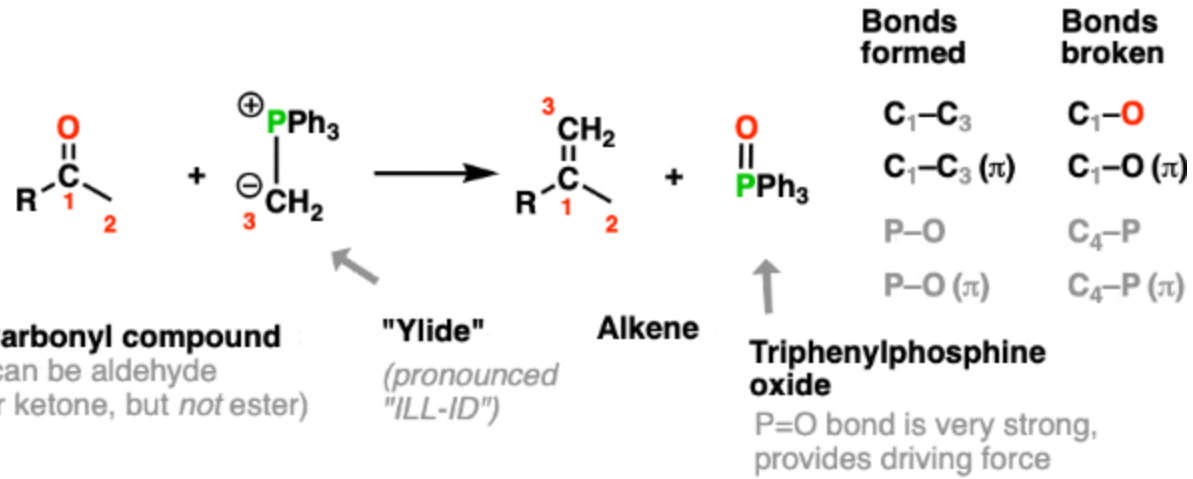
AE of 100 is ideal! (all atoms in reagent are incorporated into the product.

- DOI: 10.1039/B918763B (Critical Review) *Chem. Soc. Rev.*, 2010, **39**, 301-312
- https://www.pnas.org/doi/epdf/10.1073/pnas.0804348105

Examples of Green Chemistry in Action

Principle 2 – Atom economy/Atom efficiency; Wittig Reaction

The Wittig Reaction is useful for converting aldehydes and ketones to alkenes



cyclohexanone (M_r 98) + phosphonium ylide (M_r 276.0) →

methylene cyclohexane (M_r 96) + phosphorine oxide (M_r 278)

AE for Wittig

Wittig reaction

Considering the conversion of cyclohexanone *to methylene cyclohexane*, phosphorine oxide is generated as waste:

Typical yields: > 85% (*good, right?*)

Atom efficiency:

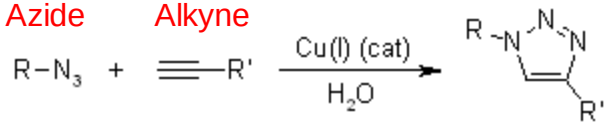
Useful product MW = *96 g/mol* (methylene cyclohexane)

Reagent MW = 98 g/mol (cyclohexanone) + 276 g/mol (phosphonium ylide) = *374 g/mol*

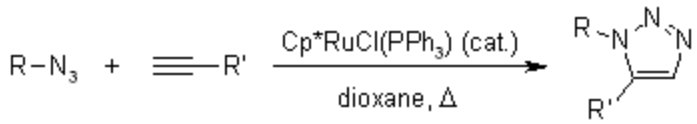
AE = 96/374 *100% = 26% (*AE is actually low!)*

"Click" Chemistry

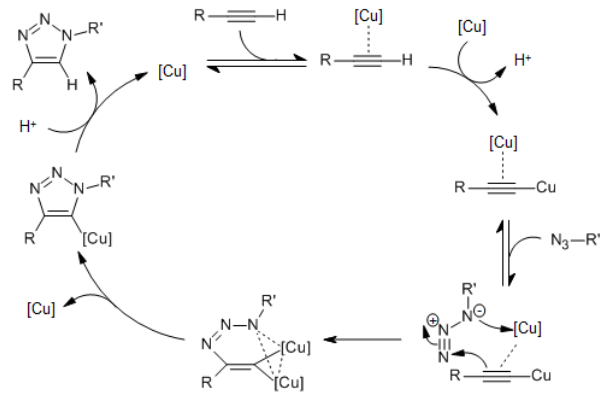
Azide Alkyne



5-membered, heteroatomic ring



Mechanism with copper catalyst:



https://www.organic-chemistry.org/namedreactions/click-chemistry.shtm

K. Barry Sharpless
Facts

Ill. Niklas Elmehed © Nobel Prize Outreach

K. Barry Sharpless
The Nobel Prize in Chemistry 2022

Born: 28 April 1941, Philadelphia, PA, USA

Affiliation at the time of the award: Scripps Research, La Jolla, CA, USA

Prize motivation: "for the development of click chemistry and bioorthogonal chemistry"

Prize share: 1/3

Also awarded: The Nobel Prize in Chemistry 2001

Work

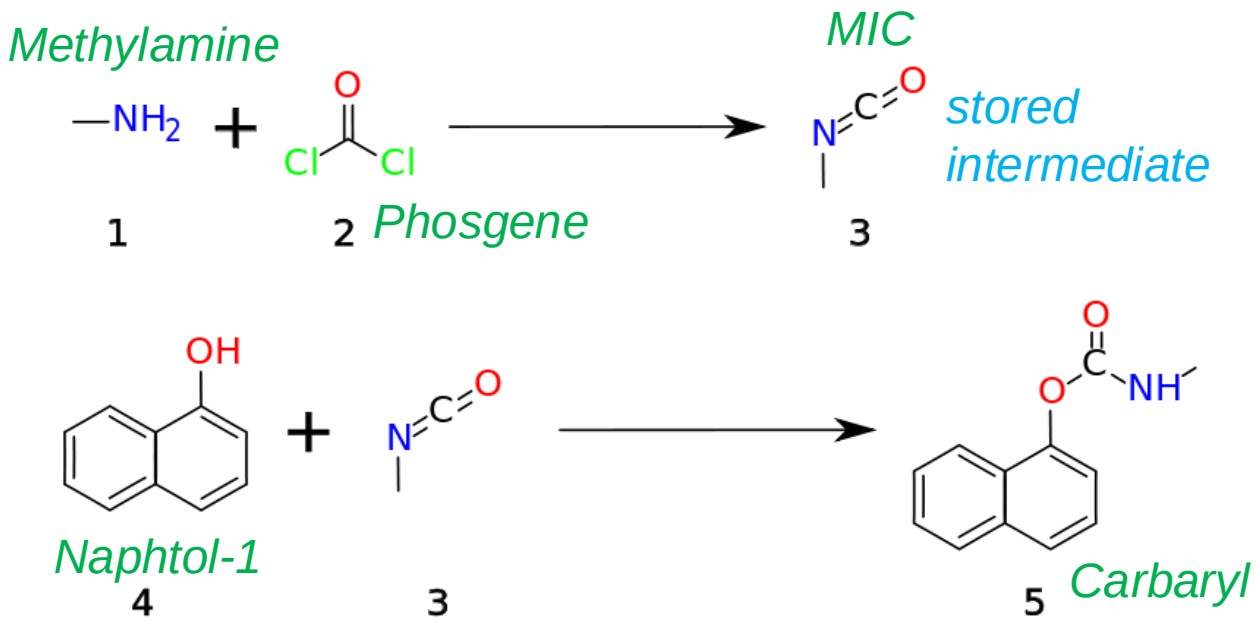
Chemists strive to build increasingly complicated molecules. For a long time, this has been very time consuming and expensive. Barry Sharpless coined the concept of click chemistry, where molecular building blocks snap together quickly and efficiently. In 2002, Sharpless and Morten Meldal, independently of each other, developed an elegant and efficient chemical reaction: the copper catalysed azide-alkyne cycloaddition. This is now in widespread use and is utilised in the development of pharmaceuticals, for mapping DNA and creating new materials.

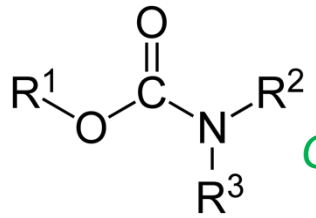
What makes it "click"?

- Efficient
- Benign solvents or easy to purify
- High yield
- One product
- Stereospecific
- low E-factor, high AE

Bhopal disaster, 2-3 Dec 1984

- Union Carbide plant in Bhopal
- World's worst industrial disaster
- Carbaryl is a wide-spectrum insecticide, controls over 100 species of insects on many crops, poultry, livestock and pets
- MIC is a liquid intermediate in carbaryl synthesis, highly reactive with water to generate CO_2, exothermic, BP is 39.1 °C (low)





Bhopal

Bhopal catastrophe, 2-3 Dec 1984

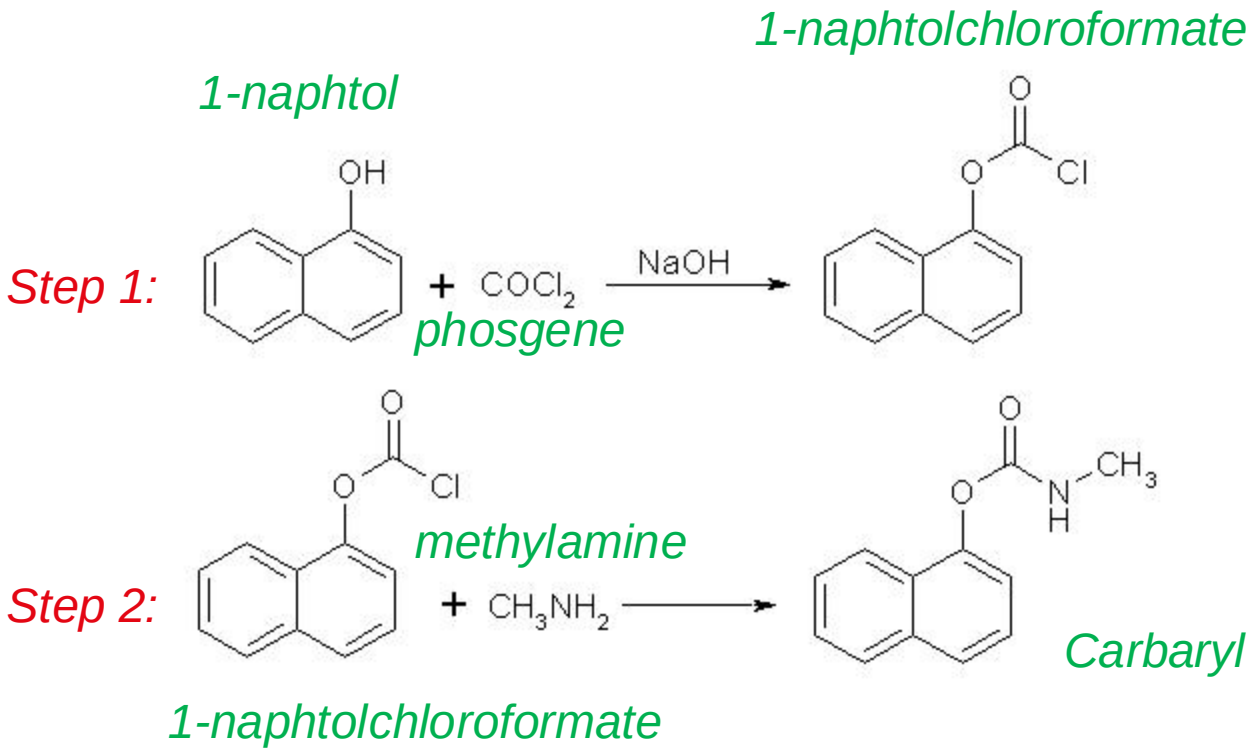
- Insecticide demand dropped in early 80s, leading to accumulation of MIC
- History of serious safety issues at plant in lead-up
- Exothermic reaction in MIC liquid storage tank, atmospheric venting!
- 500,000 exposed to toxic gas methyl isocyanate (MIC)
- 2259 immediate deaths (suffocation)
- $470 million payout in 1989
- Long terms health effects: eyes, respiratory tracts, neurological problems, PTSD, children's health
- UC acquired by DOW

Demonstrators marching through the streets of Bhopal to mark the 34th anniversary of the Union Carbide gas disaster in 2018

2023 article_The Guardian
https://en.wikipedia.org/wiki/Union_Carbide
https://en.wikipedia.org/wiki/Bhopal_disaster

Principles of Green Chemistry applied to Carbaryl?

Current common synthetic route for carbaryl:



- Avoids toxic methyl isocyanate and its accumulation

But:

- Toxic reagents used (phosgene) –used in chemical warfare in WWI
- 2 steps

Sevin

Materials Safety Data Sheet (MSDS) of phosgene

2.2 Label Elements

Contains: phosgene; carbonyl chloride

Signal Word: Danger

Hazard Statement(s):
H280: Contains gas under pressure; may explode if heated.
H330: Fatal if inhaled.
H314: Causes severe skin burns and eye damage.

Precautionary Statements

General None.

Prevention:
P260: Do not breathe gas/vapours.
P280: Wear protective gloves/protective clothing/eye protection/face protection.

Response:
P303+P361+P353+P315: IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/ shower. Get immediate medical advice/attention.
P304+P340+P315: IF INHALED: Remove person to fresh air and keep comfortable for breathing. Get immediate medical advice/attention.
P305+P351+P338+P315: IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Get immediate medical advice/attention.

Storage:
P403: Store in a well-ventilated place.
P405: Store locked up.

"Highly Toxic"

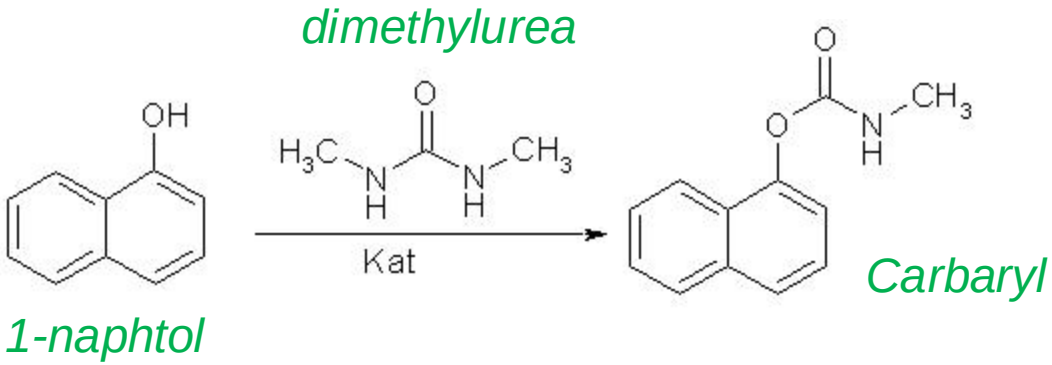
Phosgene is a highly toxic, irritating and corrosive gas to all body tissues. Inhalation can cause fatal respiratory damage.

- Exposure by inhalation to 20-30 ppm for as little as 1 minute may cause severe irritation of the upper and lower respiratory tract, with symptoms including burning throat, nausea, vomiting, chest pain, coughing, shortness of breath, and headache.
- **Brief exposure by inhalation to 50 ppm can be fatal within a few hours.**

The vapor is irritating to the eyes and skin at 4 ppm. As a condensed liquid it can cause severe skin burns and serious eye damage."

-Taken from University of New Mexico Standard Operating Protocol (SOP) for working with phosphene

1-step safer Carbaryl synthesis



https://exchemistry.com/sevin.html

Dimethylurea (DMU) (IUPAC systematic name: **1,3-Dimethylurea**) is a urea derivative and used as an intermediate in organic synthesis. It is a colorless crystalline powder with little toxicity.

Dimethylurea

Cool, but how safe is Carbaryl?

1. IDENTIFICATION OF THE MATERIAL AND SUPPLIER

1.1 PRODUCT IDENTIFIER:
TRADE NAME: **CARBARYL 4L**
1.2 RECOMMENDED USE: INSECTICIDE FOR AGRICULTURAL OR COMMERCIAL USE
1.3 SUPPLIER DETAILS:
LOVELAND PRODUCTS, INC.
P.O. Box 1286 • Greeley, CO 80632-1286
1.4 24 Hour Emergency Phone: 1-800-424-9300 - **Medical Emergencies:** 1-866-944-8565 – **Product Information:** 1-888-574-2878 (LPI-CUST)
U.S. Coast Guard National Response Center: 1-800-424-8802

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

Classification according to 29 CFR 1910.1200

Acute Toxicity – Oral	Category 4	H302
Acute Toxicity – Inhalation	Category 4	H332
Skin Corrosion/Irritation	Category 2	H315
Eye Damage/Irritation	Category 2B	H320
Carcinogenicity	Category 2	H351
Specific Target Organ Toxicity – Single Exposure	Category 1	H370
Specific Target Organ Toxicity – Repeated Exposure	Category 2	H373
Aquatic Acute Toxicity		H400
Aquatic Chronic Toxicity		H410

2.2 Label elements

Immediate skin, eye, or respiratory track irritant, or narcotic

Carcinogen or chronic long-term health hazard

Toxic to aquatic wildlife

Signal word: DANGER

Hazard Statement:
H302 – Harmful if swallowed.
H332 – Harmful if inhaled.
H315 – Causes skin irritation.
H320 – Causes eye irritation.
H351 – Suspected of causing cancer.
H370 – Causes damage to the central nervous system
H373 – May cause damage to the central nervous system through prolonged or repeated exposure.
H400 – Very toxic to aquatic life.
H410 – Very toxic to aquatic life with long lasting effects.

Precautionary Statement: (Prevention):
P264 – Wash hands and face thoroughly after handling.
P270 – Do not eat, drink or smoke when using this product.
P261 – Avoid breathing dust/fume/gas/mist/vapors/spray.
P271 – Use only outdoors or in a well-ventilated area.
P280 – Wear protective gloves/protective clothing/eye protection/face protection.
P201 – Obtain special instructions before use.
P202 – Do not handle until all safety precautions have been read and understood.
P260 – Do not breathe dust/fume/gas/mist/vapors/spray.
P273 – Avoid release to the environment.

Precautionary Statement: (Response):
P301+P312: IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician if you feel unwell.
P330 – Rinse mouth.
P304+P340: IF INHALED: Remove person to fresh air and keep at rest in a position comfortable for breathing.
P312 – Call a POISON CENTER or doctor/physician if you feel unwell.
P302+P352: IF ON SKIN: Wash with plenty of soap and water.
P321 – Specific treatment (see additional First Aid information on the product label)
P332 – If skin irritation occurs: Get medical advice/attention
P362 – Take off contaminated clothing and wash it before reuse.
P305+P351+P338 – IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do – Continue rinsing.
P337+P313 – If eye irritation persists: Get medical advice/attention.

PAGE 1 OF 6

"All things are poison and nothing is without poison; only the dose makes a thing not a poison."

-Swiss physician and chemist Paracelsus

Don't fret – Carbaryl is banned in the EU!
Since 2006… pesticide approval list

A non-comprehensive timeline of sustainability

- ~~The Silent Spring by Rachel Carson, 1962~~
- ~~Earth Day, 1970~~
- ~~Greenpeace, 1971~~
- ~~**Phase out of CFCs (1980s) – *Montreal Protocol***~~
- ~~"Our common future" by the UN Brundtland Commission (1987)~~
- ~~**Green chemistry (1990s)**~~
- ***Kyoto Protocol (early 2000s)* - Carbon as a currency**
- ***Paris Agreement (2010s)* - Climate change (1.5 °C)**
- ***UN Sustainable Development Goals* - Roadmap for prosperity *(2010s)***

FILE - In this April 23, 1970, file photo, part of crowd observing Earth Day, including, youngster wearing "Let Me Grow Up:" sign on back relaxes on hilltop in Philadelphia's Fairmount Park in Philadelphia. (AP Photo)

Silent spring summary
Earth Day
Brundtland Report

Kyoto Protocol - 1997

- Adopted in 1997, entered into force in 2005 with 192 parties
- Commits industrialized countries (only!) to GHG emission targets (with agreed individual targets), legally binding
- 2008-2012 – 1st commitment period) average of 5% emission reduction compared to 1990 levels
- Puts the burden on developed countries - largely responsible for high levels of GHG in atmosphere (developing countries had no targets)
- Under protocol, targets can be met by market-based mechanisms, e.g., International Emissions Trading

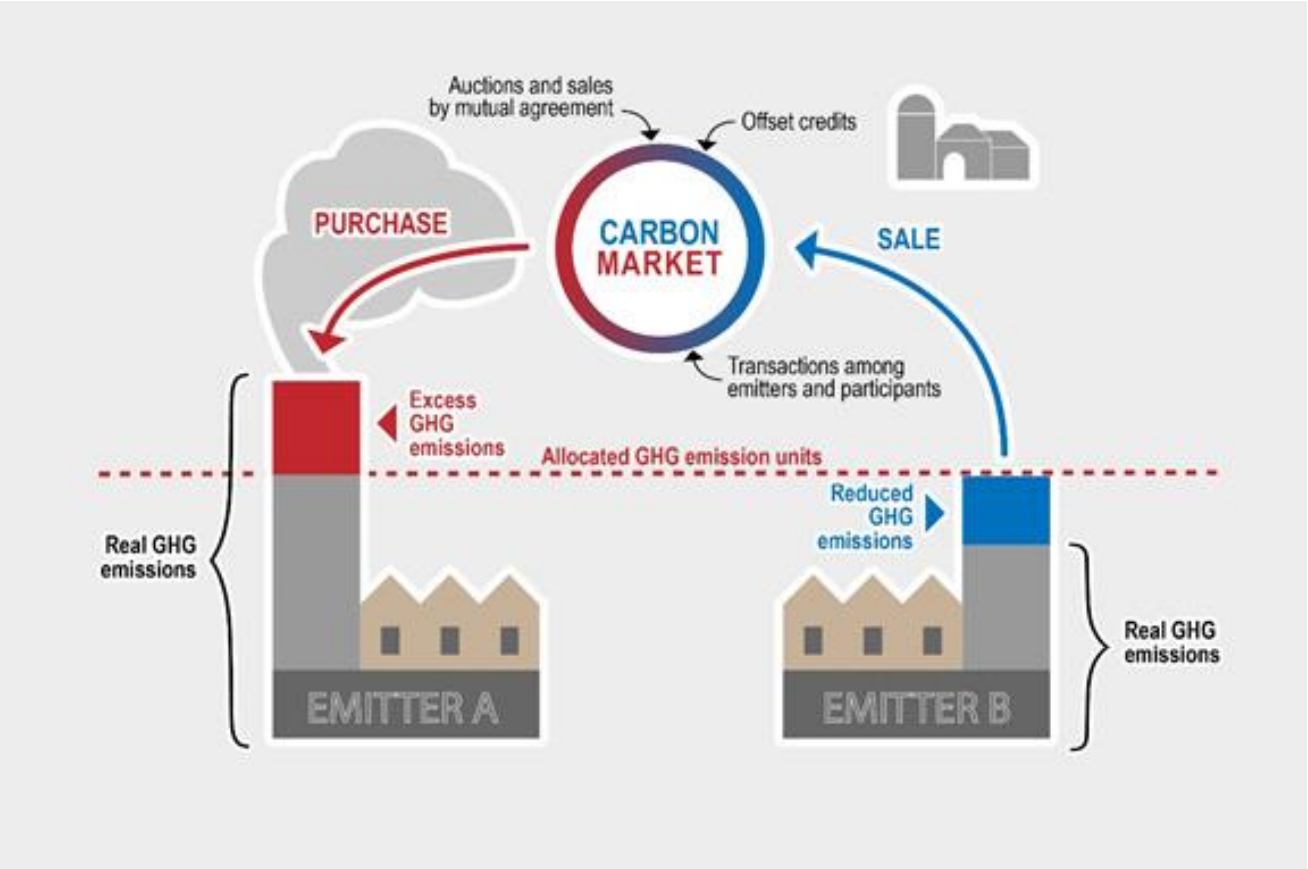
Who's part of the agreement?

US is not
China is not
Australia is not
Canada exited in 2011

Who's there?
EU
Japan
Switzerland

Kyoto Protocol

Kyoto Protocol – GHGs as a commodity



Emissions trading?

- Accepted targets for emissions
- Spare emissions can be sold from countries with unused emission units to countries that are over their targets
- "Carbon market" – carbon tracked and traded as a commodity (raw materials that can be bought and sold)

https://link.springer.com/chapter/10.1007/978-3-030-15424-0_7

Carbon offset/carbon offset credit

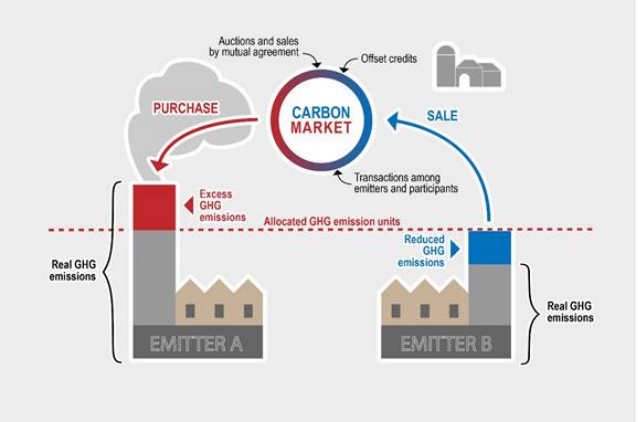
- Carbon offset = reduction in GHG emissions or an increase in carbon storage

- Carbon offset credit = certifiable unit representing the removal from the atmosphere of one metric ton of carbon dioxide or its equivalent (CO_2e) in other greenhouse gases

- Doesn't matter where the GHGs originate, so from a climate change perspective, there is no difference if a company:

    1. Stops the emissive activity
    2. Enables an equivalent emission-reducing activity anywhere in the world

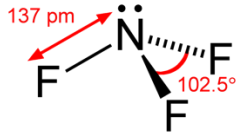
- Carbon offset market, where carbon offset credits can be bought, sold or traded by companies; companies and people can ***compensate for their GHG emission by funding an equivalent GHG saving elsewhere***



Topic be continued – Guest lecture on this topic

Carbon offset 1
Carbon offset 2

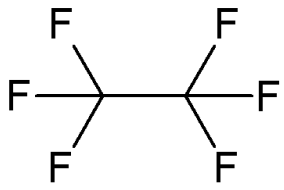
DOHA amendment



- 2nd commitment period, 2013-2020
- Reduce GHGs by 18% compared to pre-1990 levels
- Required 144 parties to ratify (3/4 of Kyoto) to enter into force, happened in 2020 with 147 parties
- Nitrogen trifluoride added to list of GHGs; GWPs of 17,200 for a 100-year time horizon, which means for instance that it is 17,200 times more potent compared to CO_2 at trapping heat in the atmosphere over the same time span

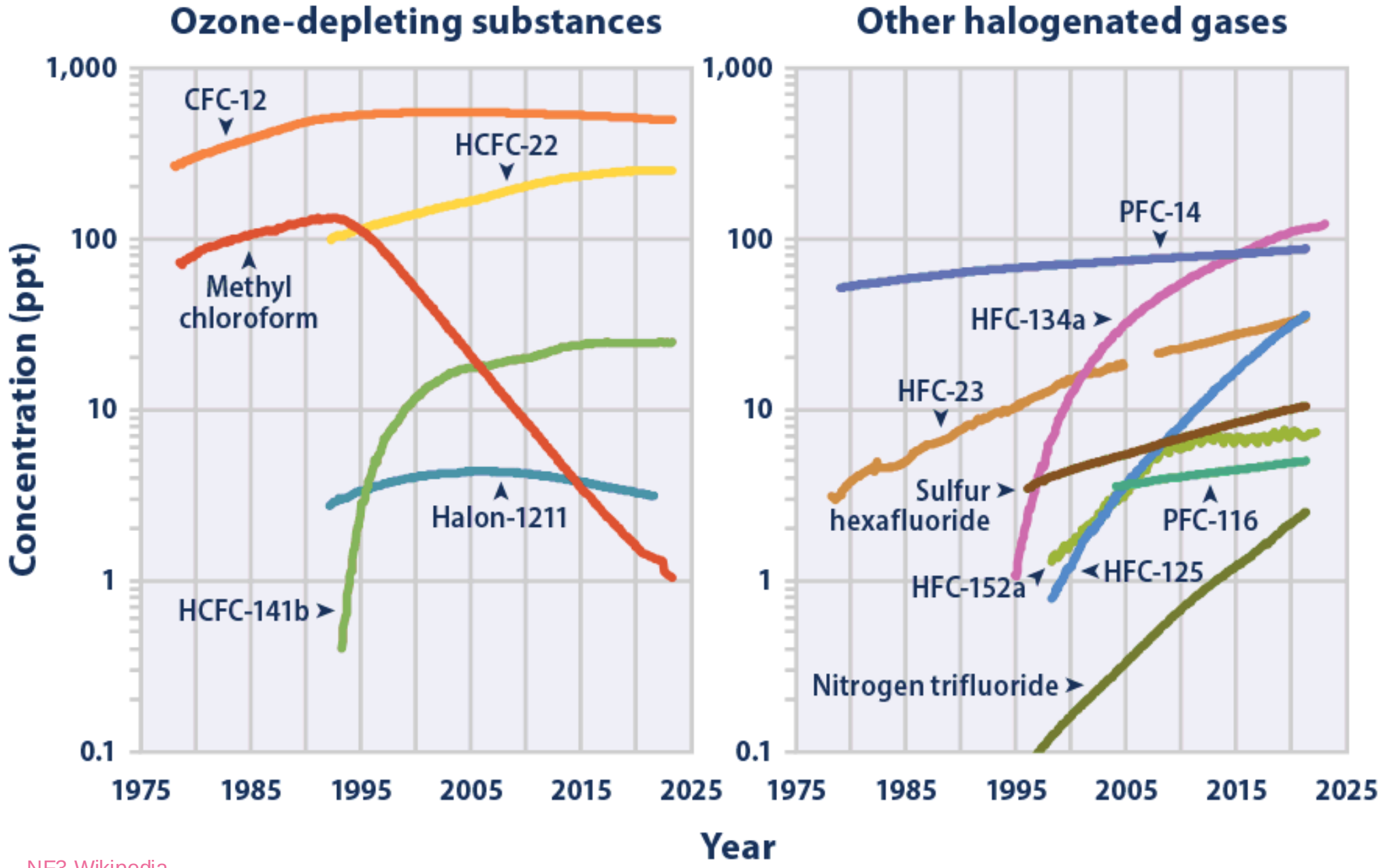
Hmmm…

- **Average life span of NF_3 in the atmosphere is 550 years**
- **Anthropogenic**
- **Used mostly for etching in semiconductor industry**
- **Wasn't listed under Kyoto, and replaced hexafluoroethane which was listed**



Hexafluoroethane
PFC -116

Kyoto Protocol



NF3 Wikipedia

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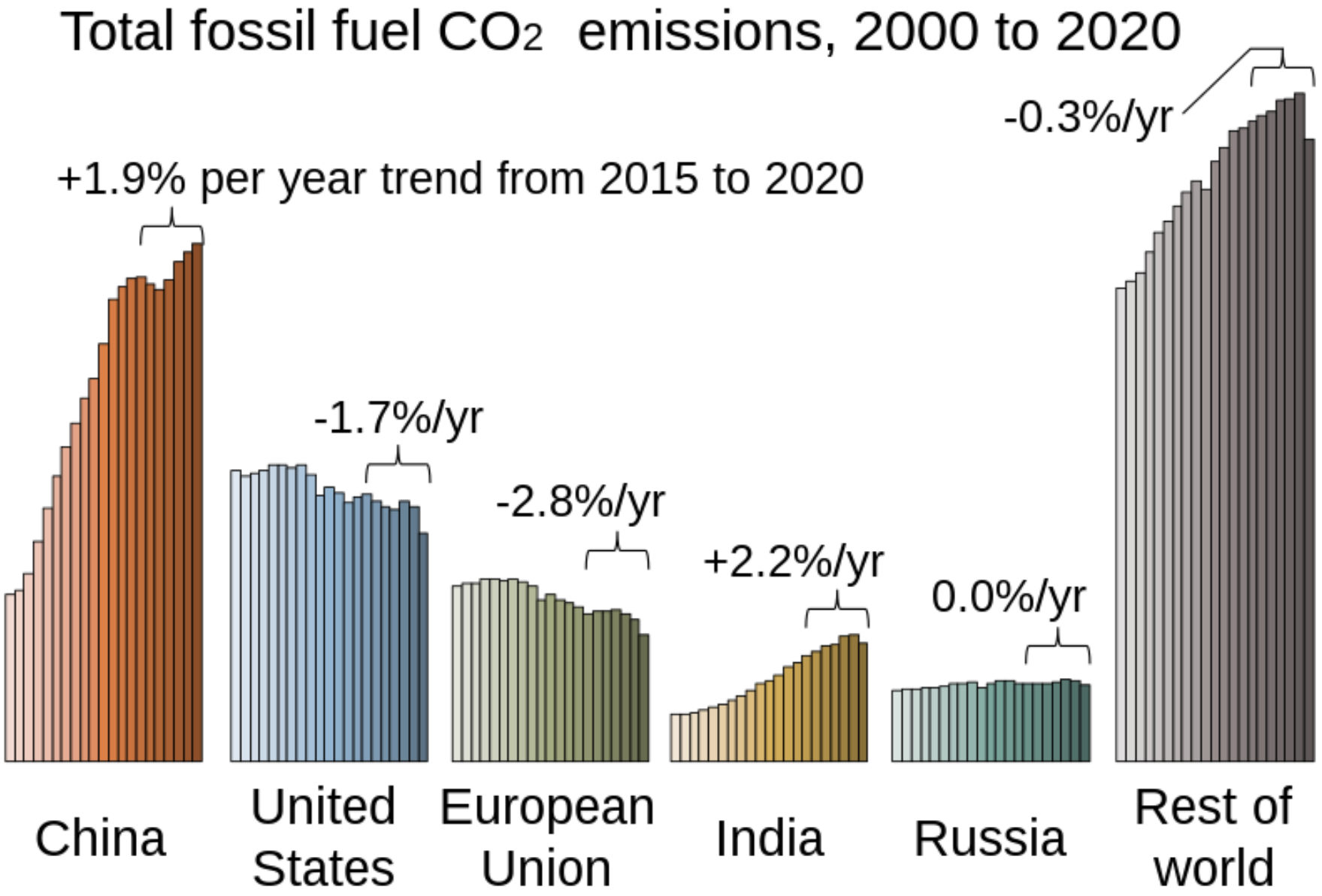
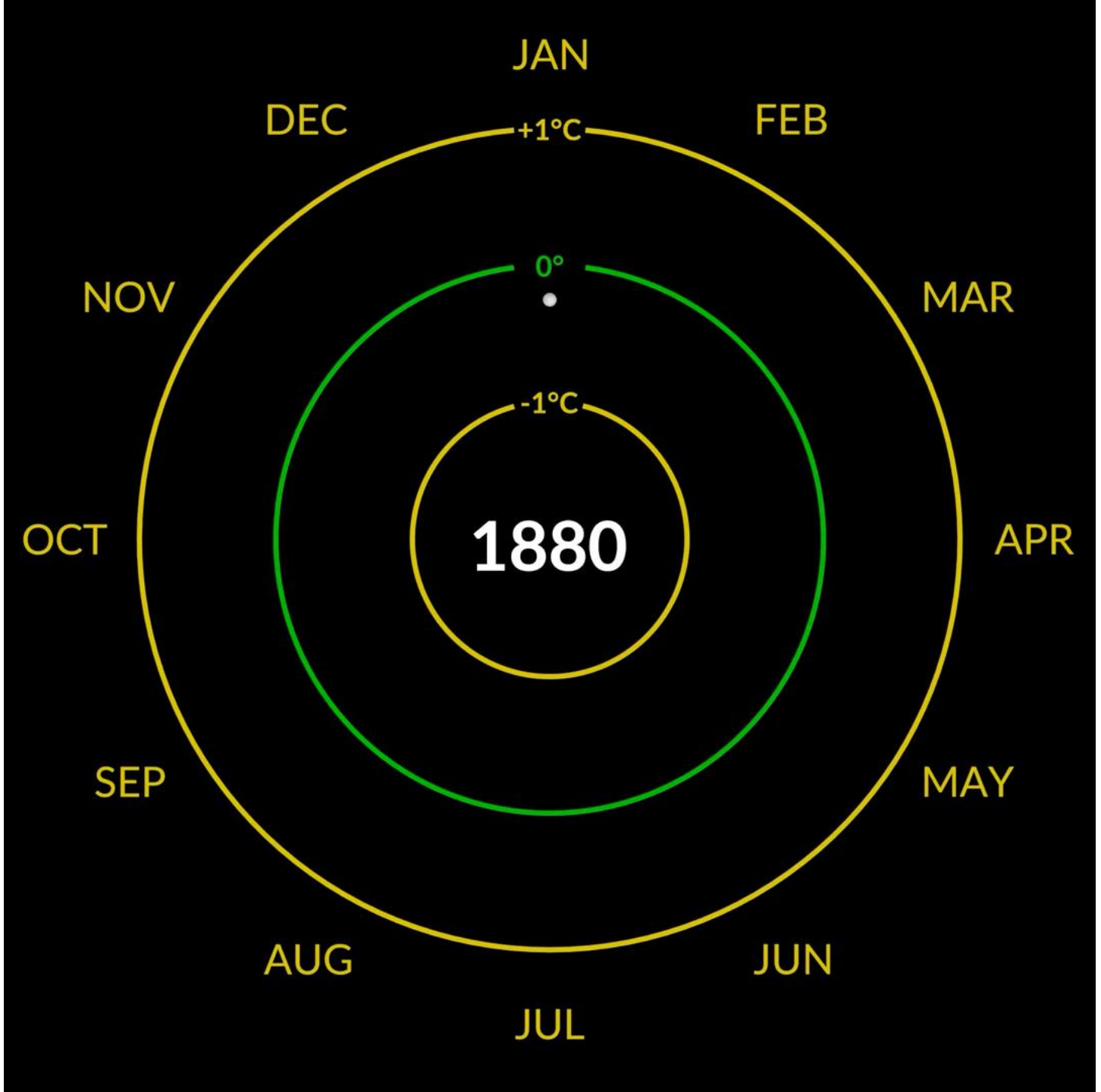
Silent spring summary
Earth Day
Brundtland Report

Paris Agreement - backdrop



By Efbrazil - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=87714574



- Temp anomaly from 1880-2022
- Relative to base period of 1951-1980

Nasa climate spiral

Paris Agreement - 2015

- Adopted in 2015, entered into force in 2016
- International treaty to reduce impacts of climate change; although Kyoto is still technically in force, Paris agreement is now the main global response to climate change
- Adopted by 196 Parties at the UN Climate Change Conference – COP 21 (US will withdraw in 2025, for the second time)
- **Limit global warming to below 2 °C, preferably 1.5 °C, to reach net-zero emissions/carbon neutrality**
  - Requires GHG emissions to be cut by 50% by 2030 – **moving towards Net Zero**

Paris Agreement

Net zero – balance between GHG emission and removal from the atmosphere

What's new about the Paris Agreement?

- Nationally determined contributions (NDCs) for all countries, not just developed countries
- Countries set their own GHG reduction goals (not like Kyoto, with 5% in 1st commitment period)
- NDCs submitted every 5 years, increasing ambition
- Carbon markets, voluntary targets, no real enforcement/peer pressure mechanism…
- What could go wrong?

Paris Agreement

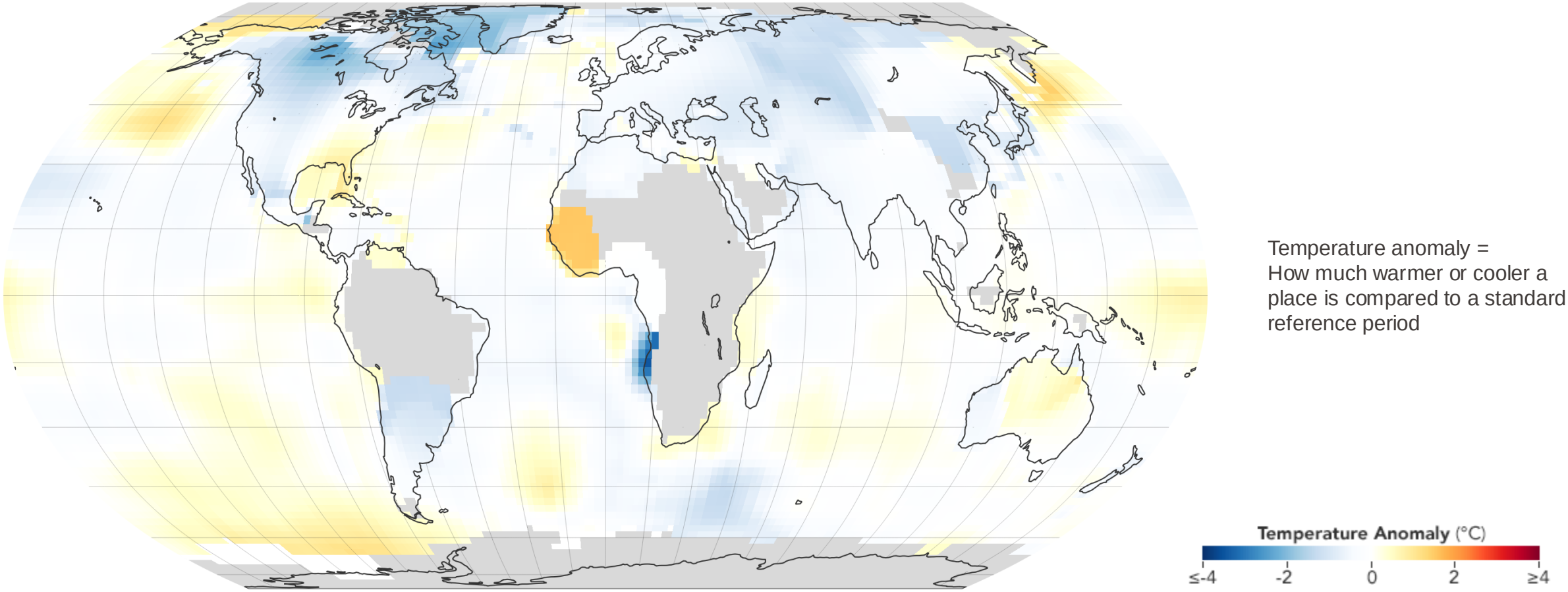
"The world is more likely to warm slightly more," said Climate Analytics and scientist CEO Bill Hare. "The more the world warms the faster we will experience more extreme weather events such as flooding, extreme hurricanes, fire, weather, drought, and heat. The U.S. will not be exempt from such events."

2025 AP News article

1.5 °C

> The World Will Likely Miss 1.5 Degrees C—Why Isn't Anyone Saying So? - *Scientific American, 2022*

1880-1884



Temperature anomaly =
How much warmer or cooler a place is compared to a standard reference period

Global temperatures

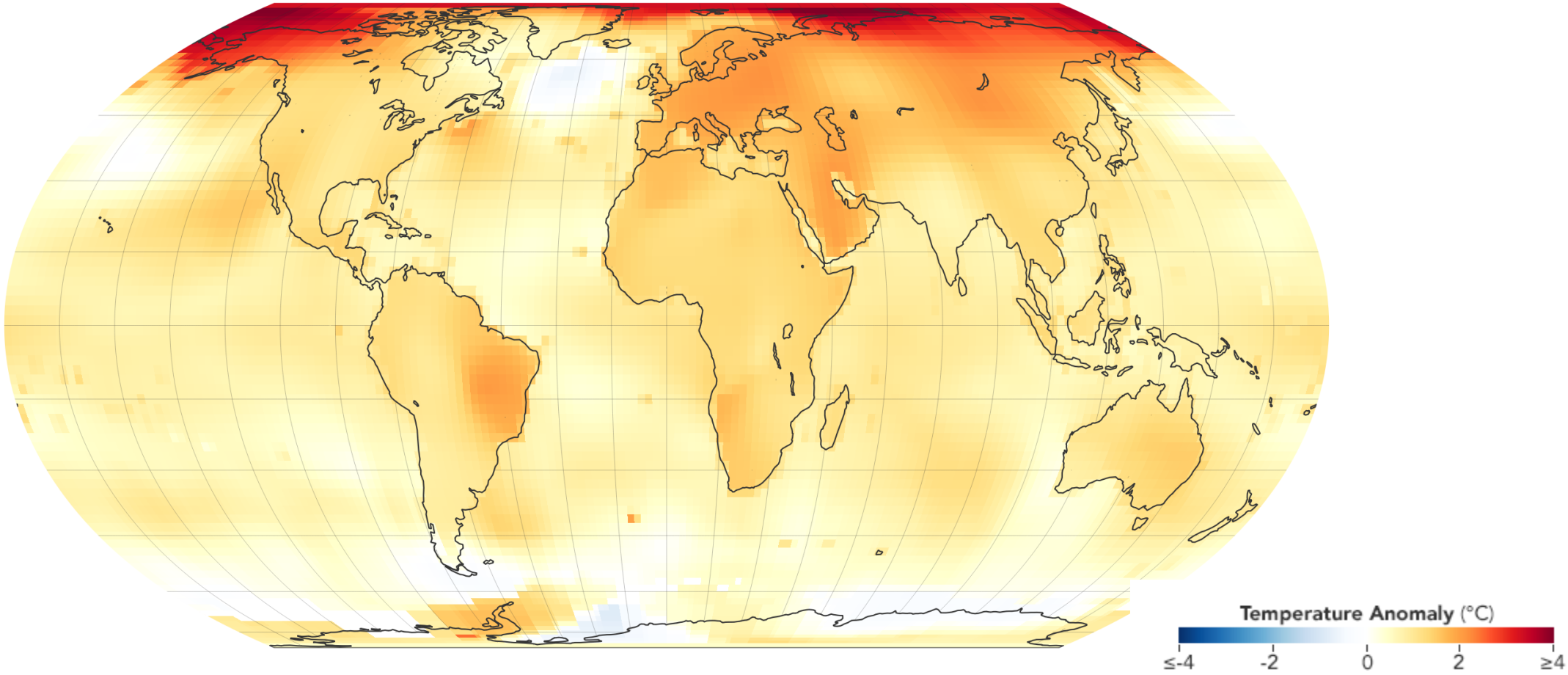
Compared to 1951-1980 average - global mean surface air temperature of 14 °C

1.5 °C

The world is going to miss the totemic 1.5°C climate target

It needs to face up to the fact - *The Economist, 2022*

2015-2019

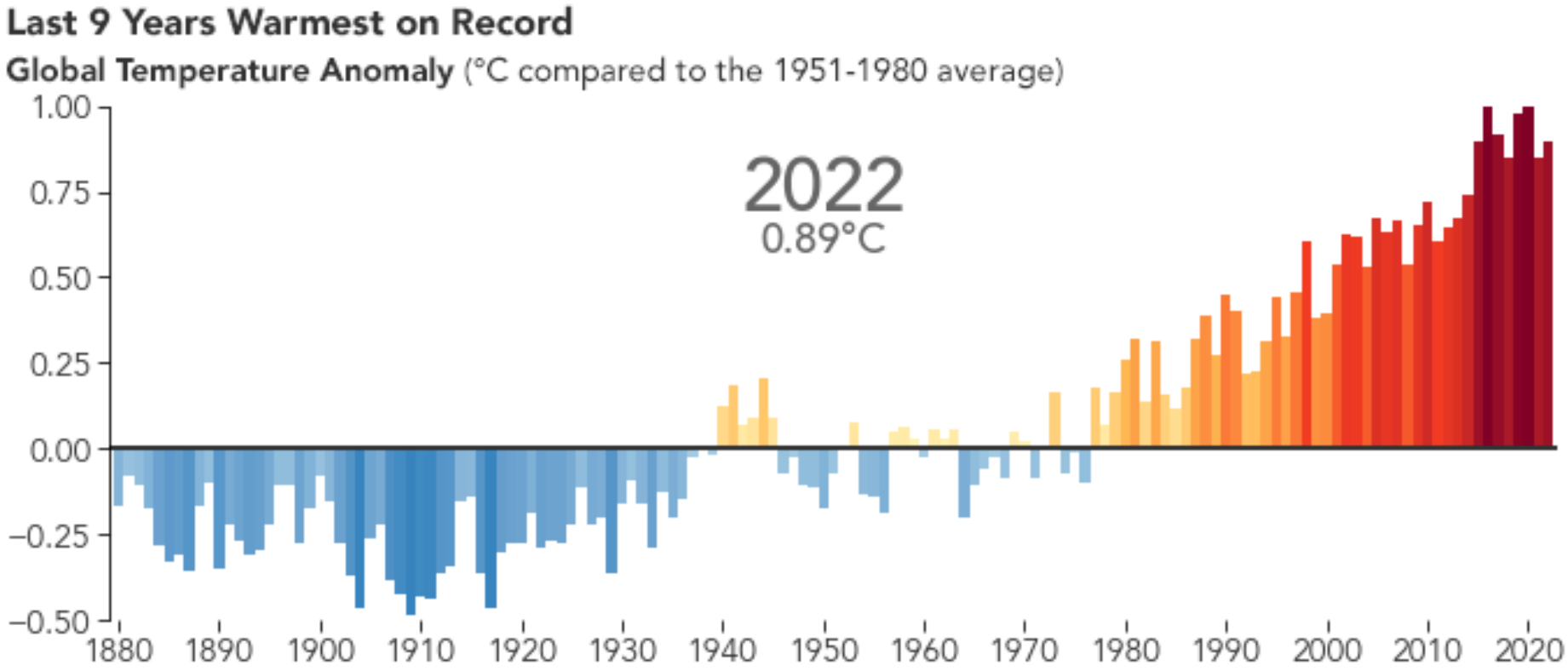


Compared to 1951-1980 average - global mean surface air temperature of 14 °C

Global temperatures

1.5 °C

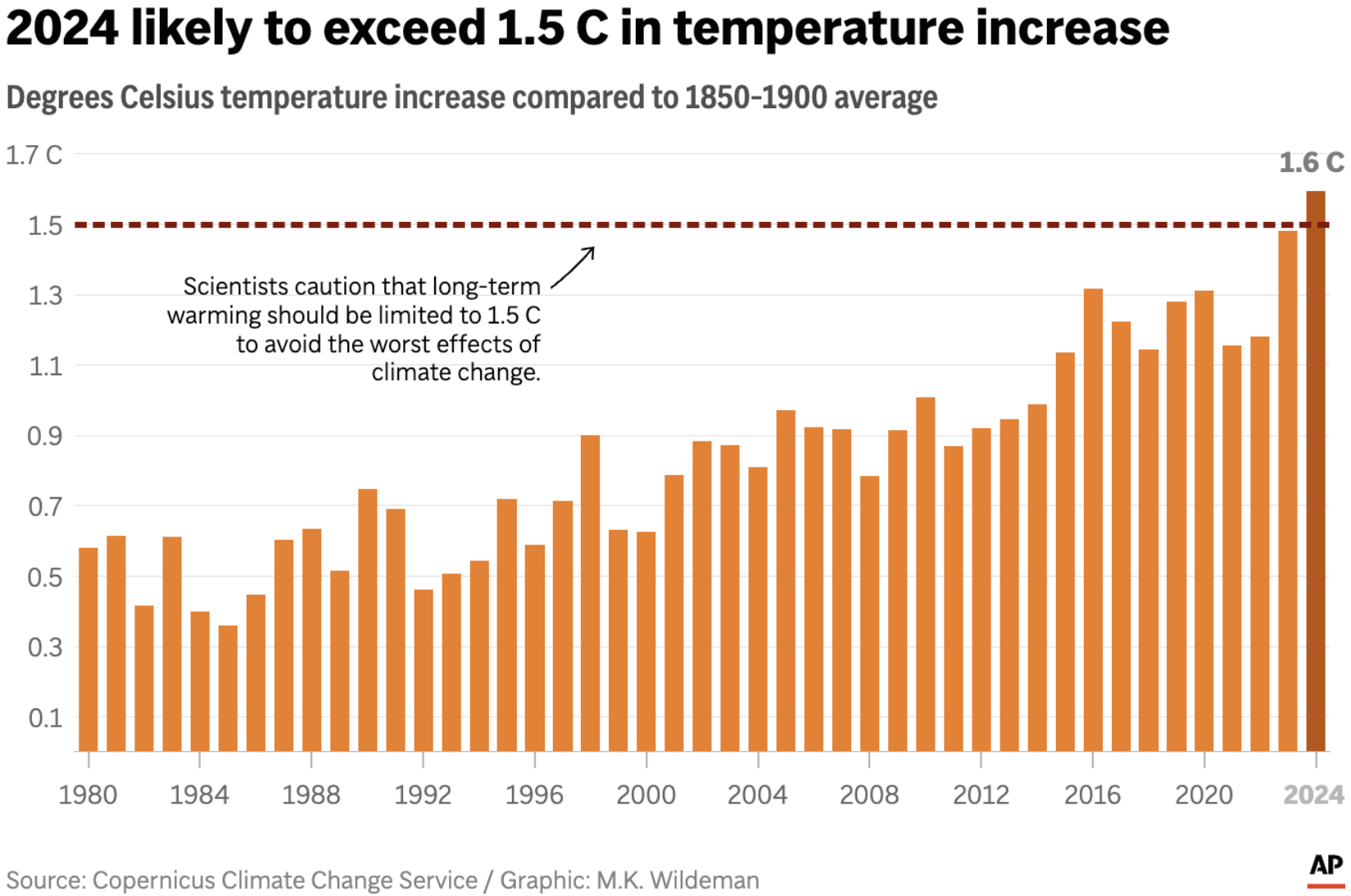
Described as a temperature tipping point to avoid climate change risks



Global temperatures

1.5 °C

2025 AP News article



- 1.5 °C goal is average over 20 years

Why is staying below 1.5 °C important?

- **Extreme weather:** Severe and more frequent storms
- **Sea level rise:** Rising sea levels from melting ice sheets
- **Ecosystems & biodiversity:** Species loss, habitats threatened
- **Food & water security:** Food shortages, freshwater shortages/drought, crop failures
- **Irreversible damage:** past a tipping point
- **Health:** heat-related diseases, deaths, pollution
- **Social & economic:** Poverty and displacements; high mitigation costs

A non-comprehensive timeline of sustainability

- ~~The Silent Spring by Rachel Carson, 1962~~
- ~~Earth Day, 1970~~
- ~~Greenpeace, 1971~~
- ~~**Phase out of CFCs (1980s) – *Montreal Protocol***~~
- ~~"Our common future" by the UN Brundtland Commission (1987)~~
- ~~**Green chemistry (1990s)**~~
- ~~***Kyoto Protocol (early 2000s)* - Carbon as a currency~~
- ~~***Paris Agreement (2010s)* - Climate change (1.5 °C)~~
- ***UN Sustainable Development Goals* - Roadmap for prosperity *(2010s)***

FILE - In this April 23, 1970, file photo, part of crowd observing Earth Day, including, youngster wearing "Let Me Grow Up:" sign on back relaxes on hilltop in Philadelphia's Fairmount Park in Philadelphia. (AP Photo)

Silent spring summary
Earth Day
Brundtland Report

https://sdgs.un.org/goals

SUSTAINABLE DEVELOPMENT GOALS

- Not legally binding

Calls for action in 2015 to be reached by 2030 (it's 2025 now…)

Goals	Basic description
1	End poverty in all its forms everywhere
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3	Ensure healthy lives and promote well-being for all at all ages
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5	Achieve gender equality and empower all women and girls
6	Ensure availability and sustainable management of water and sanitation for all
7	Ensure access to affordable, reliable, sustainable and modern energy for all
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

SD Goals

Calls for action in 2015 to be reached by 2030 (it's 2025 now…)

Goals	Basic description
10	Reduce inequality within and among countries
11	Make cities and human settlements inclusive, safe, resilient and sustainable
12	Ensure sustainable consumption and production patterns
13	Take urgent action to combat climate change and its impacts*
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

SD Goals

Deep dive: SDG 7 (by 2030)

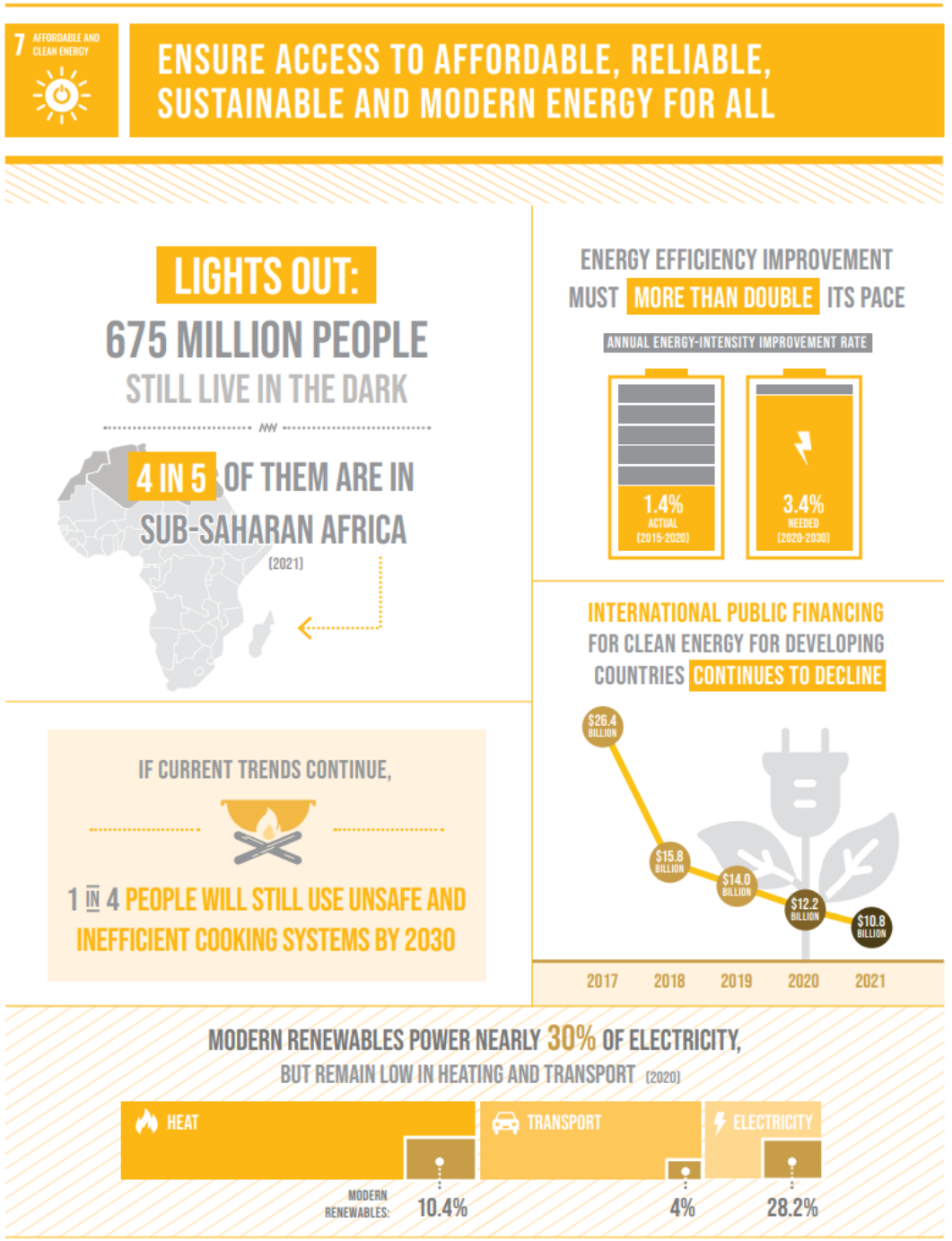
- Access to affordable, reliable, and modern energy services
- Substantially increase share of renewable energy
- Double global rate of improvement in energy efficiency

- Promote investment in energy infrastructure and clean energy technology & e[illegible] international cooperation
- Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries

SD Goals

Deep dive - SDG 7 progress

- By 2023, >2 billion will still use harmful cooking oils & 660 million will be without electricity
- Share of renewable sources in total final energy consumption rose to around 19% in 2021



https://sdgs.un.org/goals
Why the war in Ukraine is driving up Europe's use of coal—and its price

Deep dive - SDG 9 Goals (by 2030)

- Quality, reliable, sustainable and resilient infrastructure for economic development and human well-being
- Significantly raise industry's share of employment and gross domestic product, doubling share in least developed countries
- Increase access of small-scale industrial and other enterprises, especially in developing countries, to financial services, including affordable credit, and their integration into value chains and markets
- Upgrade infrastructure and retrofit industries to make them sustainable
- Enhance scientific research and upgrade tech capabilities of industrial sectors in all counties, especially developing countries

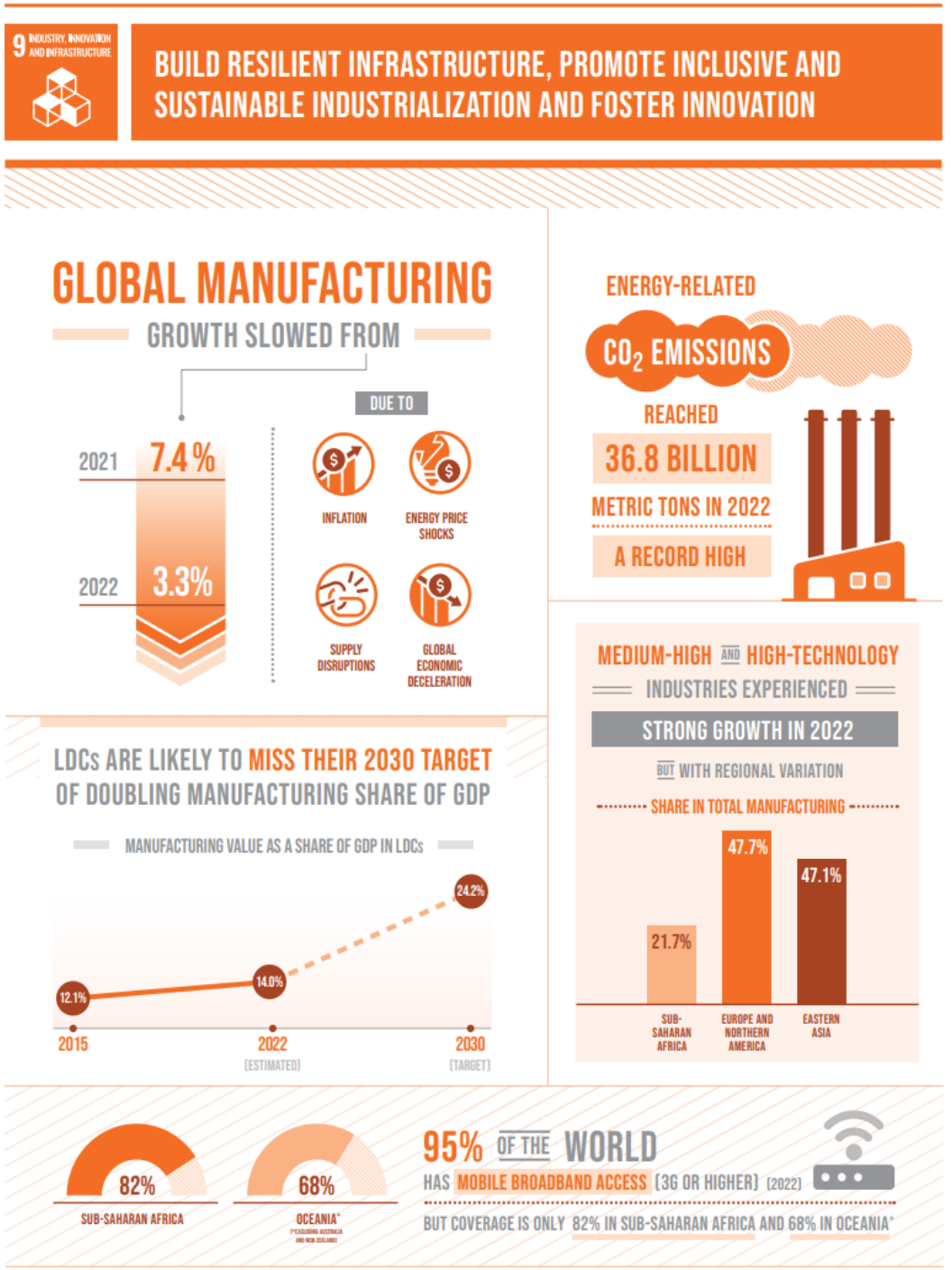
Image by Gerd Altmann

https://sdgs.un.org/goals/goal9

Deep dive - SDG 9 progress

- Since 2022, global economic slowdown
- 95% of the world has access to mobile broadband internet
- Between 2015 and 2020, 4G coverage doubles to 88%, but still a “coverage gap” with 17% without access in least developed and landlocked developing countries

https://sdgs.un.org/



Deep dive - SDG 12 Goals (by 2030)

- Sustainable management and efficient use of natural resources
- ½ per capita global food waste at the retail and consumer levels, reduce food losses along production and supply chains, including post-harvest losses
- By 2020, environmentally sound management of chemicals and all wastes throughout their life cycle (*Green Chemistry?*)
- Substantially reduce waste generation through prevention, reduction, recycling and reuse (*Green Chemistry?*)
- Encourage companies, *especially large and transnational companies*, to adopt sustainable practices and to integrate sustainability information into their reporting cycle
- Promote public procurement practices
- Ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature

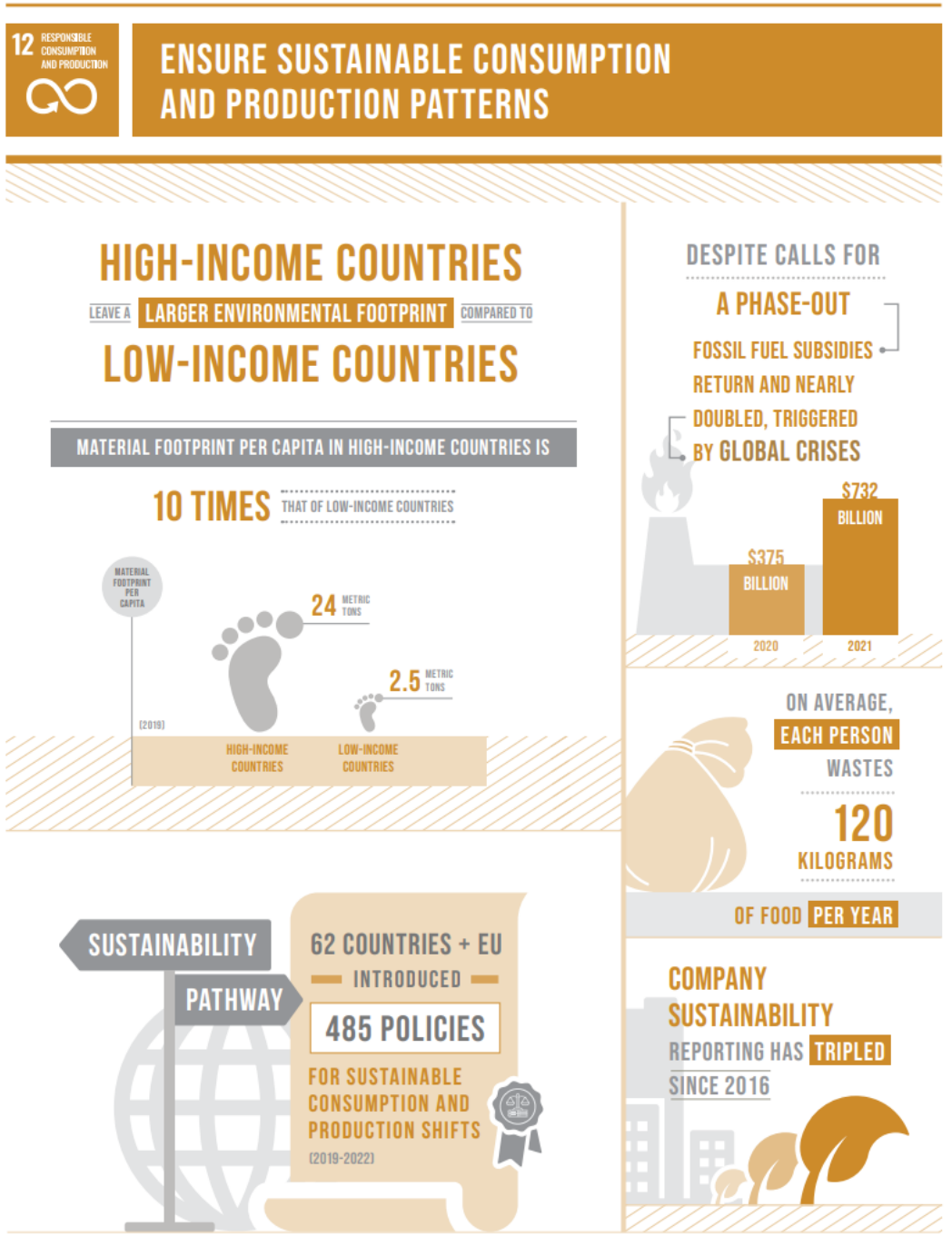
Key Elements of Sustainable Consumption and Production
Source: UNEP (2010).

https://sdgs.un.org/goals/goal12

Deep dive - SDG 12 progress

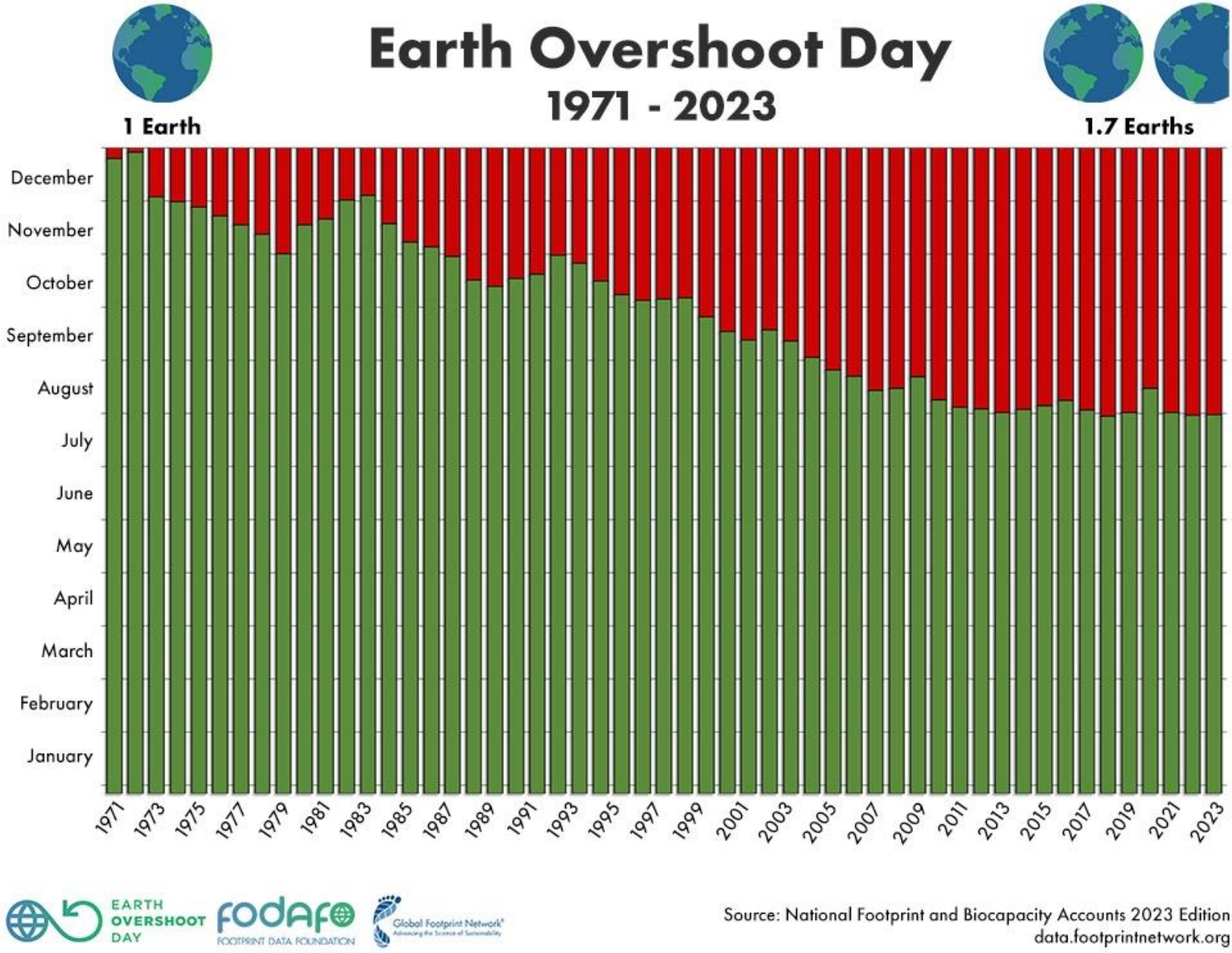
- 2000 to 2019: total domestic material consumption up by >65% globally, 95.1 billion metric tons in 2019.
- 2020: 13.3% of the world's food lost after harvest and before reaching retail markets
- 17% of total food available to consumers (931 million metric tons) wasted at household, food service, and retail levels
- 2019: 7.3 kilograms per capita of e-waste generated globally was, only 1.7 kilograms was managed in an environmentally sound way
- E-waste collection rates are relatively high in high-income countries but much lower in low- and middle-income countries – only 1.6% in sub-Saharan Africa and 1.2% in Latin America and the Caribbean
- **Good news!** Capacity of developing countries to generate electricity from renewable sources has soared, from 109.7 watts per capita in 2011 to 245.7 watts per capita in 2020
- **Good news!** Renewables represent over a third (36.1 per cent) of developing countries' total electricity-generating capacity

https://sdgs.un.org/



Ecological overshoot

- Earth Overshoot Day is a symbolic representation of ecological overshoot
- Date that marks when humanity's demand for ecological resources exceeds what the Earth can regenerate in 1 year
- Computed by dividing the planet's biocapacity by humanity's ecological footprint, and multiplying by 365
- August 1, 2024
- Using up about 1.7 Earth's/year



Overshoot

Interesting web tool to understand different levers to get to Net Zero by 2050 – give it a try at home

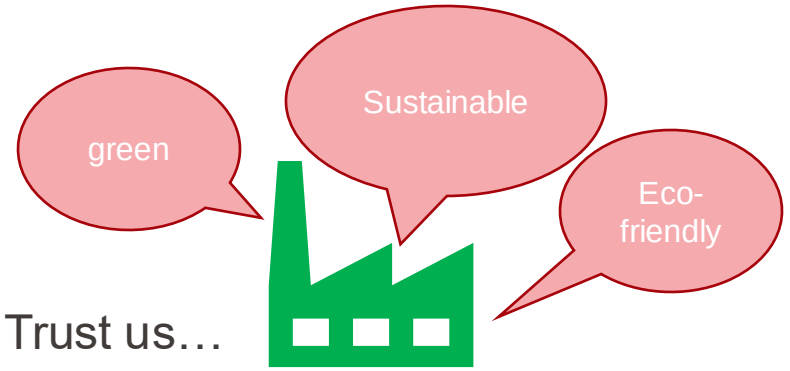
http://tool.european-calculator.eu/intro

SDG 12 touches on the responsibilities of countries, industries, and individuals

How do you define responsible consumption in your life? Does it inform your choices? Why? Why not?

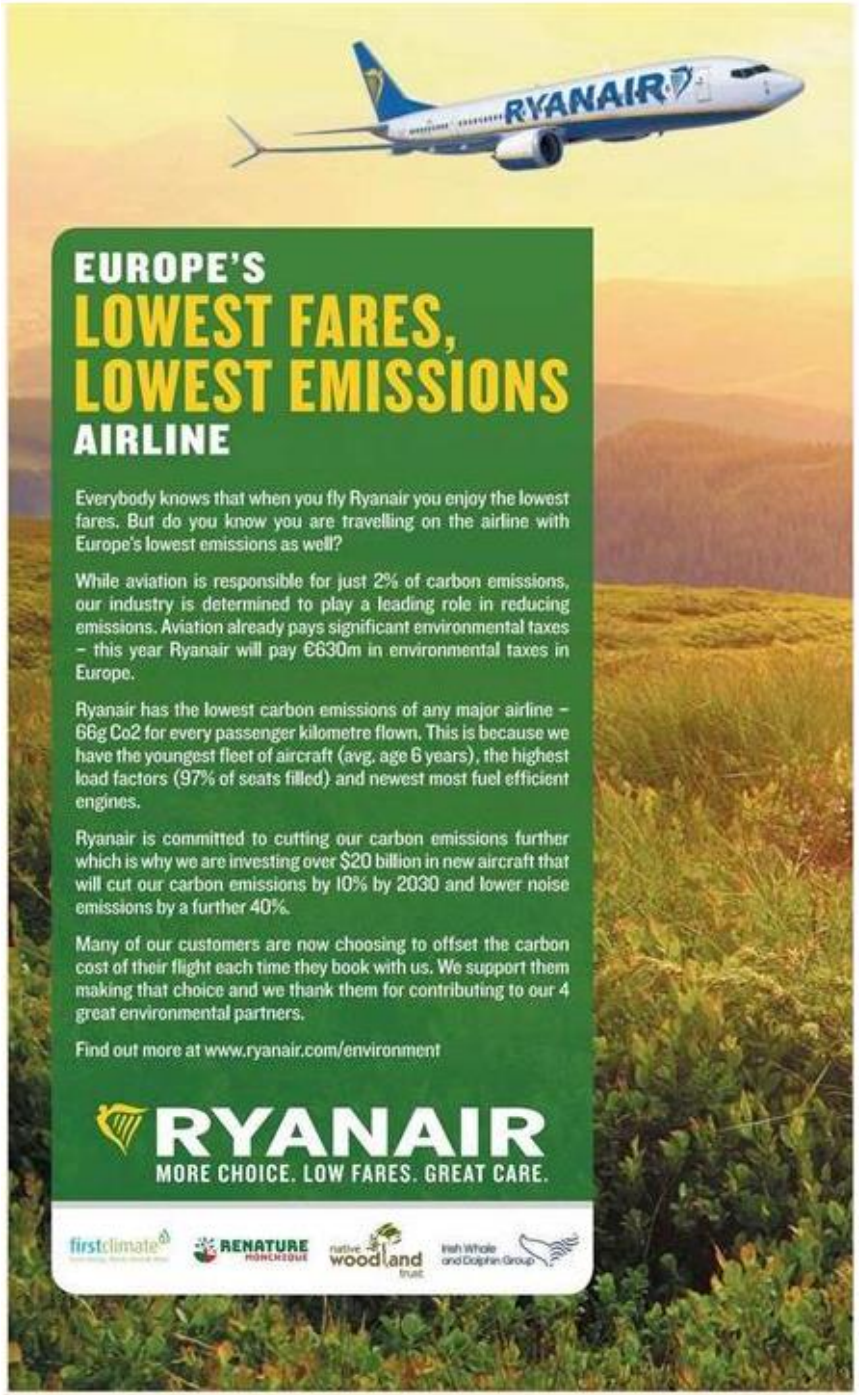
How to spot greenwashing?

- False claims
- Vague language
- Buzzwords without evidence
- Not giving the full picture across the value chain
- Carbon-offsetting
- Company ownership
- Eco-friendly product lines
- False claims of recyclability or biodegradability



Identify trustworthy certification, but not always easy…

Greenwashing



Greenwashing

So much green! It must be good, right?

Good news: EU greenwashing ban in 2024

EU approach:

- Legislative measures, regulatory guidelines, and enforcement actions to ensure transparency, accuracy, and honestly in environmental marketing or labeling
- EU ecolabels and standards
- Development of "*Green Claims Code*", setting clear criteria on what makes up an environmental claim, backed by science
- Development of "*Digital Product Passport*", where you can learn about your product – origin, composition, end of life handling
- Raising awareness on greenwashing with consumers, so that they can make environmentally sound choices

[How to spot greenwashing]

[Law banning Greenwashing and misleading product information_2024]

Ecoanxiety

eco anxiety

the anxiety associated with fear of harming **the environment**; **the fear** one experiences when they **second-guess** their actions for fear of impacting the Earth in a negative manner

- Also called climate anxiety
- "chronic fear of *environmental doom*"

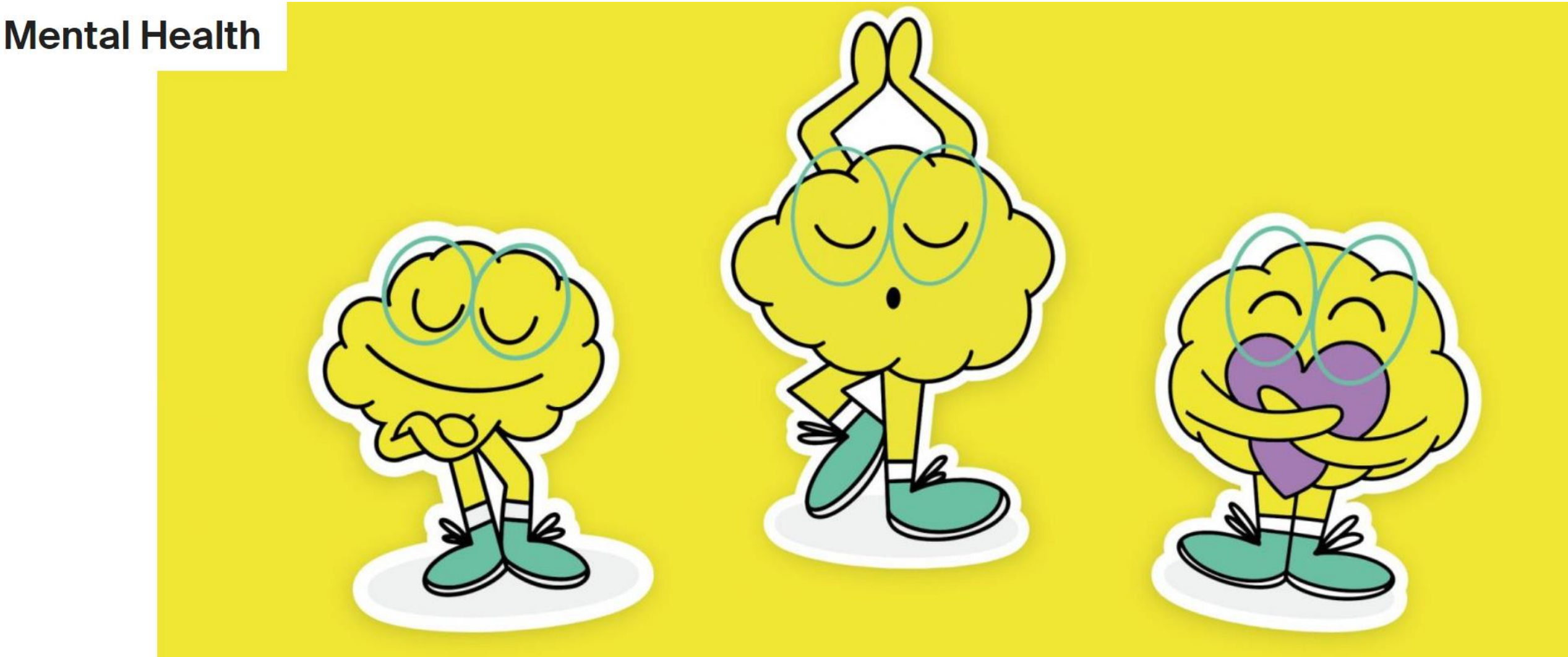
From: Mental Health and Our Changing Climate: Impacts, Implications, and Guidance, American Psychological Association, 2017

- Worry, guilt, hopelessness, powerlessness
- Be eco-angry instead?

Bears

Stanley, S, et al. From anger to action: Differential impacts of eco-anxiety, eco-depression, and eco-anger on climate action and wellbeing_2021

https://www.epfl.ch/campus/security-safety/en/sante/sante-mentale-bien-etre/mental-health/



Take aways

- Kyoto Protocol; GHGs as a commodity; carbon market
- Paris Agreement; 1.5 °C threshold
- Net zero: balance between GHG emissions and removals from the atmosphere
- UN SDGs; general idea, can you list a few?
- Ecological overshoot; Earth Overshoot Day
- Greenwashing; measures to combat it
- Exoanxiety?
- Small steps add up