Sustainable Consumption : Political Economy of Sustainable Food

Amadae, S. M.

Aalto University

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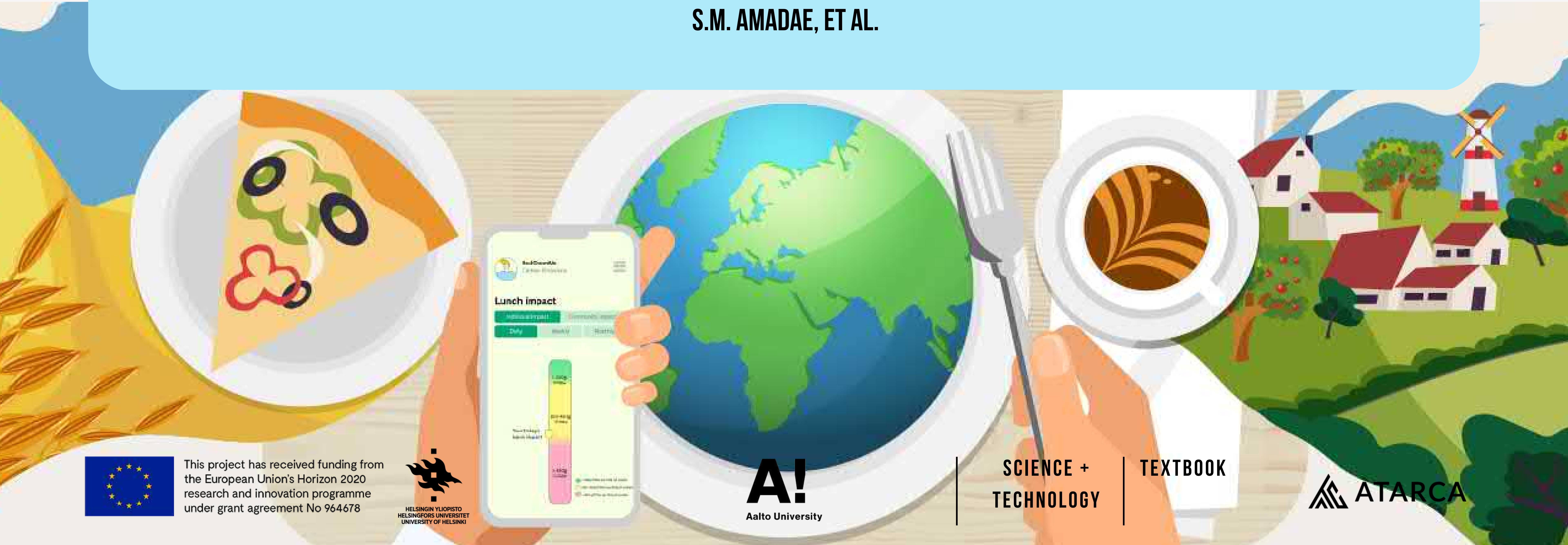
SUSTAINABLE CONSUMPTION

POLITICAL ECONOMY OF SUSTAINABLE FOOD

S.M. AMADAE, ET AL.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 964678

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SCIENCE + TECHNOLOGY | TEXTBOOK

ATARCA

Sustainable Consumption

Sustainable Consumption:

Political Economy of Sustainable Food

S.M. Amadae with

Maija Harju, Ruta Jumite, Juuso Kortelainen, Marianna Laine, Shreya Sood, Sonja Sorri

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Foreword

Sustainable Consumption: The Political Economy of Sustainable Food is the result of the ATARCA research project which has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 964678. This text was written to complement the Open University online course Sustainable Consumption offered at the University of Helsinki (see blogs.helsinki.fi/GPC to find up-do-date information on this 2-credit course).

The theoretical structure for this textbook and course were developed over the 2 years of the ATARCA project. We worked to develop a means to mitigate the environmental tragedy of the commons associated with climate change. We diagnosed that two problems to be solved are (1) the negligible impact each individual makes on the global atmospheric commons, and (2) the worry that others will not do their part in making sustainable choices. As well, individuals may not have perfect information about the impact of their consumptive choices.

This text first existed as the curricula for the Global Politics and Communication course Sustainable Consumption (GPC-001) offered initially at the University of Helsinki in November of 2022. The Faculty of Social Sciences at the University of Helsinki sponsored the development of this course to make it available to the general public as a form of continuous education. The course integrates innovative blockchain technology on an opt-in basis to provide a means to transform intent into action. This distributed ledger technology reinforces the anti-rival, positive-sum, impact of individuals’ sustainable choices.

Completing first the online course and subsequently this textbook required a large collaborative effort. Dr. S.M. Amadae (DICE, Aalto University; and Global Politics and Communication, University of Helsinki) designed the course and text with the input of MA researchers. This team of researchers were: Shreya Sood and Ruta Jumite, Creative Sustainability Design and Comnet/DICE, Aalto University; and Maija Harju, Juuso Kortelainen, Marianna Laine, and Sonja Sorri in the Faculty of the Social Sciences, University of Helsinki. We had digital support from András Rátonyi, DICE, Aalto University. Diana Wear provided professional editing for the text.

We designed this text to offer a rich visual experience that would embed dietary choices within the international community of nations, and provide historical references when possible. All images were either created by our graphic artist Jooeun Park, obtained as open-source resources, or purchased. Please use original attributions for images from open-source repositories (clearly attributed on relevant images throughout the text).

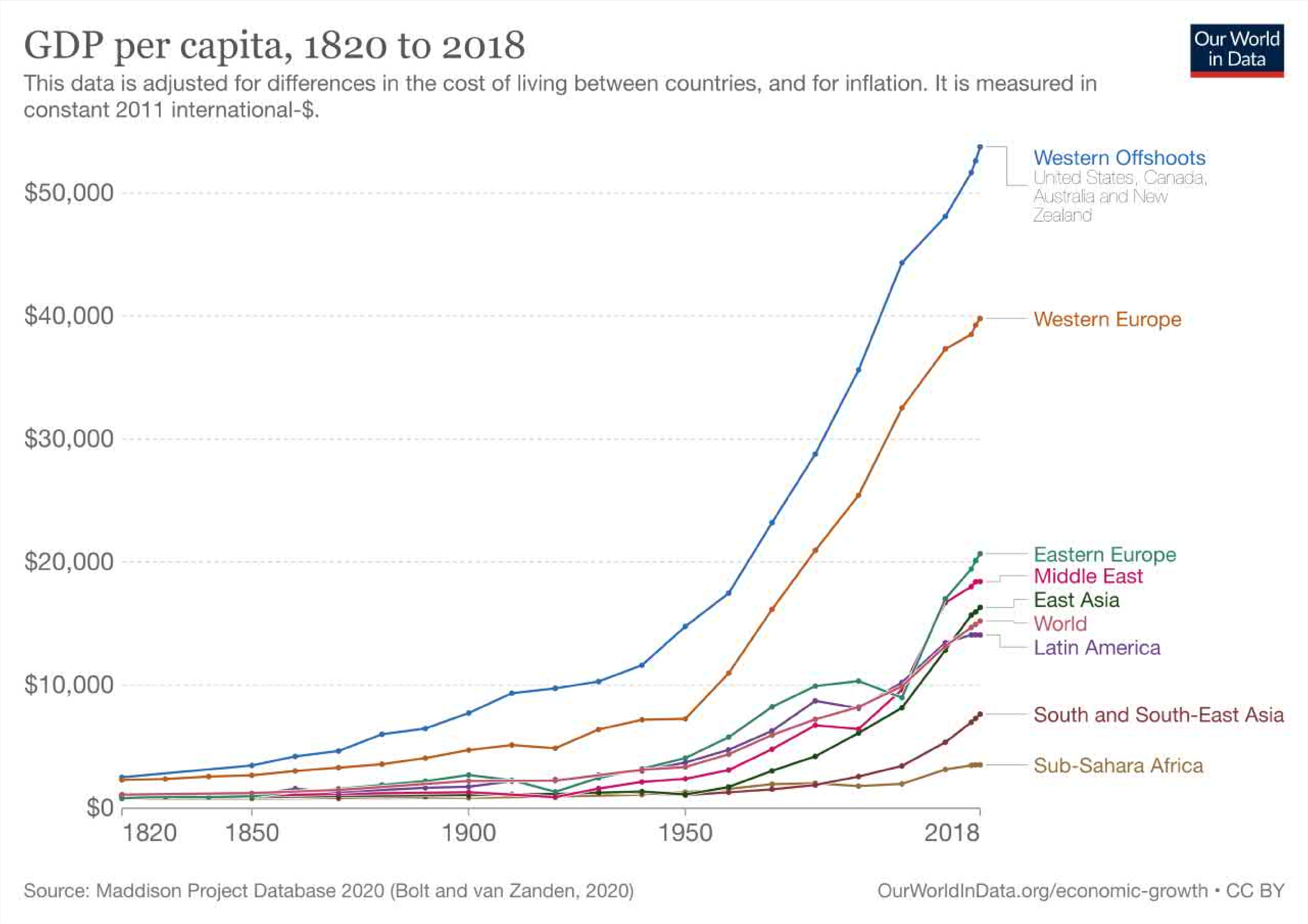
Illustration: Ruta Jumite, Jooeun Park, Shreya Sood.

CHAPTER 1
Course Overview

Section 1: Sustainable Consumption

The concept of **sustainable consumption** is that people use resources, including water and other natural materials, in a way so that they are replenished for continued use by present and future generations. Consumption is directly associated with the productive processes necessary to provide goods. Sustainable consumption focuses attention on the consumer as the agent who has the power to choose lifestyles and products that reflect the concern to live within ecosystem boundaries.

We could consider a limited ecosystem, for example Finland and the Baltic Sea. This ecosystem contains a limited amount of resources in terms of natural water, agricultural land, energy sources, fish and other natural produces including trees and minerals. Throughout history, human civilization has developed by using natural resources for food, building and infrastructure, energy, and transportation. This process of harnessing resources intensified during the 18th-century Industrial Revolution.



This graph represents economic growth since the 1400s. Its vertical axis reflects the average sum of Gross Domestic Product (GDP) per individual. This graph shows regional economic growth, which in turn indicates increasing wages and consumption. Source: https://ourworldindata.org/grapher/gdp-per-capita-maddison-2020

Exploiting the environment to achieve economic growth and development has characterised the past two to three centuries of human history. However, these large industrial processes of manufacturing, construction and massive infrastructure development, transportation and agriculture have led to depleting resources faster than they can be replenished. Examples have included overfishing, soil depletion and erosion, and emitting concentrations of carbon gas faster than they can naturally disperse.

Throughout history at times human civilizations have used resources more quickly than the environment could regenerate. Two examples of civilizational collapse are the end of the Old Egyptian Kingdom between 2760-2225 BCE, and the disintegration of the Roman Empire circa 500 AD.

Source: https://commons.wikimedia.org/w/index.php?curid=303315

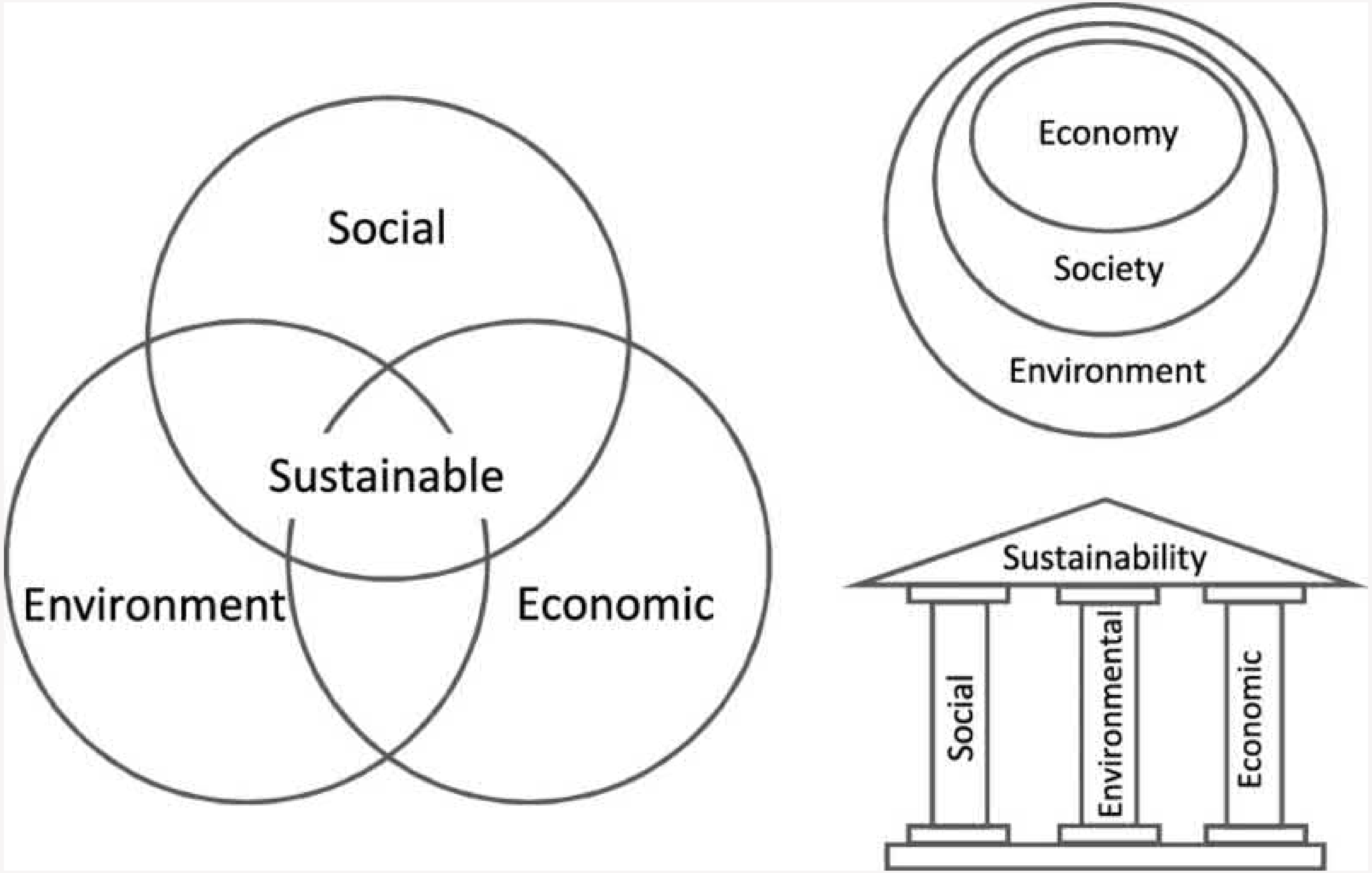
Thus, a simple way to consider sustainable consumption is that members of a population need to live within the limits of an ecosystem so that they do not deplete resources more quickly than they are naturally (or artificially) replenished. This means that resource extraction and waste products must be balanced so that the overall impact on the environment is either neutral or over time leads to gradual improvements. These improvements may include cleaner air and water, healthier forests, greater biodiversity of species, and replenished natural habitats.

There are several ways to promote the goal of sustainable consumption. We can use resources more efficiently, and at the same time reduce pollution and waste. We can use renewable resources and maintain our use rates within the bounds of their replenishment. We can develop and promote products, such as automobiles and home appliances, with longer life spans.

The United Nations has stipulated Sustainable Development Goals (SDGs) in 2015.

Within the 17 distinctive UN Sustainable Development Goals, multiple aspects of sustainability are included. For example, Goal 12 is "Responsible Consumption and Production." This leads to different ways of understanding the social, economic, and environmental factors involved in individually and collectively achieving more sustainable lifestyles. The following three graphic images display contrasting conceptions of the social, economic, and environmental aspects.

Contrasting conceptions of the social, economic, and environmental aspects involved in achieving more sustainable lifestyles.



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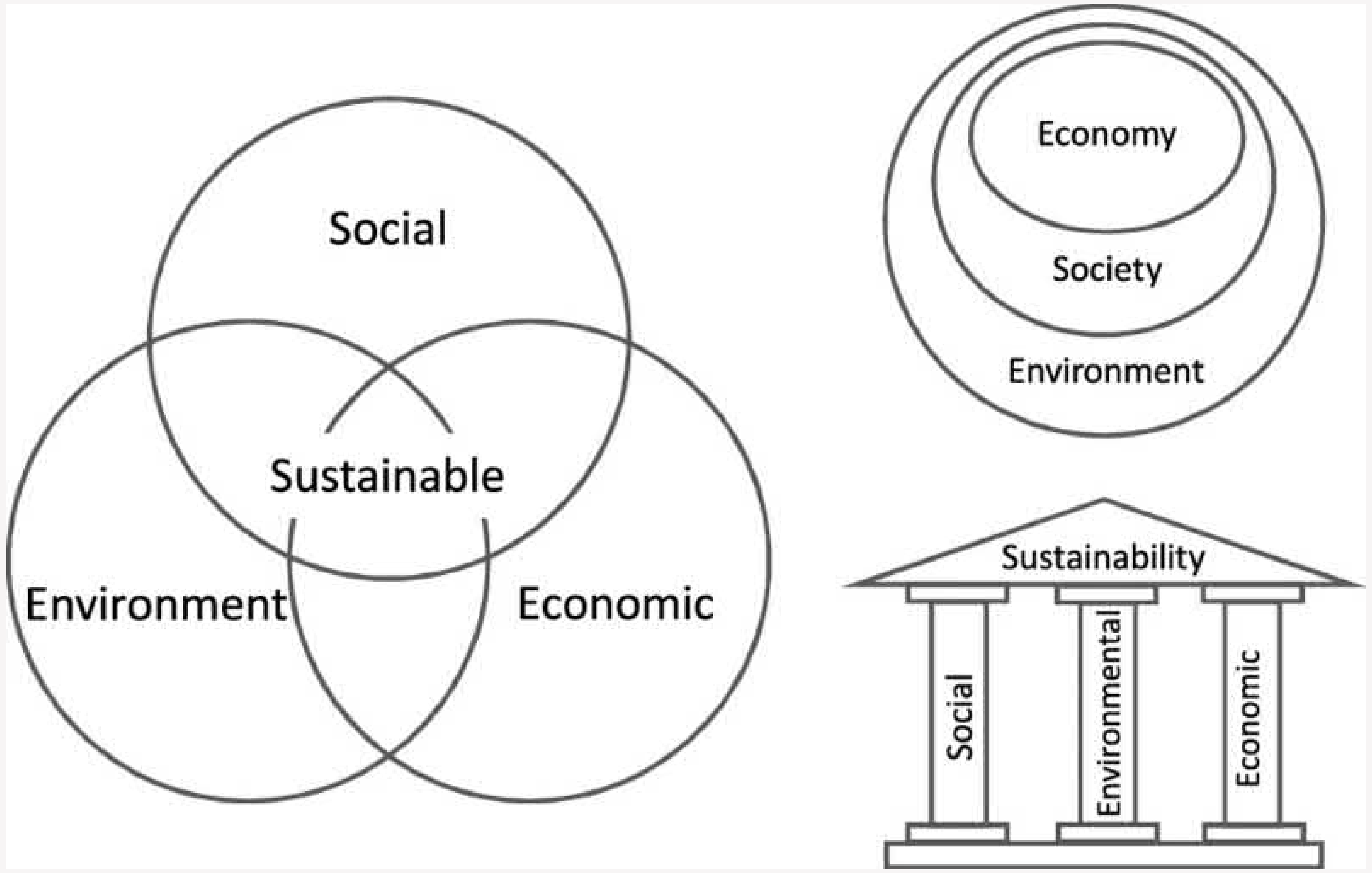
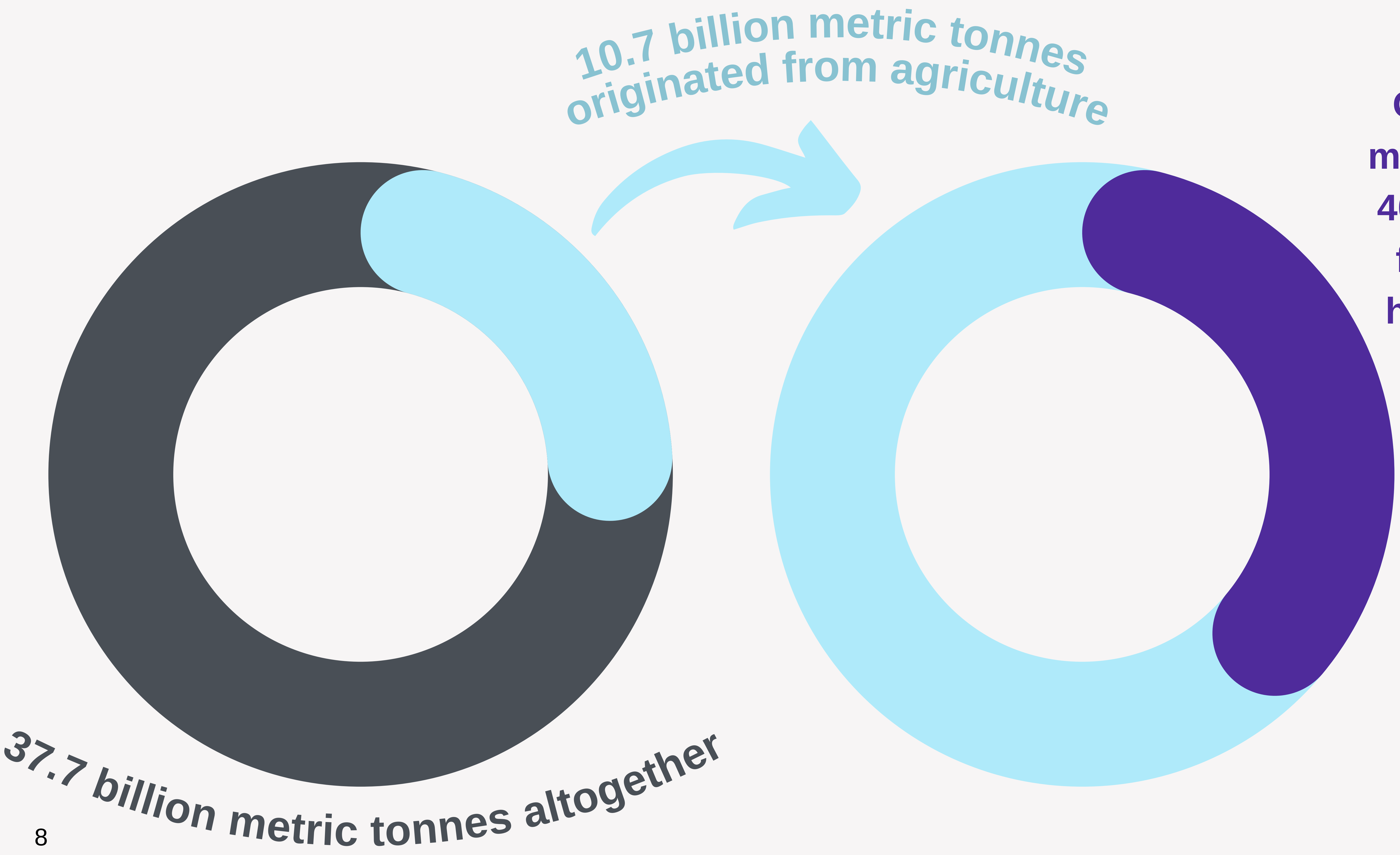


One image views the social, environmental, and economic factors as overlapping, while the second views them as concentric, with environmental resources being foundational to the social and economic, and social resources encompassing the economic aspects of human civilization. The concentric rings perspective takes the position that we cannot have a society or economy without ensuring environmental sustainability.

The third image views the social, environmental, and economic factors as three pillars that are all fundamental for achieving sustainability. The roof, depicting sustainability, may be viewed as the overarching aim or essential purpose that must be achieved to secure the future of human civilization.

Sustainable consumption emphasises the citizen consumer's role and responsibility in making choices in the market that collectively impact the planetary environment. One of the primary areas of individual choice with direct impact on the Earth's habitat is people's diets. Even though we spend comparatively little on food on a global basis of only 4% of gross domestic expenditure, agriculture has a large environmental impact. Of the total of 37.7 billion metric tonnes of carbon gasses emitted into the atmosphere in 2019, 10.7 of these originated from agriculture. Of these 10.7 billion metric tonnes of carbon gas emissions, roughly 40% were incurred by farming animals for human consumption.

Carbon Gasses Emitted into the Atmosphere in 2019



Of these 10.7 billion metric tonnes, roughly 40% were incurred by farming animals for human consumption

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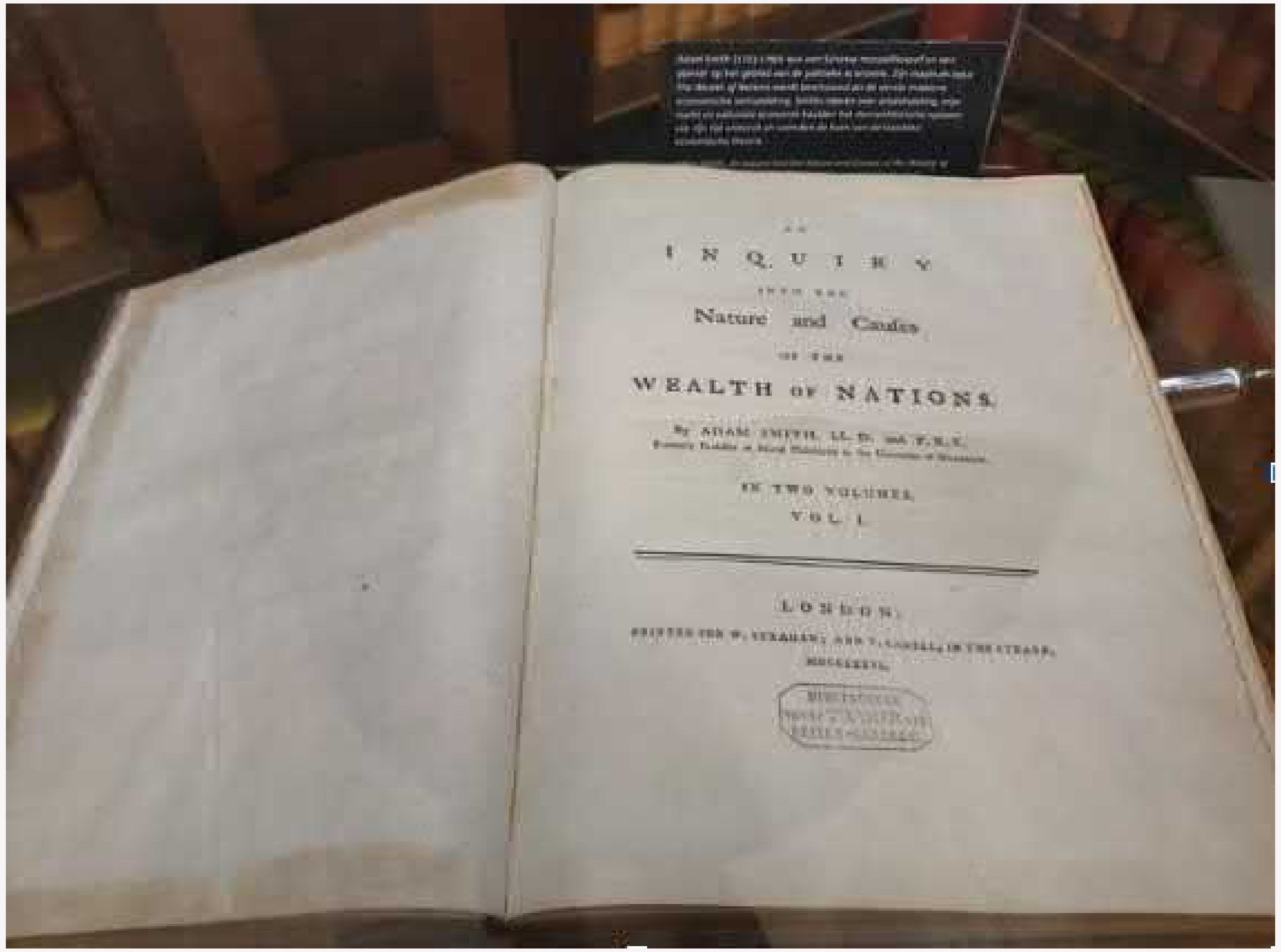
Section 2: Freedom of Choice

The prevailing theory governing planetary resource use is that the free market offers the best means to allocate resources effectively. Chicago University economist Milton Friedman (1912-2006) is a famous advocate of the free market position which he articulated with Rose D. Friedman (1910-2009) in the book *Free to Choose*. The central theme is that the free market, which assumes all actors have well-defined private property rights, leads to the most prosperous societies.

The Friedmans build on Adam Smith's *Wealth of Nations* (1776). They believe that the free market enables individuals to produce and exchange goods achieving optimal mutual benefit, and hence maximum wealth. According to this account, the government is the opponent that, through regulation, discourages individuals' creativity, self-reliance, and self-motivation.



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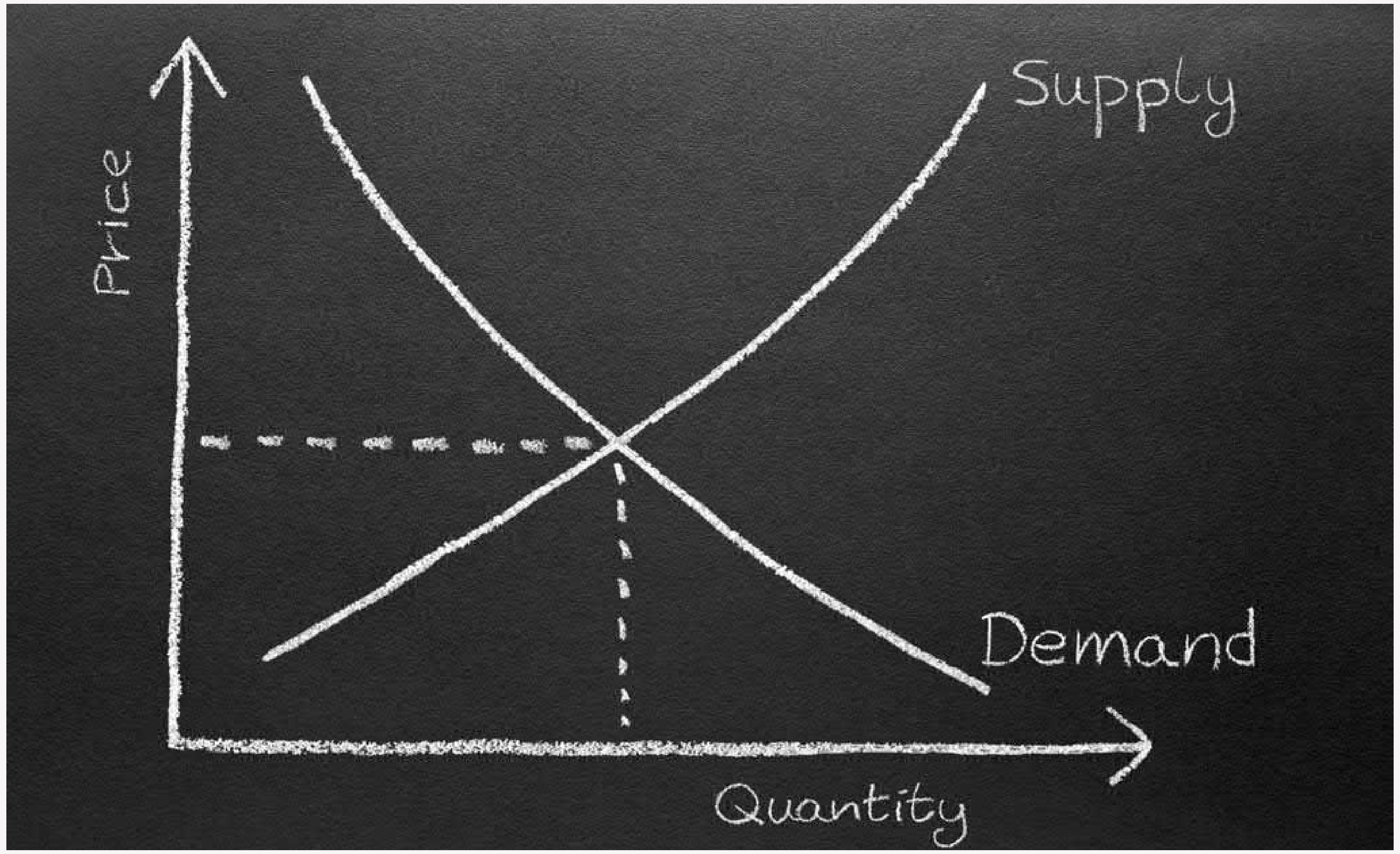
Markets work as a way to balance the supply and demand of goods. Orthodox economic theory holds that increasing demand for a good will support higher prices.



The image shows a standard economics supply and demand graph. The vertical axis is the price of the good, and the horizontal axis is the quantity. The market equilibrium is where supply meets demand, the point on the graph indicating the cost of the good, and the quantity produced.

In turn, these higher prices will lead to entrepreneurs meeting demand, and supplying additional goods which lowers their price. This market mechanism will, it is argued, in the long run best satisfy consumers' preferences.

The prices of goods are argued to transmit the "only important information and only to the people that need to know them" (Friedman, *Free to Choose*, p. 15). The price informs producers of how much more to produce and gives consumers the ability to spend their money effectively to best achieve their goals. The core concept of free markets is that all individuals should have the right to choose what to do with their resources and their property. No one should tell anyone how to spend their money, or what they must buy. The market automatically balances consumers' demand and producer's supply to lead to mutual prosperity.

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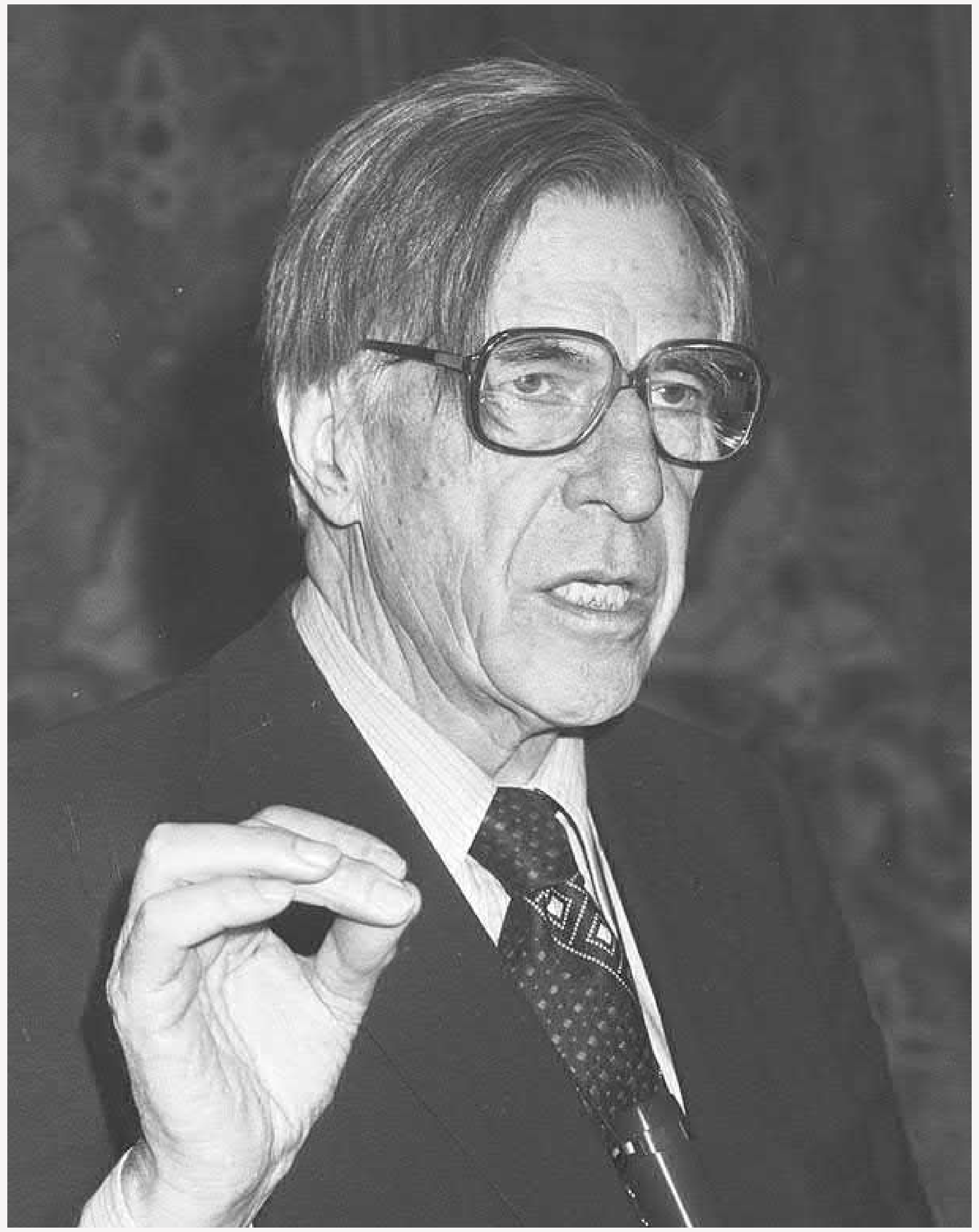
Section 3: Criticism of Market Freedom

By Marianna S. Laine

Despite its prominence in mainstream economic thought and political practice, the free market approach has also been widely criticised by scholars from different fields, including from within the economic discipline. One renowned critic is the economist J.K. Galbraith (1908-2006). He highlighted the need to place power at the centre of economic analysis, and rejected the idea of the market as a fair and apolitical entity. Galbraith was particularly interested in the power of large modern corporations to shape not only politics, but also consumer needs, preferences, and spending patterns. In the 21st century, new economic models are needed to address complex issues related to climate change and environmental sustainability. Galbraith's critique of boundless economic growth, and measuring the social and economic well-being of societies by the total amount of goods produced and consumed, is more relevant than ever.



Source: *https://commons.wikimedia.org/wiki/Category:John_Kenneth_Galbraith#/media/File:John_Kenneth_Galbraith_1982.jpg*

Galbraith argued that mainstream economic models continue to be based on outdated models of free markets, which do not reflect the reality of the advanced capitalist system. For him, free market competition no longer exists because large corporations, acting as oligopolies, are able to set the prices. Moreover, in our era of affluence and due to the continuous need to expand access to markets, corporations no longer produce goods to fulfil the needs of consumers. Instead, corporations create needs and desires by manipulation. Through corporations' political lobbying, states take on the responsibility of managing consumers' aggregate demand through monetary and fiscal policy which ensure ever-increasing levels of consumption. Advertisement, and other public relations schemes to increase consumer demand, create a distorted production pattern. As a consequence, more useless and environmentally harmful goods are produced by private companies.

A historical example of advertising influencing consumer choice from 1968.

Source: https://commons.wikimedia.org/wiki/File:Part_of_a_1968_advertising_sheet_for_Guinness_after_they_established_a_brewery_in_Sierra_Leone_(West_Africa)_(1727997539).jpg

Galbraith's work is highly relevant to understanding the economic system and how measuring economic and social success through growth of GDP relates to the questions of climate change and environmental sustainability. Almost 70 years after the release of his influential book, *The Affluent Society* (1958), Galbraith's work may be more relevant than ever. Not only does it reveal some of the myths of the free market approach, but it also demonstrates the unsustainability of our current consumption culture and how our needs and desires are manipulated by corporate interests. However, perhaps most importantly, Galbraith's work provides a glimmer of hope, as he stresses the power of human agency. Understanding the workings of the economic system and the way in which power operates within it, may have an emancipating effect that can lead to collective power, which in turn can create change.

In considering Galbraith's criticisms of the free market system, they distil down to (1) the manipulation of consumer choice by corporate influence; (2) corporate lobbying to influence state policy to increase consumer demand; and (3) large corporations' concentrated market control in contradiction of free market competition. An additional widely cited criticism of the free market is its tendency to increase inequalities, specifically by allocating increasing amounts of resources to wealthier individuals.

1. **Manipulation of consumer choice by corporate influence and power.**
2. **Corporate lobbying to influence state policy to increase consumer demand.**
3. **Large corporations' concentrated market control in contradiction of free market competition.**

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Section 4: Consumer Sovereignty

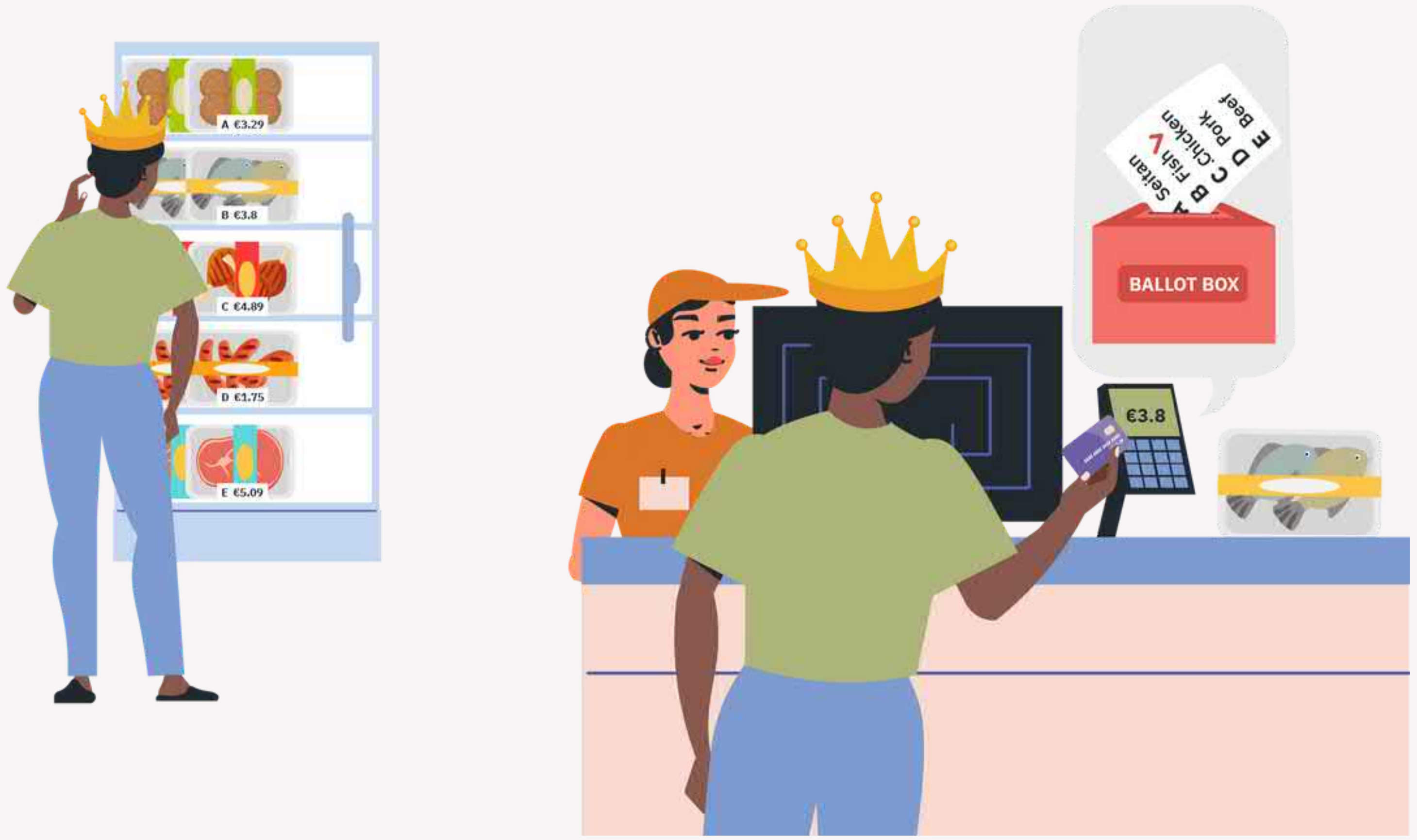
Despite criticisms, the West's faith that free markets lead to mutually beneficial outcomes has limited acceptable means by which sustainable consumption can be achieved. Trust in the free market, and the belief in individuals' right to choose how to spend their money, limits the popularity of efforts to regulate production and consumption. We tend to believe that the individual is the best evaluator of their own needs and their own wellbeing.

The faith in the free market, and the belief in individuals' right to choose how to spend their money, limits the popularity in efforts to regulate production and consumption.

The consumer is the king or queen: producers make what the consumer wants. Artist: Jooeun Park.

Economists have named this concept **"consumer sovereignty."** This term incorporates the idea that the purpose of markets is to satisfy consumers' desires, needs, and preferences. When consumers exercise their right of choice by buying and consuming products they prefer, producers will meet their demands in order to make more profit.

We have seen criticisms of the free market. There is evidence that the free market is failing to deliver environmental sustainability, witnessed by increasingly hostile weather patterns with extreme temperatures, flooding, and drought. However, notwithstanding the broad environmental impact from human activities, economists and members of the public continue to have faith in markets and private property. There is optimism that free market solutions, with minimal governmental intervention, will provide the technical innovations to secure a sustainable future.



The consumers vote with their wallets: spending money is like voting for products.
Artist: Jooeun Park.

For this reason, the approach to sustainable consumption investigated in this book emphasises the role of individuals, acting as consumers, having a collective impact on the environment. By focusing on individuals' right to choose, we can identify a path to collectively sustainable consumption that respects these rights. This approach extends the idea of democratic voting to the perspective that every time consumers spend a euro or a dollar, they are voting to support the productive processes making the products they buy. Hence, making a market choice is a way of voting as an economic act. Spending money makes concrete the values and lifestyles that individuals support.

Purchasing goods, or "voting" for them, leads to supporting that industry. Artist: Jooeun Park.

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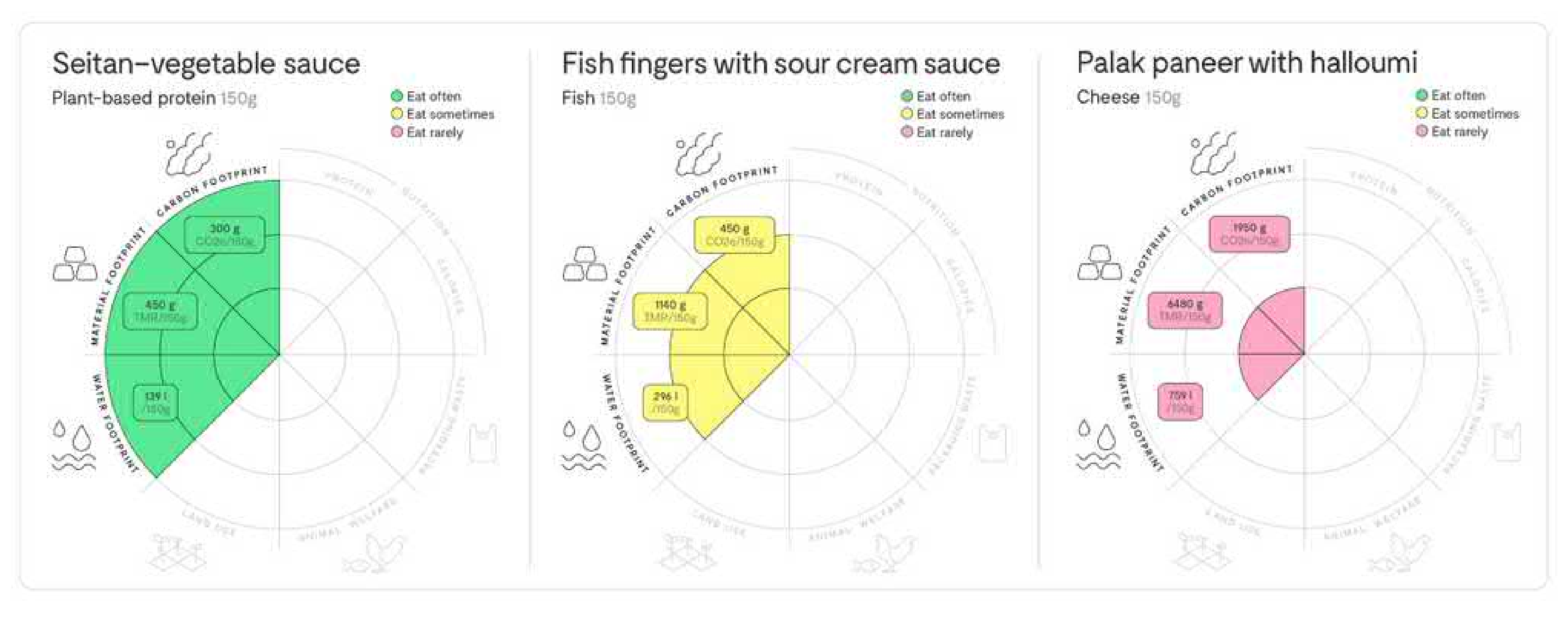
Section 5: Introduction to Food Futures App

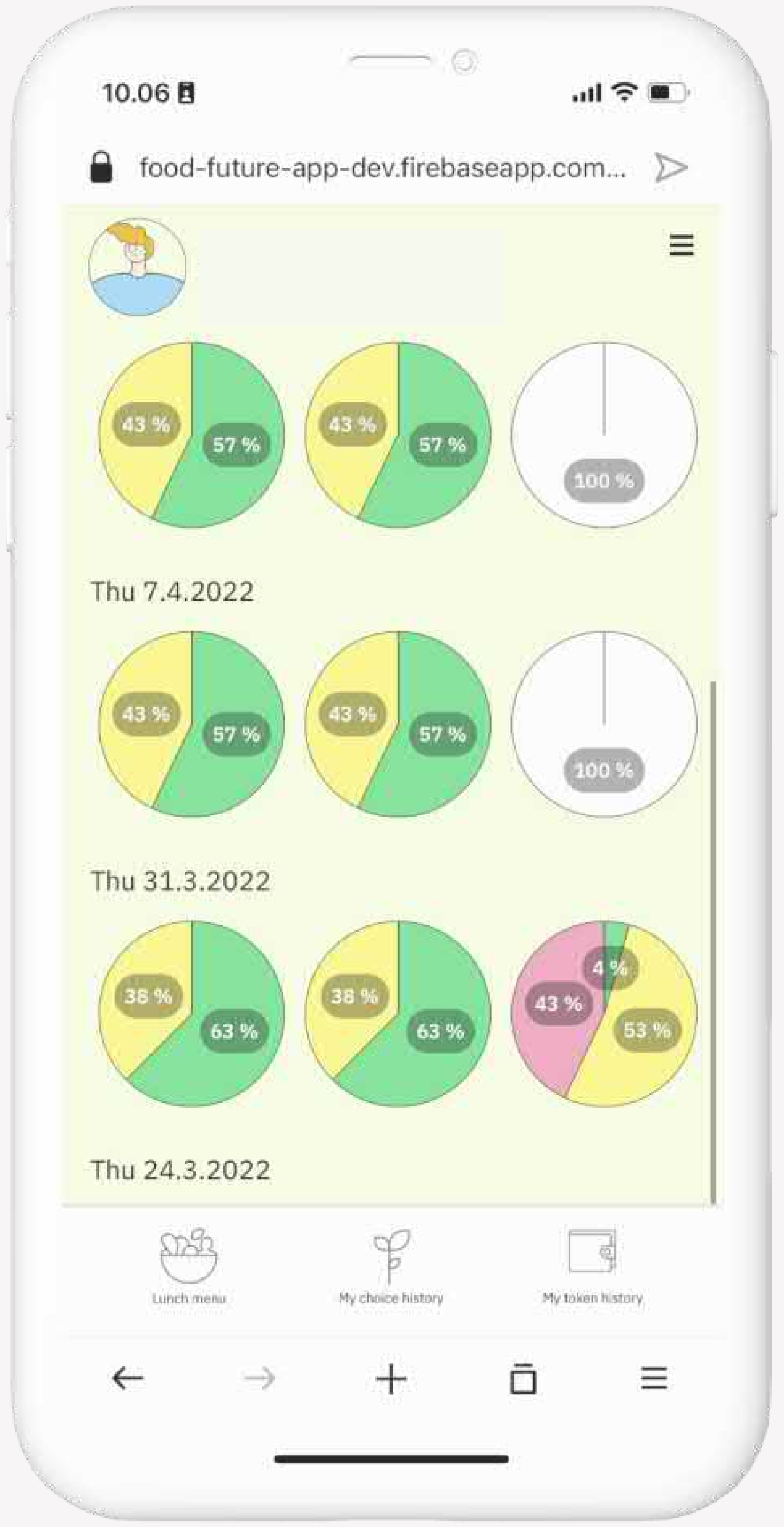
When reading this book , you are welcome to use the voluntary, opt-in Food Futures App. This is an actionable tool to empower citizen consumers to make dietary choices that reflect their values and lifestyles. When individuals make sustainable choices, this adds up to collectively viable outcomes. Readers who use the app in restaurants, or at home, will become familiar with its functions. Here is a preview of some of the app’s features and functions.

The Food Futures App pioneers the Food Wellbeing and Sustainability Index. This index has 7 variables: carbon footprint, material footprint, water footprint, nutritional facts, transportation, animal welfare, and packaging waste. The key idea is to provide easily communicated information about the quality of a dietary choice with respect to its environmental impact.

The index targets the protein sources of daily meal choices, and provides information regarding the implications of the meal on the seven variables. However, since the index is still under development, at the moment we are only able to provide information for three of the variables: carbon footprint, material footprint, and water footprint.



The data powering the index, and its indication of whether dietary protein choices are green (sustainable to eat often), yellow (sustainable to eat sometimes), or red (sustainable to eat infrequently) will be covered in detail in Chapters 2 and 3.



Collective impact visualisation.

Another feature of the Food Futures App is its communication of aggregated data concerning individuals' collective impact of their dietary choices. As discussed in Section 1 of Chapter 1, agriculture and individuals' dietary choices have a big impact on the global environment. Therefore as individuals' choices add up from one to 5.5 million people eating about three meals a day throughout Finland, we need to consider the shared impact of 5.5 daily lunches. The Food Futures App invites you to become a member of a virtual community with the power to track the impact of individual and collective meal choices. The Food Futures App shares the data on individual meal choices and their history as well as collective impact from those choices. In addition, the app enables quick comparison between the dietary choices of virtual community members and the other daily diners.

The third feature of the Food Futures App is its implementation of the measure, record, validate system for providing a history of individual and collective meal choices. This system is made possible by distributed ledger technology and blockchain tokens. The blockchain tokens pioneered by the Food Futures App are a type of cryptocurrency, but not the kind that are used as a type of currency like Bitcoin.

If the Food Futures App user makes the selection of a green-labeled or yellow-labeled meal with respect to its carbon footprint, then they will receive either one Foodprint token, or half a Foodprint token respectively. Additionally, Food Futures App users will receive a community bonus according to the percentage of users who also make green and yellow-labeled meal selections. This precise calculation and the nature of the blockchain tokens will be discussed in Chapters 3 and 7.

The theory underlying the development of the Food Futures App as an actionable and pedagogic tool to empower citizen-consumers to make sustainable meal choices with constructive collective impact is presented in Chapters 4, 5, and 6.

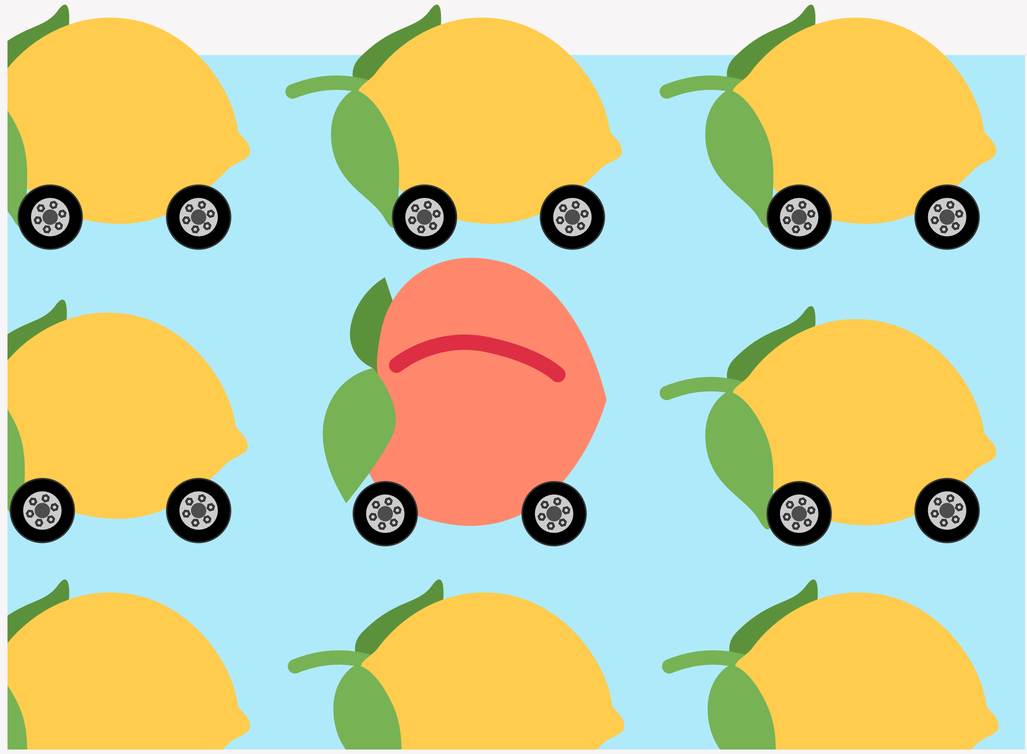
Receiving tokens.

CHAPTER 2
Data Science for Sustainability

Section 1: Perfect Information

As we saw in Chapter 1, economists assume that markets allocate goods efficiently because citizens, acting as consumers, choose products with their purchases. For this process to work, consumers need high quality information about those goods they buy. For example, suppose you are choosing which new or used car to buy. In either case, to make a good decision, you need to know all of the pertinent characteristics of the available cars regarding their performance attributes such as fuel efficiency, as well as pricing information. This is true for all products available for purchase in markets. In order for produces to meet consumers' demands, consumers must know the qualities of products and their prices.

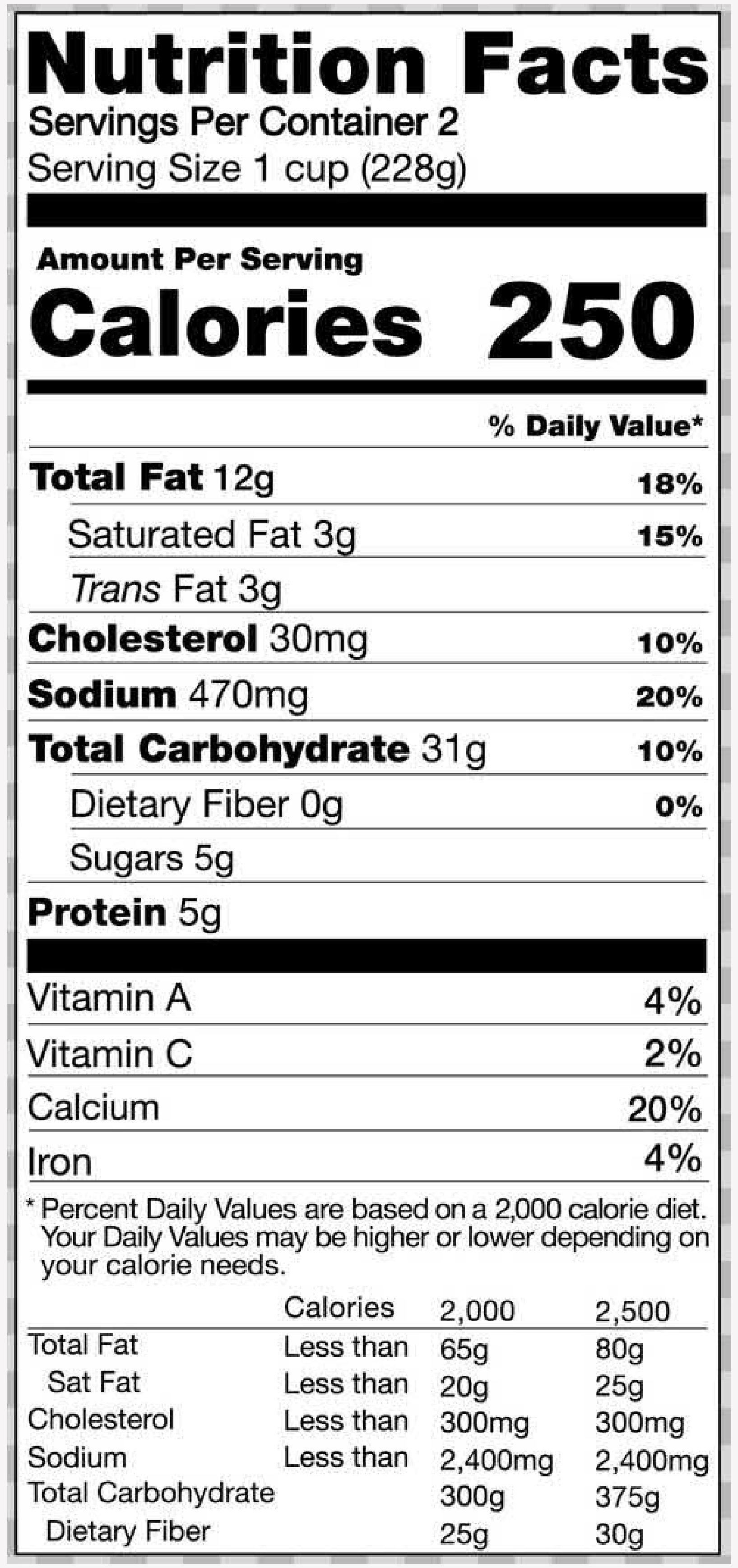
In pure economic theory, the conditions for consumers to have **perfect information** are very strict. Consumers must not only know what goods to buy, but also when to buy them by having information about past and future prices. We can relate to this need for information regarding contemporary uncertainties about energy supplies. Without knowing how much energy will cost tomorrow, it is not possible to make fully informed decisions about what energy contracts to accept today.



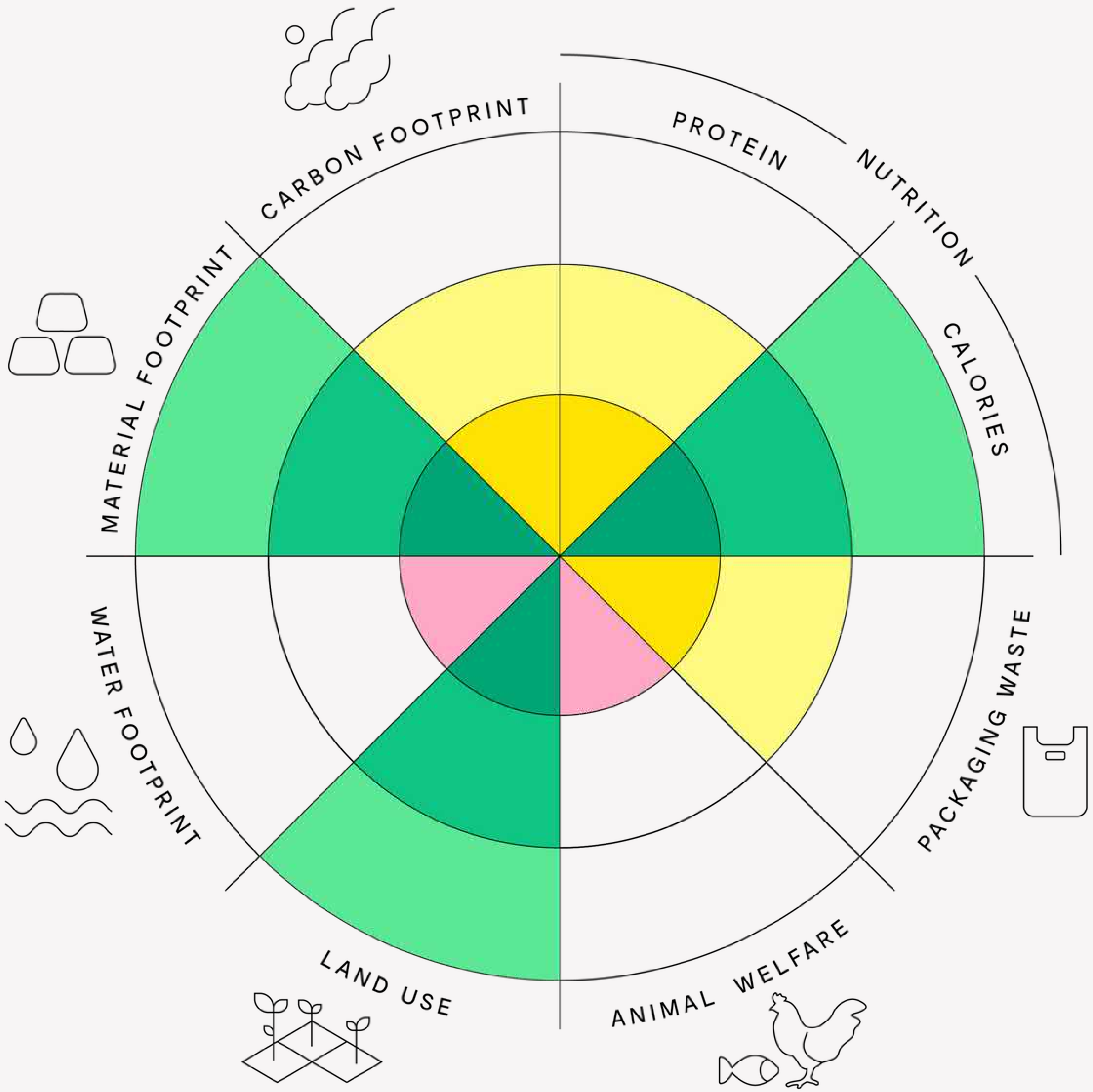
People are aware of the powerful role that knowledge plays in enabling consumers to make fully informed choices. This is a relatively uncontroversial role for government regulation. Governments can require companies to provide full disclosure of the quality of their products. We expect when we buy drugs from pharmacies that the ingredients of medicines are accurately reflected in their packaging information. Thus, we can assume we will be informed of possible side-effects and bad outcomes.

Food labeling is mandated by national and European Union laws in order to ensure that consumers have complete knowledge of the ingredients of products.

Food labeling also includes detailed nutritional information so that consumers know how much protein, fat, carbohydrate, and sodium are contained within either 100 grams of a product, or one serving size. Accurate labeling of the characteristics of a product help provide consumers with perfect information to make good decisions affording them wellbeing. Hence, this type of regulation is comparatively less controversial than restricting the production or availability of certain types of goods, including cigarettes and alcohol.



As you will see ahead, consumers can also be provided with information about the external costs associated with a product’s production. Specifically, many products including food items may entail costs that are not directly reflected in their prices. Pollution costs from production are one obvious example of how pricing can be misleading. Potentially, goods and services can seem affordable and even cheap, but these prices may not reflect that there are negative consequences from production. For example, paper products are inexpensive for consumers, but people in communities near paper factories suffer from bad air quality. Similarly, while the cost of meat is low, the conditions of the animals in industrialised agriculture are often unhealthy. The cost of dairy products may be low, but the environmental impact from animals' carbon emissions contributes to greenhouse gas accumulation and rising global temperatures.



The question arises: how can citizen-consumers obtain perfect information regarding the impact of products' production that is not contained within product disclosures and their prices?

Over the following chapters we will see how a tools, such as the Food Futures App and the Food Wellbeing and Sustainability Index, can help to provide more perfect information about dietary choices.

Section 2: Data

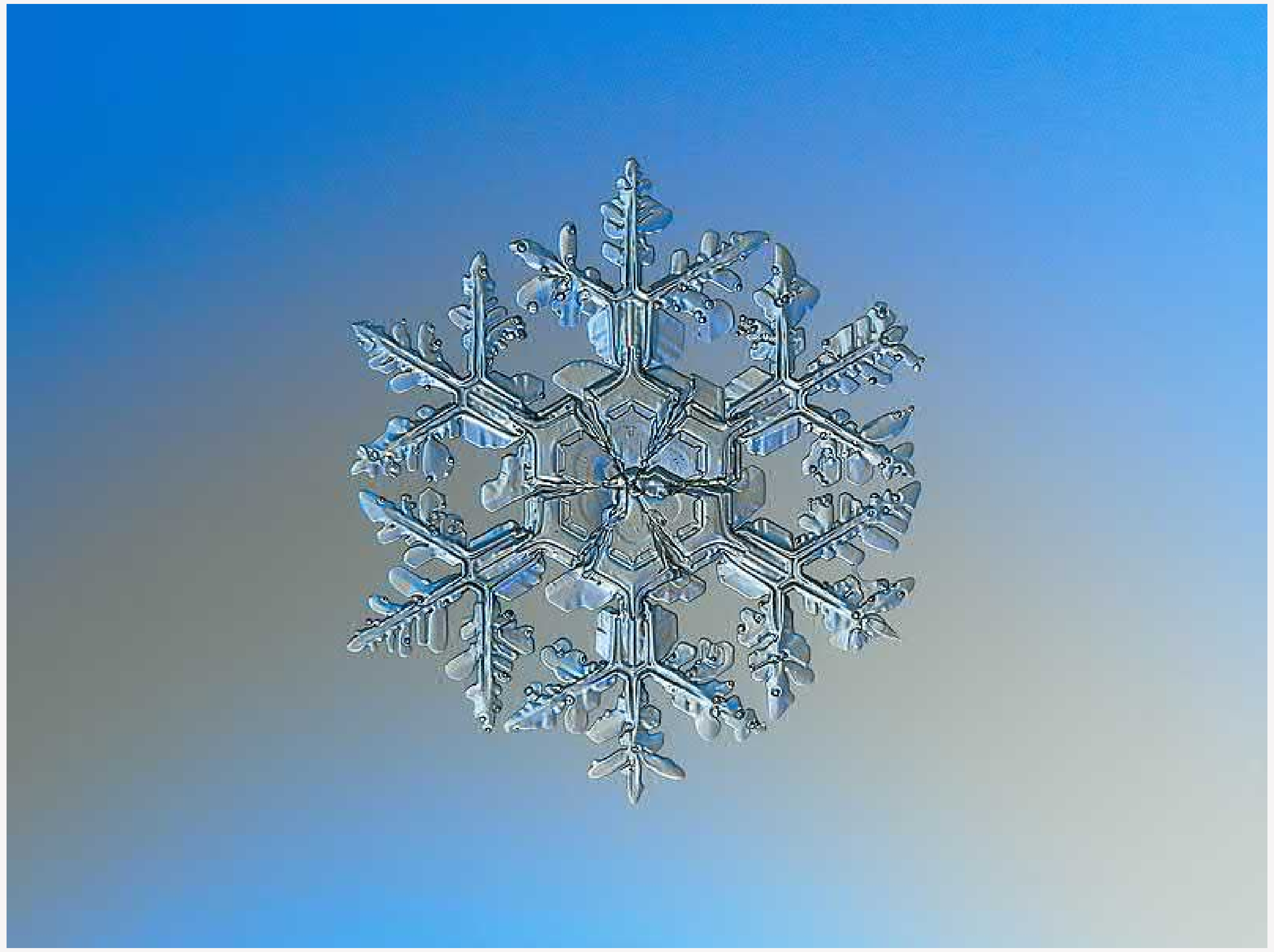
In order to provide citizens with information, we need to consider the source of information. Researchers refer to the elementary building blocks of knowledge as data. In this section we consider what data is, and how data can be used to provide more information about food products.

Data provides the basic information for generating knowledge. **Raw data** refers to individual facts about the world that are not recorded in a systematic manner. Examples of raw data include observations, or lists of facts that have not been organised or classified. Consider that we usually like to know what temperature it is when we go outside. Everyone could carry their own thermometers to detect the temperature personally to gain this knowledge. If we suppose that there is a method of reporting and recording these individual pieces of data every time a person goes outside, we could develop a database for storing all of this information. Other types of raw data are, for example, observations of insect types and numbers in specific locations at specific times, or lists of items purchased from shops on given days.

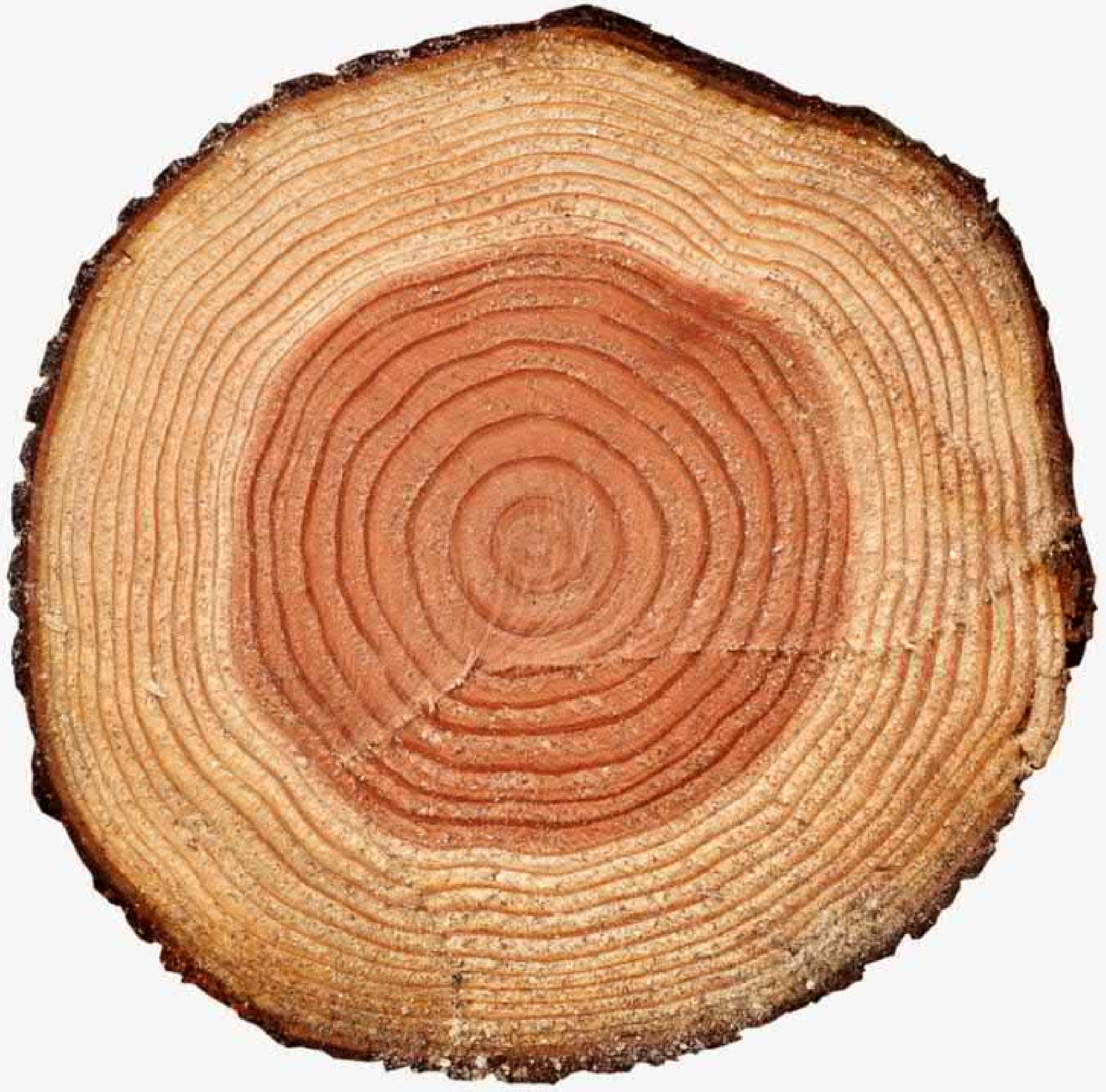
Source: https://commons.wikimedia.org/wiki/File:Data_types_-_en.svg.

When data is accurate and is imported into an analytic framework, then we can increase the amount of information available to make informed decisions. When we obtain data empirically, we get it by experience and by using various measurement processes. This process of systematic empirical observation lies at the foundation of natural science. Empirical data has definite contextual anchors that include the date, time, and place of an observation. To be systematised, it also needs a validated means of recording it in an observational statement, recording, or photograph.

Additionally, theoretical frameworks, which apply analytic tools of induction and deduction, enable using raw data to build general and usable knowledge. **Reasoning by induction** means examining increasing numbers of cases to infer, and thus have reason to predict, the outcome in additional cases. **Reasoning by deduction** means that once we establish a general principle such as "water freezes at 0°C," then when we identify a particular instance such as snowflake, we can conclude by deduction that the snowflake must be 0°C or less.



Whenever we have an accepted general principle, then we can deduce that it will apply to a particular case. Source: Alexey Kljatov, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons.



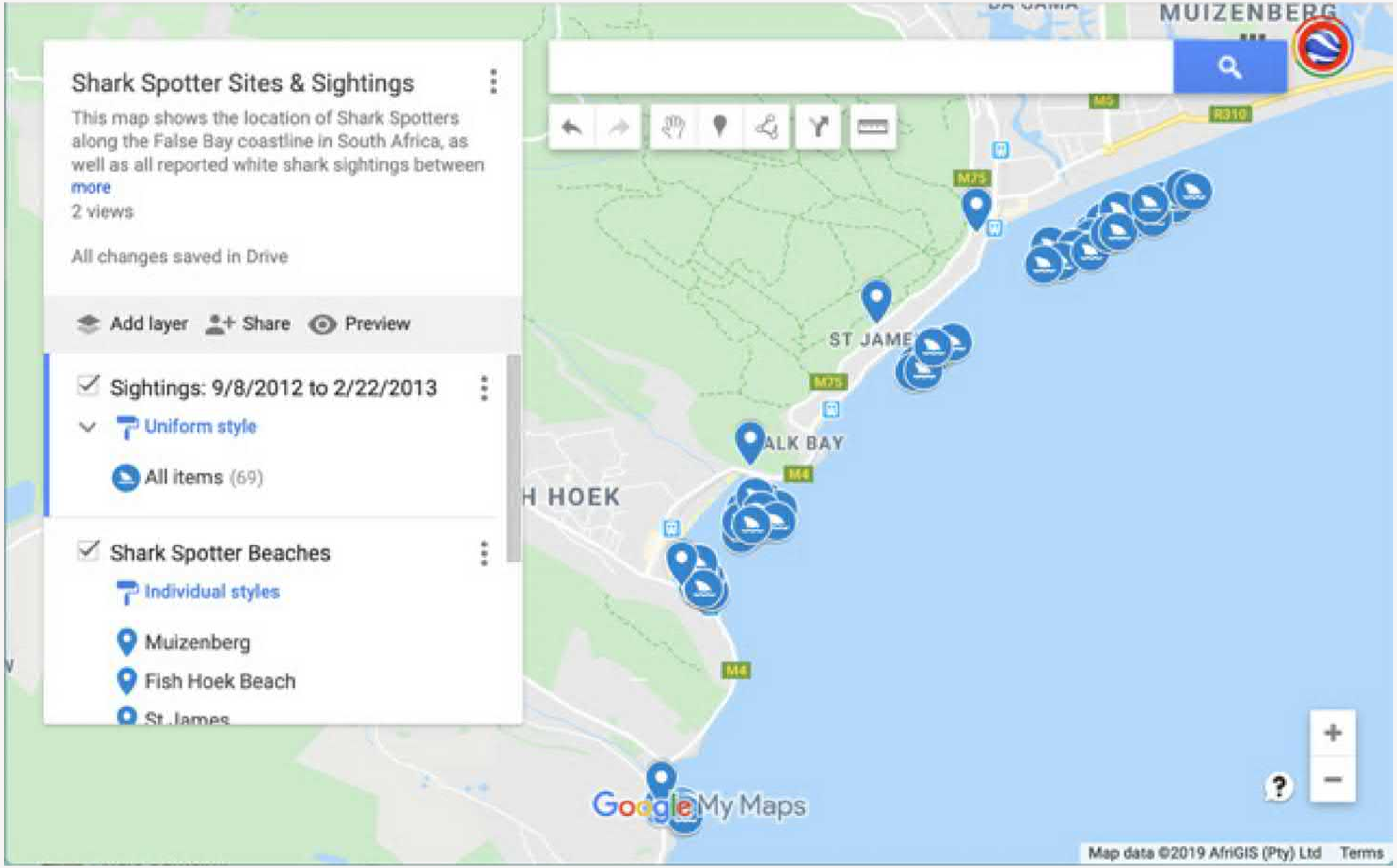
Source: https://www.nicepng.com/ourpic/u2q8e6w7q8i1r5w7_tree-rings-png/

Consider raw data in the form of countable rings in trees. Concentric tree rings are only visible when trees are cut. These tree rings exist as natural information in the world that can be counted and recorded as raw data in a database. In order to analyse this data, it is necessary to either focus on a single tree, and use the data of the rings to infer the tree's age at the time it was cut. Likewise, we might record data on a number of felled trees in an area to build a systematic database of the number of concentric rings for each of the trees in a sample.

Once we establish this database, we would then be able to perform different analyses. We could determine the average age of the trees in our sample set by correlating each ring to one year of growth. If we add data about the width of each concentric ring in every tree, we could also assess whether the trees in our sample show similar or different patterns.

These patterns could show if trees grew a similar amount in the same year. If we also collect data about, for example, the annual water-fall amounts and temperatures, we can analyse patterns of average tree growth correlated to weather patterns. We may, for example, discover that in a dry year, trees tend to grow less, indicated by a narrower width of the tree-ring for that year.

What data does this image contain?



The quality of our data results from the accuracy with which it is collected, recorded, and verified. This includes unifying measuring and reporting processes, and building a systematic data structure to store the data. Additionally, analytic frameworks must be rigorous. Peer review, or allowing other researchers to crosscheck and validate results is an important step in verifying the quality of conclusions drawn from raw data.

Whether we have faith in markets to most effectively provide the goods and services people seek, or if we believe that governments can play a role in ensuring that human activities do not harm people or contribute to an uninhabitable habitat, having reliable information is crucial to making good individual and collective decisions.

- **For data to be useable, it must be reliable, and systematically compiled and analysed.**
- **Good consumer choices, e.g., statements of nutritional facts are essential for making decisions about our proposed actions.**
- **Individual choice is deemed sacred in Western political philosophy, hence sustainable consumption is the responsibility of citizen-consumers.**

Section 3: Mobilising Data to Understand Humans' Environmental Impact

We previously considered how we can achieve actionable knowledge from data. In the case of food labeling, we have a direct example of making information available on products so that consumers can make well-informed decisions about what to purchase. Next, we consider data analyses of massive proportions that inform us about the collective impact of human activities on the global environment.

We regularly hear in the news, and may ourselves experience, hotter weather than we may seasonally expect. Additionally, we see international news stories about extreme weather events including violent storms with flooding and high winds. We are also aware of drought conditions that threaten both agriculture and the availability of water for humans and other life forms.

Year in climate: Extreme weather events prove climate change is already here

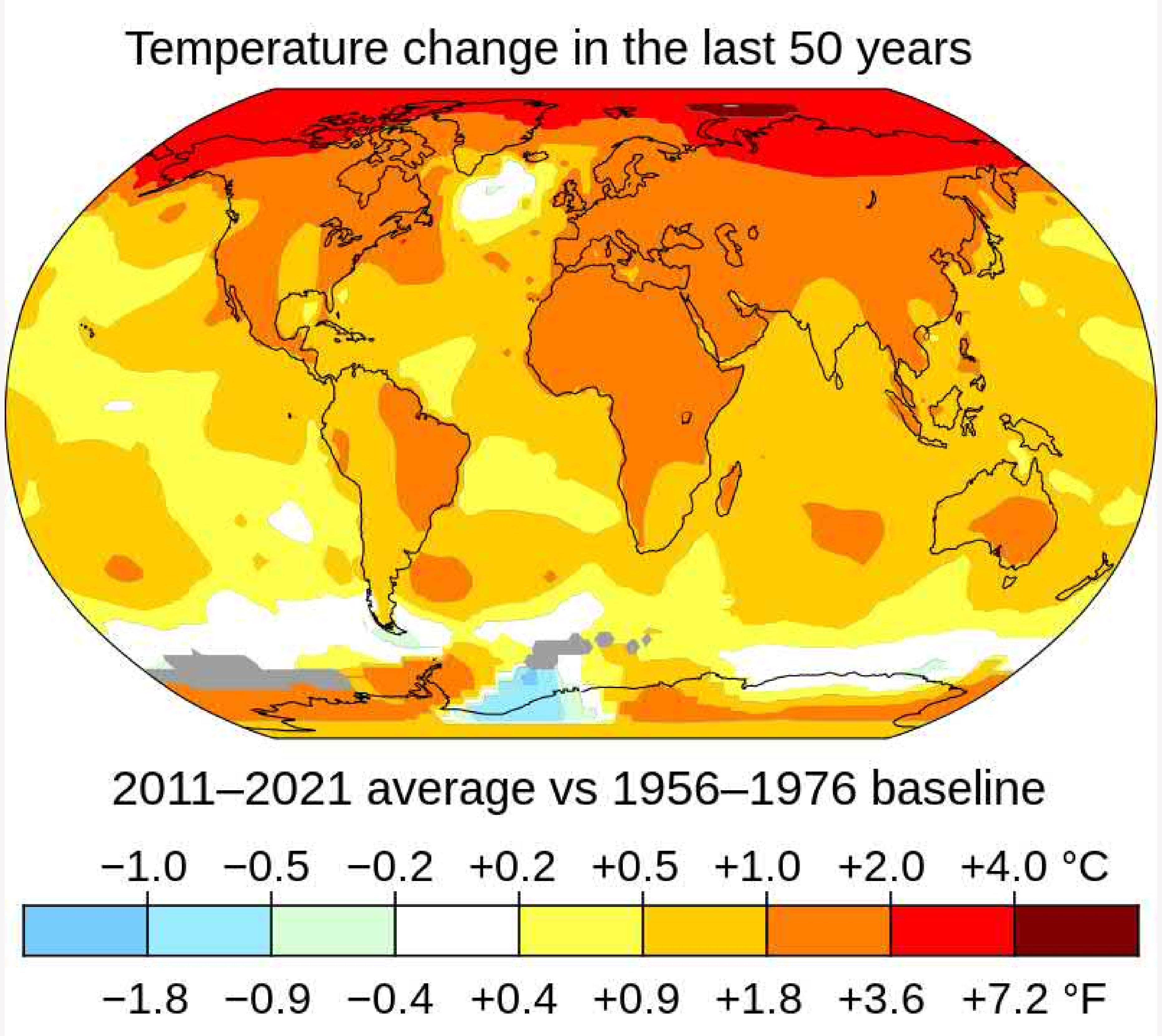
From extreme temperatures, to fires and floods, 2021 was a year of extremes.

By Julia Jacobo and Daniel Manzo
December 28, 2021, 1:05 PM

Share

Flames leap from trees as the Dixie Fire jumps Highway 89 north of Greenville in Plumas County, Calif., Aug. 3, 2021.
Noah Berger/AP, FILE

Source: https://abcnews.go.com/US/year-climate-extreme-weather-events-prove-climate-change/story?id=81771045



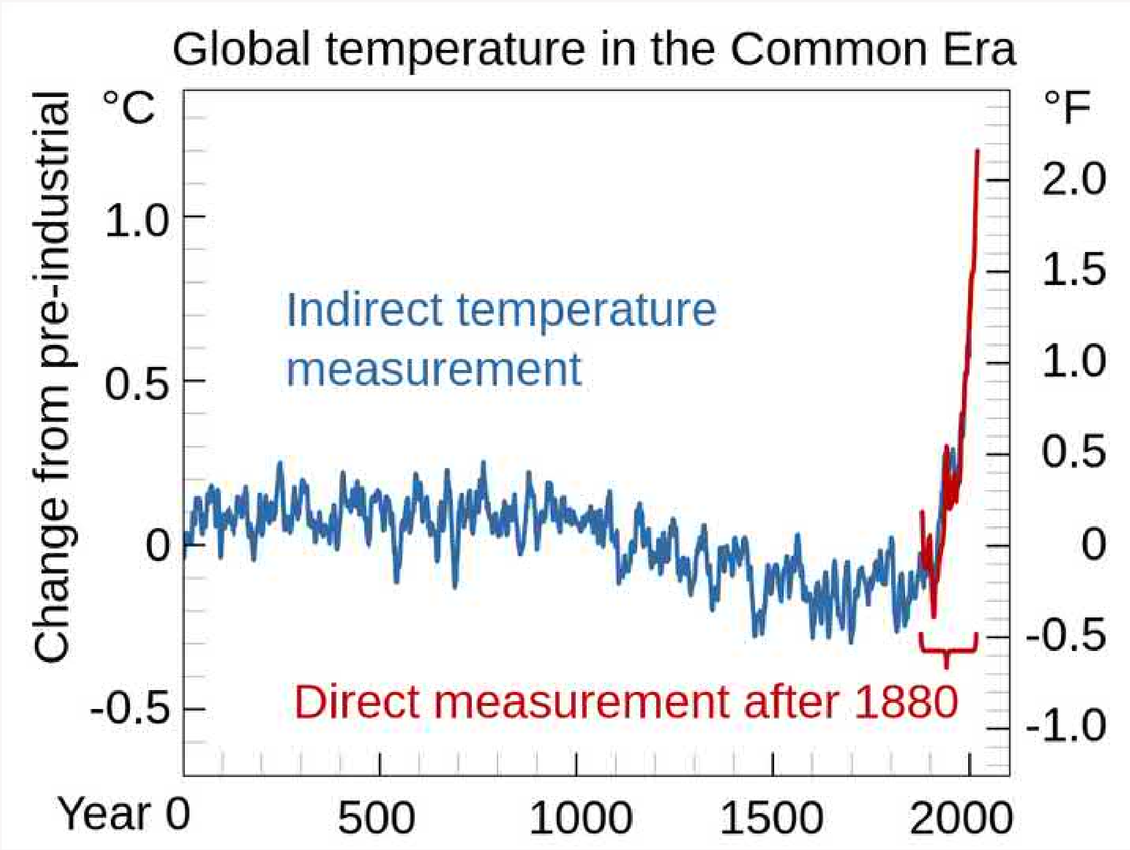
Source: https://data.giss.nasa.gov/gistemp/maps/index_v4.html

Researchers have been collecting data about temperate levels around the world for decades and even centuries. Below is a map reporting the results of systematically compiling and analysing this data.

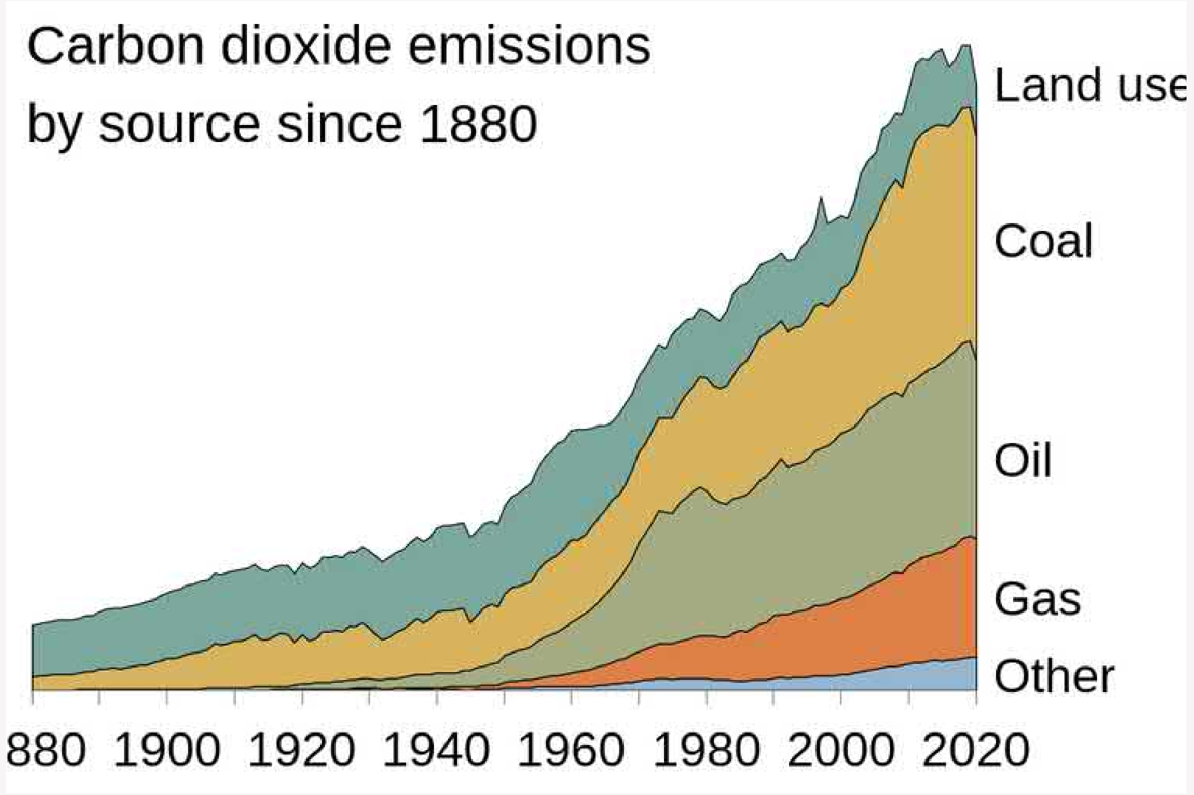
This map provides color-coding to display the average temperature increases or decreases, using annually averaged temperatures between 1956-1976 and 2011-2021. It is displayed using the Fahrenheit and Centigrade temperature scales. As is evident from the shading in the yellow to red zones, almost everywhere on the Earth's surface, the average temperature has increased between +0.2°C to +4.0°C on average almost everywhere.

Using deductive analysis, researchers have constructed theories that link the rise in the Earth's surface temperature to the levels of carbon dioxide (CO_2) in the atmosphere. They propose that CO_2 molecules in the Earth's upper atmosphere trap heat produced when high energy sunlight strikes the planet. They provide empirical evidence to support this hypothesis by showing that rising global temperatures are directly correlated with rising levels of CO_2 in the atmosphere. Consider the similarities in the data represented in the two following graphs, one indicating global temperature rises, and the second indicating rises of carbon gas levels.

These two graphs each have different time scales, with the image representing temperature changes stretching from the beginning of the Common Era to the present. The image on the right shows increasing CO_2 emissions tracked from 1880, when the Industrial Era intensified.



Efbrazil - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=87410053



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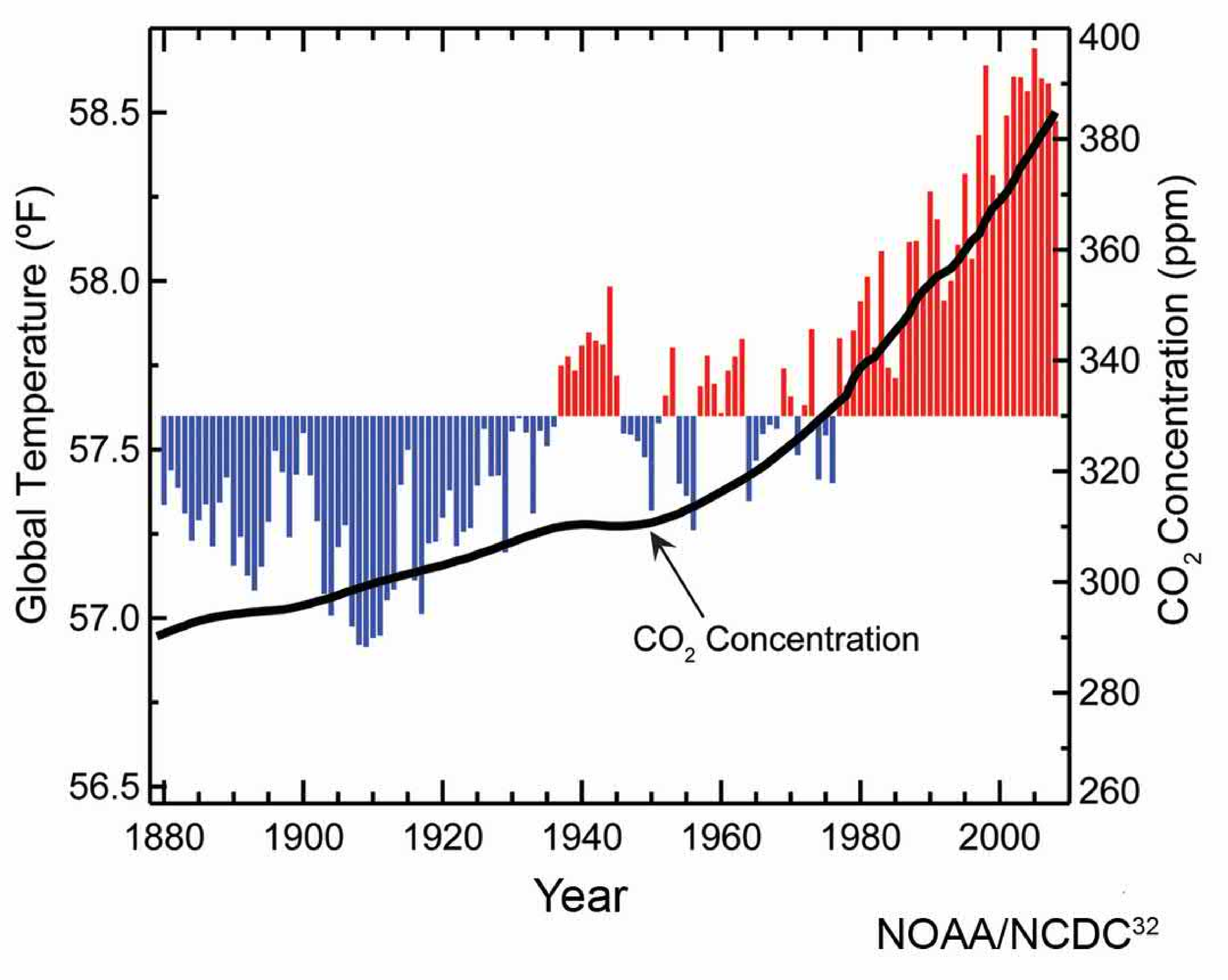


Taken from page 17 (print version page numbering) of the chapter "Global Climate Change" in the report: "Global Climate Change Impacts in the United States." Freely accessible on the web from the United States Global Change Research Program. Also available in print from Cambridge University Press, 32 Avenue of the Americas, New York, NY 10013-2473, USA. ISBN 978-0-521-14407-0

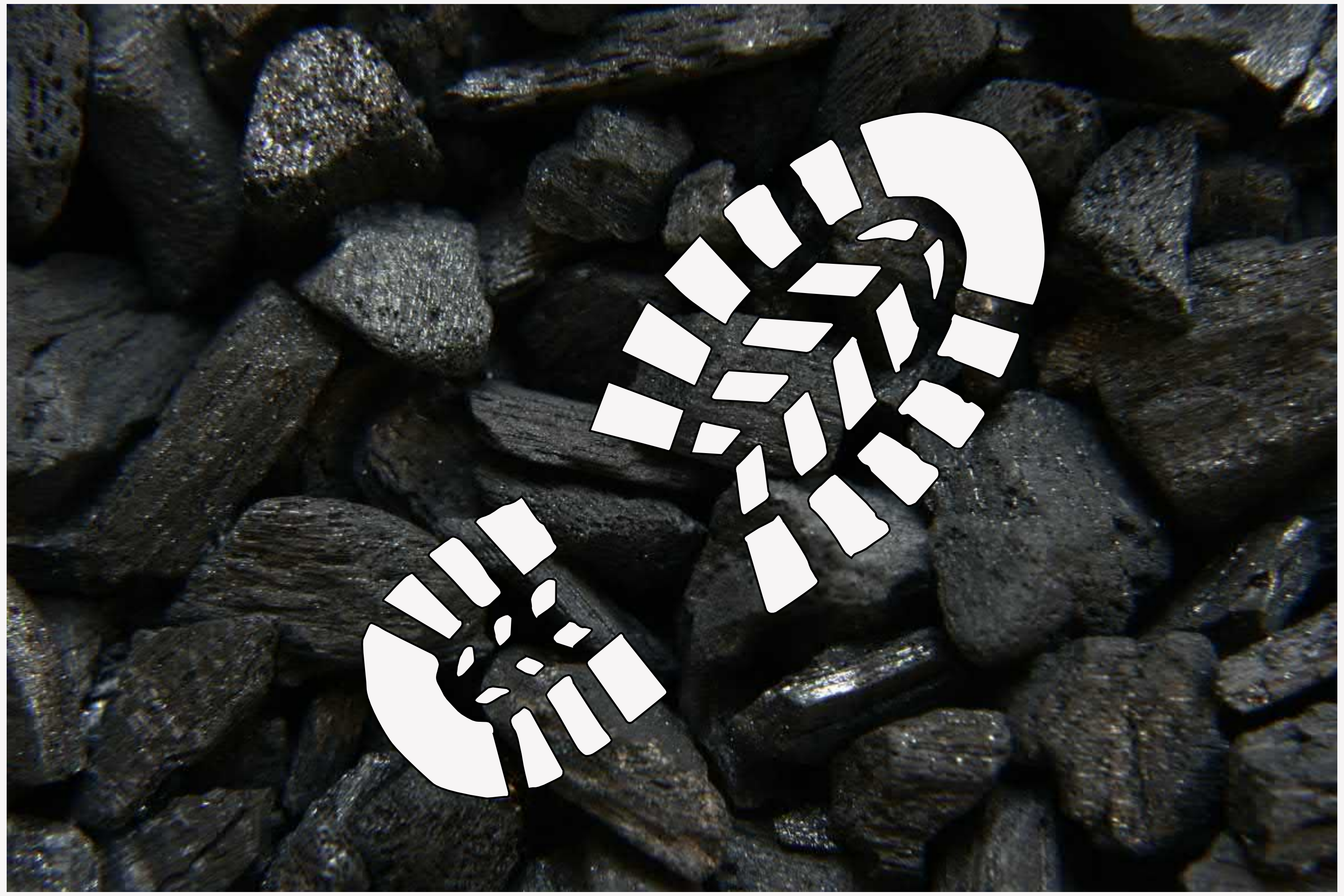
When we transpose the data onto a single graph, the correlation between Earth's average rising temperatures and atmospheric CO2 accumulation appears more vivid. Note in this graph that the left axis reflects global temperature and the right axis reflects CO2 concentration in order to correlate the data per year, reflected on the horizontal axis.

Section 4: The Carbon Footprint

In this section we consider the definition of a carbon footprint, or the amount of carbon gas released from specific activities. We also consider how to visualise the carbon emissions caused by specific activities, such as burning a liter of gasoline. The motivation is to have a means to grasp the varying proportions of carbon gas released by different processes, as well as to understand the relative quantities of CO_2 for which we are each individually and collectively responsible.

The concept of the **carbon footprint** quantifies the total amount of greenhouse gas emissions released from specific effects localized in a person, organization, service, product, event, or location. Greenhouse gasses (GHG) are those that trap heat within the Earth's atmosphere.

The Kyoto Protocol includes carbon dioxide (CO_2), methane (CH_4), which are the best-known greenhouse gases, as well as the following GHGs: nitrous oxide (N_2O) and hydrofluorocarbons (HFCs).



Less familiar molecules also contribute, including sulphur hexafluoride (SF_6), perfluorocarbons (PCFs), and nitrogen trifluoride (NF_3). The carbon footprint of an activity, event, or location takes into consideration all of these emissions. To make their impact measurable on a single scale, each substance's impact is converted to CO_2 equivalent impact. This CO_2 impact incorporates the fact that each greenhouse gas lasts in the atmosphere for a characteristic average length of time before naturally dispersing. CO_2 disperses on average within 100 years, while methane has an 80% greater heat-trapping impact but on average disperses within 8 years.

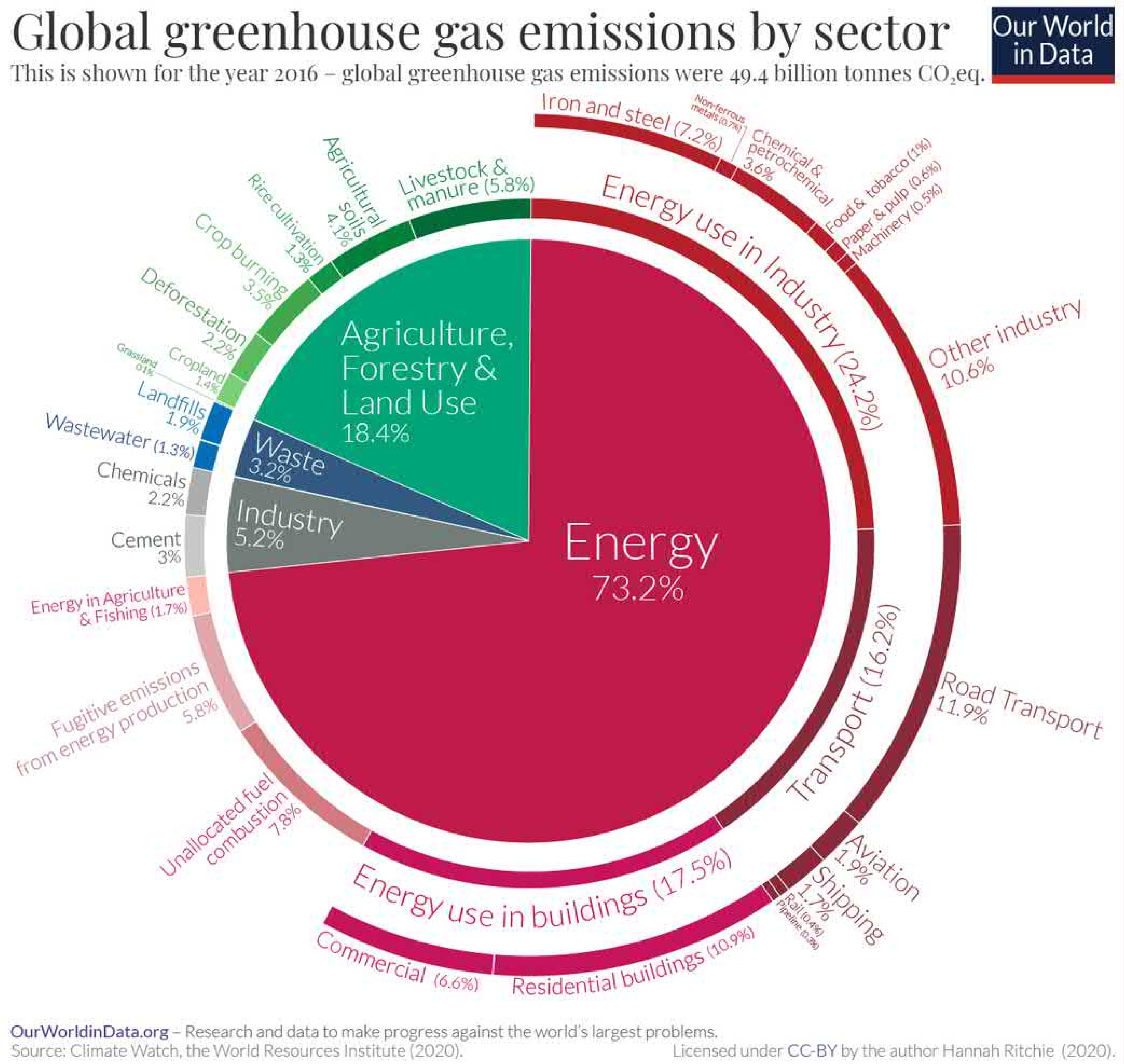
A person or organisation's carbon footprint is a measure of how much CO_2 equivalent greenhouse gasses are emitted into the atmosphere over a certain period of time. Before discussing the GHG emissions that can be attributed to individual actors, it is helpful to develop our understanding of how much CO_2 is released from familiar daily activities. We can think of the carbon gas emitted from burning a liter of gasoline.

Imagine a liter of fuel, and how that fuel is transformed during the combustion process in a standard car. Gasoline is comprised of compound molecules made up of hydrocarbons, which are molecules built with carbon and hydrogen atoms. When gasoline is burned, the carbon atoms combine with oxygen atoms to result in carbon dioxide gas.

This chemical process involves one carbon atom, with an atomic weight of 12, combining with two oxygen atoms, with an atomic weight of 16 each. In joining with the oxygen atoms, the carbon from the gasoline is incorporated into CO2, which increases in weight. A liter of gas which weighs approximately 0.75 of a kilogram, is 87% carbon. If we assume perfect combustion, this liter of gas would be transformed into approximately 2.4 kg. When we further imagine the volume of air occupied by this 2.4 kg of carbon dioxide emitted into the atmosphere, we contemplate a very large balloon.

Picture on the left: 1 liter of gasoline weighs 0.75 kg. Gasoline consists of 87% carbon, which is 0.652 kg of carbon per liter of gasoline. To combust the carbon into CO2, 1.740 kg of oxygen is necessary. The total weight after combustion then is 0.652 kg C + 1.74 kg O = 2.392 kg of CO2 per liter of gasoline. The volume of one kg of CO2, at atmospheric pressure at sea level, is 0.5458 m3. Hence 2.4 kg of CO2 is 2.4 x 0.5458 m3 = 1.3 m3. This can be visualised in a cube with 1.09 m walls, or a sphere with a diameter of 1.34 m.

Artist: Jooeun Park.

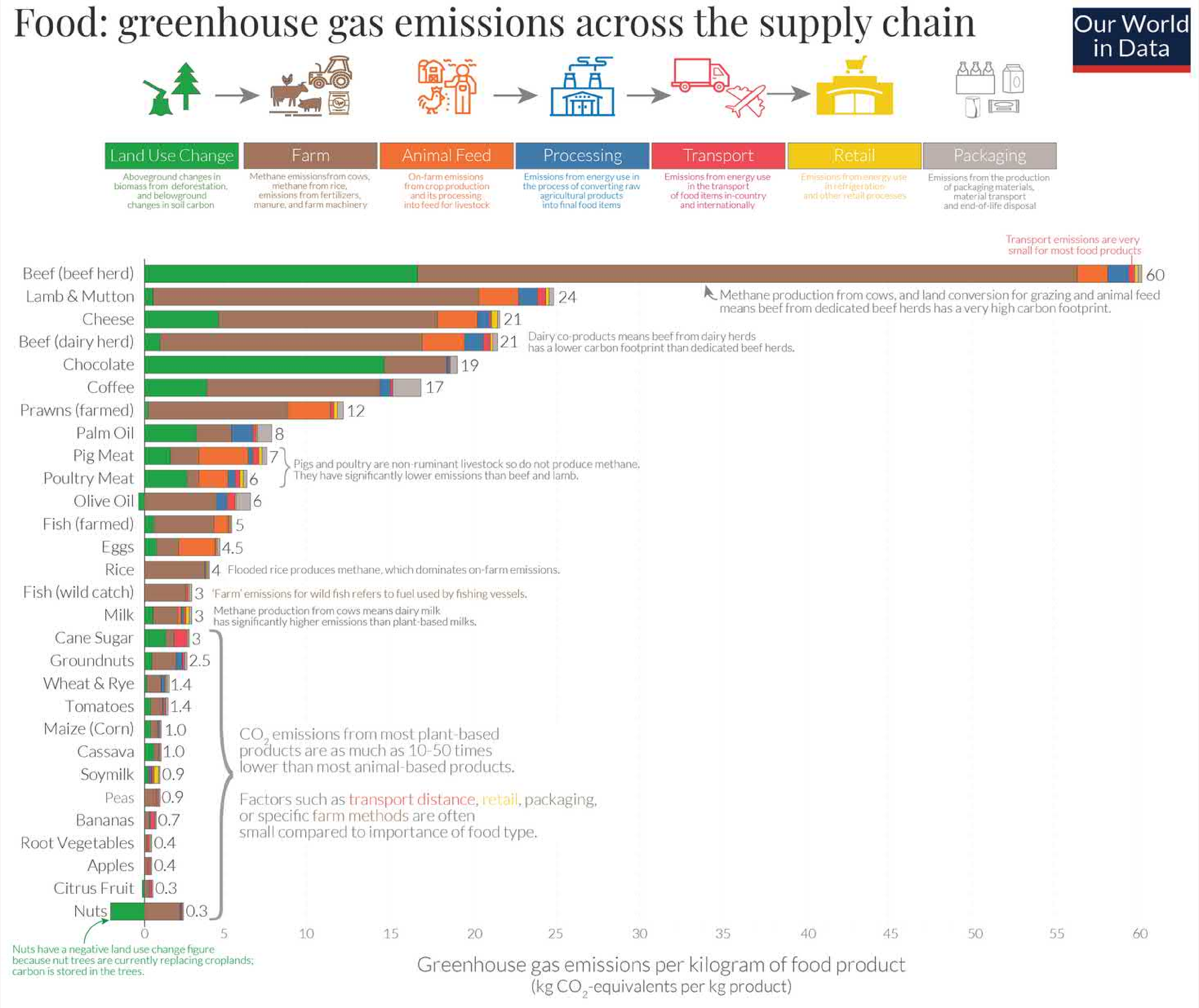


Source: https://ourworldindata.org/ghg-emissions-by-sector

Human activities cover a large spectrum of industries. Each industry has a tendency to emit a predictable amount of carbon gasses. The image on the left depicts the comparative amounts of carbon gas from distinct industrial sections.

This image shows that the energy sector emits almost three quarters of the total greenhouse gasses, and this is broken into industrial energy use: transportation, and use in commercial and residential buildings. The next largest emitter of GHGs is agriculture, forestry, and other land use, depicted at 18.4%. While energy use is technologically challenging to make more efficient, agricultural land use with respect to output correlated to GHG emissions can be achieved if consumers change their dietary consumption patterns.

That is, if people around the world ate significantly less beef, lamb, and dairy products and substituted these foods with either lower impact or even vegetable protein sources, GHG emissions could be reduced in noticeable quantities. The figure on the next page shows the disproportionately high levels of GHG emissions from beef herd, in addition to lamb, cheese, and dairy herd production.

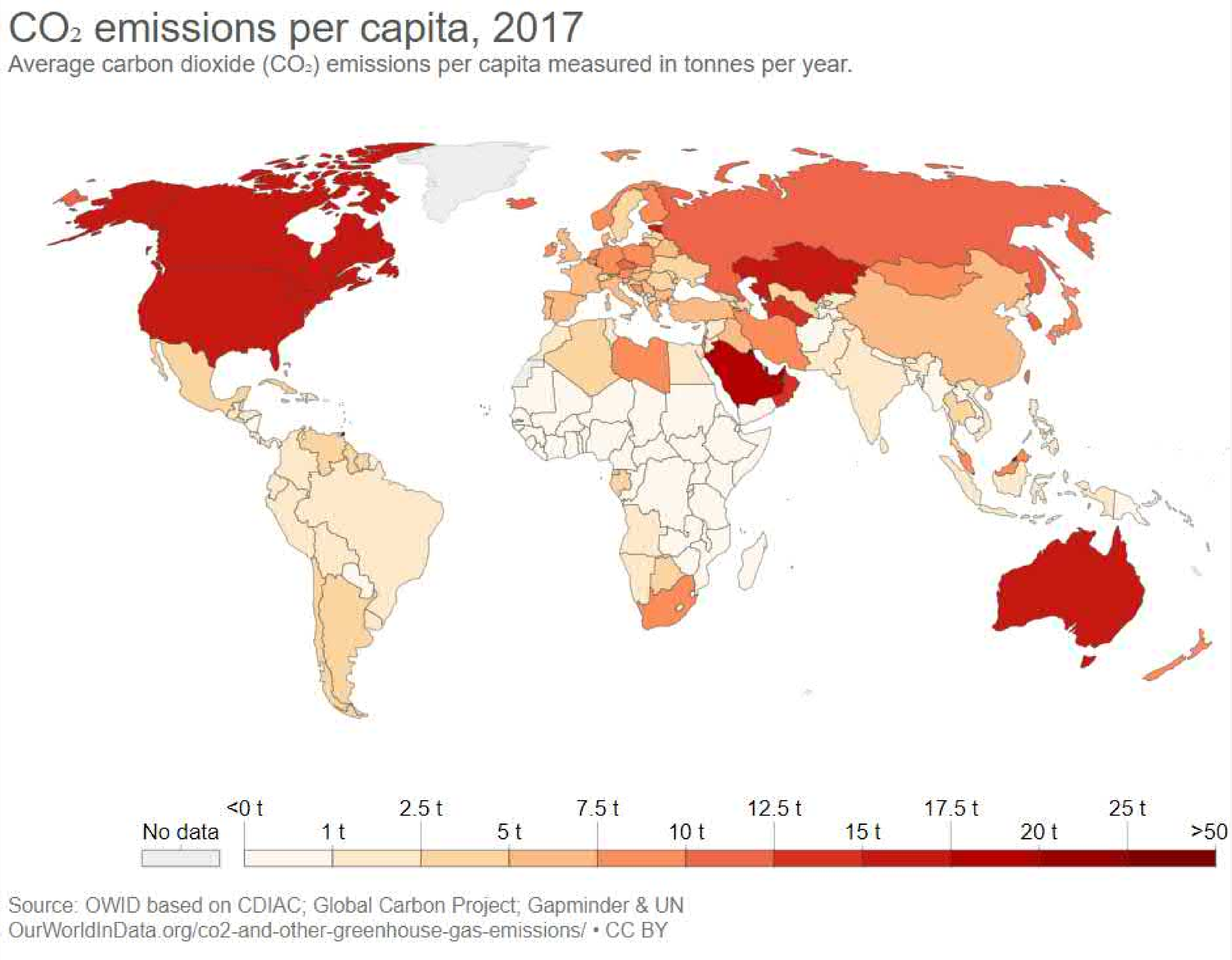


The diagram on the right displays the relative amounts of GHG emissions from different factors in the agricultural production process including: changing natural habitat to farming, farming, animal feed, processing, transportation, retail and packaging.

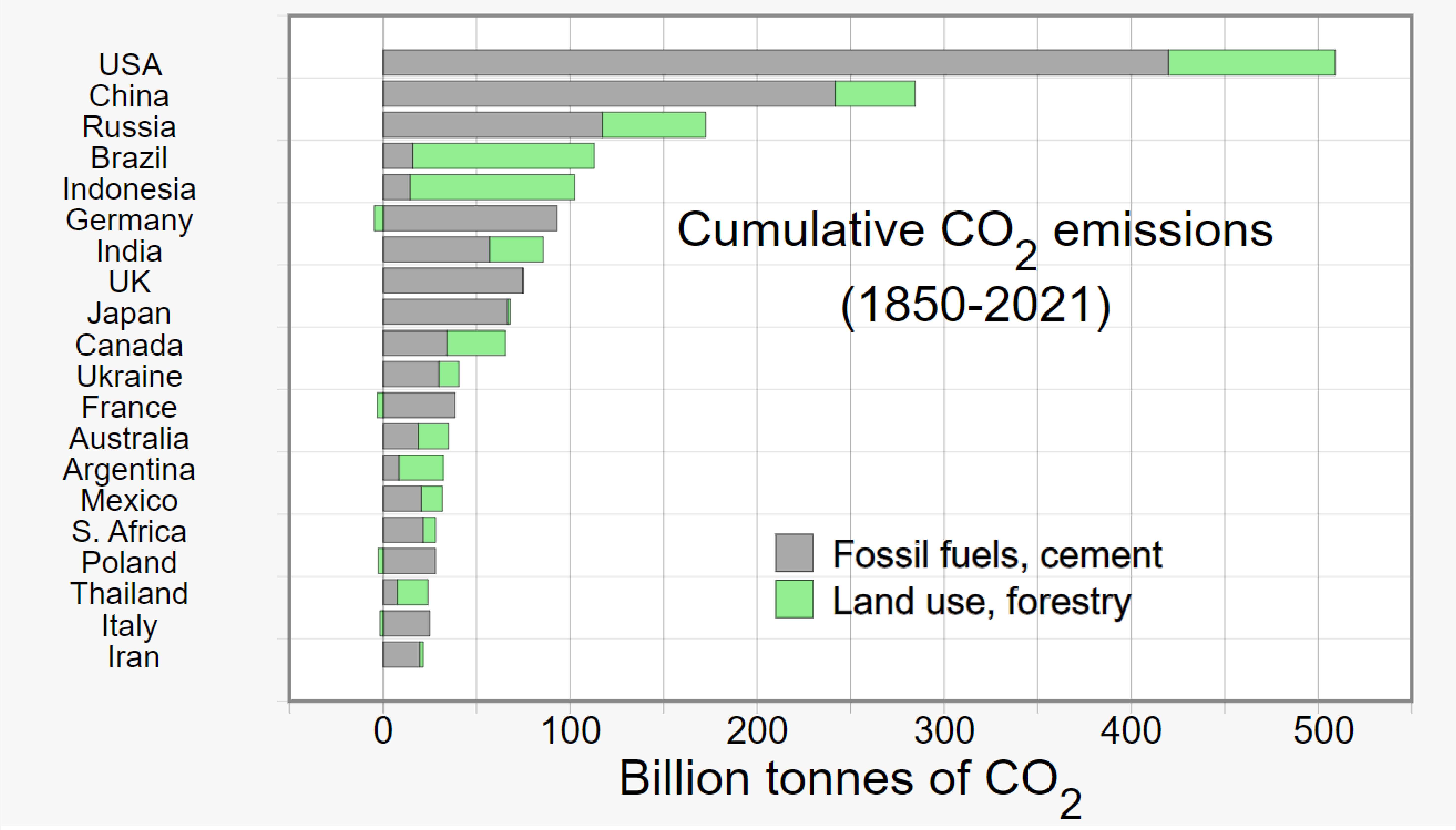
Source: https://en.wikipedia.org/wiki/Sustainable_consumption#/media/File:Environmental-impact-of-food-by-life-cycle-stage.png.

Now that we are gaining an understanding of the weight and volume of CO_2 emissions from a daily activity we are all familiar with, in this case driving a fuel burning car, we can begin to visualise the meaning of a carbon footprint. Due to our activities, which include energy consumption in heating and fuel, and through the impact of the agriculture necessary to produce food products, every individual is responsible for the economic demand resulting in carbon emissions. Given the difficulty of providing exact data, we can consider estimates. According to World Bank data, per capita (meaning every individual's carbon footprint as an average of total global population and GHG emissions) in 2019 was approximately 4.5 metric tonnes of CO_2 equivalent gasses.

The per capita estimates of individual carbon footprints varies by country. The image on the right displays the per capital carbon footprints as a function of nations. It is evident that the per capita averages from individuals in Africa and South America tend to be less than 2.5 metric tonnes per person in 2017, and tend to be upwards of 15 metric tonnes per capita in North America, the Middle East, Australia and Kazakhstan.



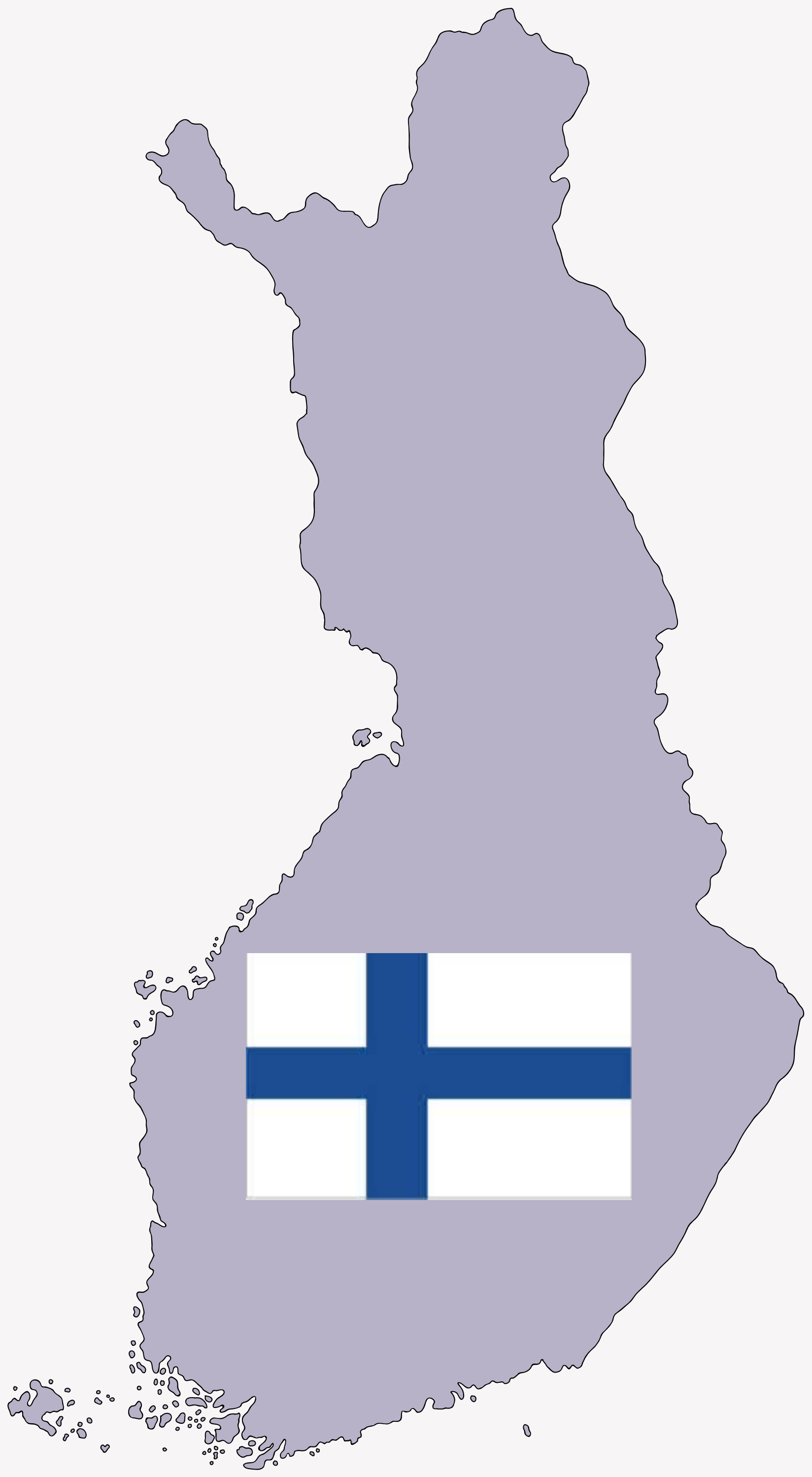
Source: https://commons.wikimedia.org/wiki/File:CO2_emissions_per_capita,_2017_(Our_World_in_Data).svg



Various nations' accumulative carbon gas emissions impact varies considerably. Source: https://commons.wikimedia.org/wiki/File:20211026_Cumulative_carbon_dioxide_CO2_emissions_by_country_-_bar_chart.svg

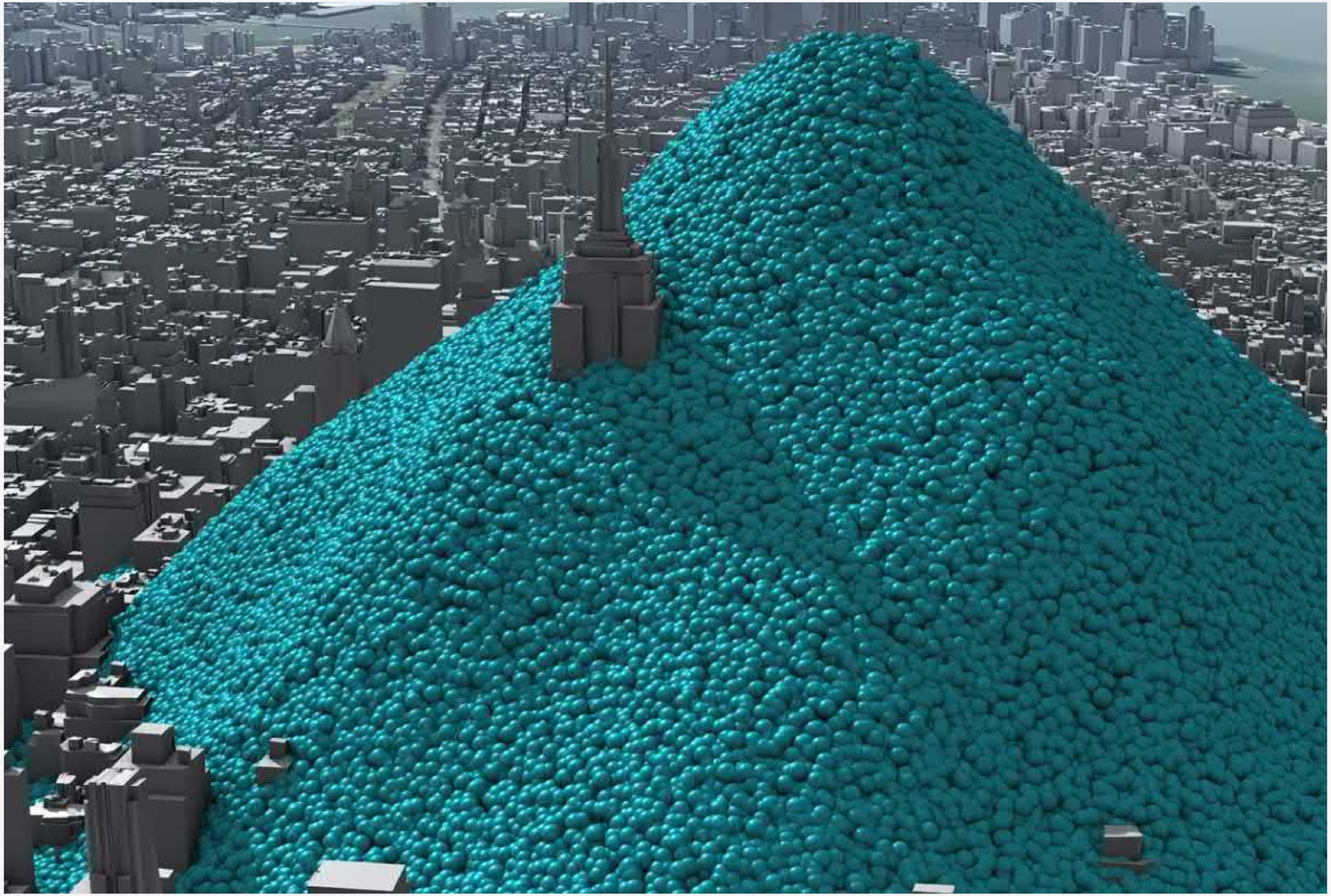
We can see that individuals' collective lifestyle habits aggregate to have an enormous total impact on the atmospheric CO2. The US, China, and Russia, respectively, have had the greatest cumulative aggregate impact to this date, evaluated on a timeline from 1850 to 2021.

Statistics Finland reports that in 2020, the total CO2 equivalent GHG emissions for Finland were 48 million metric tonnes. Given Finland's population of 5.5 million people, this is roughly 8 metric tonnes released annually per person, on average, as a function of the nation's production and consumption patterns (see, e.g., the Finnish Governments Annual Climate Report for 2022, available at: https://ym.fi/en/annual-climate-report, accessed 3 Nov. 2022).



Anthony Turner worked with the artist and scientist Adam Nieman to create visualisations of carbon emissions that are featured in the online magazine Anthropocene. The article, “Visualizing Carbon” (10 June, 2013) offers engaging imagery of what carbon gas would look like if we could see it in the quantities that are routinely released by human industrial processes and daily routines. See: https://www.anthropocenemagazine.org/2016/02/visualizing-carbon/ and the related video: https://youtu.be/DtqSIplGXOA

Try also the BBC "Climate Change Food Calculator": https://www.bbc.com/news/science-environment-46459714



CHAPTER 3
Data Analysis for Collective Impact

Section 1: Aggregating Data: Fungible and Non-fungible

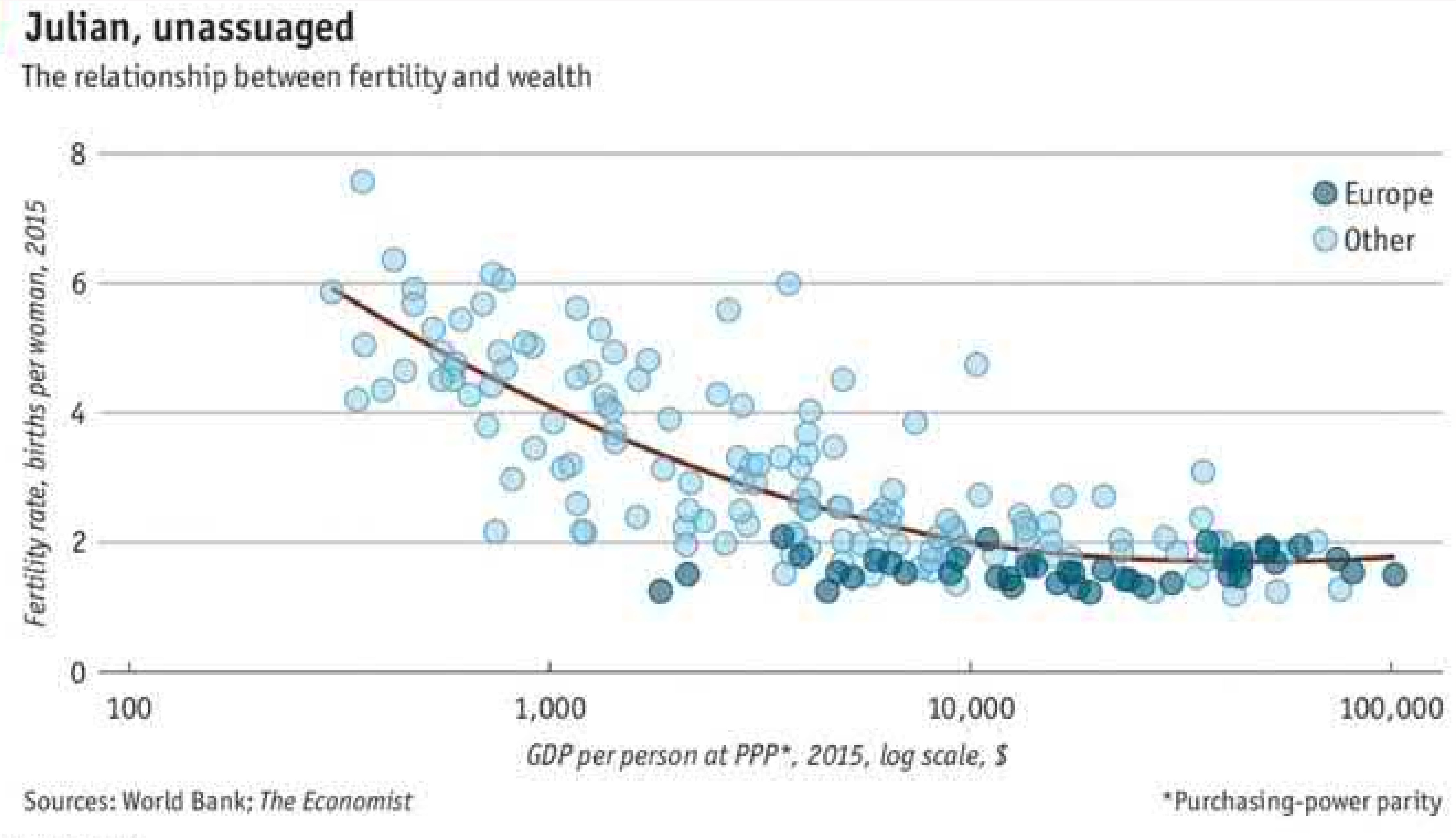
Chapter 2 focused on the importance of information in making good decisions, and on the role of data in accumulating knowledge. Gathering empirical data and applying analytical frameworks enable us to define and apply concepts such as the carbon footprint. As we saw in Chapter 2, with sufficient data used in theoretical frameworks, researchers are able to understand complex phenomena in the world. Global warming and increasing carbon gas emissions accumulating in the Earth's atmosphere are subject to such research.

In Chapter 3 we first consider additional complexities in classifying and analysing data. We learn about data that has information about fungible and non-fungible entities and phenomenon. We also learn about data gathered in social science in contrast to natural science.

The first topic concerns how we count aspects of the world, which include measuring rising temperatures or counting the Earth's total human population. The second topic concerns how we classify information about humans, as opposed to natural substances such as carbon dioxide gas molecules.

Source: https://www.freepik.com/free-photos-vectors/counting

We consider data in more depth because in assessing sustainable levels of consumption, we must go beyond understanding the correlation between the Earth's average annual surface temperature rise and increasing levels of atmospheric greenhouse gasses. The collective impact of human activities, and what levels are sustainable is a more important measurement. This is complex because levels of sustainable activity are dependent on the total demand for common pool resources. There are two important trends: human population levels are currently at 8 billion and rising, and human activities are increasing the demand for common pool resources.



This graph plots national birth rates on the vertical axis and GPD per capita on the horizontal axis, with European nations in dark blue. This graph is consistent with the observed correlation between increased wealth and lower birth rates.

Data Team, "Wealth Alone Cannot Account for Europe's Falling Birth Rates," Economist, 6 Sept. 2017.

Sulkavan linnavuori. Source: https://commons.wikimedia.org/wiki/File:Sulkava_Linnavuori_at_the_lake_Saimaa_Finland_20190930_142313.jpg

There is not a simple relationship between population rise and increasing demand for common pool resources. As families and nations increase their wealth, birth rates tend to decrease. Simultaneously, increasing per capita wealth is associated with increased consumption. Thus, lower density population can be consistent with high levels of consumption.

Consider raw data about natural phenomena. Much data of interest involves counting events and entities. One way to classify the information we gain of events and entities is whether their units are **indistinguishable** and **interchangeable**. A good example is water.

Water is measured in terms of volume, with units of liters. Molecules of carbon dioxide gas are indistinguishable and interchangeable, and can be measured by weight or volume.

To demonstrate the difference between data of **fungible** entities, and data about **non-fungible** entities, consider natural water in Finland. We could find a way to accumulate data to measure all of the existing natural water in Finland in one volume measure. We could also count natural water in terms of all of the square meters of Finland's territory it represents. Considering water in these manners treats it as a fungible entity with a single measure.

We could instead measure the number of lakes in Finland. A lake is a constructed concept, and is not measurable as a fungible entity. No two natural lakes are identical, so they are not interchangeable. However, we can count all of the natural lakes in Finland. To do so we must define the size of lakes, because at some point they are too small to be accurately reflected as a lake. Statistics Finland provides such a count.

Source: https://www.flickr.com/photos/kennysarmy/6820513924

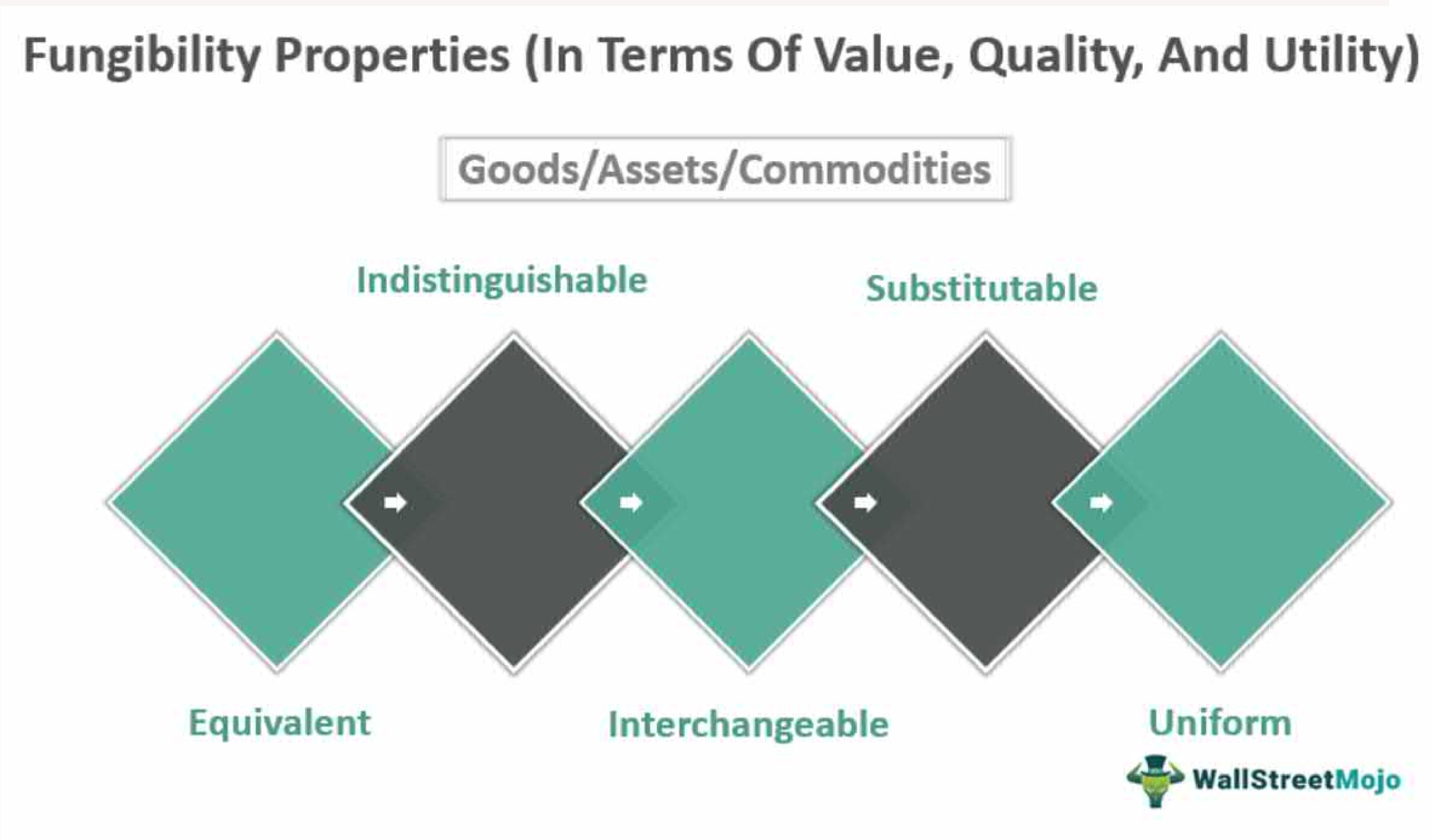


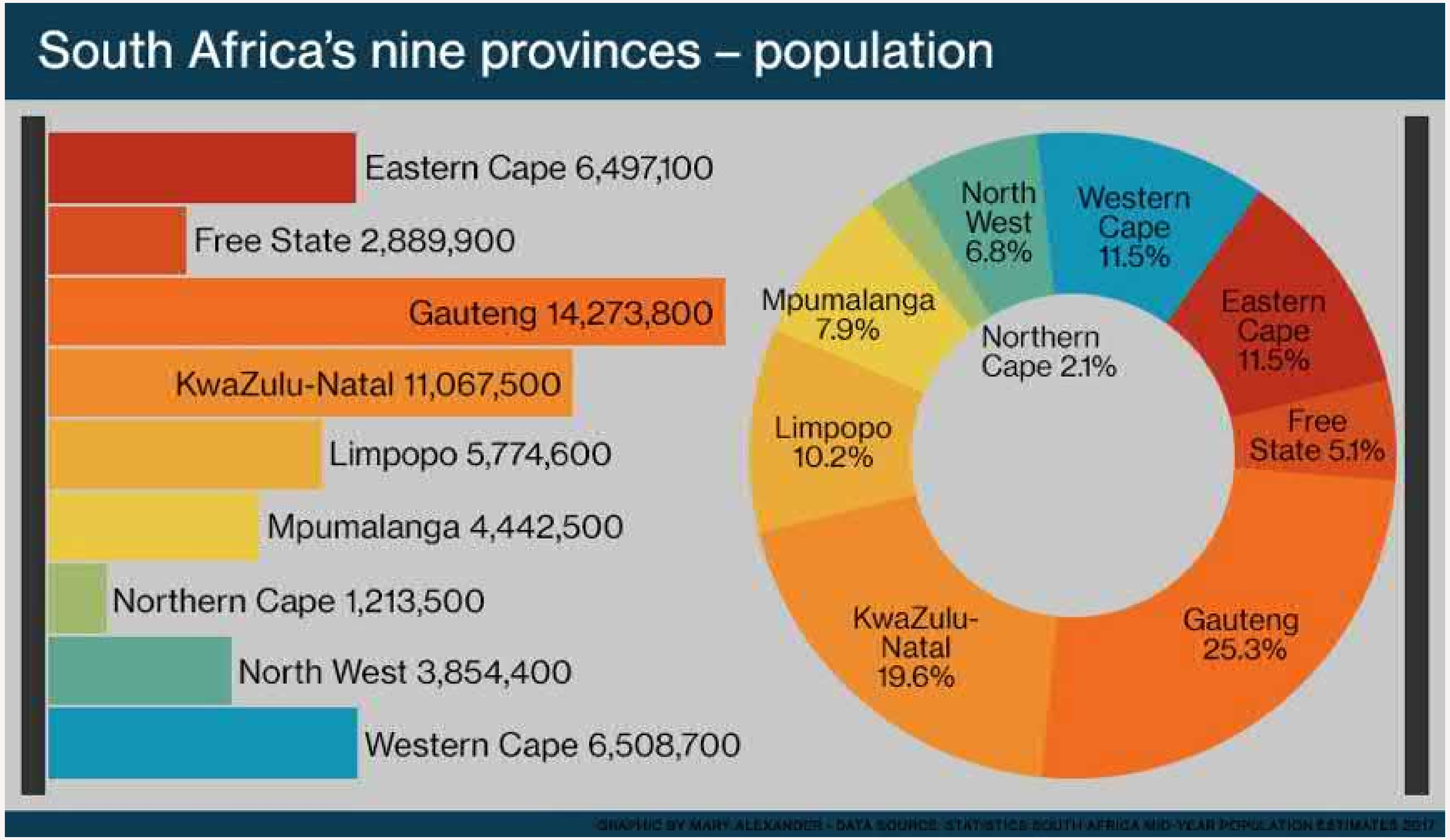
Illustration of meaning of "fungible" (left image) and examples of fungible entities (right image). Source: https://www.wallstreetmojo.com/fungibility/

Data collected in natural science can be fungible or non-fungible in nature. Data collected in social science is frequently of non-fungible entities, with the exception of data related to money. Data in social science involves people and relationships among them.

One prominent example of data collected by national governments are population counts of their residents. When governments collect census data to establish their populations, they frequently ask additional questions including subjects' age, gender identity, ethnicity, place of birth, and place of residence.

These aspects of individuals' identities cannot be considered fungible. People do not exist as fungible units, they are not individually distinguishable or interchangeable.

Census data, although a familiar category of human subject data, is complex to gather and to make rigorous. The reason for this is that aspects of people's identities are constantly changing and can be subject to interpretation and even misrepresentation. Census data could be extracted from various databases, such as a national governments' registry of births, deaths, residency and tax information, as well as medical and employment information in social security systems.



Population numbers for South Africa's provinces. Source: https://southafrica-info.com/infographics/infographic-population-south-africas-nine-provinces/

However some countries, including the United States, uphold privacy conditions on the federal government's data collection about residents. Hence, census workers are paid to go door-to-door to interview representatives of households. Given the intimate nature of the survey questions, conceivably interviewees could misrepresent how many members are in any household, as well as their birthdays, or other information. Data collected on populations typically have an estimated error interval that indicates the degree to which researchers calculate that final assessments may be off the actual target.

What are the census 2021 questions?

- What is your name?
- What is your date of birth?
- What is your sex?
- On 21 March 2021, what is your legal marital or registered civil partnership status?
- Who is (was) your legal marriage or registered civil partnership to?
- Do you stay at another address for more than 30 days a year?

The 2020 Census form will include just a handful of questions that are asked about every person in a household:

- Name.
- Relationship to Person 1.
- Sex.
- Age.
- Date of birth.
- Hispanic origin.
- Race.

Examples of the questions asked in UK (left) and US (right) population censuses.

Data relevant to economic affairs often involves measures of monetary value which are established and reported through standardised accounting procedures. This type of data appears to be relatively objective because money is fungible and therefore subject to counting and addition. Many of the graphs relevant to sustainable consumption, such as of “per capita carbon footprint” correlated to “per capita gross domestic product,” are constructed using fungible data. Calculating the carbon gas emissions from human activities and agriculture aggregates fungible units of greenhouse gasses. This fungibility enables, for example, precisely formulating a carbon dioxide equivalent for other gasses including methane: a single quantitative measure of carbon dioxide equivalent gasses is labeled CO2. Similarly, “gross domestic product” is defined as the monetary value of all of a nation’s goods and services paid for by the final user on a yearly basis. In principle it is possible to add up all annual purchases in a single measure stated in the national currency.

Finland’s Gross Domestic Product from 2000 to 2020 (horizontal axis) stated in 2010 prices (left axis) plotted in red line. Source: https://www.bofbulletin.fi/en/2018/3/finland-s-economy-booming/

To be useful, data is presented by means of easily understandable visualisation. The Food Futures App uses fungible data in the form of the carbon, material, and water footprints. The fungibility of this data enables comparing the footprints caused by various meal choices, and identifying thresholds related to less and more sustainable choices. As well, a crucial feature of the Food Futures App is the manner in which it presents data in a direct visual style so that users are able to make informed decisions based on information of a meal's relative sustainability.

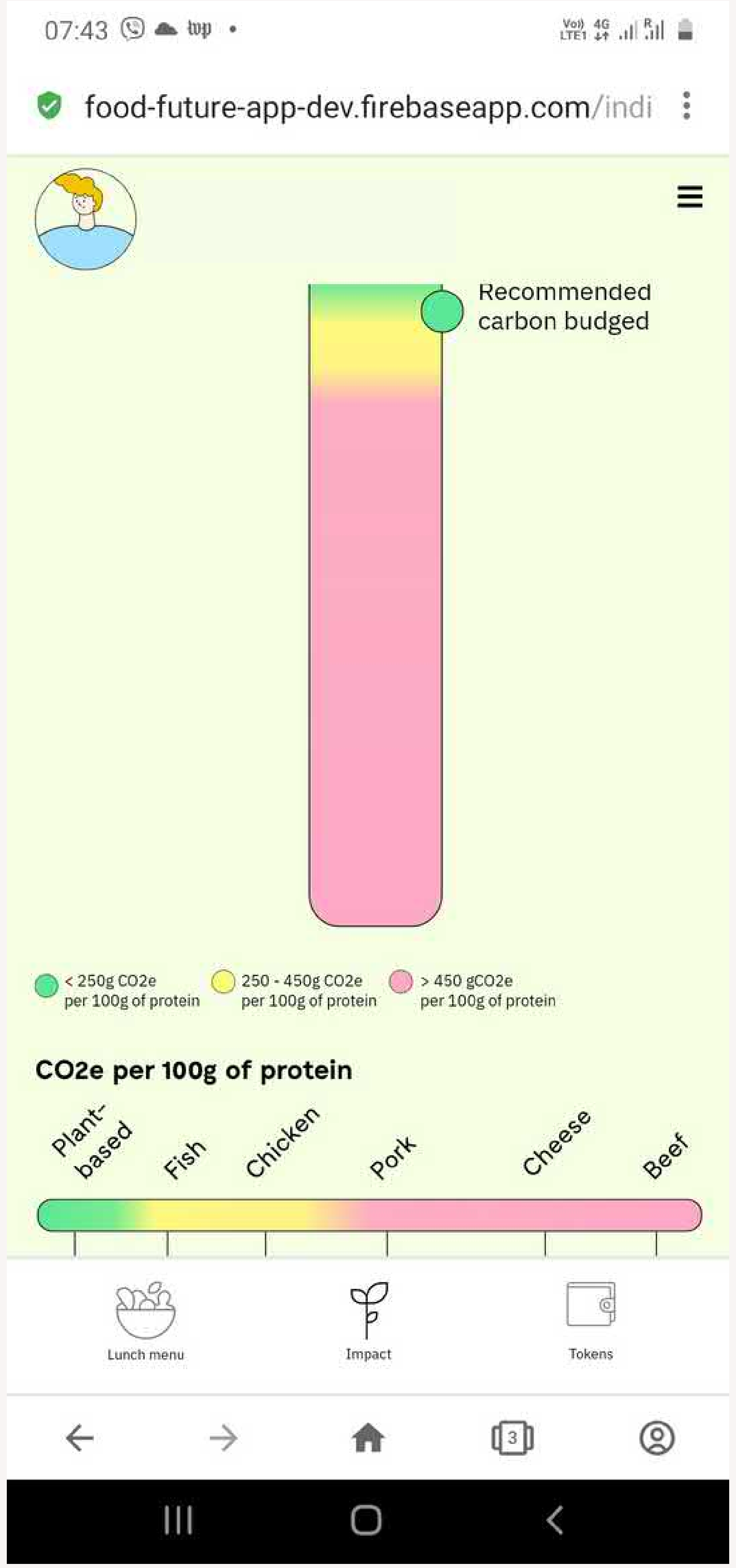


Image from the Food Futures App showing sustainability levels of meal choice.

References

Data Team (2017) “Wealth Alone Cannot Account for Europe’s Falling Birth Rates,” *Economist.* Available at: https://www.economist.com/graphic-detail/2017/09/06/wealth-alone-cannot-account-for-europes-low-birth-rates.

Section 2: 1.5°C Lifestyle

By Shreya Sood

1. Introduction to the 1.5 Degree

The concept of the 1.5°C lifestyle is consistent with the sustainable consumption approach to environmental sustainability. The name of the concept refers to the planet-wide aim of preventing the Earth's surface temperature from rising more than 1.5°C on average, with all locations considered on an annual basis of impact. Living in accordance with the 1.5°C lifestyle means acting in accordance with the values and underlying this goal.

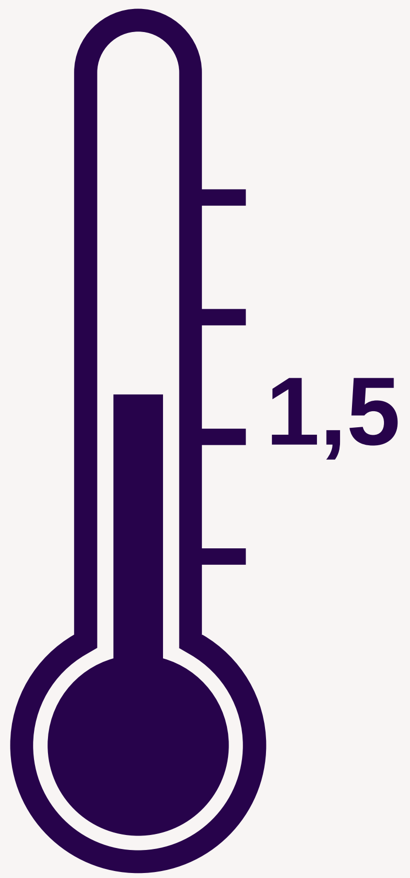
Harmonious shared lifestyle is achievable with 1.5°C lifestyle. Artist: Jooeun Park.

Artist Username: Vladischern.

If we accept the correlation between Earth's rising temperatures and the increase of accumulated greenhouse gases (GHG), then adopting the 1.5°C lifestyle requires everyone to participate in reducing individual and collective carbon footprints. Sustainable consumption is one means by which individuals can directly contribute. This book is designed to provide the necessary information for understanding global challenges to sustainability related to agriculture and food consumption. It also provides the opportunity to use an actionable tool that empowers us as citizen-consumers to make informed choices, and to measure and record our impact.

One aspect of the 1.5°C target is the natural scientific analysis underlying identifying that maximum temperature threshold for climate change as a global initiative. This goal exists independently from considerations of the Earth's population. However, if we contemplate the annual carbon emission reductions necessary to achieve this 1.5°C target, then it is necessary to consider individuals' and nations' climate impact. In less developed countries, as we saw in the data presented in Chapter 2, nations' per capita carbon footprint tended to be less than the 4.5 metric tonnes per capita (per year) evaluated for Earth's entire population of approximately 8 billion people. Similarly, for more developed countries, individuals' carbon footprints is higher than the per capita global average. The Finnish per capita carbon footprint is 8 metric tonnes per year, and in Northern American countries it is approximately 15 metric tonnes per capita.

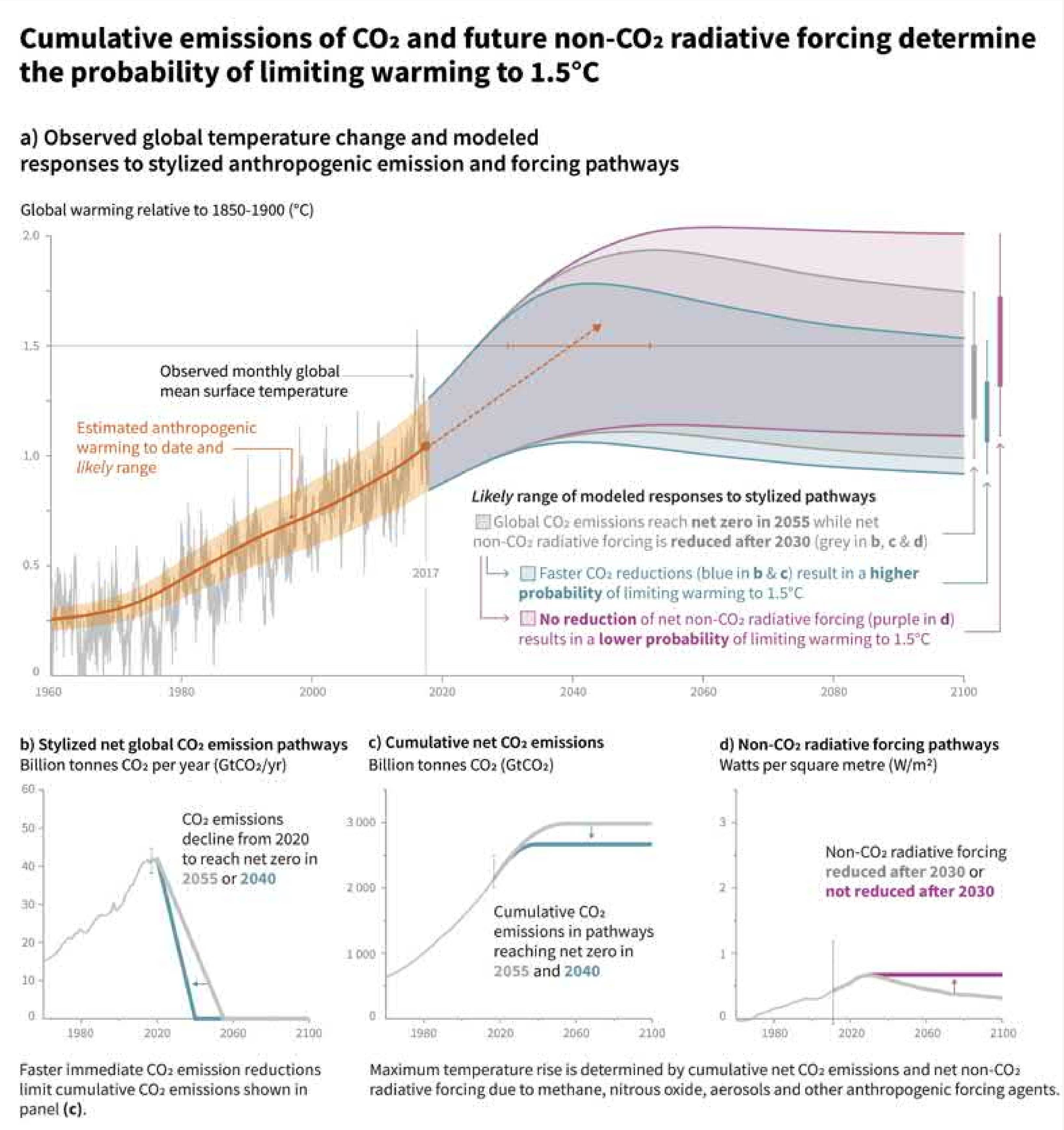
The concept of the 1.5°C lifestyle goal is consistent with the aim of achieving carbon neutral national GHG emissions: use and consume those products that have a net of zero carbon gas emissions when possible. For this reason, altering diets from red meat and dairy products which have very high carbon gas emissions is advocated. Taking individual responsibility for lowering one's carbon footprint through meal choices is an important way to make a difference and express the values of the planetwide 1.5°C goal.



2. What is the 1.5°C target?

The UN's International Panel on Climate Change (IPCC) has verified that human activities have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C (IPCC, 2018a).

The United Nations Environment Programme (UNEP) confirms that this rise is a direct consequence of anthropocentric activities that involve carbon-heavy land use and agriculture, transport, buildings and industrial processes and polluting energy sources (UNEP and the Climate Emergency). Studies have confirmed that reaching and sustaining net zero global anthropogenic CO2 emissions would halt anthropogenic global warming on a multi-decadal times scale (IPCC, 2018b).



Source: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SPM1_figure-final.png

In order to overcome the catastrophes of global warming, the Paris Agreement set a goal of 1.5°C that calls for countries to take concerted climate action to reduce greenhouse gas emissions in order to limit global warming (United Nations, 2022). The inability to keep the Earth's average temperature rise below 1.5°C would characterise a profoundly disrupted climate with fiercer storms, higher sea levels, biodiversity extinctions, melting ice, and more people dying from heat, smog, and infectious disease (Borenstein, 2022).

The SPM1 figure on the left uses data from past global temperatures in an analytic model to predict the likely future impact of cumulative GHG emissions. It models the outcome for drastic GHG emission cuts to achieve net carbon neutrality by 2040, as well as by 2055. Given the dramatic effects on the Earth's weather patterns pursuant to rising temperatures, including extreme weather events with flooding and drought, reducing individuals' and nations' carbon footprints is imperative in order to achieve sustainability for human civilization, as well as many species on the planet.

3. Significance of food systems

The three main aspects contributing to individuals' carbon footprints identified by the IPCC are a) where we live, b) how we travel and c) what we eat. These all make an important difference. UNEP shares the following statistics on the impact of food systems on various variables (Torkington, 2021):

- 60% of global biodiversity loss on land
- 33% of degraded soils
- 24% of global GHG emissions
- 61% of the depletion of commercial fish
- 21% overexploitation of world's aquifers

The most common discourse on solutions to climate change focuses on policy change, and ground-breaking revolutions in agriculture and infrastructure. However, IPCC (2018b) recommends that a shift in lifestyles and cultures and particularly dietary choices have a significant role in keeping up with the aspirational targets of the Paris Agreement. Building on this initiative, the Food Futures team of ATARCA (Accounting Technologies for Anti-Rival Coordination and Allocation) focuses on enabling informed food choices. We provide an actionable tool to give recommendations to balance individual and planetary health by implementing solutions that enable the “planetary health diet” as shown in figure 2 on the next page. Such a diet primarily involves a shift toward increased plant-based eating: more than doubling the global consumption of healthy foods such as vegetables and nuts, and a greater than 50% reduction in consumption of foods including added sugars and red meat. In our project, we empower users to make more informed decisions to reduce their impact on the planet.

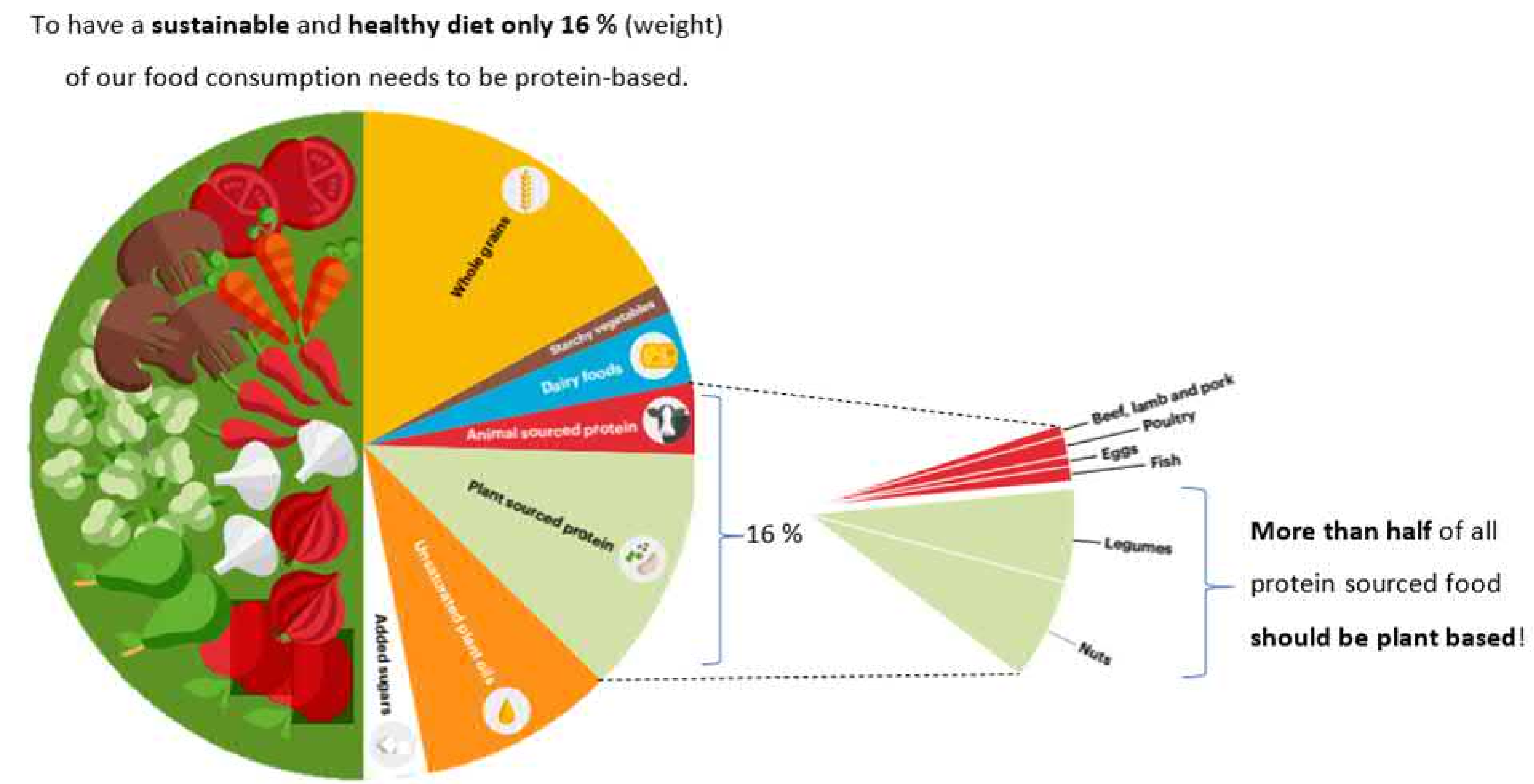
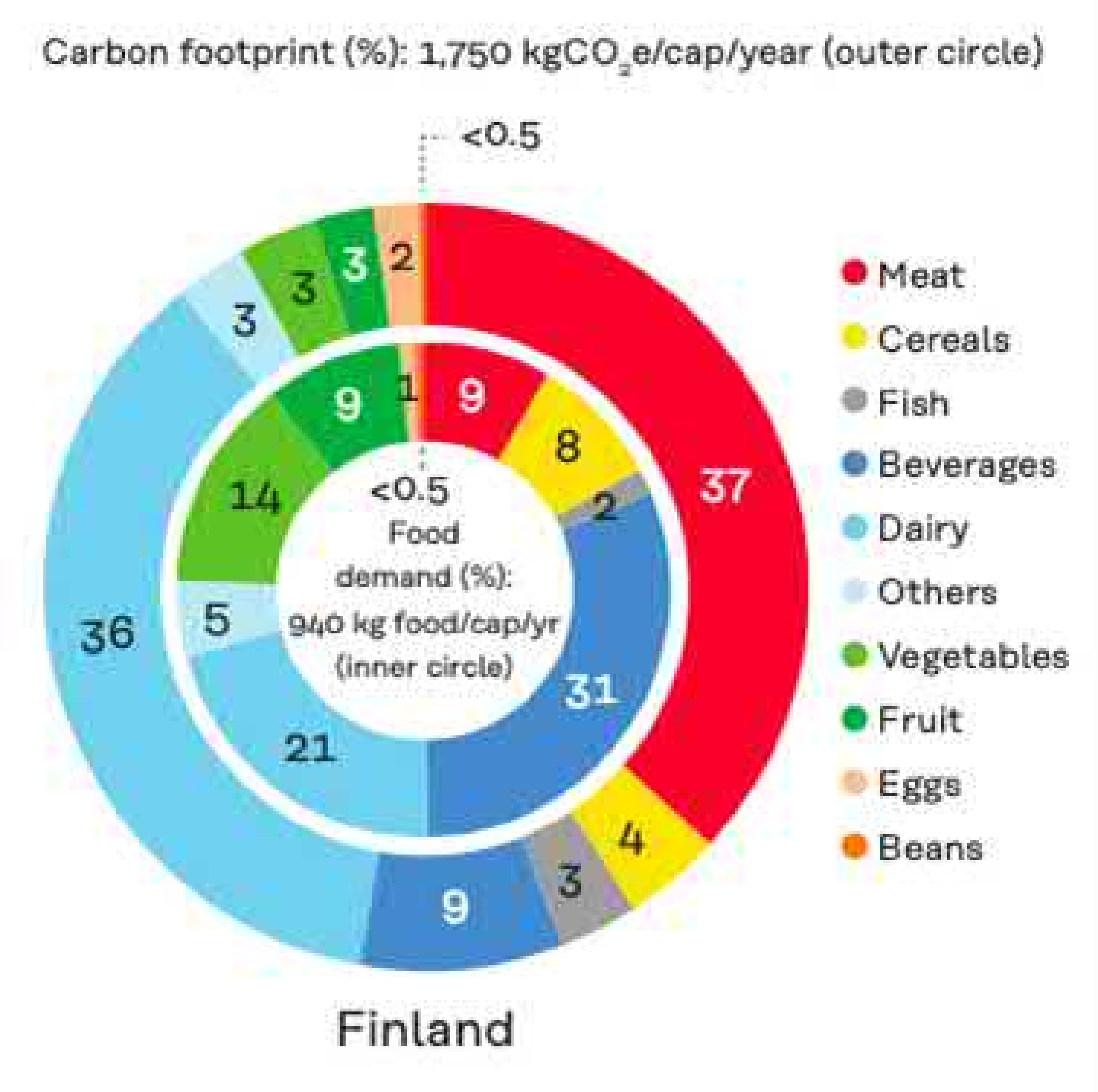


Figure 2. Planetary health diet by EAT-Lancet. Source: https://eatforum.org/eat-lancet-commission/the-planetary-health-diet-and-you/

4. Finland's food consumption and scope to enable a 1.5°C target

In Finland, the largest contributor to an individual's carbon footprint for nutrition is the high rate of meat consumption (Lettenmeier et al., 2019). It accounts for over 80 kg (per person per year) eaten in Finland. Fish accounts for almost 10 additional kg of protein source consumption. Secondly, dairy products are a significant contributor to Finland's carbon footprint, accounting for almost 200 kg per person of dairy products, including cheese.

The figure on the right shows Finland's average lifestyle carbon footprints and physical amount of consumption estimated as of 2017. Inner circles represent the share of the physical amount of consumption. Outer circles indicate the share of carbon footprints.



Source: Lettenmeier et al. (2019).

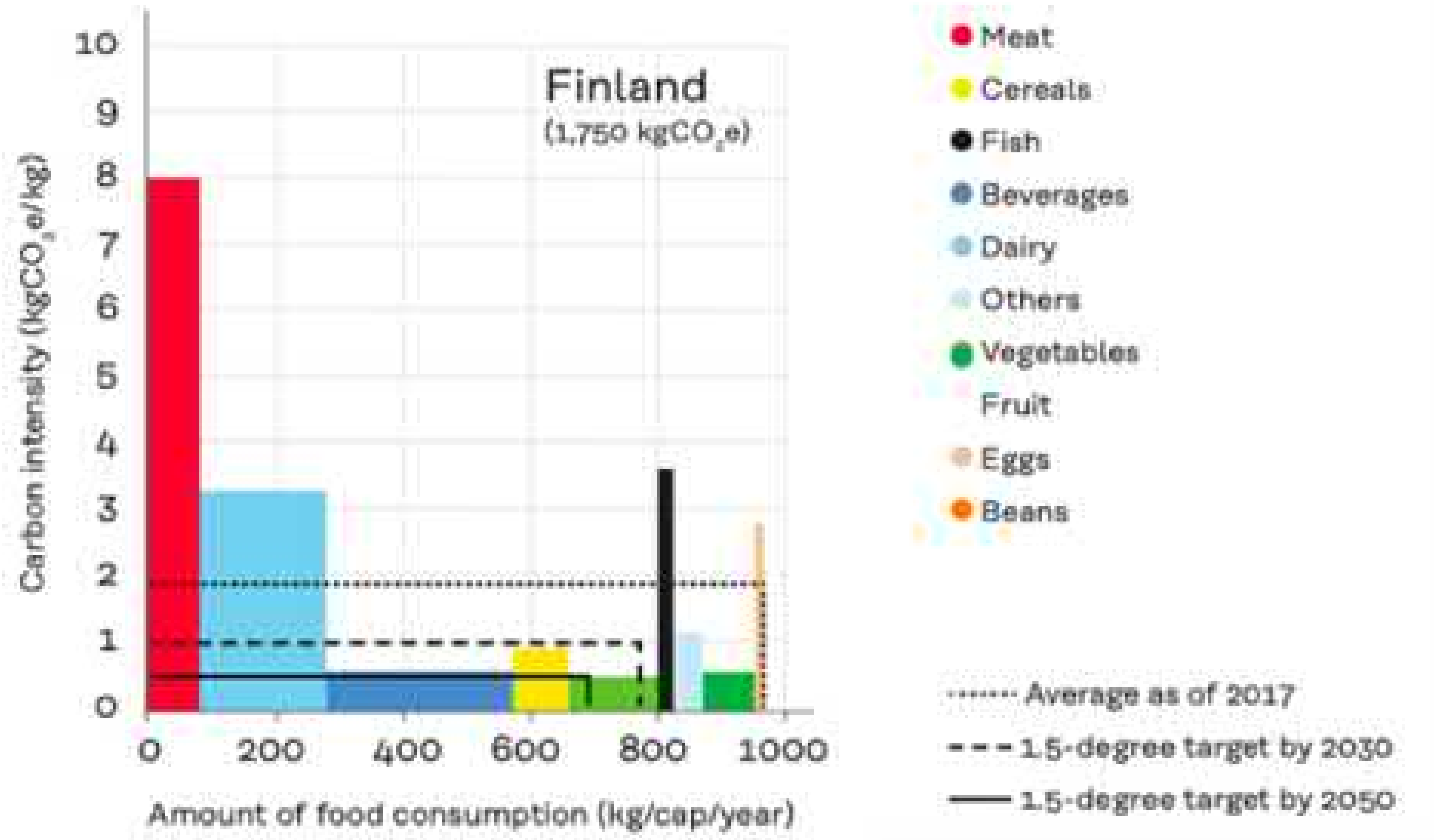


Figure 3. Food consumption patterns of Finland in 2017. Source: Lettenmeier et al. (2019).

Based on this analysis of food consumption patterns and related carbon emissions, Sitra reports that the carbon footprints for Finland's food consumption need to be greatly reduced: by 47% to 58% by 2030 and 75% to 80% by 2050.

While the reduction in carbon emissions is required, nutrition should not be compromised. A shift to plant-based protein sources such as legumes, lentils, nuts, and also fish and eggs can ensure a balance between planetary and individual health. The figure on the left illustrates the food consumption pattern as of 2017 and the desired shift in order to align with the 1.5°C targets.

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Section 3: Carbon Footprint Targets for FWSI

By Ruta Jumite

One of the **Food Wellbeing and Sustainability Index (FWSI)** metrics is the carbon footprint. As the greenhouse gas emissions (GHG) are the main cause for the climate crisis, the Intergovernmental Panel on Climate Change (IPCC) has set targets for limiting global carbon emissions to limit global warming to 1.5°C, to enable functioning ecosystems and planetary wellbeing for current and future generations. As the food industry is responsible for almost one third of global GHG emissions, specific targets have been set for this industry.

Red Jersey Cows.

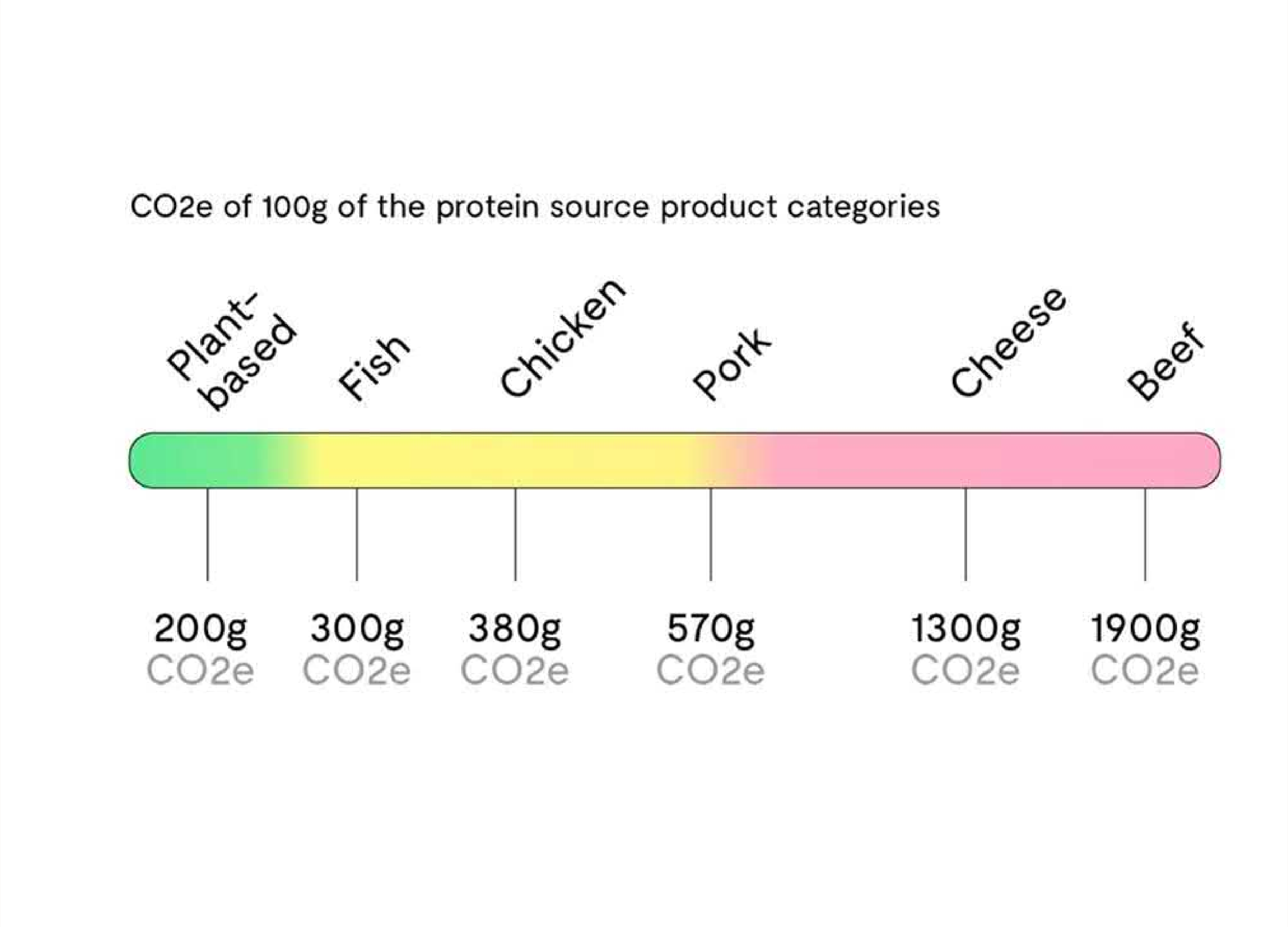

Figure 1. Impact of different protein sources. The CO2 calculations are based on the Sitra report (2019).

While it is acknowledged that the responsibility to transition the food industry toward a more sustainable system cannot be put merely on the shoulders of consumers, it is also recognised that dietary change is one of the most influential leverage points for change. More specifically, the meat industry is responsible for extensive amounts of GHG emissions; however, different meat products have drastically different impacts (Figure 1.) that consumers are often not aware of. Therefore, the Food Wellbeing and Sustainability Index is applied particularly to the protein sources. The Food Futures project does not advocate for extreme vegan diet adaptation but rather widespread adaptation of planetary diets that still allow some diversity but anticipates drastic cuts on the most carbon emissions-heavy animal-based protein sources.

The environmental Life Cycle Assessment (eLCA) approach is the most widespread approach for assessing carbon emissions of different food products. The eLCA approach considers the emissions that are produced along the whole life cycle of a food product: agriculture, production, distribution, preparation, use and waste phases. However, it is recognised that the eLCA methodology is resource intensive and time consuming, therefore, its application to the extensive amount of different food products needs to be reconsidered. Some of the leading food distributors in Finland have already created food product categorisation to limit the data needs, yet provide means for actionable food product comparison. Within the Food Futures experiment, six categories of the most common protein sources were created: 1) plant-based, 2) fish, 3) chicken, 4) pork, 5) cheese, and 6) beef.

Image portraying aspects of Life Style Assement: materials used, manufacture required, transportation, distribution, preparation, and waste

The Finnish Innovation Fund Sitra has created a consumer-citizen lifestyle-related strategy called “1.5-degree lifestyles” that is based on the international 1.5°C target for the global GHG emission reduction. As the agriculture industry transition is seen as a sensitive discussion among several stakeholder groups, and there is recognised dietary inertia, the primary criteria for defining the targets and threshold levels of FWSI was to base them on sources and targets relevant to the local Finnish context. The publication by Toivio and Lettenmeier (2018) on 1.5°C lifestyles was chosen to inform the FWSI targets and three threshold levels, as well as to inform CO2e emissions of the six protein source categories.

The Food Wellbeing and Sustainability Index has three threshold levels that are communicated by using traffic-light color coding with red, yellow and green colors. Since the Food Futures research project wants to go beyond the “on or off” thinking about sustainable food consumption and promote a more encouraging approach of sustainability as a “progress vs regress” approach, the three threshold levels do not define any of the categories as “you should never”.

The three threshold levels are conceptualized as follows: 1) green = eat often, 2) yellow = eat sometimes, and 3) red = eat rarely. Additionally, as the green category stands for the most sustainable choices, it was acknowledged that only plant-based protein sources can identify as green within the FWSI.

Plant-Based Proteins. Artist Username: Bit24.

As already mentioned, the targets and intervals of the three threshold levels of FWSI are based on the Toivio and Lettenmeier (2018) “1.5-degree lifestyles” targets and calculations. Within their publication, Sitra has divided protein sources into two categories: 1) most polluting protein sources, 1900g CO2/ 100g beef, 1300g CO/ 100g cheese 2) less polluting protein sources, pork 570g CO2/100g, 380g CO2/100g chicken and 300g /100g fish. Pork has considerably less carbon emissions than cheese or beef, however, they have included all three products in the red category to promote dietary change more effectively. The three threshold level intervals of FWSI are defined by these categories, as illustrated in Figure 2.

Carbon footprint of a product (CFP) is the sum of GHG emissions (3.1.2.5) and GHG removals (3.1.2.6) in a product system (3.1.3.2). This is expressed as CO2 equivalents (3.1.2.2) and based on a life cycle assessment (3.1.4.3) using the single impact category (3.1.4.8) of climate change.

Source: International Organization for Standardization [ISO] (2018).

	Green. Eat often.	Yellow. Eat sometimes.	Red. Eat rarely.
Threshold-level intervals	< 250 g CO2e / 100 g	250 - 470 g CO2e / 100 g	> 470 g CO2e / 100 g
Protein source categories	Plant-based proteins (200 g CO2e / 100 g)	Fish (300 g CO2e / 100 g) Chicken (380 g CO2e / 100 g)	Pork (570 g CO2e / 100 g) Cheese (1300 g CO2e / 100 g) Beef (1900 g CO2e / 100 g)

Figure 2. The three threshold level intervals and protein source category allocation used by the Food Wellbeing and Sustainability Index.

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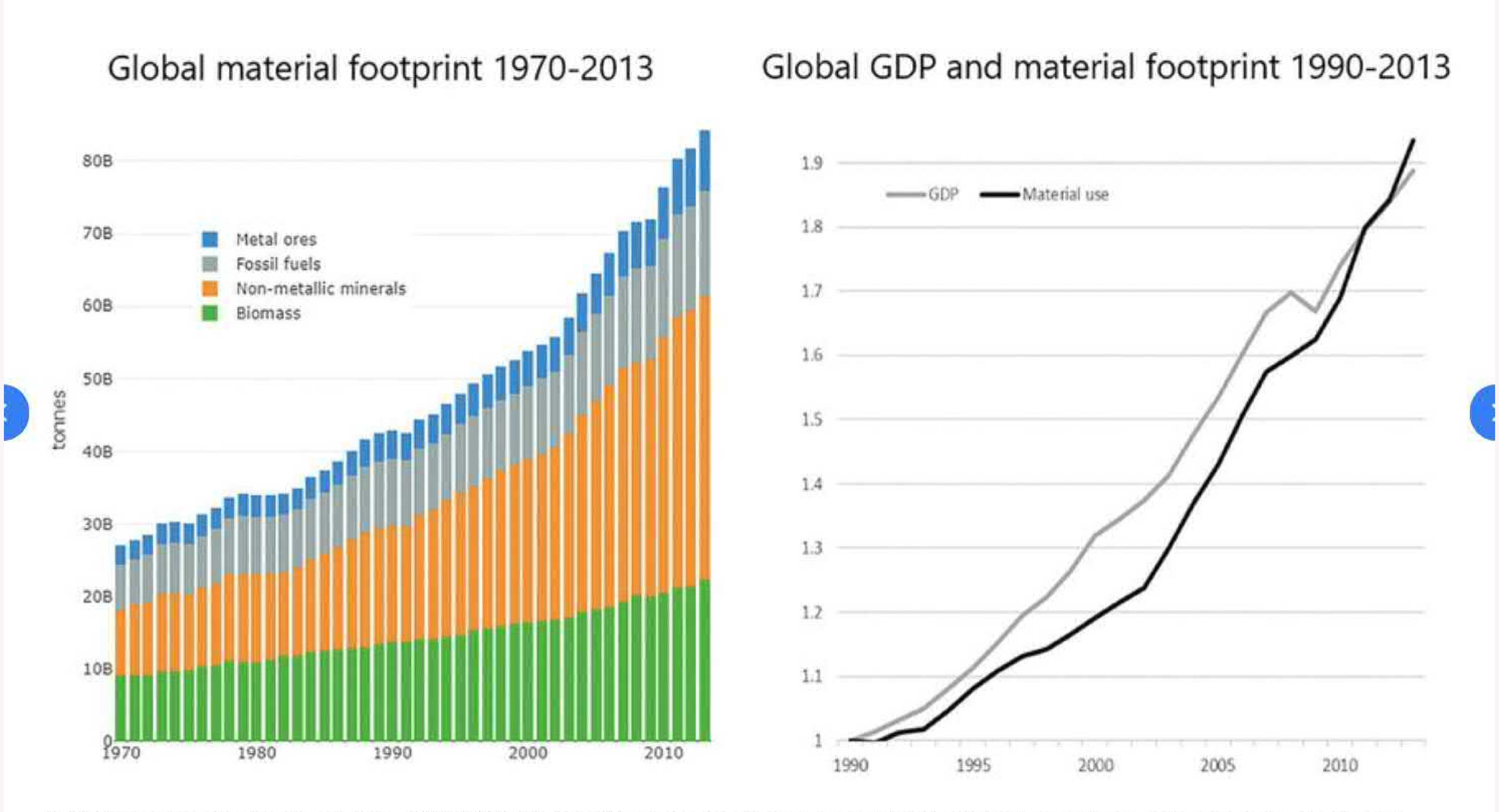
Section 4: Material Footprint

By Ruta Jumite

Agriculture is responsible for extensive depletion of natural resources, which continually increases due to population growth and the growing demand for healthy nutrition. While the most common environmental impact calculation strategy is to assess the output-oriented metrics, and the negative externalities of the production process, such as carbon emissions, **the material footprint** is an input-oriented approach that allows us to quantify the resources that are needed in production. Twofold action is needed to transition toward more sustainable agriculture systems. First, tools for sustainable resource management and productivity should be adopted within food supply chains. Second, consumer awareness about the material intensity of nutrition could shift the overall food consumption patterns toward more sustainable ones. The material footprint approach can be used to inform and balance resource use within national level companies, as well as household consumption and individual lifestyles. This metric can be used to compare, otherwise invisible, ecological costs of food products.

The material footprint metric, also called Material Input per Service Unit (MIPS) accounts for all the natural resources that have been used within the whole life cycle of a food product. The life cycle includes phases, such as agriculture and supply of raw materials, production, transportation, use and waste creation.



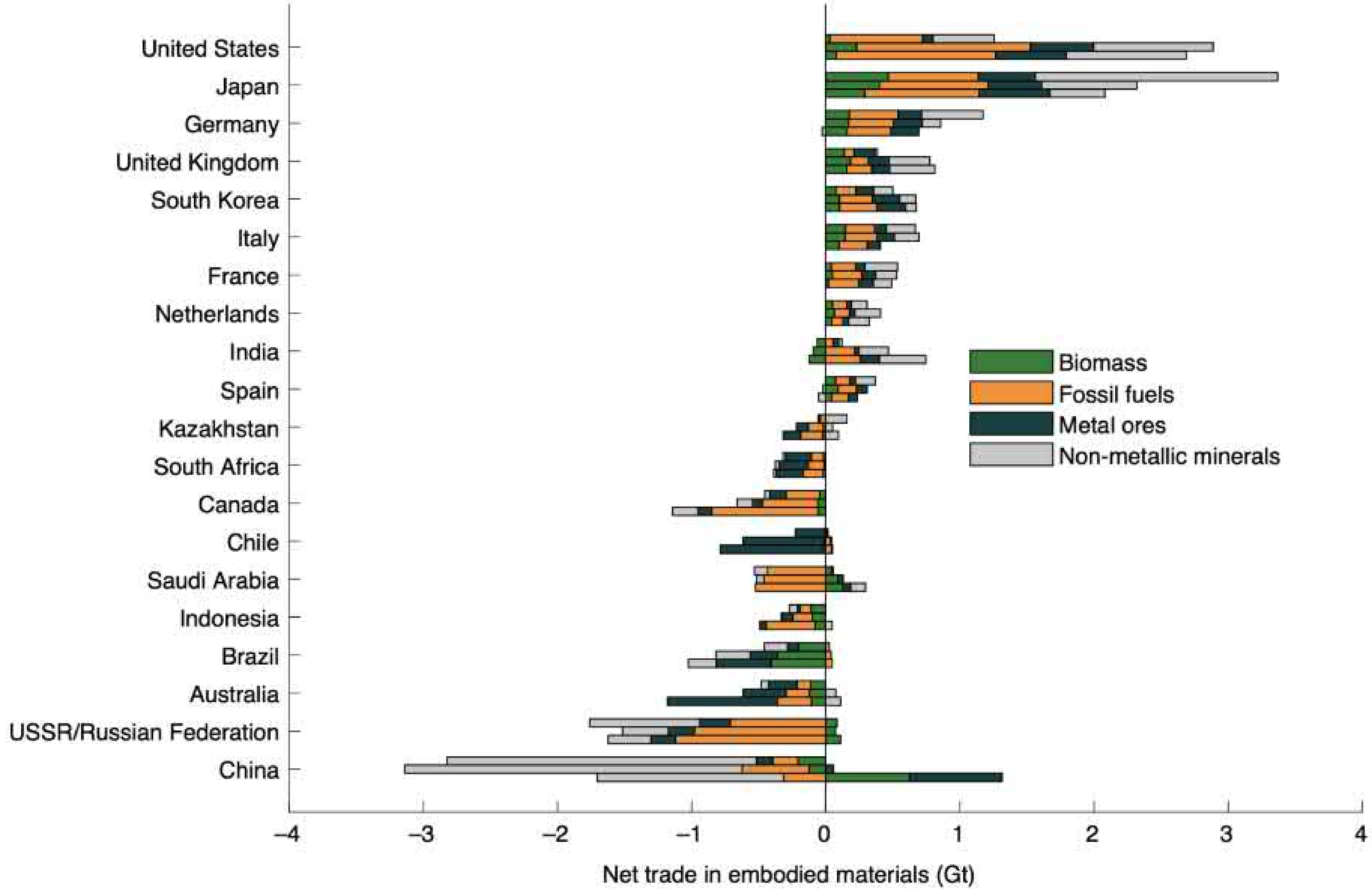
Hickel's research shows the correlation between the increasing global material footprint and global GDP. Source: https://www.researchgate.net/figure/a-Global-material-footprint-1970-2013-b-Change-in-global-material-footprint_fig2_332500379

The material footprint sums up the categories of material input:

- Abiotic materials that are non-renewable resources.
- Biotic materials that are renewable.
- Mechanical earth movement in agriculture and silviculture.
- Water use.
- Air use that is related to carbon dioxide formation.
- Erosion.

Researchers have proposed strategic targets to decrease the material footprint for household consumption in Finland. The overall suggested material footprint for a household is eight tonnes annually of the Total Material Requirement (TMR), which is 80% less than the current Finnish household material footprint average.

The researchers have defined six different consumption components: 1) nutrition, 2) housing, 3) household goods, 4) mobility, 5) leisure activities, and 6) other purposes. The current material footprint related to nutrition is 5,900 kg per person per year in Finland, whereas the suggested sustainable material footprint for nutrition is 3,000 kg, which is 49% less than the current.



Material exporters and importers. Selected top-ranking net importers and net exporters of embodied materials, $RME^r_{im} - RME^r_{ex}$, averaged over the periods 1990–1999 (top bar for each country), 2000–2009 (middle bar) and 2010–2019 (bottom bar) for four aggregate material types.

The authors of the Nutritional Footprint framework have created detailed strategic suggestions for material footprint that is related to daily meals. The Food Wellbeing and Sustainability Index targets three threshold levels for the material footprint metric that are based on these suggestions. The Nutritional Footprint framework focuses on complete meals, whereas the Food Wellbeing and Sustainability Index is applied only to the protein sources. Therefore, additional calculations were conducted to adapt these targets, as illustrated in the Figure 1.

	Green. Eat often.	Yellow. Eat sometimes.	Red. Eat rarely.
Threshold-level intervals	< 679 g TMR / 100 g	679 – 1565 g TMR / 100 g	> 1565 g TMR / 100 g
Protein source categories	Plant-based proteins (300 g TMR / 100 g)	Fish (760 g TMR / 100 g) Chicken (1290 g TMR / 100 g)	Pork (2120 g TMR / 100 g) Cheese (4320 g TMR / 100 g) Beef (4590 g TMR / 100 g)

Figure 1. Food Wellbeing and Sustainability Index and the material footprint metric application.

Material footprint is a consumption-based indicator of resource use. It is defined as a global allocation of used raw material extraction to the final demand of an economy (Wiedmann et al., 2015). The material footprint does not record the actual physical movement of materials within and among countries but, instead, enumerates the link between the beginning of a production chain (where raw materials are extracted from the natural environment) and its end (where a product or service is consumed). It opens a new perspective on global material supply chains and on the shared responsibility for the impacts of extraction, processing, and consumption of environmental resources (Wiedmann et al., 2015). It illustrates the global life cycle-wide material extraction and the final consumption of material within a region, occurring either within a country or beyond borders of countries (Giljum et al., 2013).

Material footprint is a newer term for “ecological rucksacks” (Giljum et al., 2013). Another definition of material footprint is that it is an indicator for measuring and optimizing the resource consumption of products and their ingredients and the production processes along the whole value chain (Lettenmeier et al., 2014).

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Section 5: Water Footprint

By Ruta Jumite

The field of agriculture has an environmental impact on the climate crisis, and the current agriculture patterns are not sustainable considering many common pool resources, including water. Extensive water use is one of the negative impacts of the industry. The field of agriculture is responsible for 70% of the global water footprint (De Fraiture et al., 2001). Almost one third of the water footprint caused by agriculture is used for animal-based product production, which is continuously increasing, and has doubled in the last decades. The biggest amount of water within the animal-based product production goes in growing the feed crops for animals; otherwise, the water footprint is related to animal drinking water, as well as service water, which is used for cleaning and maintaining production.

Consumers are often alienated from the food value chain; therefore, the extensive use of water that is needed to produce the food products is often invisible.

Blue surface water. Artist: Pavlo Vakhrushev.

Water used in agricultural production. Artist Username: Branex.

Once water is used in agriculture and released back into nature, it can require additional water to dilute any toxic substances to meet water quality standards – this additional water is "grey water."

Hoekstra et al. (2011) have created a **water footprint** definition that serves as the basis for widespread scientifically sound calculations. The water footprint consists of three types of water, measured in liters:

- The blue water footprint is linked to the surface and groundwater that is used within the food production process.
- The green water footprint assesses the quantity of rainwater needed.
- The grey water footprint refers to water that is used to dilute the pollutants that have been generated within the food production process, and to ultimately match the released water quality with the ambient water quality standards.

Researchers in Finland have developed the Nutritional Footprint concept, an academic framework to assess and communicate the environmental impact of food products. The Nutritional Footprint framework includes strategic suggestions for material footprint that is related to daily meals.

The Nutritional Footprint framework refers to the study and suggested targets by Mekonnen and Hoekstra (2012) and have calculated the target within the context of daily water footprint targets.

Within the Food Wellbeing and Sustainability Index (FWSI) the water footprint targets and three threshold level intervals are based on the targets suggested within the Nutritional Footprint framework. However, the targets were adapted from the complete meals to be applicable to protein sources (Figure 1.). Sixteen academic publications and databases were reviewed to rank analytical frameworks that could be applied to the product categories.

From the publication and database list, a publication by Jalava and Kummu (2018) was selected to be the most applicable within the Finnish context, however the publication did not cover all the product categories. To inform data for the cheese and fish categories, a publication by Petersson et al. (2021) was selected that represented global averages.

	Green. Eat often.	Yellow. Eat sometimes.	Red. Eat rarely.
Threshold-level intervals	< 158 l / 100 g	158 – 381 l / 100 g	> 381 l / 100 g
Protein source categories	Plant-based proteins (93 l / 100 g)	Fish (197 l / 100 g) Chicken (300 l / 100 g)	Cheese (506 l / 100 g) Pork (537 l / 100 g) Beef (1496 l / 100 g)

Figure 1. Food Wellbeing and Sustainability Index and the water footprint metric application.

Green water from rain. Artist Username: VPales.

Water footprint assessment is the compilation and evaluation of the inputs, outputs and the potential environmental impacts related to water used or affected by a product, process or organisation.

Source: International Organization for Standardization [ISO] (2014).

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CHAPTER 4
Tragedy of the Commons

Section 1: Overview of the Tragedy of the Commons

The **tragedy of the commons** conveys a rich imagery of a common area, such as a pasture, that is overused so that its richness and abundance is transformed into a barren field. We could imagine that all the trees are cut down to be used for construction materials or fuel. Perhaps there were too many grazing animals, and there is no longer any grass to feed them. Or maybe a forest area once had good hunting of wild animals with hares, pheasants, and deer, but now they are hunted into a state of nonexistence.

Picture of a medieval forest. Source: https://commons.wikimedia.org/wiki/File:Medieval_forest.jpg

Artistic rendition of commons after overuse.

In contemporary social science, “tragedy of the commons” is a technical phrase which refers to the overuse of a common resource so that its rate of replenishment is slower than its rate of use. If, for example, we have a common water well, and it is capable of generating 10,000 liters a day for a community, and if individuals collectively use less than 10,000 liters daily, demand is met. However, if that demand grows beyond 10,000 liters a day, toward the end of the day demand will overwhelm supply. This could result in a race to get water earlier in the day, or fights over water.

Alternatively, community members can organise and find a way to use the available water within natural limits. This could be achieved by each household using only a certain amount of water within specified limits. If there are 10 households, they can each secure 1,000 liters/day and live harmoniously with the natural supply. Another possibility is that a community might differentiate between members' needs. They could allocate double the water to the family with a hotel, for example, and cut back on the amounts for other families.

Today, we often apply a market solution to allocate limited resources. By this method, the community might sell water according to the highest price, and let community members obtain water based on how much they are willing to, or can afford, to pay. But market solution may result in unequal and exclusive access.

Ancient Egyptian water well. See story on well: Kamal Tabikha, "Egypt announces discovery of five ancient water wells in North Sinai, N Mena", 1 March 2022. Source: https://www.thenationalnews.com/mena/egypt/2022/03/01/egypt-announces-discovery-of-five-ancient-water-wells-in-north-sinai

Chand Baori, in the village of Abhaneri near Bandikui, Rajasthan, is one of the deepest and largest stepwells in India. For stepwells see: https://en.wikipedia.org/wiki/Stepwell. Source: https://commons.wikimedia.org/wiki/File:ChandBaori.jpg.

There are many cases of common resources that we are familiar with in our daily lives. Perhaps the most prominent is the atmosphere. We all need air, with oxygen, to breathe and live. We breathe the available air without paying for it. As well, through individual consumer choice expressed as market demand, we all benefit from industrial processes that release CO_2 and other substances into the air. These pollutants result from burning fuel, and also from agricultural wastes including the methane gas generated by farm animals.

We can therefore consider that the Earth's atmosphere is a vast common pool resource necessary for all plant and animal life. We all have non-excludable access: we can all breathe the air without paying for it, and without the need for a permit. As well, we all pay a price for the effects of how others use the air. If we live by a factory that releases toxic chemicals into the air, we are not protected from the impacts of later breathing these chemicals.

Common pool resources have the structure that all members of a community can benefit from using them; they are of limited supply, and no one can be excluded from gaining access. Another familiar example is fish in the oceans or lakes. Fishing boats, with owners and workers who seek to make a living, compete for limited supplies of fish to meet demand. As one example of industrial fishing, in the 21st century, demand for bluefin tuna led to an almost complete collapse of their population in the Pacific Ocean.

Fiona Harvey, "Overfishing causes Pacific bluefin tuna numbers to drop 96%," The Guardian, 9 Jan. 2013. Source: https://www.theguardian.com/environment/2013/jan/09/overfishing-pacific-bluefin-tuna

The oceans are a common pool resource in which private operators each do their best to make the most profitable catch to bring to the market. No one "owns" the oceans, so the fishing industry has for centuries caught wild fish, without any obligation to ensure the wellbeing of the natural habitat. In some areas, we see the depletion of natural fish stock with the result of overfishing and eventual exhaustion of the natural resource given its limited capacity for renewal.

In Chapter 4 we consider two contemporary analyses of the tragedy of the commons. Garrett Hardin provided a pessimistic analysis that, given a finite common resource with free access, individuals will tend to overuse and exhaust the resource. Elinor Ostrom provided a more optimistic view. Based on empirical research, she argues that traditional societies have in many instances been capable of governing the use of common resources within sustainable limits. Ostrom’s research team cites evidence to support their optimism.

They refer to satellite images from land use of a region intersecting the Mongolian, Chinese, and Russian national borders. Each culture has its own land-use rules. Russia has had modern state-run agricultural collectives. China shifted from agricultural collectives to adopt a policy of giving individual households private property allotments. Mongolia, by contrast, has had traditional group property norms, with entire communities rotating to different locations throughout the seasons. The satellite images showed that the Russian state-run and Chinese privatised systems visibly degraded the land, while the Mongolian traditional group property showed a fraction of this deterioration.

"Based on empirical research, Ostrom argued that traditional societies have in many instances been capable of governing the use of common resources within sustainable limits."


Mongolian green steppe landscape with yurt. Source: https://libreshot.com/mongolian-landscape-with-yurt/.

In moving into our study of the tragedy of the commons, bear in mind two important characteristics of a common pool resource. These resources are (1) either open to everyone, or very costly to exclude people from accessing; and (2) are finite and scarce so that when one individual consumes resources, there is less for everyone else. In technical economic terms we refer to common pool resources as **non-excludable** and **rival**. This means that it is difficult or impossible to exclude people from the resource, and that when one person uses part of the resource, that amount is subtracted from the total amount available for everyone else.

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Sneath, David (1998) "State Policy and Pasture Degradation in Inner Asia," *Science*, 283(5380), pp. 1147-1148.

Section 2: Garrett Hardin's Analysis of the Tragedy of the Commons

Garrett Hardin published his now-famous article, "The Tragedy of the Commons" in *Science* in 1968. His article has been cited over 50,000 times, testifying to its widespread influence. In Sections 2 and 3 of Chapter 4, we study Hardin's analysis of common pool resource overuse, as well as his solution. In the following two sections, we will study Elinor Ostrom's alternative analysis, which has become equally influential. As we develop on our path to learning we are invited to retain a critical mind. In anticipating Ostrom's more optimistic approach ahead, you are already invited to question Hardin's assumptions as they are presented on the pages ahead.

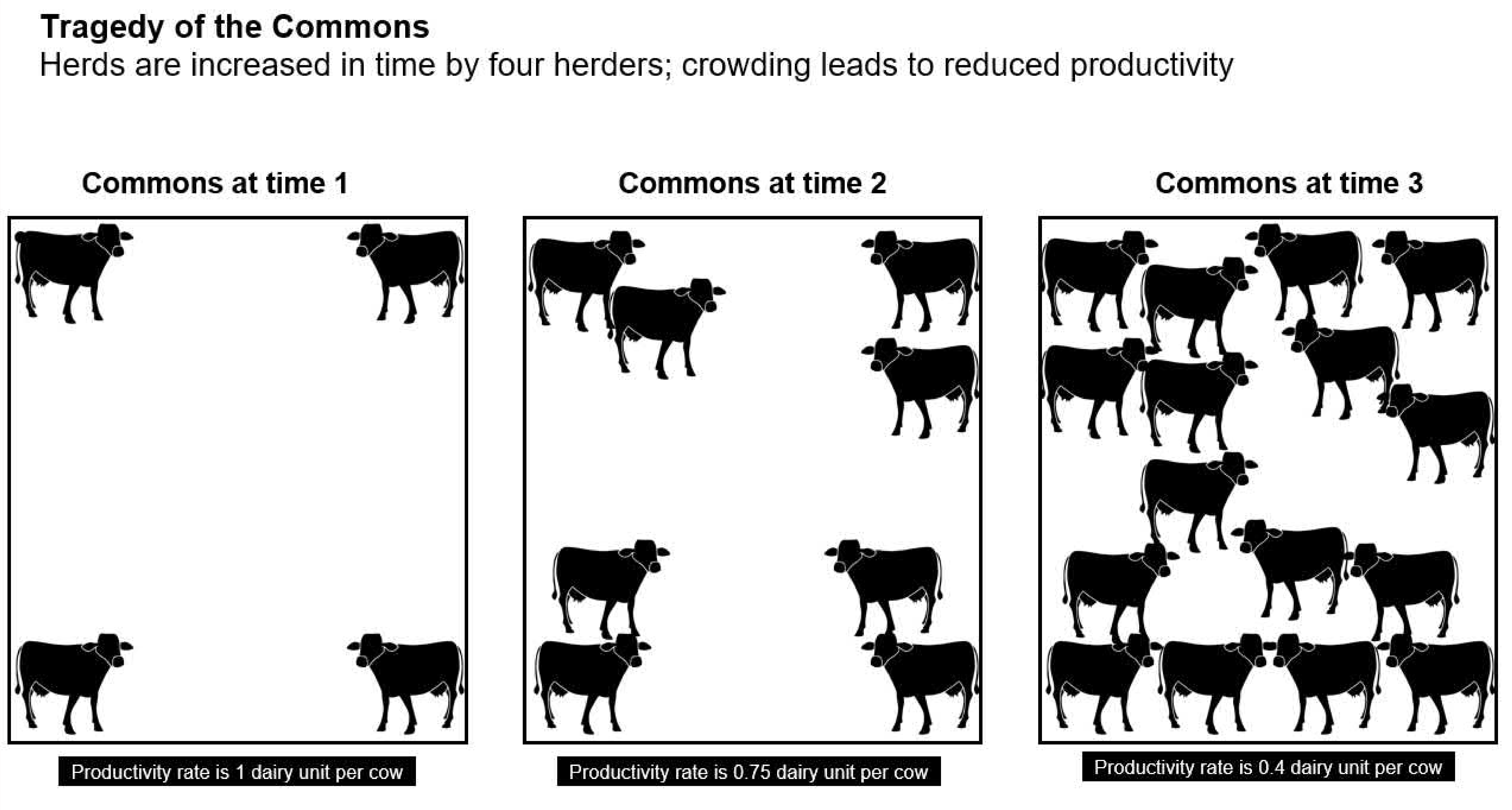
Cover of Science*, Vol. 350, Issue 6262.*

Hardin's central concern is to address large scale common resource problems, wherein overuse occurs due to individuals' demand. He views these problems as social problems for which there is no technical solution. The reason for this problem, which now is technically referred to as a resource dilemma, is the scarcity of many resources. These common resources have historically been sources of food and water, and natural habitat. The bottom line for Hardin is that the world is finite. No technical wizardry can produce an infinite amount of food, energy, or land, at least within the boundaries of science in the 21st century.

The reason that scarcity poses a problem according to Hardin is that when resources are freely available to all people without restriction, individuals will seek to exploit them as much as possible.

Hardin's leading example is that of herdsman with their cattle on an open common pasture. According to Hardin, it is natural to expect that each rancher will seek to keep as many cattle as possible on the shared land. Each rancher calculates that he or she benefits directly from adding cattle, while the costs of crowding are distributed among all the herdsman.

Source: https://farministasfeast.com/2012/04/19/not-on-my-plate-do-you-know-where-your-beef-comes-from/.



Source: Noun Project, CC0 1.0 <https://creativecommons.org/publicdomain/zero/1.0/deed.en>, via Wikimedia Commons.

Even without apparent overcrowding, methane gas from cows' digestion is a powerful greenhouse gas contributing to the tragedy of the commons. Artist: Jooeun Park.

Hardin argues that this logic that everyone will pursue individual benefit, while imposing costs onto all the other users of a common resource, is inevitable as a function of individual self-interest. He refers to Adam Smith's invisible hand of the free market, by which the market is argued to automatically balance demand and supply. However, in the case of freely accessible common pool resources, no property rights are in place to support the free market solution. Hardin imagines a pasture as a common resource that ends up in tragedy because it is depleted. When there are too many heads of cattle on a limited area of land, there is no longer sufficient grass to sustain the herds. The outcome is the poor health of many animals. Today we can also contemplate that over-reliance on dairy and beef cattle for food sources leads to a tragedy of the commons due to the excessive methane fumes caused by these animals' food digestion.

Hardin discusses many examples of the over-exploitation of a common resource. His example of the over-use of the oceans remains important as well. We know that the free market, with high consumer demand for fish, including tuna, cod, and salmon can lead to depleting natural fish stocks to the extent that they fail to replenish. The bluefin tuna, Atlantic halibut, European eel, and Nassau grouper have all been fished to the point of extreme depletion.

Source: TJ Watson (8.12.2019). The Great Pacific Garbage Patch. Youtube. https://www.youtube.com/watch?v=MnCbTTTi7ic

Pollution is another example Hardin discusses. In this case people have access to waste by discarding byproducts such as sewage and garbage into the open environment. Each polluter bears a tiny cost of the impact of their toxic dumping, while the impact of everyone’s pollution adds up to eventually impact everyone negatively. We can make an analogy to the impact of individuals’ CO2 footprints resulting from their consumption habits. I am not directly affected by my 100 km car trip to see relatives, use of 10 liters of fuel, and resulting 24 kg of atmospheric CO2. However, if everyone in the region, or world for that matter, makes a similar trip on a daily basis, then everyone is equally negatively affected by the aggregated outcome. The same is true for plastic consumer products accumulating in the Pacific Ocean in the region known as the Great Pacific Garbage Patch. This is another example of Hardin's tragedy of the commons.

The final common resource problem Hardin discusses is human population growth, another controversial topic. He refers to the current prevailing policy as one of laissez-faire sexual reproduction. By this he means that we accept that any couple who wants to have a child is free to do so, regardless of the additional environmental burden each new person places on the Earth's ecosystem. By current numbers, the average carbon footprint per capita globally is 4.5 metric tonnes of GHGs, however this is as much as 15 metric tonnes per capita for those born in North America. Hardin faults welfare states for encouraging reproduction because they sponsor procreation through subsidising the costs of additional children. He argues that left to their devices, poor people would "be unable to care adequately for their children," and therefore would "leave fewer descendants" (Hardin, 1968, p. 1246).

You may wonder how such controversial statements could proliferate in a widely cited scientific publication. Research shows, for example, falling birth rates with rising socio-economic levels. Despite Hardin's worry that individuals will choose to procreate without limit, some political actors now mandate reproduction through central state control, even when pregnant couples may seek to limit their family size. Moreover, as families' and nations' wealth increases, so does consumption, so far with unsustainable production patterns.

Failure to cooperate in using a nonexcludable and finite common pool resource leads to tragedy of the commons. Artist: Jooeun Park.

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Section 3: Hardin’s Solution to the Tragedy of the Commons

Hardin’s analysis of the tragedy of the commons pinpoints individual incentives to overuse a resource, because benefits accrue directly to the individual, while costs are distributed across all members of the population. His analysis is canonical in political science. He argued that a technological solution is out of reach: we do not expect there to be a technical breakthrough in the foreseeable future that eliminates scarcity and the finitude of the natural world. Therefore, solving the tragedy of the commons requires a social solution.

Hardin rules out that we could, or should, rely on individual conscience or morality to provide a social solution. Although it sounds reasonable that individuals can be responsible, he worries that the outcome will be that those who choose to be responsible will pay the price for those who instead choose over-consumption of the commons.

Thomas Hobbes' Leviathan, 17th century social contract theory.

Thus, Hadin puts forward a solution that is familiar in Western political thought, a social contract. Hardin refers to this as “mutual coercion mutually agreed upon.” By this he means that we can all agree that circumstances, specifically the tragedy of the commons, imposes a common necessity that we punish those who overuse common resources. This solution is reminiscent of Thomas Hobbes’ (1588-1697) *Leviathan* (1651). In Hobbes’ analysis, the only way to achieve conditions of mutual harmony, instead of perpetual conflict, is to confer power to an absolute sovereign who will impose the rule of law.

Were it possible to govern access to common pool resources through well-specified property rights, then all the government would have to do is enforce those rights. Hardin notes that assigning property rights has provided a solution in the past. Thus, open common areas were enclosed and shifted from common ownership to private ownership.

Prevailing thinking continues to suggest that private property rights encourage individual responsibility. Applying deductive reasoning, then, if a common pasture is divided into separate land portions, then no single herder would benefit from introducing too much cattle. However, as we have discussed throughout Chapter 4, common pool resources are by definition those that cannot be divided into distinct property allocations. The world’s biodiverse ecosystem, its atmosphere, and its interconnected water systems cannot be subdivided. They are complex, spatially-distributed habitats that together form the global environment.

Mutual enforcement by community watch. Source: Freshidea.

Tragedy of the commons: overcrowding

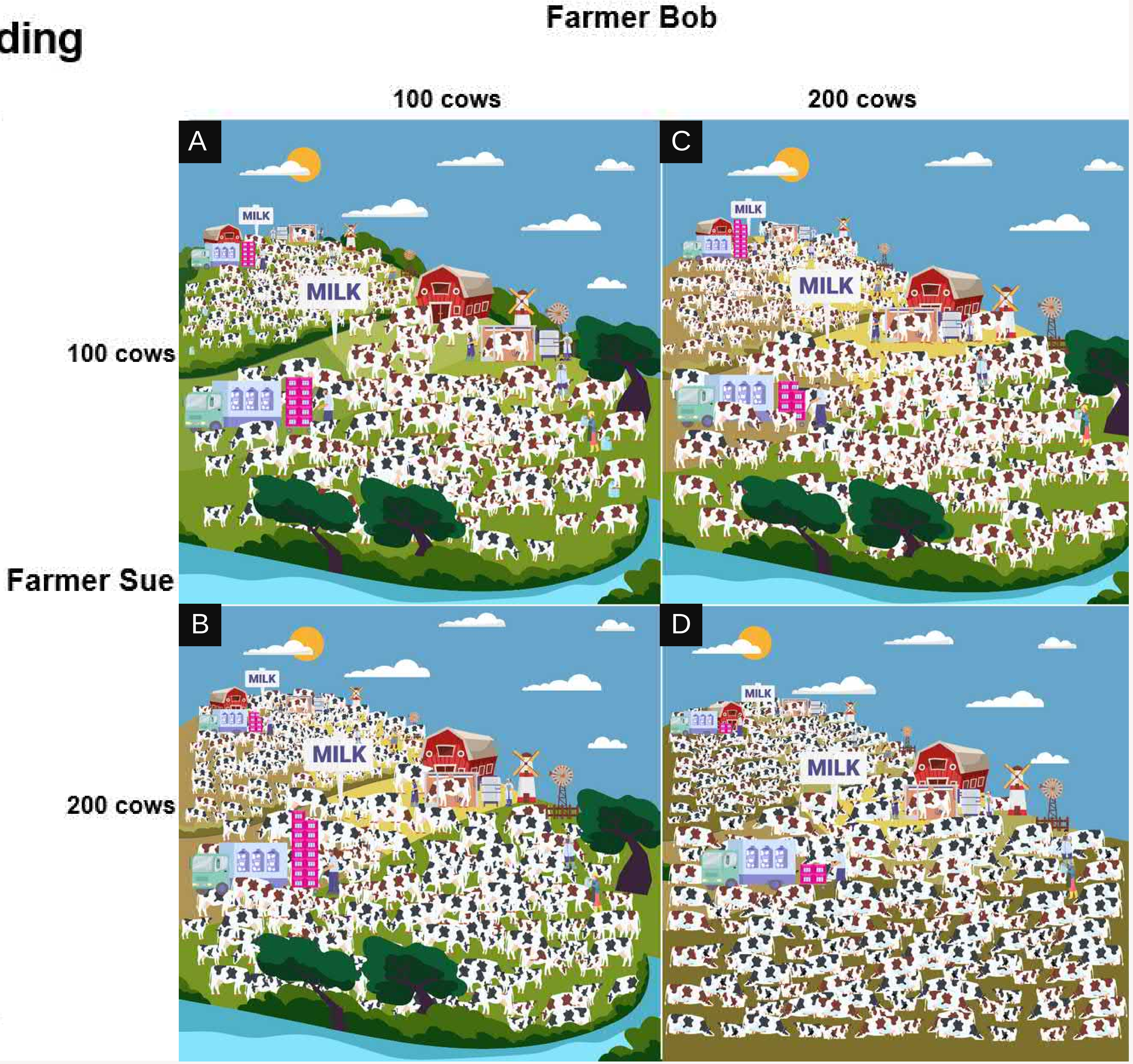
We consider the tragedy of the commons illustrated with increasing dairy cow herds. Here two dairies share a common pasture. Both farmers can choose to have either 100 or 200 cows. In this matrix diagram, there are four possible outcomes: Sue and Bob both have 100 cows (A), Sue has 200 and Bob has 100 (B), Sue has 100 and Bob has 200 (C), and both Sue and Bob have 200 (D).

The diagrams reflect milk production with numbers of pink crates. Sue has black-spotted cows and Bob has brown-spotted cows.

- 200 cows, .1 unit milk/cow = 20 units milk
- 300 cows, .075 unit milk/cow = 22.5 units milk
- 400 cows, .04 unit milk/cow = 16 units milk

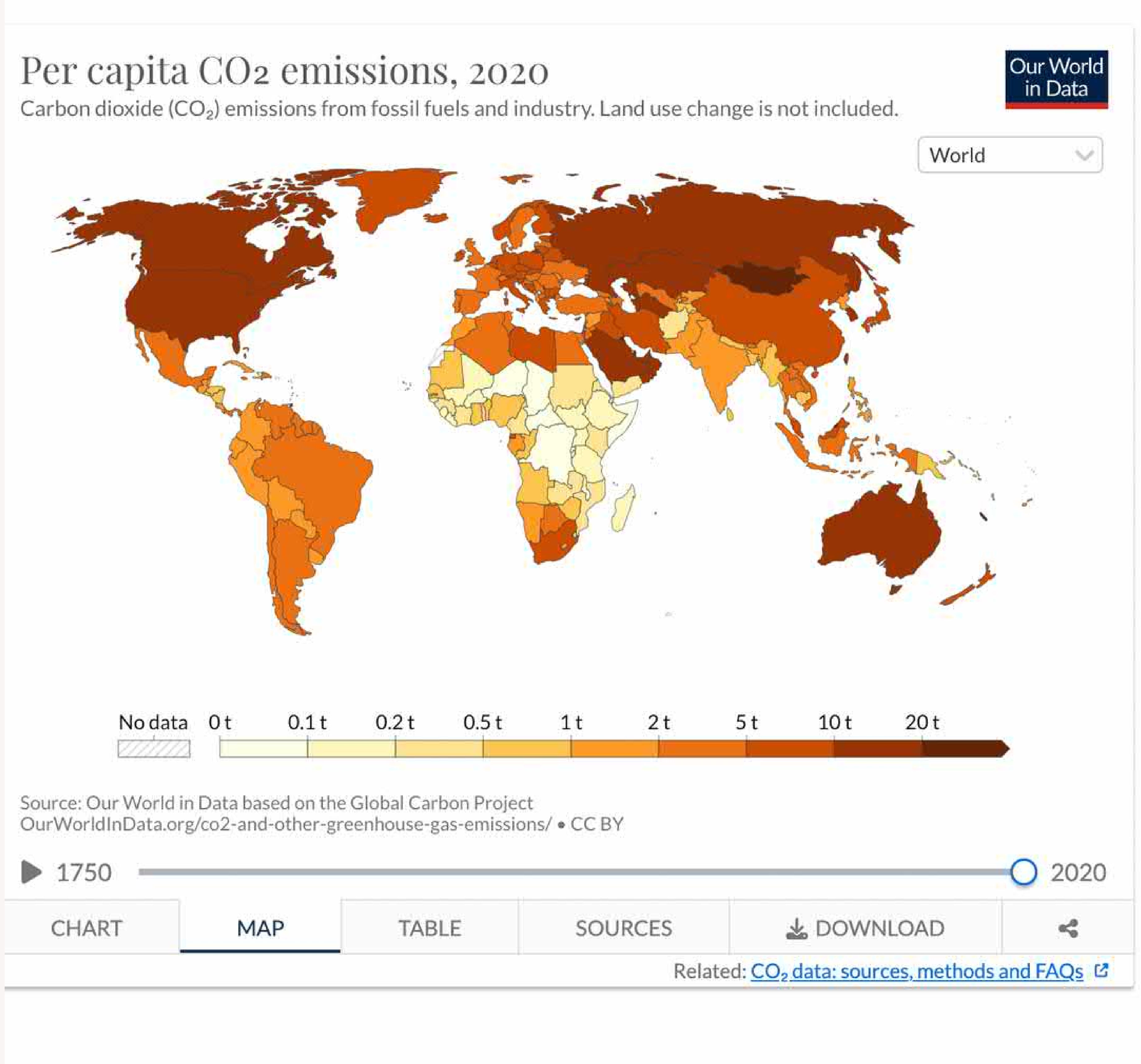
Increasing the cow herd size beyond optimum yield reduces milk productivity. Sue and Bob are in state **A** (top left square), and Sue decides to add 100 cows, increasing her yield to 15 units of milk, leading to state **B**. Now due to the shared decrease in productivity, Bob only gets 7.5 units of milk, and loses profitability. Hence Bob then adds 100 cows to his dairy herd, leading to outcome **D**, with 400 cows. However in D overcrowding leads to poor animal welfare and a lower productivity rate, with both Sue and Bob only obtaining 8 units of milk each. The inverse is true if Bob first decides to add 100 dairy cows to his herd, outcome **C**.

The tragedy of the commons is the outcome of individual choices to maximize gain, leading to collective loss: here due to the overuse of the common pool resource of the shared pasture.



According to Hardin, if each rancher is strictly guided by self-interest, each will decide to introduce a second herd, which will cause less productivity. He argues that tragedy is inevitable, and that the commons will necessarily be overused. However, in actual common pool resource cases, we cannot introduce private property laws. Therefore Hardin argues that our only possible remedy is to introduce an overarching authority with the power to coerce people to abide by environmental limits. Coercive measures are, for example, taxes or fines for over-use.

Hardin most stringently argued that the freedom to reproduce should be limited because he worried that over-population is perhaps the biggest source of stress and pressure to over use common resources. Here Hardin raises a delicate point of social justice. As we have seen, the per capital global carbon foot print is 4.5 metric tonnes/year, while individuals in North America have a carbon foot print of as much as 15 metric tonnes/year.



Source: https://ourworldindata.org/co2-emissions

Along these lines, according to Oxfam, the world's richest 1% of individuals by themselves emit 30x the limit of the 1.5°C CO_2 limit by 2030, while the carbon footprints of the 50% of poorest people remains within this limit. If we are to follow Hardin's advice and accept the need to implement "mutual coercion mutually agreed upon," how would population policies be set for various nations and regions? As well, who would decide how much GHG emissions is permitted by person, nation, or industry?

Source: Chris McAuley, CC BY-SA 2.0 <https://creativecommons.org/licenses/by-sa/2.0/>, via Wikimedia Commons.

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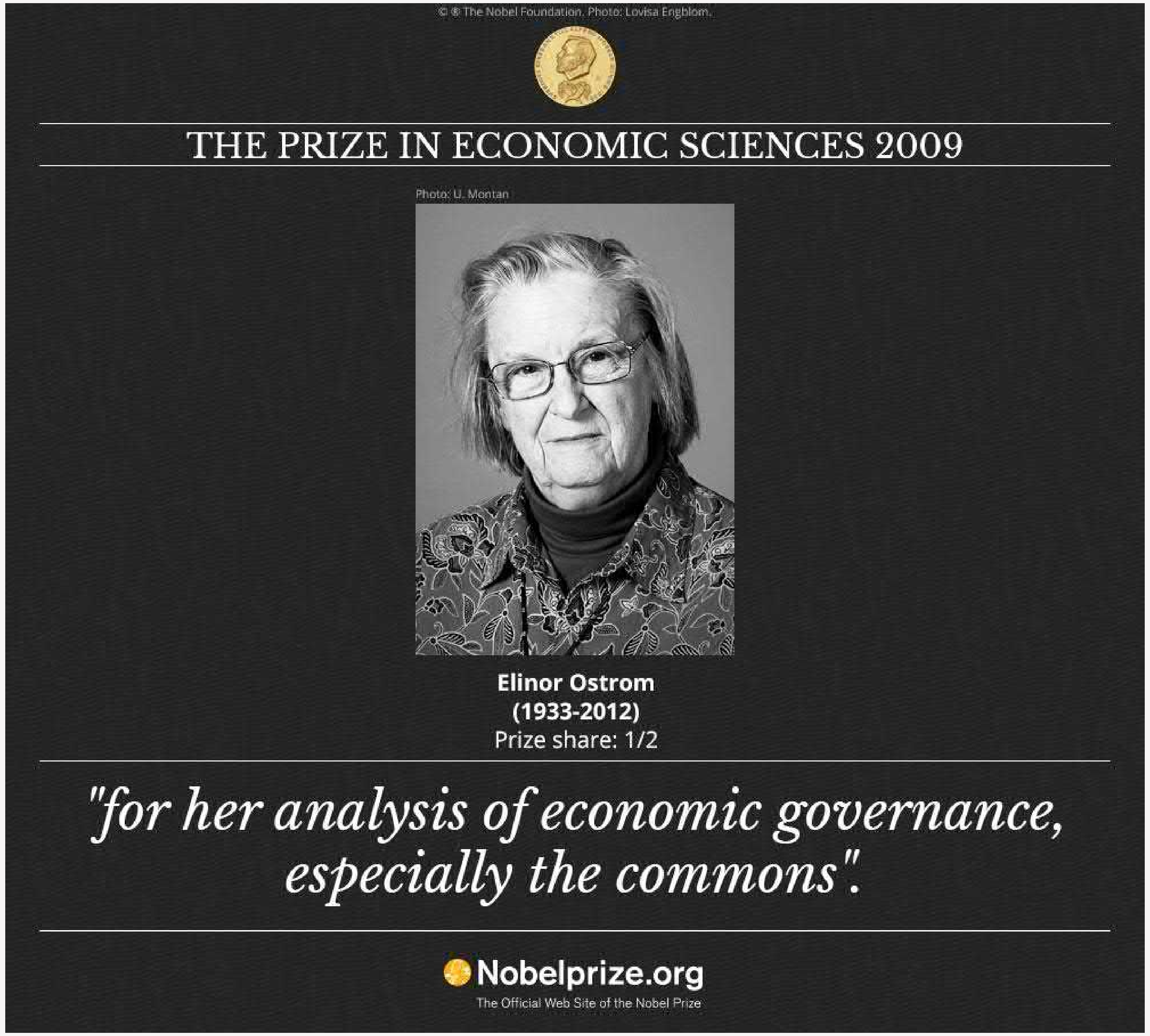
Section 4: Ostrom's Analysis of the Tragedy of the Commons

Elinor Ostrom's (1933-2012) approach to the tragedy of the commons directly responds to Hardin. She devoted her career to developing an alternative vision for how common pool resources can be collectively managed. She was awarded the Nobel Prize in Economic Science in 2009 which recognised her analysis of economic governance, and the role of common property rights.



Ostrom challenged Hardin's argument which was based on deductive reasoning. Hardin's assumptions, or general premises about the world, when put together result in a tragedy of the commons. Ostrom iterates Hardin's assumptions:

1. "Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited." (Hardin, 1968, p. 1244)
2. "Resource supply generates a predictable, finite supply of one type of resource unit in each time period" (Ostrom, 2018, p. 13779), liters of water, or tonnes of fish.
3. "Users are assumed to be short-term profit-maximizing actors who have complete information and are homogeneous in terms of their assets, skills, discount rates and cultural views" (Ostrom, 2018, p. 13779).

These premises, if they are all true, lead to the conclusion that given a common pool resource, each individual's increased use driven by calculated self-interest, necessarily results in the resource's overuse.

Ostrom cites Hardin's analysis of the tragedy of the commons as stark, but influential. The power of his deductive argument has two consequences. It supports a pessimistic and disempowering view of the possibilities of people to self-organise their activities. Yet, it also led to efforts to implement central controls to govern common pool resources.

Ostrom brought fresh analysis to the tragedy of the commons by arguing that people can have different motivations, besides the goal of maximising individual gain. She identifies four types of motivation:

1. Some individuals are narrowly self-interested, do not cooperate, and take advantage by free-riding on others' efforts.
2. Some individuals might cooperate with others, but only if they are fully assured that no one will take advantage of them.
3. Some individuals will begin by trusting others to cooperate, and will continue to cooperate if others do so, but will stop cooperating if others take advantage.
4. Some individuals are altruistic, and are willing to cooperate regardless of others' lack of cooperation.

By opening up the possibility that individuals' have different motivations, Ostrom denied Hardin's premise that actors are necessarily narrowly self-interested. This was sufficient to question his assumption that given finite and non-excludable shared resources, a tragedy of overuse must result.

Image source: https://pxhere.com/en/photo/66326

Tragedy of the commons: overcrowding

We consider the tragedy of the commons illustrated with increasing dairy cow herds. Here two dairies share a common pasture. Both farmers can choose to have either 100 or 200 cows. In this matrix diagram, there are four possible outcomes: Sue and Bob both have 100 cows (A), Sue has 200 and Bob has 100 (B), Sue has 100 and Bob has 200 (C), and both Sue and Bob have 200 (D).

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The tragedy of the commons is the outcome of individual choices to maximize gain, leading to collective loss: here due to the overuse of the common pool resource of the shared pasture.

Farmer Bob

100 cows | 200 cows

Farmer Sue

100 cows

200 cows

Here we revisit Hardin's initial tragedy of the commons: overcrowding. This results in the commons overcrowded and lower productivity.

Hardin's Tragedy of the Commons

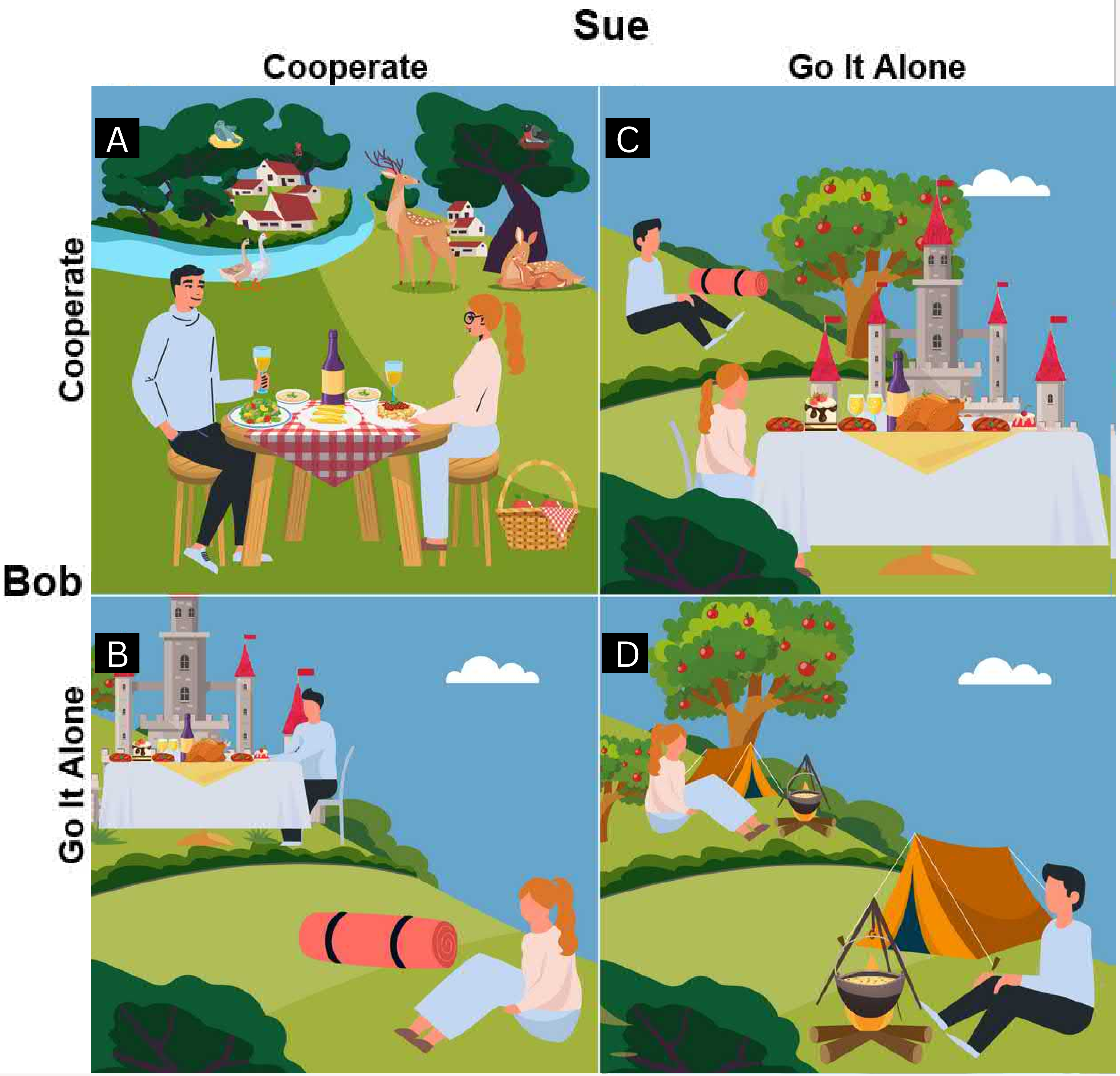
Lifestyle Choices

This image recasts Hardin's tragedy of the commons in terms of one's decision to work together toward a common goal, such as a mutually sustainable lifestyle, or making independent decisions to further individual interest.

If actors cooperate, mutual harmony is achievable (image **A**). However, Bob could be intent to maximize individual wealth regardless of how this impacts others, leaving Sue to live in a tent (**B**). Alternatively, even if Bob is willing to cooperate, Sue could decide to pursue personal gain without considering the consequences for Bob (**C**). In Hardin's tragedy of the commons, all actors prefer pursuit of individual gain, leaving everyone worse off in outcome **D**, here both intend to act alone, and have the meager consolation of having a campfire.

Obviously the illustration is allegorical, however we can think of the various levels of development in nations around the world. In some nations people are very well-off in comparison to those in other nations. However, given current levels of consumption, even wealthier countries feel the impact of climate change.

This depiction of the tragedy of the commons is used in game theory, and is called "Prisoner's Dilemma."



On this page, Hardin's tragedy of the commons is redrawn as tragedy of incompatible lifestyle choices.

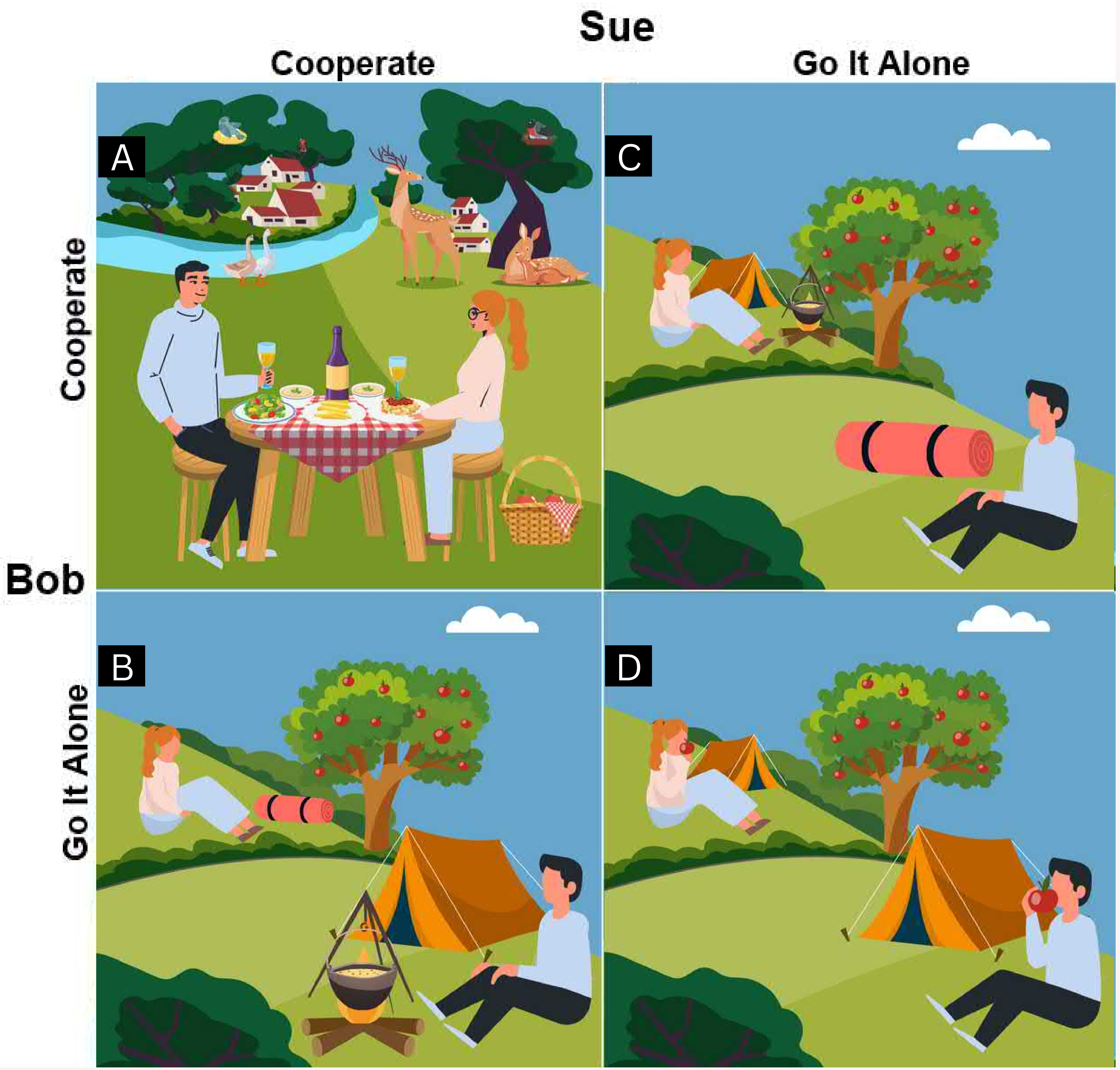
Ostrom's Common Pool Resource Dilemma Lifestyle Choices

Ostrom's analysis of the tragedy of the commons is different from Hardin's. Ostrom agrees with Hardin that given the nonexcludable access to a finite common pool resource, that it could easily be depleted with overuse. Ostrom also agrees with Hardin that individuals could in principle cooperate to achieve a mutually beneficial outcome (image **A**).

Ostrom also agrees with Hardin that given individuals' lack of cooperation (image **D**), that mutually bad outcomes will result.

However, Ostrom argues that at least some individuals decide not to cooperate and instead act alone because they worry that the other actors most prefer to strive for an individually superior outcome (as in Hardin's analysis of the tragedy of the commons in the figure above). Hence she argues that people may decide to act alone in self defense, in a preemptive step to avoid being taken advantage of. This is depicted here in images **B** and **C**. In these images, the actor who acts alone at least has a campfire.

This depiction of the failure to cooperate leading to the tragedy of the commons is described in game theory as a "Stag Hunt," or "assurance game." Actors would prefer to cooperate if assured that others will as well.



This diagram presents Ostrom's alternative interpretation.

In Ostrom’s analysis, the failure to cooperate resulting in a tragic, or mutually poor, outcome is not inevitable. In her empirically backed research, even though some actors may always prefer to act on narrow self-interest, it is just as likely that actors may simply fail to cooperate because they worry about being taken advantage of. These cautious actors will not make an effort to contribute to common goals without being assured that others will as well. Additionally, they worry that their contributions will be shared among many, and that individually they may work hard but receive little.

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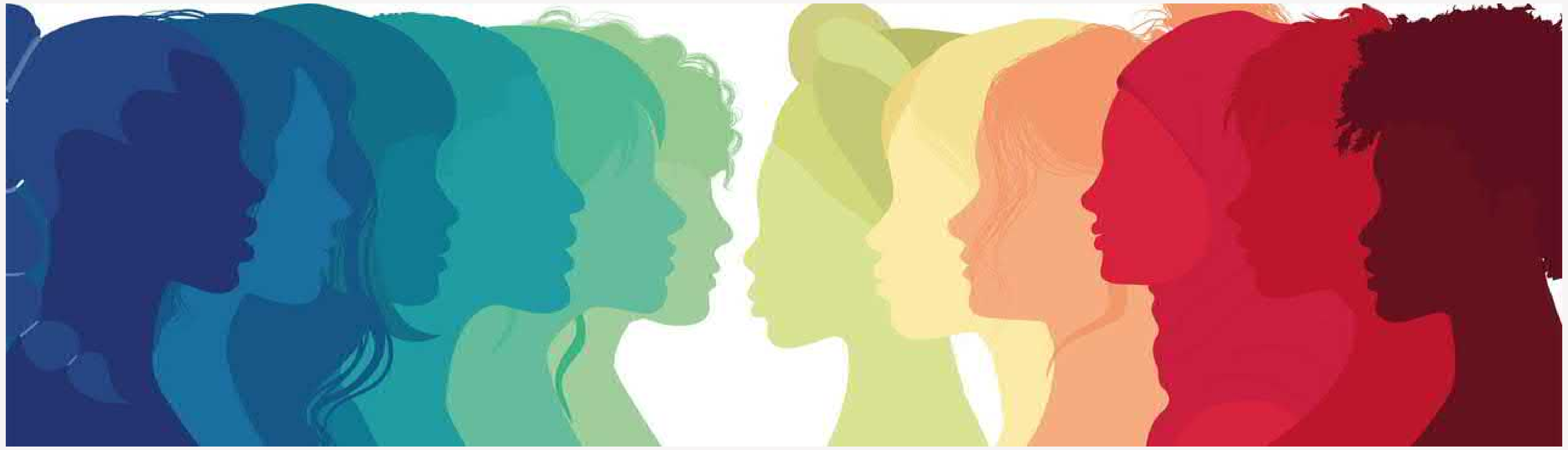
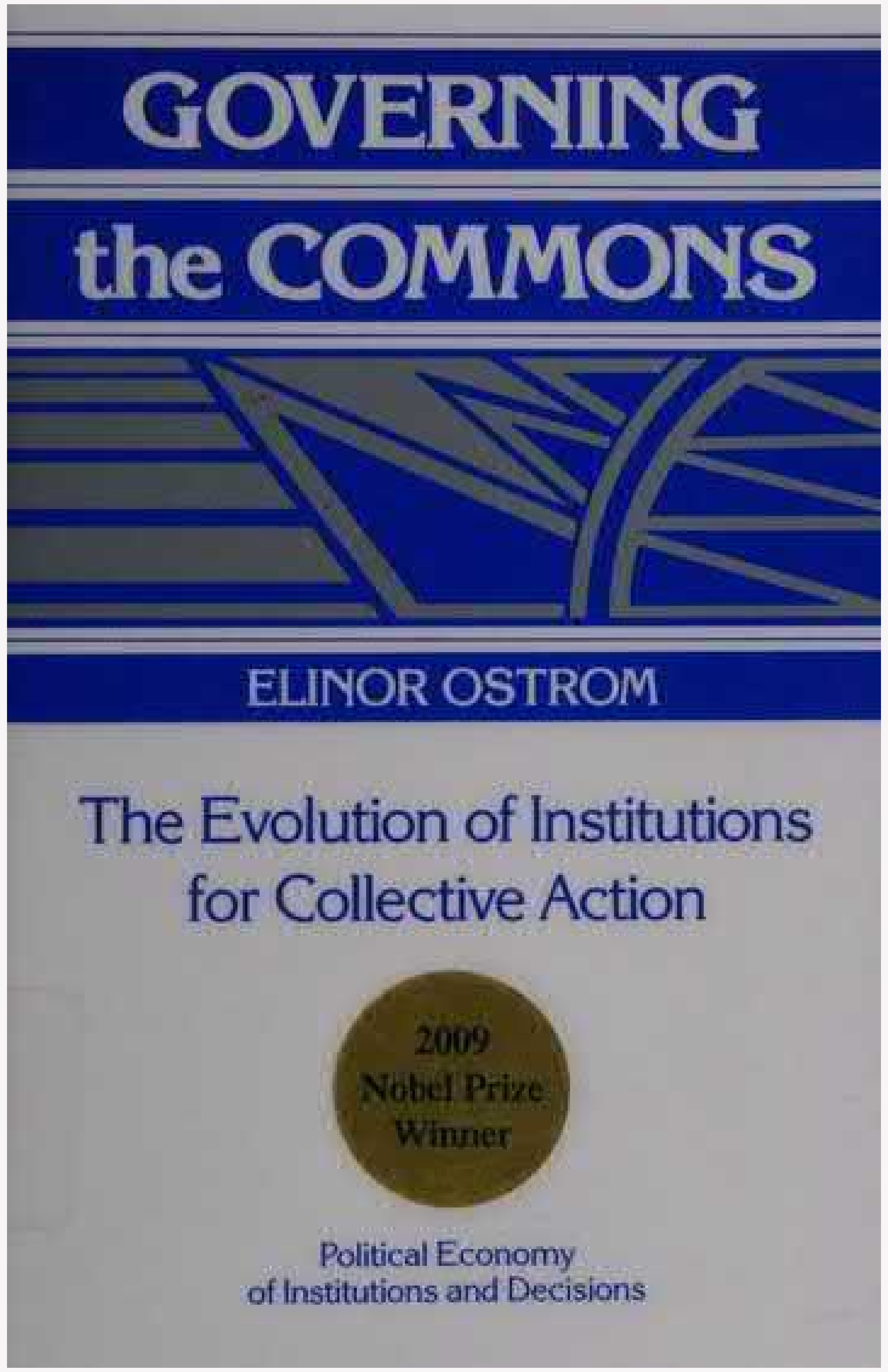
Section 5: Ostrom’s Remedy to the Tragedy of the Commons

Ostrom’s large body of research was effective in countering Hardin’s analysis because she used both deductive argument and empirical research. By studying numerous individual cases of common pool resource use throughout history and in numerous diverse cultures she provided empirical evidence to show that in many circumstances people have worked together collectively to solve common pool resource dilemmas.





Ostrom's book, Governing the Commons.

Ostrom did not argue that no one is narrowly self-interested. Rather she observed that individuals' motives cover a range from being altruistic and open to cooperation, to being afraid of being taken advantage of, or even preferring to act alone. She also used empirical analysis to support her case. One example is of the Mongolian cultural group property norms that served to share common pool resources in a sustainable way (discussed previously in Section 1).

Another example is farmer-managed water irrigation systems in Nepal which are governed by formal and informal rules developed by farmers. In Africa farmers were able to manage common pastures. These examples led her to conclude that in many cases, common pool resources are successfully governed by the communities using them.

Ostrom investigated the conditions under which community management systems for common pool resources are more likely to be successful. She discovered the following characteristics of the types of individuals who successfully manage their common pool resources:

1. They are willing to expend effort and engage in the management process.
2. They will voluntarily obey rules governing the system, as long they believe others will as well.
3. They will check to make sure others are also contributing and cooperating.
4. They will make it costly for others to benefit from common pool resources without contributing.

Therefore in cases matching the figure illustrating Ostrom's analysis of the tragedy of the commons (Chapter 4, Section 4, p. 117), the primary feature is that community members are willing to obey common use rules, so long as they are assured that others will as well. Institutions that can provide that assurance, then, are an important part of the remedy for tragedy of the commons situation.

Ostrom argues that local communities have much better knowledge of their needs, and have evolved local institutions to address the unique challenges characterising local contexts. She makes the case that common ownership of resources has empirically demonstrated effective common pool resource management. One of her recognised achievements is to have identified core design principles of effective common resource governance systems. These design principles are:

Nepalese workers are building an irrigation ditch in Dhanusha District on 18 February 2009. © ILO

1. Clearly defined community boundaries identifying community members.
2. Linkage between resource access rights and cooperative participation.
3. Methods to represent community members' interests, preferences, and opinions.
4. Means of keeping track of community members' contributions.
5. Graduated means of appreciating members' positive contributions, and if necessary disincentivising free riding.
6. Building in conflict-resolution measures.
7. Recognition of community members' freedom to associate and organise to improve resource governance systems.
8. For large-scale common pool resources, building nested layers of governance to accommodate local, regional, and even international institutions and levels of organization relevant to, for example, oceans and atmospheric habitats.

(See Ostrom, *Governing the Commons,* p. 90).

Ostrom's approach shows that community governance of common pool resources has proven historical roots. It provides a verified means of organising property rights that are alternatives to (a) no property rights and free access; (b) private property rights available on an ability to pay basis; and (c) state run property rights under a single authority.

As we will see in the next chapters, the Food Futures App provides a demonstration of a possible means to apply Ostrom's principles to runaway GHG emissions, as well as other collective environmental challenges. It integrates all 8 design principles. Most crucially, it has clearly identified members, and is built on the principle of participatory design.

The distributed ledger blockchain technology powering the app keeps track of community members' participation and provides everyone with data on the collective's contributions.

It has a built-in graduated means to appreciate individuals' contributions. It is designed to operate in numerous local regions, and simultaneously has the means to operate with different levels of governance from small enterprises in smaller localities, to regional, national, and even transnational environments.

The Food Futures App can serve as a tool to realise **polycentric governance**: diverse and overlapping institutions for governance with partial and overlapping authority. It provides a voluntary, opt-in, means to bring accountability to consumption choices that can be integrated into parallel initiatives to reduce harmful collective environmental impact. (See Ostrom Workshop, 2023).

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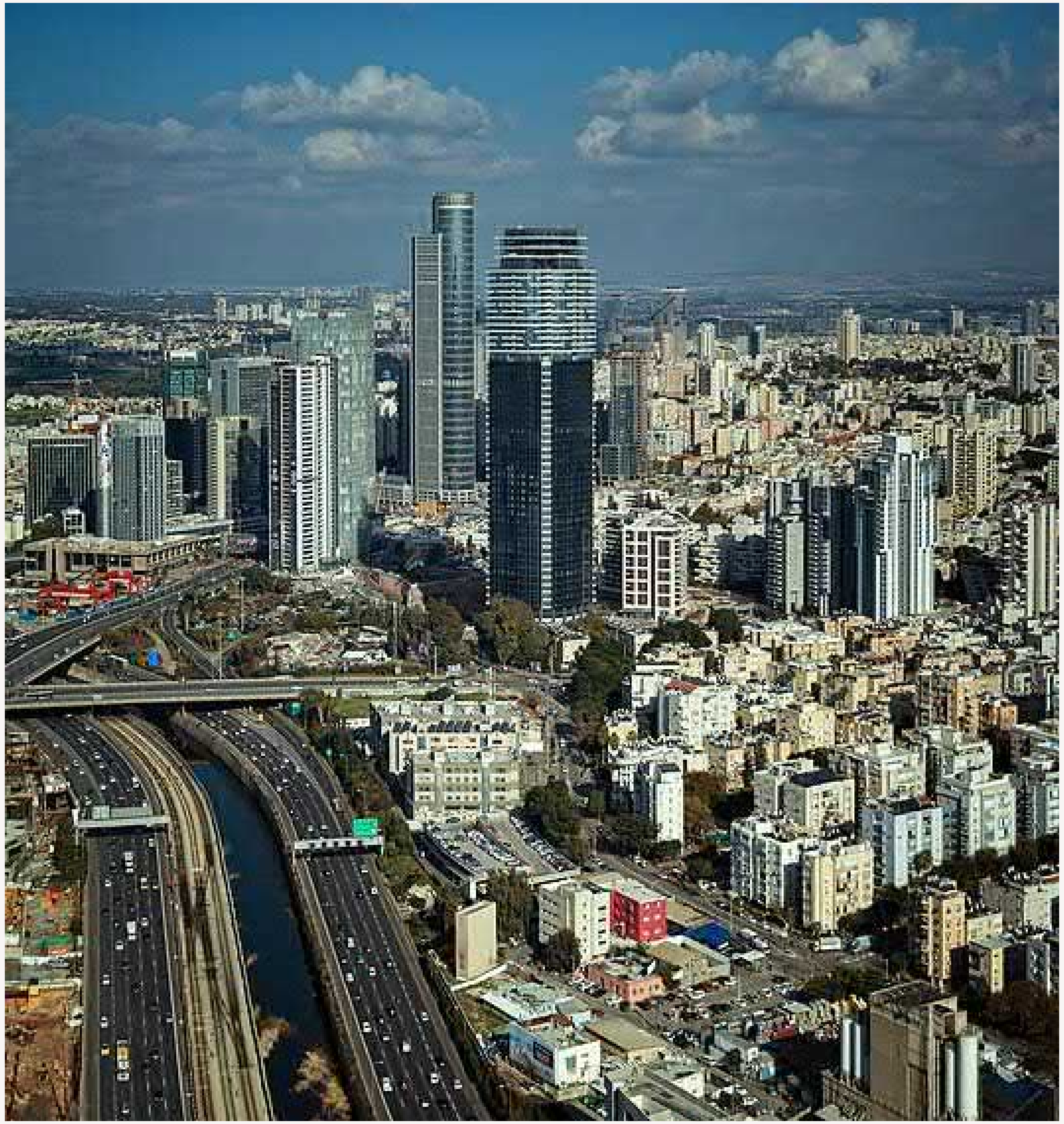
CHAPTER 5
Positive and Negative Externalities

Section 1: Introduction and Overview

Congratulations, you have read half of the material of this book. The second half of this book covers externalities, negligibility, anti-rival value, and blockchain. These topics fit together in order to continue our path toward diagnosing the underlying tragedy of the commons, and becoming part of the solution.

We have discussed the key role that information plays in making good decisions, and the various types of data necessary to build knowledge about our world. Having knowledge of our environmental impact in the form of carbon, material, and water footprints from agriculture enables us to make choices consistent with our values. Understanding the collective impact of individuals' choices further enables us to grasp the aggregated effect of our seemingly insignificant choices.



Chapter 1 explained the history and significance of consumer sovereignty: westerners believe that no one should tell individuals what to do, and that individuals should have a right to freedom of choice. Additionally, we touched on the mainstream belief that the market best serves individuals' interests by balancing supply and demand: what consumers want, producers supply. However, we are aware that consumerism is directly linked to the increasing carbon and material footprints of individuals and nations. Given the relationship between rising greenhouse gas levels and increased surface temperatures on Earth, there is a scientific consensus that we need to achieve net zero carbon emissions by 2050. Finland has agreed to do so by 2035.

Anthropocentric activity. View of Ayalon Highway running through Tel Aviv. Source: https://commons.wikimedia.org/wiki/File:Ayalon_Highway,_Tel_Aviv.jpg

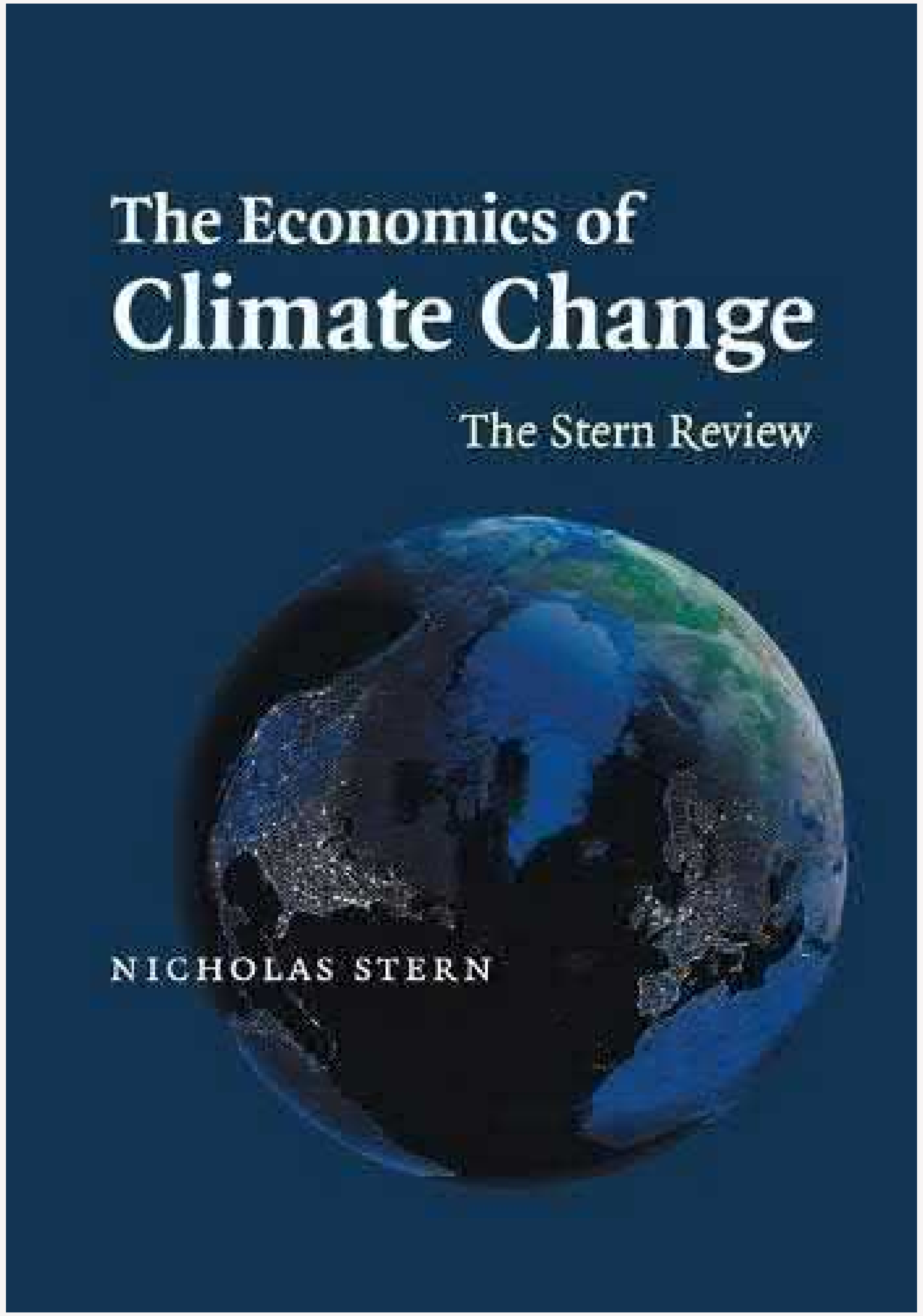
In studying the tragedy of the commons, we discussed how common pool resources are not susceptible to private property rights. The air we breathe, the water we drink, and the common atmosphere and biodiversity are vast liquid and seamless systems. We cannot isolate and own small parts of the Earth's ecosystem. Nevertheless, faith in market solutions continues to characterise approaches to solving environmental problems. Nicholas Stern authored the United Kingdom's report *The Economics of Climate Change* which argued that economic analysis alone makes the case for strictly reducing carbon gas emissions. He argued that reducing carbon gas emissions will bring financial benefits: extra costs now will be exceeded by savings from avoiding climate catastrophes later.

Stern concludes:

> Economics has much to say about assessing and managing the risks of climate change, and about how to design national and international responses for both the reduction of emissions and adaptation to the impacts that we can no longer avoid. If economics is used to design cost-effective policies, then taking action to tackle climate change will enable societies' potential for well-being to increase much faster in the long run than without action; we can be 'green' and grow. Indeed, if we are not 'green', we will eventually undermine growth, however measured.
>
> *The Economics of Climate Change,* 2007, p. 9/662

"Taking action to tackle climate change will enable societies' potential for well-being to increase much faster in the long run than without action."

Chapter 5 builds on our analysis of the tragedy of the environmental commons in Chapter 4. As we know, the increased levels of atmospheric carbon gas are a consequence of human activities. We now dwelve into the specific manner in which markets fail to address the tragedy of the commons. The culprit is “externalities,” or the consequence on others due to exercising freedom of choice. Private property rights define the conditions of market exchange. However, market exchanges and individuals’ consumption can have a much larger impact than simply satisfying consumers’ preferences.



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Section 2: Negative and Positive Externalities

In analysing the tragedy of the commons from an economic perspective, we consider the costs imposed on individuals who are not directly benefiting from the exercise of private property rights. An example of this is the potential negative impact on others caused by tobacco products.

In the case of tobacco, not only does ambient smoke interfere with others' experience of breathing fresh air, it also has negative health consequences. The United States Centers for Disease Control and Prevention (2014) reports that secondhand smoke causes 34,000 cases of premature deaths, and other adverse health consequences for bystanders. As with other cases of economic **externalities**, conflicts can arise between those who choose to smoke, and those who are negatively affected.

Image by: lil artsy. Source: https://www.pexels.com/photo/person-smoking-cigarette-2827798/

We can imagine many situations in which the activities of people around us can make us suffer the consequences. Consider some other examples. Traffic is an obvious case in which either through there being too many cars on the road, or through their exhaust fumes, we can be negatively impacted by other people. Sometimes the location where we live can be affected by another owner's decision to build an extension to their house, which might block our light or view. We can be affected by people's trash, in the form of street litter, household waste, or noxious odours. Noise from others can be a regular sort of nuisance, whether it is from a neighbor's dog, building construction, music, or overly festive parties. Another type of externality might be more hidden. In welfare states with socialised medicine, we may need to bear the costs of others not maintaining healthy lifestyles and hence being more prone to diseases, which must be collectively paid for.

Externalities = displacing costs to others

Environmental degradation can result from unrestricted consequences from individual actors

Particulates from vehicle pollution

Household waste

Noise pollution from neighbours

Air pollution from smokers

Traffic congestion

Impact of additions on family

Litter from tourists

Spillover costs from rising levels of obesity

Source: https://assets.adobe.com/public/dc90939b-14a4-4e16-46e7-bf9728287ea5

Externalities can also be produced on much larger scales by industry. In this case, business operators sell goods and services at a price that customers are willing to pay. However, it can be the case that others, who do not benefit directly from consuming a good or service, pay a price. There are many examples of this type of imposition of costs onto others who are bystanders. We are already aware of agricultural methane emissions from cattle and dairy herds. The externality here is greenhouse gas emissions contributing to climate change. Industrial waste can take many forms, many of which are toxic, and are released into the environment either in the air, the water, in landfills, or simply via abandoned sites. Here bad outcomes can be in the form of elevated cancer levels, such as from dioxins released from bleaching paper products.

Externalities = displacing costs to others

Environmental degradation results from unrestricted consequences

Air pollution from factories

Pollution from fertilisers

elmar gubisch - stock.adobe.com

Industrial waste

Noise pollution

Collapsing fish stocks

Methane emissions

Source: https://assets.adobe.com/public/dc90939b-14a4-4e16-46e7-bf9728287ea5

We discussed depleted fish stocks from overfishing, which relates directly to the tragedy of the commons discussed in Chapter 4. Commercial air traffic can pose a severe noise externality in nearby neighbourhoods to airports. Agricultural production can also have negative consequences on the surrounding environment. This can result from fertiliser products which can contaminate water and eventually seep into ocean water.

The costs imposed on all of the lifeforms on the planet from the emission of greenhouse gasses into the atmosphere is considered to be an externality: users of carbon gas emitting goods and services contribute to the accumulated gasses associated with the Earth's rising surface temperatures.

Economist Nicholas Stern states:

> Economists describe human-induced climate change as an "externality" and the global climate as a "public good". Those who create greenhouse gas emissions as they generate electricity, power their factories, flare off gases, cut down forests, fly in planes, heat their homes or drive their cars do not have to pay for the costs of the climate change that results from their contribution to the accumulation of those gases in the atmosphere.

The Economics of Climate Change, 2007, p. 10/662

There are also **positive externalities**. This occurs when a person's or company's actions positively impact others' welfare, without those others paying for the benefit. The classic example is beekeeping. Another example is how public education can increase the wellbeing of not only those who are educated, but other community members because they live in a more informed society. Democratic nations rely on accessible education to have informed voters.

Public education can increase the wellbeing of other community members because they live in a more informed society.

Negative externalities pose a social problem: others are harmed by actions permitted under the rule of law and free market system. One could think this is a moral problem: wrongdoers should be subject to justice in a court of law. However, due to the advancement of economic reasoning into most realms of life, currently externalities are considered to be an economic problem. We will consider critiques of this mainstream position in Section 5 of Chapter 5.

In order to construct an economic analysis of the costs imposed on others, it is necessary to evaluate those costs in economic terms. As Stern notes: “The externality requires a price for emissions: that is the first task of mitigation policy” (2007, p. 80/662). However, the question arises how can we place a cost, or a price, on the harms done to others? The first step is to identify those who are negatively impacted. Then we assess the nature of the harms. Thirdly, we identify how much it would cost to resolve (by fixing or avoiding) those harms. An example is to identify a cost for additional medical impacts of pollution on a neighbourhood community with specified members. We consider the natural level of disease, and how many extra cases we expect due to the pollution. Then we can ask either (a) how much would it cost to insure the members of the community against this additional risk; (b) how much would it cost to treat the extra instances of disease in those neighbourhoods, (c) or how much would it cost to avoid the problem altogether, by moving people out of toxic areas.

Obviously, in the case of additional metric tonnes of CO2e (carbon dioxide equivalent) gasses, with the global average being 4.5 metric tonnes per person, it is difficult to assess the costs associated with each additional metric tonne. Stern completes this calculation. In setting up his analysis, he observes the following:

> Climate change is an externality that is global in both its causes and consequences. The incremental impact of a tonne of GHG on climate change is independent of where in the world it is emitted (unlike other negative impacts such as air pollution and its cost to public health), because GHGs diffuse in the atmosphere and because local climatic changes depend on the global climate system. While different countries produce different volumes, the marginal damage of an extra unit is independent of whether it comes from the UK or Australia.
>
> *The Economics of Climate Change*, 2007, p. 70/662

Stern points out that we all suffer from excessive greenhouse gas, regardless of its source.

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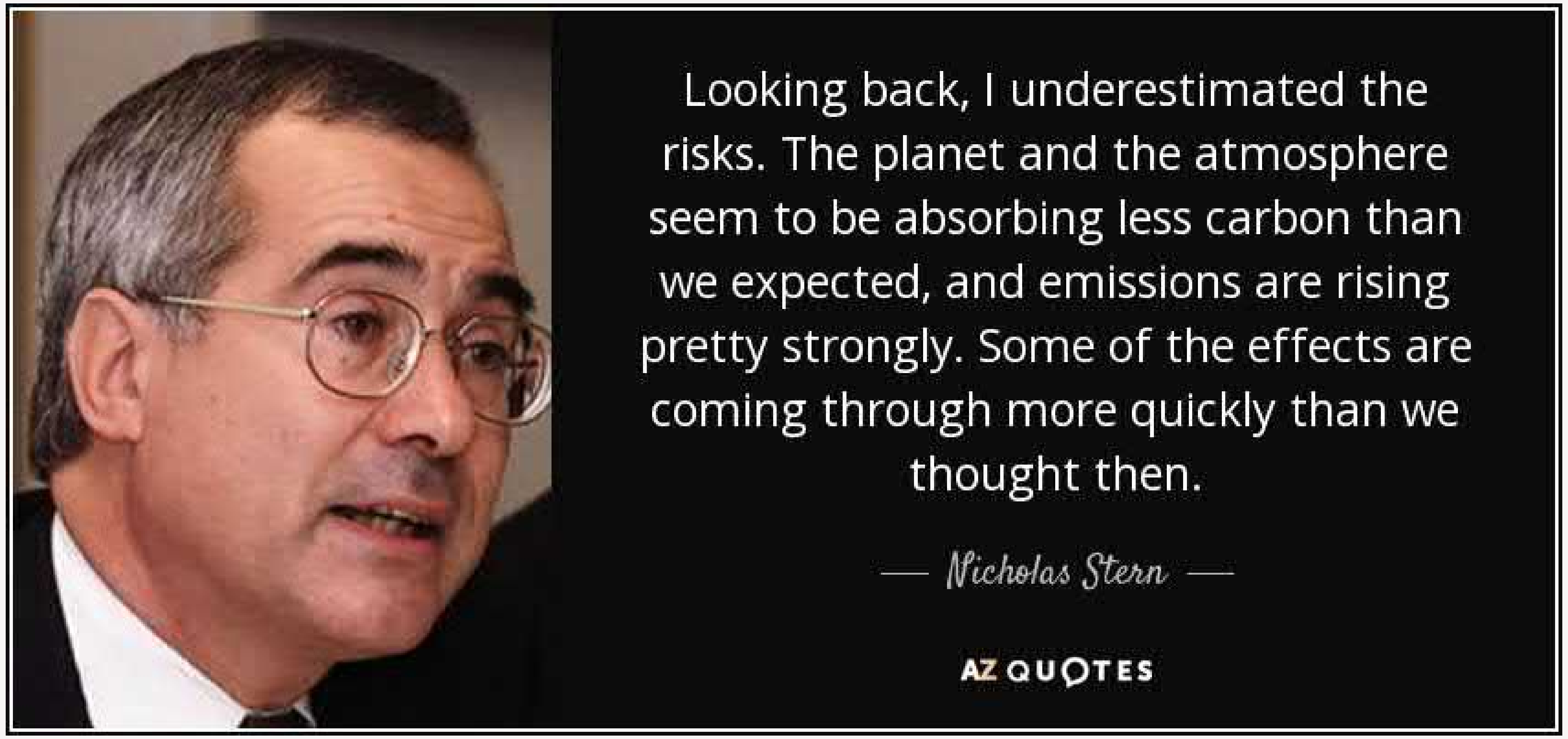
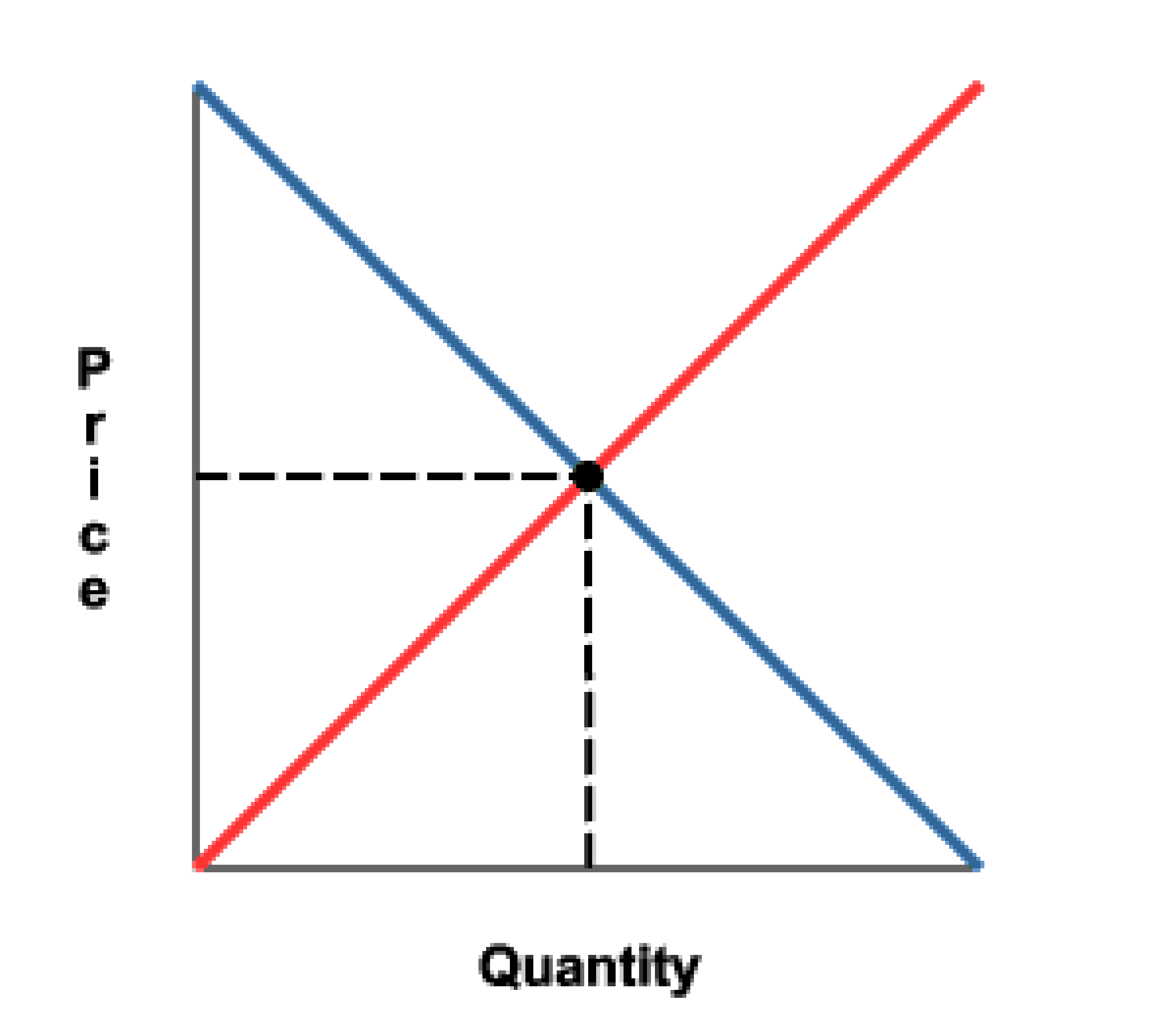
U.S. Department of Health and Human Services (2014) *The Health Consequences of Smoking—50 Years of Progress: A Report of the Surgeon General.* Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health.

Section 3: Market Failures and Tragedy of the Commons

Taking all of the costs into consideration caused by climate change is an enormous task. This is due to the scale of the problem, affecting everyone on Earth, and the vast diversity in different impacts from drought and fire to flooding, proliferations of disease, and malnutrition. The Stern Review calculations range from a lower-bound cost of 25-30 USD/metric tonne, to an upper-bound of 85 USD/metric tonne of CO_2 (*The Economics of Climate Change*, 2007, Box 13.3, p. 349/662). Stern has since said he did not estimate the risks of rising temperatures and associated harms adequately.



Source: https://www.azquotes.com/author/22350-Nicholas_Stern



Source: https://commons.wikimedia.org/wiki/File:Basic_supply_demand.png

Leaving aside the problem of underestimating the costs of the damage from GHG emissions and global warming, the economic analysis of climate change might be considered a **market failure**.

Even though *Sustainable Consumption* is not an economics text, it is important to have a basic understanding of market theory. This helps us to understand the concept of market failures. Recall a basic supply and demand graph indicating that markets balance at the point at which supply meets demand.

At least in principle, starting with the basic supply and demand curve, we can visualise the impact of externalities. Externalities are defined as causing a cost to bystanders who do not themselves produce or consume the product. In the image to the right, we see the new demand curve that incorporates the costs of the negative externalities. However, even though these costs can be captured on the figure, the market will not take them into consideration. We will see in the next section that public policy interventions must be made in order to achieve a market equilibrium that offsets the harms that the free market would otherwise result in.

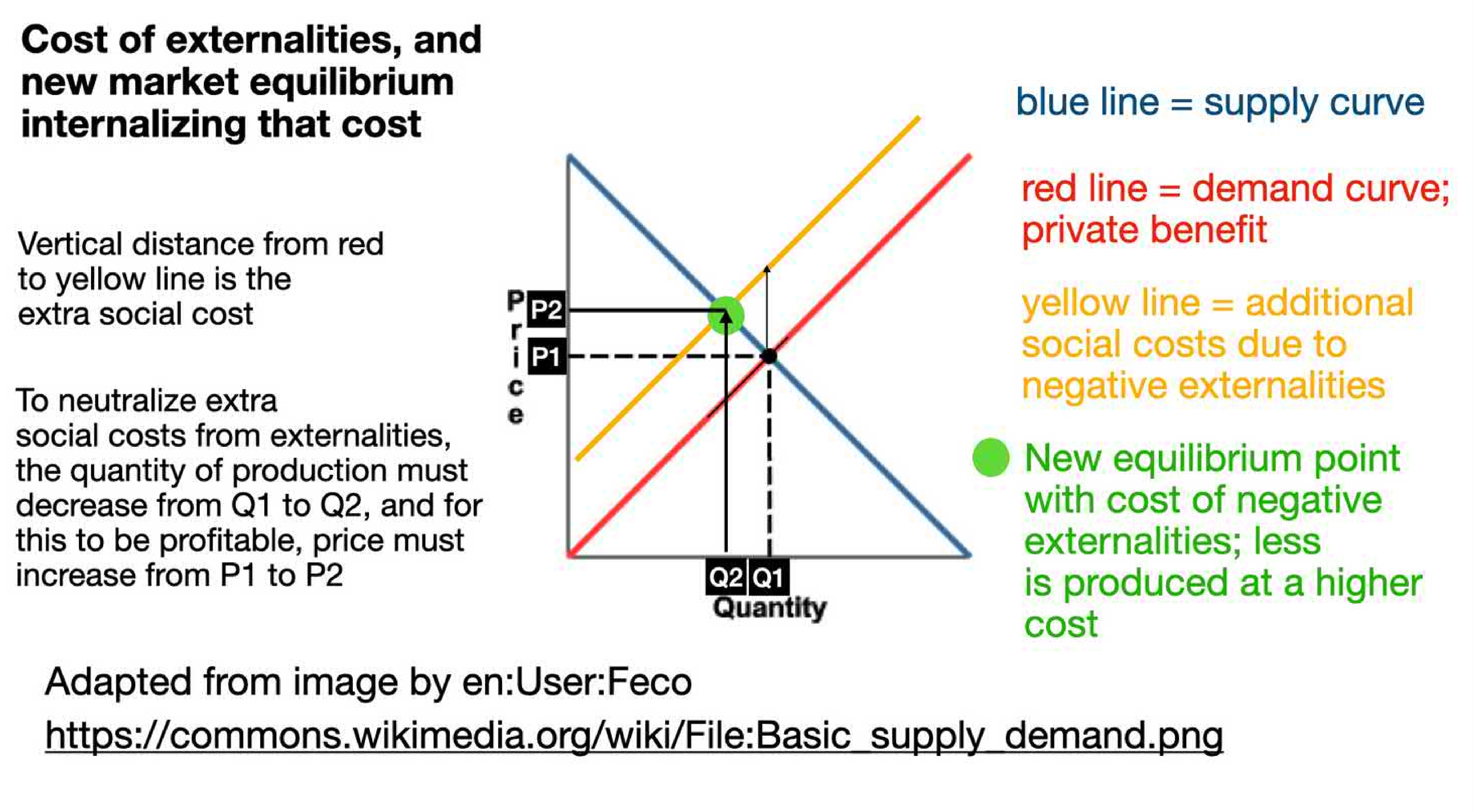
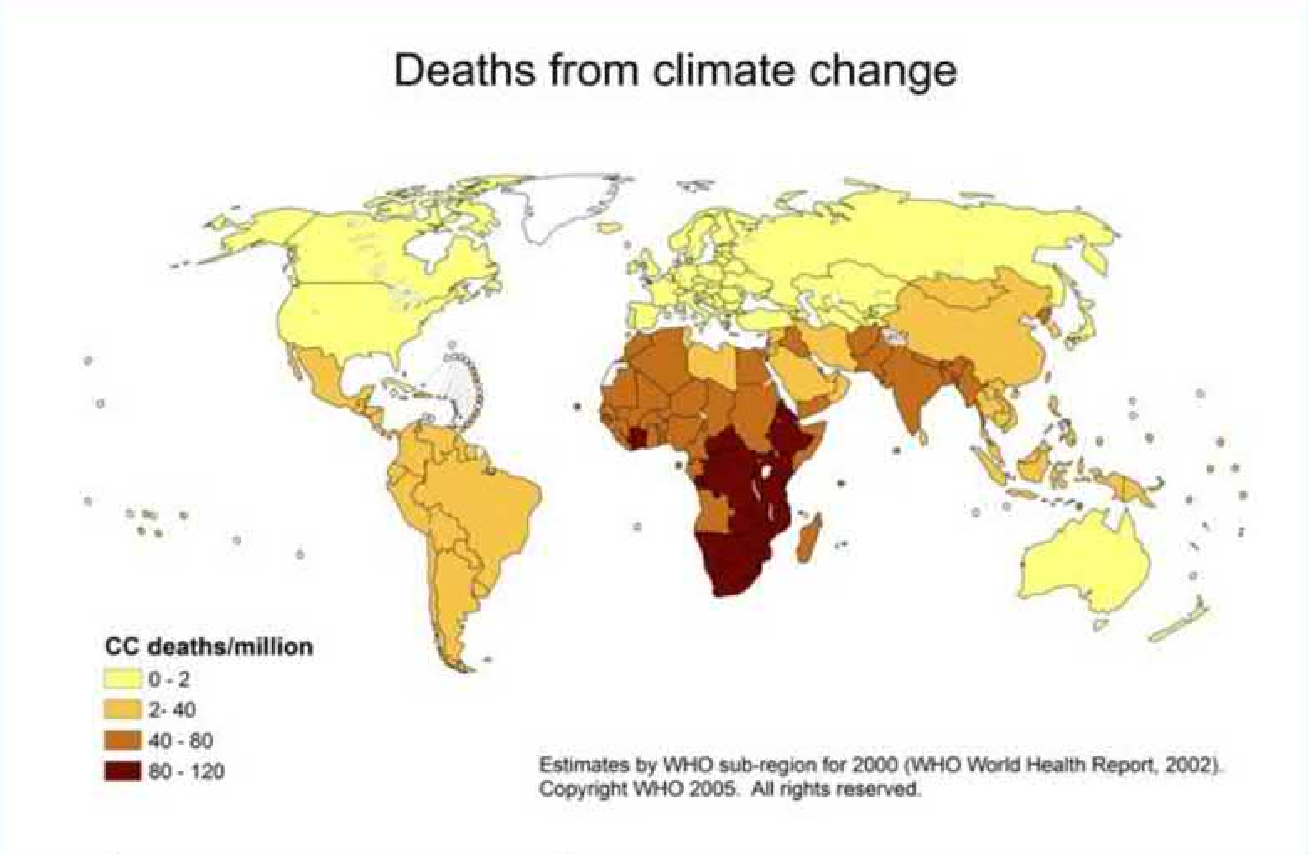


Figure 1. Supply and demand curves with added line showing the additional costs due to the negative impact on others. Market equilibrium, then, is at a higher price with less demand.

Figure 3.8 WHO estimates of extra deaths (per million people) from climate change in 2000



Disease/Illness	Annual Deaths	Climate change component (death / % total)
Diarrhoeal diseases	2.0 million	47,000 / 2%
Malaria	1.1 million	27,000 / 2%
Malnutrition	3.7 million	77,000 / 2%
Cardiovascular disease	17.5 million	Total heat/cold data not provided
HIV/AIDS	2.8 million	No climate change element
Cancer	7.6 million	No climate change element

Source: WHO (2006) based on data from McMichael et al. (2004). The numbers are expected to at least double to 300,000 deaths each year by 2030.

Given the vast number of harms from climate change, the Stern research team covers numerous in the report. On the left is an example of one type of harm, increased deaths due to climate change. The extra deaths are reported in the third column.

The World Health Organization estimates of extra deaths from climate change in 2000, as reported in The Economics of Climate Change*, 2007, p. 120/662.*

This analysis of the costs of externalities depends on an accurate way of pricing them. One of the drawbacks of the way that economists count the costs of harms to others is that they introduce a concept of discounting the cost of future harms. Hence, we also need to consider the cost of avoiding future harms that we would pay in the present. Those who are more worried about the future, possibly because they are younger, may be willing to pay more to avoid bad outcomes. Those who are older may not wish to pay so much because, for example, if they will only live for 10 more years, they may not confront some of the negative consequences of climate change. Research shows that children, specifically in the Global South, may be even more adversely impacted by global warming in the present, as well as experience long term consequences (Gibbons, 2014).

Source: https://pxhere.com/en/photo/1368629

Establishing prices to charge today to offset costs that will be experienced in the future is challenging. Some recommend that wealthier nations finance less developed nations where people are more vulnerable to the effects of climate change (see the Paris Agreement, 2016).

To solve the market failure caused by negative externalities resulting in the tragedy of the commons, economists argue that we must identify a means to achieve the adjusted market equilibrium. This adjusted equilibrium internalises the costs of the externalities, and thus corrects for the market failure.

Establishing prices to charge today to offset costs that will be experienced in the future is challenging.

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United Nations [UN] (2016) The Paris Agreement. Paris: United Nations. Available at: https://unfccc.int/sites/default/files/english_paris_agreement.pdf

Section 4: Proposed Solutions

We have considered estimating the costs of damage to bystanders (that is, everyone on Earth) from the negative externalities of climate change. We consider again the previous analysis that incorporates the extra social costs from negative externalities into the classic economics supply and demand graph. This graph, depicted previously and again on the next page, shows that in order to incorporate the harmful externalities into the cost of products, less of the product must be produced. This corresponds to a higher price for the product. From the economics perspective, then, the question is how to achieve a new equilibrium of supply and demand with the negative externalities included.

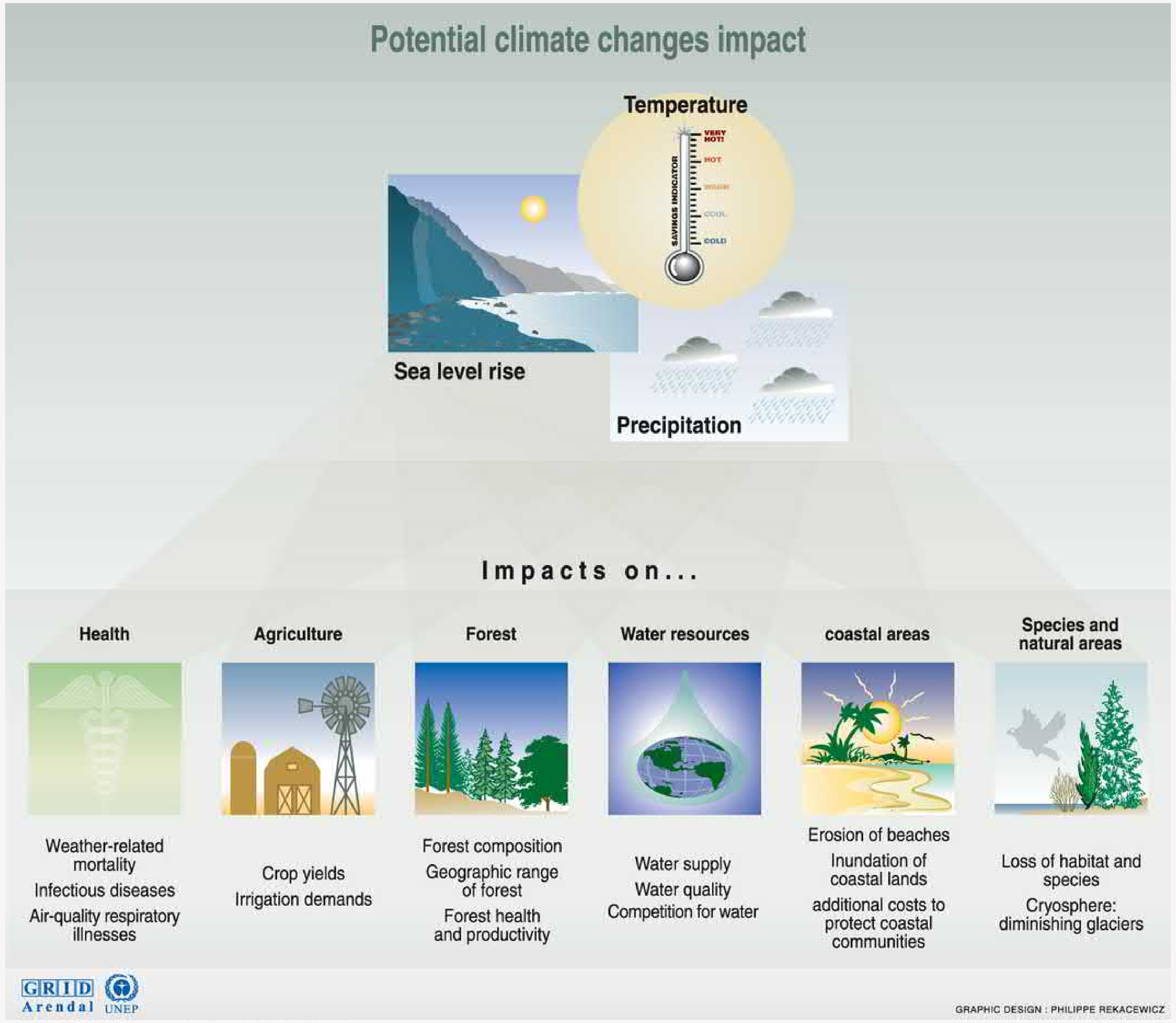
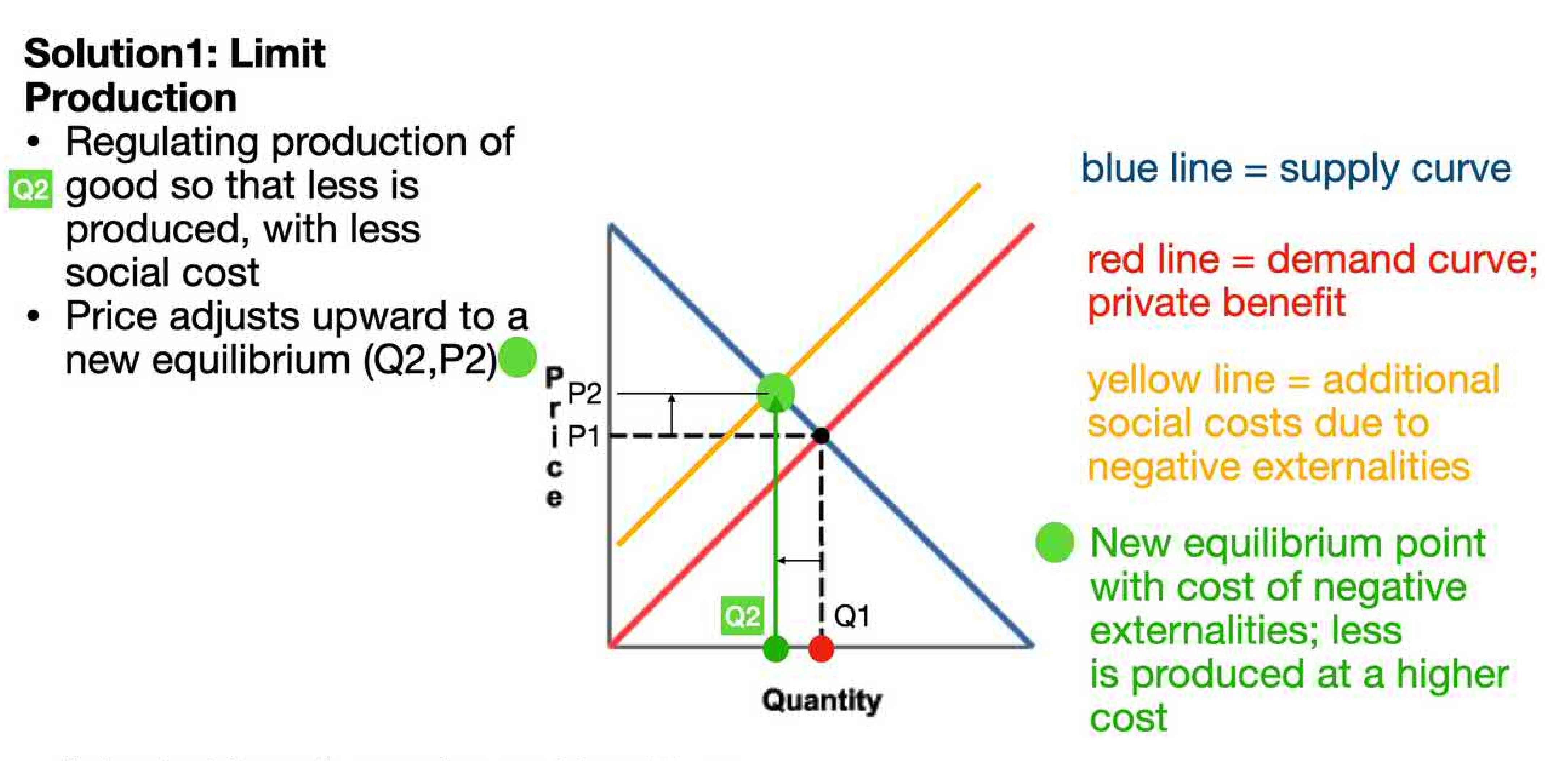


Image showing types of harms that need to be avoided by a solution to the market failure due to negative externalities from carbon gas emissions. Source: www.grida.no/resources/6891



Source: https://commons.wikimedia.org/wiki/File:Basic_supply_demand.png
Adapted by: Jooeun Park.

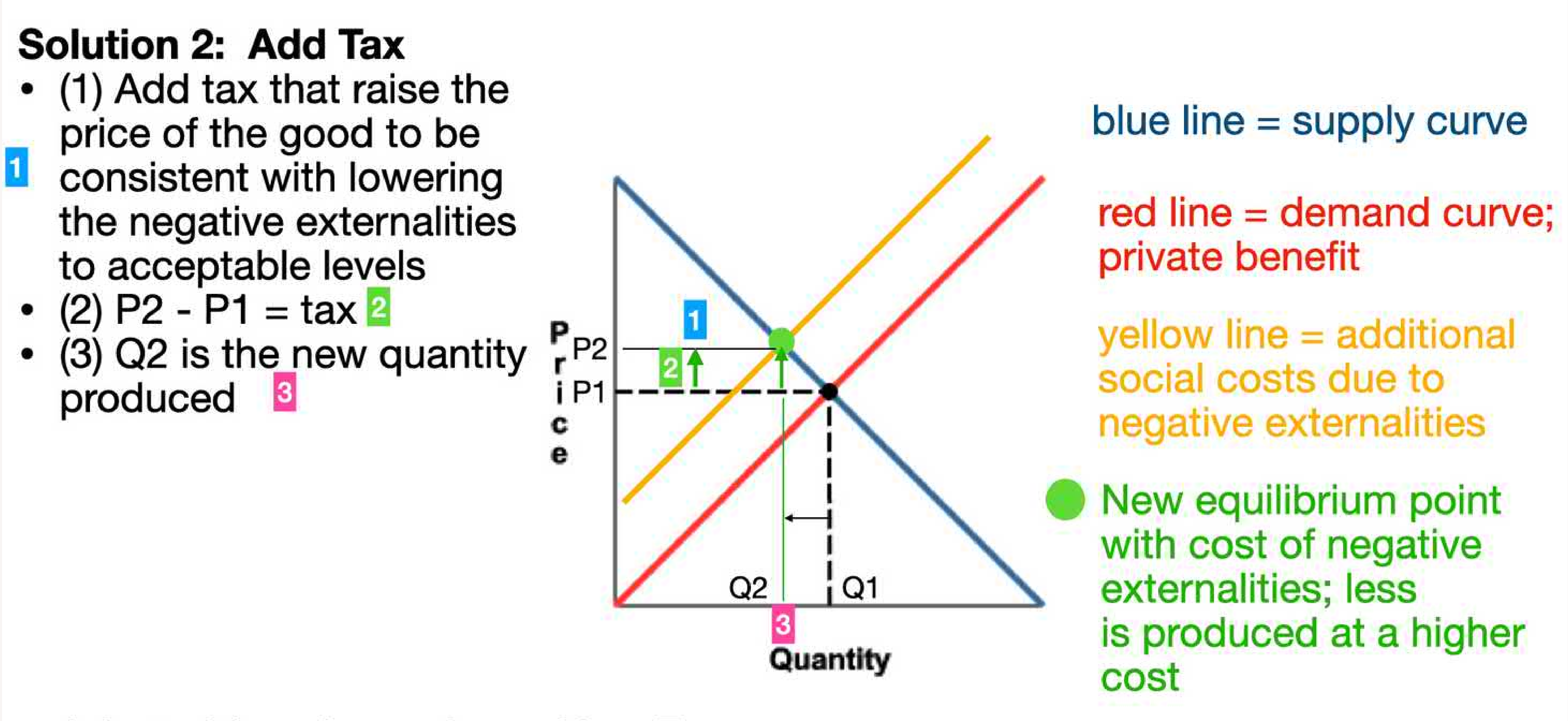
Economists identify two solutions to this type of market failure. The first is a regulatory policy intervention that mandates less production of a good, thus producing less negative externalities. This policy may target the quantity of a good, or instead stipulate that goods that are produced must cause less of the harmful externality. We can see the impact of targeting the quantity of the good in this adaptation of the classic supply and demand graph on the left.

In this graph, the new market equilibrium is created by a regulatory policy that mandates reduced production of a good. This is measured either in units of a good, or the quantity that correlates to the amount of acceptable externalities. With respect to carbon gas emissions, we could think of a stipulation on various industries that they only release a fixed amount of carbon gasses into the atmosphere. Economists have combined this regulatory step by giving industrial actors permits stipulating how much toxic substance (carbon gas emissions) they can release. These permits can be traded by companies. This can encourage leadership in emissions reduction measures: if a company has excess permitted emissions, they can sell their remaining permits to increase their profits.

This system is referred to as “**cap and trade**”: first the total quantity of externalities is capped, and then the limited amounts of externalities allowed in the form of permits may be traded.

Economists propose a second solution in the form of increasing taxes added to the price of the good creating negative externalities. The mechanism by which this operates is evident in the adapted graph on the next page.

In this graph, the added tax which is depicted as P2 – P1, the price in the new equilibrium minus the former price, has the impact of raising the price of a good, and hence reducing the quantity of a good purchased. Economists tend to favour the second approach to addressing the market failures from negative externalities (see Mankiw, 2018). This is because taxes directly impact prices. The first solution attempted to regulate the quantity of externalities produced, but permits trade of the rights to pollute. The added tax still lets markets function to establish the equilibrium of supply and demand.



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Adapted by: Jooeun Park.

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Section 5: Conclusion

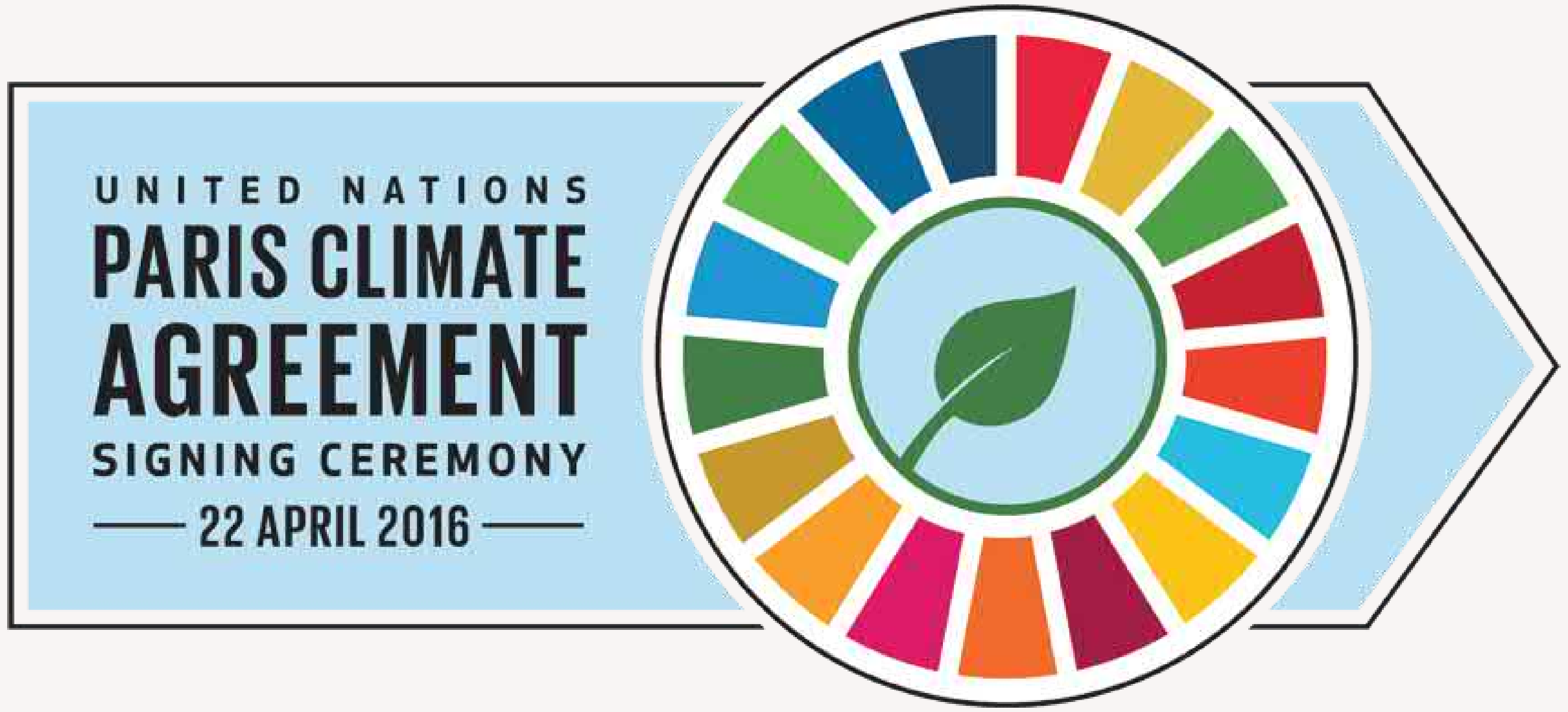
Economists evaluate the tragedy of the commons using the concept of negative externalities. This is when individuals' use of a common pool resource has negative consequences for others. With respect to individual actions, we considered smoking, noise, trash, building extensions, traffic, poor diets and unhealthy lifestyles. Industrial causes include aviation noise, air, land, and water pollution, over-fishing, and methane from agriculture. In each case individuals who do not directly benefit from using a service or consuming a good are harmed. In many cases the harm has no boundaries: pollution affects everyone who comes into contact with the toxic substance. The same goes for noise. With respect to increasing greenhouse gas accumulation, all of Earth’s inhabitants are affected by rising temperatures.

Artist: Jooeun Park.

In order to make a policy recommendation, economists place a cost on the bad outcomes caused by negative externalities. Again, negative externalities represent each increment of harm caused by exploitation of a common pool resource. We have already studied the data required to measure carbon footprints for individuals and nations in Chapter 3. Now, we place a price on the damages caused by the amounts of excessive carbon gasses produced by human activities.

In 2007, Nicholas Stern estimated that the environmental cost for damages from carbon gas emissions ranged from a low of 25-30 USD/metric tonne to a high of 85 USD/metric tonne. These numbers are speculative due to the uncertainties inherent in modelling the impact of increased accumulated CO2e gasses in the atmosphere. It is also not clear that policies actually lessen the harms caused to vulnerable populations.

Consider Finland's goal of reaching carbon neutrality by the year 2035. Recall that the annual per capita carbon footprint in Finland is approximately 8 metric tonnes. With Stern's economic estimate of environmental damage, this would be about 25 EUR x 8 = 200 EUR damage per person for the lower estimate. Alternatively, we can calculate 80 EUR x 8 = 640 EUR of potential harms. Given that even Stern has now accepted that his 2007 report underestimated the bad consequences of climate change, let's accept, for the sake of argument, the higher estimate.



Although economists recommend regulatory interventions mandating reduced quantities of toxic externalities as well as taxes (such as on petrol), these are not widely popular. Voters often prefer political candidates who promise lower taxes. Given the difficulties in achieving consistent national policies, the challenges at international level are even greater.

The economists' analysis of the tragedy of the commons, and their monetary valuation of damages due to the harms caused, remains our contemporary leading means to tackle this type of problem. However, due to the enormity of the global tragedy of the commons related to atmospheric carbon gasses, we can see limitations to the economists' approach. If a common pool resource challenge occurs within one nation, such as industrial pollution impacting one region, then a national approach applying regulation or taxes may work. However, in the international arena, nations must work together to make agreements such as the 2005 Kyoto Protocol and the 2016 Paris Agreement.

Source: https://www.connect4climate.org/infographics/paris-agreement-turning-point-climate-solution

Given the emphasis on freedom to choose and consumers' sovereignty governing our current approach to political economy, achieving the planetary aim of a 1.5°C limit on global warming will require individuals to act consistently with that aim. Presently, it is hard to see how individuals, acting alone, can make any difference to planetary outcomes.

In Chapter 6, we will study the problem of negligibility, or the breakdown of instrumental rationality when one's actions cannot make a perceptible difference to collective outcomes. We also analyse the implications of externalities, whether positive or negative, that do not exclude who they effect. The conceptual blocks we are mastering will help us to construct a comprehensive approach to solving the tragedy of the commons caused by excessive greenhouse gas emissions.

Food for thought: how could individuals make a difference to planetary outcomes?

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CHAPTER 6

Negligibility and Anti-Rival Goods

Section 1: Negligibility

In starting Chapter 6, we are delving straight into our topic of **negligibility**. This word refers to a detail that is almost imperceptible. The Merriam-Webster dictionary defines it as referring to something that is “so small or unimportant or of so little consequence as to warrant little or no attention.” When we analyse the tragedy of the commons resulting in Earth’s rising surface temperature, the negligibility of each of our actions is a key component. Thus, in this chapter we reframe the tragedy of the environmental commons as a problem of negligibility.

We continue to build on the data science concepts we acquired in Chapters 1 and 2, and their application to the carbon, material, and water footprints in Chapter 3. We learned that for agricultural products, these three types of impact are strongly correlated.

Plant protein products have a significantly lower environmental impact on all three registers than animal-protein sources. The costly environmental impact comes from ruminant animals. These are sheep, eaten mainly as lambs in developed countries, and cattle used for beef and dairy products.

Chapter 4 was devoted to analysing the tragedy of the commons. We studied Garrett Hardin's pessimistic analysis that the tragedy results from everyone using a common pool resource regardless of how it impacts others. In economic modeling his analysis is sometimes referred to as a **Prisoner's Dilemma:** each person seeks more for him or herself, while others pay the price. Elinor Ostrom countered Hardin's analysis, arguing that some actors prefer to get more for themselves while others get less. Yet, she pointed out a variety of motives.

These include that some people prefer to cooperate with others to receive the collective benefits, yet may be worried that they will be taken advantage of if others fail to cooperate. This analysis is sometimes referred to as a **Stag Hunt**.

In earlier centuries, common pool resources, such as local water or fishing supplies, were specific to smaller regions and scales. However, globalised commerce has resulted in vast global supply chains flooding well-off consumers with products. The scale of industry is enormous, with sectors having significant impact on the atmosphere given their emissions of carbon gasses. In earlier centuries with local common pastures, overcrowding of herds and their impact on plant life could be readily visible. Now in the 21st century none of us can see the impact of our individual lives on the planetary common atmosphere, or even on our local habitats.

Hence, we focus our attention on the concept of negligibility. We can be immediately aware of the fact that even if one of us were to achieve a carbon neutral lifestyle by 2025, this impact would not be visible on the annual CO2e emissions of Finland. The issue of negligibility relates to a theoretical problem of vagueness involved in identifying when enough tiny parts add up to being a whole entity. The classic example is that of a heap of sand or salt. Not only would it be difficult to count all of the individual particles of sand or salt, it is also difficult to tell when crystals turn into a heap of crystals.

Onslow Salt Stockpile, producing piles of salt. Source: Rob McGregor, CC-BY-3.0 <https://creativecommons.org/licenses/by/3.0/deed.en>, via Wikimedia Commons.

Pile of rocks. Source: Photo by Pixabay.

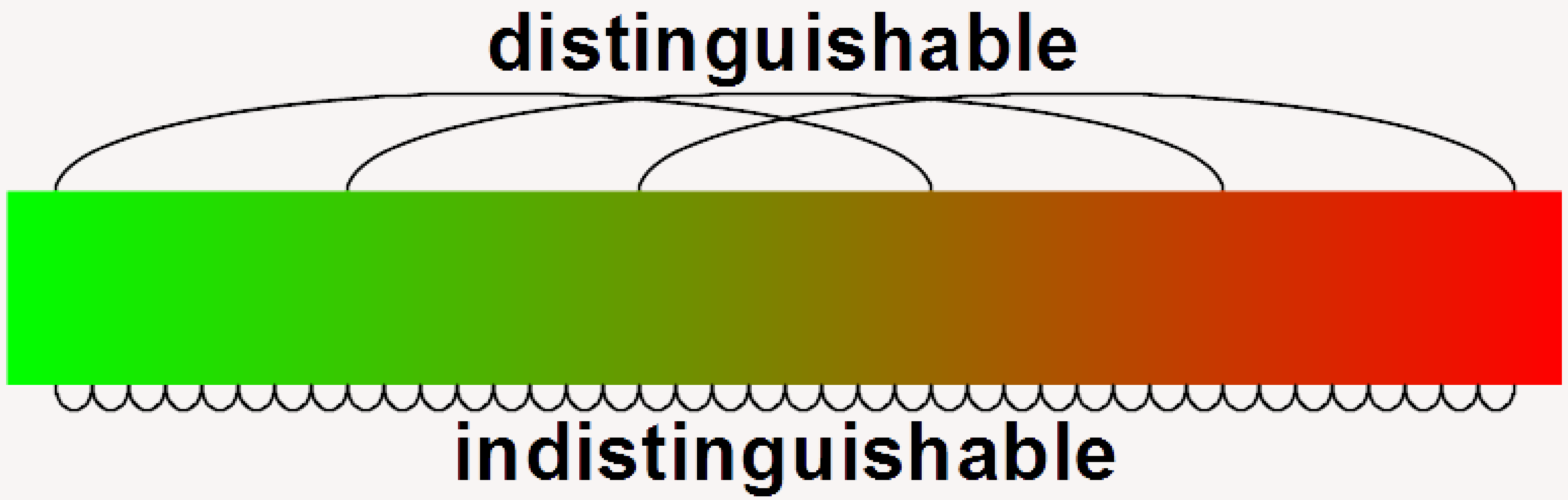
The question of when a number of some tiny particles can be identified as a heap has occupied the attention of philosophers since ancient times. It is called the **"Sorites paradox."** The paradox is that there is no clear way to define when a number of grains, or bits, added together results in a recognizable and definitive pile. Despite this, we are all familiar with piles.

The logical paradox, attributed to the Greek philosopher Miletus, can be stated as follows (quoted from the Wikipedia article on the Sorites paradox):

> **Premise 1:**
> **1,000,000 grains of sand is a heap of sand.**
>
> **Premise 2:**
> **A heap of sand minus one grain is still a heap.**

No matter how many grains of sand there are in a heap, a heap minus one grain is still a heap. Eventually, after 999,999 grains are removed from the heap, the argument concludes that one grain of sand is still a heap. This logical puzzle applies to the application of many common concepts: old, young, tall, rich, red, and bald are examples. One way to resolve the puzzle is to define a strict threshold so that, for example, 500,000 grains of sand is a heap, but not 499,900. Obviously this is not a practical solution because counting grains is difficult. We could stipulate a given weight or height for a threshold, but even so this would merely be an arbitrary definition. Yet, this wouldn't solve the problem, because weight must have a margin of error, such as 0.001 kilogram. If a pile is still a pile if it is missing 0.001 kg, then we are back to not being able to actually define the threshold making a pile.

Contemporary thinking in science and philosophy has developed a solution to this paradox by inventing a non-binary approach to whether concepts applied to the world can said to be true or false. Instead of thinking there is a clear answer to when a number of sand grains becomes a heap, we can instead think of a continuum. Here a continuum is displayed using a color scale that starts out as vivid green and gradually transforms into vivid orange. The idea is that we can define a transitional scale.



Color gradient from green to red, any adjacent colors being indistinguishable for the human eye. Source: https://en.wikipedia.org/wiki/Sorites_paradox#/media/File:Color_gradient_illustrating_a_sorites_paradox_with_labels.png

We use the Sorites paradox because it directly relates to the tragedy of the commons resulting from runaway carbon gas emissions. After which kilogram of carbon gas emitted does a crisis arise? Given global efforts toward GHG emissions abatement, after which kilogram (or even metric tonne) of CO2e is the climate crisis resolved? Like with a pile of sand grains, no individual grain’s removal will alter the fact that a pile of sand exists. Similarly, even if one of us stopped emitting any CO2e gas into the Earth’s atmosphere for the foreseeable future, it would make no difference. Therefore, analogous to the role of the individual crystals or grains, no single individual (short of possibly the top fractional percentage of the Earth’s wealthiest and most powerful individuals) can make a difference to global warming and the climate crisis.

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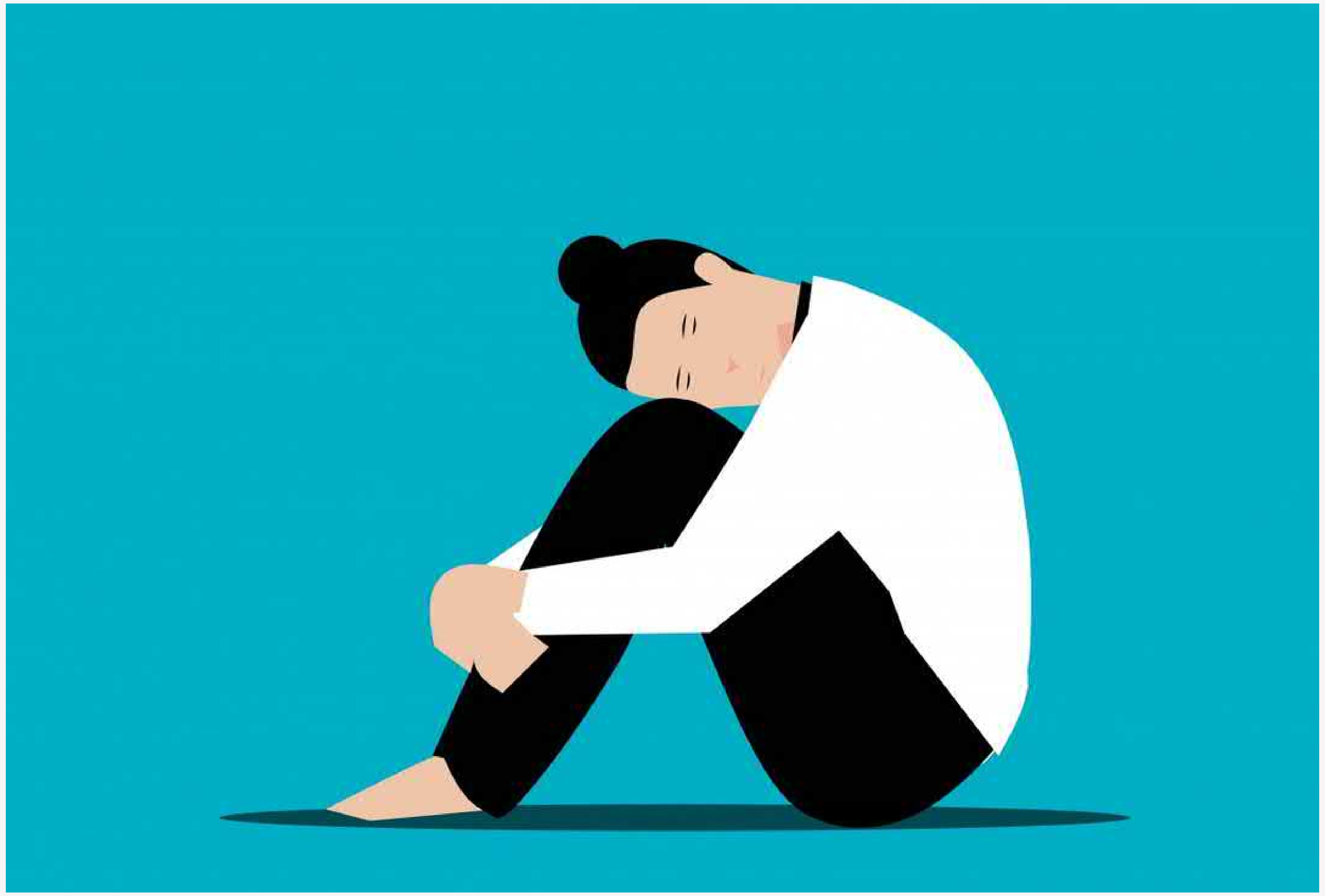
Section 2: Negligibility and the Tragedy of the Commons

The Sorites paradox applied to global warming captures the anxiety many of us may feel with respect to our individual roles in releasing CO2 gasses into the atmosphere. Even if each of us were to seek to make a difference with all of our activities, it is hard to see how any of us can make a difference. The truth is, individually, none of us can make a difference. And yet we see our collective impact in the daily news headlines addressing the impending climate crisis, and the dire need to reduce global CO2 emissions.



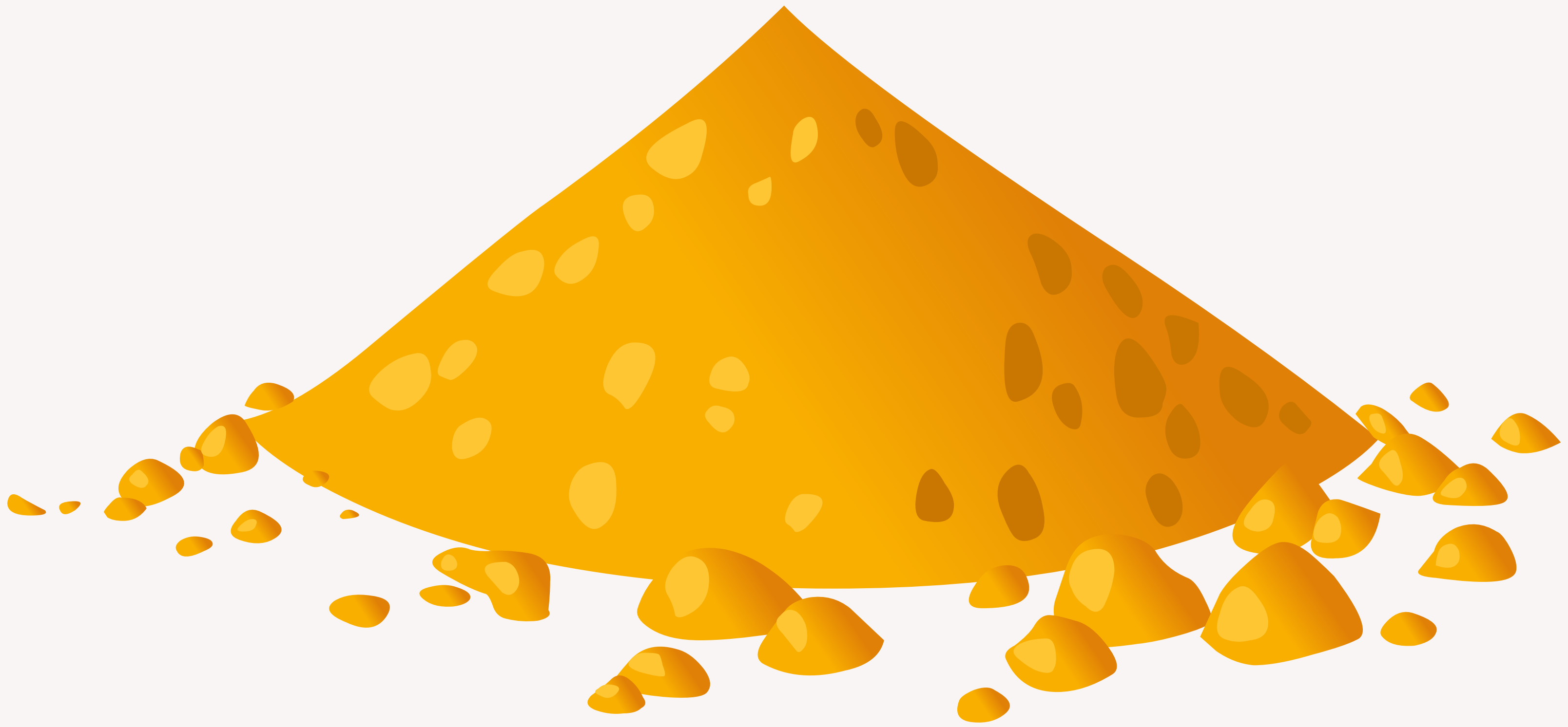
Source: https://pxhere.com/en/photo/1639768.

Political scientist Richard Tuck analysed the Sorites paradox in relationship to collective action failures like the tragedy of the commons. His argument counters the widespread belief that collective action typically fails because individuals prefer a free ride on others' efforts. Recalling Chapter 4, Garrett Hardin argued that every person seeks to maximise personal gain, even knowing the bad consequences for others. Hardin's initial version of the tragedy of the commons occurs in an intimate pasture in which even few ranchers can add too many animals to their herd. In these cases a person's impact on others is noticeable, even if small when divided among several others.

By contrast, Elinor Ostrom argued that people have many motives. People may be narrowly self-interested, with no concern for others. Research corroborates that many people would like to cooperate in joint ventures, when assured of others' cooperation. Other people are openly altruistic, and hopeful to set a cooperative example for others to follow. However, what if the common resource dilemma is on a planetary scale? In this case we must confront the fact that no one of us alone can make a difference.

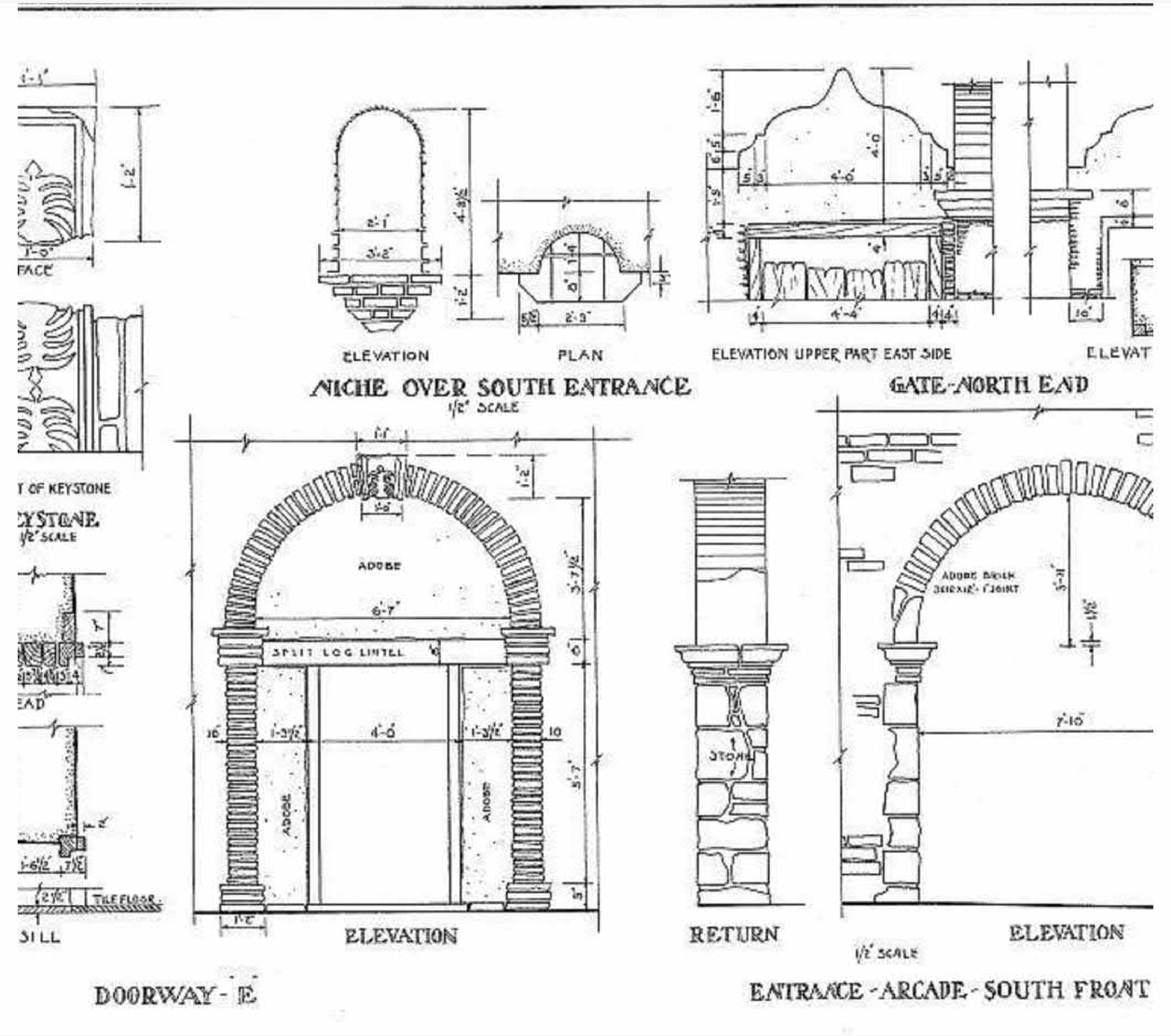
In this case, each of our individual efforts is like a grain of sand in a large pile, or even a sand dune. We cannot be motivated by the knowledge that we can make a perceptible difference acting alone. That assumption that we can change the climate crisis would be false. Thus, we must consider an additional reason that people may fail to make sustainable choices consistent with a 1.5°C lifestyle. Everyone acknowledges the global tragedy of the commons is much greater than any individual's ability to make a difference.

We are now ready to combine the concepts of the tragedy of the commons, externalities in the form of harms to bystanders, and also the negligibility of our contributions. Whether we act in a sustainable way, or in an unsustainable way, by increasing or decreasing our carbon footprints, the impact of each of our actions cannot be perceived on the global scale. We cannot mitigate the impending climate crisis.



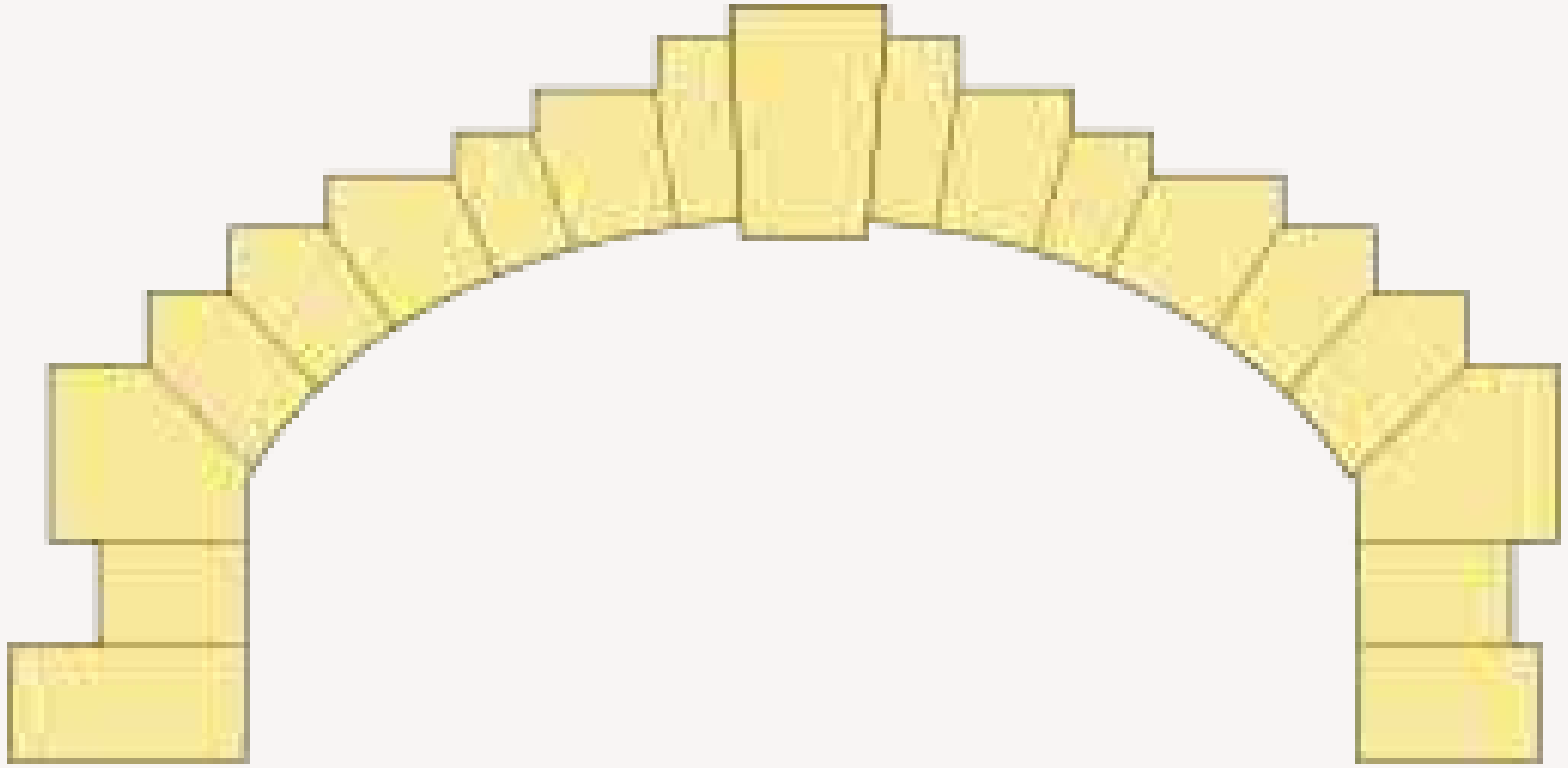
However, we have the tools to systematically analyse our current dilemma. Having grasped the concept of negligibility, we can shift our focus from a tragedy arising from individual self-interest to that of being rationally overwhelmed by the magnitude of our present common pool resource crisis. We need to contemplate how to accept the imperceptibility of individual contributions, yet recognise that, as with a pile of sand, when aggregated, individuals' actions do in fact matter.

One way to move forward is to consider how even in very large structures, individual parts can play an important role in maintaining structural integrity. Let's start by considering a Roman arch built of large and countable stones.



Mission San Juan Capistrano, Olive Street, between U.S. Highway 101 & Main Street, San Juan Capistrano, Orange County, CA.
Source: https://picryl.com/media/mission-san-juan-capistrano-olive-street-between-us-highway-101-and-main-street-39

We are all familiar with Roman arches because they continue to be used in architecture as a means to provide structural support for ceilings and roofs. We can conceive of an archway structure with few support stones, as below, or many as seen in other images.

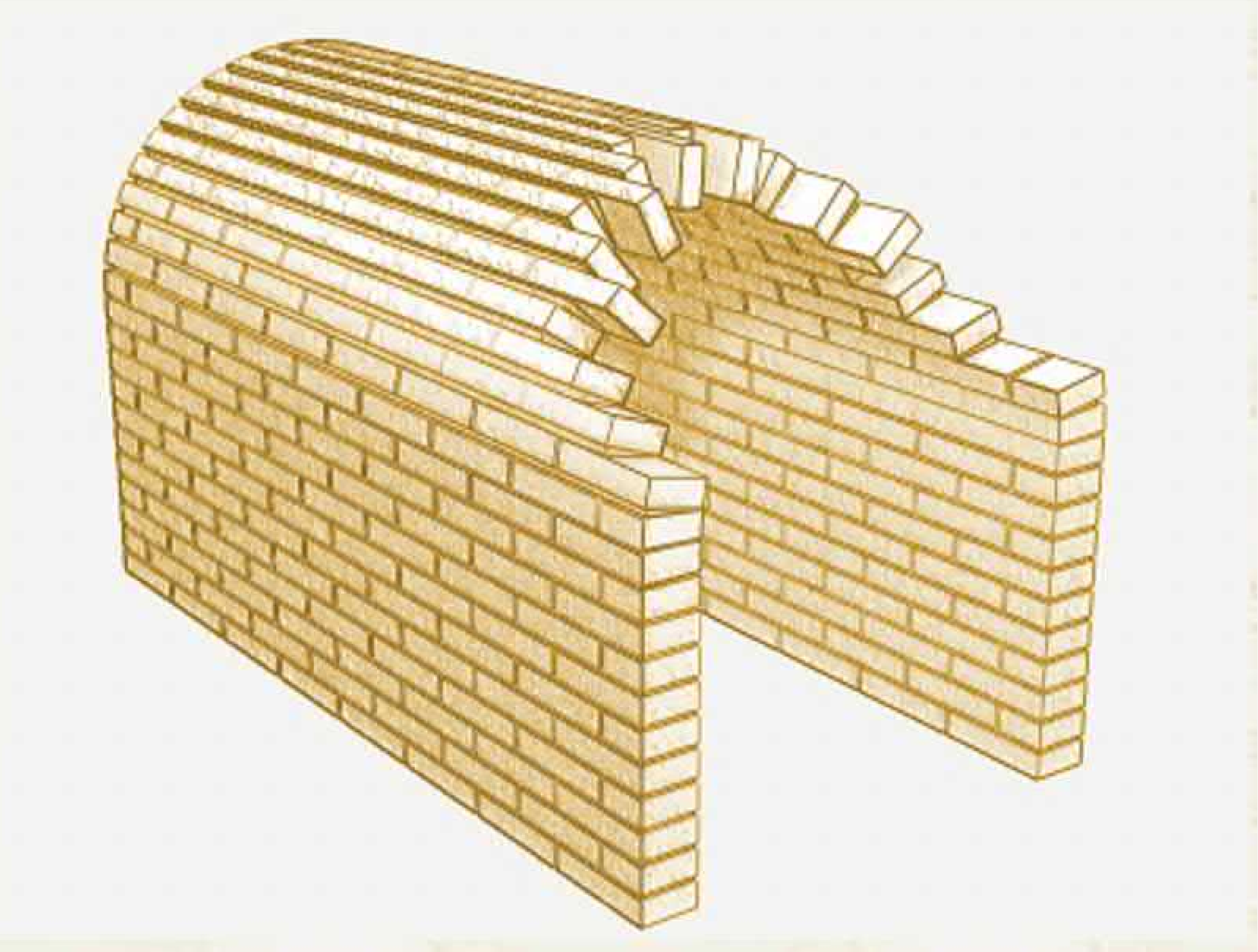


Source: Roulex 45, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons.

The structure is made up of 19 stones, each one looks fundamental to its physical structure. If any one stone were removed, the whole structure would become unstable. Even though the keystone in the center is usually attributed with the causal power to maintain the archway structure over empty space, in fact, if any of the other stones were to be removed, structural integrity would be violated. Every stone matters in a physical and causal way.

However, we can also consider Roman arch structures made with much smaller stones or bricks.

In the image on the right, the bricks are still countable, but the structure is more complex, and we could imagine that when it is completed, a single missing brick could likely go unnoticed visibly and structurally. However, by removing increasing numbers of bricks, the structure would in time fail, and we could ask what that threshold of integrity is: how many bricks are necessary to hold up the archway?



Source: http://www.prix-construction.info/renovation/Structure_et_gros_oeuvre/Arcs_et_voutes/Demolition/GVD010_Demolition_d_une_voute_de_maconneri.html

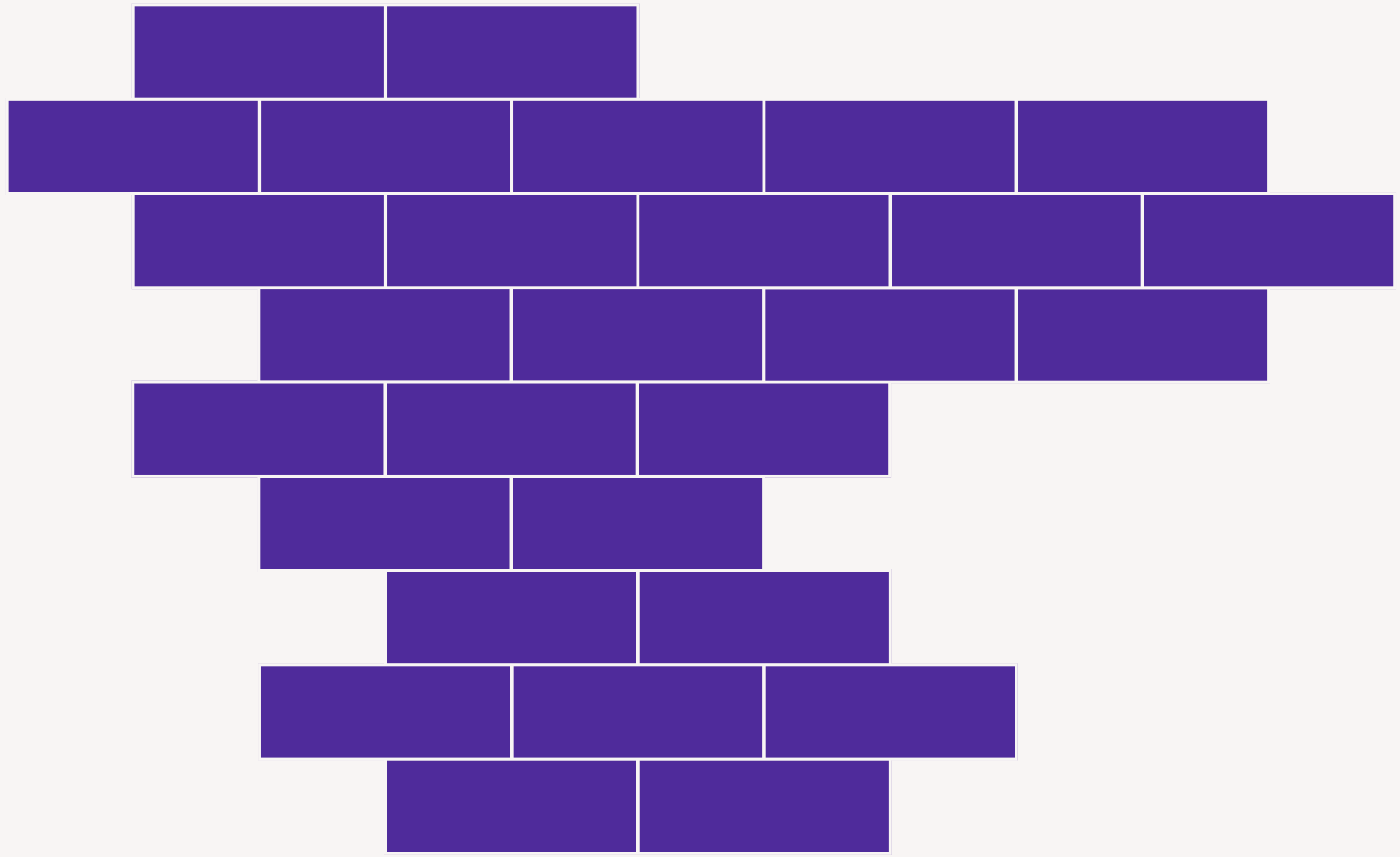
In human societies of national scale, people number in the millions. Thus, we could contemplate much larger building structures which have also existed even in the ancient world. Consider the following Roman aquaduct structure.

“The Pont du Gard is an aqueduct in the South of France constructed by the Roman Empire, and located in Vers-Pont-du-Gard near Remoulins, in the Gard département.” Source: https://www.worldhistory.org/image/125/the-roman-aqueduct-of-pont-du-gard/

This Pont du Gard aqueduct was constructed in the first century CE, and is obviously quite a feat of engineering. The fact that it still stands with its structure intact demonstrates this. Here the Roman keystone arch architecture is magnificently displayed. Each stone in the arch, and also the stones in the vertical structures, are important to maintain the aqueduct’s erectness despite two millennia of gravity. We could think of human societies in this way. Like in this photo of Pont du Gard, each stone seems insignificant in size compared to the entire structure. Some stones could be removed and the structure would remain standing. However, in its small contribution to the structural integrity of the entire aqueduct, each stone contributes a unique causal role to keeping the construction intact.

Unlike with the way bricks can be placed in complex structures to withstand gravity for long periods of time, in human society people act individually with their own goals and lifestyles. This is deemed to be an advantage of advanced modern civilization characterised by free markets and democracy. At the same time, even if people seek to coordinate their efforts to have collective impact, as in solving the climate crisis, it is enormously difficult to identify a way to act together. Thus, individuals can feel more superfluous than small bricks in a large structure with respect to making any contribution to common aims, including to maintaining a habitable planet.

Recognising the impossibility of individually making a difference provides a new diagnosis of the mechanism underlying the tragedy of the global environmental commons. If it is true that none of us can make a perceptible difference on global outcomes, then how can any of us be rationally motivated to make tiny and insignificant contributions?



The key here is to recall that just like the individual bricks and stones in the gigantic Roman structures, each action plays a causal role that, when aggregated, sums up to an entire planet-wide pattern of human activities. These patterns can either be collectively destructive or constructive.

The Romans pioneered not only building structural arches to span space, and domes to span the ceilings of buildings: they also mastered concrete, which is a composite of small grains of sand and rock. One takeaway is that piles of sand can be turned into large structures when applying the correct architectural principles. Similarly, if human societies function using effective organising principles, then they too can be structured to achieve good collective outcomes. The question we ask in this book is what types of social structures can successfully address the global environmental tragedy of the commons?

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Section 3: Anti-Rival Goods

We continue to add to the building blocks we need to consider new ways to achieve collective action and solve the tragedy of the commons. We have seen that collective bad outcomes result from externalities, or harms caused as byproducts of individuals' actions. These harms affect innocent bystanders who can be negatively affected by others' actions. Bad outcomes result from individuals being selfish, and not caring about others. However, in considering the concept of negligibility, we understand that even if we want to make a difference toward achieving collective good, none of us acting as citizens and consumers can make a perceptible difference on the global environmental commons. If we can't make a difference, each being like a grain of sand, then why bother trying?

Now we consider types of harms, or externalities in more detail. Recall that externalities, those side effects on others caused by our actions, can be either negative or positive. We have focused on the tragedy of the commons being caused by negative externalities. In this section we will also consider positive externalities: in these cases our actions have positive consequences for others. Other people do not pay for these benefits, but receive them.

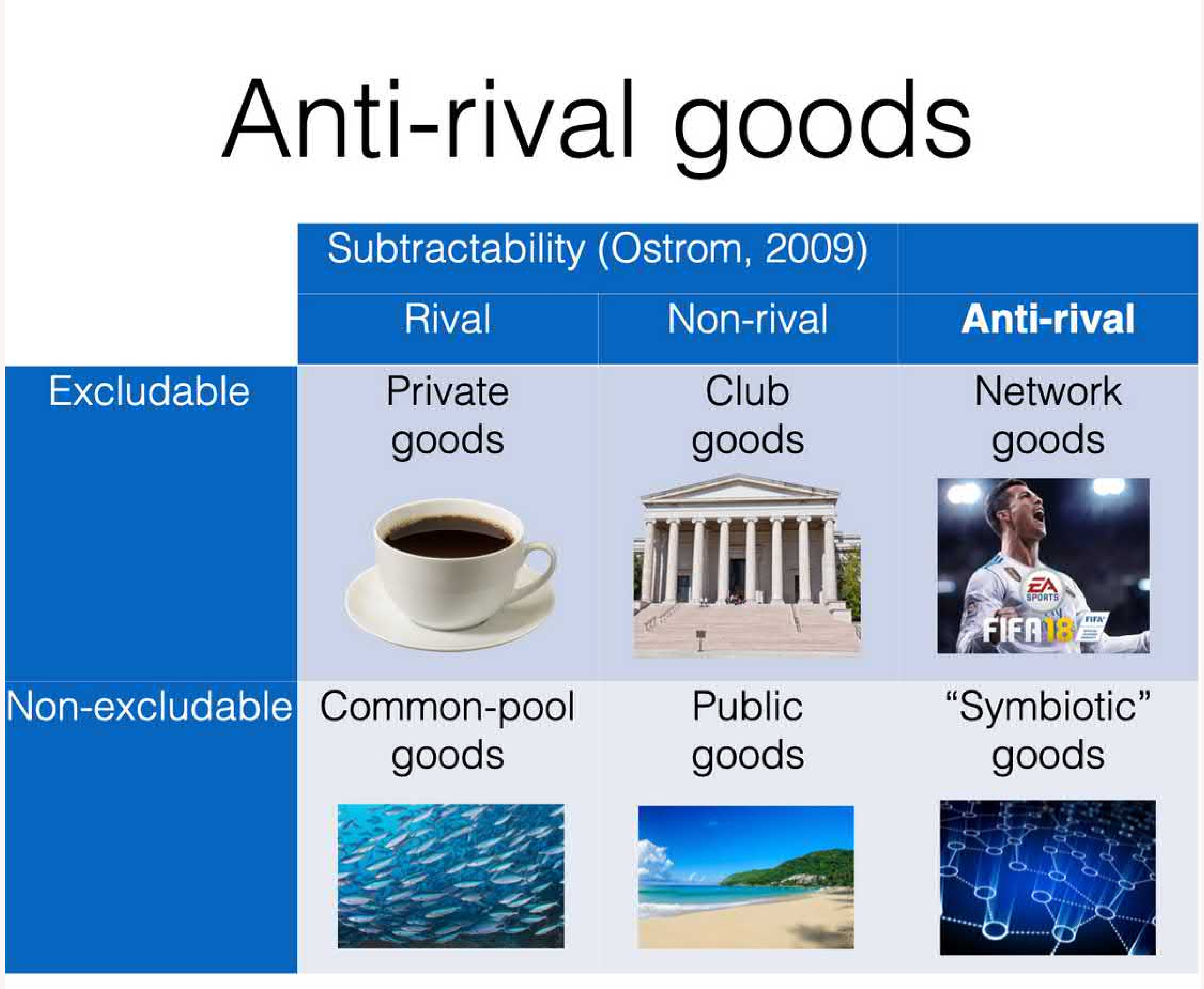
We now take one more step in understanding standard western economic theory. The aim of this exercise is to be able to develop a critical distance to expand our thinking. We are confronted with the fact that free market solutions are not able to resolve the tragedy of the commons. This is because the Earth’s ecosystem, its air, water, biodiversity, land, and minerals are a single interconnected biosphere.

Our current economic system is designed mainly on the principle of exclusive private property rights and free trade only works with goods that are classified as “rival.”

Economists hold that nothing can have value unless it is scarce. One could argue that non-economic values, such as love, courage, and appreciation are inherently not scarce. However, the contemporary approach to economics denies that non-economic values exist, and therefore imposes the view that everything valuable to people must be scarce.

Despite this mainstream and orthodox treatment by economists, there are, in fact, goods less abstract than love that we can readily identify as not scarce. Some of these goods are not only not scarce, they actually *gain* value as their supply circulates and expands. The table on the next page represents categories of **“excludable,”** and **“non-excludable”** goods. We have already discussed how it is impossible to exclude individuals from access to the ecosystem, including the atmosphere and oceans. Common pool resources are nonexcludable. Private property rights are excludable.

Now we directly consider the nature of a good to be consumed. This is represented by the columns in the table. Economists focus on rival goods which can only be consumed or used by one actor. Classic examples are virtually everything for which we spend money. When I buy groceries or a cup of coffee, ownership is transferred from the grocery store or the café to me; I alone control the consumption of that good. The good is subtracted from the inventory of supply, and enters my possession, until it is consumed. Even though fish in the ocean are a common pool resource, they too have this rival quality: what one fishing company catches is not available for another fishing company to catch. This rival good is “subtractable.” This means that for rival goods, my possession and consumption subtracts from the total amount available for everyone else.


Anti-rival goods

	Subtractability (Ostrom, 2009)		
	Rival	Non-rival	**Anti-rival**
Excludable	Private goods	Club goods	Network goods
Non-excludable	Common-pool goods	Public goods	“Symbiotic” goods

Source: https://www.gameskinny.com/oirze/economics-of-video-games-the-knowns-and-unknowns

Source: https://commons.wikimedia.org/wiki/File:Hietaniemen_uimaranta_1.jpg

Non-rival goods are recognised by economists, but are a much smaller category of goods. “Non-rival” refers to available resources that are not depleted when used. Imagine a private club with artwork and a community room. A private club is excludable, individuals must pay, or be approved, for their membership. However, no matter how many people see the artwork and enjoy the facilities, they are not used up (unless misused). Public beaches are an example of a non-rival and non-excludable good. The beaches are open to the public on a non-exclusive basis, and (if used appropriately) are always available—beaches have so far lasted for centuries and millennia, well beyond a single person’s lifespan.

Economists recognise rival and non-rival goods. We now expand our thinking to **anti-rival** goods. These are best explained using some examples. An anti-rival good is one that is not scarce; and the more people who have access to it, the more benefit is achieved. An example of an excludable and anti-rival good is called a network good. This is a good available to subscribers of networks, such as sport channels. Individuals pay to have access to viewing events. However, once the infrastructure to distribute the recorded event is in place, billions around the world can watch the same event. The more people who have access, the more who benefit. When it comes to watching a sporting event, no additional person's watching decreases others' satisfaction from watching. Moreover, the bigger an audience, typically the net value of the sporting event is experienced to increase.

In the case of non-excludable, anti-rival goods we use the term **"symbiotic"** goods. This means that the more connections and synergies, and sharing of value, the greater the total amount of value. Unlike with rival goods, anti-rival goods are not exchanged, or subtracted from a finite scarce total sum when they are consumed. Information is a classic example of an anti-rival good. We all know that in our digital age, the cost of sharing information is negligible. Downloading a PDF is almost costless, and certainly we do not pay for most of the PDF files we download. Yet no matter how many people download a PDF, this does not subtract from the value that any of its other users' experience. In fact, if the PDF contains vital information, such as a public service announcement, the more who gain the information, the better for everyone.

Economists have yet to provide an analysis of how to proliferate anti-rival goods. This is because the character of the good, defined by not being scarce and being of greater benefit with more use, defies contemporary economic theory. In the next section we see how incorporating anti-rival goods into our thinking, and institutional design, to combat the global tragedy of the commons may provide a constructive path forward.

Victoria Falls from Zimbabwe side, 2018. Nature has abundance which is subject to compromise by inefficient use. Source: Doc James, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons.

Section 4: Positive Externalities, Anti-rival Goods, and the Tragedy of the Commons

This book has covered topics that provide building blocks to tackle solving the tragedy of the commons in new ways. Mainstream faith in the free market system provides technical solutions for contemporary problems. However, as Garrett Hardin argued, how we use Earth's resources is not a technical problem, but rather a social problem. The tragedy of the global environmental commons is a social dilemma, not a technical one.

Chapter 5 explained how we can analyse the tragedy of the commons in terms of negative externalities: those incidental harms caused to others by our activities. Economists have devised market-like solutions. One is to impose taxes on polluters to incorporate the costs of negative externalities. The other is to give rights to a certain amount of pollution, and to entitle possessors of those rights to trade them in the free market in the "cap and trade system."

These efforts supported by mainstream economics are further supported by international global treaties to achieve carbon neutrality in successive stages by 2050. So far, these efforts are insufficient to achieve the goals of limiting the temperate rise to 1.5°C.

The State of the Paris Agreement. Source: https://www.statista.com/chart/9656/the-state-of-the-paris-agreement/

Sections 1 and 2 of Chapter 6 provided a new analysis of the mechanism underlying the tragedy of the commons. Instead of focusing on individuals' selfishness and lack of concern for others, or even people's caution in cooperating with others due to distrust, we examined the problem of negligibility.

Scarcity with money.

This challenge asserts that no individual citizen-consumer can affect the global tragedy of the commons, regardless of their consumption patterns. Consumers may be sovereign, but no individual alone can achieve the 1.5°C goal for planet Earth.

Section 3 of Chapter 6 introduced rival, non-rival, and anti-rival goods. These are either excludable as private property rights or on a membership basis; or they are freely accessible to everyone. We have seen how anti-rival goods are not subtracted from a finite amount, and in fact gain value when they are proliferated and shared. Yet economists are only able to analyse goods that have monetary value. Money itself, in its construction is rival and excludable. Therefore, money cannot be used to evaluate the worth of anti-rival goods. This is specifically the case for anti-rival, non-excludable goods which are accessible to everyone.

Outside of the realm of standard economics, the traditional supply and demand model of exchange fails. The cost of production for anti-rival goods decreases with every unit produced. These goods are not inherently profitable if they are open access. They must be made artificially scarce so that they can first be produced and then be profitable.

Now we examine the nature of externalities, and in our case, those harms caused by overuse of common pool resources. Many externalities, whether harmful or beneficial, are anti-rival. This means that they have a non-subtractible impact on others' wellbeing. Take defacing public property for an example. It takes one person to mar a public monument with paint. Yet no matter how many people see the monument in its defaced state, everyone is negatively impacted.

Statue de femme nue couverte de graffitis, Paris, France. Artist: Bruno Bleu.

Fresh caught halibut drop from the bottom of a transport basket after being hoisted by crane from a fishing boat at a dock in Alaska Artist Username: wakr10.

It may seem that over-fishing the ocean would be an example of rival-externality: we are simply competing for the same total number of fish. What one fisher gains is subtracted from what others can gain according to simple arithmetic. But it is not so simple. By depleting fish stock, and other natural resources, over time we can decrease the total supply projected forward in time. We damage ecosystems so that their tendency toward abundance is destroyed. Once a species is extinct, it cannot be brought back. Even if we were to find a way to technically do so, ecosystems change and other species occupy bio-niches previously occupied by a natural population.

Similarly, with pollution around a factory, or from a nuclear power plant disaster. No matter how many people get sick from radiation, this does not mean that others will avoid sickness or become less sick. These negative externalities are anti-rival in the harms they pose to others.

The same is true of positive externalities. Recall that a positive externality is a side effect of an action done by one person, but that can benefit bystanders who did not contribute. If I clean defacement off a public monument, or even any public-facing building, many will benefit. This is a positive externality that is anti-rival in nature.

Source: https://www.flickr.com/photos/nycstreets/26106545031.

Let's go further and think about over-fishing tuna or halibut in the Pacific Ocean. As we discussed, even though the good itself, the tuna and halibut we eat, is rival, over-fishing it is anti-rival. The impact of over-fishing has an impact on the entire stock of the species as well as on the ocean's ecosystem. Over-fishing has negative externalities, or harms, that are amplified and hence anti-rival. Over-fishing can lead to the entire collapse of a fish species.

Extending this reasoning to our planet-wide emissions of greenhouse gasses, we may think that every metric tonne of carbon gas emitted is rival in nature: if I emit less, you can emit more. Certainly the economists' cap and trade system works on that principle. Given a restricted number of carbon emission licenses, they can be traded, for a fixed number of reduced metric tonnes of atmospheric carbon pollution. However, we know this current approach is insufficient to achieve net global carbon neutrality by 2050 according to recent trends.

Thinking instead of the defaced public monument example, we can understand that every metric tonne, and indeed every kilogram, of CO2e gas that is not emitted is contributing to achieving a sustainable planetary ecosystem. When common pool resources are used efficiently, they are replenished, and remain abundant.

Source: Heikki Valve, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0/deed.en>, via Wikimedia Commons.

We have considered GHG emissions from agriculture which are 18% of the total of human carbon emissions, and 30% of individuals' carbon footprints. As well, we have considered how agriculture offers the technologically easiest way to reduce GHG emissions. However, it is dietary resistance, or habits, that prevent people from shifting to eating more plant-based proteins. Agricultural businesses within countries are often deeply interwoven with culture and history. Let's recall that the average Finn eats just under 80 kg of meat a year. Of this 19 kg of beef and 25 kg of cheese, we see that according to the most conservative figures, this consumption contributes almost 0.7 of a metric tonne of CO_2, and 3.1 million metric tonnes nationally on an annual basis. This exceeds the 2.1 million metric tonnes for Finland's landuse footprint for 2021 (Finland has previously been carbon neutral for landuse).

It may seem that any single plant-based meal makes an imperceptible, negligible, and inconsequential difference to the global environmental commons. Just as when one grain of sand is taken from a heap, the heap remains exactly as it was before: a sizeable heap. No single difference can be recognised. Yet, just like when we take heaps of sand and make them into structures, each tiny part of the whole plays a role in the causal integrity of that structure. At the moment, with consumers' sovereignty being one of our primary principles for social and economic organisation, we are each like grains of sand, unable to change the global outcome with our actions.

Reducing CO2e emissions is a positive externality. Others benefit from our acts of GHG reduction. However, none of us can individually make a perceptible difference, and cannot be rationally motivated to try.

Traditionally, to act rationally is understood to mean to act with an intention to achieve an outcome. Hence, our dietary patterns remain entrenched. Collectively our actions do not add up to achieving the 1.5°C target, and we may live inconsistently with our own values. If we each knew we could make a difference, we may be more motivated to act.

Reducing GHG emissions is an anti-rival positive externality. This is because we are so far from achieving the global goals consistent with the 1.5°C target that we should all do everything possible so that collectively the Earth's climate remains viable and sustainable for most life forms. Given the vast amount of accumulated CO2 gas, and its natural time for dissolution of 100 years, all current actions are like drops in a bucket. However, there are 8 billion people on Earth, and those drops add up quickly.

Achieving the 1.5°C target will give us a much greater chance to maintain environmental sustainability. Achieving this target would be a non-excludable and anti-rival public good. Environmental sustainability is a condition for environmental security: weather patterns that do not kill people and destroy crops, and temperatures that are viable for Earth's life forms. Security is a positive sum good because one agent's security does not subtract from another agent's security.

Thus, everyone benefits, whether by avoiding direct damage or by having access to crops depending on hospitable conditions. Individuals' positive externalities toward GHG reduction may individually seem inconsequential. However, not only do they add up to large-scale outcomes, they can also be anti-rival. Contributing to the collective 1.5°C target, our contributions are positive sum. They result in a sustainable environment that everyone benefits from by having access to food and nutrients as well as safe weather patterns.

Drops of water add up to entire bodies of water. Source: Bicanski on Pixnio, https://pixnio.com/media/ripple-rain-raindrop-rainy-season-close-up.

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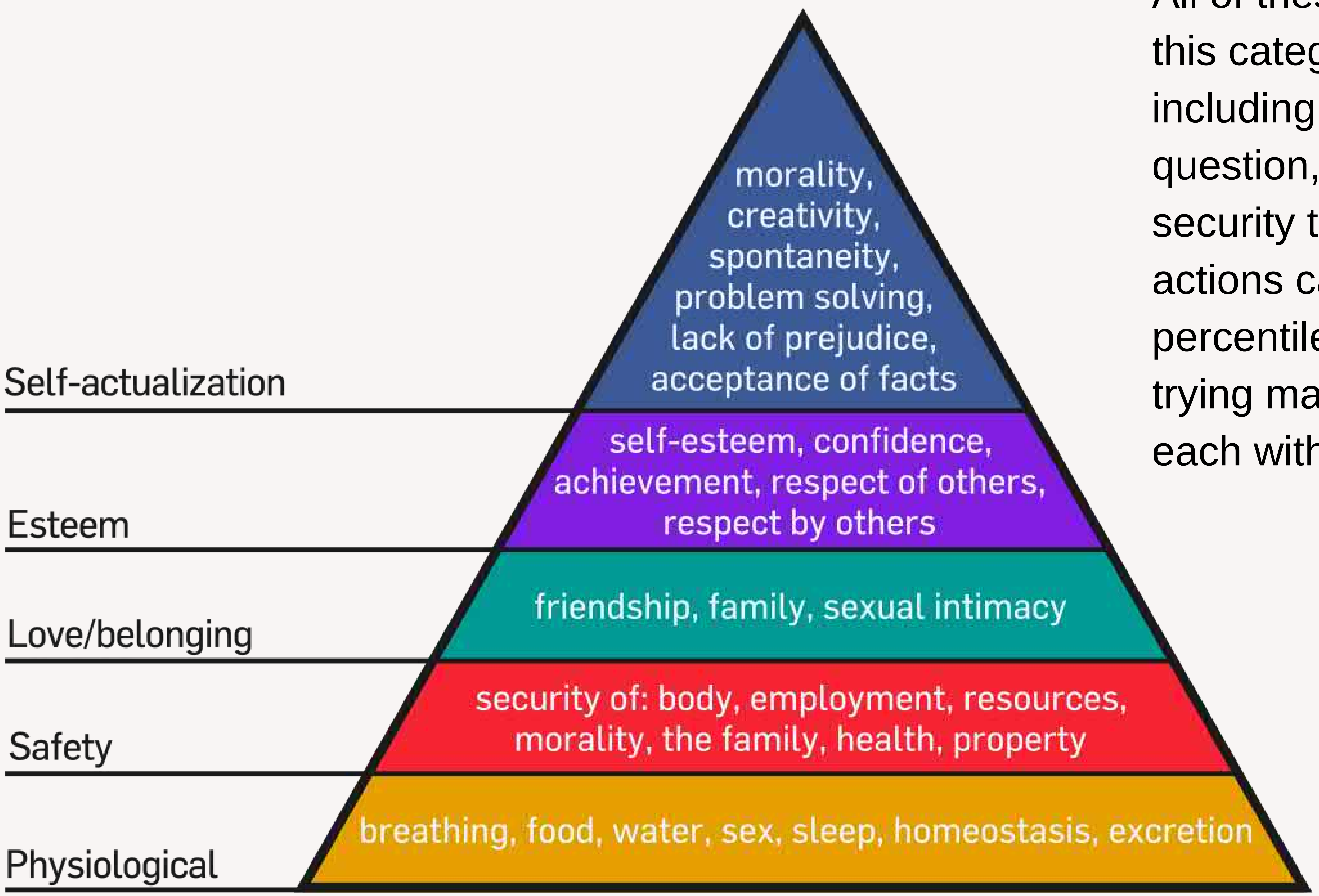
Section 5: Using Tools to Construct 1.5°C Lifestyle Individually and Collectively

Many of the goods recognised by psychologist Abraham Maslow are positive sum, and thus are anti-rival. The lower tier of the pyramid involves physiological goods necessary for life. These include air, food, water, sex, sleep, homeostatis, and excretion. Sleep for example should be anti-rival, one person's sleep should not detract from another's. However, we also need safety, which entails security of the body. Security is generally regarded as a positive sum good, necessary for all of the other factors of individual identity and social wellbeing. As we go higher in Maslow's hierarchy of needs, the goods are definitely in principle non-excludable and anti-rival. Hence, many social goods are not competitive and positive sum.

Flooding - Minot, N. D., June 24, 2011 – Red Cross shelter in an auditorium that is housing flood evacuees. Burleigh and Ward counties were designated a federal disaster area, opening the way for federal disaster assistance from FEMA. Andrea Booher/FEMA. Source: https://nara.getarchive.net/media/flooding-minot-n-d-june-24-2011-red-cross-shelter-in-an-auditorium-that-is-c80be8



Source: Factoryjoe (username), CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons.

All of these goods entail security, and a large factor of this category now is environmental security. Security, including environmental security, is positive sum. The question, though, is how can we achieve environmental security together? Given that none of our individual actions can make a difference (unless we are in the top percentile of global wealth), we can be blocked from trying make a difference. We are like grains of sand, each without impact on the collective heap.

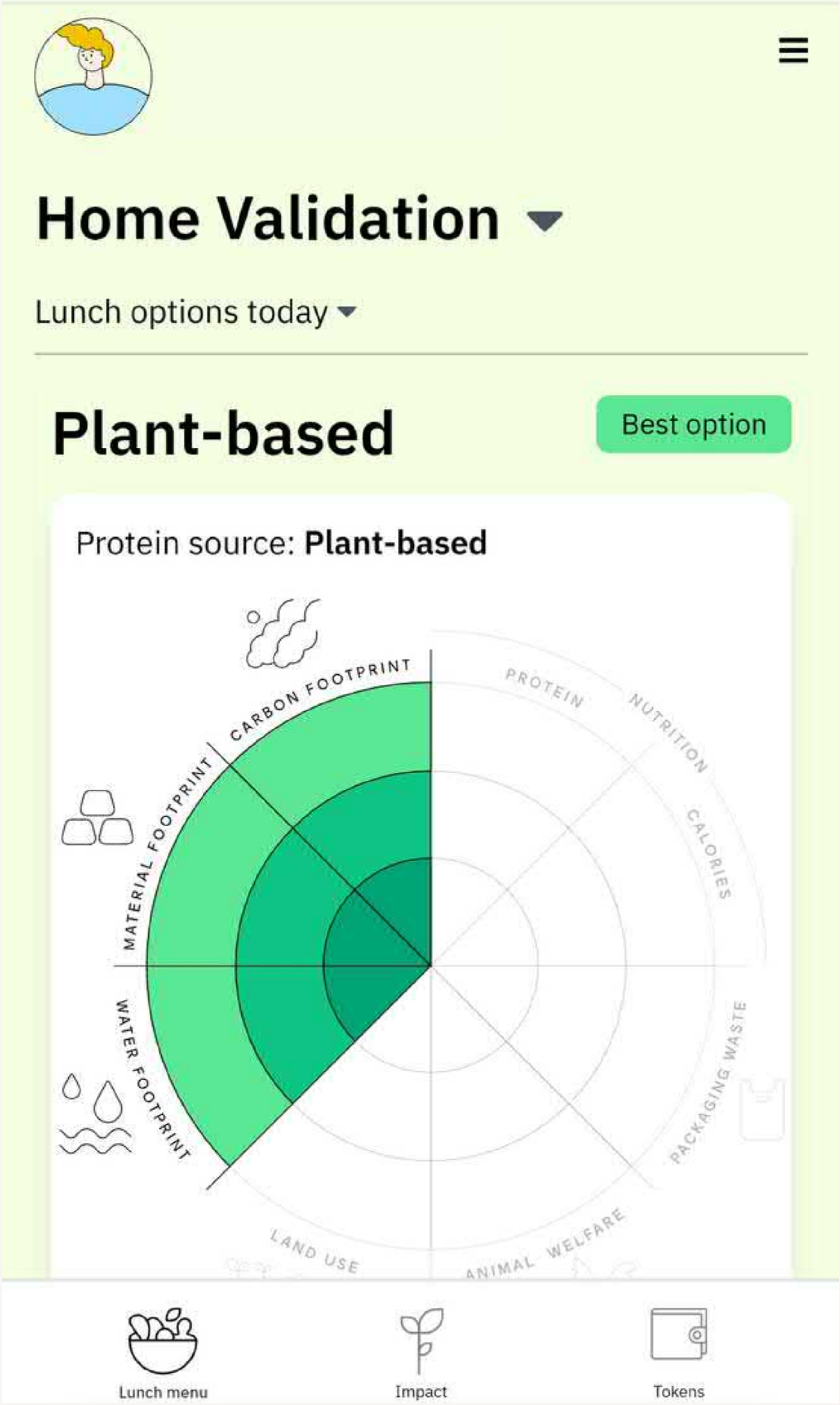
Like the stones and cement in Roman architecture, the millions and billions of people living on Earth can either be as tiny parts of an unsustainable whole pattern of political economy and consumer capitalism, or we can build social structures that enable defying the laws of physics by spanning space, and finding other ways to efficiently use natural resources.

In the analysis of the tragedy of the commons assembled with the building blocks in Chapters 5 and 6, we can understand that given individuals' inability to make any difference to the global atmosphere, it can seem pointless to even try. Still, many people may be committed to making a positive difference if it seems possible. We have seen how externalities can be positive and negative. Reducing individual GHG emissions, and other environmentally costly activities, is a positive externality. Others are positively impacted by such actions.

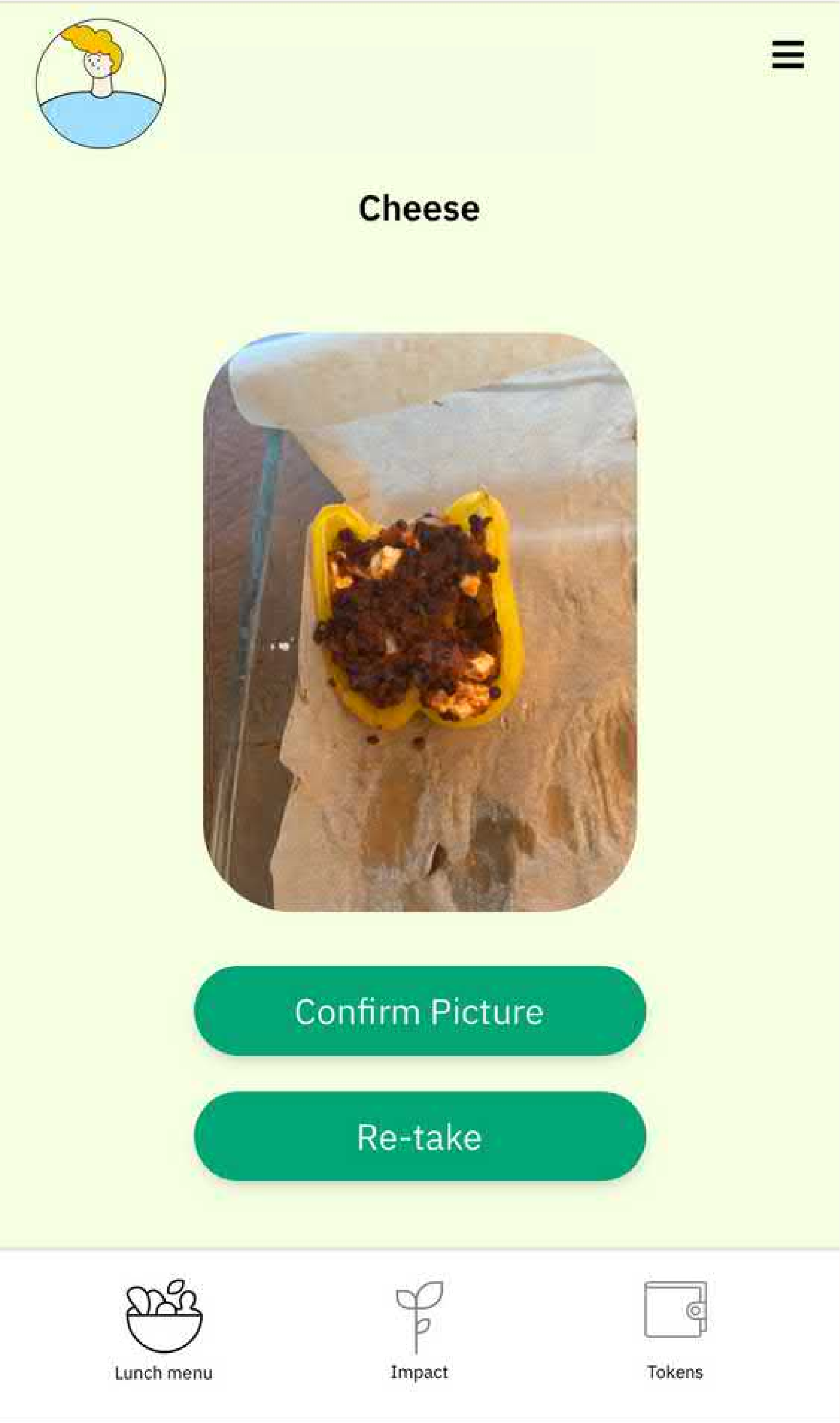
Inside vision of concrete dome structured by intersecting arches, circa 100 AD, Pantheon, Rome. Source: Mohammad Reza Domiri Ganji - Own work, CC BY-SA 4.0, <https://creativecommons.org/licenses/by-sa/4.0/deed.en>, via Wikimedia Commons.

On an individual level, such positive externalities are inconsequential. Trying to change climate change by reducing individual greenhouse gas emission is irrational because it cannot make an appreciable difference. It is not like joining a neighbourhood cleaning team where a group of neighbours can immediately enjoy a more comfortable living space without defaced or damaged property.

Thus, an effective way to combat the global tragedy of the commons is to find a way to make individuals' contributions visible, and to visualise collective impact through the contributions of individuals' positive externalities. Others will benefit. As well, with respect to achieving planetary ecological and environmental security, these positive anti-rival externalities aggregate for a positive sum impact.



Measure: Data visualisation of sustainability impact of meal choice.

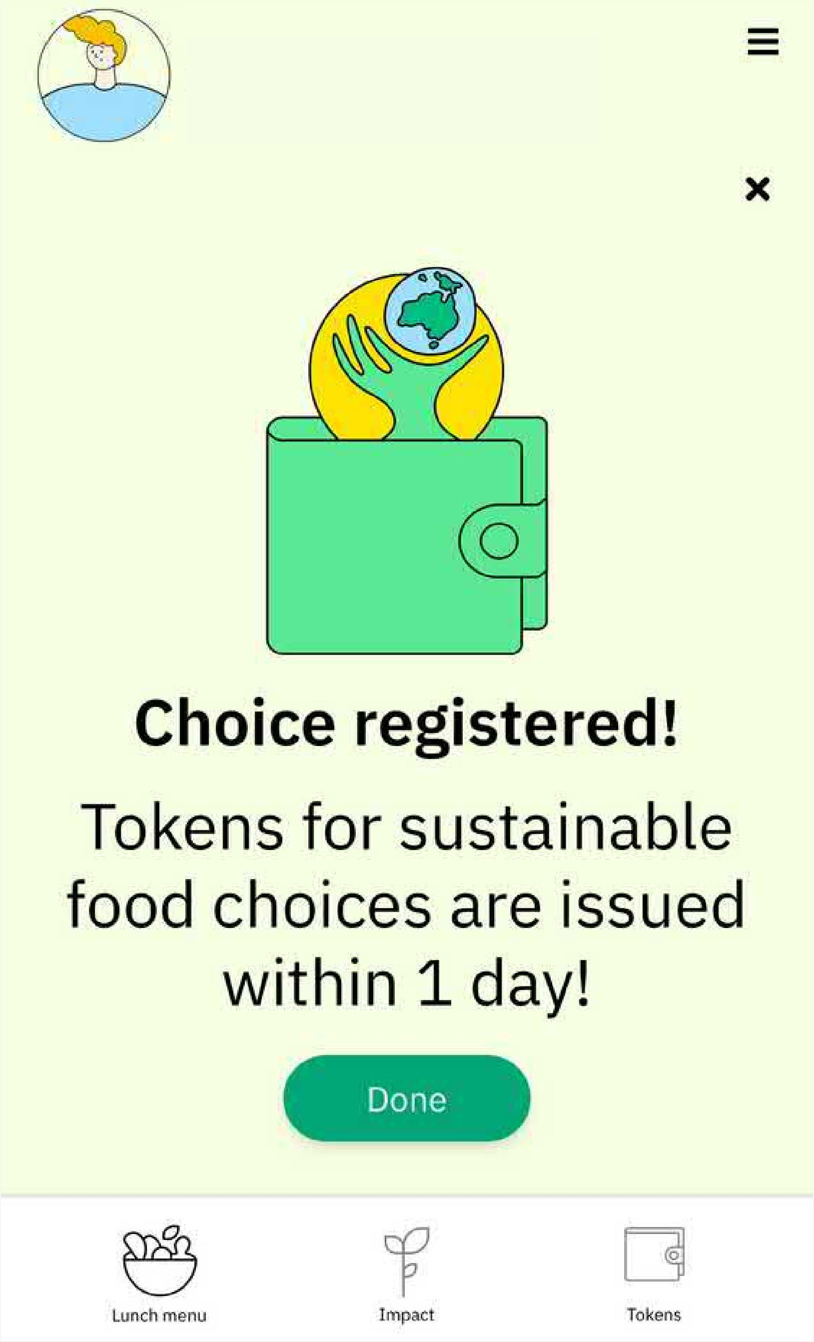


Record: validate your meal choice via the Food Futures App.

The Food Futures App design builds on all of these concepts and practices. We integrate data into a highly communicable visual form to provide citizen-consumers with the sustainability impact information of various meal choices. We acknowledge that no single individual can make a difference to planetary wellbeing that will be appreciable on a global scale. We develop the **measure, record, validate system** that counters the negligibility paradox undermining an individual's effort. With this system, we are able to provide a measure of the sustainability impact of various meal choices. Users' meal choices are recorded on an opt-in voluntary basis. This record is kept using distributed ledger technology blockchain. We issue blockchain "Foodprint" tokens to record individuals' sustainable meal choices.

The token minting algorithm verifies individual and collective impact. One Foodprint token is issued for a green-labeled meal, and ½ of a Foodprint token is issued for a yellow-labeled meal (none is offered for a red-labeled meal choice). Community effort and impact provides a bonus to the tokens. If 100% of the community selects a green meal, the bonus is another Foodprint token; if a lesser percentage selects green, then the effective percentage of contributers is the number used to calculate the bonus. The calculation is halved for yellow meal selections: the bonus is half of the total percentage that selects a yellow meal. Those who select the green meal choice also receive the same bonus given for the yellow meal choosers. Additionally, yellow meal choosers receive half of the bonus received by the green meal choosers.

If the Food Futures App becomes widely used, it could be an important tool in verifying individuals' contributions, and it will have a collectively shared sense of individual agency. Environmental damage from excessive GHG emissions is a reality. Selecting to live a 1.5°C lifestyle is a value choice. The Food Futures App makes being informed about making these values practical and easy. It also helps to counter the feeling of powerlessness we can have as individuals when we cannot perceptibly shape our common future.



Validate: users who make sustainable meal choices receive Footprint tokens.

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CHAPTER 7

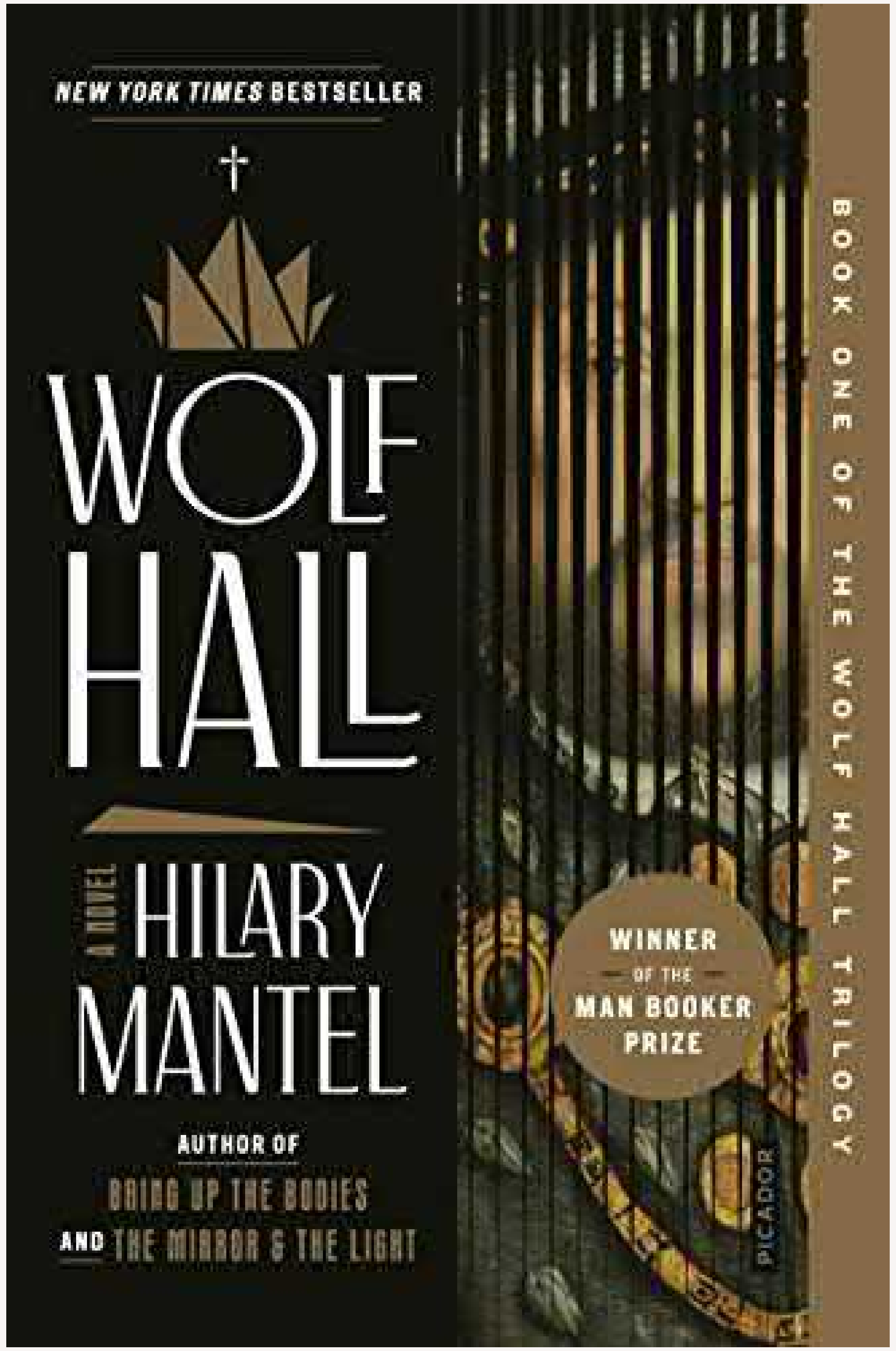
Cryptocurrency, Distributed Ledger Technology and Blockchain Tokens

Section 1: Introduction to Blockchain and Distributed Ledger Technology

Chapter 7 introduces blockchain tokens and distributed ledger technology. This may seem like a fringe topic since it is closely tied to the recent collapse of cryptocurrency prices.

Cryptocurrencies remain a steady fixture in the news, with a well-known example being Bitcoin. They function using distributed ledger blockchain technology. The aim of Section 1 is to become familiar with this new technology. This enables understanding of how Foodprint tokens, which are a cryptocurrency, can function to facilitate governance of common pool resources, as discussed in Chapter 4. The most important point here as we learn more about cryptocurrency, blockchain, and distributed ledger technology, is that the Foodprint token is not a form of money to be exchanged for goods.

Source: Satheesh Sankaran, CC BY-SA 2.0 <https://creativecommons.org/licenses/by-sa/2.0>, via Wikimedia Commons.



There are 3 main aspects to blockchain and distributed ledger technology. The first is how the technology functions, that is, the computer programming underlying blockchain. We are only covering this superficially, since our focus is not computer science per se. The second is how blockchain and distributed ledger technology provide a new way to organise currency systems. Thirdly, we explore the types of cryptocurrency functions. These are augmented considerably beyond both standard physical currencies, such as euros and dollars, and their digital means of being passed between accounts.

Let's proceed step by step. First, consider the concept of **Distributed Ledger Technology**, commonly referred to as DLT. This technology can be demystified by thinking of it as an accounting system. Accounting is a discipline in itself: managing accounts and keeping financial records is fundamental to any political economy. (For a dramatic account of this significance see Hilary Mantel's 2009 historical novel *Wolf Hall* about Thomas Cromwell's leading role under King Henry VIII). A ledger is a record of accounts. Banks keep records of our accounts, acting as our accountants, so that users may access a copy of their financial records.

Distributed Ledger Technology has a specific feature unlike typical ledgers. For example, a standard ledger from a bank is centrally administered. We do not expect that we can alter our bank account directly by personally updating transactions. DLT is precisely that: distributed, and not centralised. This means that it can be updated by all of the partners participating in a ledger system. This is made possible by a peer-to-peer (P2P) computer network, and any update to the system is acknowledged as legitimate by all using the network. Rather than having one central authority oversee and register all changes to the ledger, permissions are distributed over the network of actors. Every actor in the network can alter the ledger and record, for example, through a transaction, but the update must be agreed on by consensus of all the actors on the network. The key to making this distributed ledger accounting system function securely is blockchain technology.

Blockchain provides a high level of security from fraudulent changes to the ledger to make this multi-party ledger updating possible and safe. Blockchain provides a means to implement a distributed ledger, but is not itself equivalent to a distributed ledger.

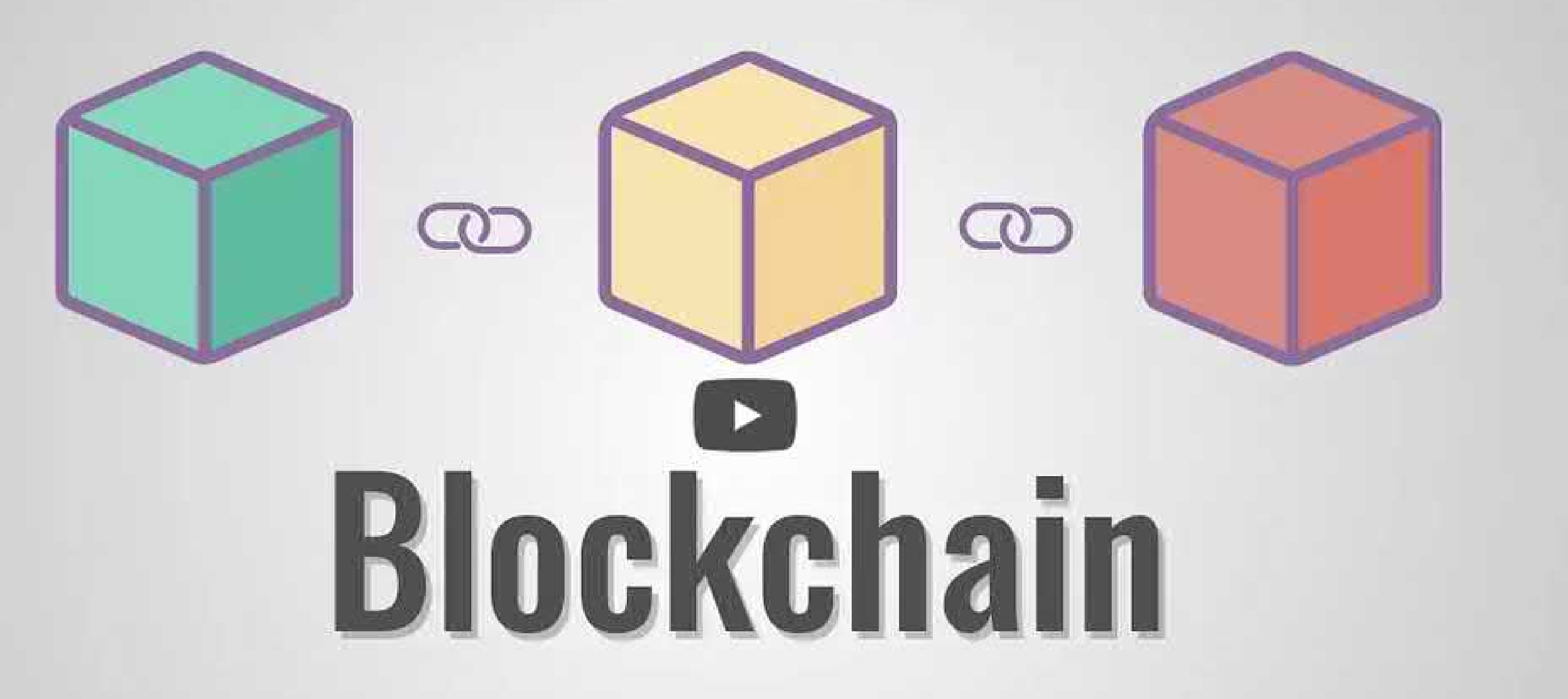
To learn more about DLT, see the video "Blockchain technology": https://www.youtube.com/watch?v=4sm5LNqL5j0

Artist Username: LuckyStep.

Next, let’s consider the pioneering **blockchain technology**. Recall that the function of the blockchain is to provide the infrastructure for a distributed ledger system. Blockchain has several different elements, mainly blocks of data containing the history of earlier transactions that are identically available to every user on the network. Blockchain technology provides a means to secure that the data is valid, provided all of the users on the system use appropriate protocols to update data. On this point we can cite an example from the Food Futures App which mints and distributes Foodprint tokens in a graduated scale according to individual and collective contributions. The current transaction validation method relies on individual reporting and double-checks a transaction (the double-checking is centralised, but eventually this, too, will be decentralised).

As long as the recorded transactions are valid, then once they are imprinted into the blockchain data, they will remain as a permanent record of all individuals’ contributions. All users on the network receive notice of their transactions in the permanent Foodprint tokens issued to users’ digital wallets.

Bitcoin was developed by the person or group using the name Satoshi Nakamoto in 2008-09, and was the first use of blockchain. The vision was to create a fully electronic currency that would not need the oversight and policing of a central authority. Once the currency system was set up, actors could exchange standard currencies (euros and US dollars) for units of the limited supply of Bitcoin. These accounts are managed on a DLT system whereby anyone, without being a member of a bank, can make exchanges using Bitcoin, and maintain their accounts.



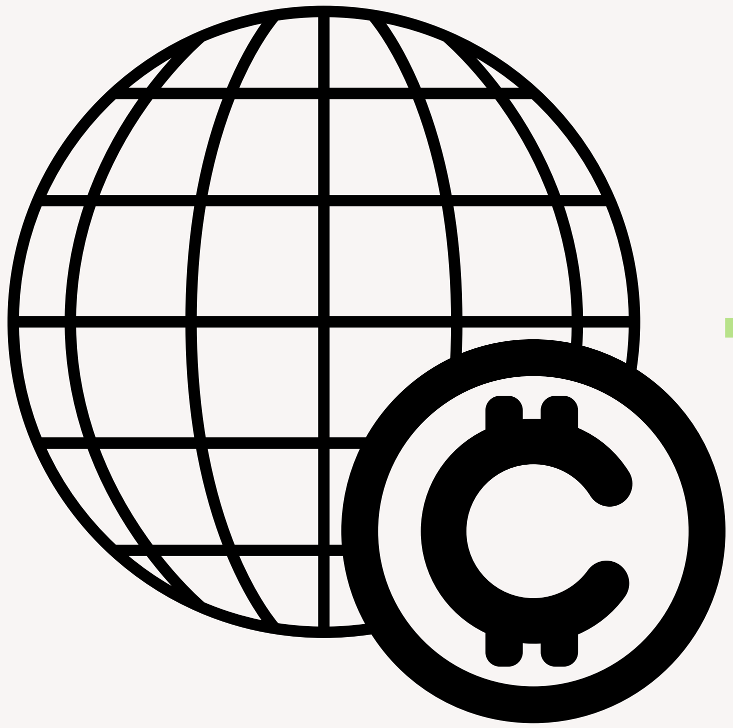
"How does a blockchain work - Simply Explained." Source: https://www.youtube.com/watch?v=SSo_EIwHSd4

Blockchain represents an innovative way to maintain public accounts. Over time, its effective use to manage large scale common pool resources without a central government will likely be demonstrated. Specifically, it is well-suited to work within voluntary, opt-in communities that have an identifiable membership group. As well, it provides a means to record activities. The Food Futures App relies on blockchain to implement the measure, record, validate system to acknowledge individuals' contributions, and to provide data to visualise the collective impact.

For more, see blockchain video introduction "How does a blockchain work - Simply explained": https://www.youtube.com/watch?v=SSo_EIwHSd4

Cryptocurrency is a particular application of blockchain technology, much as blockchain technology is a way to implement a distributed ledger. The most famous cryptocurrency is Bitcoin. However, if you watched the video “Blockchain and Distributed Ledgers” you saw that there are currently about 1,000 cryptocurrencies. These currencies all function in unique ways specified by their developers. Bitcoin, and other cryptocurrencies, attempt to serve the same function as money. In the modern era, monetary systems are state-operated systems that control the amount of money in circulation (otherwise everyone could print their own money). Cryptocurrency systems that seek to play the same role as standard money must therefore have a means to control their money supply. But, since their advantage lies in using DLT and blockchain, they are not controlled by a central authority. Instead they function in computer protocols and algorithms that use computer programs to enforce the rules the system designers set up to regulate the currency.

Bitcoin has received a bad reputation because people have sought to get rich by investing in it, instead of treating it as a currency like any other currency. Certainly it is possible to make money by speculating on the rise of one currency’s price against other currency prices. (This is what George Soros did in 1992, by betting against the Bank of England and making approximately one billion US dollars.) Financial tools will always be subject to speculation. However, the strength of cryptocurrency lies both its decentralised nature, and its high level of security against fraud and theft achieved by blockchain technology.



Ether is a cryptocurrency whose blockchain is generated by the Ethereum platform. Artist Username: Quatrox Production.

One liberating feature of cryptocurrencies, in addition to their decentralised character, is that they can fulfil unique purposes within the different communities that use them. Bitcoin attempts to replace standard money for some market transactions. However, the function of cryptocurrency is much broader than standard money.

Food Futures offers a community cryptocurrency in the form of blockchain Foodprint tokens. These are in the Ethereum standard, and are awarded to users of the Food Futures App who have made sustainable choices. Over time this community currency system may be expanded so that tokens will serve a utility function to receive donated surplus goods (these are non-rival in character because they would have been wasted otherwise). Since Food Futures is built on the concept of anti-rival value, with the externalities produced from sustainable choices, the Foodprint token itself is anti-rival. This means there is not a limited total supply. Tokens are minted when positive externalities are measured and recorded. They serve to indelibly and permanently recognise individuals' contributions toward achieving lower GHG emissions.

The future of human civilization hinges on whether people learn to collectively manage the atmospheric commons. The Food Futures community cryptocurrency provides a tool to achieve this aim, consistent with Elinor Ostrom’s principles of managing common pool resources. Think of the insignificant items we pay small amounts of cash for on a daily basis. We can appreciate that the value of contributing to achieving net carbon gas neutrality has more value than the pennies we spend on trivial items, such as chewing gum and pastries. Yet we have detailed accounting systems for these petty consumables, and as yet no currency system to measure, record, and validate the far greater value of living together sustainably.

Candy Shop in Sweden. Source: Guillaume Speurt, CC BY-SA 2.0 <https://creativecommons.org/licenses/by-sa/2.0/deed.en>, via Wikimedia Commons.

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Section 2: Double-Entry Bookkeeping Versus Triple-Entry DLT Record-Keeping

Just as with our discussion of DLT, blockchain and cryptocurrency, we do not expect to become experts on double-entry bookkeeping through this book. However, we can respect the role that this accounting technology has played in the rise of modern capitalism. Our goal is to understand how record-keeping, as an innovation in itself, can be revolutionary.

First, let's imagine doing basic calculations using Roman numerals. This number system was used throughout Europe into the 1400s. Try completing the sum of CDVII plus XCII. Imagine needing to keep track of quantities of items exclusively using Roman numerals. We will leave that aside for the reader to calculate as an exercise if they wish. Science and engineering would be held back by such a numbering system. The mere symbolic representation of concepts itself therefore is a type of technical innovation.

Individual decimal places

	Thousands	Hundreds	Tens	Units
1	M	C	X	I
2	MM	CC	XX	II
3	MMM	CCC	XXX	III
4		CD	XL	IV
5		D	L	V
6		DC	LX	VI
7		DCC	LXX	VII
8		DCCC	LXXX	VIII
9		CM	XC	IX

Roman numerals. Source: *https://en.wikipedia.org/wiki/Roman_numerals*

Luca Pacioli. Source: https://commons.wikimedia.org/wiki/File:Luca_Pacioli_in_the_Summa.jpg

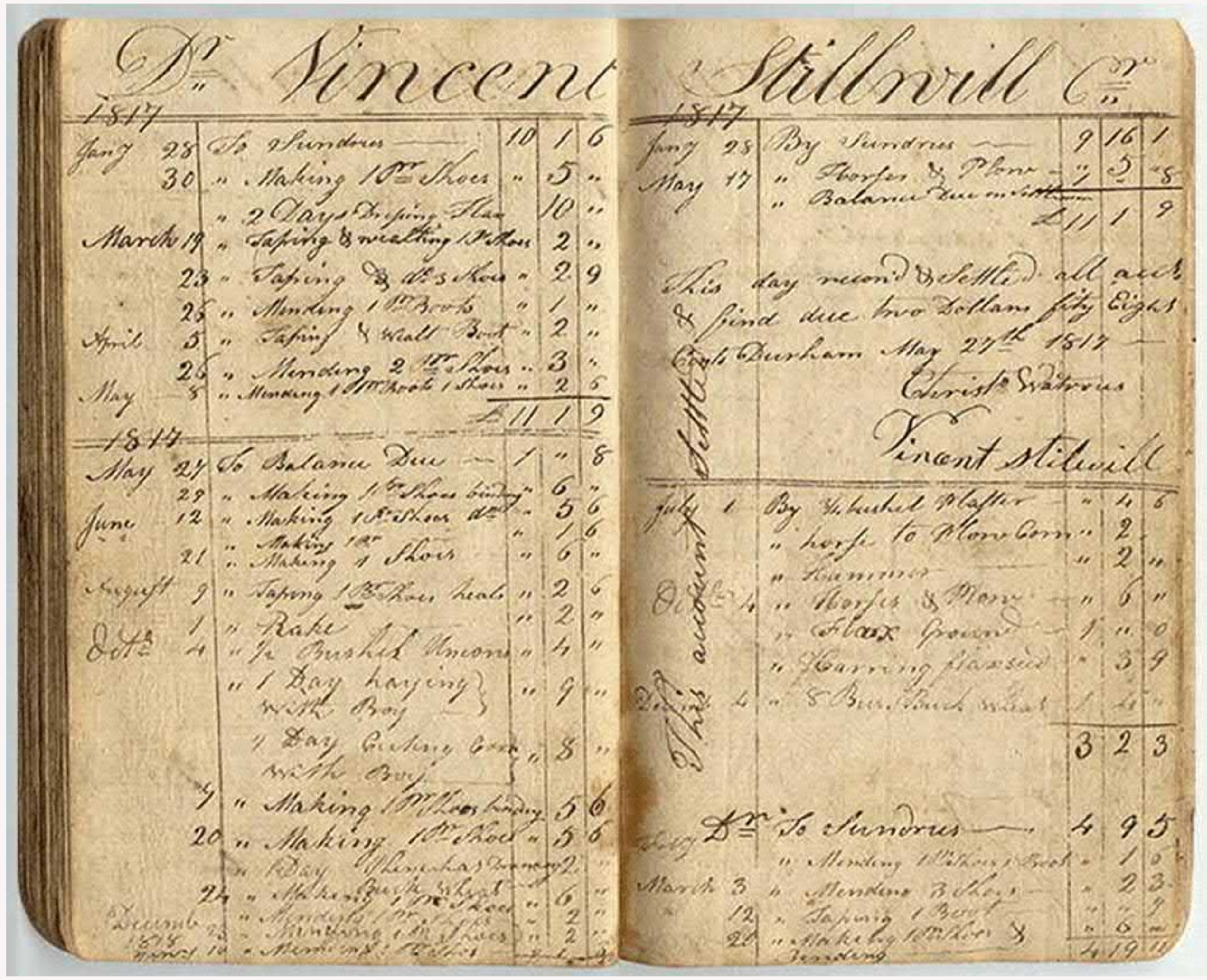
One basic element of the breakthrough into the principles of **double-entry bookkeeping** was the gradual cultural adoption of the Arabic number system used throughout the world today. Before modern accounting methods (“modern” is used in the historical sense dating from Early Modern Europe between 1450 and 1789), records show that people kept diaries of their possessions, detailing inflow and outflow of traded goods.

The breakthrough of double-entry record keeping was sufficiently profound that observers at that time recognised its significance. We are aware of this breakthrough because an Italian monk, Luca Pacioli, codified the method as it was used in Venice. Earlier incidences of this new technique date back to the 13th century in Provence. Pacioli took an action vital to the advancement of knowledge. He wrote an encyclopedia about mathematics in 1494 with an article about double-entry bookkeeping. Due to the newly invented printing press, his encyclopedia was mass produced. Today Pacioli remains known for his entry on accounting.

The innovation of this new accounting practice was the concept of balancing credits and debts, and devising a method to rigorously keep track of these numbers. The term “double-entry” thus refers to treating every transaction as an exchange. If I go to the store and buy and orange for one euro, then the euro is debited from my account, and I receive the orange in return (which is valued at one euro). The consequence of this record-keeping system means that if I am running a shop selling oranges, I can keep the following accounts (shown in the table on the right). These entries reflect that I purchase oranges for 0.5 EUR each, and I buy 20 oranges, for 10 EUR in total. Then I sell the oranges for 1 EUR each, and receive 20 EUR. This type of calculation, as well as the entire conceptualisation of economic exchange, is so basic to us that we barely think of it as a fundamental innovation in the history of human civilization.

	Debit	Credit
Cash for 20 oranges	10 EUR	
Receipt of 20 oranges		10 EUR
Sale of 20 oranges	10 EUR	
Receipt of payment 20 oranges		20 EUR

This method of accounting makes it straightforward to grasp the profitability of buying and selling oranges for this vendor. Such accounting enables comparing the revenue flows of different products. It records the value of an item in terms of the amount of money paid for it. An aspect of the double-entry system is that merchants can match their accounts, and there should be no discrepancies. If I record receiving 10 EUR from you, then you should record a debit of 10 EUR to me.



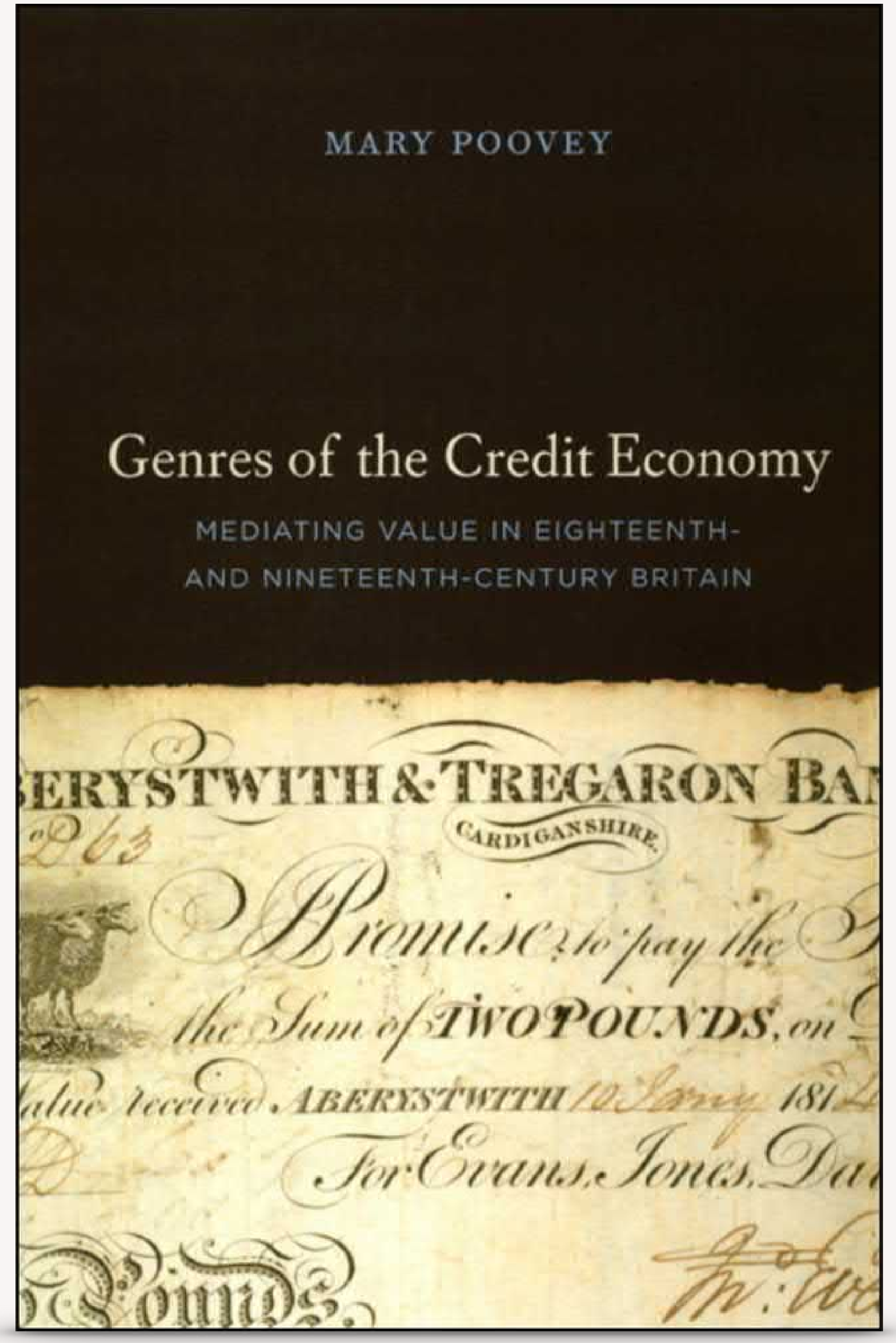
Debits on the left, credits on the right—the hallmark of double-entry accounting. Every financial event brings two transactions, a debit in one account and an equal, offsetting credit in another account. Photo: Christopher Watrous' account book, Debits and Credits for Vincent Stillwill accounts*, Durham, Connecticut, 1817. Source: "Double-Entry Bookkeeping Accounting Systems: Double-Entry vs. Single-Entry Systems," Business Case Website, Solution Matrix LDT. https://www.business-case-analysis.com/double-entry-system.html*

Double-entry bookkeeping conceptually intersects with the dawn of what would become the conservation principles of physics. Coupled with the cultural assimilation of Arabic numerals, and the spread of double-entry bookkeeping throughout Europe, this process took place over centuries. Double-entry bookkeeping is based on the following principles:

- Accounts (credits and debts) must balance.
- The money in circulation must be constant (unless a sovereign state issues new currency, but it must be accounted for, i.e. how much new money is put into circulation).
- All money paid out must be exchanged for goods and services of that value which become an asset on hand (in the orange sale example above, what is paid out is exchanged for goods of that same value).
- This accounting method enables the calculation of profit: profit is the surplus value after all expenses are paid for production.

Double-entry bookkeeping may now be revolutionised by a new chapter in accounting: Distributed Ledger Technology (DLT). This brief historical overview is provided to ignite our imaginations about the possibilities of a potential breakthrough in accounting. DLT can be viewed as **“triple-entry bookkeeping.”** This system maintains the credit and debit balance crucial for the double-entry method, but adds publicity to all records, meaning that transactions are not only recorded in private ledgers, but are maintained in a distributed manner by all of the participating nodes of the system.

Double-entry bookkeeping keeps account of debits and credits to everyone’s account. An aspect of this which we are familiar with is that the buyer and seller of a good each (in contemporary times) maintains their own accounting record of any transaction. In this way, accounts can be checked against each other. For an easy example, consider your own personal bank account. We take it for granted that what I put into the bank, in the form of cash or a digital deposit, is credited to my account. We assume that our records, which we also rely on the bank to maintain, ar identical to the bank’s records. We do not expect to have more or less credit in the account than we deposited, or deducted when we paid for goods.



Historian Mary Poovey’s book on the history of financial instruments, Genres of the Credit Economy*, 2008.*

DLT maintains a triple-entry accounting system. This third entry, beyond credits and debits, refers to every transaction recorded on every node of the networked peer-to-peer system.

The third entry is the public nature of the record. The transaction is not only recorded between buyer and seller in their own double-entry records, it is also recorded publicly. The entire blockchain system typically used to implement DLT also keeps track of all the currency units in circulation. This additional concept introduces the next section on the functions of money. This idea refers to that, for example, in Bitcoin exchanges, not only are transaction records made public to all participants supporting the Bitcoin network, but the transaction records keep track of individual transactions against the total amount of Bitcoin tokens in circulation. The blockchain system supporting Bitcoin has the information of all of the Bitcoin in circulation.

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Section 3: Brief History of Money and Monetary Functions

The aim of this section is to give a panoramic overview of the history of money and introduce the functions that money serves. Money is a large topic, with intimate relevance to most of us, hence this section serves to help us to understand the new innovations in monetary systems made possible by cryptocurrency. Recall that cryptocurrency is one application of blockchain, which is one means to implement distributed ledgers. We focus on the use of DLT and blockchain to generate community cryptocurrencies.

Money developed as a means to conduct trade more easily. Pre-historic peoples, who lived before 1200 BCE, initially traded goods either as a form of gift-exchange, some type of debt obligation, or by barter. Barter is the closest form to contemporary monetary exchanges. This is because it involves two goods being traded having equal value. Barter evolved into a form of exchange we now refer to as **"commodity money."** This is relatively simple. Certain goods needed by everyone, such as basic food substances like grain, have a value to everyone.

Thus, some items could be routinely used for exchange. These needed to be easy to carry around and store. The complexity of finance even in the ancient world is evident from the Code of Hammurabi. This is the Babylonian text dating from 1755-1750 BCE, carved into a stone pillar of basalt for Babylonians (see Horne, 1915). This code discusses the obligations of debtor to creditor, and the forms of acceptable payment. Payment could be in kind (giving back what one took, or a replica), an item of common value, such as an animal, or in terms of labour.

"Olaus Magnus - On Trade Without Using Money." Source: https://commons.wikimedia.org/wiki/File:Olaus_Magnus_-_On_Trade_Without_Using_Money.jpg

Part of the code of Hammurabi. By John Ross. Source: https://www.flickr.com/photos/37351539@N05/3681068075/

The forms of commodity money that developed historically were easy to exchange, and could be in the forms of gold, silver, barley, or shells. Coins, as a form of money, are dated to 500 BCE, and there is evidence they developed in three cultures: Lydia, India, and China (see Heymans, 2021, p. 4). The invention of money is argued to have had a revolutionary effect on social relations, and on the ability of cultures to advance (Heymans, 2021). The early invention of coins shares with cryptocurrencies that they served a particular function to the specific communities using them. Early coins did not have universal value in themselves (although the substance of which they were made held value as a commodity, with value in use), but coins developed within communities as a means of payment. As such coins were issued by a sovereign who stamped an identity into an otherwise amorphous piece of precious or semi-precious metal. They could have different denominations, for example, 1-unit and 10-unit coins.

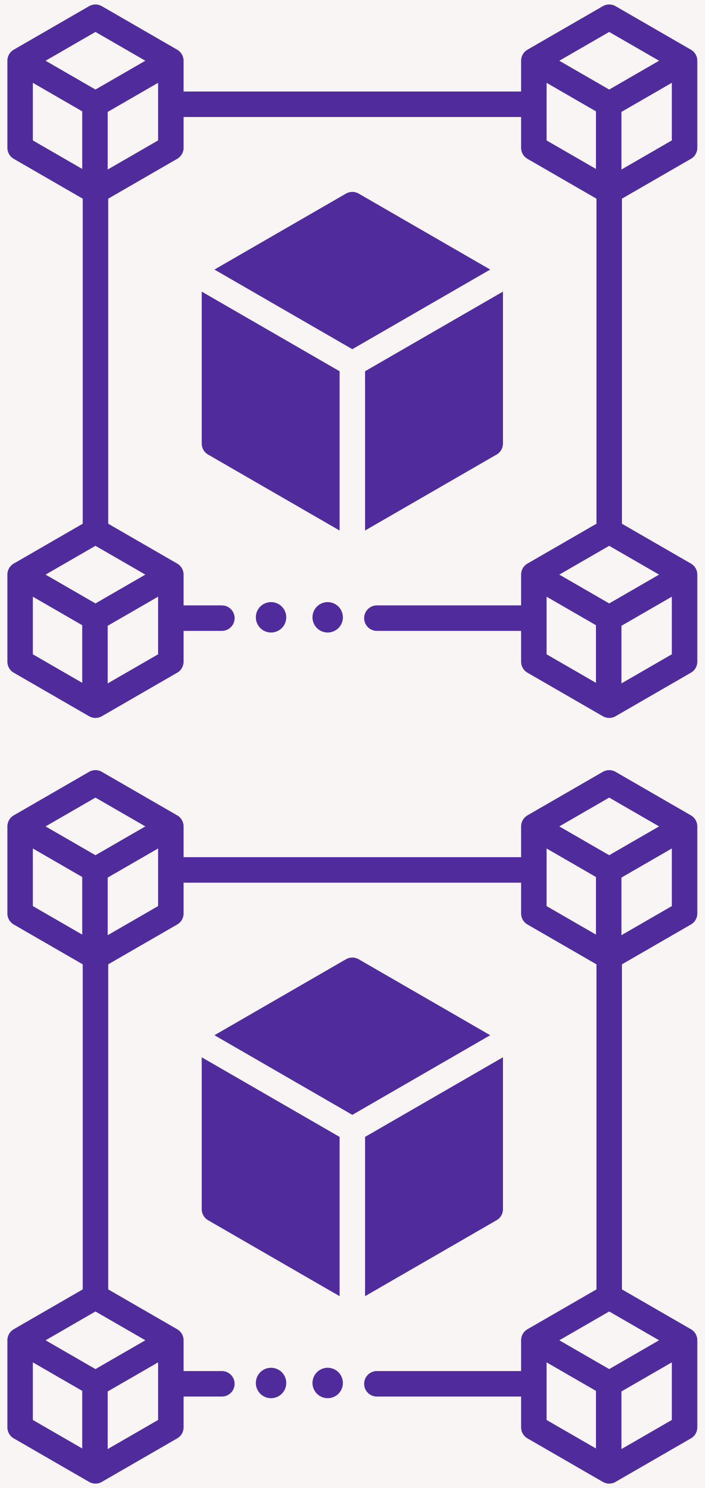
The first known example is attributed to the King of Lydia, in roughly 600 BCE, who established the Lydian stater coin. Early coins had value in terms of the precious metals they were made of, but acquired an additional value from being state-sanctioned. The coins' minting by the sovereign, with the sovereign's imprint, served to guarantee that their composition was of the appropriate quantity of precious metals.

Ancient Lydian coins made of electrum, a naturally occurring mixture of silver and gold. Source: Classical Numismatic Group, Inc. http://www.cngcoins.com, CC BY-SA 3.0 <http://creativecommons.org/licenses/by-sa/3.0/>, via Wikimedia Commons.

This invention had the advantage of providing a means to trade value with three functions that are now defined to be characteristic of money. Money plays three roles: as a medium of exchange; a unit of account to measure value; and a store of value that does not deteriorate over time. The first forms of money as coins had an intrinsic value due to their substances. Over time a derivative form of money developed that strictly had value because it was backed by a sovereign. This is the paper form of money we are familiar with today.

Paper money obviously does not have intrinsic value, as do coins made out of precious metal. Since their invention, first attributed to Chinese authorities in the 13th century CE, paper notes have gone from being backed by precious metals to merely having value “by fiat.” This phrase “by fiat” refers to holding value by law, and in principle means that these notes can be used to pay taxes levied by the sovereign government. As well, when owed money as a creditor, and needing to take a debtor to court for failure to replay a loan (which is evident in the Code of Hammurabi), the law stipulates that these paper notes minted by the sovereign government must be accepted as legal payment of debts. Up until 1971 the US dollar was backed by a gold standard. This meant that the up until 1971 holders of US dollars could trade their paper dollar bills for gold. After 1971 only faith in the value of the US dollar maintains its value globally.

Money has become increasingly abstract, evidenced by the transition of coins made of valuable metals to global currencies backed by faith and the sovereign's decree that it be used to pay taxes and debts. It can be hard to pin down the source of its value, other than by referring to its value lying in the faith in its value. Today, monetary sums are often exchanged digitally, without a physical record of transactions in the form of physical money. Despite this abstract quality of the value of money in today’s economy, it enables global trade and makes advanced commerce possible.



In this chapter we have focused on DLT, blockchain, and cryptocurrency as a possible next step beyond the historical barter systems and fiat monetary systems combined with double-entry bookkeeping to a new generation of functions. Recall the three functions of money: medium of exchange, unit of account, and store of value. It must be limited in supply because it tracks the value of rival goods.

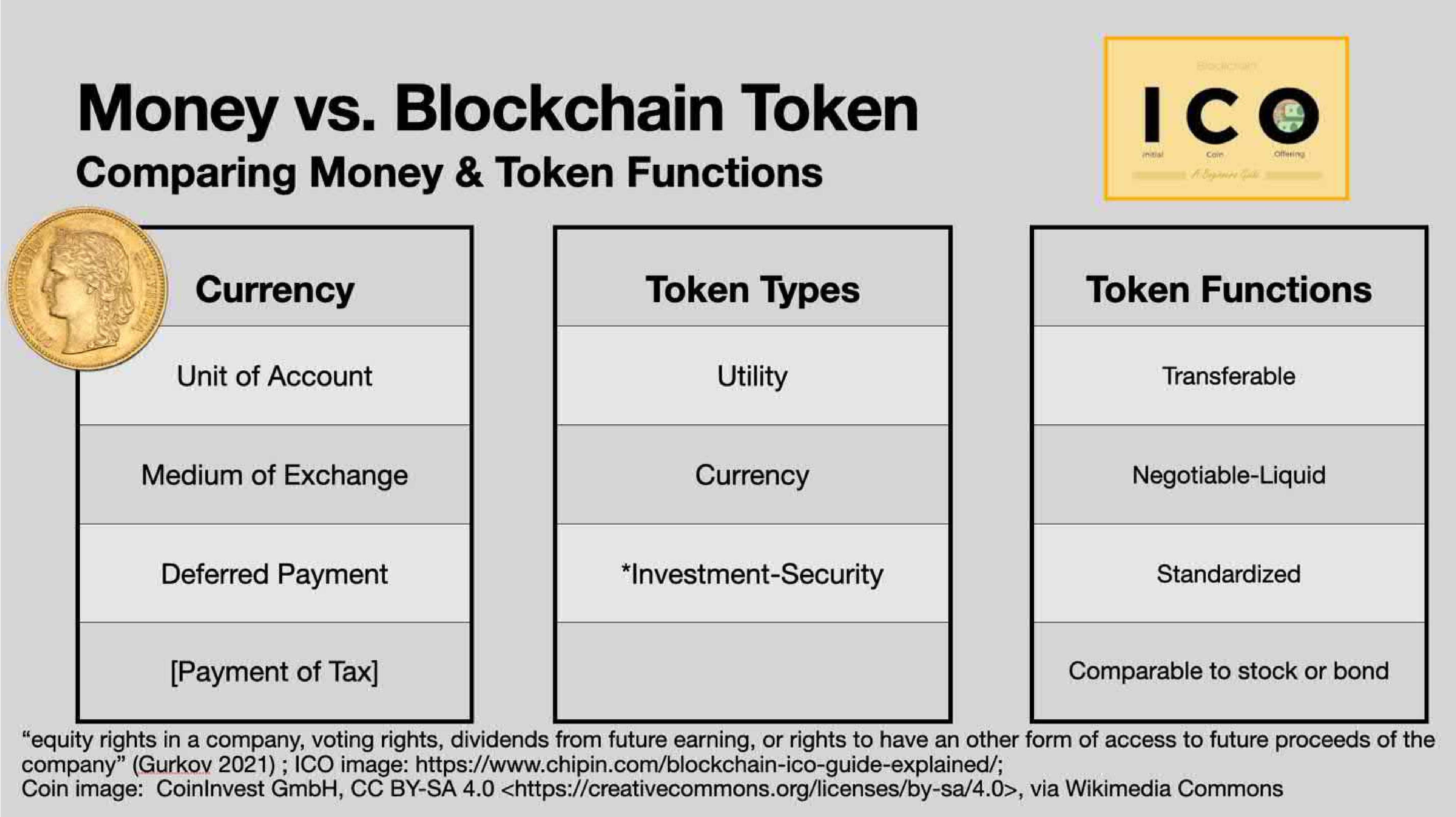
For more information, see "Money creation in the modern economy": https://www.bankofengland.co.uk/quarterly-bulletin/2014/q1/money-creation-in-the-modern-economy

Consider also the properties that money must have to serve these functions. It must be durable in order to serve as a store of value. It must serve as an acceptable payment, which is enabled by the sovereign law backing it up as legal tender to repay debt. It must be portable so that people can take it with them to buy goods. As well it must be fungible, which we studied in Chapter 3. This means it must be divisible with uniform indistinguishable units.

When we consider cryptocurrency, and Bitcoin as the best-known example, it can function as a medium of exchange, a unit of account, and a store of value. It is durable so long as digital systems continue to exist. It is portable because people can have access to payment over virtual connections. Bitcoin is also designed to be fungible. If it were not, each of its units would be unique and distinguishable from another unit.

We conclude this section considering the broader range of functions of cryptocurrency. Cryptocurrency exists as blockchain tokens, for example, such as one unit of Bitcoin. The key point is that cryptocurrency can serve more complex purposes than standard physical money, or even its digital representation that we currently use.

The figure on the right compares the functions of standard physical and digital currencies against the contemporary expansion of monetary forms to cryptocurrency blockchain tokens. A token is one unit of the blockchain currency. The left column represents standard currency. Remember that money is defined to serve the functions of unit of account, medium of exchange, and store of value. Its acceptability is supported by the sovereign state that issues the currency as a means to pay tax. Examples are the euro, the US dollar, and the UK pound sterling.



Cryptocurrency tokens as they have come to be used in the 21st century can also serve the functions of holding utility, serving as a currency (with all of those functions), and serving as an investment security. Due to the programming that makes cryptocurrencies possible, they can have added functions made possible by their executing code. (The latter relates to operational function as “smart contracts,” which is not explored here.)

The new functions of cryptocurrency expand how money could be used in the future. Returning to the first section of this chapter, this is because a blockchain is updated by consensus across all participating nodes, and has a high level of security guaranteeing the accounting information it contains.

In summary, cryptocurrencies can serve a function of utility, which means that they can serve as a ticket for a particular kind of good only offered to holders of those tickets. Thus, it could serve as a membership pass, or access to an event. Cryptocurrency can serve all of the functions of a traditional currency, and there is speculation over how popular a nationally backed cryptocurrency could be. China released its digital Yuan in January 2022, leading to speculation over its further development as blockchain, which is not yet the case (Raud & McKinnon, 2022). Cryptocurrency can also serve directly as an investment tool, operating as a investment stock.

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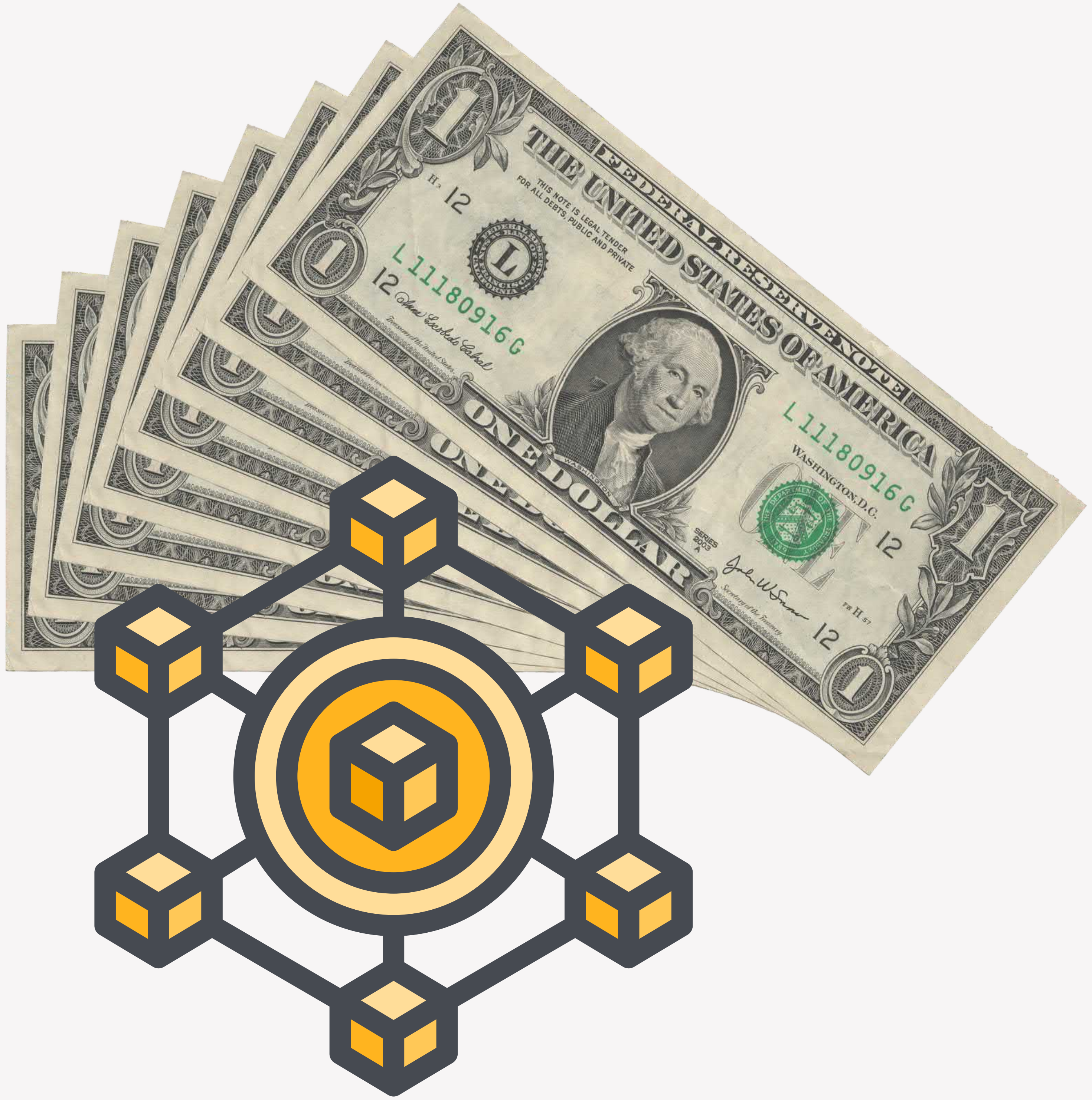
Section 4: Positive Externalities, Anti-rival Goods, and the Tragedy of the Commons

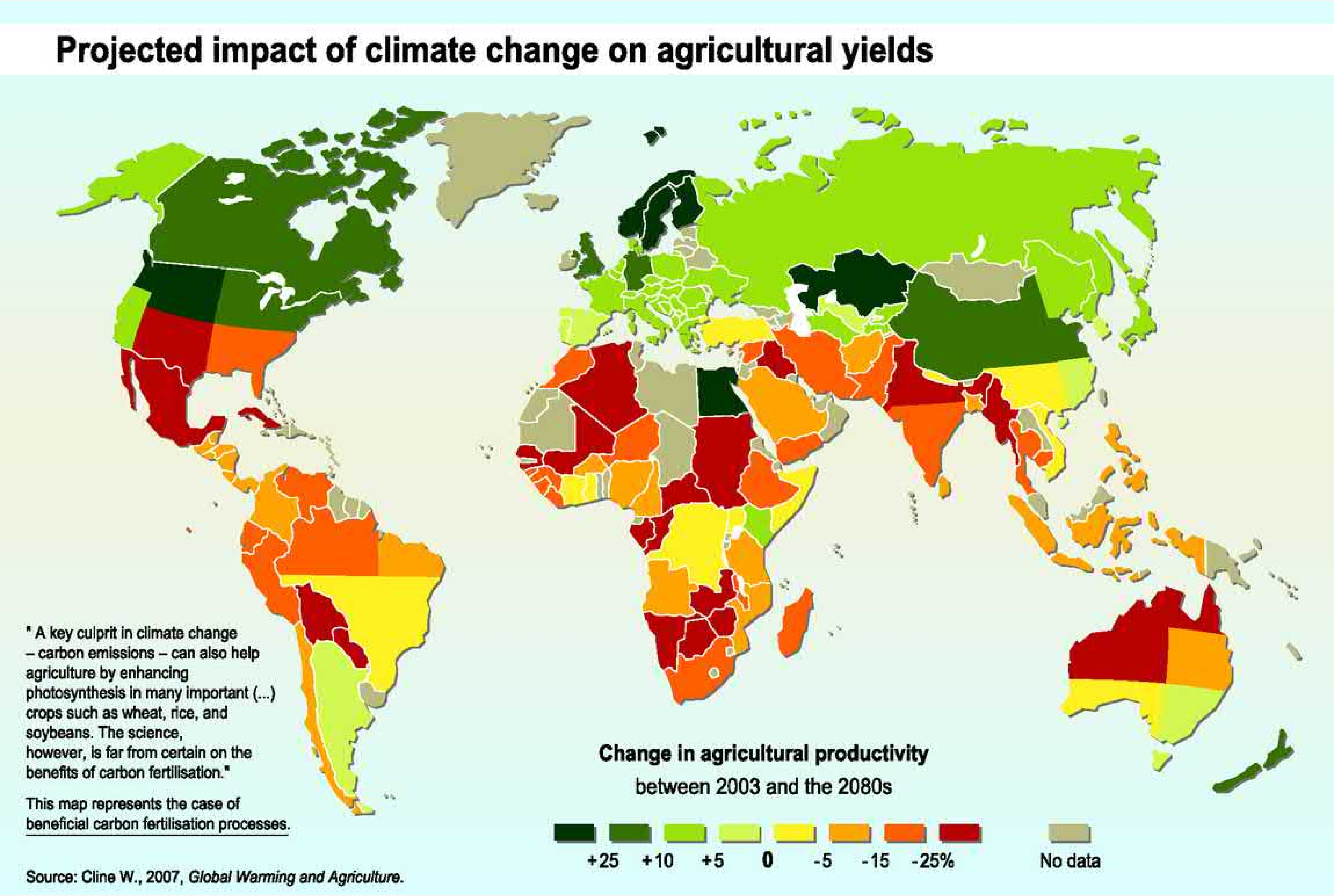
DLT, blockchain, and cryptocurrency are revolutionary new ways to maintain financial records, circulate currency, and give new functions to tokens (formerly coins or bills in standard monetary systems). We have discussed the advantages of the new currency systems. Their ledgers can be decentralised, and simultaneously updated by consensus on the ledgers kept by all participants. They provide a secure way to maintain currency systems due to the blockchain technology: once one block of transactions has been mutually confirmed and updated by all participants, it cannot be altered. Finally, the currency units—tokens—can serve many more functions.



We now go more deeply into the additional types of functions made possible with blockchain tokens. Blockchain tokens have all of the functions of standard money: unit of account, medium of exchange, and store of value. Leaving aside their potential new function as an investment tool (such as a share of stock), we focus on their additional utility function: they can be offered to give access to a particular good or service that only holders of the token can obtain. Blockchain currency systems can be tailor-made to serve the needs of particular communities. Those communities can determine which functions the tokens of their currency should have.

To link the use of blockchain as a community currency to the major theme of this book we can ask: how do we solve the environmental tragedy of the commons?

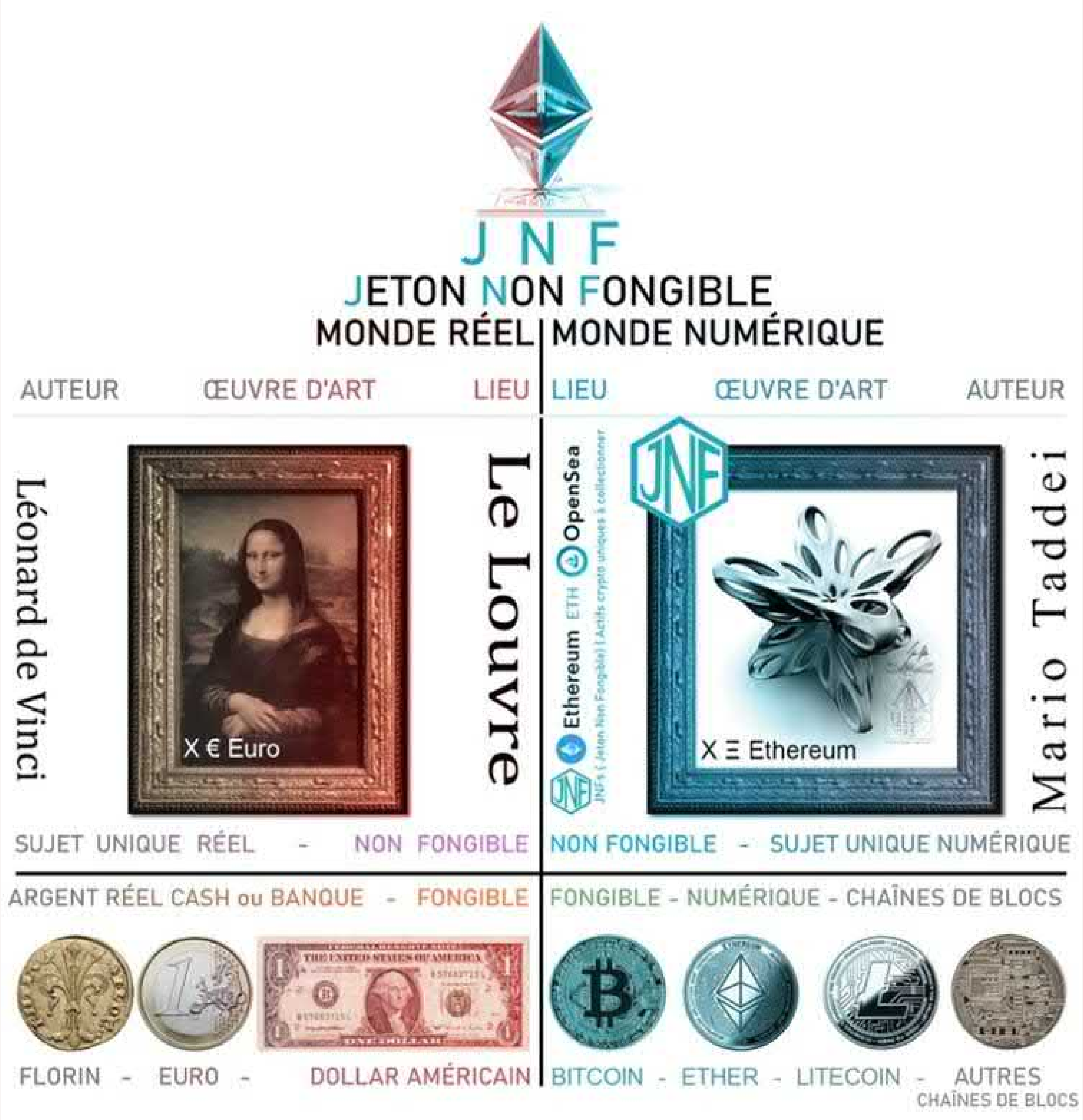
We return to the concept of externality. Negative externalities are those harms to bystanders that can arise from the exercise of private property rights. One example is air pollution, through excessive GHG emissions. Positive externalities are those that benefit bystanders, such as how a public education system makes everyone in that society better off.



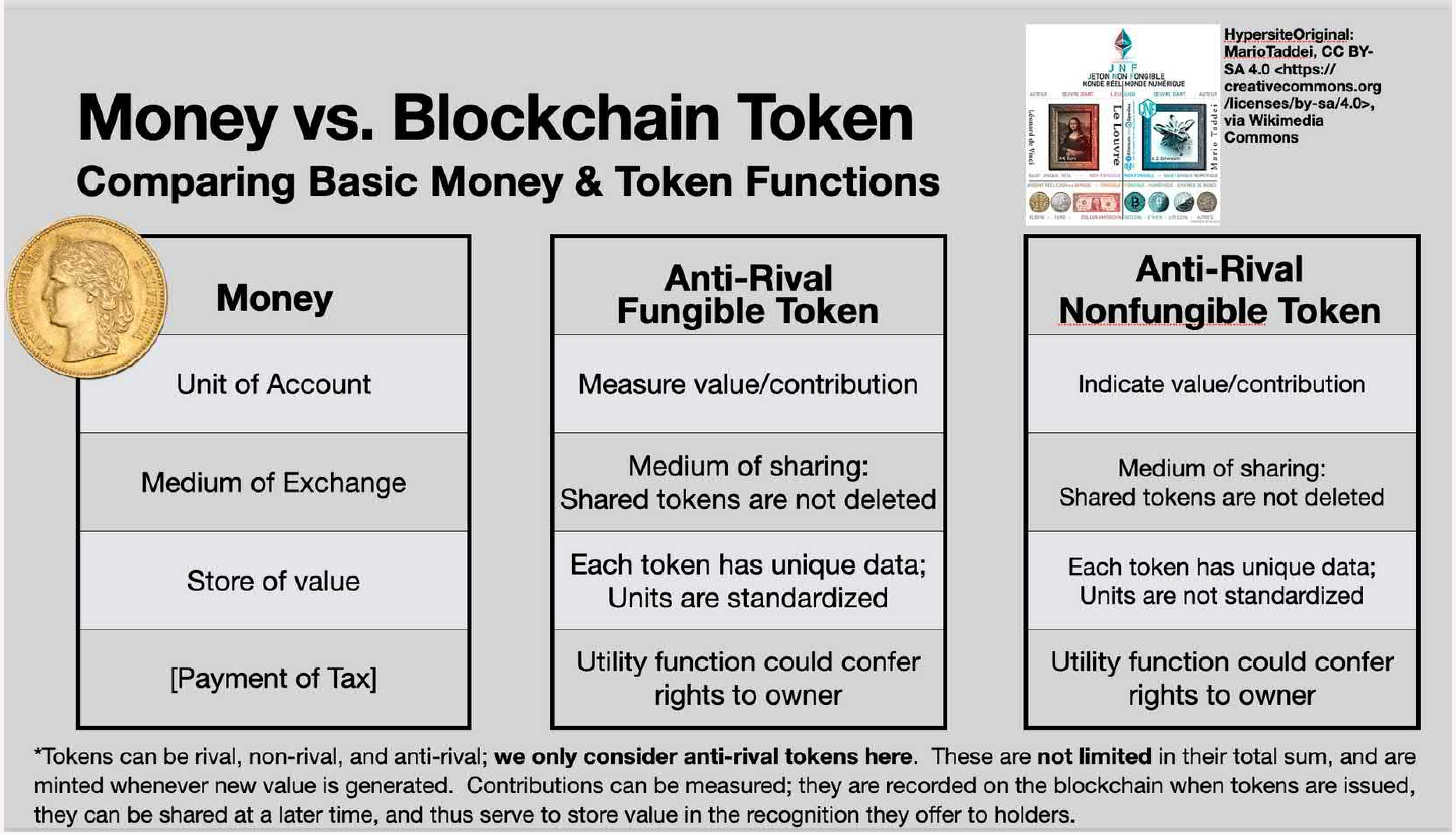
Disparate impact on agriculture across the globe projected from 2003 to 2080. This is based on predictive modeling and shows differential impact of climate change; greener areas may benefit (note projected impact on the Nordic region), and those marked red may suffer from decreasing agricultural productivity. Source: European Environmental Agency. https://www.eea.europa.eu/data-and-maps/figures/projected-impact-of-climate-change/trend09-1m-soer2010-eps

As we discussed in Chapter 6, externalities are often anti-rival in their impact on bystanders. The example related to the defacement of public property demonstrated this property of an anti-rival negative externality. Excessive greenhouse gas emissions, at least until the time when we have achieved net carbon neutrality and capped the total amount of atmospheric CO2e gasses under the 1.5°C threshold, also exists as an anti-rival negative externality. This is because, for example, when individuals and corporations in developed countries have high carbon footprints, not only are members of their nations confronted with dangerous weather conditions, but so are citizens of developing nations who are already more vulnerable.

Given the anti-rival nature of the harms produced by excessive GHG emissions, especially because they place us on a trajectory to an unsustainable environment, we can see that reducing GHG emissions is an anti-rival positive externality. This is much like in the case of defaced public property, everyone benefits when the damage caused is repaired. Recall that standard money serves as a medium of exchange of market goods. These are scarce, rival, and subtractable. To serve as a medium of exchange for rival goods (what one person owns, no one else can own), money must also be scarce, rival, and subtractable. However, given the new functions of cryptocurrencies, tokens can be designed to circulate and record anti-rival value, as well as rival value. This means that anti-rival cryptocurrency tokens can be designed to measure, record, and validate the generation of anti-rival positive externalities.



Conveys different types of currency, including one-of-a-kind, non-fungible Ethereum tokens. Source: HypersiteOriginal: MarioTaddei, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons



Before discussing how this measure, record, validate system works in the Food Futures App with Foodprint tokens, consider the range of functions that cryptocurrency can have. The table on the left illustrates these new functions.

We are now combining the concepts of anti-rival goods and cryptocurrencies created to serve the function of tracking the value of anti-rival goods. Traditional currencies only track the value of scarce and limited goods. They have a limited supply. When we consider anti-rival value, this is unlimited, and the more it increases, the more of the anti-value is generated. As an analogy related to our example, imagine if it were possible to track all of the times passersby were not disturbed by damage to public property because it had already been repaired: the total amount would keep growing every time a person looked at the building. Cryptocurrency makes it possible to develop a system to measure, record, and reward these contributions of positive externalities.

To understand the power of cryptocurrency to keep track of how value circulates in a community, consider an abstract example based on vaccine distribution, and the concrete example of Food Futures. Imagine a cooperative effort to develop a vaccine for a new disease. If this vaccine were to be open-sourced, it would need crowdfunding where many participants join to give relatively small amounts of capital. In order to avoid being an investment with an Initial Coin Offering (subject to regulation), people who contribute could be given a Vaccine Fund Token for contribution—these could be fungible, reflecting the amount of this contribution, or non-fungible, reflecting any threshold amount set by the community. These tokens could then later serve the function of giving contributors access to the vaccine, once developed.

Vaccine distribution and take up provides positive externalities in helping everyone in a community jointly to achieve so-called herd immunity and to collectively suffer less harms from an illness that could otherwise be devastating.

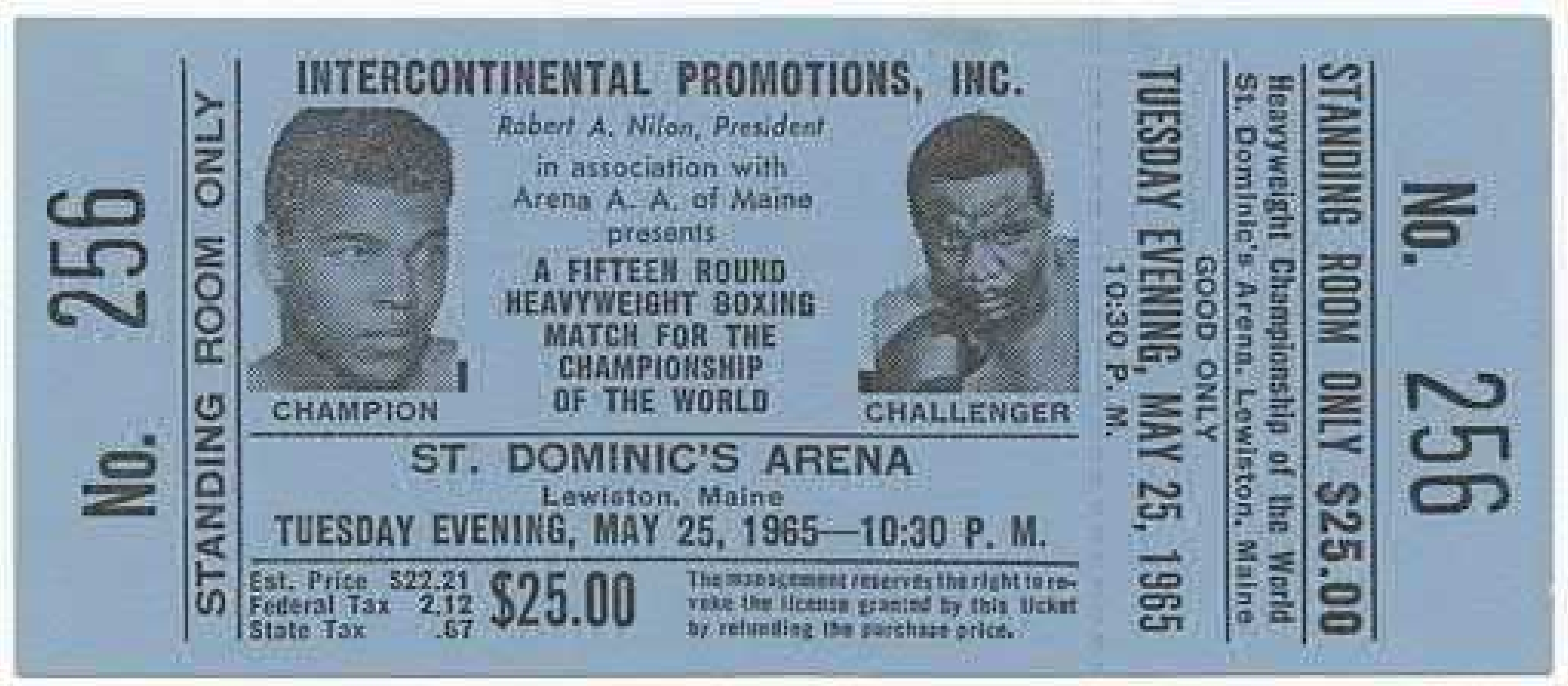
Source: "Congresswoman Mary Scanlon has partnered with Rite Aid and Union Memorial Church in Darby to host a COVID-19 vaccine clinic," https://yeadonborough.com/one-day-vaccine-clinic-in-darby-wednesday-march-31/

The Food Futures App with Foodprint token balance.

Food Futures developed the cryptocurrency Foodprint token. All tokens are on a spectrum from being fully fungible, like money, to each token being wholly unique, such as contemporary non-fungible tokens representing artwork (see Mitchell, 2022). Foodprint tokens are fungible in the sense that they are issued in denominations and can be aggregated. They serve to measure, record, and reward individuals' contributions of the positive externality of lessened CO2e emission. The Food Futures index provides data on the relative sustainability of meal choices. This enables Food Futures App users to have information about the sustainability impact of their meal selection. By validating a meal selection, that choice and its impact is recorded into the blockchain system. The blockchain system then issues cryptocurrency Foodprint tokens that serve to recognise individuals' meal selections, as well as the sustainability impact of those choices. This is how the Foodprint community currency operates to measure, record, and validate the value of the positive externalities contributed by Food Futures App users.

In the future, the Foodprint tokens can be shared for donated surplus items. These are non-rival in the sense that they are surplus, and would go to waste if not used. Examples are magazines that would be destroyed if they do not sell, or tickets to cultural events that result in empty seats. The concept is that, using participants' input, an anti-rival sharing space would be developed that would offer donated surplus items on a shared basis for Foodprint tokens. These might be issued through a lottery, first-come first-serve, or an auction system. The key aspect is that possessors of Foodprint tokens received through the measure, record, validate system would share tokens: they retain a permanent record of the kilograms of CO2e gasses not emitted, and share their token with the donor who would then be able to show their Foodprint token account balance publicly to show how many kg of CO2e gas they donated goods to recognise and sponsor.

This system acts proactively. Rather than the cap and trade system that promises an offset after the negative externality has been committed, in Food Futures, the positive externality may be recognised subsequently.



Example of a ticket to a cultural event. Source: Public Domain, accessed https://www.lookandlearn.com/history-images/YSH000712/Ticket-for-boxing-match-between-Muhammad-Ali-and-Sonny-Liston

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Section 5: Conclusion—Using Tools to Construct 1.5°C Lifestyle Individually and Collectively

As you can tell from the amount of press coverage blockchain tokens from Bitcoin to NFTs are getting in today's media, DLT, blockchain, and cryptocurrencies are ready to revolutionise money and accounting practices (see Tett, 2022). But there is a more orthodox and more revolutionary way to understand their innovative potential.

Source: Stably https://medium.com/stably-blog/history-of-money-and-currency-in-the-world-5942b3554f5f

The more mainstream interpretation of the breakthrough of cryptocurrencies is that they can substitute for normal anti-rival money. In the Stably blog, from which the image on the previous page was copied, the history of money we discussed in Section 2, included commodity money, money as precious metals, paper money with and without backing of precious metals, digital money forms, and cryptocurrency. Stably is a particular kind of cryptocurrency that holds its value and is backed by precious metals. This backing is designed to overcome a major problem with rival cryptocurrencies: their values can move up and down in extreme variations. Stably refers to other obstacles in the widespread adoption of cryptocurrencies: their difficulty to use, difficulty of denominations that scale to large and small transactions, and resistance from well-entrenched financial corporations and practices (see Stably, 2020).

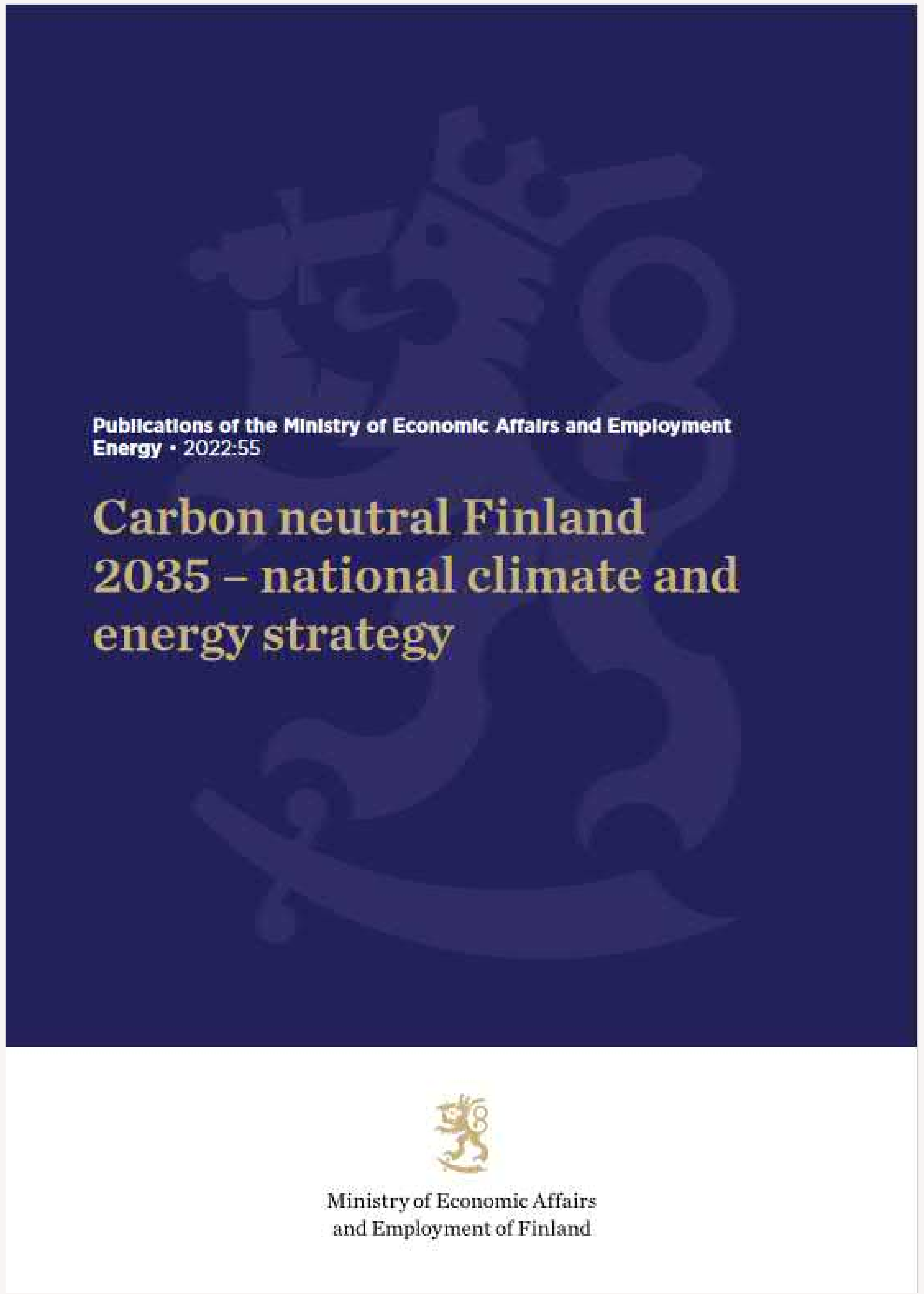
These standard obstacles to the development and application of cryptocurrency do not apply to Food Futures and the Foodprint token because this is a cryptocurrency developed initially within partnership with Unicafe in Helsinki, Finland. Food Futures takes advantage of the ability to create a local currency with particular functions. A more visionary view is that cryptocurrency may offer a means to empower individuals to exchange and share value in local networks (see Laurin, 2018). The advantage of these local networks is that they keep value within the network, instead of perpetually extracting units of resource to accumulate at the top of the socio-economic pyramid of wealth.

Stably cryptocurrency representation.

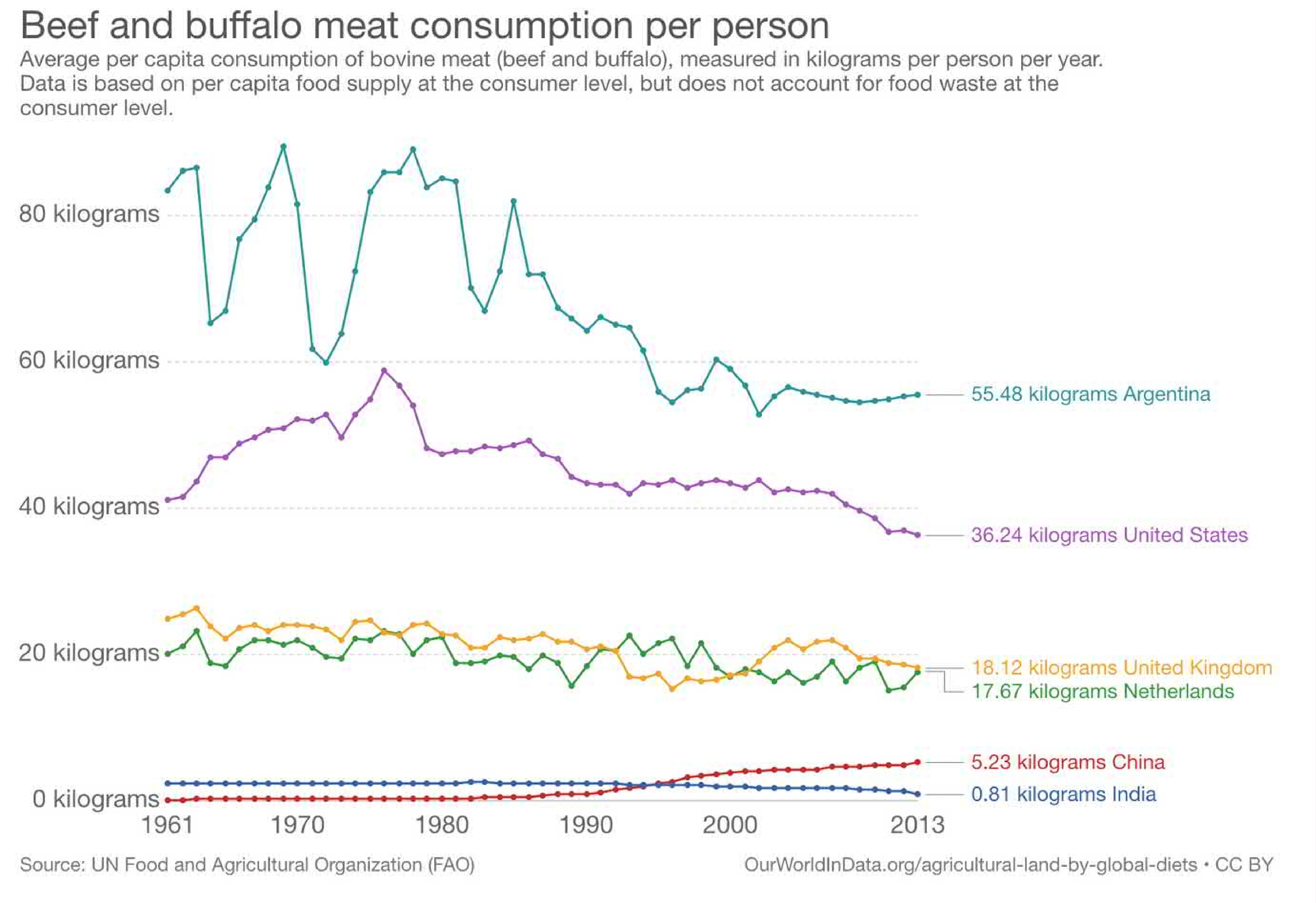
Source: Image from https://kemlaurin.medium.com/the-graeber-effect-the-rise-of-the-barter-economy-the-death-of-bs-jobs-ee6f9fd17add

We close Chapter 7 and this book on sustainable consumption, by bringing together the themes of the global environmental tragedy of the commons, positive externalities, and Elinor Ostrom's design principles for polycentric governance. Additionally, the breakthrough technologies of DLT and blockchain community currencies provide a tailor-made way to measure, record, and reward positive externalities. Chapter 4 pointed out that agents have different motives. Some actors may seek to use as many resources as possible, despite how this affects everyone else. Some actors may prefer to cooperate with others, but worry that they will be taken advantage off. Even more significantly, most of us probably realise that even though consumers are sovereign and generate market demand, no single consumer can change runaway greenhouse cases by changing personal consumption patterns.

Finland has the stated public policy goal of achieving net carbon neutrality by 2035. This is a statement of the democratic will of the Finnish people. Yet we know that the Finnish per capita carbon footprint is currently about 8 metric tonnes. Diet is the easiest set of consumer choices to change with respect to the technological innovation required (as opposed to transportation and the energy sector). Two percent of Finns are reported to be vegan, and thus consume food in the most sustainable way. An additional 10% are vegetarian.To give an idea of the change in consumption patterns that could add up significantly, Finns could reduce their meat consumption to avoid imported beef products, which are currently approximately 4 kg/person annually; and they could reduce cheese consumption by half to 12 kg/person/year. At its lowest feasible number, producing one kg of beef emits 19 kg of CO2e gas; 1 kg of cheese emits 13 kg of CO2e gas. Given the per capita numbers, this reduction in consumption would come to 0.4 million metric tonnes less for beef consumption, and 0.86 million metric tonnes less for cheese consumption, for a total of 1.2 M metric tonne reduction annually. This is a modest shift that helps restore net carbon neutrality for land use in Finland, which currently has a carbon footprint of approximately 2.2 M metric tonnes per year.



Source: https://julkaisut.valtioneuvosto.fi/handle/10024/164323



Source: Our World In Data, CC BY 3.0, <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons.

Dietary change, while the easier to achieve technically, meets resistance because supply chains and individuals' habits are entrenched. Producers do not have a motive to alter their products unless consumers' demand patterns change. Yet consumers have little motive to alter their dietary habits because each, acting alone, cannot make a difference. The common pool resource of the atmospheric commons thus faces collective tragedy as individuals' consumption patterns produce negative externalities of excessive CO2. The heavier carbon footprints are those of consumers in advanced capitalist societies with more money to exercise consumer sovereignty.

However, if citizen consumers value a 1.5°C lifestyle, which many reportedly do, then we can build voluntary virtual communities to realise this goal. Steps on this path include the steps taken in *Sustainable Consumption*: gathering data and information to make appropriate choices. We need a means to counter the tragedy of the commons, and the anxiety that none of us can make a difference alone. We can implement a means of measuring, recording, and validating individual contributions. Any reduction of CO_2 emissions toward the global goal of maintaining a 1.5°C temperature rise is surely as worthy of keeping track of as is the exchange of pennies for trivial consumer goods. These positive externalities that anti-rival cryptocurrency systems can measure, record, and validate, amplify to empower the individual and collective achievement of environmental sustainability and security.

Our final note is to point out the video explaining the new environmentally friendly way to mint blockchain tokens. Cryptocurrency and blockchain have received a bad reputation because the means of achieving security in updating the blockchain for Ethereum currencies was "proof of work." This required solving a mathematical problem requiring enormous computing power. However, in the new "proof of stake" method, those minting blockchain additions are recognised as providing valid updates because they have invested in the value of the cryptocurrency. See the video "Proof-of-Stake (vs proof-of-work) here: https://www.youtube.com/watch?v=M3EFi_POhps

Source: https://publicdomainvectors.org/en/free-clipart/Data-center-vector-illustration/13239.html

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CHAPTER 8
Conclusion

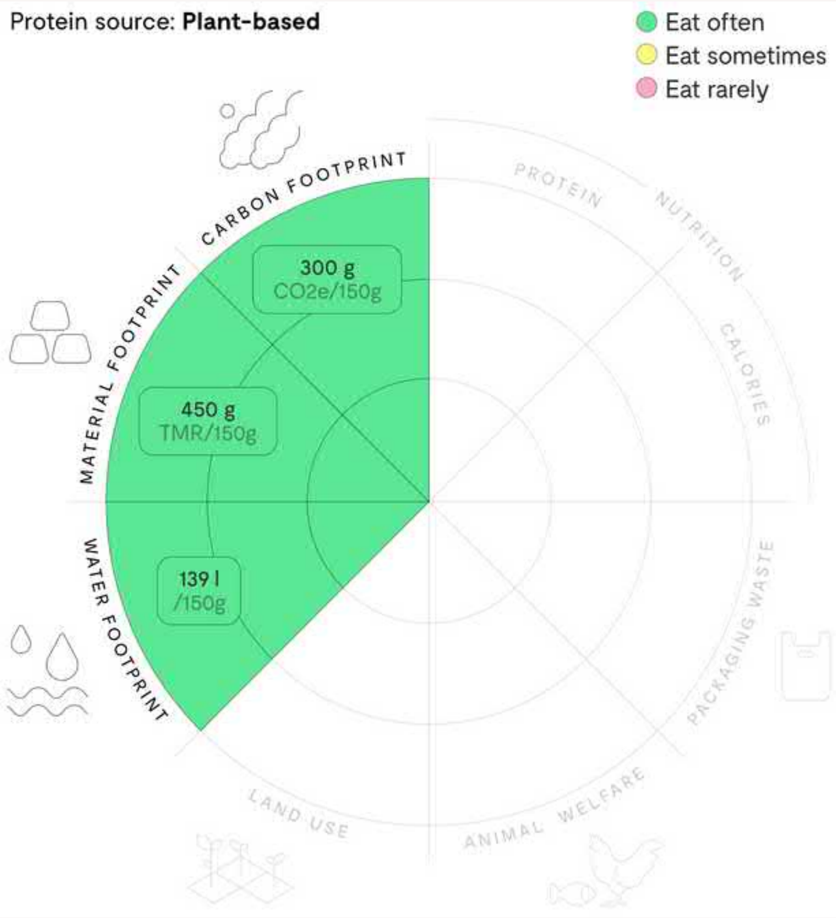
Book Summary

The western nations generally advocate individual determination and celebrate the freedom of individual choice in free markets with private property. However, we know this system fails to solve problems classified as “tragedy of the commons”: common pool resource dilemmas with finite resources and non-excludable access.

Despite the challenges common resource dilemmas pose, the West continues to propose that minimal market interference, in the form of taxation policies and cap and trade systems will be sufficient solutions. Evidence shows that so far, regarding climate change, Earth’s commercial systems and population demands are not heading toward net carbon neutrality by 2050. *Sustainable Consumption* has focused on the principle of consumer sovereignty: what consumers demand, producers produce.

If consumers do not make choices, and demand products consistent with a 1.5°C lifestyle, producers will not meet this market demand. And yet, individual consumers are actually powerless to make a difference on the atmospheric commons. Individual consumer-citizens may endorse the 1.5°C lifestyle, and other sustainable production systems, and still cannot individually have a relevant impact.

This book has combined contemporary analyses of the tragedy of the commons put forward by Garrett Hardin and Elinor Ostrom. These lessons result in an approach to common pool resource dilemmas that respect western freedom of choice, and also empower citizen consumers to individually and collectively realise a sustainable future. Specifically, while individuals cannot alone change global outcomes, communities can build systems to acknowledge individuals' contributions and to visualise collective impact.



The role of the Food Futures App has been pedagogic. This app shows how a distributed ledger system combined with community cryptocurrency can provide a means to measure, record, and validate individual and collective contributions.

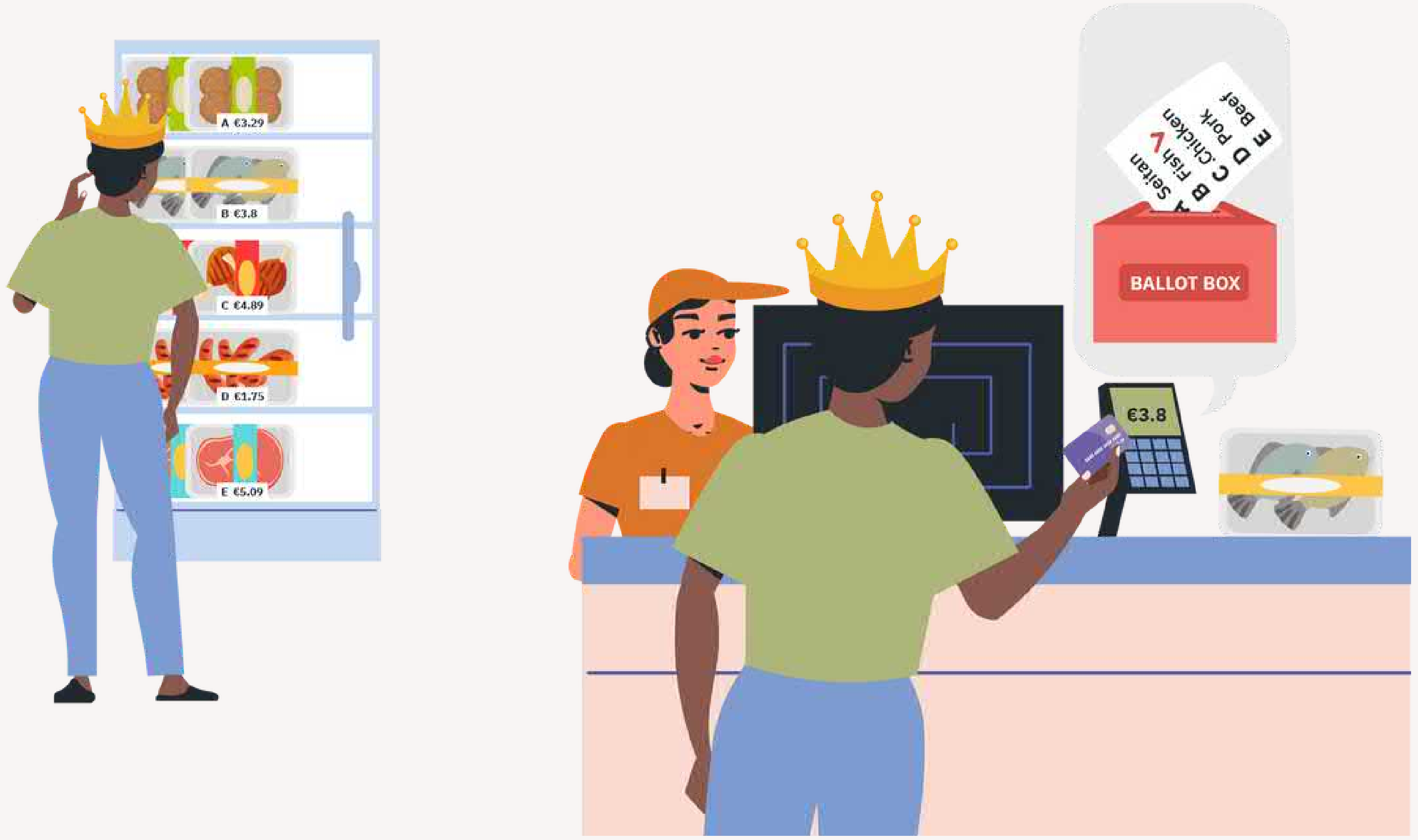
This approach is consistent with Elinor Ostrom's polycentric governance. Ostrom's design principles include identifying community members, incorporating their preferences and opinions, and recognising their contributions on a graduated scale. Many communities can develop similar strategies, and could also mint their own versions of Foodprint tokens directly related to CO2e (e = equivalent) abatement (and other sustainability metrics). This voluntary, opt-in governance structure can intersect and overlap with municipal, state, and national initiatives to achieve net carbon neutrality by 2050, or 2035 in the case of Finland.

Section 1: Introduction

The aim of Chapter 8 is to assemble all of the building blocks from Chapters 1-7. *Sustainable Consumption* integrates the Food Futures App on a voluntary, opt-in basis. The purpose of the app is to illustrate a means to achieve inclusive governance of the global environmental commons.

Three of our first course topics were **sustainable consumption, market freedom**, and **consumer sovereignty**. Western political economy has a lot of faith in market institutions to solve problems and generate a mutually prosperous future. However, we know from Chapter 4 that markets fail when common pool resources, such as the global atmospheric commons are at stake. One reason is that with the lack of private property rights, no particular individual or party is responsible for maintaining the sustainable use of these resources.

We briefly revisit these three interlocking themes to more completely motivate the use of anti-rival blockchain tokens to address global common pool resource dilemmas. Throughout this book, we have incorporated the Food Futures App as an illustrative practical example of how common pool resource could be collectively governed. This is so that we do not allow the enormity of the challenge to disempower us from participating in finding solutions and making sustainable choices.

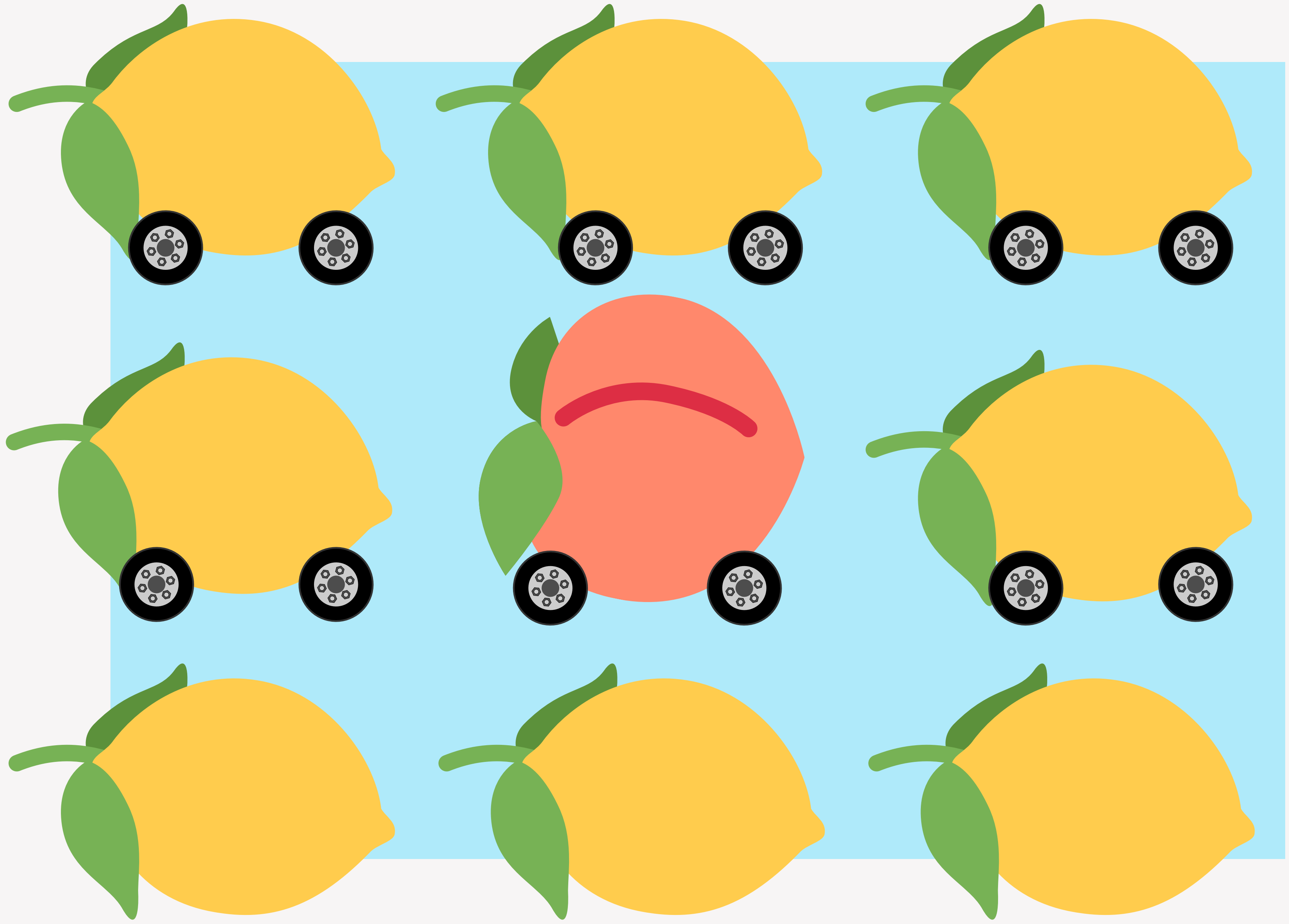


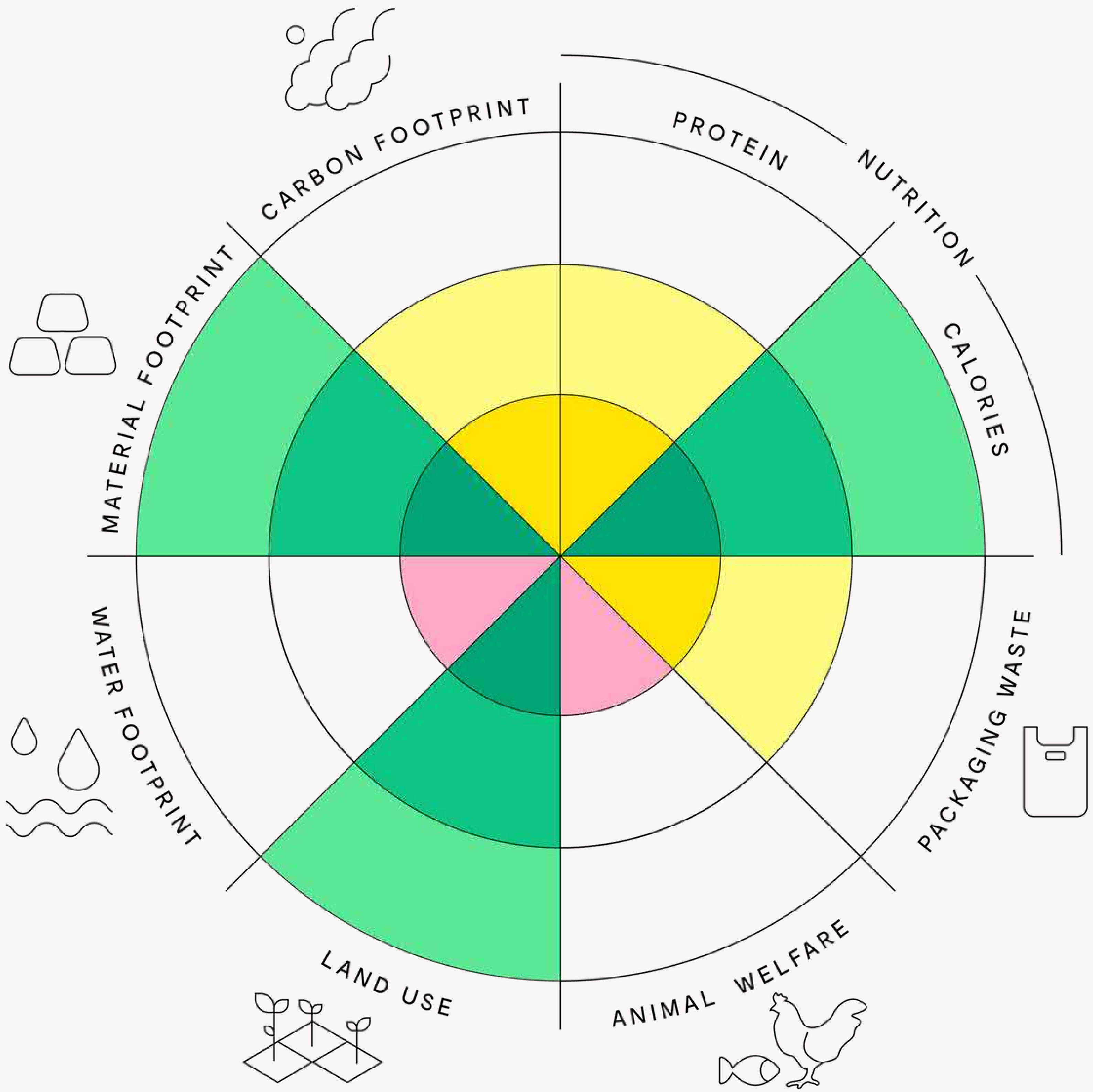
In order for the Earth to accommodate 8 billion people, and especially those in the advanced industrial countries with the high carbon footprints of up to, and even over, 15 metric tonnes per person annually, we must individually and collectively adopt sustainable consumption patterns. Our emphasis on free market solutions to social problems means that populations and corporations have little tolerance for government interference in markets, either by taxes or quota systems for production. Therefore consumer sovereignty, or individuals’ preferences, are a crucial force in shaping sustainable production patterns. What people want, expressed in market demand, producers supply.

Section 2: Data

Chapters 2 and 3 covered data and using it to build reliable information to help us make decisions. We covered the following topics in Chapter 2:

1. Perfect Information
2. Data
3. Mobilising Data to Understand Humans' Environmental Impact
4. Carbon Footprint
5. Visualising Actors' Carbon Footprints





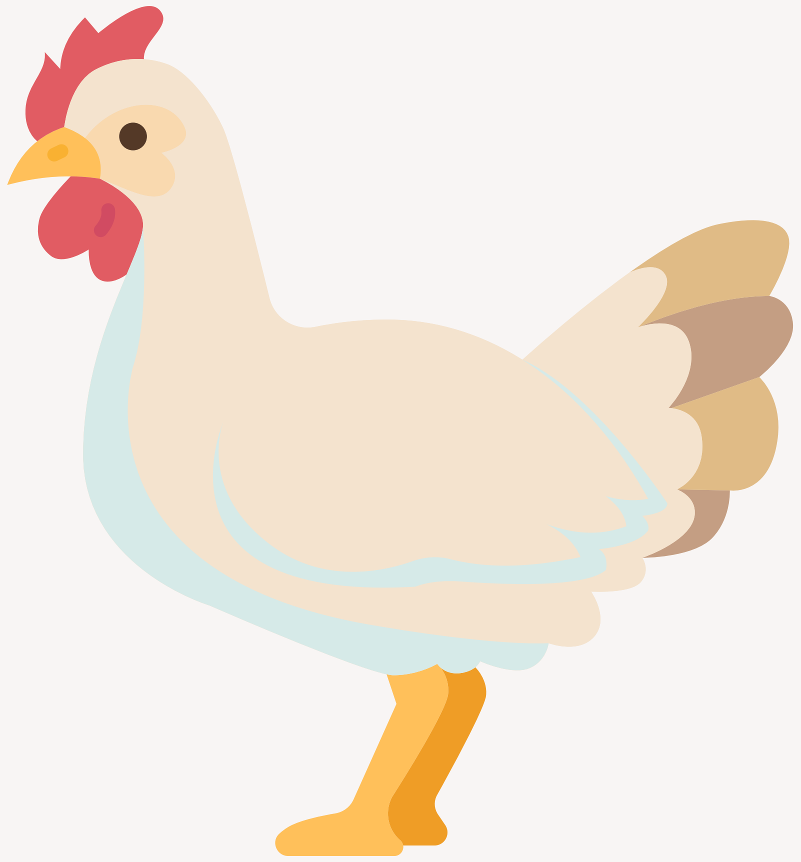
We can appreciate how the sections of Chapter 2 come together and build on Chapter 1. Faith in free markets depends on consumers' having **perfect information** about the goods they purchase. How can anyone make a good choice if they do not know the different options? Economists emphasise that a high level of knowledge is necessary for markets to effectively satisfy consumers' preferences. This includes all price and quality information about various goods, as well as their past and future prices.

Economists' ideal of perfect information is unattainable for most goods, especially given the impossibility of knowing future prices. However, the concept of perfect information reminds us how important it is to have reliable information on which to base consumer choice. This is especially the case if we rely on consumer sovereignty to make sure that producers produce what consumers demand.

Hence, we turned our attention to data. Data can be information about different sectors of life. Food Futures emphasises data about the sustainability impact of various meal choices. Raw data are the basic pieces of information that must be aggregated and systematised in order to produce reliable knowledge. We discussed **raw data** from natural phenomena, such as the number of rings in a tree. Data about natural phenomena is different from social science data about people, their interactions, and their groups.

Raw data about natural phenomena must be accurately recorded and is typically given labels including time, place, and size of the phenomena. Data can then be used in empirical induction. **Inductive reasoning** moves from individual cases to establishing general conclusions.

An example of raw data is recording the origin of chickens. Watch a group of chickens over a year and record every instance a new chicken is hatched. We discover that in all cases, a new chicken grew from a small chick that hatched from an egg. From all of our empirical observations, we thus generally conclude that chickens originate as chicks hatched from eggs.



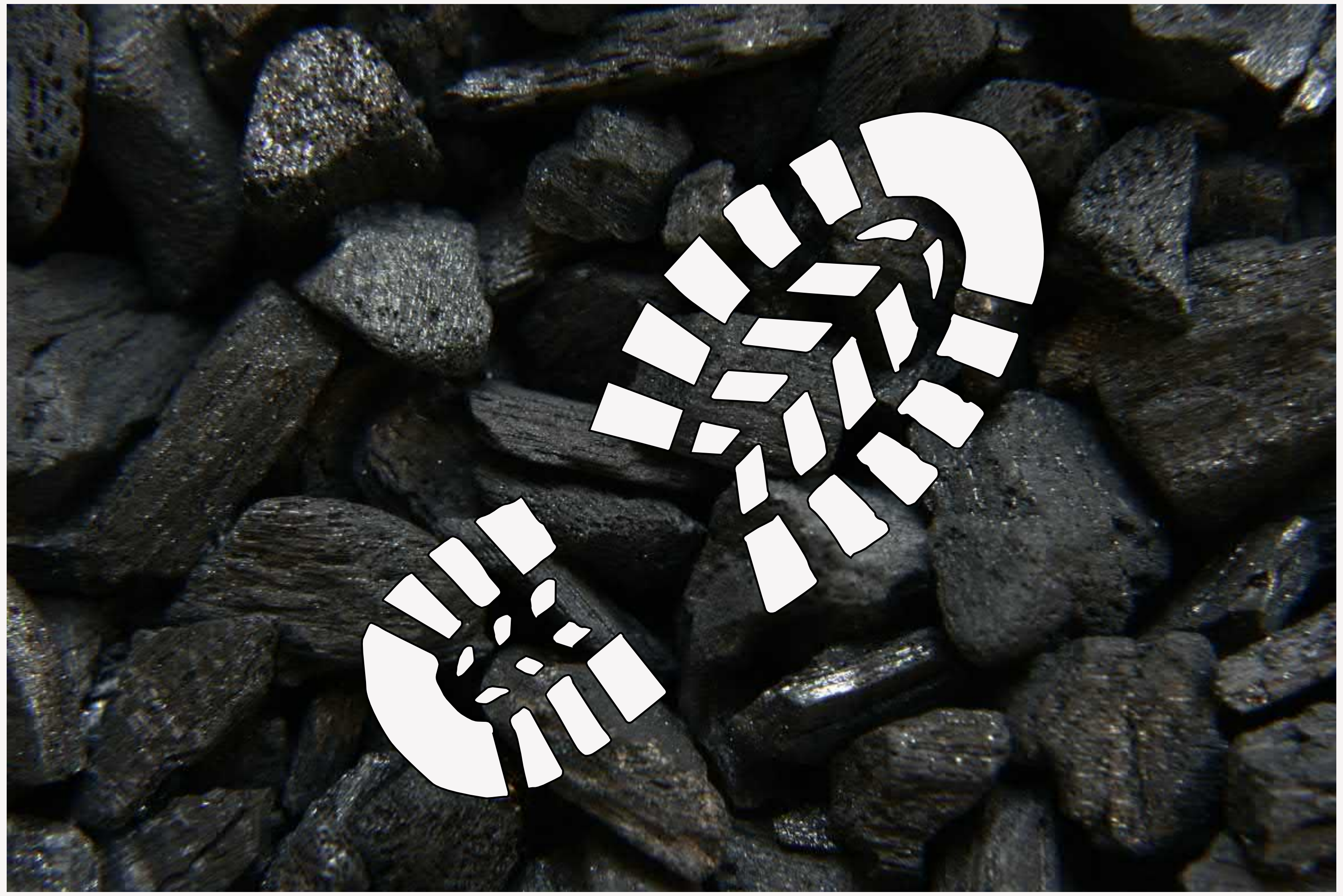
Deductive reasoning is built on a set of general statements (premises) that we hold to be true. Deductive reasoning moves from general principles to conclusions that apply to particular cases. We first establish general principles. For example, (1) water freezes at 0°C; and (2) snowflakes are comprised of frozen water. From these two premises, we can conclude that (3) snowflakes are 0°C or less.

Some conclusions are supported both inductively and deductively. Take, for example, our conclusion that when there is smoke, there is fire. We can support this inductively by observing repeatedly that when we see fire, we also see smoke (not vapor or steam). Therefore, we reach a general conclusion. We can also state the following premises: (1) fire is the combustion of a material; and (2) combustion has the byproduct of smoke (air with molecular traces of combusted material). We then conclude that (3) when there is smoke, there is fire (combustion of a material).

We turned our attention to mobilising data to understand humans' environmental impact. Specifically we focused on environmental data: the average surface temperature of Earth over centuries and millennia, and the concentration of greenhouse gasses in the atmosphere. We emphasised how complex it is to acquire and aggregate this data. Nonetheless, there is a wide scientific consensus on global historical data correlating the Earth's average surface temperature and the CO_2 in the atmosphere. Both are rising.

Next we stepped beyond the Earth's average temperature level increase and atmospheric CO_2 levels to consider actors' carbon footprints. The carbon footprint is defined as the amount of CO_2 equivalent (CO_2e) gas generated by a process, individual, group/nation, or activity during a length of time. This could be, for example, the carbon footprint of the agricultural sector of production for the globe. Alternatively it would be the per capita CO_2e footprint of citizens of a nation, such as India, Finland, and the US.

We concluded the chapter by visualising how much volume CO_2 occupies when released from combustion. We discovered that the weight and volume of gas both increase significantly when they are transformed into CO_2 upon combustion. Note that some carbon gasses, notably methane, are produced by other processes than combustion, and can have a much greater impact on trapping heat within the Earth's atmosphere.



Section 3: Data Analysis for Collective Action

In Chapter 3 we covered data in more depth, delving into aggregating data concerning people and groups of people. This included the following:

1. Aggregating Data: Fungible and Non-Fungible
2. 1.5°C Lifestyle
3. Carbon Footprint Targets for the Food Wellbeing and Sustainability Index
4. Material Footprint
5. Water Footprint

Source: https://www.wallstreetmojo.com/fungibility/

We began by considering data of different types of phenomena classified as either **fungible** or **non-fungible**. That concept refers to whether units of a substance of an entity are interchangeable and indistinguishable. We usually apply the term fungible to money and commodities such as barrels of oil that can be traded according to their units. One dollar can be exchanged for one dollar, one euro for one euro, or one barrel of similarly graded crude oil for another such barrel. We applied the concepts of fungible and non-fungible in Chapter 7 to cryptocurrency because in the realm of blockchain, tokens can be either fungible or non-fungible. Data about humans typically is classified in categories that are not fungible. This stems from the fact that people are not interchangeable, each is different, with unique DNA and life histories.Yet although lakes and humans are not indistinguishable or exchangeable, we can still count these entities.

Next, we introduced **the 1.5°C lifestyle.** This concept was built on identifying sustainable impact levels for people living on Earth, recognising that there are now 8 billion people, and each nation has its own sustainability impact. In order to prevent Earth's average surface temperature from rising more than 1.5°C, researchers have concluded that human activities should have a net zero carbon footprint by the year 2050, at the latest. Some countries have aimed to achieve this sooner. Finland intends to be carbon neutral by 2035. To achieve this, achieving net zero CO2e emissions for agriculture is important because this is technically easy, even if difficult due to entrenched dietary habits and production chains. We examined how in order to live a 1.5°C lifestyle entails frequently eating plant-based proteins, occasionally eating pork, chicken, and eggs, and rarely eating beef, lamb, and cheese products.

We covered in detail how the thresholds of "eat frequently," "eat sometimes," and "eat rarely" were determined for the **Food Wellbeing and Sustainability Index (FWSI)**.
To establish the sustainability rating of various protein sources, we projected the type of per capita CO2e footprint that would be generated by various protein source choices. The only protein source diet that is consistent with a carbon neutral lifestyle is one that mainly adopts plant-base protein products. We discussed how the FSWI classifies pork as red, even though it is relatively less CO2 emitting than either cheese, or beef (and also lamb).

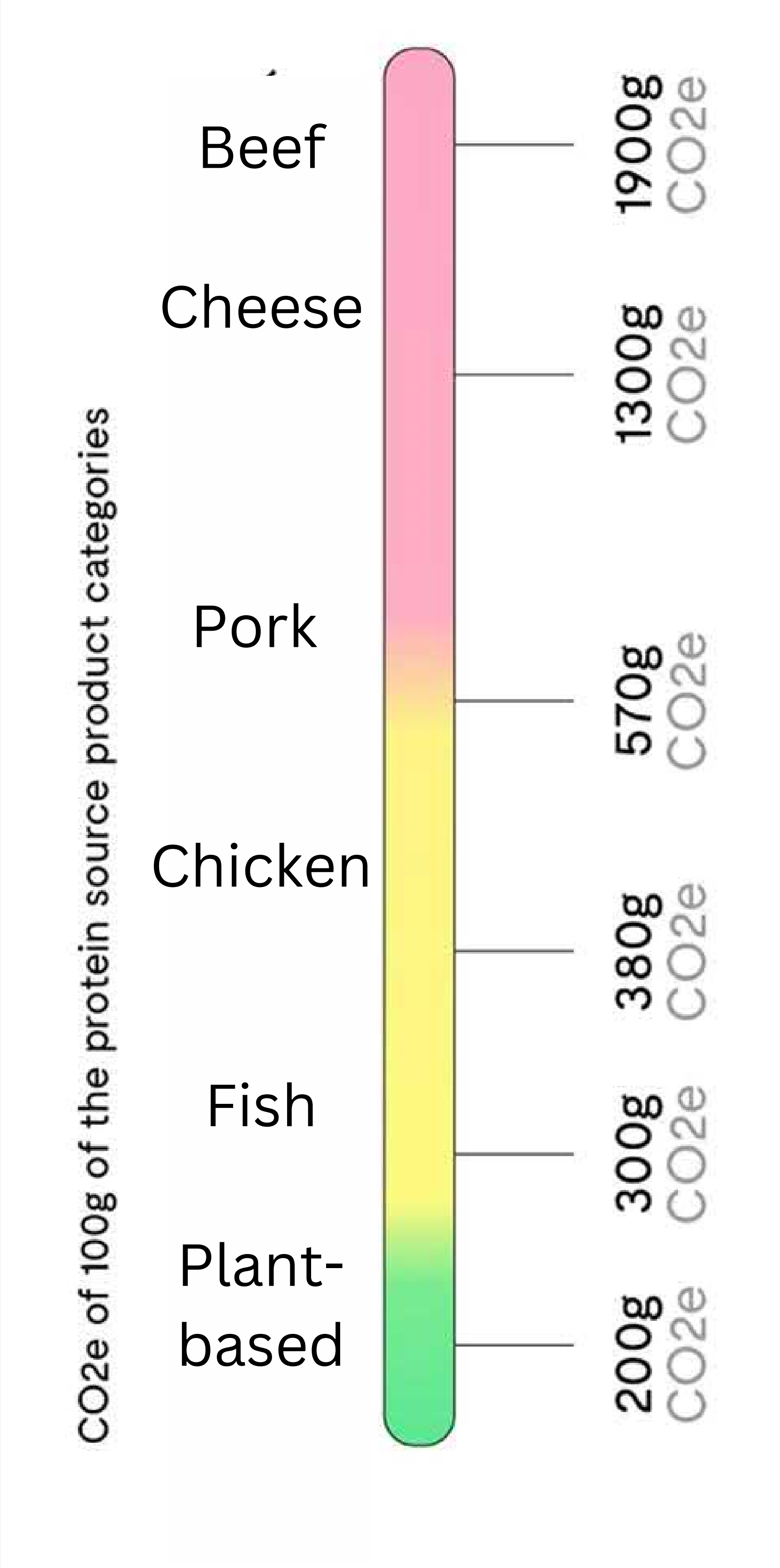


Image portraying aspects of Life Style Assement: materials used, manufacture required, transportation, distribution, preparation, and waste.

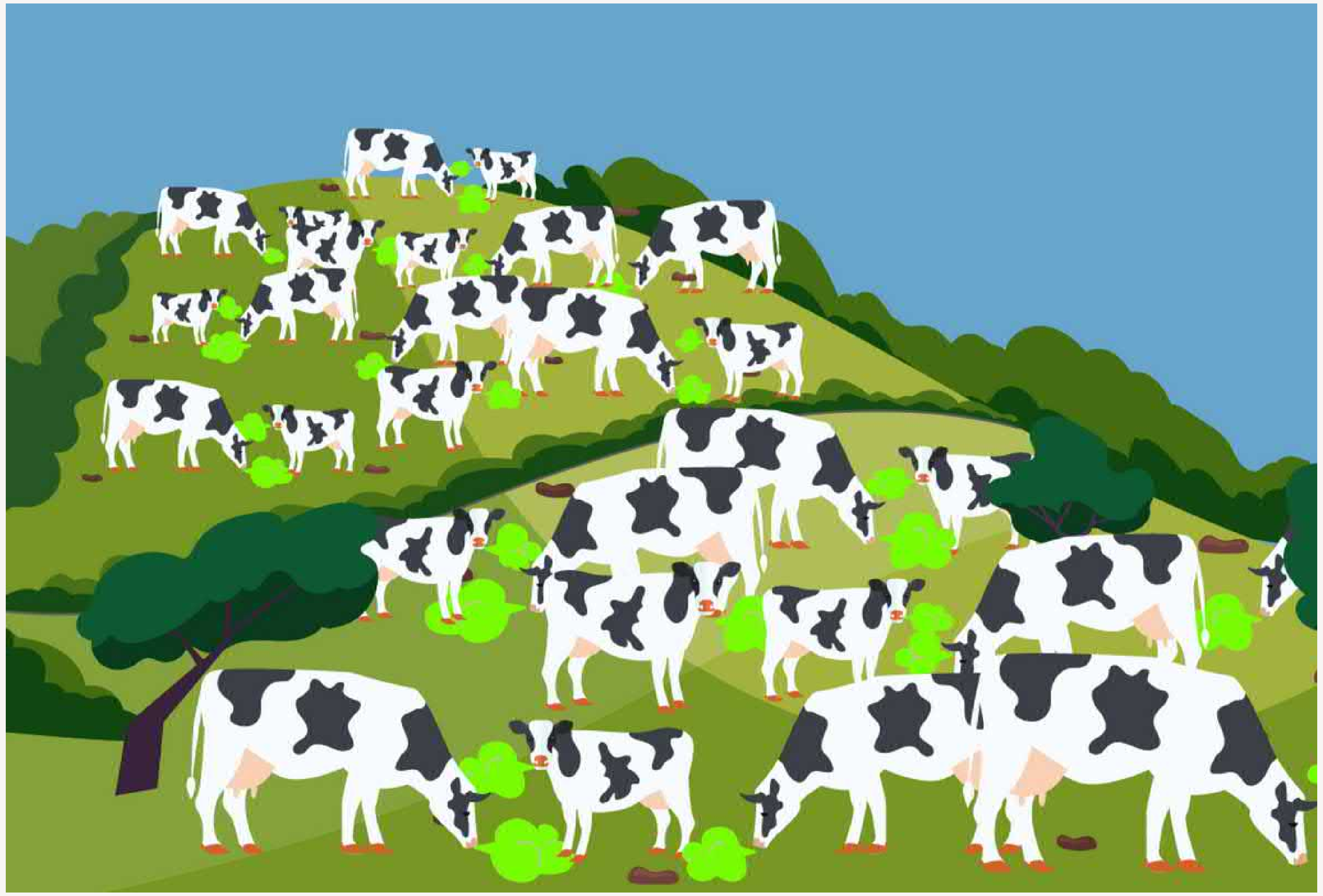
The Food Wellbeing and Sustainability Index was designed to provide a holistic measure of the environmental impact of food choices. Eventually the index will also cover the variables of animal wellbeing, packaging waste, nutrition, and source, in addition to carbon, material, and water footprints. **The material footprint** is the total quantity of resources needed for the lifecycle of a product, from its origin to its consumption and disposal (or recycling). **The water footprint** is the total amount of water required to bring a product to the market. In agriculture this decomposes into the blue, green, and grey water footprints. These refer to the amount of surface and ground water used, the rain water used, and the water required to dilute waste water from agriculture to release it back into the natural environment. Research indicated that for protein sources, these carbon, material, and water footprints are in the same sustainability range, higher for beef and cheese, and the lowest for plant-based protein sources.

Section 4: Tragedy of the Commons

Chapter 5 focused on the **tragedy of the commons** which is the problem of how to manage common pool resources so that they are not depleted. This chapter covered the following topics:

1. Overview of the tragedy of the commons
2. Hardin's analysis of the tragedy of the commons
3. Hardin's solution to the tragedy of the commons
4. Ostrom's analysis of the tragedy of the common
5. Ostrom's solution to the tragedy of the commons

Source: https://commons.wikimedia.org/wiki/File:Medieval_forest.jpg



Artist: Jooeun Park.

The tragedy of the commons is epitomised by the current climate crisis due to the rapidly accumulating CO2e gasses in Earth's atmosphere. **Common pool resources** are at the heart of the tragedy of the commons. They are finite and non-excludable: everyone has access, but overuse can lead to a collapse in supply. Examples include water, common pastures, and the Earth's atmosphere. Garrett Hardin provided a pessimistic account of the tragedy of the commons. He argued that individuals' narrow self-interest leads them to seek to use more of a common pool resource at others' expense. Elinor Ostrom offered a more optimistic view. She argued that people have many motivations: while some hope to take advantage, others may prefer to cooperate if they are assured others will as well.

Hardin's analysis dates from 1968 and argues that in issues of common resources, the free market fails and overuse inevitably results. His argument is analytic and is built up from basic assumptions. One of his fundamental assumptions is that people are narrowly self-interested, and that they will seek more of a resource, despite how this impacts others and the community. He argues the tragedy of the commons is a social problem, not a technical one: technical innovation cannot create infinite fresh water supplies, endless new fertile land, or an endless ability of the atmosphere to absorb CO_2e gasses. Given that resources are finite, and his assertion that people are narrowly self-interested, the tragedy will inevitably result.

See "Hardin's Tragedy of the Commons - Lifestyle Choices," Chapter 4, Section 4, p. 116.

See "Ostrom's Common Pool Resource Dilemma - Lifestyle Choices," Chapter 4, Section 4, p. 117.

He argues that the solution to the tragedy of the commons is “mutual coercion mutually agreed upon.” By this he means that we need to police each other so that each is forced to use common pool resources within limits. Although Hardin prefers private property and free market solutions, he acknowledges that these fail with common pool resources.

Ostrom devoted her lifelong research to challenging Hardin’s pessimism. Her argument was based both on empirical evidence that throughout history and across cultures, people have in fact worked together to successfully manage common pool resources. She also constructed an analytic argument based on alternative assumptions. Her main assumption is that people have many different motives. They may be narrowly self-interested, and may prefer to exploit others. They may be cautious cooperators, waiting for others to lead, and going it alone until then.

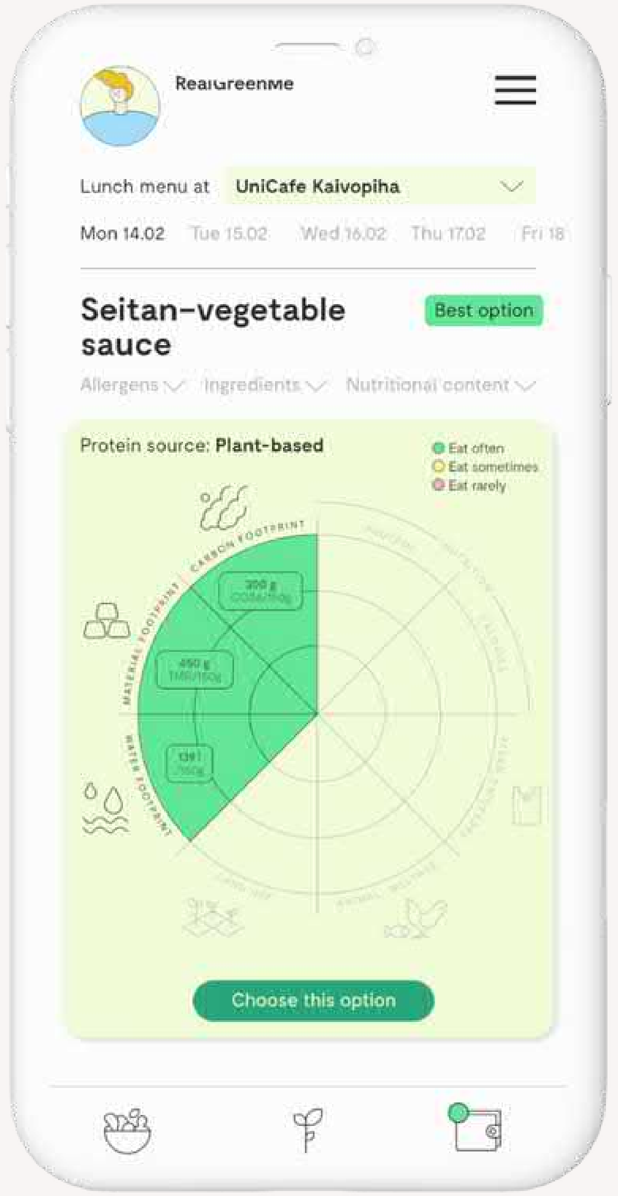
People may be eager cooperators who will set an example, but opt out of cooperation if others fail to cooperate. Or people can be ambitious cooperators, preferring altruistic actions, even when others fail to cooperate. One key example Ostrom used of actors’ ability to successfully manage common pool resources was the cultural tradition of common property rights in Mongolia.

Source: https://libreshot.com/mongolian-landscape-with-yurt/

Ostrom’s solution was the result of the empirical study of communities that successfully managed their common pool resources. She identified a number of characteristics shared by those communities. The following are some of them:

- Well-defined membership boundaries
- Linking resource access rights to participation
- Representing participants’ preferences and opinions
- Keeping track of participants’ contributions
- A graduated means of appreciating participants’ contributions

The Food Futures App is designed to provide a means to achieve these attributes Ostrom identifies as characterising successful common pool resource management. The app represents an opt-in virtual community that functions in accordance with Ostrom’s solution to the tragedy of the commons.



Section 5: Externalities

In Chapter 5, we introduced externalities in order to provide a clearer analysis of the tragedy of the commons, and to lead to a solution in Chapter 6 discussing negligibility and anti-rival goods. Chapter 4 discussed how market solutions fail for common pool resources. Economists have studied this problem and developed the concept of **“externalities,”** or the (typically negative) impact on bystanders from the exercise of free market choice. Chapter 5 covered the following:

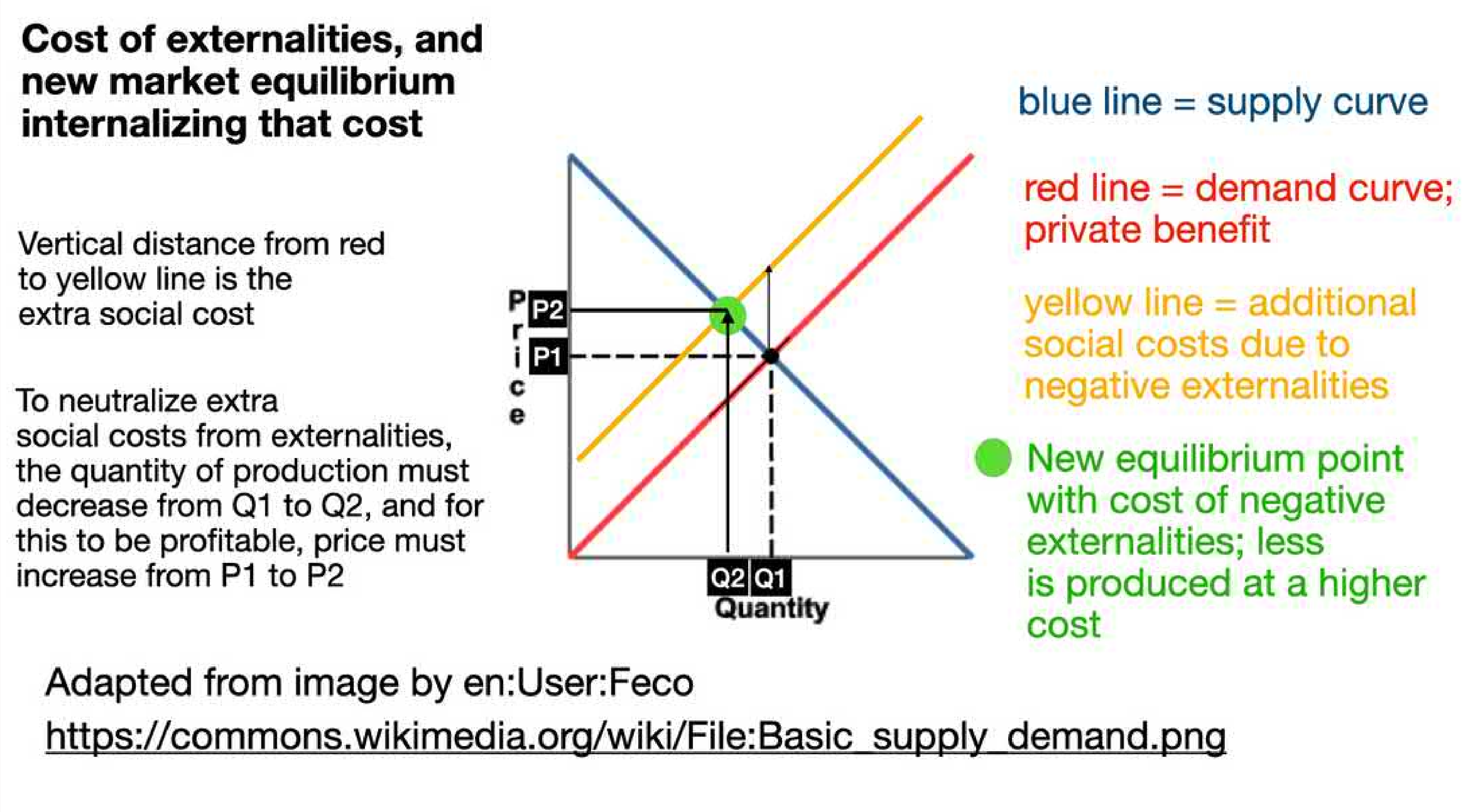
1. Negative and Positive Externalities
2. Market Failures and the Tragedy of the Commons
3. Proposed Solution
4. Conclusion

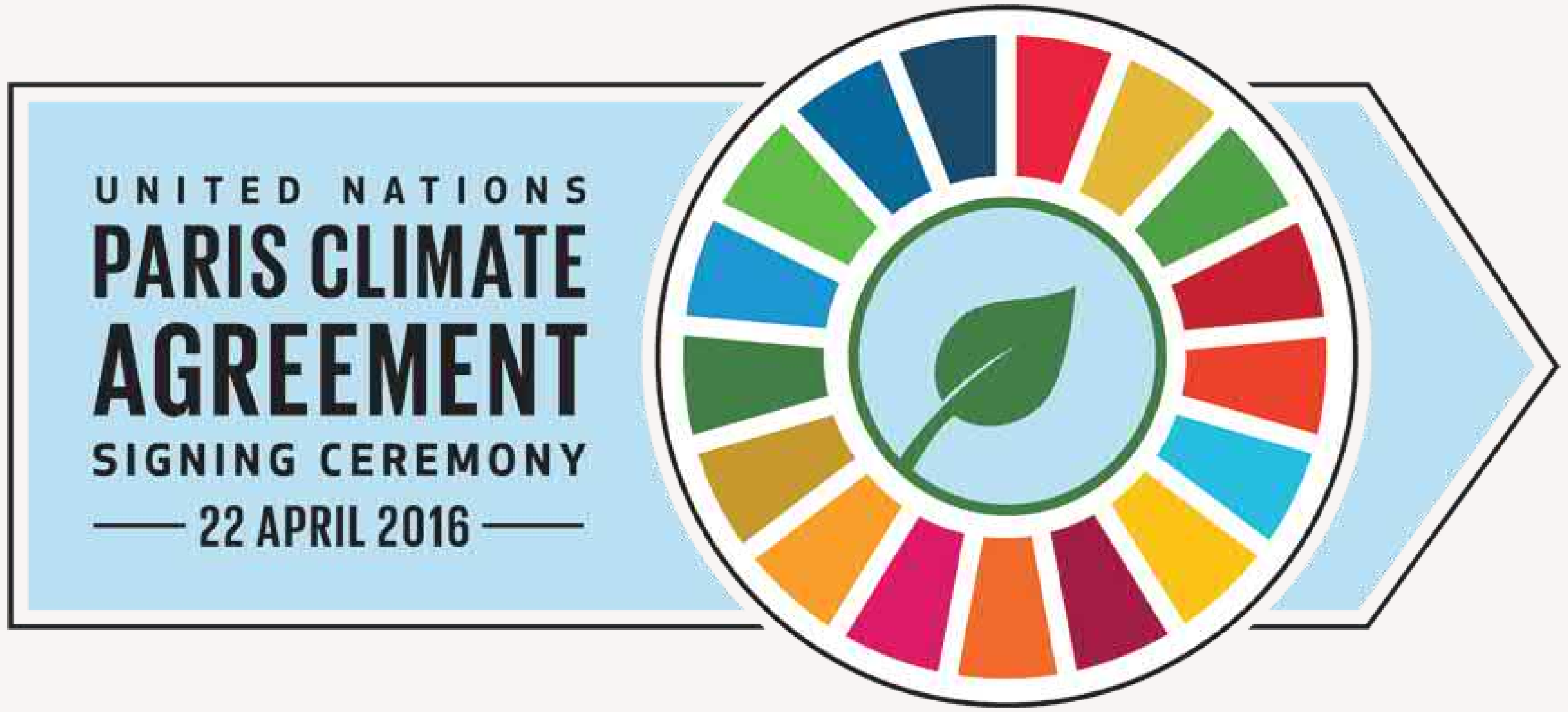
Negative externalities are the harms caused to bystanders from the exchange and use of private property. Section 2 provided numerous examples of negative externalities caused either by individuals or corporations. Economists argue that in order to remedy negative externalities, their cost to others must be estimated. This is especially true of the cost of runaway GHG emissions that are causing climate change and hostile weather patterns. The difficulty is, how do we place a price on these damages? By placing an aggregated price on these damages, we can determine how much society should spend to avoid these harms, or alternatively, what the actual market price of the goods causing the harms should be.

Negative externalities, which impose costs on others, do not factor into the market price of goods. Thus, the price paid for goods does not reflect their actual social cost, which includes the cost of the harms done to others (see Chapter 5, Section 2). This social cost is a way of pricing the **market failure** caused by negative externalities.

Nicolas Stern (2007), working for the United Kingdom government generated a research report that placed the price of harms at somewhere between a low of 25 USD/metric tonne of CO2e gas to 85 USD/metric tonne of CO2e gas. He later said his estimates for the atmosphere's ability to absorb CO2e gasses without excessive collateral harms were too low. With these numbers in hand, we can see that an upper-bound estimate of the average Finn's CO2e footprint causes an economic harm of 680 euros/year in USD from 2005/6.

The economists' idea is that if the price of the harmful good, in this case products with a CO2e footprint, go up by this amount by levying a tax, when consumers adjust their demand to increased prices, then their overall purchase of the product will decrease. This is estimated to decrease harms to an acceptable quantity. However, we know that these market-based solutions as yet are not leading to an abatement of CO2e gas emissions.





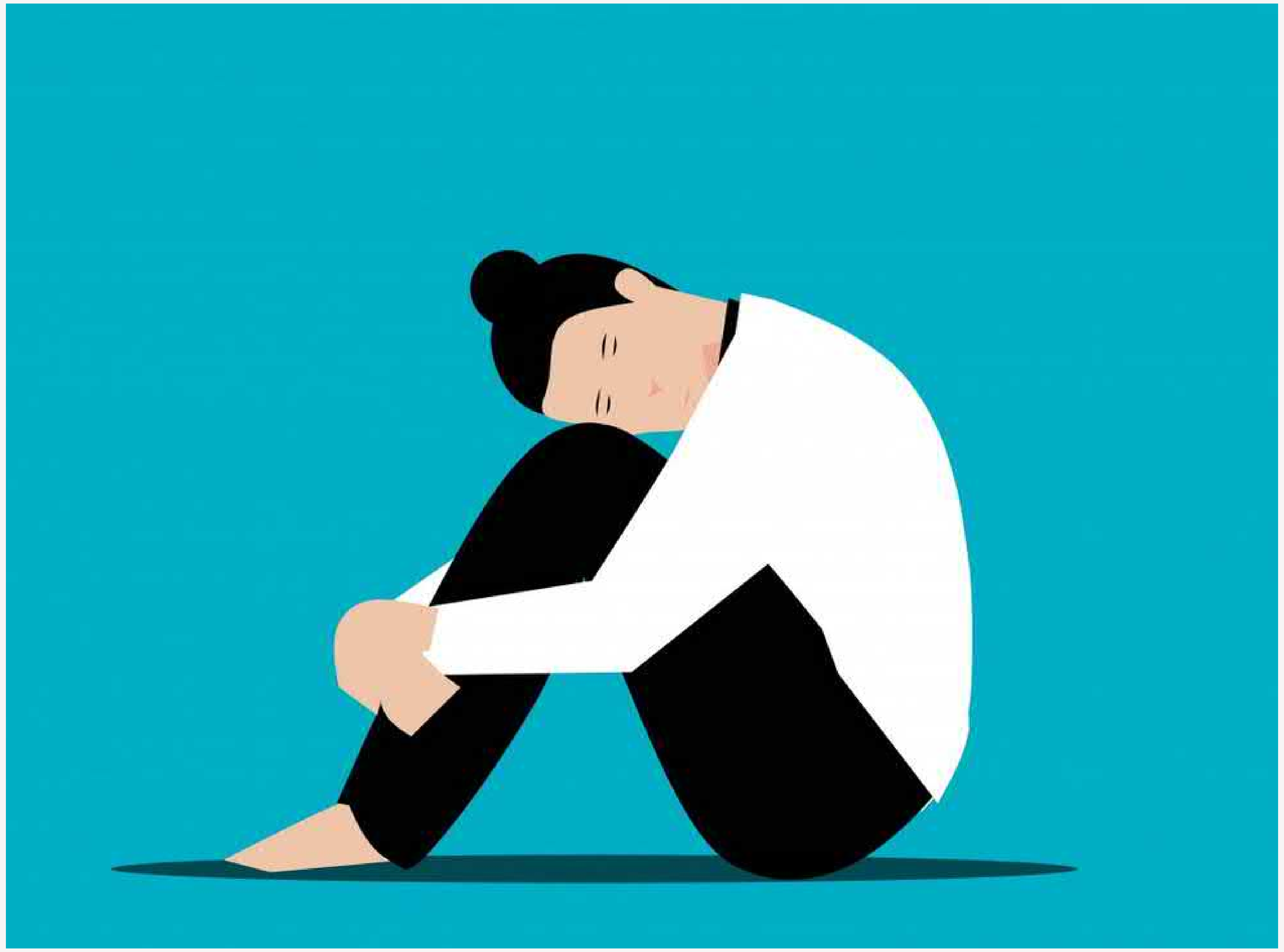
Besides adding a tax, another solution proposed by economists is the **cap and trade** system. Here the government sets a maximum number of permits to produce harmful goods. These permits are distributed or sold to private companies. In turn, each of these companies can sell their permits if they produce less CO2e gas than their permits allow. This cap and trade system is argued to lead to efficiency because, to be profitable, companies will strive to reduce the harmful externalities produced by their products.

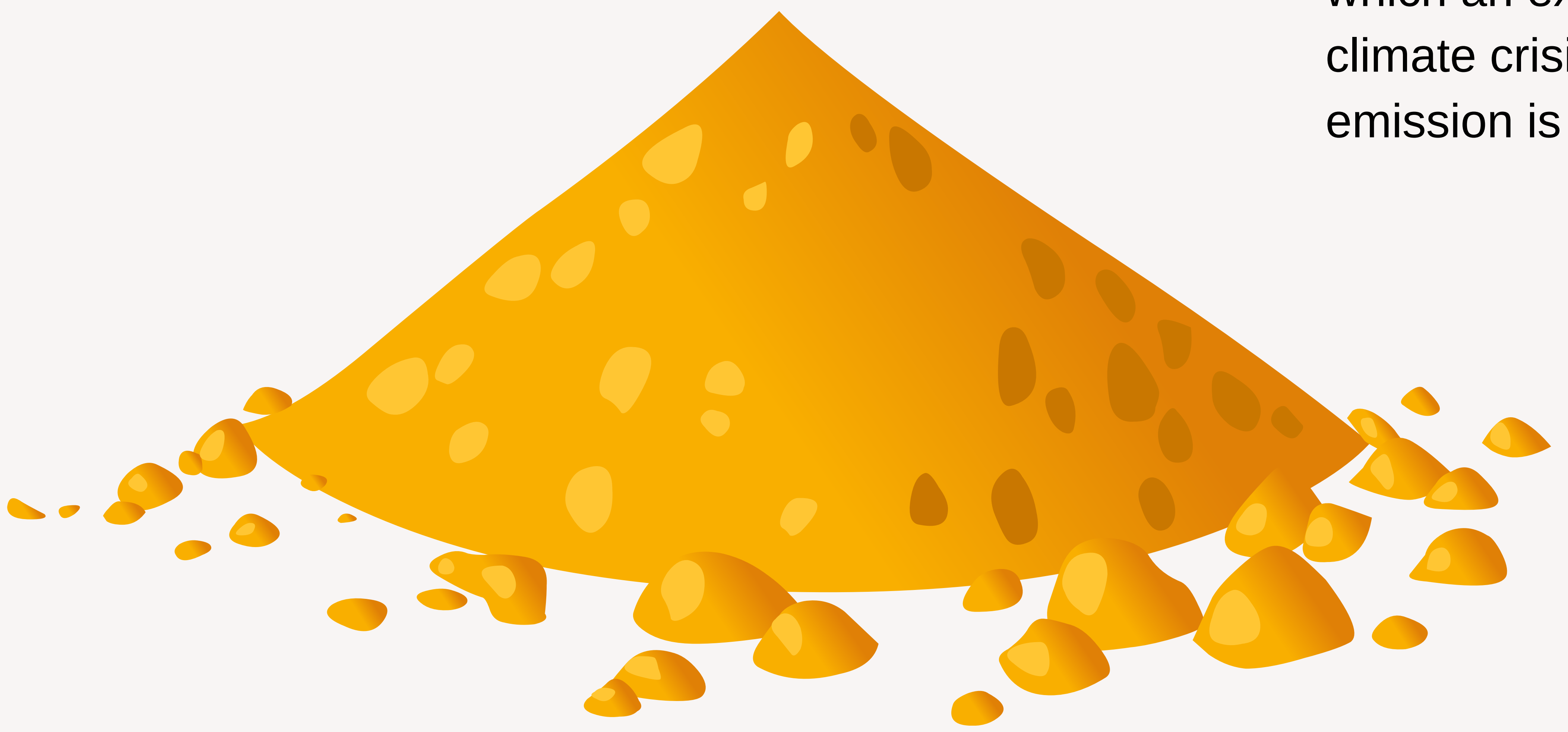
The conclusion introduced international agreements as an additional part of the effort to reduce GHG emissions. These include the 2005 Kyoto Protocol and the 2016 Paris Agreement. These instruments tend to rely on traditional economic tools, e.g., taxation policies and cap and trade regimes.

Section 6: Negligibility and Anti-Rival Goods

Chapter 6 builds directly on the tragedy of the commons and negative externalities. It frames the problem of market failures from negative externalities (such as excessive GHG emissions) as one of **negligibility**: the breakdown of instrumental rationality that one can make a difference by one’s actions. We also discussed how positive and negative externalities can be either “rival” or “anti-rival” in nature. The topics covered were:

1. Negligibility
2. Negligibility and the Tragedy of the Commons
3. Anti-Rival Goods
4. Positive Externalities, Anti-Rival Goods, and the Tragedy of the Commons
5. Using Tools to Construct 1.5°C Lifestyle Individually and Collectively

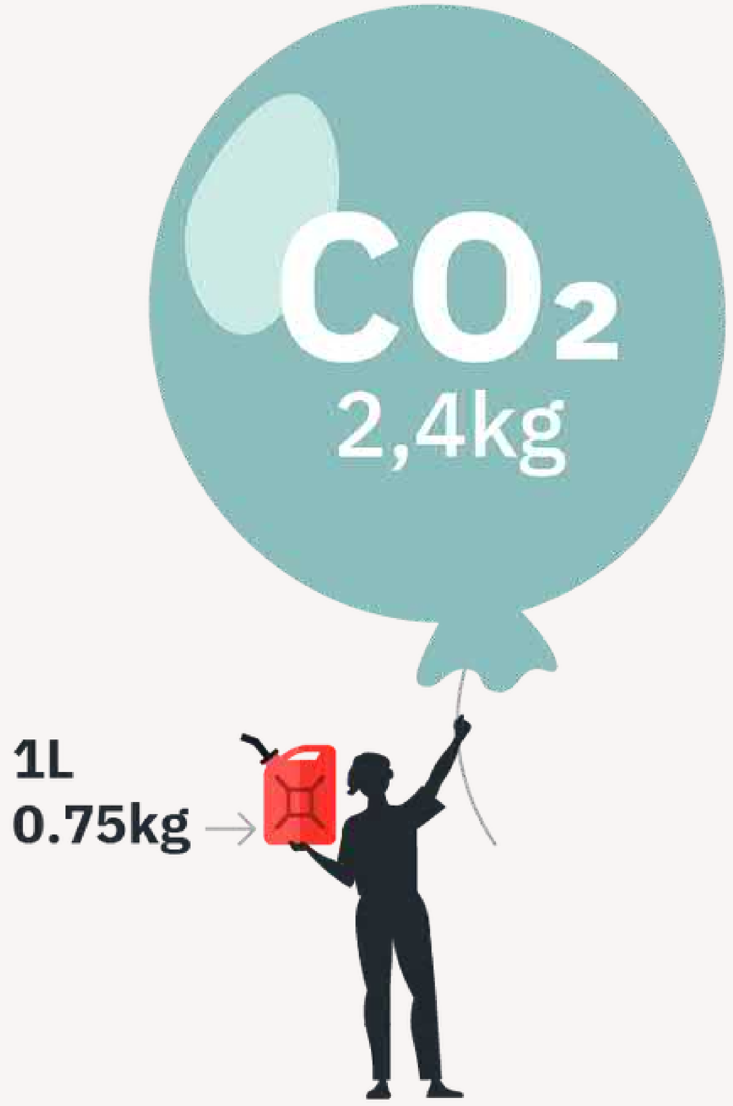


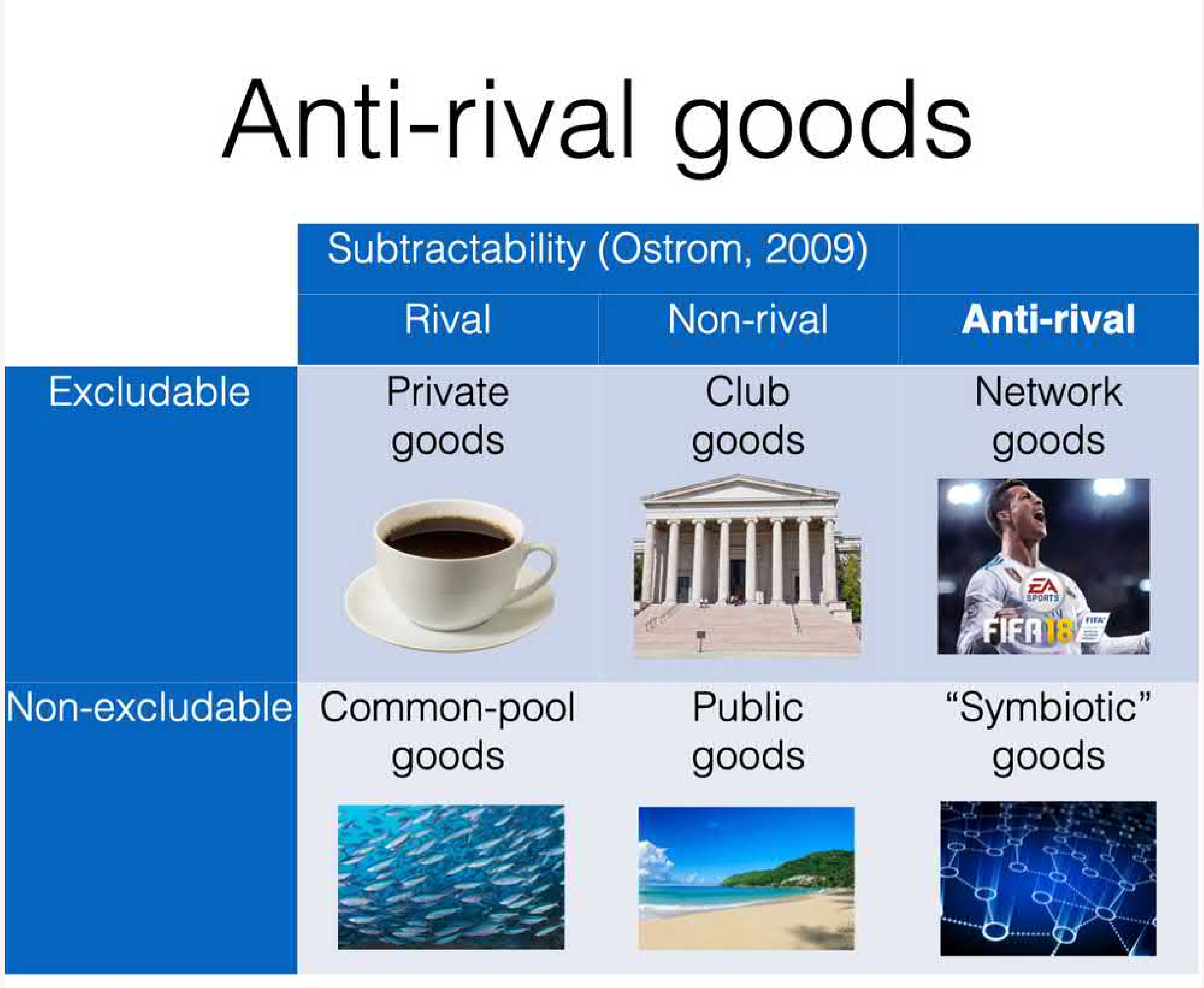


Once introduced, the challenge of negligibility is relatively easy to grasp. It has long been understood as a paradox referred to as the **Sorites paradox**, or the paradox of the heap. Given a pile of sand grains, at which point when we remove sand grains, does the heap cease to exist? How can an object exist if it doesn't have clearly defined properties marking its existence? We might think of the global climate crisis as a type of Sorites paradox: after which an extra metric tonne of CO2e gas does the climate crisis arise? At what level of reduced annual emission is the climate crisis resolved?

The problem of negligibility directly relates to the planetary tragedy of the commons of the run-away carbon gas dilemma. In Chapter 2 we were invited to visualise just how much CO2 gas, in terms of enormous volumes, is generated by routine activities such as driving cars. Yet even if one person became carbon neutral by 2030, this change of behaviour could not be noticed at the global, or even the local level. Hence, when it comes to our individual efforts to combat climate change, they cannot be classified as instrumentally rational. Instrumentally rational action is taken to achieve a feasible goal, such as getting to work on time. We realise that the climate crisis is at least in part driven by individuals' inability to make a difference with their choices.

Thus, we realise that the problem is even more complex for global common pool resources than the analyses put forward by Hardin (everyone seeks to ride on others' contributions) and Ostrom (people may well contribute, if guaranteed that everyone else will as well). Overcoming negligibility requires a means to measure, record, and validate individual contributions that otherwise would, on a global scale, be smaller than a drop in a bucket.



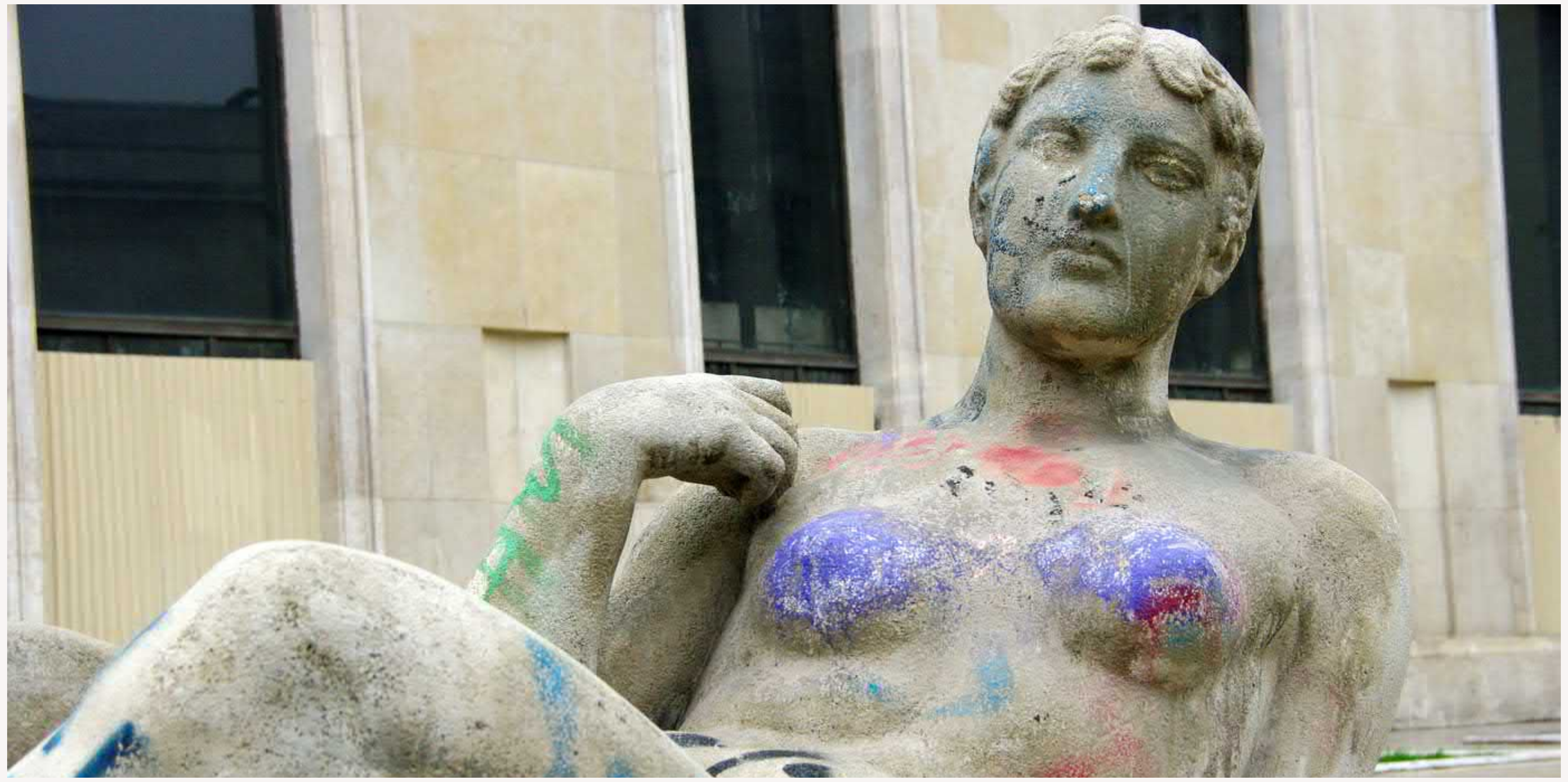


Source: https://www.gameskinny.com/oirze/economics-of-video-games-the-knowns-and-unknowns

Goods studied by economists are typically rival, and sometimes non-rival. Recall that a **rival** good is scarce, only one person can consume it at a time, and the consumption of one rival good subtracts from the total quantity available of that rival good. We already understand the concepts of **excludable** and **non-excludable** goods: common pool resources are non-excludable. **Non-rival** goods are those that are not depleted by continual use, such as a public park or a community room: they can also be excludable (private club) or non-excludable (public beach).

Then we introduced **anti-rival** goods. This category of goods defies standard economic analysis which assumes that only scarce goods can have value clearly defined by market prices. Anti-rival goods are not only not scarce, they also increase in value the more they are shared. Information is the classic example. Knowledge of how to build a fire cannot be depleted after every use. In fact, we are mostly better off as it becomes common knowledge how to make fire.

Next we discussed that externalities can be rival or anti-rival in nature. It is straightforward to see that many negative externalities are anti-rival. A radiation leak from a nuclear power is an example: no matter how many organisms are harmed by the radiation, their harm does not make it less likely or less harmful for other organisms to be exposed to the radiation.

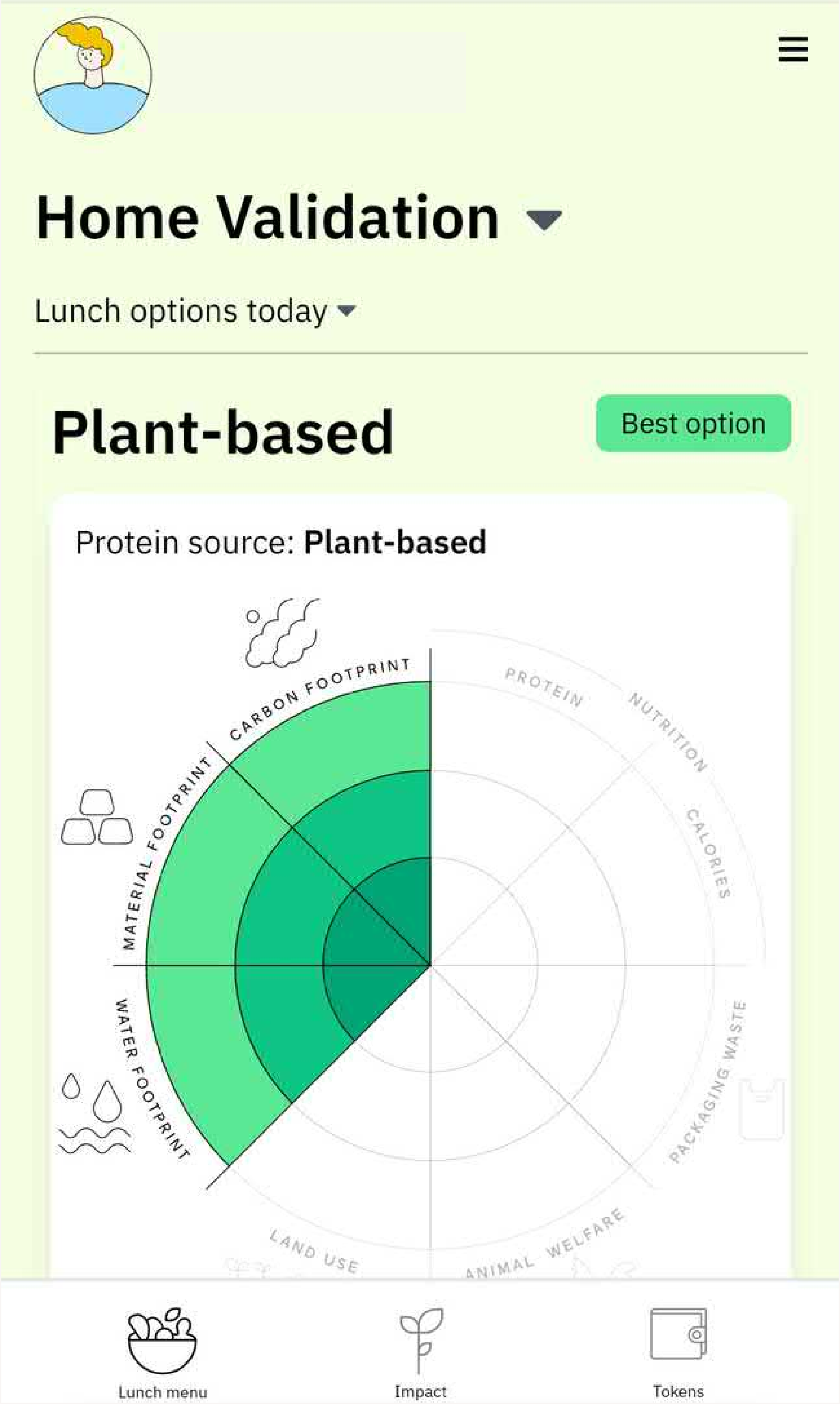


Statue de femme nue couverte de graffitis, Paris, France. Artist: Bruno Bleu.

Similarly, positive externalities can be anti-rival. We touched on the example of the beekeeper whose bees will fertilise neighboring crops. Beekeepers contribute to the natural abundance of life's ability to procreate under the right circumstances to produce the agricultural bounty we have known over millennia. Similarly with carbon gas abatement, every kilogram and metric tonne not released into the environment contributes to a collectively beneficial and sustainable future. Security is a positive sum good. When people are secure in a community, everyone feels at ease. Climate crisis, with harmful weather patterns that damage lives, property, and biodiversity, threatens the future of humans and Earth's other life forms.

To achieve climate security is a positive sum good. The positive externalities contributing to this are positive sum. We are metric tonnes of CO_2e gas emissions from being able to declare net carbon neutrality, which is necessary to prevent greater amounts of carbon gasses from accumulating in the atmosphere beyond the 1.5°C point.

The Food Futures App is a pedagogic tool that incorporates all of the lessons of this course: data, aggregated data, the tragedy of the commons, negligibility, and anti-rival positive externalities. It provides a tool that enables understanding the 1.5°C lifestyle, and its relationship to consumer sovereignty. Individuals know what is best for themselves, and western political theory does not generally accept regulating what individuals can buy. Many may seek to live a sustainable lifestyle, but can be overwhelmed by not having enough information, and also by not being able to make a difference. The app integrates Ostrom's conditions for successful management of common pool resources. The **measure, record, validate system** is a way to visualise, and noticeably contribute to achieving a 1.5°C lifestyle. Living in a sustainable way and reducing CO_2e emissions, in our case with our dietary habits, provides anti-rival positive externalities. So far, economists do not have a way to either measure these positive externalities, or to construct a social system that would provide a structure to proliferate these positive externalities.



Section 7: Cryptocurrency, Distributed Ledger Technology and Blockchain Tokens

The role of Chapter 7 was to develop familiarity with the new accounting and currency systems that may be useful for governing common pool resources. Elinor Ostrom presented design principles, including identifying community members and having a graduated method of recognising individuals’ contributions. DLT, blockchain, and cryptocurrency tokens provide a novel means to achieve these ends. The topics covered were:

1. Introduction to blockchain and distributed ledger technology (DLT): covering
   - *DLT*
   - *Blockchain*
   - *Cryptocurrency*
2. Double-entry bookkeeping versus triple-entry DLT record-keeping
3. Brief history of money and monetary functions
4. Positive externalities, anti-rival goods, and the tragedy of the commons
5. Using tools to construct 1.5°C lifestyle individually and collectively

Distributed ledger technology (DLT), blockchain, and cryptocurrency stand ready to offer human societies a leap forward with respect to accounting practices, secure financial transactions and records, and specialised currencies tailor-made to communities' needs.

Distributed ledgers enable decentralised ledgers for transactions. They do not require a centralised authority to update, legitimate, and control interactions. Instead, all participants in a network update records simultaneously by consensus, in accordance with specified rules all parties agree to for conducting their affairs.

Blockchain provides a secure means to implement DLT. It was first implemented in 2009 as the computational infrastructure to invent Bitcoin. The term blockchain refers to blocks of data, each representing transactions occurring within a given time period, that are packaged together and once validated by all participants are permanently fixed as a record of past interactions. These blocks are added chronologically, each new block being a chain in the data link containing all the information of past transactions. All participants have access to the data.

Cryptocurrency is one application of blockchain technology. Its best-known example is Bitcoin which serves as an international currency accepted by some as valid payment for goods and services. Due to the programming code making cryptocurrencies possible, these new currencies can serve numerous functions that are not feasible with standard physical, or even digital, money. The Food Futures Foodprint token is an anti-rival cryptocurrency designed to measure, record, and validate positive externalities in the form of sustainable meal choices.

Portrait of Luca Pacioli with a student, painted by Jacopo de' Barbari.

The best way to understand the potential revolutionary implications of DLT, blockchain, and cryptocurrencies is to consider the historical development of accounting practices, as well as money. We first considered double-entry bookkeeping which dates back to the 13th century, and was explained in Luca Pacioli's 15th century encyclopedia on mathematics.

Double-entry bookkeeping required that debits and credits balance. Hence, every transaction has a double record: a debit for a payment, and a credit for what is received in exchange. As well, if my account is debited, someone else's account should be credited by the same amount. Double-entry bookkeeping was fundamental to modern European capitalism that developed from the 18th century onward. It is based on conservation principles including that debits and credits must balance, and the total amount of currency in circulation is fixed (unless the sovereign increases the money supply).

Triple-entry bookkeeping is made possible by DLT. It represents and advance over double-entry bookkeeping because all records are public to all participants. Instead of accounts being private to those conducting transactions, everyone on a network using a currency system has the data on transactions. This data includes the information of how much value is in circulation throughout a system. All records update simultaneously and holistically, including all transactions and participating nodes.

Understanding DLT, blockchain, and cryptocurrencies makes more sense against the millennia-long history of money. Money first existed as a type of commodity valuable to everyone, such as precious metals or gain. Around 500 BCE coins with a sovereign's imprint were established as legal currency within specific communities. Sovereigns could demand that taxes be payable in their currency, and that their currency was a valid means to pay debts.

In the 13th century, Chinese authorities invented paper money. In the modern era, paper currencies were backed by the sovereign who promised to pay gold or silver on demand at a specified exchange rate. The US was on the gold standard backing its paper fiat money until 1971. Since then, people around the world accept the US dollar as payment on the faith that others will continue to find it valuable. In addition, the US has the coercive force to require payment of taxes in US dollars.

Money has three attributes: unit of account, medium of exchange, and store of value. Cryptocurrency represents a new form of money with no need of a sovereign government to validate its value. There are many cryptocurrencies already functioning. They serve as means of payment to those who participate in the community by holding accounts of that cryptocurrency. Due to their programming code, cryptocurrencies can have more and different functions from those of standard money. They can also serve functions of utility (members' access to particular goods and services only available to those with tokens), and also for investment purposes (under tighter regulation for operating as investment securities like stocks).

We next studied positive externalities, anti-rival goods, and the tragedy of the commons as they relate to DLT, blockchain, and cryptocurrencies.

We focused on how cryptocurrencies can provide new means to serve as a unit of account, medium of exchange and store of value. Standard money systems are invented to make exchange of rival good easy. Instead of trading a cow for 6 months of labor, we simply pay people income using money. The goods that money is used to buy are rival. As such, money itself is rival: there is a finite and limited supply in circulation at any given time. If the sovereign or banks add new money into circulation, this must be exactly accounted for.

Cryptocurrencies can be designed to meet the needs of the communities whose members use the currency. Therefore, if we seek to have a means to measure, record, and validate individuals’ contributions of positive externalities, then a cryptocurrency can be uniquely designed to serve these functions. The positive externalities of reducing CO2e emissions are anti-rival.

This is because security is a positive sum good, and environmental security is necessary everyone to live without fear of hostile weather and food shortages. Every kilogram of CO2e gas not emitted provides a positive sum good.

We know that no single individuals’ complete reduction of carbon gas emission can make a detectable difference to the Earth’s atmosphere. Yet we also know that accounting systems already exist to record individual transactions, such as purchasing a pack of gum or a cup of coffee, that also make no planetary difference on an individual basis. Of course, all the coffee we consume as a nation can be detected and is evident in the flow of commodities through supply chains. However, as yet no standardised or widely accepted accounting system exists to measure, record, and validate individuals’ positive contributions of CO2e abatement.

With DLT, blockchain, and cryptocurrency, we now have such an accounting system. This system can counter the negligibility we confront when our individual actions cannot make a difference on the planetary ecosystem. As an example, the Foodprint token is designed to be anti-rival. As individuals contribute the positive externalities of sustainable meal choices, the value in circulation measuring, recording, and validating this value also increases. App users are provided with the data to make informed meal choices, all meal choices are labeled with a sustainability graduated value. App users' meals are voluntarily validated, then checked (eventually the checking process will be distributed, although now it is centralised), and permanently recorded in blockchain. App users' sustainable meal choices, and positive externalities of CO_2e abatement are recognised with the receipt of Foodprint tokens.

We concluded Chapter 7 discussing using DLT blockchain, and cryptocurrency to construct tools to foster the 1.5°C lifestyle, individually and collectively. Cryptocurrency can be introduced to function as a form of rival currency without any centralised control or sovereign government to regulate its use. However, cryptocurrency can be more revolutionary in enabling individual communities to introduce tailor-made currencies that can keep value within their membership. This is in distinction to global financial systems which enable the extraction of local value to the possession and control of a few elite actors.

The tragedy of the global environmental commons has been the main theme throughout this book. Capitalist systems are unable to sufficiently mitigate the excessive carbon emissions from corporate and individual actors to stay below the threshold of a 1.5°C global temperature rise. While we are often taught that everyone most prefers to free ride on everyone else's contributions, research shows that in fact people have many different motivations. Elinor Ostrom used empirical research to support that, while some individuals may prefer to take advantage of others, many people seek first and foremost to cooperate when they are assured that others will cooperate as well.

When we consider the themes of this book, including the global tragedy of the environmental commons and anti-rival positive externalities, we can focus on the kinds of large-scale shifts in habit and production that would be necessary to mitigate GHG emissions.

The Finnish diet has just under 80 kg of meat per capita annually, including almost 20 kg of beef and 24 kg of cheese. We discussed the impact of reducing beef consumption 4 kg per capita annually (the quantity of imported beef), and potentially reducing cheese consumption by half. These two changes, which still include 75 kg of meat consumption (15 for beef) per capita annually, as well as 12 kg of cheese per capita annually, and yet would offer approximately 1.2 M metric tonnes less emissions. This is just over half of the 2.1 M tonnes that Finland exceeded net carbon neutrality for land use in 2021.

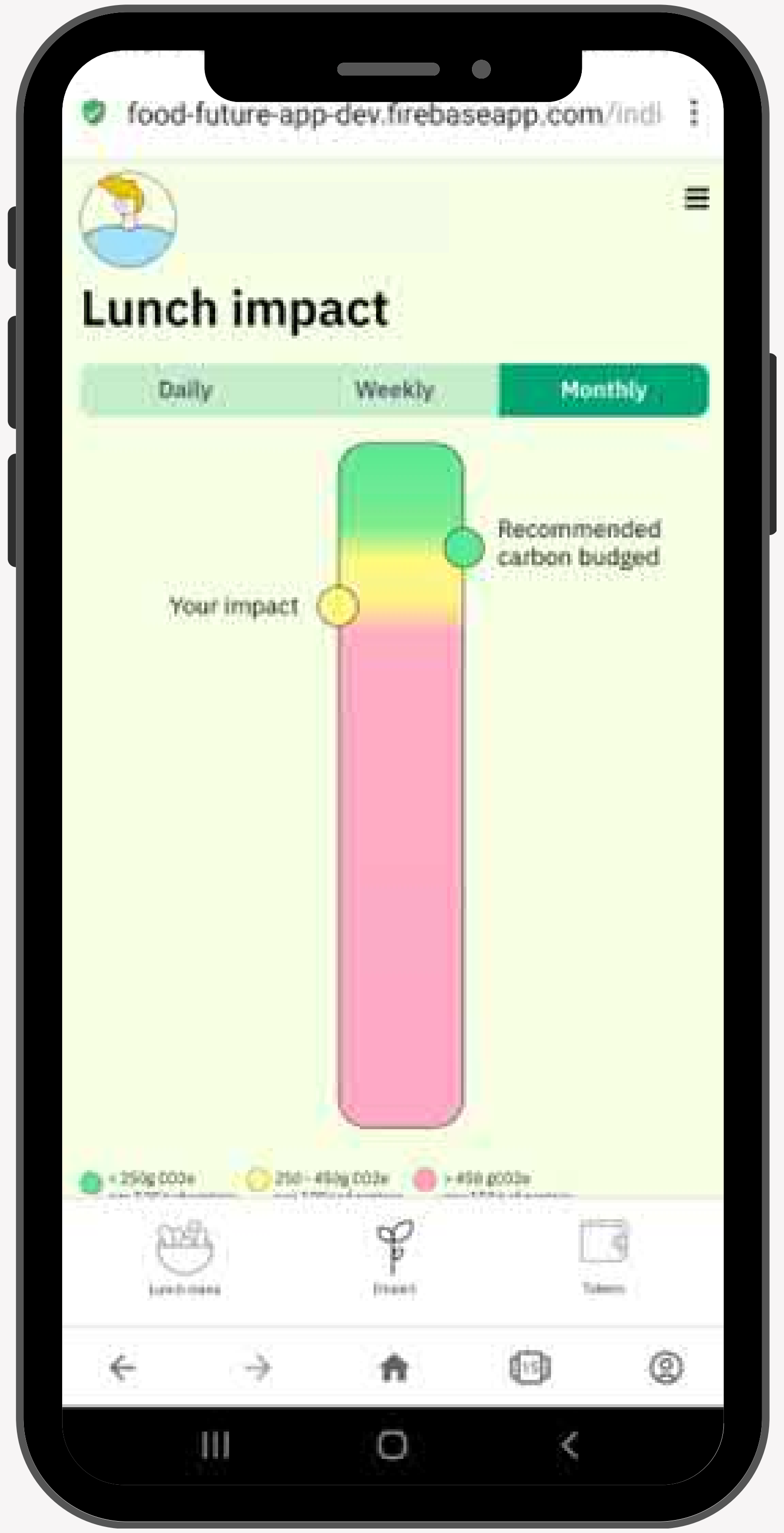
Capitalist systems will not solve the environmental tragedy of the commons. This is because as we have seen their property rights system does not incorporate a means to stop the harms (negative externalities) of individuals' consumption. Cap and trade systems, and taxation policies have been introduced to help. However, these rely on industry cooperation and individuals' willingness to accept unpopular taxation on energy sources. Limitations on free choice of diets is not contemplated in western countries. Yet diet is technologically the easiest to change, while it remains entrenched in cultural patterns of food consumption and production.

Many people are aware of the climate crisis and yet feel stymied to make a difference, even if they radically alter their individual consumption habits. Finland has the stated policy goal of achieving carbon neutrality by 2035. Shifting away from heavy CO_2e emission foods provides a feasible way to contribute significantly to this goal. For those seeking to realise the values of the 1.5°C lifestyle, participating in the measure, record, validate system illustrated by the Food Futures App and Foodprint token provides a means to empower and validate individual and collective contributions.

Section 8: Polycentric Governance Using DLT Anti-Rival Blockchain Tokens

Congratulations on reading all of the materials in *Sustainable Consumption*. You have learned a lot in this course, from collecting and analysing data, to solving the tragedy of the environmental commons with blockchain tokens to measure, record, and validate each individual's and the community’s contributions.

We hope you have had the opportunity to try the Food Futures App, and to experience its instructional role illustrating this approach to achieving a sustainable 1.5°C lifestyle. The Food Futures App was developed by an EU Horizon 2020 grant, and represents public funding. It has been developed with a process of participatory design by integrating users' feedback into app iterations. It provides a tool for **polycentric governance** by enabling a community of users to self-regulate consumption patterns with direct impact on planetary sustainability. Its DLT blockchain "measure, record, validate" system can dovetail with local, regional, national and also transnational efforts to resolve the tragedy of the environmental commons.



We recognise that individuals are powerless to single-handedly alter the future of the planet's ecological security acting as citizen-consumers. Just like grains of sand, we could be randomly positioned in a vast heap. Alternatively, being human actors with individual and shared goals, we can work together to build sustainable patterns of activity. Community-based cryptocurrency can help us moderate our actions so that we can each act independently, and yet collectively achieve sustainable consumption patterns. Environmental security is a positive sum good that enables us, future generations, and all of Earth's flora and fauna to live together harmoniously within planetary ecological boundaries.

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