FOOTPRINT

Why?

What good is a plane without cockpit dials? Sure, it flies. But how high, how fast, and in which direction? What is its exact position? In rough weather or at night, flying without instruments becomes sketchy. Even in good weather. Particularly if basic instruments—like the fuel gauge—are missing. Without knowing how much fuel is left in the tanks, any flight becomes unsafe.

Operating an economy is similar. Like a plane, an economy is fueled. The difference is that an economy not only requires kerosene but also devours coal, food, timber, water, and many other materials our planet provides. How many resources does it take for each breakfast, vacation, or new apartment each person may enjoy? How much nature does a city, a power plant, a nation, or the entire human enterprise use? If we are so utterly dependent on all these resources, how come our economies do not have fuel gauges?

In our daily lives, we pretty much know the dollar value of everything. Why? Because our financial budgets are limited. We want to know what we can afford. Like our own financial budget, nature's resource budget is limited too. And the mother of all resources, the most limiting resource, is, as we will see, the biological assets—our planet's *biocapacity*. So how much nature can we afford? And if indeed nature's budget is limited, why don't we measure it?

Would you get on a plane that does not have a fuel gauge? If not, how come we continue operating countries without having an equivalent gauge? How resource secure is your country? And what is the trend?

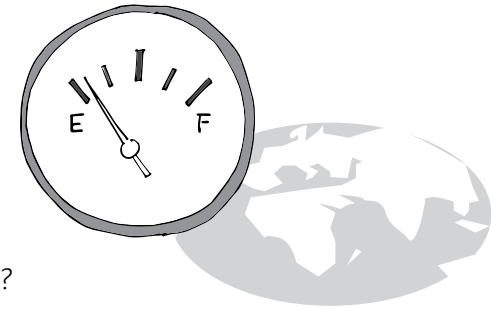


Illustration: Phil Testemale

One possible answer is that we did not have a reasonable instrument for measuring our demand on nature. Also, for a long time, no tool was needed, since nature appeared to be immense and endless. It is different today. Now nature's limits have become obvious, whether it is groundwater depletion, climate change, or decline of the oceans' fish stocks.

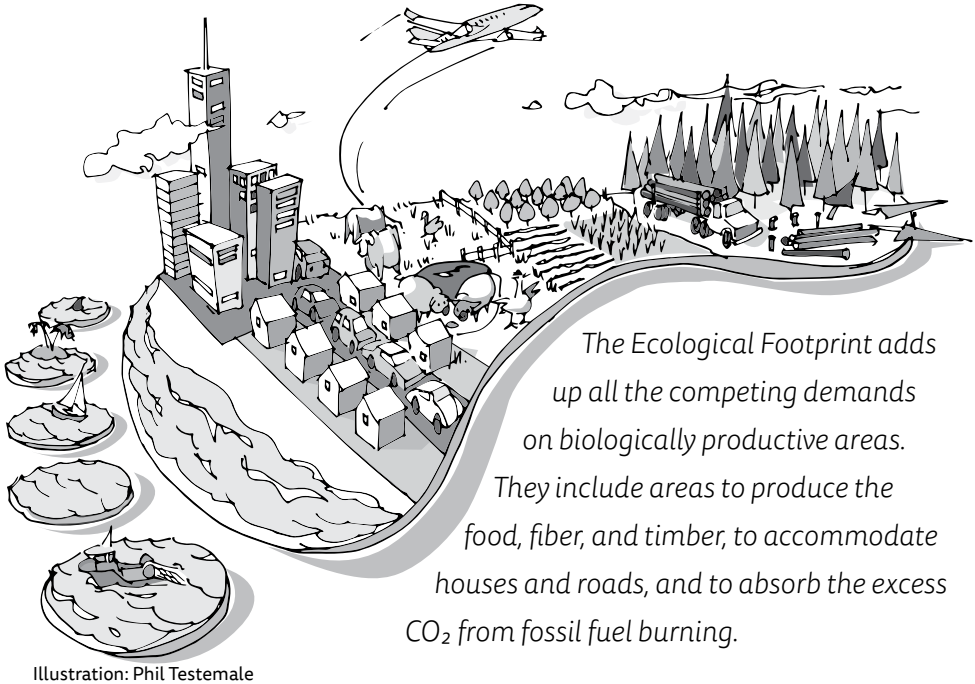
Good measurement instruments finally exist: with the Ecological Footprint, we can measure our use of nature. It offers a basic ecological accounting system. While for the economy, money is typically used as the accounting unit, the Footprint uses *biologically productive surfaces of the Earth* as its currency. These surfaces harbor the most significant resource on our planet: the capacity of Earth to renew itself. On surface areas, photosynthesis transforms sunlight, water, nutrients into plant matter, over and over again. Therefore, every demand of the economy on nature's ability to produce and renew plant matter can be expressed as the corresponding surface area needed to meet this demand. Yield figures tell us how much cropland, a forest, or grazing land provides each year. This is the demand side of the story.

We can also measure with ever greater precision what nature supplies, thanks to modern technology. Satellites deliver us up-to-date images of our planet. They show where forests, cities, streets, deserts, lakes, pastures, or grasslands are located. Those satellite pictures can be verified by direct measures in the field. On-the-ground measures track, for instance, how many potatoes or how much wheat is

actually grown. At the country level, United Nations statistics provide detailed numbers for most of these resource flows: land areas, yields of the various land types, amounts produced and traded, population size, energy use, and so on.

Financial accounts always look at two sides: income against expenditures, or assets against liabilities. Footprint accounting is tracking demand on nature against what nature renews. It is a basic, straightforward, science-based description: How much nature is available (income)? How much nature do people use (expenditure)?

To manage the ecological capital of our planet merely on gut instincts does not make much sense. No one would bring their money to a bank that does no bookkeeping. A bank statement gives us an objective financial review—a status report. This is exactly what's needed for the resource situation of the planet at this time. That's the reason why the Footprint primarily aims at government and business decision-makers. But these accounts also need to be understood by the citizenry so they can hold their decision-makers accountable.



The Ecological Footprint adds up all the competing demands on biologically productive areas. They include areas to produce the food, fiber, and timber, to accommodate houses and roads, and to absorb the excess CO_2 from fossil fuel burning.

Illustration: Phil Testemale

The Footprint reveals how much of our planet's productive area is used for each human activity. Complex processes can be summed up in one single number, similarly as money gets reported in simple numbers like Return on Investment or Revenue versus Costs. This boils complex issues down to their essence and makes them accessible. It allows us to negotiate. The Footprint, therefore, is not only a communication tool that is intuitively understood by a broad public. It also serves as a transparent tracking tool to measure the performance of policies and the implications of decisions in public and private domains.

The parallels between economy and ecology goes beyond their names. In both domains, mismanagement is characterized by spending more than you earn. Physics and value creation have to go hand in hand: how can the value of real estate expand continuously, even if the actual real estate object does not change? How can we continuously accumulate a huge amount of debt and hope that somehow sometime it can be paid off? How can we continuously increase money supply without adding commensurate tangible value (even Google searches are "material," and so are bitcoins, digital photographs, or iTunes). How can we presume that expansion works forever? How can we expect an economy to forever deliver more, without expanding the natural capital needed to fuel the economy accordingly? How come we commonly forget that income generation depends on resource availability?

According to the latest Footprint calculations, humanity overused nature's biological budget (the biocapacity of the planet) by 75% in 2019. In other words, humanity uses nature currently 75% faster than it renews. This overuse is called ecological *overshoot*. Most estimates predict that the global population will rise from about 7.7 billion today to 9 or 10 billion in 2050. And the residents of the BRICS countries (Brazil, Russia, India, China, South Africa) will continue to work hard to raise their standards of living. And so will many others, in spite of potential economic turmoil. All these forces turn resource security into the central challenge of the 21st century.

Some might wonder whether we are in the midst of water, climate,

fisheries, or food crises. The answer is that all those crises root in the same cause: our tremendous hunger for resources. This becomes evident as we examine the human resource metabolism a bit closer.

With rising ecological pressures, everybody, from individual to company, city or country, has "skin in the game" since no one can operate without the availability of sufficient resources. While demand is still going up, a lot of ecosystems on the planet are already overused and weakened. Such overuse destabilizes climate, guts fish stocks, or erodes biological productivity. It threatens adequate access to food and water for all. It might lead to conflicts, migration, economic hardship.

The financial crisis of 2008 provided the planet's ecosystems with a little breather. Resource and waste flows did not grow as fast as before. In some areas they are even declining. But such forced decline is not the goal. Because overshoot will end. Peter Victor astutely observes that humanity will only benefit if we end overshoot "by design, not disaster."[1] In other words: How can we decelerate humanity's metabolism without strangling the economy? How do we strengthen our resource security without burdening those who are struggling economically and are left behind? How fast can we end overshoot while ensuring high quality of life for all? How slowly can we end overshoot without putting everybody's well-being at risk?

The answer is simple. Ecological health and human well-being is not a real trade-off. Rather, resource security is the enabler of lasting human progress. Yet often we are tempted to believe that sustainability is just about keeping everything as it was. In high-income cities of Europe, for instance, many are under the false impression that maintaining things as they are is a workable strategy. So many architectural details of Paris and London look exactly the same as they did 100 years ago. This continuity covers up the rapid change characterizing the world and leaves inhabitants of those places in an illusion. In reality, the world is shifting at the speed of light: Consider, for instance that just during the lifetime of the authors, humanity has burnt 80% and 84% respectively of all fossil fuels ever used. What portion of fossil fuel ever used was burnt during your life?

Year you were born	Percentage of fossil energy burned since then	Year you were born	Percentage of fossil energy burned since then	Year you were born	Percentage of fossil energy burned since then
1896–1905	96	1972	73	1996	43
1906–12	95	1973	72	1997	42
1913–18	94	1974	71	1998	40
1919–23	93	1975	70	1999	39
1924–28	92	1976	68	2000	37
1929–33	91	1977	67	2001	36
1934–37	90	1978	66	2002	34
1938–41	89	1979	65	2003	32
1942–45	88	1980	64	2004	31
1946–48	87	1981	63	2005	29
1949–51	86	1982	62	2006	27
1952–54	85	1983	61	2007	25
1955	84	1984	59	2008	23
1956	84	1985	58	2009	21
1957–58	83	1986	57	2010	19
1959–60	82	1987	56	2011	17
1961	81	1988	54	2012	15
1962–63	80	1989	53	2013	13
1964	79	1990	52	2014	11
1965–66	78	1991	50	2015	9
1967	77	1992	49	2016	7
1968	76	1993	48	2017	4
1969	75	1994	46	2018	2
1970–71	74	1995	45	2019	0

Figure I.1. What percentage of all the fossil energy ever used throughout human history has been burned since you were born? Here a scandalous fact about Justin Bieber: during his short life, 46% of all fossil fuel ever used was burnt (he was born in 1994). The figures are for 2019. If you read the table in 2020, then go back one year as a first estimate, two years, if you read this two years after 2019. This means, for Justin Bieber the approximate result will be 46% in 2020, 48% in 2021, and so on.

During Mathis's life, the global population has more than doubled, the pressure on nature tripled. History is playing itself out at breathtaking speed. That turns one question into our central challenge: How can all thrive within the means of our one planet?

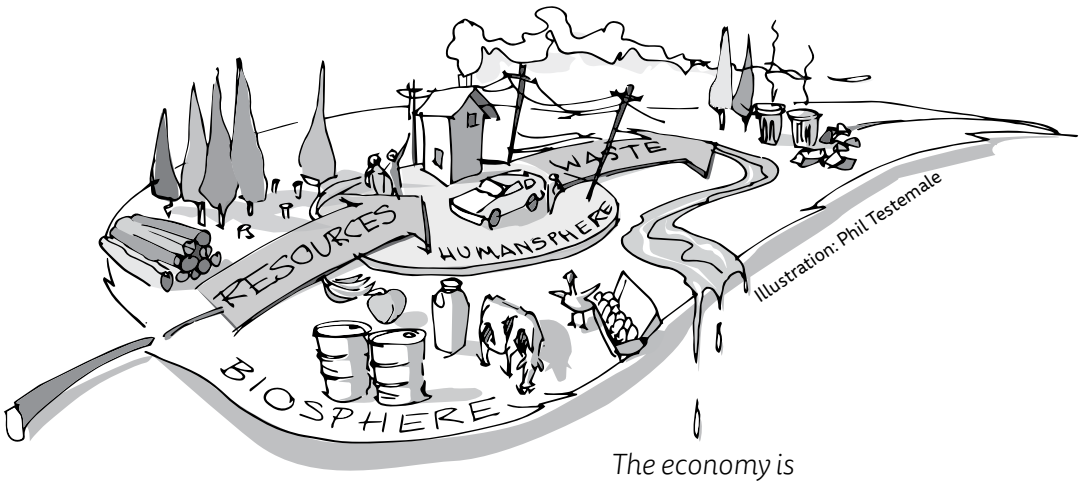
The Footprint metric delivers some navigational support.

For example, Footprints capture cities' use of nature for all it takes to make the city tick: food, housing, heat, light, mobility, and waste management. If the Footprint of a resident of a compact Mediterranean city like Siena or Salamanca is only ½ or ⅓ of a resident living in the sprawling city of Canberra, Atlanta, or Los Angeles, then Siena undoubtedly has an admirable and significant advantage. Those who prepare themselves better for a world with resource constraints (or already live in cities with such built-in advantage) will have a much better chance to thrive. Those who hesitate to adapt will struggle. Implementing a thoughtful long-term resource policy is in your own self-interest, whether you are a city, a region, or a nation. It is needed right now. Los Angeles will not become a Siena overnight.

Since most of humanity lives in cities (which also concentrate CO_2 emissions and consumption),[2] it is cities that will largely define the fate of human civilization in this century. As we shape our cities with every infrastructure update, housing project, traffic policy, the Footprint can help to make investment choices fit for the future. Let's look at traffic, for example: As complex as the discussion about buses, trains, and cars, connection and steering of the systems may be, the Footprint reduces all this information to one single number: the required biologically productive area to fuel these systems. That's something one can work with. The Footprint thus isn't just a measurement but also a management tool.

Human cities and communities need to ask themselves: Where do we get our energy from? Our food? How much do we use compared to our competitors? How much do we use compared to that available per capita in the world? A reoccurring topic is efficiency: Are we already using all our possibilities to live better with fewer resources?

For regions and countries, the supply side (their biocapacity) as well as their resource management is at least as critical. What is our resource base? How much biocapacity is in our territory? Using more biocapacity than available within the boundaries of our country pushes us into biocapacity deficit spending. In contrast, having more biocapacity available than we use leaves that country with an



The economy is embedded within nature. It is a "wholly owned subsidiary" of the biosphere. All material ingredients come from Earth, and all used up materials that are not recycled are returned to Earth. Therefore, Earth's regenerative capacity is the materially most limiting factor for the human enterprise.

ecological reserve. The more countries and regions know about their biocapacity balance, the stronger their ability to guide and accommodate the radical change that will become part of our landscape. There is no doubt: The tightening competition for our planet's biocapacity will be a major challenge in the future.

> *The message of the Footprint is: We can measure not only the availability of nature, but also human demand on it. Knowing both sides gives us the full picture of our ecological foundation and empowers us to manage our destiny. It's a practical tool for those wanting to prevent ecological bankruptcy in the 21st century.*

The Footprint is a descriptive indicator. It can monitor the course of events and show whether the chosen path is producing the hoped-for

success or not. Footprint numbers are also free of moral preconceptions or imposed values. They don't tell anybody what they should or shouldn't do. They empower us merely to consider how much biocapacity is available, how much we use and who uses what, and what the implications might be for us and others. At the end of the day, Footprint analysts are motivated by the idea that thriving lives for all are possible within the means of our one planet. Pooran Desai from Bioregional call this "one planet living."[3]

Ultimately, we cannot escape the fact that humanity, with all its activities and in all areas of life, is part of nature. It is a dependency we cannot break. Yes, there are some philosophical and religious scriptures that try to tell us otherwise: That humans are separate from nature, that nature can and must be subdued, that it needs to be exploited and "civilized." As a result, humanity has subjugated and dominated ever more of nature, pushed back pristine parts to an extent that overuse has systematically become the norm. We have maneuvered ourselves into a cul-de-sac. Even evangelical ministers are now making the case that preserving creation is true worship.[4]

The Footprint is an accounting system that documents our ecological performance, nothing more and nothing less. By revealing the limits of nature, it contributes to building a globally sustainable economy. Its science-based description of what we use and what we have will hopefully feed into a consensus on where to go. By making visible basic physical boundary conditions, it helps define the playing field for societies and economies. Sustainability will only become reality if economic incentives are aligned with ecological possibilities. At the moment, they obviously are not.

Today, the most comprehensive Footprint accounts track the performance of countries. They cover all countries for which complete (or near complete) data sets in the United Nations statistics exist.[5] Over 245 national entities exist, and many are small. The 190 largest house about 99% of humanity. To assess its Footprint and biocapacity, each country is tracked using up to 15,000 data points per year. For 194 national entities, there are enough data in the UN statistics to produce the Footprint results.

The accounting method is not alarmist. On the contrary, it intentionally errs on the side of underreporting overshoot. Humanity's demand—its Ecological Footprint—is undercounted as not all demands are captured in UN statistics. The biocapacity side, however, is most likely overestimated since some damaging activities such as soil erosion or groundwater loss are not yet factored into the current accounts for lack of comprehensive and consistent data. This means that, in reality, the biocapacity deficits are most likely larger than what current accounts report, as discussed in more detail later in the book.

The Footprint is a highly aggregated measure of people's use of nature. The accounts capture a broad array of aspects. The Footprint captures all the aspects that compete for the productive surfaces of this planet. This leads to the method's communicative power: it summarizes human demand in one single number. It also compares overall demand to overall availability. It views everything from the perspective of the planet's ability to regenerate, its biocapacity. For instance, the use of fossil fuels like coal, gas, and oil is also included in terms of the biologically productive area such as the forests needed to absorb the resulting carbon dioxide emissions. Absorption of those greenhouse gases is one of the competing demands on the planet's biocapacity. There are trade-offs. Simply explained: we could either absorb more carbon dioxide or grow more carrots.

The Footprint is not the only ecological indicator. It does not claim absolute coverage, nor a monopoly. It rather focuses on one specific, yet fundamental question: How much of the biologically productive capacity of the planet is being used to power the human enterprise? For other relevant questions, other methods are needed. Like the different navigational instruments in the cockpit of an airplane, which are complementary to each other. Ultimately, we need a few clear and robust metrics that are simple to understand and can be used by many. We need a common "currency" that bundles the complexity of human dependence on nature, and makes choices comparable. This is the Footprint's ambition.

The Footprint framework affirms human vitality and aspiration. People want to live, and live well. But to thrive depends on how humanity will manage its ecological home. The challenges are considerable. They require us to employ all creativity and ingenuity we can get. In this context, the Footprint is a decisive tool to provide foresight, and to unleash our intellectual and innovative power.

Who Is behind This Effort

Mathis Wackernagel and William Rees conceived the Footprint in the early 1990s at the University of British Columbia. The method has evolved and been deployed widely by hundreds of cities, over a dozen countries, uncountable institutions as well as international agencies, such as the European Commission, the European Environment Agency, the International Organisation of La Francophonie, and the United Nations, including its Convention on Biological Diversity.

Global Footprint Network, with headquarters in Oakland (California), was established in 2003 to steward the methodology, develop standards, advance the accounts, and find novel applications in collaboration with partner organizations around the world. In 2018, Global Footprint Network joined forces with York University in Toronto (Canada) to build a global academic network that will host and maintain the National Footprint and Biocapacity Accounts as an independent, public-benefit venture, thereby improving accessibility, independence, and robustness of the results.[6]

In 2005, Global Footprint Network set itself the goal to have at least ten national governments officially test the Footprint before 2015.[7] In 2012, the Philippines and Indonesia became country number ten and eleven. More than twelve national government agencies have tested the Footprint already. They mostly concluded that the accounts adequately reflect their reality.[8]

There is still a long way to go. Switzerland, for instance, held a referendum on the Ecological Footprint in September 2016 where its citizens were asked whether Switzerland should strive to reach a Footprint by 2050 that could be replicated worldwide (currently

it would take over three Earths if everybody on the planet lived like the Swiss).[9]

A breakthrough would be to have United Nations agencies adopt the Footprint broadly and contribute to its improvement, standardization, distribution, and application. Imagine if the world community realized that we need an instrument to measure our physical dependence on our planet, in the ways that GDP measures economic activity.

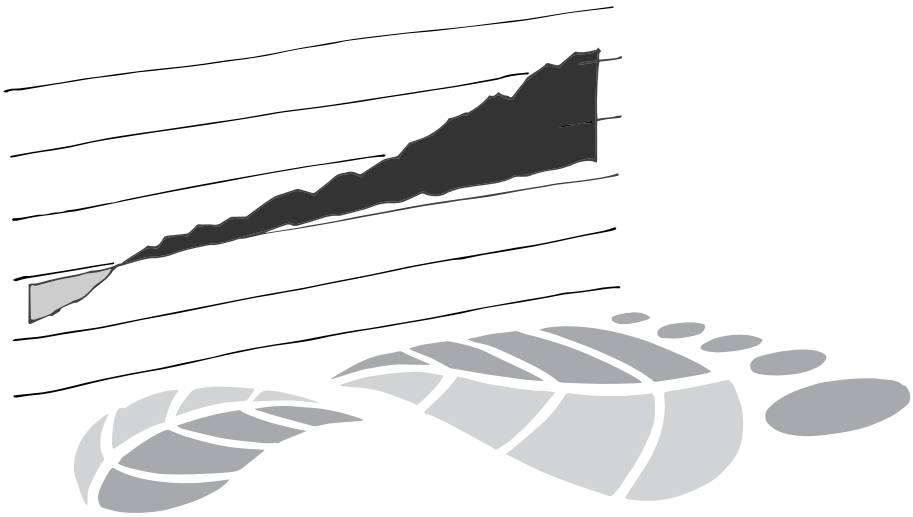
Our dependence on nature needs to be measured, in physical units. This is not unprecedented. Not everything in public policy is measured in financial units. For instance, we don't measure unemployment, longevity, or population size in dollars either.

There are significant options for shaping our various pathways. Even more so if we have access to the most relevant information and ideas. And possibly most importantly, the courage and wisdom to implement them. Here's the good news: The Footprint doesn't make our life more difficult—it enables us to make our cities and countries livable and our successes long-lasting. If you accept physics, knowing the biocapacity of one's own country and managing its Footprint will be as important in the future as financial accounting already is today. Knowing biocapacity is beneficial, as it is helpful to know about gravity. Knowing gravity still does not make it easier walking uphill. But it helps us build more robust houses and stronger bridges. Knowing about biocapacity and having robust Footprint accounts works for us. It gives us foresight and enables us to build a future that serves us all.

PART I

FOOTPRINT

The Tool



CHAPTER 1

AREA AS CURRENCY

How Much Biocapacity Does a Person Need?

Everyone, big or small, has an Ecological Footprint. How much nature people need depends on what they eat, how they dress, what their home is like, how they move around, and how they get rid of their waste. All of that can be measured. The resulting data allows us to determine the area of biologically productive land and water that is required to grow food, produce fiber for clothing, build houses to shelter people, and absorb their waste. We can measure the carbon dioxide from burning coal, gas, and oil. In the end, we all live on what the "global farm" provides, and we can accurately measure what the farm provides, and what people consume.

Everyone understands money. People with money have more options, and possibly fewer worries, at least material ones. Those with enough money can live how and where they like. Everyone welcomes them. As long as they can pay, no one will show them the door. We can do many things with money. For example, we can compare things. Money also tells us how much everything costs. Once we know the prices, we can relate them to our income. How long do I have to work so I can afford this mobile phone? How much do I earn, compared to my expenses? Compared to last year? Or compared to the income of someone in Singapore?

Ecological Footprint accounting is a tool that, like money, asks the core question: How much nature does everything cost? How much

How the Footprint Works: Just Think of a Farm

The productive area of a farm is the farm's biocapacity. What it can produce is determined by the area, as well as the productivity of each acre. In the US, pastures are sometimes measured in "cow-calf acres"—how many cow-calf pairs can be maintained on one acre. It is both the area and its productivity that counts.

The Ecological Footprint estimates how much farm it takes to produce what we consume, including everything we eat, all the fiber and timber we use, all the space to house our roads and buildings, and to absorb all our CO_2 waste from burning fossil fuel. There is competition for our farm's productive areas as a farmer can't graze cows where she places her house, and can't plant tomatoes where she builds her pond.

A farm family may want to know how hungry they are for food, materials, heating fuel compared to what the farm can provide. We can create the same comparisons to the world, countries, regions, cities, and even individuals.

Humanity's biggest farm is our planet. Thanks to Ecological Footprint accounting, we come to realize that the way we operate our "farm" now is out of balance, as our collective demand exceeds by at least 70% what our planet's ecosystems replenish.

Nature can make up for the difference by depleting stocks. Examples are cutting timber faster than it regrows, emitting more CO_2 than the planet's ecosystems absorb, pumping up more groundwater than is being recharged, or catching more fish than restocks. This business model only works so long—whether for farmers or humanity as a whole.

As you look at the world from a biological perspective, you start to recognize that every country is essentially a farm with forests, pastures, cropland, etc. How big is this farm compared to the resource demand of its residents?

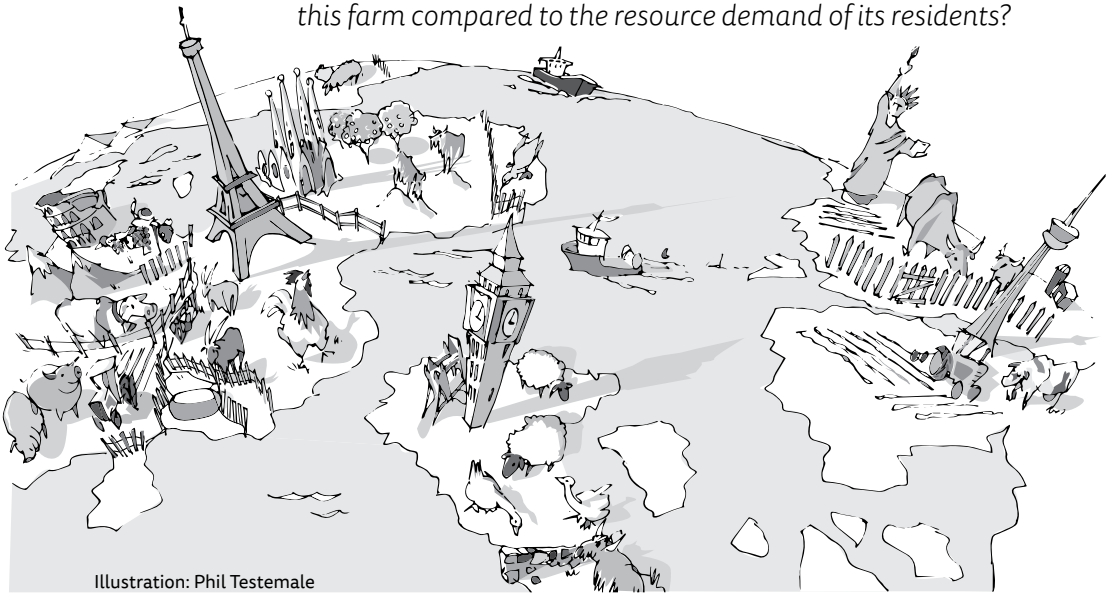


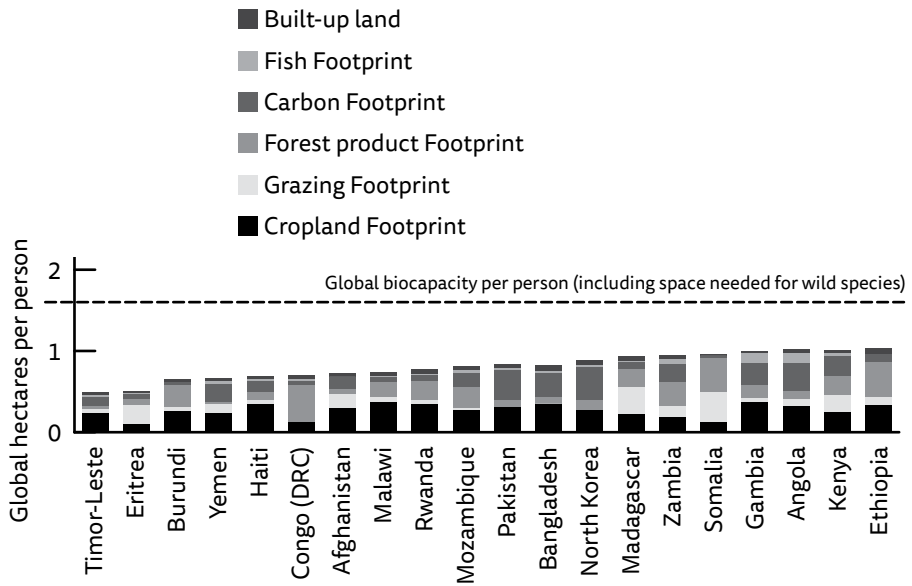
Illustration: Phil Testemale

biocapacity is required for a glass of orange juice, and how much for a liter of gas? And we can go further: How much nature does a person need? A person's Footprint is a "currency" which is spent to provide services, to offer space for our buildings, to produce goods and to dispose of them. For a person, their Footprint is the sum total of all they require, including their waste (because waste too draws on nature). What the Euro, Dollar, or Yuan is to money, the hectare—or more precisely the global hectare—is to the Ecological Footprint.[1]

Just as different currencies can be set off against each other, so can the Footprint's area units. This is the point: that there is a single unit—a *tertium comparationis*—that everything refers to. Obviously, not every global hectare is identical, only sufficiently similar. But the same is true for money since one dollar for a person with minimum wage means something quite different than one dollar for a billionaire.

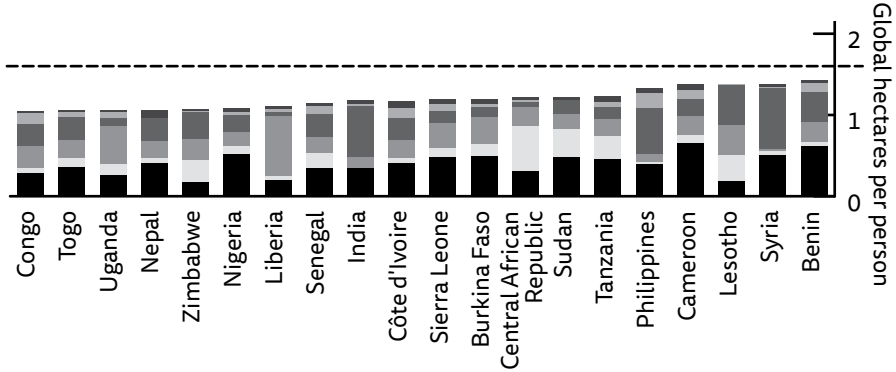
Therefore, in the same way one financial figure cannot describe the health of an economic entity, mapping the entire ecological reality with just one number is obviously crude and insufficient. In fact, Ecological Footprint accounting is not suggesting it is mapping the entire ecological reality. Rather it puts emphasis on biological resources (as we will discuss in more detail). The reason is that *biological resources* are materially more limiting for the human enterprise than the non-renewable resources like oil or minerals. For instance, while the amount of fossil fuel still underground is limited, even more limiting is the biosphere's ability to cope with the CO_2 emitted when burning it. The burning and coping are competing uses of the planet's biocapacity. Similarly, minerals are limited by the energy available to extract them from underground and concentrate them.

Figure 1.1. Ecological Footprint in global hectares per person, by country, 2016 data. In 2016, the world's biocapacity averaged 1.63 global hectares per person. Credit: Global Footprint Network—National Footprint and Biocapacity Accounts 2019 edition, data.footprintnetwork.org.



Since biology and area are interconnected, Ecological Footprint accounts take areas of biologically productive land or water as their measurement unit. As we will see, such a simple unit makes communication more accessible, and our situations more understandable. Prices allow people to communicate with others about the high or low cost of a good. The Footprint enables us to have productive dialogues about the different ways we consume nature: about high or low consumption, about its impact on this or that ecosystem—summarized as one single number, the sum of all our demands on nature.

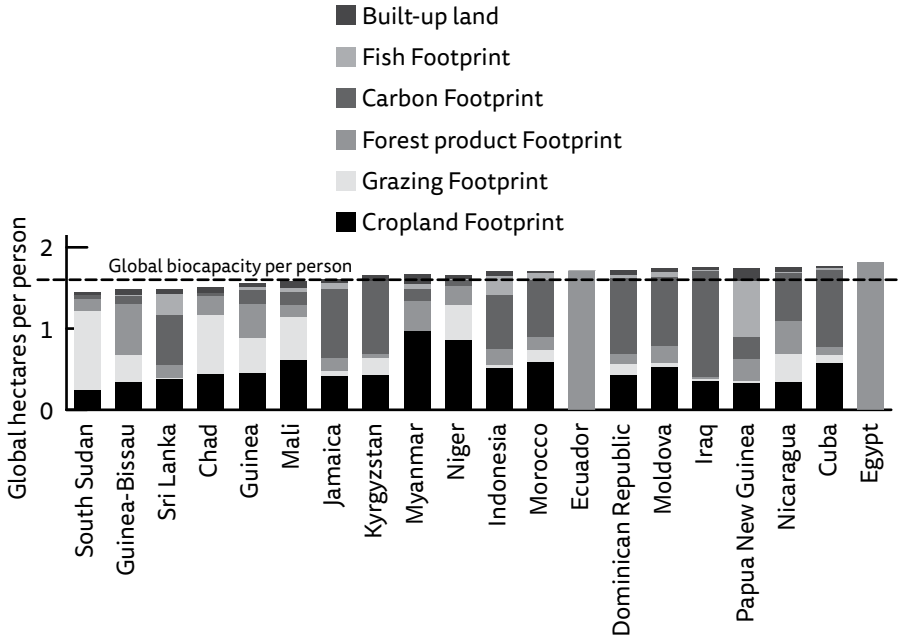
Let's visit a department store. Just as the goods on offer carry price tags that identify their monetary value, and just as food products come with information about nutrients and ingredients, all products could come with an additional number that identifies the biocapacity that has gone into the product. The front of the price tag would tell us what we must pay, while the back would tell us how much nature was used. A block of cheese, a pair of jeans, a holiday trip—everything can be measured in biocapacity: what size of area is required to provide this product or service? For cheese, it is mainly the grazing land a cow needs to produce milk and of course the energy needed to turn milk into cheese. For jeans, it is the cotton field. Trips are enabled by many things, from aviation or car fuel to electricity for the trains, food, maintenance and cleaning of the hotel and washing of the linen. For many city dwellers, electricity may seem to come magically from the socket and milk from a carton, but behind everything we use there is a piece of nature.



Here, too, we have a parallel to money: as long as we have enough, all seems well and we take it as a given. But what if there isn't enough? To have no biological capacity feels not that different from having no money. If, for example, you are stranded in a foreign city without cash or credit card, what will you eat? Where will you sleep?

What would happen if nature all of a sudden could no longer provide its wonderful services? If there wasn't enough water to support life and economic activity in the first place? What if the oceans' fishing grounds shrank or even collapsed while demand for fish continued to rise and fish became rarer and more expensive? What if the fields in one's backyard couldn't produce enough to sustain one's family and people—like many in rural Bangladesh—didn't have the money to buy additional food? What if the forests and oceans one day all of a sudden no longer absorbed carbon dioxide but instead released the gas they had stored into the atmosphere? What then?

Money is our core economic measure for assessing value. But money can do more than simply measure value: it is also a means of payment and, as such, gets passed from person to person. The Footprint can't do that. We can exchange the fruits of biocapacity, for example by importing timber and exporting meat. People or trade

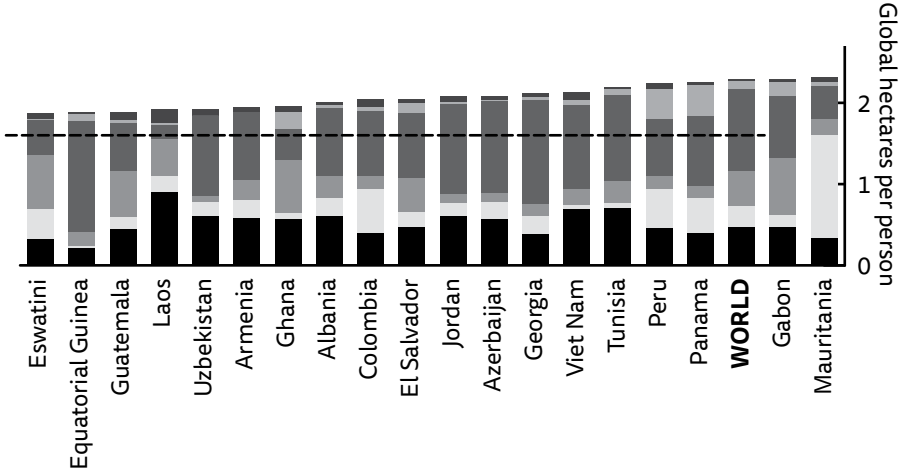


statistics may not recognize that, since it is not actual Footprints units that get traded. Rather, we can measure the Footprints of timber and meat that is traded.

Money is also a kind of storage system for one's assets (as in a savings account or a portfolio), but that, too, is different with the Footprint. Nature's assets always exist in nature itself, and the Footprint, as an accounting method or a code number, only measures and identifies them. Whereas money is recognized if not idolized as valuable, nature's capital is undervalued. We behave as if nature were infinite and inexhaustible in its provision of riches to humanity. In the long term, however, it is nature that is the most valuable asset, whereas money is just a symbol.

Of course, things exist that we cannot buy, such as true love. We cannot assign it a monetary value. Another example is the atmosphere. People have developed the habit of treating our atmosphere as a free garbage dump for their emissions. As with money, there are areas where the Footprint does not apply. A rock, for example, has no Footprint. It simply is, and its existence requires no measurable consumption. Animals, on the other hand, do have a Footprint; they breathe, drink, and feed, consume biocapacity and hence area. A fish eaten by a seal is no longer available to us, or only indirectly when in turn we eat the seal or use its pelt.

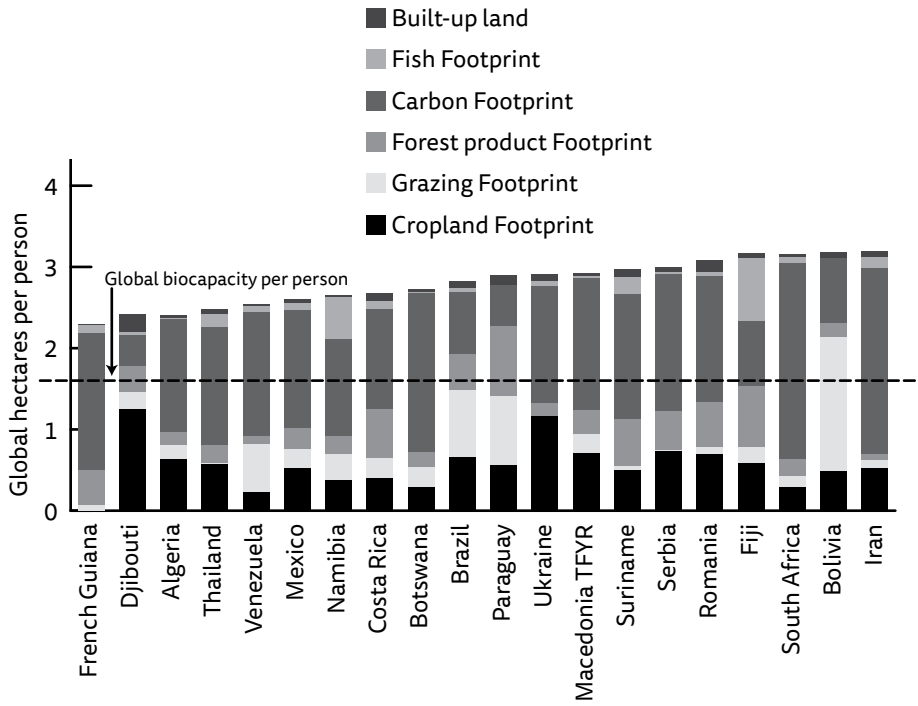
How much biocapacity do we need? In order to eat, to clothe ourselves, to build our houses and heat them, also to travel and to transport any goods, we need the supplies that nature provides. In the



process, we leave behind solid, liquid, and gaseous waste. Nature has to cope with that too. As we move through the world, we leave behind our "Footprint." Some of us tread with heavy steps, while others have such a small and light step they hardly touch the ground. But every human being, big or small, leaves a trace as long as they live. It is this trace that the Footprint metaphor refers to.

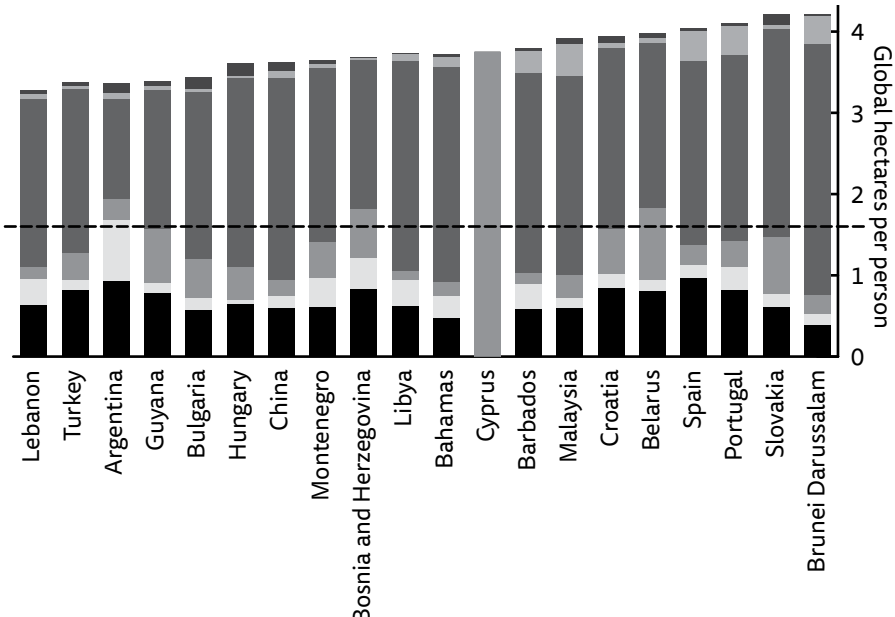
The Ecological Footprint measures not only the demands an individual puts on nature but can equally be applied to the population of cities, nations, or humanity as a whole.

Let's take fossil energy as an example: Since the Industrial Revolution, we have availed ourselves of massive amounts of nature's resources of coal, oil, and gas, when in fact these are non-renewable resources, or to be more precise, resources that renew themselves only over enormous periods of time. We extract them from the Earth's crust and bring them to the surface and hence into the biosphere. For Footprint calculations, the amount of coal or oil underground does not enter into the equation. After all, these materials are not part of living nature but came to be over millions of years; in that sense, they



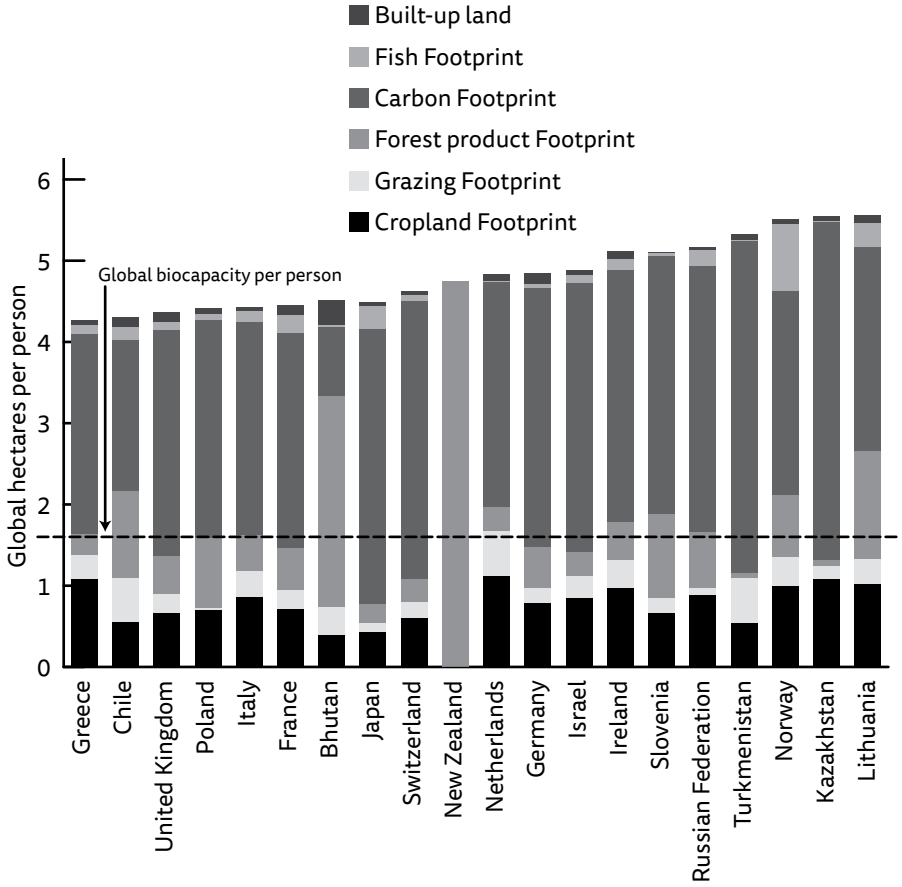
are assets more like a piece of gold or a painting by Picasso. Also, they turn out to be rather plentiful compared to what the biosphere can handle. It is by using coal or oil that we consume nature, and this consumption is what Footprints measure.[2] When such quantities of fossil energy are burned, carbon dioxide is released. And then our biosphere has to cope with that, because this is new carbon dioxide that previously was not part of the natural cycles.

To prevent an increasing concentration of carbon dioxide in the atmosphere that will lead to a long-term destabilization of our climate, that additional carbon dioxide should be removed—but, so far, only a small portion has been removed. The remainder we leave for nature to cope with it. A good percentage of the excess carbon dioxide is now being absorbed by the oceans (and further acidifies them), some is absorbed by ecosystems on land, but some land uses also lead to net emissions. A lot of the carbon dioxide is left in the atmosphere and accumulates. The Footprint method therefore asks: how big an area, how much forest, is necessary to absorb the remaining amount of carbon dioxide? Research shows that an average hectare of forest on this planet, if managed for climate protection, can annually absorb roughly the same amount of carbon dioxide as is released by burning 900 liters (or 240 gallons) of gasoline.[3]



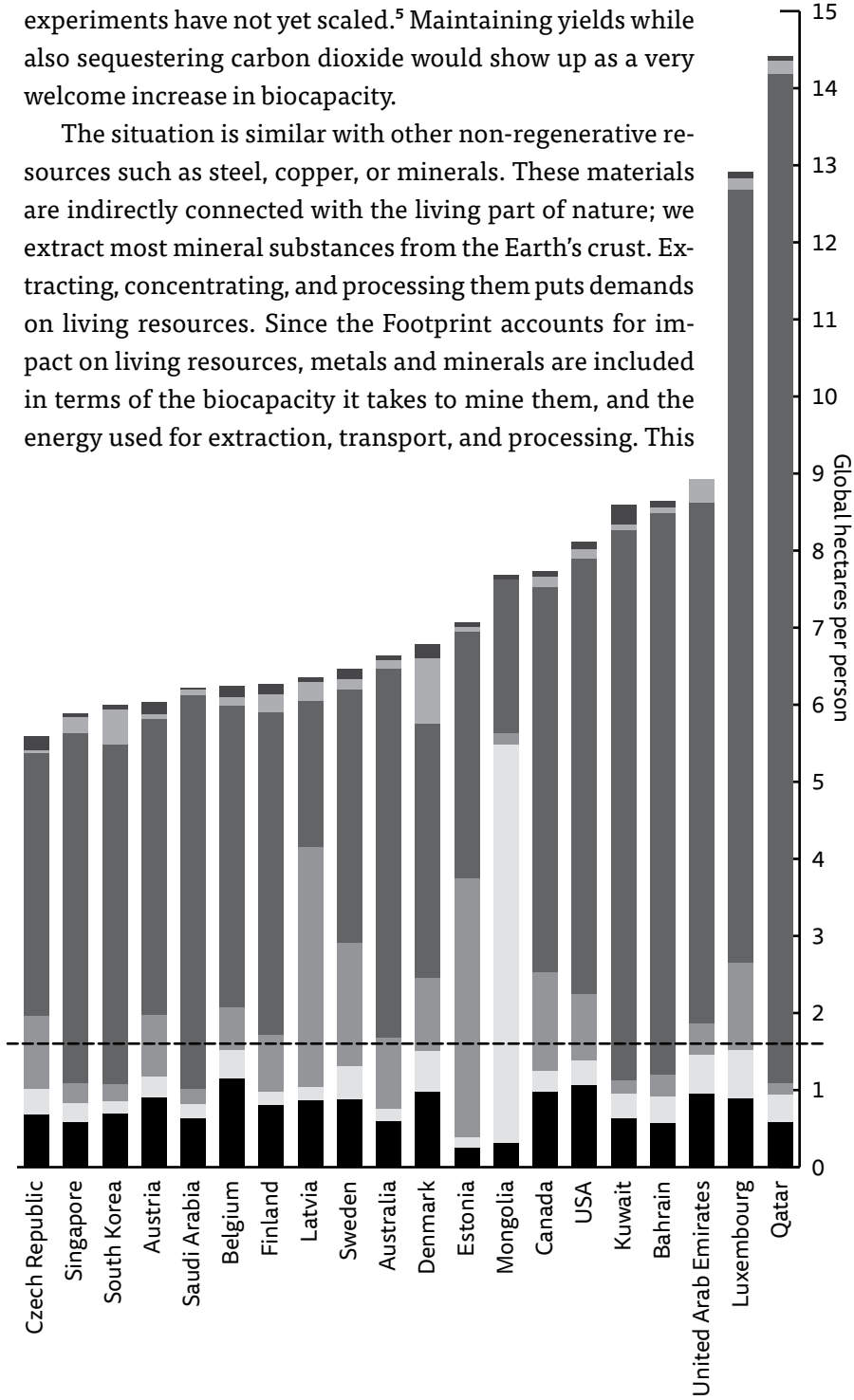
Over the past 200 years, the atmosphere's carbon dioxide level has risen by about ⅓ from 278 ppm to more than 410 ppm, and more if we include other greenhouse gases. We are obviously not dedicating enough of the planet's biological capacity—mainly forests and oceans—to sequester the combustion residues as quickly as we generate them.[4] One reason is that there are many other competing demands for the planet's biological capacity as well. Plus, there isn't enough to do that: Recently, the carbon Footprint has become so large that it alone is now exceeding the Earth's regenerative capacity.

Still, if we deploy area to sequester more carbon dioxide, we could have considerably less biocapacity left for other purposes, such as the production of food, fiber, or fuelwood, or the creation of urban areas. Grazing and crop agriculture can in some ways sequester car-



bon. We can point to promising experimentation, but the experiments have not yet scaled.[5] Maintaining yields while also sequestering carbon dioxide would show up as a very welcome increase in biocapacity.

The situation is similar with other non-regenerative resources such as steel, copper, or minerals. These materials are indirectly connected with the living part of nature; we extract most mineral substances from the Earth's crust. Extracting, concentrating, and processing them puts demands on living resources. Since the Footprint accounts for impact on living resources, metals and minerals are included in terms of the biocapacity it takes to mine them, and the energy used for extraction, transport, and processing. This

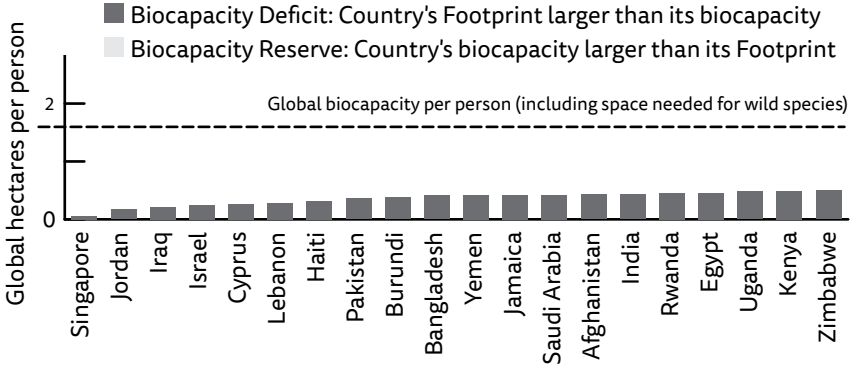


is the demand metals and minerals put on nature. And that, in turn, brings us back to carbon dioxide and to the biocapacity required to store carbon through photosynthesis in solid biomass. Put differently, mineral substances and ores are valuable assets like gold or shares, but in contrast they consume additional energy to make them available to the human economy. That energy, too, requires biocapacity.

For a long time, most people paid attention primarily to the non-renewable resource aspect of natural capital. People recognized that the supply of fossil energy sources as well as of ores and minerals is ultimately finite, that they will sooner or later be exhausted, or that certain resources are left only in low concentrations, making it too hard to extract them. This concern is understandable, given that industrial production processes depend on such materials. Indeed, some of these materials have already become rare. But recently we have come to realize that renewable resources with their life-supporting functions are even more scarce, and that even though they can be replenished, they can also be depleted.[6]

Renewable resources—forests, fish stocks, wetland—can be entirely used up through overuse. This happens eventually when people exploit renewable resources faster than they can regenerate.

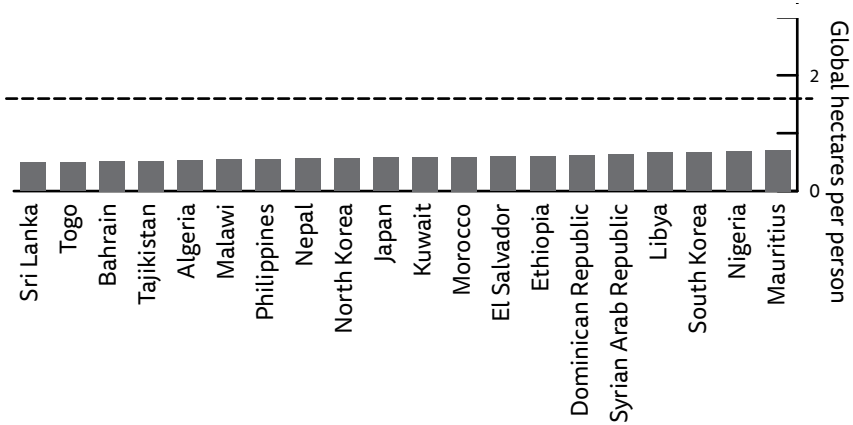
Figure 1.2. Biocapacity in global hectares per person, by country, 2016 data. In 2016, the world's biocapacity averaged 1.63 global hectares per person. Credit: Global Footprint Network—National Footprint and Biocapacity Accounts 2019 edition, data.footprintnetwork.org.



Whereas most non-renewable resources are less fundamental for the support and conservation of life, renewable resources are a *conditio sine qua non*, a non-negotiable condition, for the existence of all life on Earth. For this reason, it is especially the renewable resources, and with them the biosphere's overall potential to regenerate, that constitute the materially most limiting factor for human life and well-being. This constraint is shared, of course, with the world's more than ten, or possibly hundred, million animal and plant species.

In short, the Footprint looks at the world as if it were a farm. How big is it? How much does it yield? How much do we use, compared to what the farm grows? Farmers, too, take area as their point of reference—and it is those very same areas that provide the ecological services upon which life depends.

A farmer's perspective on nature can be translated into a science-based accounting system. The framework behind Ecological Footprint accounting brings together millions of numbers culled from satellites, trade statistics, censuses, and questionnaires. The United Nations has created comprehensive data sets for the entire world that has tracked the world consistently since 1961. The UN stamp makes the data official, and turns them into the most neutral and accepted data set for comparing nations. This data set makes possible to calculate with consistency the Footprint of nations all the way back to 1961. Today, Global Footprint Network calculates them for all the 220 countries included in the UN statistics. Out of the data sets, about 194 are complete enough to produce results, at least for one year. For every single country, and for every year, the method presently requires up

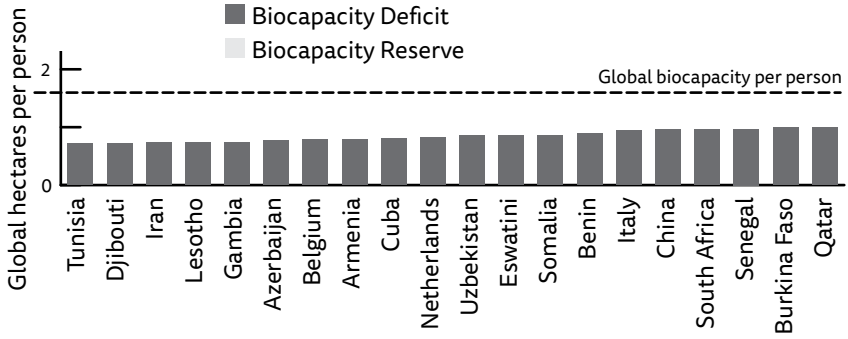


to 15,000 bits of data stemming from all kinds of data sets: energy, agricultural production, land use, population, fisheries, forest, and so on.[7]

This way, every country gets a number that indicates its residents' average consumption of nature's resources—their Footprint—as well as an estimate of the ability of the country's natural environment to renew what people demand—its *biocapacity*.

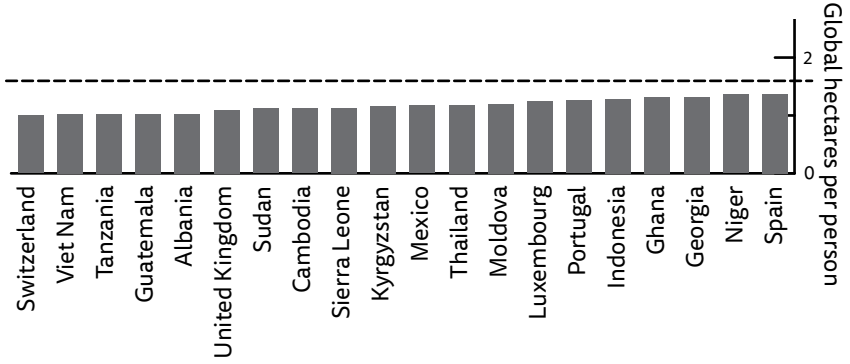
To repeat the question: How much biocapacity does a person occupy? Today we can answer this question with ever better statistics, even though we know for sure that our answers remain somewhat imprecise because reality is just too detailed, and even the best statistics cannot capture everything. Even though they are not absolutely exact, still our answers point in the right direction, can be verified and improved upon. They are merely the best available answers to our questions. Because Global Footprint Network, its partner organizations, and other institutions continue to improve the science involved, the results are increasingly reliable, too.

This is also the reason why Global Footprint Network, together with York University in Toronto, is now gathering a coalition of countries, supported by a rigorous global academic network, that will own and produce the future editions of independent, transparent, and robust National Footprint and Biocapacity Accounts.[8] This will be more powerful than just having one organization, Global Footprint Network, produce the accounts. Then, the results will be more trusted and seen as unbiased, which makes it more likely they will inform public and private decision-making.



The results for the 2019 edition, the latest ones at the time of printing, cover all the countries up to 2016. (The time lag reflects the time delay in UN data compilation.) The Footprint captures each person's "global farm"—forests, fishing grounds, grazing lands, croplands—that this person needs for his or her resource consumption, waste absorption, and to accommodate the buildings and roads she or he occupies. They show that the average Footprint of a person in Haiti—a country whose ecological devastation and intense setback through an earthquake was accompanied by economic turbulence and intense political upheaval—is 0.68 global hectares. The demand for biocapacity in Kenya or Uganda amounts to 1.0 and 1.2 global hectares per person, respectively. A German, on the other hand, claims on average 5.0, a Frenchman 4.7, an American 8.3, and a resident of the United Arab Emirates 10.2 global hectares.

A number of Footprint calculators are available online that let individual people easily calculate their own Footprint. Not to brag, but we like ours best.[9] We like it not just because it uses cute graphics, but because it is directly calibrated against national calculations. Also, it builds on easy questions anybody can answer without having to get up and look at utility bills or weigh their garbage for a week. Like any quiz, it asks simple questions about your nutrition—for example, how many times a week you eat meat—about features of your house, and about your mobility habits. The answers allow for a rough estimate of your individual Footprint, including the translation of how many Earths it would take if everybody lived like you. It even tells you the date of Earth Overshoot Day, if all people on our planet lived like you.

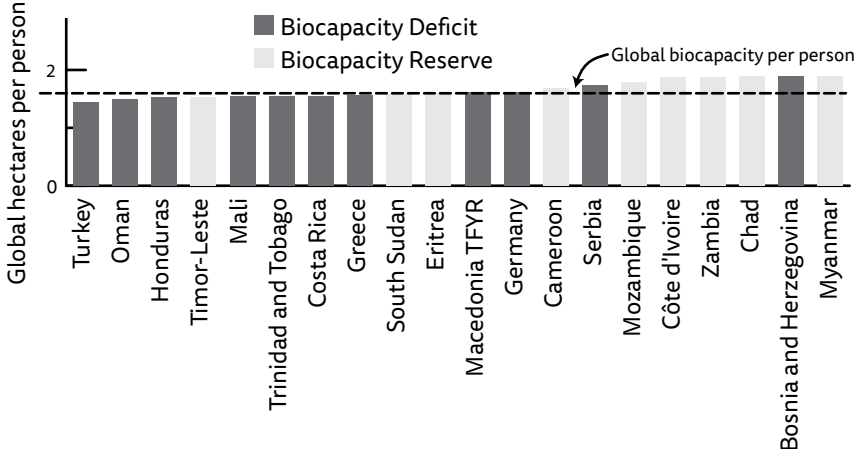


Calculating the Ecological Footprint of Cardi B in Six Easy Steps

Let's take singer Cardi B to illustrate how Footprints are calculated. Say Cardi B's coffee comes from Guatemala, the wheat to feed the chickens that lay her eggs comes from Iowa, and the wool used for her jacket is from New Zealand. Thus her Footprint is spread all across the world.

To assess her current Footprint, we track:

1. How much pasture does it take to feed the cows for the dairy and meat she consumes this year, the wool she uses, and the leather for her shoes, jackets, and furniture?
2. How large are the fields needed to produce all her beans, cotton, rubber, sugar, cereals—not only for her croissants and spaghetti, but also for feeding the chickens and pigs she might eat this year? How much for the cotton and silk?
3. How much ocean area is necessary to produce the fish that she eats this year?
4. How much land for her homes (or portion of them, if she shares her homes with others), her gardens, and her share of the roads, city squares, airports, and parks?
5. How much forest area is necessary to absorb the CO_2 from fossil fuel she uses this year—for heating and cooling her homes,

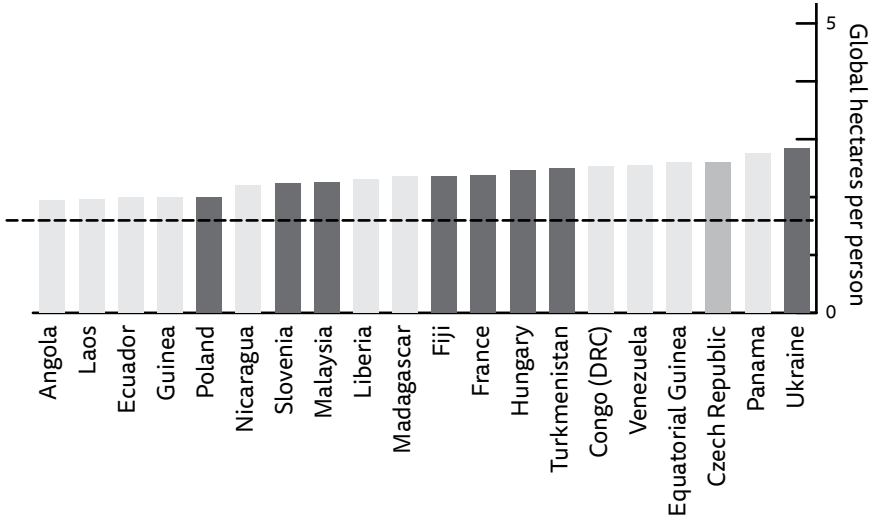


producing the goods and services she consumes, driving and flying her around?

6. How much area is needed for the energy and resources used to provide Cardi B's share of social expenditures like hospitals, police forces, government services, educational facilities and museums, and military activities?

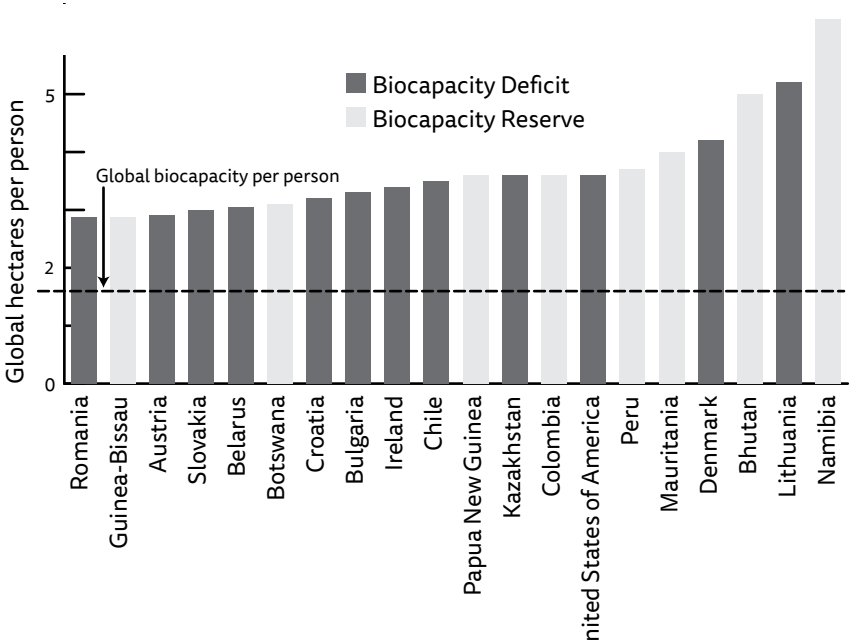
To get Cardi B's Footprint, we first itemize all the areas from the above questions—all the actual areas needed for everything she uses. Then, we translate every actual area into standardized *global hectares* with world average productivity or growing potential. Hectares that are highly productive, let's say three times more than world average, would be counted in this case as three global hectares. These global hectares become the common currency that allows us to compare all hectares on an equal footing. Then we simply add all those global hectares up and get her Footprint for this year. Voilà.

This is the area Cardi B occupies for the entire year to provide what she consumed in the entire year. Next year, her Footprint will be different again as her consumption, technological efficiency, as well as the productivity of the biosphere may change. Check out your own at footprintcalculator.org.

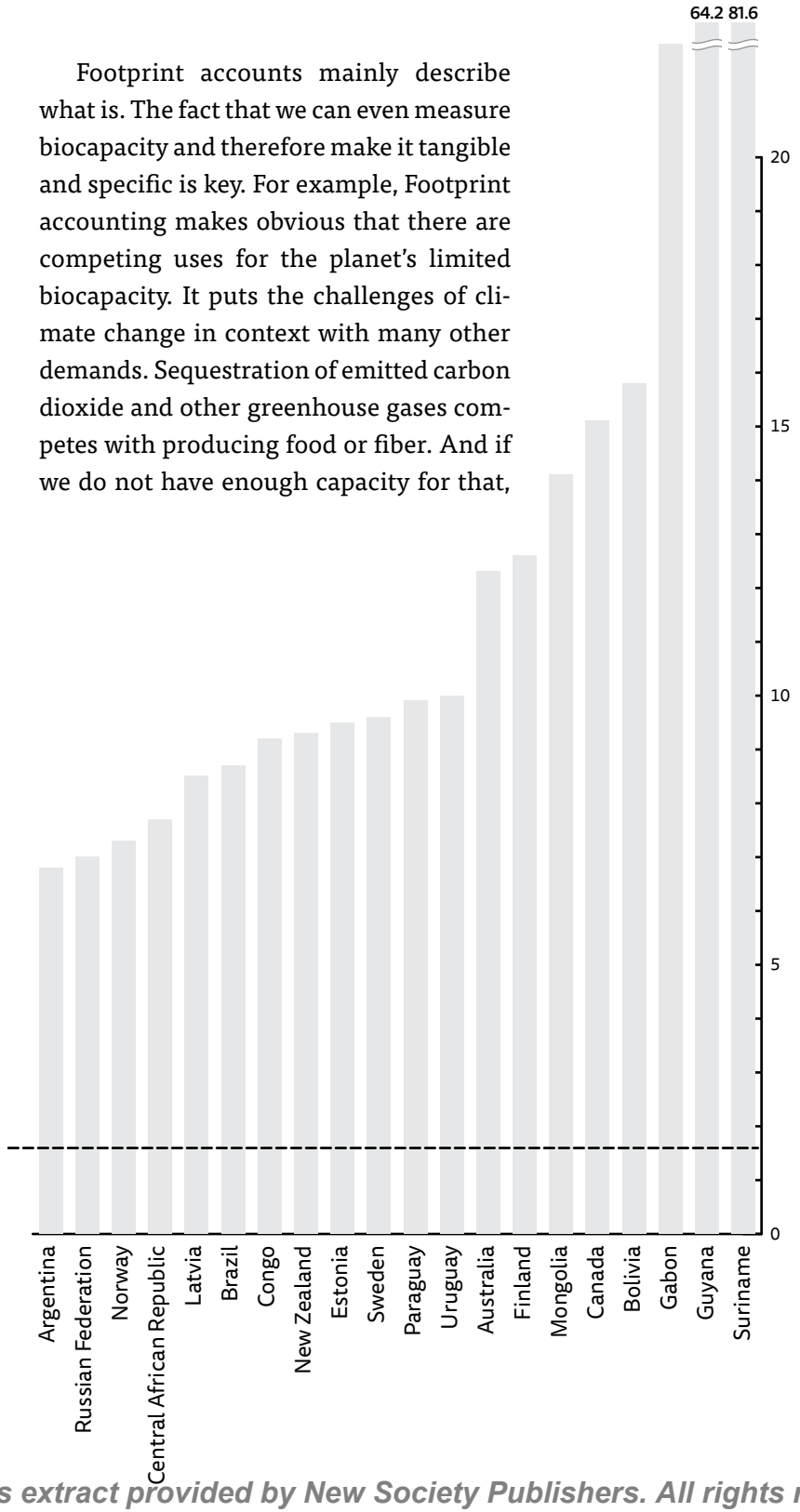


The method, however, is applicable not only to lifestyles but also to any other activity, product, and service, from a shower, a piece of bread, to a breakfast or an air trip or a doctor's visit.

The Footprint method gives us a new perspective. We can now see the actual physical "costs" of the things we use day in and day out. Some of those things give us a rich and fulfilled life. Others we just use out of habit. For each thing, we can see how much biocapacity it requires. It shows in numbers how our individual existence is directly linked to the planet's ecological capacity, something city dwellers sometimes forget. With this fresh perspective, we realize that the flows of materials and energy are not somewhere out there, separate from the economic realm. Instead, the numbers show how these resources flow through our lives. It makes obvious how human life and our economy are subsystems of the biosphere. The Ecological Footprint method is a tool that details the physical metabolism of humans and nature; it is both a micro- and a macro-instrument. On both a small and a large scale, we can quantify what nature provides and how we consume its provisions.



Footprint accounts mainly describe what is. The fact that we can even measure biocapacity and therefore make it tangible and specific is key. For example, Footprint accounting makes obvious that there are competing uses for the planet's limited biocapacity. It puts the challenges of climate change in context with many other demands. Sequestration of emitted carbon dioxide and other greenhouse gases competes with producing food or fiber. And if we do not have enough capacity for that,



Earth's biocapacity deteriorates. For instance, carbon dioxide builds up in the atmosphere, which over time could significantly erode the planet's biocapacity through changing and more volatile weather patterns.

About 60% of humanity's Footprint today is the result of our consumption of fossil energy. Our carbon Footprint has grown rapidly. About 150 years ago, at the onset of the coal and steam revolution, humanity's carbon Footprint was essentially zero. Since 1961, when reliable data collection by the United Nations started, it has more than doubled. Our energy consumption has grown even faster, especially for natural gas, which emits less CO_2 when combusted and therefore has a smaller carbon Footprint per energy unit than coal or petroleum. But this climate benefit only holds true, though, if little of natural gas' methane escapes uncombusted. Methane itself is a powerful greenhouse gas. Even small methane losses in the extraction and distribution of gas—in the order of 2%—void the climate advantage of gas compared to coal.[10]

The demand for resources hardly knows an upper limit. We can live in ever bigger homes, own more residences, and drive cars or ride planes almost as much as we like, provided we have the money. As for our food, transportation of food products over greater distances, increased meat consumption, and ever more sophisticated food preparation are increasing humanity's Footprint, too. Carbon dioxide emissions accumulate in the atmosphere and contribute to lasting climate change. With the help of Footprint accounts, we can assess what would happen if we drew a considerable amount of our energy supply from renewable resources, such as agrofuels. In most cases, the atmosphere might become less burdened—but would we perhaps shift more demand on other biological systems? Footprint assessments would capture that.

Most of the common techniques to obtain energy from regenerative sources—water, wind, and biomass energy—emit less carbon dioxide, yet they often also require biologically productive areas, even windmills that stand on cropland. Different methods exist for the extraction of energy from biomass. For biofuels, typically the fruits

of agricultural produce are used, such as corn grains, canola, rapeseed or palm oil kernels. Second-generation methods, on the other hand, use the entire plant with a correspondingly higher efficiency while ideally not competing with food crops. However, they have not become viable yet. The Footprint can quantify the demand on nature per unit of energy for each method.

The climate implications also become more obvious from a Footprint perspective. Fossil fuel allowed humanity to overcome biocapacity constraints; cheap fuels became versatile alternatives to the products of the planet's biocapacity. Fossil fuel is not just high-quality energy but can be used to produce plastics, fibers, and chemical products. The cheap and plentiful fossil energy also enabled the intensification of agriculture. In the US, it takes currently about 6 calories of fossil fuel to produce 1 calorie of food.[11]

In return, the emission from fossil fuel use, particularly CO_2, has overwhelmed the capacity of the biosphere to absorb this gas. The result is greenhouse gas accumulation in the atmosphere. If we allow for further accumulation of carbon in the atmosphere, the possibility of climate instability increases. This could erode food production, since agriculture depends on predictable climate. It was the magically stable climate conditions of the 10,000 years of the Holocene that enabled the emergence of agriculture. Therefore, the prospects for humanity are brighter if we stop fossil fuel use very soon and learn how to live only off biocapacity. Eventually we have to live only from what the planet can regenerate, so the more effectively we prevent climate change, the more biocapacity we will have.

These interactions between climate, fossil fuel, and biocapacity reveal the challenge of global warming and the significance of biocapacity. These interactions emphasize the reality of our astoundingly robust yet vulnerable planet Earth. We are biological beings on a biological planet. To bring all these aspects together is at the heart of the Footprint.

The Footprint functions like a map. It provides a description of the physical reality in which we live. As defined by its core principle, it translates human demands on our ecosystems into a common

denominator. An extensive data set exists in the background, just as with a map. But the map shows only the essentials: cities, roads, borders. If it were to show every single tree or house, we could no longer read it. This reduction of complexity of Footprint accounting allows us to capture an intricate and convoluted reality. Like a map, the Footprint enables us to better understand and navigate in our world with its complex and diverse life-support systems. It helps us evaluate risks and opportunities; it supports us in finding a viable path forward.