



CENTER FOR EDUCATIONAL RESEARCH, LEARNING & INNOVATION

A Sustainable Future Based on Environmental Education





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ABSTRACT

Accelerating environmental degradation is one of the greatest challenges of our time, and its consequences are already affecting education systems directly. Extreme weather events disrupt the schooling of millions of students, demand new investment, and force us to rethink how we build systems capable of responding to an increasingly challenging environment.

At CERLI, we analyze the relationship between education and sustainability by separating scientific evidence from exaggeration, examining the major environmental debates, and studying the educational models proposed to address them. Through this analysis, we seek to understand how environmental education can move beyond theoretical knowledge and become a practical tool for building more sustainable societies.

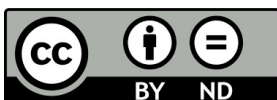




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To our readers,

Talking about sustainability has become surprisingly difficult. Climate change, pollution, ecosystem loss, waste, and our consumption patterns appear constantly in public discourse, campaigns, news, and everyday conversations. This constant presence has helped many people better understand environmental problems, but it has also created a space where rigorous information coexists with useful simplifications, exaggerations, economic interests, ethical positions, and messages designed to provoke a reaction rather than reflection.

This report grew out of precisely that unease. At CERLI, we wanted to understand which of the claims we repeat about sustainability are firmly supported by evidence, which need context, and which become distorted when they leave the scientific arena. That is why we began far from the classroom. We examined climate change, the carbon footprint, waste management, plastic pollution, e-waste, ecosystem protection, and some of the controversies that often surround these issues.

That journey then led us to the question that truly belongs to our field: what do we do with all this knowledge in education? Informing a student about an environmental problem is relatively straightforward. Helping students understand its causes, interpret conflicting data, connect different areas of knowledge, evaluate possible solutions, and use what they have learned once the school assessment is over presents a much more interesting challenge. This is where we find the real purpose of environmental education: developing the capacity to tackle complex problems without reducing them to slogans.

We also wanted to keep one idea in mind throughout the report. The severity of a problem does not require us to exaggerate it. We can speak clearly about significant environmental risks, acknowledge uncertainty where it exists, question weak arguments even when they come from causes we support, and trust that well-informed readers can reach their own conclusions. For CERLI, that is precisely what education means: providing tools good enough for knowledge to endure even when it no longer fits comfortably with our expectations. We hope we have succeeded.

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Introduction

The 2030 Agenda for Sustainable Development, comprising 17 goals and 169 targets aimed at eradicating poverty, promoting peace and prosperity, and protecting the planet, includes several commitments of particular relevance to education worldwide. One of the most important is Target 4.7, adopted by the United Nations General Assembly in 2015:

“By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture’s contribution to sustainable development”

- Transforming our world: the 2030 Agenda for Sustainable Development (Resolution A/RES/70/1, 2015).

When discussing this target, we tend to pay particular attention to human rights, equality, global citizenship, or a culture of peace. Yet another equally important component is sometimes overlooked: adopting sustainable lifestyles. This includes responsible resource consumption, waste reduction, management of our environmental footprint, and many other factors related to how we interact with the planet.

But a much more interesting question arises here: what do we really mean when we talk about teaching sustainability? It is not simply a matter of introducing isolated concepts about renewable energy, recycling, or ecosystems. It means building the critical awareness that

enables students to understand the relationship between their everyday decisions, the systems they belong to, and major environmental challenges.

The 2030 Agenda invites us to rethink curricula in pursuit of cultural transformation, at a time in history when environmental issues are becoming increasingly visible in daily life, public debate, and the concerns of younger generations. Our challenge in education, then, is to help learning move beyond the classroom and into everyday life, so that every student understands sustainability well enough to consciously develop their own relationship with it.

This process cannot happen in isolation. It will require coordination among educational institutions, public policy, families, and communities to create an impact that endures beyond the classroom. At CERLI, we embrace this commitment as an educational, ethical, and social responsibility. We are convinced that environmental education must move beyond theory and become an everyday presence within our education systems.

Throughout this report, we therefore propose understanding sustainability as a thread running through different areas of knowledge rather than as an isolated subject. From this perspective, every educational experience can become an opportunity to understand our surroundings, question our decisions, and explore new ways of relating to the planet.

The Age of Environmental Awareness

Contemporary societies face a combination of environmental pressures closely linked to our energy, production, and consumption systems. Climate change, biodiversity loss, and various forms of pollution are already having observable consequences for ecosystems and human populations in different parts of the planet.

At the same time, history shows that major technological and social challenges can bring about profound transformations. The expansion of low-emission energy sources, greater resource efficiency, technological innovation, and new production models offer tools to reduce some of these pressures without sacrificing human development. As with other social transformations, education has a fundamental role to play here.

The issue, then, is not choosing between development and sustainability, but discovering how to make the two compatible. For centuries, we used our knowledge to expand the boundaries of what was possible; now we will need to use that same ingenuity to reconsider some of the consequences that progress has left behind. And, as with any transformation intended to last more than a generation, education will have a fundamental role to play.

Unlike other major technological transformations, today's challenge also requires us to rethink some of the foundations of how we produce, consume, and develop. And there is an interesting opportunity:

environmental issues now occupy a much larger place in daily life and in the concerns of younger generations, who are growing up surrounded by debates about climate change, pollution, biodiversity, and responsible consumption.

Learning about sustainable lifestyles means, by definition, first understanding the problem we are trying to solve. After all, it is difficult to take a real interest in something we do not understand. This is where an enormous opportunity for education emerges: instead of presenting these issues as theoretical, abstract concepts traditionally confined to subjects such as the natural sciences, we can turn them into real, tangible problems. We will present students with a problem and give them the tools they need to understand its causes and explore alternatives. Some will be better than others; some will even fail. But that is precisely where a particularly valuable part of learning takes place.

Projects that involve students as active participants in their communities have a particular appeal: they stop asking students merely to learn about a problem and begin inviting them to try to solve it. Of course, no one expects a schoolchild to find the solution to climate change, ocean pollution, or biodiversity loss single-handedly. But that is not the real objective either.

What matters is the process. Investigating a problem, discovering that it involves more variables than were initially apparent, discussing alternatives, making mistakes, and trying again help develop creativity, critical thinking, and an interdisciplinary perspective. In the long run, those same abilities can stay with students when they have much more technical knowledge and the tools to turn a good idea into real innovation.

In a way, we are looking into a mirror of our own history. Just as our past decisions defined our place on the planet, today's decisions will determine whether we can preserve it. With our unparalleled ingenuity, we humans have shown ourselves capable of turning adversity into opportunity. The great unknown is whether, this time, we will have the

maturity to do so for the benefit not only of our own species, but also of all the life that shares this world with us. Taking such an important step as a society would demonstrate that our progress need not come at the expense of the environment that makes it possible.

Will we be able to put our collective future ahead of some of our immediate interests? At CERLI, we have always been optimistic about human potential, and we firmly believe that education is one of the best tools we have for developing it. Although this optimism may be dismissed as naive, we need only look inside and outside classrooms to find examples of young people putting theory into action, and of seemingly small school projects that ultimately involve entire communities.

We know firsthand that educating citizens who are committed to their environment and capable of thinking globally and acting locally is the most valuable investment humanity can make in its own future. And how could we not dream of a sustainable, environmentally aware future? Education has served as a tool for transformation in settings far less receptive to change, although it is true that we have never faced a race against time.

The challenge is considerable, time is short, and we are ready to do our part. So let us begin this journey through education for sustainability at the most logical starting point: understanding exactly what we are facing. What are the main environmental challenges of our time?

Climate Change and the Carbon Footprint

Throughout our history as a species, many of our greatest advances have been linked to the same ability: finding new ways to harness available energy. First, we used our own labor and that of other animals; then we learned to harness fire, wind, and water. Over time, we adopted sources capable of powering increasingly complex machines.

This relationship between energy and development is no coincidence. The more energy we can obtain and control, the more complex our tools, industries, and societies can become. The problem arises when the very thing that accelerated our progress also begins to produce consequences we had not anticipated.

For this reason, many of the major changes in how we live were accompanied by new ways of obtaining, converting, or using energy. Domesticating animals multiplied our capacity for work; fire allowed us to produce heat and transform materials; wind powered boats and mills; and water became a source of mechanical power long before modern electrical grids existed. Each of these advances made it possible to perform tasks more quickly, produce more, and expand the possibilities available to our societies. For much of our history, this relationship between greater energy availability and better material conditions seemed to offer only advantages.

However, this relationship became much more apparent in the eighteenth century, with the Industrial Revolution. Steam engines already existed, but improvements introduced during that period, including those developed by James Watt, made it possible to use them

much more efficiently and expand their application in industry, mining, and transportation.

The next major leap came with the expanding use of other fossil fuels. Coal already played a central role and was gradually joined by oil and natural gas. All three eventually became pillars of modern economies because of their energy density, ease of transportation, and enormous versatility. Oil, for example, made it possible to power internal combustion engines and transform transportation worldwide. It also opened the door to the petrochemical industry, which would produce plastics, fertilizers, synthetic fibers, medicines, and an enormous variety of products that are now part of our everyday lives.

This model was so successful that, in just a few generations, fossil fuels went from being a technological advantage to becoming the energy foundation of much of the modern world. Beginning in the nineteenth century, and with much greater intensity during the twentieth, our economies became deeply dependent on fossil fuels. Factories, transportation, much of electricity generation, and numerous processes in modern agriculture came to rely on the ability to extract, transport, and consume coal, oil, and gas.

For a long time, the environmental consequences of this model were poorly understood, difficult to observe on a global scale, or simply pushed aside in favor of its enormous economic and technological benefits. Yet while we used these fuels to expand the limits of production and human comfort, we were also releasing into the atmosphere, over an extraordinarily short period, carbon that had remained stored underground for millions of years.

This is where the monster we failed to see growing emerges. The same energy sources that made much of the modern world possible also became the main cause of the global warming we are now trying to contain. We call this phenomenon anthropogenic climate change: a sustained alteration of the climate system caused by human activity, mainly through greenhouse gas (GHG) emissions since the beginning of industrialization. The word anthropogenic means “originating in human

activity,” and it is very important to include it when discussing climate change because Earth’s climate has always changed naturally.

The question we want to answer is a different one: why is it changing now, at this speed, and in the direction we observe? And, most importantly, why should we worry if it is natural? Earth’s climate has never been static. Over millions of years, it has changed because of variations in Earth’s orbit, changes in solar activity, major volcanic events, changes in atmospheric composition, and numerous interactions among oceans, continents, and living organisms. Some of these processes were slow; others produced much more abrupt transformations, with profound consequences for ecosystems.

The important question arises when we examine current warming. Its speed, distribution, and accompanying atmospheric changes cannot be explained by known natural factors. When we include human activity, especially the increase in greenhouse gases since industrialization, the pieces begin to fit. The available evidence has led the scientific community to attribute the warming observed since the mid-twentieth century unequivocally to human influence.

But let us not get ahead of ourselves; let us begin at the beginning. How can the climate of an entire planet change? Think of the climate system as a vast energy balance. Earth receives energy from the Sun, absorbs some of it, and sends some back into space. Any phenomenon capable of altering that balance on a sustained basis can push the climate toward a different state. These initial drivers are known as climate forcings.

Feedbacks then come into play. An initial change can trigger other processes that amplify or diminish its effect. For example, an increase in greenhouse gases makes it harder for heat to escape into space, raising temperatures. That warming can reduce snow and ice cover, exposing darker surfaces that absorb more solar energy. As a result, temperatures rise again, further accelerating melting. This capacity to trigger chain reactions is what makes the climate system so complex. An initial

change can activate mechanisms that continue modifying the planet long after that change began.

What is this carbon cycle? Let us look at an example. Suppose we have a forest full of plants and trees that absorb carbon dioxide from the atmosphere through photosynthesis, incorporating that carbon into their trunks, leaves, roots, and other tissues. That carbon does not remain there forever. The plants themselves release some through respiration, and when leaves, branches, animals, or trees die, decomposers gradually return some of the carbon to the atmosphere. Another fraction remains stored in soils for varying periods. As the forest continues to grow, die, and regenerate, carbon circulates continuously among the atmosphere, organisms, and soil.

Fossil fuels operate on an entirely different timescale. For a small fraction of organic matter to become coal, oil, or gas, it must be buried and preserved under particular geological conditions for millions of years. In the case of oil, much of it originates from organic matter accumulated in ancient marine or lake sediments, which subsequently undergoes long processes involving burial, pressure, and heat. That is why the oil we extract today is not simply the result of trees that died and were buried in a forest. It is ancient carbon, stored through extraordinarily slow geological processes.

Now imagine that temperatures begin to rise. One of the first feedbacks we can visualize occurs in regions covered by snow and ice. Their light-colored surfaces reflect a substantial portion of solar radiation back into space. As they shrink, they expose much darker oceans, soils, and rocks, which can absorb more energy. The result is straightforward: the more ice we lose, the more energy the surface absorbs, and the easier it becomes for warming to continue.

Another important process occurs in permafrost, ground that remains frozen for extremely long periods in the planet's cold regions. It stores enormous quantities of organic matter. As it thaws, microorganisms can begin decomposing that material and release some of its carbon as carbon dioxide and methane. Both contribute to further

warming, fueling another feedback. The intensity, speed, and reversibility of these processes vary considerably. Some respond gradually to warming, while others may approach thresholds beyond which returning to the previous state becomes extremely difficult on human timescales. We will return to these so-called tipping points later.

Today, we have multiple ways to reconstruct and measure changes in Earth's temperature. Modern instrumental records can be complemented by information obtained from ice cores, sediments, corals, tree rings, and other natural indicators that reveal how the climate changed long before thermometers existed.

Comparing all this information reveals a signal that is hard to ignore: the planet is warming rapidly. Scientists have studied the main natural explanations we know of, including changes in solar activity, major volcanic eruptions, orbital variations, and internal ocean dynamics. None can independently reproduce the warming trend observed in recent decades. When the effects of human greenhouse gas emissions are included, however, models reproduce observed temperature changes much more accurately. This agreement among measurements, atmospheric physics, historical records, and climate models is one of the main lines of evidence for the anthropogenic origin of current warming.

Measuring changes in atmospheric carbon dioxide shows that its concentration has risen rapidly since the Industrial Revolution. But there is something even more interesting: the atmosphere retains a kind of fingerprint that allows us to investigate where much of that additional carbon comes from. Carbon occurs in nature mainly as three isotopes: carbon-12, carbon-13, and carbon-14. The first two are stable, while carbon-14 is radioactive and gradually decays over time. During photosynthesis, plants incorporate proportionally somewhat more carbon-12 than carbon-13, so organic matter ends up with an isotopic composition slightly different from that of atmospheric carbon.

Fossil fuels retain part of that signature. Coal, oil, and gas come from extremely ancient organic matter, so they contain a relatively low proportion of carbon-13. Moreover, after millions of years

underground, virtually all their carbon-14 has had enough time to decay. This means that fossil carbon has a very distinctive combination: it is relatively depleted in carbon-13 and contains virtually no carbon-14.

Here, an extraordinary clue emerges. As the concentration of CO₂ in our atmosphere increased, the relative proportion of carbon-13 also declined, and carbon-14 became diluted. This is exactly the behavior we would expect if enormous quantities of fossil carbon were being added to the air.

Other evidence adds to this picture, such as the observed decline in atmospheric oxygen concentration caused by combustion. Individually, none of these signals tells the whole story. Together, they function as pieces of the same puzzle. The modern rise in atmospheric carbon dioxide clearly bears the signature of fossil fuel combustion.

Remember the tree example? Now let us think about two entirely different carbon reservoirs. On one hand, we have the tree, which took carbon from the atmosphere through photosynthesis as it grew. If we burn it, much of that carbon will quickly return to the air as carbon dioxide. If we subsequently allow the forest to regenerate, new trees can capture some of that carbon again as they grow.

Something different happens with fossil fuels. When we extract oil, coal, or gas, we recover carbon that remained outside the surface carbon cycle for millions of years. By burning it, we return it to the atmosphere in a matter of hours. The problem, then, lies in the speed and the balance: we are adding ancient carbon much faster than oceans, soils, and vegetation can remove it from the air again. This is one reason why atmospheric CO₂ concentrations continue to rise even as ecosystems and oceans absorb enormous quantities of carbon every year.

Carbon, however, is just one part of a much larger mechanism. Our activity also alters other natural cycles, and one of the most important for understanding modern agriculture is the nitrogen cycle. Large areas repeatedly planted with the same crop can develop problems when the

agricultural system removes certain nutrients faster than they are replenished. Erosion, loss of organic matter, compaction, water management, and many other variables that determine soil health add to this picture. Monoculture can exacerbate some of these processes, especially when combined with unsustainable management practices.

To maintain high productivity, modern agriculture uses fertilizers that return essential plant nutrients to the soil. Among the most important are nitrogen fertilizers, such as urea ($\text{CH}_4\text{N}_2\text{O}$) and ammonium nitrate (NH_4NO_3). Their use enabled an extraordinary increase in global food production, although it also introduced new environmental challenges when the nitrogen applied exceeds the amount crops can use.

Plants absorb some of the available nitrogen, but the system rarely manages to use all of it. Some remains in the soil, some can move with water, and some undergoes a series of transformations driven mainly by microorganisms. Two of these processes are known as nitrification and denitrification. During them, nitrogen changes among different chemical forms, and some may ultimately be released into the atmosphere as nitrous oxide (N_2O). This gas occurs at much lower concentrations than carbon dioxide, but it has a very strong capacity to contribute to the greenhouse effect.

For this reason, nitrogen fertilizer application must be carefully managed. Using more nitrogen than a crop needs can increase losses to the atmosphere and water without producing an equivalent improvement in the harvest. For example, some of these nutrients may take another route. Rainfall, irrigation, and drainage transport nitrogen and phosphorus from agricultural soils into streams, rivers, lakes, and coastal areas. When they arrive in excessive quantities, they can cause a phenomenon known as eutrophication.

Excess nutrients stimulate disproportionate growth of algae and other photosynthetic organisms. The real problem comes afterward. When that biomass dies, the microorganisms responsible for decomposing it consume large amounts of the oxygen dissolved in the

water. If the process becomes intense enough, zones begin to form where oxygen concentrations are too low to sustain fish, crustaceans, and many other organisms. A fertilizer originally intended to increase crop productivity can thus end up altering an ecosystem kilometers downstream. This is another good example of an idea that will recur throughout this report: natural systems are connected, and our interventions rarely end exactly where they began.

As you can see, a single human activity can alter several natural cycles at once, producing effects that interact and may amplify climate change. Although our understanding of these mechanisms continues to improve, significant uncertainties remain about the magnitude of some consequences and the exact moment when particular components of the climate system might reach critical thresholds. This is especially important when discussing so-called tipping points: changes capable of profoundly altering a system and making it difficult to return to its previous state for very long periods. We do not know precisely where all these limits lie, and that is exactly why it is prudent to avoid approaching them unnecessarily.

If we have been able to conclude that current climate change is rooted mainly in human activities, our response must focus on reducing the emissions and environmental alterations that drive it. This may involve replacing certain technologies, improving the efficiency of others, changing production practices, protecting ecosystems that store carbon, and developing mechanisms to remove some of the carbon dioxide we have already added to the atmosphere.

This is where the concept of net zero comes from. Achieving it does not mean eliminating absolutely all human emissions. The goal is to reduce them substantially and ensure that any remaining residual emissions are balanced by an equivalent amount of carbon dioxide removed from the atmosphere. For this reason, many climate strategies combine emissions reductions with the conservation and expansion of carbon sinks.

There are also regulations and environmental certification systems designed to establish criteria for how particular production activities should be conducted. Their usefulness depends on the standards used, the controls applied, and the ability to verify that declared practices are actually followed. The forestry sector offers a good example. Certification systems assess aspects such as the origin of wood, regeneration of harvested areas, ecosystem conservation, and product traceability. The underlying principle is to manage the resource in a way that allows it to renew itself and reduces the impacts of its use.

However, planting new trees after logging does not automatically produce a perfect carbon balance. A young tree needs years to accumulate the amount of carbon stored by a mature one, different species have different capacities, and some of the harvested carbon may return to the atmosphere depending on how the wood is used. The balance must therefore be assessed across the whole system and over time.

Of course, responsibility for greenhouse gas emissions is distributed very unevenly. Countries have different energy mixes, industries produce very different impacts, and the alternatives available to individuals depend heavily on the infrastructure, prices, technology, and policies where they live.

This does not make our everyday decisions irrelevant either. Consumption habits can influence demand for particular products and services, especially when those changes occur on a large scale. Their effect is part of a much larger system that also involves businesses, governments, technological innovation, and collective decisions. For this reason, it is more useful to think of sustainability as a shared commitment than to try to assign blame simplistically.

Of all greenhouse gases, carbon dioxide is the one we can most readily help reduce through our consumption habits. One tool used to visualize our relationship with these emissions is the familiar carbon footprint. When applied to a person, it seeks to estimate the greenhouse gases associated directly and indirectly with their lifestyle: the energy they

use, how they travel, what they consume, the food they buy, and the services they depend on, among many other variables.

Calculating it precisely is complex because it requires deciding which emissions to attribute to each activity and how far to trace a production chain. A product we buy in Uruguay, for example, may have been manufactured in another country using energy generated in a third. Its climate impact does not disappear because it lies beyond our borders. There is, however, a much simpler measure for comparing countries: territorial CO₂ emissions per capita. To obtain it, we take the emissions produced within a country in a year and divide them by its population. This measure does not represent each resident's actual carbon footprint, but it shows how much CO₂ an economy emits per person on average.

Below, we will use precisely this second measure. The table presents examples of several countries and divides their annual territorial CO₂ emissions by their respective populations. It is not intended as a global ranking; its sole purpose is to let us compare economies of very different sizes on the same scale. Emissions figures use data provided by the Emissions Database for Global Atmospheric Research (EDGAR).

COUNTRY	POPULATION millions of people	2023 EMISSIONS millions of t CO ₂	CO₂ PER CAPITA metric tons
CANADA	38.8	575	14.8
RUSSIA	140.8	2,070	14.7
U.S.	342	4,682	13.7
CHINA	1,416	13,260	9.4
GERMANY	84.1	583	6.9
SPAIN	47.3	217	4.6
CHILE	19.8	84	4.2
FRANCE	68.5	282	4.1
ARGENTINA	45.7	184	4.0
MEXICO	130.9	487	3.7
URUGUAY	3.4	9	2.7

COUNTRY	POPULATION millions of people	2023 EMISSIONS millions of t CO ₂	CO ₂ PER CAPITA metric tons
BRAZIL	212	480	2.3
INDIA	1,451	2,955	2.0

* Per capita figures were obtained by dividing each country's territorial CO₂ emissions by its population. Because the population and emissions data used refer to different years, the values should be interpreted as approximations.

It should be made clear that “splitting the bill” among a country's residents is merely a statistical tool. The result does not mean that each person actually generated that amount of CO₂, nor does it automatically establish responsibility. Territorial emissions depend on the structure of production, the energy mix, transportation, industry, the level of economic activity, and many other country-specific characteristics. Although we may consider it unfair to measure industrial and personal consumption within the same framework, it does help us understand the overall scale of the problem.

Even so, the table reveals something interesting. Countries with the highest total emissions do not necessarily have the highest per capita values, because population size substantially changes the result. China, for example, can be among the largest emitters in absolute terms while also having lower emissions per person than other countries with much smaller populations. This kind of comparison also helps explain why climate solutions must be adapted to each context. Transforming a small country's energy mix, electrifying its transportation, or changing particular industrial sectors presents very different challenges from carrying out those same transformations in an economy with hundreds of millions or billions of inhabitants.

But many variables come into play here. Suppose you own a relatively new diesel car and are considering replacing it with an electric one. To determine which option produces fewer emissions, we need to look far beyond what comes out of the exhaust pipe. If the diesel vehicle already exists, the emissions from manufacturing it have already occurred. The decision now is to compare the future emissions from continuing to use it with those required to manufacture and use the new electric vehicle.

This balance is influenced by the efficiency of both cars, the size and manufacture of the battery, the number of kilometers driven, the source used to generate electricity, and each vehicle's useful life.

The source used to generate electricity remains fundamental. An electric vehicle charged from a grid dominated by coal or gas will indirectly generate more emissions than one powered by wind, solar, hydropower, or nuclear energy. However, the presence of fossil fuels in an electricity mix does not automatically eliminate the benefits of electrification either.

Electric motors use energy much more efficiently than combustion engines, and comparisons must consider the entire life cycle. According to the International Energy Agency, a medium-sized battery electric car sold in 2023 generates, on a global average, approximately half the lifetime emissions of an equivalent vehicle with a combustion engine. Even if the electricity mix remained unchanged, without the decarbonization improvements expected over the coming decades, the advantage would still be significant.

For this reason, transportation electrification and the transformation of the electricity mix reinforce each other. The cleaner electricity generation becomes, the greater the climate benefit of also using it to replace fossil fuels in transportation. Our list provides several interesting examples. Uruguay generated 92% of its electricity from renewable sources, while Brazil reached a renewable share of 87.9% in its electricity mix. France followed a different path: about 65% of its electricity came from nuclear energy, hydropower accounted for 11.9%, and wind and solar together contributed approximately 15%.

This also shows why it is useful to distinguish between renewable energy and low-emission energy. The electricity mixes of these three countries differ greatly, but all allow electric technologies, such as vehicles, to draw on generation with a comparatively low carbon intensity.

The challenge takes on an entirely different scale in the world's largest electricity systems. Countries such as China, the United States, and India manage annual electricity demand measured in thousands of terawatt-hours ¹. Transforming systems of this size means expanding grids, generation, storage, and distribution capacity while millions of households, industries, and services continue to demand energy.

Moreover, a substantial share of electricity in several of these systems still comes from fossil fuels. The challenge is therefore to electrify activities that previously depended directly on oil or gas while electricity generation itself progressively reduces its emissions. The precise composition of these mixes changes fairly quickly, so understanding this relationship is more useful than remaining tied to a percentage from a single year. A grid with a greater fossil fuel share reduces some of the climate advantage of electrification, but does not automatically erase it. And every subsequent addition of low-emission generation can also reduce emissions from electric vehicles already on the road.

As this analysis shows, responses to climate change occur simultaneously at different levels. Individual decisions matter, but so do technological innovation, business strategies, available infrastructure, and public policy. Governments have tools that can change these conditions through regulations, standards, investment, incentives, and infrastructure planning. For citizens, understanding how these tools work makes it possible to analyze public proposals, their costs, their benefits, and their results from a better-informed perspective.

As for the highest-emitting industries, their behavior responds to many forces at once: regulation, technology, costs, investment, competition, and demand. Our consumption habits are part of that last

¹ Let us clarify the units of measurement. A watt (W) is a unit of electrical power equivalent to one joule (J) per second. A watt-hour (Wh) measures the energy consumed by a one-watt device operating for one hour. We usually measure individual consumption in watt-hours and kilowatt-hours (kWh), while industrial consumption often requires larger scales, such as the megawatt-hour (MWh). For the consumption of entire countries, we need much larger scales, such as the gigawatt-hour (GWh) or terawatt-hour (TWh). To put these in perspective, each unit is exactly one thousand times larger than the previous one. A TWh therefore equals 10^{12} Wh—a one followed by twelve zeros!

variable, and when they change on a large scale, they can alter the incentives businesses receive.

Their reach depends, of course, on the alternatives available. Choosing a sustainable option is much easier when infrastructure makes it accessible, technology makes it price-competitive, and a system facilitates its adoption. Individual changes therefore become much more powerful when they advance alongside technological, business, and institutional transformations. This does not diminish their value on a much more immediate level either: our everyday decisions require us to keep the environmental impact of what we consume, use, and discard in mind.

At CERLI, we encourage people to learn about and develop a deeper understanding of climate change. Believe it or not, it can be revealing and enlightening, showing us fascinating aspects of the world we live in and of human nature itself.

Waste Management

If you were born between the 1970s and today, you will have heard of the famous three Rs: reduce, reuse, recycle. Their precise origin is difficult to pin to a single moment, although their popularization is closely linked to the environmental awakening of the 1970s and 1980s. Oil spills, industrial pollution, plastic waste, and growing concern about the impact of our consumption model began to occupy a much larger place in public debate.

One landmark moment occurred on April 22, 1970, when U.S. Senator Gaylord Nelson spearheaded the first Earth Day. Nearly twenty million people participated in demonstrations, educational activities, and mobilizations across the United States, making environmental issues impossible to ignore. That same year, the U.S. Environmental Protection Agency (EPA) was established, while new regulations on air pollution, water quality, waste, and environmental protection began to transform the country's legislation.

Two years later, the debate would reach an international scale with the United Nations Conference on the Human Environment, held in Stockholm in 1972. It was the first United Nations world conference devoted to the environment and helped firmly establish the relationship among development, pollution, quality of life, and environmental protection on the international agenda.

Just as events matter, so do symbols. In 1970, Gary Anderson, then a student at the University of Southern California, entered a competition organized by the *Container Corporation of America* to create an emblem related to recycled paper. His design, consisting of three arrows

continuously chasing one another, became the recycling symbol now recognized virtually worldwide.

Interestingly, its three arrows fit almost perfectly with the later educational popularization of the three Rs, although the symbol had not been designed specifically to represent the words reduce, reuse, and recycle. Over time, the two ideas became associated, creating one of the most recognizable images in environmental education.

Although all this is essential to understanding how we got here, at CERLI we believe that environmental education begins when a problem no longer feels distant. To achieve that, we first need to understand what is happening, why it is happening, and what its consequences are. Let us begin, then, with one of the easiest problems to visualize: what do we do with all our trash? The amount of waste we produce places management systems under increasing pressure. The United Nations Environment Programme estimates that the world generated around 2.3 billion metric tons of municipal solid waste (MSW) in 2023 and projects that this figure could reach 3.8 billion by 2050 if current trends continue.

Population growth clearly contributes to this phenomenon, but it explains only part of it. The amount of waste a society generates also depends on its levels of consumption, urbanization, income, infrastructure, product design, opportunities for repair and reuse, and capacity to recover materials after use. Two populations of the same size can produce completely different amounts of trash.

We must also consider our patterns of production and consumption. The traditional linear model follows a fairly simple logic: we extract raw materials, manufacture a product, use it, and finally discard it. The shorter its useful life and the harder it is to repair, reuse, or recover its materials, the more waste will ultimately require some form of final disposal. This is one reason why modern waste management increasingly focuses on the so-called circular economy: keeping materials in use for as long as possible, extending product life, recovering what still has value, and reducing the amount that ultimately becomes trash.

How we manage waste locally can also multiply its consequences. A deficient collection system, combined with dumping in streets, on land, in waterways, or in open spaces, can turn an environmental problem into a public health problem. Accumulated waste can encourage the presence of flies and rodents, while containers and objects that retain water provide breeding sites for certain mosquito species. When informal waste burning also occurs, additional pollutants enter the air.

An important distinction is therefore useful. An open dump and a properly designed sanitary landfill may contain the same types of waste, but they function in entirely different ways. The former leaves many of its impacts uncontrolled; the latter uses infrastructure specifically designed to reduce soil, water, and air pollution. Even with proper management, waste that ultimately reaches disposal must remain controlled for a long time. To understand why, we need to look at what happens after it is buried.

When organic matter is buried, the available oxygen is eventually consumed, and anaerobic decomposition processes begin to dominate. Microorganisms progressively transform that matter and generate what we know as landfill gas, composed of approximately equal shares of methane (CH_4) and carbon dioxide (CO_2), along with small amounts of other gases. Methane is especially important because of its effect on the climate. If it escapes into the atmosphere, it contributes to global warming. For this reason, many modern sanitary landfills incorporate collection systems. Depending on the facility, the gas may be flared under controlled conditions or even used as an energy source.

The gas generated during decomposition also contains small amounts of other compounds, including various volatile organic compounds and hydrogen sulfide. Their significance for health depends on the substance present, its concentration, and the duration of exposure. One of the most recognizable is hydrogen sulfide (H_2S), which is among the main substances responsible for the unpleasant smell of waste². Exposure to

² Hydrogen sulfide smells like rotten eggs because it forms when certain bacteria break down sulfur-containing organic compounds in the absence of oxygen. Ammonia, mercaptans such as methyl mercaptan (CH_3SH) or ethyl mercaptan ($\text{C}_2\text{H}_5\text{SH}$), and volatile organic acids such as acetic acid (CH_3COOH) or butyric acid ($\text{C}_3\text{H}_7\text{COOH}$) also contribute to the unpleasant smell of trash.

air heavily contaminated with hydrogen sulfide would cause headaches, nausea, or even severe respiratory problems.

Water presents another challenge. As it passes through a mass of waste, it can carry dissolved substances and particles, forming a contaminated liquid known as leachate. Its composition depends heavily on the waste present and site conditions, but it may contain organic matter, ammonia, salts, metals, chemical compounds, and microorganisms. If this liquid escapes untreated, it can contaminate soil, groundwater, and nearby bodies of water. For this reason, modern sanitary landfills incorporate impermeable barriers and systems to collect leachate and prevent it from migrating into the surrounding environment.

All these potential consequences explain why a sanitary landfill requires far more engineering than its outward appearance suggests. Its design may incorporate impermeable barriers to protect soil and groundwater, leachate drainage and collection systems, covers to reduce water infiltration, gas collection mechanisms, odor and vector control, and environmental monitoring during operation and after closure. The challenge is to keep all these systems functioning as additional metric tons of waste continuously arrive. The more trash requires final disposal, the more land, infrastructure, maintenance, and treatment capacity we must devote to it.

After collection, the path each waste item takes depends on the system available. In some places, materials are separated at the source; in others, some sorting takes place later at specialized facilities. Recyclable materials can be cleaned, separated, and processed to recover raw materials, while certain types of organic waste can be used to produce compost or treated through anaerobic digestion. E-waste requires specific processes capable of recovering valuable materials and controlling potentially hazardous components. Chemical waste, medical waste, and other special waste streams require even greater care, with treatments adapted to their characteristics and risks.

Each type of waste therefore presents a different problem. In the following pages, we will focus on three groups that are particularly useful for understanding these challenges: waste that cannot be recovered through conventional systems, plastics, and e-waste. Their challenges differ, but they all require us to answer the same question: what do we do with what we leave behind after consumption?



Non-Recyclable Waste

When waste can no longer be reused, recycled, composted, or recovered through the systems available, it becomes part of what we call residual waste. For many of these materials, one of the most widely used options remains disposal in sanitary landfills, where waste is distributed and compacted in areas called cells, making better use of available space and keeping its accumulation under control. As each area fills, the waste is covered with soil or other suitable materials to reduce odors, windblown litter, the presence of animals, and other problems associated with exposure.

Another fundamental part of the infrastructure lies beneath the waste. Modern sanitary landfills incorporate impermeable systems and drainage networks to collect leachate, which must then be treated before discharge or disposal. At the same time, a network of pipes and wells collects much of the gas generated during decomposition. That gas can be flared under controlled conditions, reducing the direct release of methane, or used for energy when facility conditions allow. In this way, an inevitable consequence of waste decomposition can be converted, at least in part, into an energy source.

The scale of the problem is enormous. According to the United Nations Environment Programme's Global Waste Management Outlook 2024, between 2.1 and 2.3 billion metric tons of municipal solid waste were generated worldwide in 2023. This is equivalent to approximately 5.8 to 6.3 million metric tons each day. If current trends continue, the annual figure could reach 3.8 billion metric tons by 2050.

However, all this trash does not arrive at the same type of facility. Some may be reused, recycled, composted, treated through anaerobic digestion, used for energy recovery, or managed through other processes. The rest requires some form of final disposal. Converting those millions of metric tons per day into an exact number of sanitary landfills would therefore be misleading: each facility's capacity, the composition of the waste, and the proportion that is actually buried vary enormously across regions.

Even so, the scale helps us understand the challenge. Even a facility capable of receiving several thousand metric tons per day represents only a fraction of the global waste flow. The problem requires thousands of local systems operating simultaneously, each connected to networks for collection, sorting, recovery, treatment, and disposal.

A geographic difficulty adds to this challenge. Waste is generated where we live and carry out our activities, while facilities capable of managing it need space, infrastructure, road access, and suitable environmental conditions. Transporting large quantities of trash over long distances increases costs, requires enormous logistical capacity, and creates additional impacts. Nor can just any piece of land become a sanitary landfill. Before choosing a location, planners must consider soil characteristics, groundwater, surface drainage, geological stability, proximity to communities, accessibility, nearby ecosystems, and many other factors. Finding a technically suitable and socially acceptable site can, in itself, become a substantial part of the problem.

The cost of building and maintaining all this infrastructure is also enormous. In 2020, the direct global cost of waste management was estimated at about \$252 billion annually. When indirect costs associated with pollution, health effects, and climate change are included, the figure rises to about \$361 billion. If current trends continue, UNEP estimates that the annual global cost could reach approximately \$640 billion by 2050.

These resources are not evenly distributed either. While some countries have systems capable of financing collection, sorting,

recycling, treatment, sanitary landfills, and environmental monitoring, others still struggle to provide the most basic service. An estimated 2.7 billion people lack access to basic waste collection services, and only about 60% of the world's waste is managed in controlled facilities. This inequality explains part of the problem. Regions with fewer resources are often precisely those where inadequate infrastructure makes it more likely that waste will end up in informal disposal sites, waterways, open burning, or open dumps.

Those who cannot take their waste to adequate, modern processing facilities end up choosing the traditional option: open dumps. There, waste accumulates with few engineering controls, if any, exposing problems that a sanitary landfill seeks to keep under supervision. Impermeable barriers, adequate leachate collection systems, gas collection, covers, fire control, slope stability, and mechanisms to prevent waste from spreading into the surrounding environment are often lacking. As the mountain of trash grows, the risks of fire, pollution, vector proliferation, and landslides may also increase.

Open dumps have been the sites of tragedies that show how far these risks can go. In July 2000, after several days of heavy rain, an enormous mass of waste at the Payatas dumpsite in the Philippines slid onto homes built along its slopes. Estimates vary by source, but more than two hundred people died, and hundreds of families lost their homes. A similar tragedy occurred in 2017 at the Koshe dumpsite on the outskirts of Addis Ababa, Ethiopia. A mountain of waste collapsed onto nearby homes and areas where informal waste pickers worked. Later reports put the death toll above one hundred.

In both cases, trash had ceased to be merely a pollution problem. Its physical accumulation had become a direct threat to surrounding communities. Managing increasing amounts of waste without sufficient infrastructure is extremely difficult, and waiting until all the trash reaches the end of the chain makes the problem even more expensive. Sustainable management therefore seeks to intervene much earlier: reducing what we generate, extending product life, reusing materials,

recovering what still has value, and reserving final disposal for what we truly can no longer use.

We will never be able to make our waste disappear completely. But we can decide how much we generate, what we do with it, and how much of all that material ultimately ends up buried. That is the difference between a mountain of trash and a system capable of managing it.



Plastic Waste

Plastic is one of the types of waste that has received the most attention in recent decades. The scale helps explain why. In 2019, the world used about 460 million metric tons of plastics, more than twice the amount used in 2000. That same year, approximately 353 million metric tons of plastic waste were generated.

A plastic is a polymer ³, generally synthetic, whose raw materials come largely from oil and natural gas. Depending on its composition, structure, and the additives used in manufacturing, we can obtain materials with completely different properties: flexible, rigid, transparent, heat-resistant, insulating, or impact-resistant. This enormous versatility explains much of its success. It also means that the word “plastic” encompasses materials that behave very differently when it is time to manage them as waste. Among the most widely used are five major families:

- Polyethylene (PE), made from the monomer ethylene (C_2H_4), is lightweight, moisture-resistant, and very difficult to degrade naturally. It is therefore used for plastic bags, food wraps, some bottles, and more flexible packaging.
- Polypropylene (PP), made from the monomer propylene (C_3H_6), is lightweight but hard, has good heat resistance, and can be mechanically recycled when suitable sorting and processing systems are available.
- Polyethylene terephthalate (PET), which uses a mixture of terephthalic acid ($C_6H_4(CO_2H)_2$) and ethylene glycol ($C_2H_6O_2$) as its

³ A polymer is a long molecule made up of repeating units of the same substance, which we call a monomer.

monomer inputs, is transparent, very strong, impact- and moisture-resistant, and recyclable. It is commonly used for beverage bottles, food containers, and polyester textiles.

- Polystyrene (PS), which uses styrene (C_8H_8) as its monomer, is lightweight, very brittle, and capable of expanding and providing thermal insulation. For these reasons, it is used for disposable items, protective packaging, and insulation ⁴.

- Finally, there is polyvinyl chloride (PVC), which uses vinyl chloride (C_2H_3Cl) as its monomer. It is highly resistant and can be mixed with additives to make it rigid or flexible. It is used mainly for pipes, cable coatings, rigid packaging, flooring, and windows.

Many of these plastics are technically recyclable, although the practical possibility depends on many factors: the type of polymer, the additives used, the product's form, its level of contamination, the ability to separate materials, the infrastructure available, and the existence of a market for the recovered material.

Broadly speaking, we can distinguish between virgin plastic, manufactured from new raw materials, and recycled plastic, produced wholly or partly from recovered material. Increasing the share of the latter can reduce demand for virgin raw materials, make further use of resources already extracted, and prevent some waste from going directly to incineration, landfills, or the environment.

However, plastic rarely moves through this cycle indefinitely. Mechanical recycling can degrade some of its properties, some products combine several materials that are difficult to separate, and certain applications require characteristics that the recovered material can no longer provide. In some cases, the plastic is used to manufacture

⁴ Polystyrene can be recycled, although some forms present significant logistical difficulties. Expanded polystyrene, for example, has a very low density: it occupies a large volume and contains very little material per unit of space, which can make collection and transportation costly relative to the amount recovered.

products with less demanding requirements before ultimately reaching the end of its useful life.

This is where the true scale of the challenge becomes clear. Of the 353 million metric tons of plastic waste generated worldwide in 2019, around 55 million were collected for recycling. After losses in the process itself were deducted, only 33 million metric tons were actually recycled: approximately 9% of the total. About 19% was incinerated, roughly half ended up in sanitary landfills, and the remaining 22% was mismanaged, burned in the open, deposited in dumps, or released into the environment.

The problem thus lies in the combination of enormous production, an often short useful life, recycling rates that remain low, and material losses throughout the system. In 2019, the OECD estimated that around 22 million metric tons of plastic were released into the environment. Most of that pollution still consisted of relatively large objects and fragments. Some reach ecosystems through deficient collection and disposal systems; others arrive through direct littering, maritime activities, rainfall, rivers, or urban drainage. Once there, many plastics can persist for extremely long periods, travel enormous distances, and progressively break down into ever smaller particles.

Plastic waste can block drains and waterways, accumulate along coastlines and on the seafloor, and directly affect wildlife. Nets, bags, ropes, containers, and other objects can entangle animals, hinder their movement, cause wounds or suffocation, or be ingested when mistaken for food. But plastic does not necessarily retain its original form. Ultraviolet radiation, temperature changes, waves, wind, and physical abrasion can break it into increasingly small fragments. When these particles become smaller than five millimeters, we generally refer to them as microplastics.

The fragmentation of large objects is only one source. Microplastics also come from tire and road marking wear, fibers released from synthetic textiles during washing, losses of industrial pellets, and particles manufactured directly at microscopic sizes. Some plastics also

contain additives intended to modify their flexibility, strength, color, flammability, or stability. Depending on the polymer and product, these may include compounds such as certain phthalates, bisphenols, stabilizers, pigments, or flame retardants. Environmental exposure, material aging, and the chemical characteristics of each substance determine the extent to which these compounds can be released.

The potential effects depend heavily on the substance, particle, organism, concentration, and exposure duration being studied. Microplastic ingestion has been observed in various aquatic organisms, and research documents physical and biological effects under certain conditions, including changes in feeding, growth, reproduction, inflammation, and other physiological processes.

This makes the problem especially complex to study. The category “microplastic” can include particles with completely different sizes, shapes, polymers, additives, and concentrations. A microscopic polyester fiber and a polyethylene fragment several millimeters long belong to the same broad category, but are unlikely to interact identically with an organism. The question becomes even more delicate when we turn to humans. Microplastics have been found in drinking water, food, air, and various human biological samples.

This demonstrates that we are exposed to them through different routes, although detecting a particle and demonstrating that such exposure causes a specific disease are two different scientific problems. The World Health Organization has reviewed the available evidence on exposure through water, food, and air. So far, uncertainties remain significant enough to prevent a definitive estimate of the health risk posed by microplastics and nanoplastics to the general population. Unanswered questions include the effects of the smallest particles, the doses actually absorbed by the body, how long they remain in tissues, and the consequences of prolonged exposure.

This does not make the problem irrelevant. Plastic pollution already has sufficiently documented environmental impacts to justify reducing it, and limiting our exposure while science advances is a reasonable

precaution. But we must also maintain a distinction fundamental to any responsible science education: finding microplastics inside the human body does not, by itself, demonstrate what harm they cause there.



E-Waste

Finally, the last major waste management problem we will address in this report is electronic waste, or “e-waste.” This category includes electronic devices, household appliances, tools, batteries, screens, computer equipment, and many other products that rely on electrical or electronic components. As you can imagine, in an increasingly digital society, this waste stream is growing extremely rapidly and combines two particularly important characteristics: it contains materials of substantial economic value and, at the same time, substances that require especially careful management.

According to the “*Global E-waste Monitor 2024*”⁵, 62 million metric tons of e-waste were generated worldwide in 2022, equivalent to about 7.8 kilograms per person. Only 22.3% was documented as formally collected and recycled in an environmentally sound manner. The report projects that, if trends continue, global generation could reach 82 million metric tons by 2030. The remainder cannot automatically be considered abandoned, but it falls outside the fraction documented as managed through formal, environmentally sound systems.

Those 62 million metric tons contain a real mix of materials. The same report estimates that e-waste generated in 2022 contained around 31 million metric tons of metals, 17 million metric tons of plastics, and 14 million metric tons of glass, minerals, composites, and other substances. Metals may include iron, aluminum, copper, gold, silver, palladium, lithium, lead, cadmium, and mercury, although composition varies enormously by device and manufacturing date.

⁵ The Global E-waste Monitor 2024 is the fourth edition of the report produced by UNITAR, through its SCYCLE program, and the International Telecommunication Union (ITU), with the participation of Fondation Carmignac.

This mixture explains why burning or dismantling e-waste without controls can be especially dangerous. The problem does not arise from supposed “high concentrations of methane” generated by the devices. The risks come from deliberate burning of cables and casings, accidental fires, battery breakage, unprotected shredding, and improvised chemical treatments intended to recover metals. When these processes take place without adequate infrastructure, substances present in the devices or generated during treatment can end up in the air, soil, water, and dust.

The World Health Organization notes that more than one thousand potentially harmful substances have been identified in e-waste or as products of unsafe recycling practices. These include lead, cadmium, mercury, nickel, dioxins, polycyclic aromatic hydrocarbons, and brominated flame retardants ⁶. Their harmfulness depends on the substance, dose, exposure route, and duration of contact, so it is more accurate to speak of a mixture of risks than to attribute the same toxic effects to every electronic component.

Informal practices can expose workers and communities through inhalation of smoke and particles, ingestion of contaminated dust or water, and direct contact with hazardous substances. Burning cables to recover copper, heating components, shredding circuit boards, and using acids to extract metals are among the procedures documented by WHO. In children, the concern is even greater because of their stage of development, and exposure associated with informal recycling has been linked to changes in neurodevelopment, lung function, and thyroid function, as well as adverse pregnancy outcomes and DNA damage.

Nigeria offers a particularly useful example because it combines formal activity, informal recycling, imports of used equipment, and large waste disposal systems. The Olusosun dumpsite in Lagos covers just over 40 hectares and has received nearly ten thousand metric tons of municipal waste daily. E-waste also arrives among those materials,

⁶ A flame retardant is a chemical additive incorporated into combustible materials to reduce their flammability or slow the spread of fire and prevent fires when the material is exposed to a heat source or flame.

although it would be incorrect to describe the site as consisting primarily of e-waste. UNEP has also documented nearby sites where informal workers burn cables and dismantle devices to recover copper, aluminum, and other metals.

The national scale is also substantial. UNEP states that Nigeria processes more than half a million metric tons of discarded electronics each year and estimates that around 100 thousand people work in its electronics recycling sector. For many families, this activity is a real source of income, making any solution based solely on bans insufficient. The challenge is to formalize material recovery, offer viable economic alternatives, and reduce the exposure of those who currently extract value from waste using methods that put their own health at risk.

After reading all this, you may wonder how e-waste should be processed properly. The first step is usually to sort and dismantle equipment before shredding it. Batteries, lamps, cartridges, capacitors, screens, and other components requiring separate treatment can be removed at this stage. Parts that can still be reused or repaired are also recovered. This stage is fundamental because indiscriminately mixing all materials makes subsequent recovery more difficult and may release hazardous substances that were much easier to control while contained within the device.

After dismantling, physical separation of the materials begins. Depending on the facility, waste may be shredded and pass through magnetic systems to recover iron and steel, eddy current systems to separate certain nonferrous metals, density-based methods, electrostatic separation, screening, and optical sorting. The aim is to concentrate materials with similar characteristics before sending them to more specialized processes. The better this initial separation, the easier it is to recover valuable metals and prevent plastics, glass, or hazardous substances from contaminating the recoverable fractions.

Circuit boards contain some of the most valuable materials. After mechanical separation, copper, gold, silver, palladium, and other metals can be recovered through pyrometallurgical processes, which use high

temperatures, or hydrometallurgical processes, which use chemical solutions to selectively dissolve and separate particular elements. No single technique works equally well for all waste, and plants usually combine several stages. The fundamental difference from informal recycling lies in controlling temperatures, emissions, reagents, wastewater, and worker exposure.

Screens clearly illustrate why this initial sorting is necessary. Older cathode-ray tubes contain leaded glass and require different management from modern screens. Some older LCD screens used fluorescent lamps containing small amounts of mercury, while LED systems employ different technologies and should not automatically be placed in the same category. Analytical techniques such as XRF spectroscopy ⁷ can help identify the composition of certain materials before deciding how to treat them, reducing the need to apply a single process to very different types of waste.

All this effort also has an enormous economic dimension. The *Global E-waste Monitor* estimates that e-waste generated in 2022 contained metals worth approximately \$91 billion. Copper alone accounted for about \$19 billion, gold for around \$15 billion, and iron for approximately \$16 billion. However, secondary materials actually recovered through documented recycling had an estimated value of \$28 billion. The difference helps explain why e-waste is increasingly discussed as a form of “urban mining.”

Recovery also avoids some of the impacts of extracting those materials again. According to the same report, documented e-waste recycling in 2022 avoided the extraction of approximately nine hundred million metric tons of primary ore and nearly 93 million metric tons of carbon dioxide-equivalent emissions. This directly connects waste management to the previous chapter: recovering copper, iron, gold,

⁷ XRF spectroscopy involves illuminating a glass sample with high-energy X-rays, causing it to emit X-rays characteristic of each chemical element. ICP analysis, in turn, involves dissolving or atomizing the sample and introducing it into an argon plasma at about 10,000 K. This excites the atoms of the metals present in the glass and causes them to emit light at different wavelengths distinctive to each metal. A spectrometer detects the light, identifying each metal and measuring the exact amount present in the glass.

aluminum, and other materials reduces pressure for new extraction activities, although recycling is still far from capturing all the available value.

However, improving recycling solves only part of the problem. If we put more devices into circulation every year and shorten the time we use them, the volume of waste can grow faster than our capacity to recover it. And no demand grows as quickly as demand for electronic devices, largely because of a highly controversial concept in the technology industry: planned obsolescence.

This limits the contribution individual consumers can make; even when we want to control our own consumerist impulses, the industry conspires against us by creating artificial obsolescence that forces us to buy a new device even when our current one can still function. This brings an uncomfortable question back to the center of sustainability: how much responsibility can we demand of consumers when a product's durability, separability, compatibility, and support depend largely on decisions made before it reaches their hands?

Choosing to keep a phone longer does little good if its battery cannot be replaced, parts are no longer available, or its software loses support. A circular economy therefore requires more conscious consumers, but also products designed to last, accessible repair systems, available spare parts, and clear responsibilities for manufacturers.

This tension between individual and corporate responsibility will reappear later when we examine some of the main criticisms of sustainability. Now we will turn to the final ecological issue covered in this report and examine how its impact has traditionally been underestimated.

Ecosystem Protection

So far, we have explored two major consequences of our activity on the planet: emissions that alter the climate and waste that overwhelms our management systems. Yet there is a third dimension to the problem that tends to receive less attention, perhaps because its effects are quieter and harder to quantify in the short term. We are talking about the destruction of the ecosystems that sustain all life on Earth, affecting every aspect of what makes our planet what it is.

Let us begin with one of the most visible examples: the destruction of forests. According to FAO, approximately ten million hectares were lost annually to deforestation between 2015 and 2020. Since 1990, about 420 million hectares of forest have been converted to other uses. Agriculture is the main driver of this transformation; between 2000 and 2018, agricultural expansion was associated with nearly 90% of global deforestation, including both crops and new areas devoted to livestock farming.

The scale varies by region, but some of the most important fronts are in the tropical forests of South America, Central Africa, and Southeast Asia. There, agricultural and livestock expansion, logging, mining, infrastructure, fires, and other land-use changes exert various pressures on ecosystems that contain an enormous proportion of terrestrial biodiversity.

Forests are major participants in the water cycle. Their roots affect infiltration and help stabilize soils, while vegetation returns enormous quantities of water to the atmosphere through evapotranspiration. When large areas disappear, runoff, erosion, soil moisture, and regional precipitation patterns may change. The ultimate impact depends on the

ecosystem and the scale of the intervention, but eliminating a forest means much more than removing the visible trees.

We are also intervening in one of the great terrestrial carbon reservoirs. Some of this carbon remains in vegetation, and some is stored in soils. Logging, fires, and certain land-use changes can release a substantial fraction, while the loss of vegetation also reduces the ecosystem's future capacity to continue capturing carbon dioxide.

This is not limited to forests. Oceans absorb approximately one-quarter of the carbon dioxide emitted by human activities each year, partially buffering its accumulation in the atmosphere. Peatlands offer another extraordinary example: they cover only 3% to 4% of the land surface but store up to one-third of the carbon in the planet's soils, approximately twice the amount contained in the biomass of all the world's forests. Nearly 12% of global peatlands are already degraded.

Mangroves perform different but no less important functions. They protect coastlines from waves, provide nursery areas for numerous species, store carbon, and support the economic activities of coastal communities. FAO estimates that about 14.8 million hectares of mangroves existed worldwide in 2020. More than 20% of their global area was lost over the preceding forty years, although the rate of loss has declined and some regions have recorded new expansion.

Something similar occurs with reefs, grasslands, inland wetlands, forests, and other systems. Each responds to different pressures, and none can be reduced simply to its capacity to store carbon. When they disappear, we lose habitats, water regulation, coastal protection, food, raw materials, economic opportunities, and ecological functions that we often notice only when they are no longer available.

In all these cases, two losses occur simultaneously. Species lose the conditions they need to survive, and societies lose ecological functions on which they depend every day. Perhaps no resource illustrates this as clearly as freshwater. Although approximately 71% of Earth's surface is covered by water, only about 2.5% of the planet's water is fresh.

Even that small fraction is not entirely at our disposal. Nearly 68.7% of freshwater is stored in glaciers, ice caps, and permanent snow, while approximately 30.1% lies underground. Just over 1.2% of freshwater consists of surface water and other near-surface reserves. Lakes, rivers, and wetlands therefore represent a tiny fraction of the planet's water, yet they are essential to ecosystems, cities, agriculture, energy generation, and numerous human activities.

These systems face pressures from many directions. Industrial and agricultural pollution changes water quality; withdrawals for consumption and irrigation alter flows and reserves; dams transform river systems; and invasive species can profoundly change biological communities. When a freshwater ecosystem is degraded, the consequences can be felt so quickly that they become much harder to ignore.

Lake Chad offers one of the best-known examples of how a freshwater system can transform in just a few decades. In the early 1960s, its open-water area was around 25,000 to 26,000 square kilometers. Then came the severe Sahel droughts of the 1970s and 1980s, accompanied by increasing water withdrawals for irrigation and other uses. At certain times, the open-water area fell below 2,000 square kilometers, a reduction of more than 90% compared with early-1960s levels.

However, the lake's history is more complex than continuous shrinkage toward disappearance. It is extremely shallow, responds very quickly to rainfall, and varies considerably in area between seasons. Since the 1990s, a partial recovery associated with improved rainfall in the Sahel has been observed, although the system remains highly variable and vulnerable to climatic and human pressures. The World Bank specifically cautions that describing the lake as a body of water that simply continues to disappear can obscure this much more dynamic evolution.

That clarification does not make what happened any less striking. The transformation of an enormous expanse of open water into a mosaic of shallow water, wetlands, vegetation, and temporarily dry areas changed

the conditions for fishing, agriculture, grazing, and access to resources. The case is even more interesting from an educational perspective because it shows that ecosystems rarely follow a perfectly linear path.

But what happens to people? The Lake Chad Basin supports the livelihoods of tens of millions of inhabitants through agriculture, fishing, grazing, and trade. When water availability, flooding cycles, cropland, or access to pasture changes, communities must adapt activities that often constitute their main source of food and income. In regions where poverty is already widespread and economic alternatives are scarce, that environmental pressure can considerably increase vulnerability.

The relationship with violence requires greater care. Conflicts in the basin have political, economic, social, historical, and security-related causes that extend far beyond water availability. The Boko Haram insurgency, which began in Nigeria and later spread to neighboring countries, is one of the main drivers of insecurity and displacement in the region. Climate variability, environmental degradation, and competition over particular resources can aggravate existing tensions and undermine livelihoods, but it would be incorrect to present them as the sole explanation for the conflict.

The humanitarian scale remains enormous. According to UNHCR data published in July 2026, more than 3.53 million people were forcibly displaced in the Lake Chad Basin, while 8.2 million needed humanitarian assistance. These figures reflect primarily years of violence, insecurity, and displacement in a region that simultaneously faces poverty, environmental degradation, pressure on resources, and high exposure to climate change. The Lake Chad case therefore leaves us with a more interesting lesson than a simple causal relationship.

A degraded ecosystem can increase pressure on societies already facing serious problems, while a society affected by conflict simultaneously loses the capacity to manage its resources sustainably. Environmental degradation and social fragility can end up reinforcing one another. One of the most widely used responses to ecosystem degradation has been the creation of protected areas. National parks,

biosphere reserves, marine protected areas, ecological corridors, and other designations make it possible to restrict particular human activities and conserve especially valuable territories. However, protecting an ecosystem involves much more than conserving species within a boundary drawn on a map.

At CERLI, we believe this protection should be explained in terms of what sustains our own everyday lives. Ecosystems store carbon, regulate water, protect soils, buffer floods, enable pollination, maintain food chains, provide raw materials, and support entire economic activities. Many of these processes can be complemented by technology, but recreating them artificially at the scale and complexity at which they function in nature would be extraordinarily difficult and expensive.

Nevertheless, formal protection is not enough on its own. Without support from local communities, institutions, and budgets, a protected area becomes a statement of intent on a map. In this sense, we favor approaches that combine protection with the sustainable development of the communities living in those areas. When people living alongside a forest or watershed participate in its management and receive tangible benefits from preserving it, conservation can become much more firmly integrated into the community's economy and everyday life.

Conservation policies must also address the factors driving degradation from outside protected areas. Protecting a wetland does little good if the river feeding it continues to be polluted upstream. Creating a marine reserve does little good if illegal fishing has no consequences. Ecosystem protection requires a systemic perspective that connects the local with the global and recognizes that a park's boundaries are not the boundaries of the problem.

Controversies Surrounding Sustainability

Sustainable living, however positive it may sound on paper, has never been free from criticism. Some criticisms point to real costs, contradictions, or an unfair distribution of responsibility. Others rest on incomplete data, individual experiences turned into general rules, or claims that sound convincing until they are compared with the evidence. This last group is of particular interest to us at CERLI because it presents an obvious opportunity for education: a criticism built on confusion can change considerably once we understand the problem better.

Something else should be clarified before we begin. All of us lack knowledge about an immense range of subjects, and acknowledging that is precisely what allows us to learn. The problem arises when an intuition becomes a certainty before being tested. We have therefore reserved this section for some of the most common criticisms of sustainability, including those with reasonable foundations, those requiring more context, and those that begin to unravel when we look carefully at the surrounding data.

Without further ado, let us turn to the arguments and counterarguments:

1. *“Climate change does not exist, or, if it does, it could well be natural rather than directly caused by humans. It is all a great conspiracy aimed at controlling our consumption habits for the benefit of the*

wealthiest. Besides, individuals are always blamed, whereas, if the greenhouse effect exists, large industries would be the main culprits, and our individual impact would be completely negligible.”

As we saw in the section on climate change, attributing current warming to human activity rests on several independent lines of evidence. In 2024, the global average concentration of carbon dioxide reached approximately 422.8 parts per million, 52% above the preindustrial level. Methane reached about 1,930 parts per billion, around 165% above its preindustrial concentration. Both gases reached record levels in modern records.

Methane’s percentage increase is greater, although this does not mean it makes the largest overall contribution to anthropogenic warming. Among the long-lived greenhouse gases measured by NOAA, carbon dioxide remains the main contributor to increased radiative forcing, followed by methane. Added to this is the isotopic composition of atmospheric carbon: the relative proportions of carbon-13 and carbon-14 are declining, a signature consistent with increasing inputs of carbon from fossil fuels.

Water vapor completes another part of the mechanism. Its concentration responds rapidly to temperature: a warmer atmosphere can hold more moisture, and that additional vapor traps more heat. For this reason, it functions primarily as a feedback to warming initiated by other forcings, such as increased CO₂. The process amplifies the original change, but attributing the initial cause of modern warming to it would reverse the physical order of events.

The claim that climate policies “benefit the wealthiest” is not correct in every case either. The transformations needed to reduce emissions generate costs, opportunities, investment, new markets, and changes in existing activities. Their effects are distributed differently across sectors, regions, businesses, and households. The IPCC explicitly recognizes that a climate transition can increase or reduce inequalities depending on how measures are designed and who ultimately bears their costs.

This gives the criticism a point that deserves to be taken seriously. Environmental campaigns can become unfair when they present a systemic problem as a collection of individual failings. Our consumption habits influence demand, but the options available also depend on infrastructure, prices, regulations, technology, and business decisions. A person can hardly choose public transportation if it does not exist, or repair a product when its manufacturer has stopped supplying spare parts.

At CERLI, we believe environmental education gains credibility when it presents both scales at once. We can examine our own decisions while also understanding the systems that shape them. Individual responsibility exists, but its capacity to generate change increases enormously when institutions, markets, businesses, and policies are able to support it.

2. *“Waste management is inefficient and unreliable. Sorting every item takes time, and then the garbage truck mixes everything together again. Besides, what is the point of being more careful with our own waste if large industries generate far more and dump it carelessly in foreign countries? They want us to feel guilty about every container we throw away, but large corporations cause the real pollution. My individual effort is practically useless.”*

This criticism combines two different questions: does separating waste at the source help, and does the system that receives it afterward work properly? The answer to the first is fairly clear. Keeping materials with different characteristics separate reduces cross-contamination and makes subsequent recovery easier. Paper, cardboard, glass, metals, plastics, and organic waste can lose much of their value when they arrive mixed with food scraps, liquids, hazardous substances, or incompatible materials.

The World Bank identifies a direct relationship between separate collection and higher-quality recycling precisely because mixed

materials tend to become contaminated and degraded. This does not mean that every household sorting system works well. If categories are poorly designed, people receive confusing instructions, or downstream infrastructure mixes incompatible materials again, the result can be frustrating and inefficient.

When the system works properly, separation at the source increases the quantity and quality of material that can be recovered through recycling, composting, digestion, or other treatments. Individual effort therefore serves a concrete purpose. Its usefulness depends on a downstream chain capable of collecting what we sort, keeping waste streams separate, processing them properly, and finding a use for the recovered materials.

The criticism of large corporations also deserves more care than the familiar line “they pollute, and we pay.” Regulations require many producers to manage particular types of waste, and extended producer responsibility systems also exist. Even so, noncompliance, poor management, and international waste trafficking persist. The Basel Convention maintains specific mechanisms to control these movements and treats certain forms of illegal traffic in hazardous waste as criminal.

A person correctly sorting a bottle does not solve the global waste problem alone, but that does not make sorting it useless either. Once again, we are dealing with a chain: product design, consumption, separation, collection, transportation, treatment, recovery, and final disposal. If any of these links fails systematically, the effectiveness of the overall result declines.

Here, individual responsibility is more tangible than in other environmental problems because we ourselves generate a significant share of household waste and decide what to buy, how much to use, how much to reuse, and how to discard what no longer serves us. Even so, the final volume also depends on decisions made long before a product reaches our hands: design, packaging, durability, repairability, sales models, and the availability of return systems.

Reducing waste therefore requires working from both ends of the chain. We can consume more thoughtfully and better sort what we discard, while producers and public waste management systems change the conditions that determine how much waste is generated and what happens afterward. The advantage is that, in this case, many small improvements can add up and reduce pressure on the system quite directly.

3. *“Protecting forests, rivers, or nature reserves sounds nice, but it takes away our land, resources, and business opportunities, and the worst part is that I almost never see a direct benefit. They spend a fortune on this, and those of us who live there get nothing in return. Sustainability seems like an excuse to delay development and keep everything under control. Especially when they talk about preserving insect populations... Why does it matter if certain insects disappear? All the better! We would no longer have to worry about mosquitoes or bees that are so annoying during the warm months, when we are on vacation.”*

This criticism points to a genuine conflict: protecting an area can limit certain productive uses, and these restrictions can impose costs on those who live or work there. Conservation therefore works much better when local communities participate in decisions and receive concrete benefits from preserving the ecosystem. But assuming that an area creates value only when we extract something from it leaves out an enormous range of services we normally take for granted.

Clean water, flood regulation, soil fertility, carbon storage, coastal protection, fishing, pollination, tourism, and the availability of raw materials all depend to varying degrees on functioning ecosystems. Some of these benefits translate directly into income; others take the form of costs we avoid. A mangrove that reduces the impact of a storm or a wetland that retains water can have enormous economic value even if it never appears as a product sold in a store.

As we saw in the Lake Chad example, degrading an ecosystem can transfer environmental costs to the economy and everyday life of communities. At CERLI, we therefore advocate conservation mechanisms that benefit those who live directly alongside protected areas. Asking a community to give up particular activities without offering economic alternatives, participation, or compensation can turn a well-intentioned environmental policy into an entirely avoidable source of conflict.

Finally, we come to insects. Their importance becomes much easier to visualize when we look at our food. According to FAO, about three-quarters of the world's main food crop types depend at least partly on pollinators, and around 35% of the volume of global agricultural production is affected by animal pollination. Bees, flies, butterflies, moths, beetles, and other animals participate in this quiet work that takes place around us every day.

This does not mean that the disappearance of pollinators would eliminate all our food. Essential cereals such as wheat, rice, and corn depend mainly on wind or other mechanisms. The impact would fall especially heavily on many fruits, vegetables, nuts, seeds, and crops associated with nutritional diversity. IPBES estimates that between \$235 billion and \$577 billion in annual agricultural production depends directly on pollinators' contribution.

Other organisms perform entirely different functions. Beetles, ants, termites, and numerous invertebrates participate in decomposition, nutrient recycling, soil structure, and food chains. Earthworms also play an important role in soils, although it should be clarified that they are not insects. When a species disappears, the actual problem depends on the function it performed, which organisms can replace it, and how much the ecological network it belonged to changes.

4. *“They are telling me to change my habits, buy more expensive products, consume less, and live ‘sustainably.’ But if industries and wealthy countries cause all these problems, why should I have to pay the price?”*

Polluting, anti-consumer practices such as planned obsolescence are allowed, yet I am the one to blame for buying again? In the end, green policies only make life harder and more expensive for ordinary citizens while benefiting powerful interest groups.”

This may be the most understandable argument of all because it starts from a real difficulty: our economic system and infrastructure still do not always make the most sustainable option the cheapest, most convenient, or most accessible. Electric cars offer a good example. In many markets, their purchase price remains higher than that of equivalent combustion-engine vehicles, although the gap has narrowed considerably and lower lifetime energy and maintenance expenses can make their total cost competitive or even lower.

There are also obstacles that individual consumers can hardly resolve. Buying an electric vehicle does little good if there are no convenient places to charge it, and electrifying millions of cars requires grids capable of responding to growing demand. More than 1.3 million public charging points were installed worldwide in 2024, bringing the total to over five million. Even so, their distribution remains highly uneven across countries, cities, and rural areas.

Something similar occurs with electricity generation. Wind and solar technologies are already well developed, but integrating large shares of variable generation requires expanding grids, storage, interconnections, backup systems, and mechanisms to balance supply and demand. These transformations require public and private investment whose costs, one way or another, are borne within the economy. Presenting them as if they were free to consumers would not contribute to a particularly transparent debate either.

For businesses, changing production processes also involves costs, risks, new technologies, training, and changes in suppliers. Some transformations can reduce expenses over time; others require investments that take years to yield a return. It would therefore be unrealistic to expect all industries to change spontaneously solely out of consideration for environmental benefits. Economic incentives,

regulation, buyer requirements, competition, and technological innovation act simultaneously on these decisions.

Consumers participate in this system, but their power is not absolute either. Our purchases send signals to the market, especially when millions of people begin changing their preferences, but we can choose only among the alternatives someone makes available to us. A company may respond to new demands, anticipate them, ignore them, or be constrained by its own costs and technologies. Reducing sustainability to “buying correctly” therefore leaves out much of the structure that determines how our goods are produced.

Beyond these consumption decisions, some industrial practices can shorten product life and unnecessarily increase waste generation. This is where so-called planned obsolescence comes in, although the term should be used precisely. In its strictest sense, it involves a deliberate design decision intended to limit a product’s useful life or cause it to lose functionality earlier than technically necessary.

In practice, premature replacement can arise in many different ways. A battery that is difficult to replace, the disappearance of spare parts, disproportionate repair costs, software incompatibilities, the early end of updates, components that cannot be replaced individually, and certain design decisions can reduce the number of years we continue using a device. There is also so-called perceived obsolescence⁸, in which a still-functional product begins to seem old or unattractive compared with newer models.

The distinction matters. A phone that stops working because a component naturally reached the end of its useful life presents a different problem from a device whose repair was deliberately made difficult. A consumer who replaces a device for fashion’s sake is not in the same position as one whose equipment has lost essential support. Grouping all these phenomena into a single industrial conspiracy may

⁸ Perceived obsolescence describes the replacement of products that remain functional because of aesthetic changes, trends, new features, advertising, or shifts in consumer expectations. It may be commercially encouraged, but it should be distinguished from a deliberate technical limitation on a product’s useful life.

be appealing, but it prevents us from identifying the specific mechanisms we should correct.

There is, of course, an economic tension behind durability. Businesses need to sell products and maintain revenue, while a circular economy model seeks to extend the useful life of what we have already manufactured. However, that tension does not imply that businesses need to design products to fail. Repairs, spare parts, updates, refurbishment, partial upgrades, related services, new customers, and new generations of products can sustain economic activity without requiring every earlier device to become prematurely useless.

In fact, the difficulty of repairing goods has become important enough to prompt new regulations. In 2024, the European Union adopted a right-to-repair directive requiring easier repair of certain products, improved access to spare parts, and an extension of the seller's liability period by at least twelve months when the consumer chooses repair. Member States were required to incorporate it into their national legislation by July 31, 2026.

The environmental scale helps explain this interest. The Council of the European Union estimates that premature disposal of repairable goods generates around 35 million metric tons of waste, consumes about 30 million metric tons of resources, and produces approximately 261 million metric tons of greenhouse gas emissions each year within the European Union. These figures are large enough to make repair and durability environmental, economic, and consumer protection issues.

Rules have also been adopted against certain practices associated with early obsolescence and to improve information about durability and repairability. This shows that the initial criticism has a legitimate basis: consumers can hardly reduce their waste when products are designed in ways that make repair impossible or absurdly expensive. Responsibility must therefore extend to design, manufacturing, access to spare parts, support, and product management at the end of its useful life.

At CERLI, we believe this is a good example of why sustainability loses force when presented solely as a succession of individual sacrifices. We can consume more carefully, keep our devices longer, and repair them when reasonable, but these decisions work much better when the system itself makes them easier. The useful question is no longer who should bear all the blame, but how we distribute responsibilities so that production, consumption, repair, and disposal generate progressively less waste.

5. *“Are all species really that important to an ecosystem? I can understand that hunting white tigers might drive them to extinction because there are so few of them. But is hunting deer or wolves really so bad? There are plenty of those. Hunting a couple will not change anything.”*

One idea we have repeated throughout this report is that ecosystems function through networks of relationships. A species may provide food for another, disperse seeds, modify vegetation, compete for resources, alter the soil, or influence populations that appear far removed from it. That is why we often use the image of the “domino effect”⁹: touching one piece can have consequences elsewhere in the system.

But we must avoid taking the metaphor too far. Removing one individual from an abundant population does not automatically cause an ecological catastrophe. The effect depends on the species, its population’s size and distribution, its reproductive rate, the age and sex of the individuals removed, the time of year, the presence of predators, habitat quality, and the intensity of removal.

Recreational hunting also introduces an ethical discussion that each society may assess differently. From a strictly ecological perspective, however, the main question is different: what effect does that removal

⁹ The domino effect is a teaching analogy for a chain reaction: an initial event triggers a series of effects in nearby elements that eventually affect others much farther away. Its name comes from dominoes, a tile game: when the tiles are arranged in a line following a pattern and the first is knocked over, they fall in sequence until all have toppled.

have on the population and ecosystem? Excessive, poorly regulated hunting, hunting that selectively targets particular individuals, or hunting vulnerable species can cause significant harm. In other contexts, limited, scientifically managed removal can remain within levels compatible with conservation.

The International Union for Conservation of Nature recognizes the sustainable use of wild species, including various forms of hunting, as a tool that can be compatible with conservation when it maintains the viability of populations and associated ecosystems. Similarly, the European Union allows certain forms of hunting under sustainability and conservation criteria. A species' abundance alone is not sufficient to decide how many individuals can be removed from a population.

Regulation becomes especially important when hunters select particular sizes, ages, or sexes. Biased removal can change a population's demographic structure and even alter certain biological characteristics over time. Management programs therefore use data on abundance, reproduction, mortality, distribution, and habitat condition to decide when removal can occur, how many individuals may be taken, and which restrictions should apply.

In some places, regulated hunting is also used as a management tool when particular populations reach densities capable of causing agricultural damage, increasing conflicts with people, promoting certain diseases, or putting excessive pressure on vegetation. The U.S. Fish and Wildlife Service, for example, explicitly recognizes regulated hunting as one of the tools available for managing populations according to scientific criteria.

Yellowstone offers a much more interesting case for understanding this complexity. Wolves were eliminated from the park during the first decades of the twentieth century, while different management policies, hunting outside its boundaries, climatic conditions, and changes in other predator populations also influenced large herbivores. Decades later, the park began a program to restore a missing component of that ecological network.

In 1995, 14 wolves from Canada were relocated to Yellowstone, and another 17 arrived in 1996, bringing the first phase of the program to 31 individuals. Ten additional wolves from Montana were introduced in 1997. Their recovery made it possible to observe again how a large predator could influence elk, bison, scavengers, other predators, and different components of the vegetation.

Wolves helped reduce certain elk populations and change their behavior, and several studies found recovery of willows and aspens in some areas. However, the famous story that “wolves changed the rivers” oversimplifies what happened. The National Park Service itself notes continuing debate over how much vegetation recovery can be attributed to wolves and how much depends on other factors, including groundwater, climate, other predators, human hunting, and changes within herbivore populations themselves.

That complexity makes the example much more useful. Today, Yellowstone’s elk are regulated simultaneously by wolves, cougars, bears, weather conditions, food availability, and human activity outside the park. Wolf recovery restored an important ecological interaction, but we can hardly attribute every subsequent ecosystem change to a single species. That is precisely the lesson: intervening in a population requires understanding as many relationships as possible before assuming what the consequences will be.

How, then, can we respond to the original criticism? By explaining that hunting “a couple” of animals can have completely different effects depending on the context. In a large, stable population managed through evidence-based quotas, limited removal may represent an ecologically small fraction. In an isolated, vulnerable population facing other pressures or whose reproductive structure is already altered, even a seemingly modest removal can have much greater consequences.

Sustainability requires us to escape both simplifications. Removing wildlife is not automatically harmless because a species appears abundant, nor does every form of hunting inevitably cause ecological degradation. Answering the right question requires data on the

population, ecosystem, method used, intensity of removal, and capacity to maintain those levels over time.

6. *“Become a vegetarian? Absolutely not! Meat is essential for our bodies because it provides proteins that no plant can provide. Besides, even if that were not true, I like meat. Are they really going to make me sacrifice everything I enjoy for the sake of a planet I will eventually no longer live on?”*

This is another excellent example of how different debates can become intertwined until they seem to be a single issue. A substantial part of the animal rights movement pursues a fairly clear ethical objective: reducing or eliminating the consumption of animal products. That position can be defended on the basis of moral consideration for animals, and each person may accept or reject it according to their convictions. The problem arises when sustainability becomes an additional banner under which that ethical choice is presented as the only possible environmental conclusion.

In some campaigns, this combination has helped establish the idea that sustainable living necessarily requires a vegetarian or vegan diet. That conclusion goes considerably further than the data allow. Livestock farming has significant environmental impacts, and reducing certain types of consumption can diminish them considerably. But there is a leap between recognizing those impacts and concluding that everyone committed to sustainability must give up meat entirely—a leap that environmental evidence alone does not require.

At CERLI, we maintain that the context of the data matters as much as the figure used to make an impression. Before turning a dietary choice into a test of environmental commitment, it is therefore worth examining what we actually know about livestock farming, how much depends on the production system, and what changes when we change our diet. Let us begin with one of the most frequently repeated arguments: water consumption.

One frequently cited figure states that producing one kilogram of beef requires around fifteen thousand liters of water. The figure exists and comes from work by Mesfin Mekonnen and Arjen Hoekstra on the water footprint of crop and livestock products. Their global average for beef was 15,415 liters per kilogram, while they calculated approximately 4,055 liters per kilogram for pulses. At first glance, the difference seems enormous, and it is. But we still need to understand what we are adding together.

The authors divide the water footprint into three components. Green water is rainwater stored in the soil and used by plants. Blue water comes from rivers, lakes, reservoirs, and aquifers. Finally, gray water represents a theoretical volume of water needed to dilute pollutants to specified water quality standards. The three values therefore measure related but environmentally different things.

For beef, the calculated global average was 14,414 liters of green water, 550 of blue water, and 451 of gray water per kilogram. For pulses, the values were 3,180 liters of green water, 141 of blue water, and 734 of gray water. Even when comparing only blue water using the same methodology, beef retains a footprint nearly four times that of pulses per kilogram. When comparing per gram of protein, the same study estimates a total water footprint approximately six times greater for beef.

This does not mean we can treat those 15,415 liters as if they all represented drinking water withdrawn from a river. The impact of a water footprint depends on where, when, and how the water is used. Withdrawing five hundred liters from an aquifer under severe water stress can be far more problematic than using a larger amount of rainfall in a water-abundant region. A global figure is therefore useful for comparing orders of magnitude, but it does not, by itself, describe the impact of each livestock system.

Green water also has an opportunity cost. Pasture can use rainfall to feed livestock, be conserved as a natural ecosystem, or, under certain conditions, be put to other uses. But we must avoid oversimplification

here too, because much grazing land is unsuitable for growing food for direct human consumption. Ruminants have precisely the ability to turn grasses, forage, and other fibers we cannot digest into usable food.

The environmental question ultimately becomes much more interesting than the isolated figure. What matters is the origin of livestock feed, local water availability, pressure on aquifers and rivers, previous land use, possible deforestation, and system productivity. A cow raised on natural pasture and another fed irrigated crops in a dry region may produce the same kilogram of beef yet have completely different water impacts.

The water footprint is only one part of the discussion. Livestock farming also contributes significantly to greenhouse gas emissions, especially through methane. FAO estimates that livestock systems generate around 32% of global anthropogenic methane emissions, mainly through enteric fermentation and manure management.

Enteric fermentation occurs during digestion in ruminants such as cattle, sheep, goats, and buffalo. Microorganisms in the rumen break down food and produce methane as a byproduct, which the animal then expels, mainly through belching. Manure, in turn, can generate methane when stored or decomposed under low-oxygen conditions; its nitrogen content can also promote nitrous oxide emissions under certain conditions.

The unit kg CO₂-eq/kg ¹⁰ is commonly used to compare foods, expressing different greenhouse gases in a common unit. In the Poore and Nemecek data processed by *Our World in Data*, beef from herds raised specifically for meat averages approximately 99.5 kg CO₂-eq per kilogram of product. Beef from dairy herds has a considerably lower value, about 33.3 kg CO₂-eq/kg, already showing how much the same category can vary according to the production system.

¹⁰ Carbon dioxide equivalent (CO₂-eq) allows different greenhouse gases to be expressed according to the warming they produce compared with CO₂ over a given period. In this way, emissions of methane, nitrous oxide, and carbon dioxide can be combined into a single measure to compare the climate impact of different products or processes.

In that same dataset, lamb and mutton are around 39.7 kg CO₂-eq/kg, pork is 12.3, and chicken is approximately 9.9. Pulses are much lower: the group called “other pulses” is around 1.8 kg CO₂-eq/kg. These are global averages, with considerable variation among producers, regions, and production methods, but the overall difference between ruminant meats and most plant-based foods is very pronounced.

These data point to a much less dramatic conclusion than the idea that every environmentally responsible person must immediately give up meat. Reducing the frequency or quantity of foods with especially high footprints, particularly ruminant meat, can substantially lower the emissions associated with our diets. The specific effect depends on what we consumed before, what food we use as a substitute, how much we reduce, and how both products were produced.

In the study of Swedish diets “*Sustainability benefits of transitioning from current diets to plant-based alternatives or whole-food diets in Sweden*,” published in Nature Communications in 2024, different flexitarian scenarios reduced food-related emissions by approximately 20% to 30%, while the vegan scenarios studied achieved reductions of 52% to 56%. This is an entirely understandable difference, considering that a flexitarian diet still includes occasional consumption of animal products.

From an environmental education perspective, the most useful tool is understanding these differences and making informed decisions. One person may greatly reduce meat consumption, another may focus particularly on beef, and another may adopt a vegetarian or vegan diet. All these decisions have different impacts. Turning any one of them into the only possible proof of environmental commitment would simplify precisely the kind of problem this section seeks to explain.



After examining these six arguments, we arrive at a much more interesting conclusion than simply dividing the debate between those

who “understand” sustainability and those who do not. Some criticisms weaken considerably when we examine the evidence. Others contain a legitimate concern hidden behind an exaggerated conclusion. We also find cases where environmental campaigns themselves have communicated data poorly, distributed responsibility unfairly, or turned complex issues into overly simple slogans.

For CERLI, that distinction is fundamental. Environmental education should give us tools to ask where a figure comes from, what it measures, what it leaves out, what interests surround the problem, and how far the evidence actually extends. An informed person may still disagree about costs, priorities, values, or specific policies, but at least they will be discussing the real problem rather than a caricature of it.

This brings us to the central point of this report. So far, we have devoted many pages to understanding the environmental problem. From here, the question changes: what can education do with all this knowledge? To answer it, we first need to understand why the very functioning of our education systems is already being affected by these changes.

Foundations of Environmental Education

The relationship between environmental conditions and the functioning of our education systems is becoming increasingly visible. Heat waves, floods, storms, droughts, fires, and other events can close schools, damage infrastructure, alter calendars, disrupt transportation, and directly affect the conditions in which students try to learn. Environmental education thus begins with an interesting paradox: while we try to teach younger generations how to relate better to their environment, that same environment is changing the conditions in which we can educate them.

Let us start with the most visible effects. In its report *“Learning Interrupted: Global Snapshot of Climate-Related School Disruptions in 2024,”* UNICEF estimated that at least 242 million students in 85 countries or territories experienced educational disruptions caused by climate events during 2024. This is equivalent to approximately one in seven students worldwide. Heat waves affected the largest number of students, reaching about 171 million over the year.

The impact was not evenly distributed either. Approximately 74% of the 242 million affected students lived in low- or lower-middle-income countries, where education systems tend to have fewer resources to make up for lost class time, repair infrastructure, or temporarily relocate their activities. The challenge is no longer simply to build schools and prepare teachers. We must also learn to keep education

functioning when surrounding conditions stop behaving as we expected.

This means buildings capable of withstanding particular hazards, warning systems, evacuation protocols, temporary learning alternatives, infrastructure prepared for extreme temperatures, and mechanisms to maintain some continuity when a school must close. We have explored many of these problems in greater depth in our report *Education in Emergencies; Disasters and Refugees*, which analyzes what happens when an education system must continue functioning under circumstances for which it was not originally designed.

Once again, the scale is revealing. The World Bank estimated that more than four hundred million students experienced school closures related to extreme weather events between 2022 and 2024. In low-income countries, an affected student lost an average of around 18 school days per year, compared with about 2.4 days in higher-income countries. The same environmental threat can therefore have radically different educational consequences depending on the system's capacity to respond.

Adaptation also requires money. The World Bank calculates that a one-time investment of approximately \$18.51 per student would make it possible to implement a set of measures to reduce learning losses from climate impacts, including infrastructure improvements, temperature control, planning, and teacher training. Viewed individually, the amount seems small; multiplied across entire education systems, it represents a new budgetary need competing with many other equally important priorities.

This does not mean education systems could disregard emergencies in the absence of climate change. Floods, earthquakes, storms, droughts, fires, and other hazards have accompanied societies since long before industrialization. What changes in a warmer climate is exposure to certain events, their intensity or frequency in some regions, and the need to incorporate that uncertainty permanently into educational planning.

We can imagine a school built beside a river whose behavior begins to change. Perhaps we can raise facilities, improve drainage, design evacuation routes, install warning systems, and develop teaching alternatives for days when reaching the building is impossible. All these measures are useful and, in some places, indispensable. But they also consume resources that could previously have gone to teachers, materials, infrastructure, technology, food, or any other educational need.

The problem becomes especially delicate because many systems already operate with limited budgets. UNESCO's *Global Education Monitoring Report* notes that median public expenditure on education fell from 4.4% to 4% of GDP between 2015 and 2022, while education's share of total public spending declined from 13.2% to 12.6%. At the same time, analyses cited by the World Bank indicate that only about 1.5% of climate finance reaches the education sector.

This is the relationship we want to emphasize. Every school that must be rebuilt, every calendar that must be reorganized, and every system that needs new adaptation measures also represents a decision about educational resources. Resilience is necessary and can offer substantial protection for learning, but it would be strange to celebrate having to invest more and more in defending education against a problem we are simultaneously trying to contain.

But how far can this problem go? How much time do we have? And how much do we really know about what might happen? Climate issues are often communicated through extreme scenarios because their potential consequences are enormous. At CERLI, we understand knowledge as a right, and we believe urgency loses force when it needs exaggeration to sustain it. We have enough evidence to be concerned without adding certainty where science is still working with probabilities. One of the best examples is so-called climate *tipping points*. These are thresholds beyond which particular components of the system can undergo large, self-sustaining changes after a relatively

small disturbance. Some processes could be extremely difficult to reverse for centuries or millennia; others behave differently¹¹.

In our view, tipping points are very dangerous concepts. Unlike measures such as the carbon footprint, which vary with human activity and can be reduced through sustained change, a tipping point functions more like a switch: once the state changes, the system does not return to its previous state on its own. But their importance lies precisely in the combination of consequences and uncertainty. We can estimate risk ranges using observations, paleoclimate records, models, and physical knowledge, but we rarely know an exact temperature that acts as a universal boundary. In some cases, we do not even know whether the transition will be abrupt, gradual, regional, or capable of spreading to other components of the system.

The Amazon illustrates perfectly why searching for a single magic number is dangerous. Its stability depends simultaneously on global warming, rainfall, the length of the dry season, deforestation, fires, and other disturbances. The study *“Critical transitions in the Amazon forest system,”* published in Nature in 2024, estimated that by 2050, between 10% and 47% of Amazonian forests could be exposed to combinations of pressures capable of triggering unexpected ecological transitions.

A subsequent study, *“Deforestation-induced drying lowers Amazon climate threshold,”* published in Nature in May 2026, found that, in its model, warming alone produced a critical threshold at around 3.7 to 4 °C. When accumulated deforestation of 22% to 28% was included, widespread transitions appeared at much lower warming levels, approximately 1.5 to 1.9 °C. This shows how much risk can change when several pressures act simultaneously.

Another extensively studied component is the Atlantic Meridional Overturning Circulation (AMOC), an enormous system of currents that transports heat, water, salt, and carbon through the Atlantic. The IPCC

¹¹ The IPCC uses the concept of a tipping point to describe critical thresholds associated with qualitative changes in a system’s state or development. The speed and reversibility of the change depend on the climate component considered.

considers it very likely to weaken during the twenty-first century, although there is considerable uncertainty about the extent. Its assessment maintains medium confidence that this weakening will not cause an abrupt collapse before 2100.

Research published in 2025 reinforced this caution. Simulations using 34 climate models found mechanisms capable of maintaining a weakened AMOC even under extreme climatic conditions, suggesting that a complete collapse during this century is less likely than some earlier studies had proposed. This does not make its weakening irrelevant: a substantial change in circulation can alter temperatures, precipitation, marine ecosystems, and regional climate patterns without requiring a complete collapse.

Here lies perhaps the most uncomfortable feature of tipping points: we understand some mechanisms well enough to recognize the risk, but broad uncertainties about their exact thresholds remain. That uncertainty works in both directions. A system may prove more resilient than expected, as some recent AMOC studies suggest. Several pressures may also interact and reduce the remaining margin, as some Amazon simulations show.

In 2022, a study published in *Science* titled *“Exceeding 1.5°C global warming could trigger multiple climate tipping points”* brought together evidence on different components susceptible to these transitions. Its authors concluded that the approximately 1.1 °C of warming observed at the time was already within the lower end of the estimated uncertainty ranges for some tipping points, and that several could begin to be triggered within the 1.5 to 2 °C range.

So, indeed, we are in a minefield. But it is also true that we do not know exactly where each threshold lies, and not all the “mines” have the same size, probability, or consequences. Yet we know something important: as warming increases, so does the possibility of abrupt responses and low-probability events with enormous impacts. The IPCC considers this risk to increase progressively with each additional level of warming.

Reducing future warming therefore has value even when we cannot identify a perfectly precise boundary. Every fraction of a degree changes probabilities, intensities, and risks. Scientific uncertainty, in this case, means that we know a range of possibilities and must make decisions without yet having all the answers. In a sense, the less we contribute to the drivers of climate change, the less likely we are to cross critical thresholds.

The main international reference remains the Paris Agreement, which currently has 194 Parties. Its objective is to hold the increase in the global average temperature to well below 2 °C above preindustrial levels and pursue efforts to limit it to 1.5 °C. This is slightly different from saying that countries committed to preventing temperatures from exceeding 1.5 °C in any particular year.

That distinction is already particularly important. In 2025, the World Meteorological Organization estimated an 86% probability that at least one year between 2025 and 2029 would temporarily exceed 1.5 °C, and a 70% probability that the five-year average would also do so. However, WMO itself clarified that long-term warming, calculated over much longer periods, still remained below that level. An exceptionally warm year and the long-term climate target measure different things.

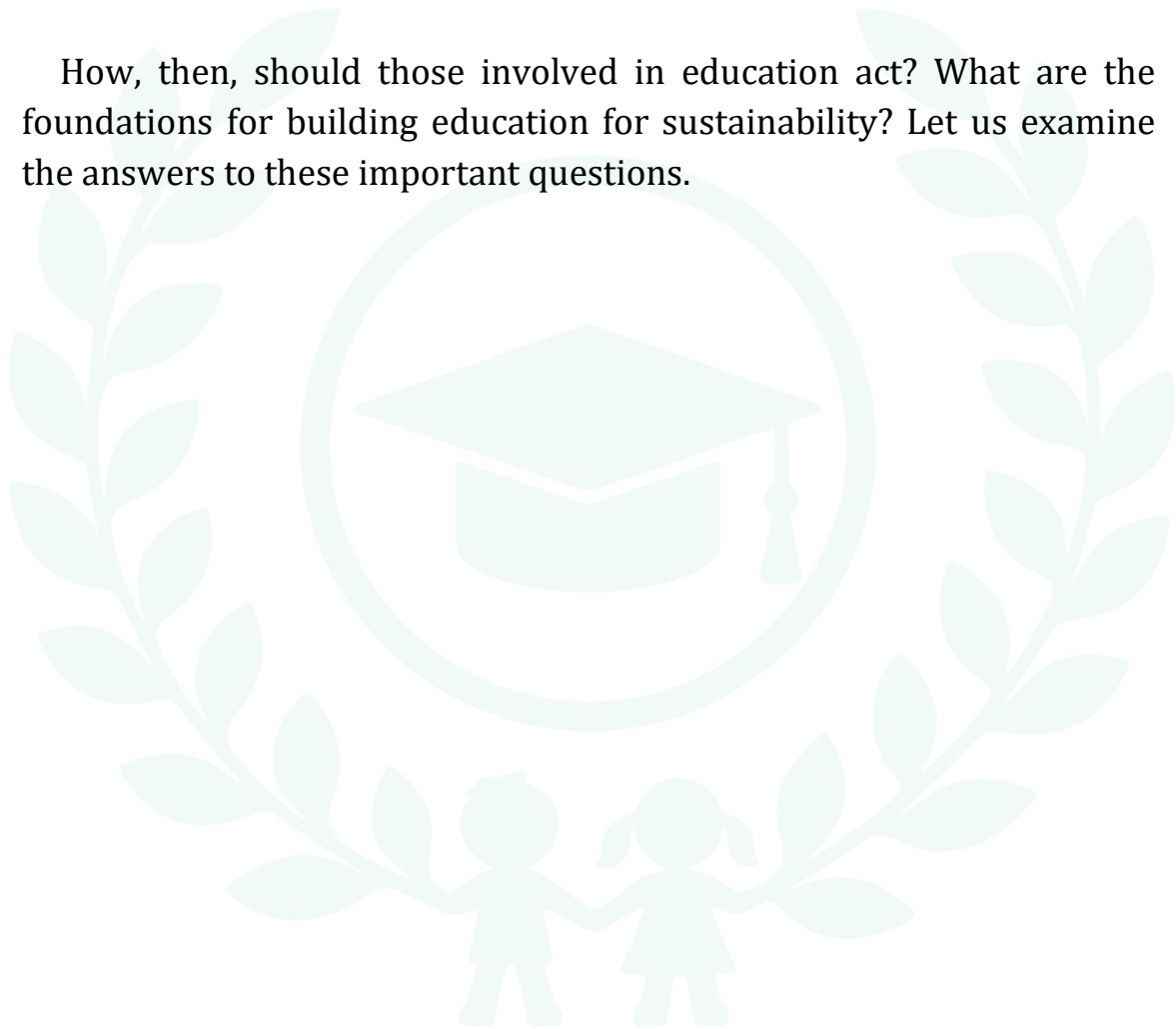
We must also clarify what the familiar 2050 horizon means. The IPCC does not propose eliminating absolutely all human “carbon footprint” by that date. Scenarios that limit warming to 1.5 °C with little or no overshoot reach global net zero CO₂ emissions, on average, in the early 2050s, accompanied by deep reductions in other greenhouse gases. Remaining residual emissions must be balanced by equivalent carbon dioxide removals.

Here, a second clock appears, one that belongs directly to education. Target 4.7 of the 2030 Agenda states that, by 2030, students should acquire knowledge and skills related to sustainable development and sustainable lifestyles, among other dimensions. That deadline does not exactly match the climate horizons, but both place education within a

transformation that is happening now and whose results take many years to mature.

If environmental education aims to prepare those who will need to understand and manage many of these challenges in the coming decades, the present is an especially important window. We know that education slowly transforms knowledge, habits, capacities, and cultures; that is precisely why we should begin before we need immediate results.

How, then, should those involved in education act? What are the foundations for building education for sustainability? Let us examine the answers to these important questions.



A Green Educational Model

We now understand the importance of being well informed about the environment, its conservation, its effects, and sustainable lifestyles. But how do we move that knowledge beyond theory so that it influences how we act? If you have read any of our previous reports, you probably already know our answer: through education. The advantage is that we do not need to start from scratch in this field either. For decades, different education systems have experimented with gardens, community projects, recycling, conservation, energy efficiency, outdoor learning, and many other environmental initiatives.

Today, we have enough evidence to ask what results they are producing. The study *“Does environmental education benefit environmental outcomes in children and adolescents? A meta-analysis,”* published in 2022 in the Journal of Environmental Psychology, brought together 169 studies, 512 measured effects, and 176,007 participants under twenty years of age in 43 countries. Overall, environmental education produced significant improvements in environmental knowledge, attitudes, intentions, and behaviors. The improvement was especially large in knowledge, while effects on behavior were positive but more modest.

This last point deserves attention because, although teaching works, knowing more about a problem does not automatically guarantee a change in behavior. There is a gap between understanding that waste should be sorted and actually developing the habit of doing so, and education must learn to bridge it. This is where experience, autonomy,

context, emotions, and the possibility of turning an abstract idea into a recognizable action in everyday life begin to matter.

One principle that appears repeatedly in current approaches is active participation. In its 2024 publication *“Greening curriculum guidance: Teaching and learning for climate action,”* UNESCO proposes climate education that is student-centered, participatory, action-oriented, problem-based, and able to connect content with learners’ personal experiences and natural surroundings. The intention is for students to investigate, discuss, experiment, make decisions, and observe the consequences of what they do.

Consider something as simple as sorting waste. We can explain which materials are recyclable, ask students to memorize different categories, and then assess whether they remember the classification. But we can also give them real waste, ask them to investigate what happens to each type in their own city, find out what the local system actually accepts, design a sorting system for the school, and measure how much material is recovered. The scientific content may be similar; the second experience requires students to use it to solve a tangible problem.

This does not mean that every hands-on activity is automatically superior to a well-designed explanation. The 2022 meta-analysis we just mentioned found considerable variability among environmental programs and could not identify a single pedagogical approach that, on its own, explained which ones achieved better results. Active participation is a tool with important advantages, but its quality depends on what students do, what they learn in the process, and how the experience is integrated with educational objectives¹².

Outside the environmental field, we also find considerable evidence in favor of active learning. The study *“Active learning increases student performance in science, engineering, and mathematics,”* published in 2014 in Proceedings of the National Academy of Sciences, brought

¹² Authors such as Piaget, Vygotsky, Kolb, and many others were already using the principles of active learning and constructivism as teaching strategies through projects and experiences. These effects are extensively documented and reviewed, making active learning an objectively better approach than its passive alternative.

together 225 studies in undergraduate STEM education. On average, students taught through active methods improved their results on examinations and concept assessments by approximately 6%, while the likelihood of failing was greater in classes based exclusively on lectures.

The value of these methods lies in the range of cognitive operations they require of students. Solving a problem, explaining a decision, comparing alternatives, recalling prior knowledge, and applying concepts to new situations require working with information more deeply than merely receiving it. This participation can support a stronger understanding and provide more opportunities to use what has been learned later in different contexts.

Sustainability also involves another especially important variable: self-efficacy, or the perception that we have some capacity to act on the problem we are studying. This idea also appears in the UNESCO guidance mentioned earlier, which emphasizes strengthening students' autonomy, agency, and confidence in using what they learn.

This makes considerable educational sense. It is difficult to build lasting commitment around a problem presented as enormous, inevitable, and entirely beyond the learner's reach. Students do not need to believe they can stop climate change individually, but they can discover that they have tools to investigate a local problem, change certain practices, work with others, and contribute to broader solutions. That difference turns an abstract threat into an area where a capacity to act still exists.

Another very important principle is cross-curricular integration. Our education systems divide knowledge into subjects because this organization allows depth within different disciplines, but the problems we encounter outside the classroom rarely respect those boundaries. A flood can simultaneously involve hydrology, urban planning, statistics, economics, history, public policy, communication, and human behavior. By its very nature, sustainability provides especially fertile ground for connecting knowledge that normally appears separately in the curriculum.

A related idea appears in the book *“Situated Learning: Legitimate Peripheral Participation,”* published in 1991, which helped develop the concept of situated learning. Its central argument assigned a fundamental role in the learning process to social context and participation in real activities. Over time, this perspective influenced different pedagogies that seek to bring school knowledge closer to the contexts in which it will later be used.

For education for sustainability, this connection is especially useful. In *“Education for Sustainable Development Goals: Learning Objectives,”* UNESCO was already proposing participatory, collaborative, problem-oriented, interdisciplinary methods capable of linking formal learning with experiences outside the classroom. Cross-curricular integration allows the same problem to be studied through natural sciences, mathematics, history, technology, literature, or artistic expression, depending on what we want to understand and what students are trying to produce.

This does not mean every piece of content must be artificially turned into a concrete experience. Some concepts require abstraction, reading, explanation, individual practice, and disciplinary study. The opportunity arises when we alternate those tools with experiences in which students must draw on different kinds of knowledge to interpret the same problem. We can then see whether what they learned in one subject remains useful when the familiar classroom cues disappear.

In sustainability, this strategy also greatly expands the possible entry points. A student interested in mathematics can work with consumption and emissions; one who prefers history can study how our production systems have changed; the natural sciences help explain ecosystems; and the arts can explore how we communicate these problems. Everyone looks at the same challenge from a different position, then needs to bring those perspectives together to construct a shared response.

Having considered the previous two principles, we arrive at the third: the emotional dimension. Environmental problems are rarely

emotionally neutral. They can generate concern, hope, indignation, curiosity, fear, pride in a place, or frustration at what seems impossible to change. Trying to remove these emotions from education would be as artificial as teaching about forest fires without acknowledging that the loss of an ecosystem can provoke a human response.

The problem arises when emotion replaces evidence. Imagine a campaign announcing: “If we do not stop emissions today, our families will be dead in two years.” Such a message might immediately attract attention, but it would build that attention around a false prediction. Once the deadline arrived and the promised event failed to occur, the campaign would have handed any skeptic an extraordinarily powerful reason to distrust subsequent warnings, even scientifically supported ones.

An important clarification is needed here, because fear is not necessarily useless. The study *“The impact of fear appeals on individuals’ climate change attitudes and behaviors: A meta-analysis,”* published in 2026 in the Journal of Environmental Psychology, brought together 37 experimental studies and found that fear-based messages produced, on average, a small positive effect on climate engagement.

The current evidence therefore does not support claiming that any fear-based communication automatically causes paralysis or rejection. Our criticism targets something else: alarmism that invents certainties, deadlines, or consequences the evidence cannot support. A real threat can be communicated in all its seriousness without turning a probability into a prophecy. And if we expect students to act on what they learn, we must also show them what options exist, what results are possible, and where their responsibility reasonably ends. Creating concern without providing understanding or a capacity to act risks leaving only helplessness.

Environmental education can therefore use emotions much more productively. A river in the student’s own city, trash accumulated on a familiar beach, a park visited with family, or even changes to the school can bring a planetary issue closer to home. The aim is for understanding

the problem to help build a relationship with what we are trying to protect.

That closeness makes it possible to combine knowledge, emotion, and a capacity to act. Concern can coexist with curiosity; emotional attachment to a place can inspire a desire to conserve it; and the experience of solving a small problem can build confidence for tackling a larger one later. Education for sustainability has an extraordinary advantage here: much of its subject matter is literally outside the classroom door.

When we bring together active participation, cross-curricular integration, and emotional connection, a method especially compatible with these principles emerges: project-based learning. We do not need to regard it as the only valid method in order to recognize its usefulness. It allows us to begin with a relatively open-ended problem, bring together knowledge from different areas, distribute responsibilities, investigate alternatives, develop a proposal, make mistakes along the way, and finally produce something that can be observed, explained, or presented to others.

There is also favorable general evidence for this approach. The study *“A study of the impact of project-based learning on student learning effects: a meta-analysis study,”* published in 2023 in *Frontiers in Psychology*, analyzed 66 experimental or quasi-experimental studies conducted over twenty years. Overall, project-based learning had a positive effect on educational outcomes, including academic achievement, thinking skills, and affective dimensions, although results varied by subject, context, and implementation characteristics.

In environmental education, we can use this structure to work on nearby problems that are sufficiently complex. Students could investigate the amount of waste their institution generates, study water consumption, restore a green space, analyze temperatures in different areas of the schoolyard, design an information campaign, or propose improvements to reduce particular types of consumption. The project may originate with the teacher or, when feasible, with students

themselves. Giving them a say in that decision also makes the objective feel like their own.

At CERLI, we see these experiences as one of the most promising tools for environmental education. They allow sustainability to move beyond a collection of enormous problems and become something that can be observed, investigated, discussed, and tested. They also leave room for each institution to adapt its activities to students' ages, available resources, and the environmental challenges of the surrounding community.

Fortunately, we are not proposing to build this entire model from scratch either. Over recent decades, international frameworks have been developed to bring these same principles into entire education systems. The most important for our analysis is Education for Sustainable Development, promoted by UNESCO and directly linked to the 2030 Agenda.

We now have the ingredients. Let us see what happens when we try to turn them into education policy.

Education for Sustainable Development

Who decides what is taught, and how does all this translate into actual curricula within education systems already overloaded with content? The institutional history of this proposal began well before the 2030 Agenda. In 2002, the United Nations General Assembly proclaimed 2005-2014 the United Nations Decade of Education for Sustainable Development and designated UNESCO as its lead agency. Those ten years sought to incorporate sustainability principles into different educational levels and settings worldwide.

That phase was followed by the Global Action Programme on Education for Sustainable Development, implemented from 2015 to 2019. The same period coincided with the adoption of the 2030 Agenda and Target 4.7, which explicitly incorporated Education for Sustainable Development into international education goals. ESD thus ceased to appear as a parallel initiative and became directly linked to the educational commitments established for 2030.

In 2019, UNESCO adopted the framework *“Education for Sustainable Development: Towards achieving the SDGs,”* known as ESD for 2030. Its roadmap organizes work into five priority action areas: advancing policy, transforming learning environments, building capacities of educators, empowering and mobilizing youth, and accelerating local level actions. The framework was subsequently introduced globally at the UNESCO World Conference on Education for Sustainable Development in 2021. Each of these areas essentially responds to the

same question we asked in the previous chapter: how do we make changes in habits authentic rather than imposed?

What is interesting about this framework is that it establishes shared objectives and action areas without turning them into a single pedagogical recipe for every country. Implementation depends on each educational, social, economic, and environmental context. UNESCO even proposes a whole-institution approach in which curriculum, pedagogy, school management, teacher education, infrastructure, and community relationships can move in the same direction. The educational institution thus becomes part of what it teaches.

This flexibility is especially important in sustainability. A coastal community may need to work on erosion, marine pollution, or fisheries management, while another may focus on water availability, deforestation, waste, or adaptation to heat. The general principles remain, but the problem that makes them tangible changes according to what students can observe around them.

Latin America and the Caribbean also have their own regional tradition. The Environmental Training Network of Latin America and the Caribbean was established in 1982 and currently functions as an intergovernmental platform bringing together officials responsible for environmental education in the region's ministries. Coordinated by UNEP, it seeks to facilitate the exchange of knowledge, experiences, practices, and cooperation among countries that share environmental challenges but have very different educational realities.

More recently, the Organization of Ibero-American States published the 2025 study *“Alianzas para la esperanza activa. Educación ante el cambio climático con impacto en Iberoamérica,”* developed in collaboration with Spain's Ministry of Education, Vocational Training and Sports. The study brought together around forty experiences implemented in sixteen countries, along with supranational initiatives, and selected eight cases for deeper study to identify elements that could explain how they work and their potential for adaptation to other contexts.

One of those eight experiences particularly caught our attention, in part because it originated in Uruguay. In 2016, TAGMA built Latin America's first sustainable public school in Jaureguiberry, Canelones. The project had begun to take shape several years earlier and ultimately became a reality through collaboration among the organization, ANEP, the local community, businesses, technical specialists, volunteers, and participants from different countries. The building was designed according to principles of bioclimatic architecture and self-sufficiency in resource use.

Its infrastructure itself serves as educational material. TAGMA reports that around 30 metric tons of waste were reused during construction, including about 2,200 tires, 14,000 aluminum cans, 4,000 glass bottles, and 2,000 plastic bottles. The school also has 18 photovoltaic panels and can store 30,000 liters of rainwater, which then passes through different stages of use and treatment within the building.

The project's educational value lies precisely in that combination. Energy, water, waste, food production, biodiversity, and thermal comfort cease to be concepts explained exclusively in a book and become part of the place where students learn every day. The school literally becomes one of the pedagogical resources used to teach sustainability.

Since that first experience, TAGMA has extended the model to other territories. Its network currently includes ten educational communities across Uruguay, Argentina, Chile, Colombia, Brazil, Ecuador, and Peru. They are not all the same, however, because each project adapts to its environmental conditions, available materials, educational needs, and the characteristics of the community where it is established.

Another detail is worth remembering. The Jaureguiberry school began as an idea around 2012 and took almost five years to bring together permits, resources, partnerships, and technical capacity before construction could begin. Its history demonstrates the potential of community initiatives, but also shows that such projects require

planning, funding, institutional coordination, and an enormous amount of work before an idea can become a real educational experience.

We highlight this case in particular because it brings together several elements developed so far: learning connected to the environment, community participation, visible environmental problems, infrastructure consistent with what is taught, and opportunities to work with content from different disciplines. It also shows how an initiative originating outside the state system can become integrated into public education when it builds the necessary partnerships.

At CERLI, we believe experiences like this deserve to be studied, documented, and adapted wherever their principles are useful. But the building, garden, solar panels, or any other sustainable infrastructure are only one part of the process. For the experience to produce learning, we need to decide what students will do with those resources, what knowledge they will draw on, and how we will connect what happens around them with the curriculum they need to learn.

Curricular integration then opens up a second decision: where do we teach sustainability? UNESCO has long advocated a cross-curricular approach in which its content and competencies can appear across different subjects and educational levels. The logic is simple: climate change, biodiversity, production, energy, consumption, inequality, technology, and human behavior belong simultaneously to several fields of knowledge. Confining them entirely to one subject can limit connections fundamental to understanding them.

This does not require rejecting specific subjects, modules, or spaces devoted to sustainability. They can be highly useful when they allow deeper exploration of content that would otherwise remain scattered. What matters is preventing that space from becoming the only place where these issues appear. Genuine cross-curricular integration allows what is learned there to be used again in science, mathematics, history, technology, economics, the arts, and community projects.

The difference between meaningful cross-curricular integration and a merely cosmetic version lies in the role the environmental problem plays in learning. We can ask students to calculate percentages using an emissions table, just as we could have used fruit or cars. Sustainability then serves simply as context. But we can also ask them to compare emissions, identify trends, analyze uncertainty, select an appropriate mathematical representation, and use the results to answer a specific environmental question.

In the second case, mathematics remains a fundamental part of learning, but the problem also requires understanding what the numbers represent. Neither dimension is merely decorative. That is the interdisciplinary approach we are interested in: different disciplines contributing real tools to understand a problem that cannot be properly solved through just one of them.

For this reason, at CERLI we see project-based learning as a tool especially compatible with cross-curricular environmental education. The specific evidence is still considerably more limited than the evidence for PBL in general, although promising results exist. In 2015, Murat Genc published the study *“The project-based learning approach in environmental education,”* conducted with 39 students, in which he found improvements in environmental attitudes after project work on ecological problems. The sample’s size and context call for caution in interpreting the result, but it offers a precedent directly related to our proposal.

Broader evidence appears in the systematic review *“Investigating effective teaching and learning for sustainable development and global citizenship,”* published in 2021. It analyzed 14 studies with statistically significant results and identified recurring elements such as combining theory and practice, student participation, and connecting content with students’ interests. Its authors also caution that more evidence is needed on the institutional conditions that determine when these programs work best.

Drawing on these precedents and the principles developed in the preceding pages, we propose four stages designed by CERLI to organize this type of project. We do not present them as a formula experimentally validated as a whole, but as a working model that combines elements supported by the literature with pedagogical decisions we consider useful for bringing them into the classroom.

We begin with identifying and taking ownership of the problem, which means that every project must start with a concrete problem. Choosing it cannot depend solely on the teacher, nor can it be presented as something distant from students' reality. It must be an environmental challenge close to the community, one that students can observe, understand, and change in some way.

There are many examples, from analyzing waste produced by the institution and water and energy waste in classrooms to the lack of green spaces or pollution in a nearby area. This creates a direct connection between what is being studied and the everyday life of the person studying it. Whenever conditions allow, we recommend that students participate in selecting the problem they will address. The teacher can narrow or filter the choices to viable, educationally rich options while providing some autonomy from the outset.

The next stage is investigation and multidimensional understanding. With the problem defined, students begin investigating its characteristics. Although this may seem to be the stage of greatest student autonomy, the teacher must prevent the problem from being fragmented into small pieces of knowledge that are never reconnected.

Since environmental problems rarely belong exclusively to one subject, and students learn while carrying out the project, teachers must help them identify where different fields of knowledge add value. Consider energy waste in an institution: to understand it, we will need to calculate consumption, compare data tables, study energy sources and conversions, analyze consumption habits and their causes, understand how they have changed over the years, and develop strategies to change the situation and communicate them to others.

Through cross-curricular integration, students should be able to answer the main research questions: What is happening? Why is it happening? And what aspects of this situation can we actually change? Each subject provides the tools students need to move forward, while students collect information, make observations, compare alternatives, interpret data, and gradually build an explanation of their chosen problem.

Then comes the third stage: design and intervention. By this point, we understand the problem, so it is time to try to solve it. This is the richest stage of the project because it turns acquired knowledge into a tangible intervention. Students must design a proposal that responds to their earlier diagnosis. If the problem was water waste, they might study the institution's consumption and design mechanisms to reduce it. If it was waste generation, they could change sorting systems, study which materials predominate, or experiment with reusable alternatives.

What matters is that the solution is not ready-made. A project in which the teacher knows from the beginning what students must do, what results they will obtain, and what conclusion they must present becomes just another practical activity. Furthermore, if the teacher already has a preconceived idea of what students should present, they will inevitably create a mental model against which to compare the result.

This exact point brings us to the final stage: assessment. The teacher needs to measure, quantitatively and qualitatively, whether the project achieved its educational objective for students. We need to observe their ability to connect different areas of knowledge, justify decisions, analyze evidence, propose solutions, and recognize the limitations of their own ideas. In some cases, we may also study changes in their perceived self-efficacy, emphasizing how much they believe their actions can actually influence the problems they are trying to solve.

Assessment must reflect the variety of learning outcomes we aim to produce. An examination can be very useful for checking conceptual knowledge, interpreting data, or verifying whether a student

understands particular environmental mechanisms. A project, however, also seeks to develop abilities that are difficult to observe through a single written test: formulating questions, connecting disciplines, justifying decisions, working with evidence, reviewing errors, collaborating, designing solutions, and explaining why an intervention succeeded or failed.

For this reason, at CERLI we propose combining different sources of evidence. A report or portfolio can document how the project evolved, what decisions the group made, what information it used, which hypotheses it discarded, and what changes it made during the process. It also preserves photographs, measurements, graphs, drafts, results, and reflections that would be impossible to reconstruct solely from the final product.

An oral presentation can complement this, allowing students to explain and defend their work before teachers, classmates, or community members. Questions help establish how well they understand the decisions made and distinguish a genuinely understood project from one in which tasks were simply divided among members. Where possible, we can also incorporate indicators of the problem addressed, comparing, for example, water consumption, the amount of waste sorted, or any other variable observed before and after the project.

This model does, however, present a very concrete problem: assessing complex processes takes time. The more students and projects there are simultaneously, the harder it becomes to read evidence, offer useful feedback, observe presentations, and follow each team's progress. Cross-curricular integration can distribute some of that load among different teachers, especially when each area assesses criteria related to its own curricular objectives, but coordination also requires time and organization.

Digital tools can reduce some of the administrative work. An LMS (Learning Management System) centralizes submissions, versions, rubrics, evidence, and feedback, while certain artificial intelligence tools

can help organize information, identify incomplete documents, generate initial feedback drafts, or compare a submission against predefined criteria. Their use should support the teacher, especially when assessment involves reasoning, originality, collaboration, or decisions requiring knowledge of the project's actual context.

We would therefore avoid setting a universal number of students or classrooms beyond which the model stops working. Capacity will depend on the number of teachers involved, project duration, available tools, institutional time reserved for coordination, the complexity of the evidence, and the frequency of assessment. The challenge of scale is real, but its limits will differ from one institution to another.

One very important consideration is that, throughout the process, there must be room to make mistakes and discover that some initial hypotheses were incorrect. Solving a real problem means confronting equally real constraints and learning to adapt when our first hypotheses fail to withstand contact with reality. All this learning is as valuable as the final result, so we suggest including it in the accompanying document submitted for assessment.

To ensure that room for mistakes does not remain merely a statement of principle, we believe assessment should be distributed across the project's different stages. Each stage can have a small set of progress criteria, defined in advance and known to students, that establish whether there is a sufficient foundation to continue. These criteria serve as pedagogical reference points, allowing teachers to manage the time and knowledge needed to advance the project.

For example, before an extensive investigation begins, the problem should be clear and bounded. Before moving to intervention design, there should be sufficient evidence about causes and opportunities for action. If any of these aspects has not yet reached the expected minimum level, the teacher can offer specific feedback that allows students to review, adjust, and resubmit. Once these criteria have been satisfactorily met, the group can focus on aspects that still need development.

This means accepting that groups will not necessarily progress at the same pace, and that this is not a problem in itself. As long as there is identifiable progress and well-documented decision-making, the objective is not for everyone to arrive at the same time, but to arrive with learning that is truly consolidated.

At the formal final assessment, the teacher must go beyond simply determining whether the proposed solution worked. Even an intervention that does not achieve its initial objective can be an excellent educational experience, provided students understand why that happened and can identify what they would do differently on a second attempt.

The group must compare the initial situation with the results obtained, enabling reflection on the decisions made. Whether or not the project succeeds, the connection to the investigation and learning process remains intact, offering a valuable lesson in how some ideas, however good and beneficial they initially seem, can fail in particular contexts.

At CERLI, we also recommend a communication stage in which results can be presented and defended before classmates, families, or other community members. This effectively turns the experience into knowledge that can be communicated, because students must explain what problem they found, how they investigated it, what they did to solve it, and what they learned along the way.

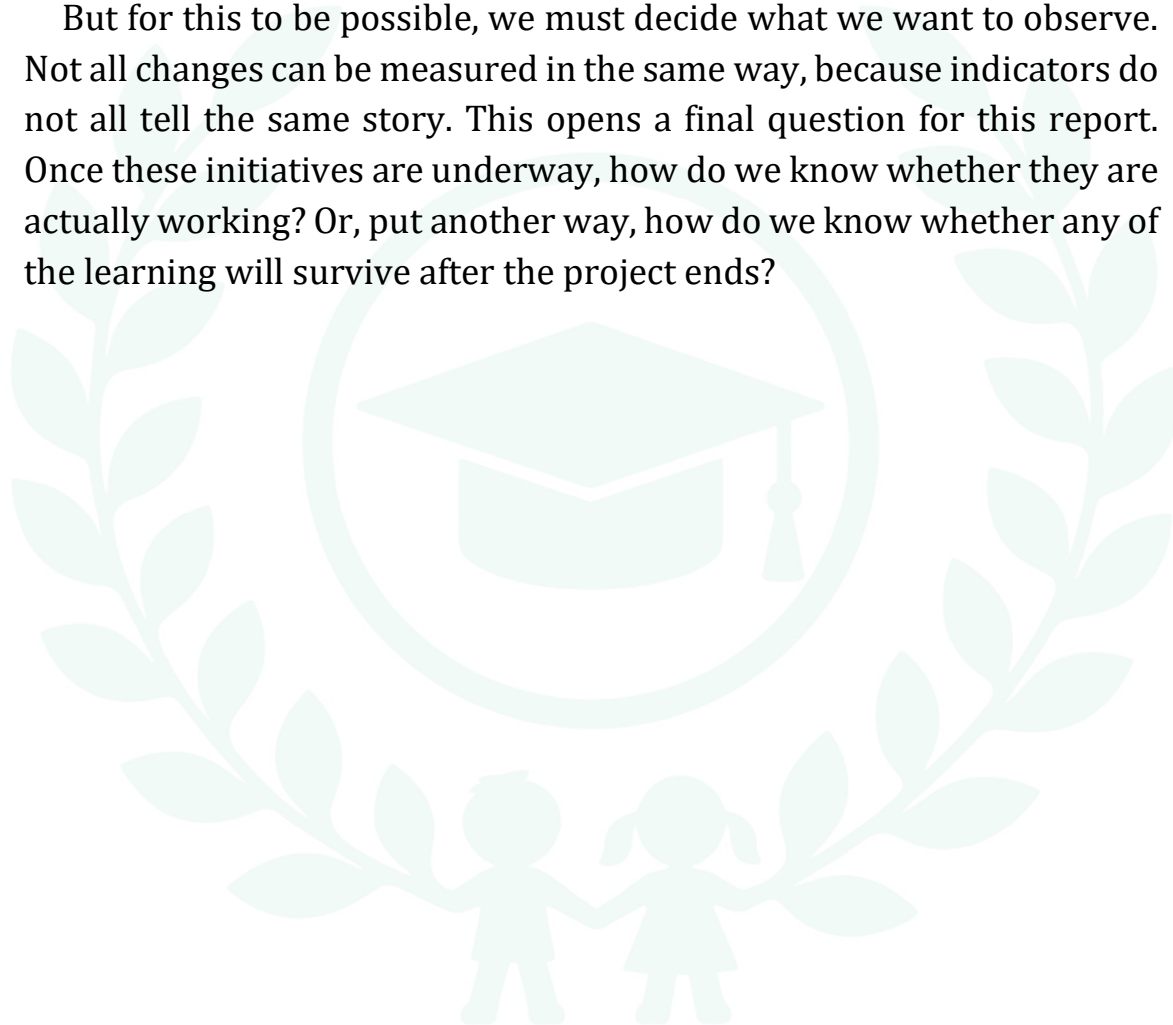
Some projects may even continue or follow up on earlier ones, analyzing whether previous teams' communication strategies were effective in sustaining improvements or whether those gains disappeared when the project ended. Monitoring itself thus becomes a new educational experience in which students receive a problem, an earlier solution, and data they can analyze critically.

For example, one group could spend a year designing a system to improve waste sorting within its institution. Later, another group could analyze how much of that intervention remains, which measures were

abandoned, which became naturally integrated into everyday operations, and why. Based on these results, it can retain what worked, change what did not, and design a second intervention.

This has a particularly interesting consequence for educational development: projects cease to have clearly defined beginnings and endings. Each generation of students inherits information from earlier participants and leaves new data and ideas for those who follow.

But for this to be possible, we must decide what we want to observe. Not all changes can be measured in the same way, because indicators do not all tell the same story. This opens a final question for this report. Once these initiatives are underway, how do we know whether they are actually working? Or, put another way, how do we know whether any of the learning will survive after the project ends?



Monitoring Environmental Education

An environmental education initiative can produce results at several levels simultaneously. We can observe how much students learned, whether they connected knowledge from different disciplines, how their perceived self-efficacy changed, what decisions they made during the project, and whether certain practices began to extend beyond the curricular activity.

We can also examine observable transformations within the institution itself: changes in resource consumption, new ways of managing waste, modifications to particular procedures, restoration of spaces, or any other result directly related to the intervention. The challenge is that none of these dimensions tells the whole story on its own. A project may greatly improve knowledge without changing behavior, or transform an institutional practice without all students understanding equally deeply why it worked. Monitoring must therefore bring together different sources of evidence and analyze them jointly.

Before interpreting any result, we need to know what actually happened during implementation. Did the planned subjects participate? Did students have real decision-making power? Was there a concrete environmental problem around which to organize the project? How long did the experience last, which activities were actually completed, and what resources were available?

This dimension is often associated with implementation fidelity, which allows us to analyze how closely what happened in practice resembles what was originally designed. This does not mean that every adaptation is a problem. A situated project needs enough flexibility to respond to different students, institutions, and communities. What matters is recording those modifications so we can later interpret which components were actually present when the results emerged.

UNESCO itself uses a multidimensional approach to track ESD implementation, observing policies, educational environments, educator capacities, youth participation, local action, and other indicators. The *“Mid-term evaluation of the ESD for 2030 framework, 2021-2024,”* published by UNESCO in 2026, again highlighted the need to simplify and strengthen these monitoring mechanisms to better understand progress and its limitations.

We can then observe what changed in the setting where the intervention took place. Depending on the project, there may be new waste sorting mechanisms, reductions in certain types of consumption, changes in institutional purchasing, restoration of green spaces, or changes in everyday procedures. These are very different results, but all help establish whether what was designed produced any transformation beyond a purely academic exercise.

The duration of those changes provides further information. A practice may persist while teachers and students focus all their attention on it, then disappear a few weeks later. Another may become part of the institution’s routine operations, survive into the next school year, or even be adopted by groups that never participated in the original project. We will call this dimension persistence: how much of the transformation remains after the initial stimuli disappear.

We can also observe whether learning carries over to other settings. A student may begin applying a practice at school and later adopt it at home, share it with family, or use the same principles to interpret a different problem. This transfer is especially interesting because it shows that learning has begun to move beyond the specific situation in

which it originated. A behavior repeated only within a project and one that reappears spontaneously in different contexts tell us quite different things about what happened during the educational process.

Based on these considerations, at CERLI we propose organizing monitoring around several complementary dimensions. The first is implementation: recording what was done, for how long, with what resources, and under what conditions. The second examines learning, including knowledge, understanding of the problem, interpretation of evidence, and the ability to connect different disciplines. A third dimension focuses on possible changes in students' self-efficacy, decisions, and behaviors.

Where the nature of the project allows, we will also include an environmental or institutional outcome dimension. Here, we analyze what happened to the problem that prompted the intervention: how much waste was recovered, what consumption changed, what procedure improved, or what space was transformed. Finally, there are dimensions that require the passage of time, such as the persistence we just defined and the possibility of transferring some of that learning to different contexts.

No single indicator can answer all these questions. The system's value lies precisely in bringing together evidence describing different parts of the same experience and using it to reconstruct what happened during the project, what it left behind, and which effects appear to endure afterward.

For that reconstruction to be possible, we need to document the project from the outset. Which subjects participated, how long each stage lasted, how much autonomy students had, which activities were completed, what resources were needed, what difficulties arose, and what changes were made to the original design are all data that will later help us interpret the results. An educational experience rarely unfolds exactly as imagined on paper, and those variations are also part of what we need to understand.

Whenever possible, we should also decide which variables to observe before intervening. The initial measurement serves as a baseline that establishes our starting point. If we want to reduce water consumption, we need to know how much was used previously; if we seek to improve waste sorting, we first need to know what percentage was separated correctly, which materials caused the most difficulty, and where the main errors occurred.

Follow-up assessments may take place weeks, months, or even years later, depending on the type of change studied. No universal timeframe applies to every initiative: some practices may disappear quickly, while others need time to become fully integrated into an institution's everyday operations. Whenever possible, we must decide what to measure before carrying out the intervention, because even if a situation appears to have improved by the end of a project, that tells us very little if we do not know its original condition. The initial measurement provides our point of comparison, allowing us to distinguish real transformation from a mere impression.

Some projects allow us to work with variables that are relatively easy to measure. Water and electricity consumption, the amount of waste generated, the percentage of correctly sorted materials, the use of particular products, or even the area devoted to certain spaces can be compared before, during, and after the intervention. These indicators offer an important advantage: they show concrete changes without relying solely on participants' perceptions.

But even an apparently objective figure needs context. Suppose electricity consumption falls by 15% after our project. The figure is real, although during the same period the number of students may also have changed, operating hours may have been reduced, equipment replaced, building insulation improved, or temperatures differed. We will therefore try to compare equivalent periods and record external variables capable of influencing the results. A measurement can show that something changed; demonstrating why it changed requires connecting it with the rest of the evidence. The more pieces fit together,

the stronger our basis for arguing that the intervention contributed to the observed result.

Other dimensions require different tools. Perceived self-efficacy, particular environmental attitudes, the ability to connect a problem with everyday decisions, or students' assessments of their own participation can be explored through questionnaires, interviews, observations, learning journals, rubrics, focus groups, and other instruments. The choice depends on what we want to know and on the participating population's age, characteristics, and size.

Whenever a previously validated instrument exists for studying the variable of interest, using it is advisable. When we must construct our own indicators, we need to define in advance what we want to observe, how we will record it, when measurements will take place, and what kind of change we would consider meaningful. Establishing these criteria only after seeing the results makes it easier to interpret whatever matches our initial expectations as success.

Nor must every objective become a rigid boundary between success and failure. It may be much more informative to know how much a variable changed, in which direction, for how long, and whether different sources of evidence tell mutually compatible stories.

Before constructing the final matrix, we need to add another important question: how much of what worked depends on the particular context in which it was tested? We will call this dimension transferability. A project may achieve excellent results within one institution while also depending on conditions that are difficult to find elsewhere: teachers with specialized training, particular facilities, exceptional financial resources, an especially committed community, or highly specific environmental characteristics.

Related to this is scalability. An initiative may work very well with a small group yet encounter entirely new difficulties when expanded to several classrooms, schools, or regions. Coordinating more teachers, maintaining the quality of support, funding materials, and preserving

sufficient student autonomy can become progressively more complex as the intervention grows.

This does not diminish the value of a project that works only in a specific context. An experience may be extraordinarily useful to a community even if it never becomes a national model. Transferability and scalability become important when we try to learn from it and decide which components could be replicated, which would need adaptation, and which depend too heavily on the conditions that made the original experience possible.

This distinction also requires us to choose indicators whose scale matches the intervention. If a group of students develops a project to reduce water consumption in their school, subsequently evaluating its success using the total consumption of a predominantly industrial city would make little sense. The initiative's possible effect would be buried beneath thousands of variables over which students never had any real influence.

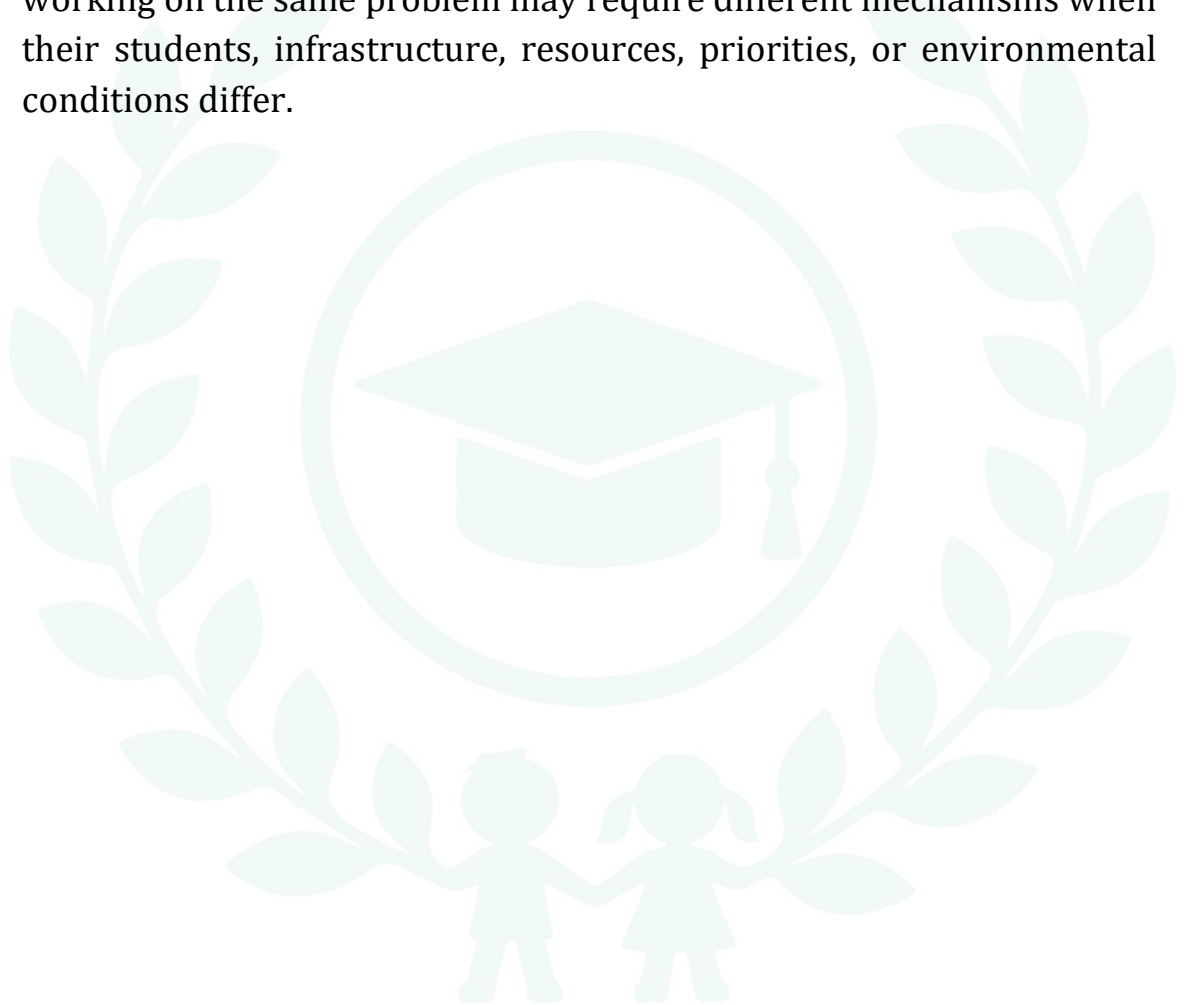
The reasonable starting point is to observe the settings where the project could make a difference: the institution, participants, their homes when there is evidence of transfer, or any other setting directly related to the actions taken. If the experience later grows and reaches new populations, we can also progressively expand our measurement scale.

This principle prevents two opposite errors. On one hand, it prevents us from demanding results an educational experience was never designed to produce. On the other, it prevents us from crediting it with enormous social transformations when we have demonstrated only a localized change. In both cases, the precision with which we define the scope of our conclusions is as important as the results themselves.

All these dimensions allow us to build a monitoring matrix that accompanies a project from design through follow-up assessments. As a methodological exercise, we share below a structure developed by CERLI to organize the relationships among implementation, learning,

behavior, observable outcomes, persistence, transferability, and scalability. Its purpose is to help us formulate questions and organize evidence, not to establish universal indicators to be applied identically in every institution.

Each initiative must select its own variables, instruments, baselines, measurement points, and interpretation criteria. A waste project requires different information from one focused on biodiversity, energy consumption, or the availability of green spaces. Even two institutions working on the same problem may require different mechanisms when their students, infrastructure, resources, priorities, or environmental conditions differ.



ENVIRONMENTAL EDUCATION MONITORING MATRIX

PROJECT: _____	PROBLEM ADDRESSED: _____	PARTICIPANTS: _____
DURATION: _____	BASELINE: _____	PLANNED FOLLOW-UP: _____

DIMENSION	KEY QUESTION	POSSIBLE INDICATORS OR EVIDENCE	OBSERVATION TIMING
IMPLEMENTATION	Did the project follow its underlying principles?	Participating subjects, duration, completed activities, student autonomy, resources used, difficulties, changes to the original design, connection to a real problem.	Throughout the project.
LEARNING	What did students understand, and what can they do with what they learned?	Knowledge gained, data interpretation, connections across disciplines, quality of explanations, justification of decisions, identification of causes and possible solutions.	Baseline where applicable, during the process, and at completion.
SELF-EFFICACY, DECISIONS, AND BEHAVIOR	Did students' perceptions of their capacity to act and their decisions about the problem change?	Perceived self-efficacy, autonomy, intention to act, adoption of practices, voluntary participation, transfer of behaviors to home or other settings.	Before, at completion, and during follow-up assessments.
ENVIRONMENTAL OR INSTITUTIONAL OUTCOME	Did the intervention produce an observable change in the problem addressed?	Water or energy consumption, waste generation and sorting, purchasing changes, restoration of spaces, procedural changes, or other indicators directly linked to the project.	Baseline, during the intervention, at completion, and, where possible, at follow-up.
PERSISTENCE	How much of the change remains after the initial stimuli disappear?	Continuation of practices, maintenance of procedures, lasting environmental outcomes, spontaneous use of learning, adoption by new groups.	Months later and, where feasible, during the next school year.
TRANSFERABILITY	Which parts of the experience can be used in other contexts?	Dependence on specific resources, required teacher knowledge, adaptations made, institutional conditions, community characteristics, elements that could be replicated or need modification.	Mainly at completion and during follow-up assessments.
SCALABILITY	What happens if we try to apply the experience to a larger population?	Teacher workload, costs, infrastructure, coordination across subjects, material availability, number of students, additional training needs, changes required to expand the intervention.	At completion and before any expansion.

Note: This matrix is a guiding structure developed by CERLI. Indicators, instruments, measurement points, and interpretation criteria must be defined for each project. Not every initiative will need to measure every variable with the same intensity, and the absence of an applicable indicator does not mean a dimension lacks relevance.



International Reference Organizations

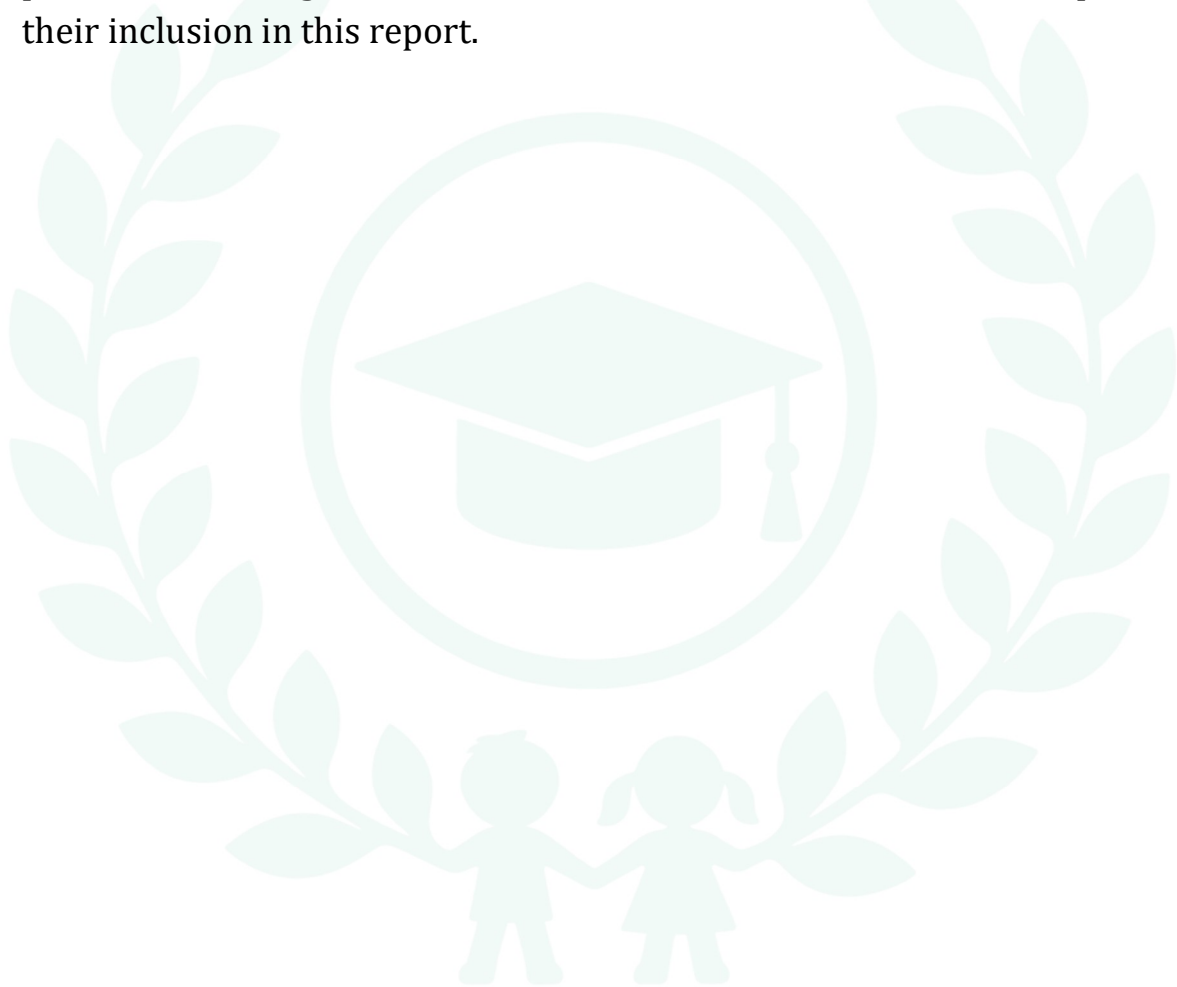
Environmental education can hardly develop in isolation. Many of the problems explored in this report cross borders, disciplines, institutions, and entire sectors of society. The same is true of possible responses. Scientific research can help us understand a phenomenon, environmental organizations contribute experience from interventions on the ground, and educational organizations help turn some of that knowledge into tools that can reach students, teachers, and communities.

At CERLI, we understand international partnerships as a way to broaden that conversation. Working with organizations that approach issues from different perspectives allows us to compare ideas, incorporate specialized knowledge, learn about experiences developed in other contexts, and bring education closer to those who study or directly confront environmental challenges. Each institution contributes different capacities, and that is precisely the value of building networks that connect education, conservation, research, and sustainability measurement.

The organizations presented below represent three approaches particularly relevant to the topics developed in these pages. UNESCO plays a central role in building international frameworks for education and sustainable development; The Nature Conservancy works directly on conservation, biodiversity, climate, and ecosystem protection; and Global Footprint Network has helped develop tools to observe and

communicate the relationship between human consumption and the planet's regenerative capacity.

Their fields of work differ, but they share something fundamental to our perspective: they turn extremely broad environmental problems into knowledge, tools, experiences, and methods that can help us better understand reality. For CERLI, building these connections enriches our own projects while bringing knowledge often developed outside education into the educational sphere. The following pages briefly present these organizations' work and the connections that explain their inclusion in this report.



UNESCO

The United Nations Educational, Scientific and Cultural Organization was born at one of the most delicate moments of the twentieth century. Its Constitution was adopted in London on November 16, 1945, a few months after the end of World War II, and entered into force on November 4, 1946.



The idea that inspired its creation was as simple as it was ambitious. Although political and economic agreements could temporarily halt a conflict, lasting peace also required intellectual cooperation, shared knowledge, education, culture, and understanding among societies. That conviction was reflected from the outset in the organization's Constitution.

Since then, UNESCO has considerably expanded its scope of action. It currently brings together 194 Member States and 12 Associate Members and develops programs related to education, natural and social sciences, culture, communication, heritage, freedom of expression, access to knowledge, and international scientific cooperation. Its distinctive role within the United Nations system lies precisely in that combination: many of the challenges it addresses simultaneously involve the production of knowledge, its transmission across generations, and the cultural conditions necessary for that knowledge to be used.

Sustainability gradually assumed a central place in this mission. UNESCO led the United Nations Decade of Education for Sustainable Development from 2005 to 2014, subsequently coordinated the Global

Action Programme, and currently leads the Education for Sustainable Development for 2030 framework. As we saw earlier in this report, this process seeks to incorporate sustainability into education policies, curricula, teacher education, institutions, communities, and learning experiences, preventing it from being reduced to an isolated topic within particular subjects.

In recent years, this work has focused especially on preparing education systems for climate change. The Greening Education Partnership, led by UNESCO since 2022, organizes that transformation around four major areas: educational institutions, curricula, teacher education and system capacities, and communities. Its objectives include ensuring that climate education extends across different levels and disciplines, that educational institutions themselves adopt practices consistent with what they teach, and that teachers and communities have better tools for addressing nearby environmental problems.

This perspective has produced tools closely related to several of the ideas developed in these pages. In 2024, UNESCO published guidance for integrating climate change into curricula and introduced an international standard for green schools for the first time, organized around institutional governance, infrastructure and operations, teaching and learning, and community engagement. Rather than concentrating all environmental education in a single activity, the proposal seeks to make sustainability part of how an institution operates every day.

For CERLI, UNESCO's work is especially relevant because it connects two worlds that too often move forward separately. On one hand, there is an enormous body of scientific work on climate change, biodiversity, consumption, resources, and sustainability. On the other, education systems need to turn some of that knowledge into understandable, applicable experiences for millions of students. Much of the challenge explored in this report lies precisely in that bridge: deciding what to teach, how to teach it, and how to ensure that learning retains value when students leave the classroom.

The Nature Conservancy

The Nature Conservancy, commonly known as TNC, is an international nonprofit organization with a particular focus on environmental protection and, as its name indicates, nature conservation worldwide. Its roots lie in the development of ecology as a scientific discipline.



In 1917, a group of members of the Ecological Society of America established the Committee on Preservation of Natural Areas for Ecological Study, driven by scientists interested in conserving natural areas where relatively undisturbed ecosystems could also be studied. After that committee was dissolved, several members formed the Ecologists Union in 1946, which a few years later would formally become The Nature Conservancy. The organization was incorporated as a nonprofit in 1951.

Its early years were closely tied to direct land protection. In 1955, it completed its first acquisition, Mianus River Gorge, a forest of approximately 24 hectares in New York whose conservation required combining community contributions with the organization's own funding. Over the following decades, that initial model expanded into partnerships with public agencies, landowners, communities, businesses, scientists, and local organizations. Over time, TNC moved from focusing primarily on acquiring and protecting natural areas within the United States to developing conservation programs on multiple continents.

Today, the organization pursues its mission to conserve the lands and waters on which all life depends. Its work reaches 83 countries and territories, through direct conservation projects or through partnerships and public policy engagement, and it has more than one thousand scientists within its international structure. Its approach combines scientific research, land conservation, financing, public policy, ecological restoration, and collaboration with local and Indigenous communities. TNC currently presents climate change and accelerating biodiversity loss as the two major interconnected challenges around which it organizes much of its strategy.

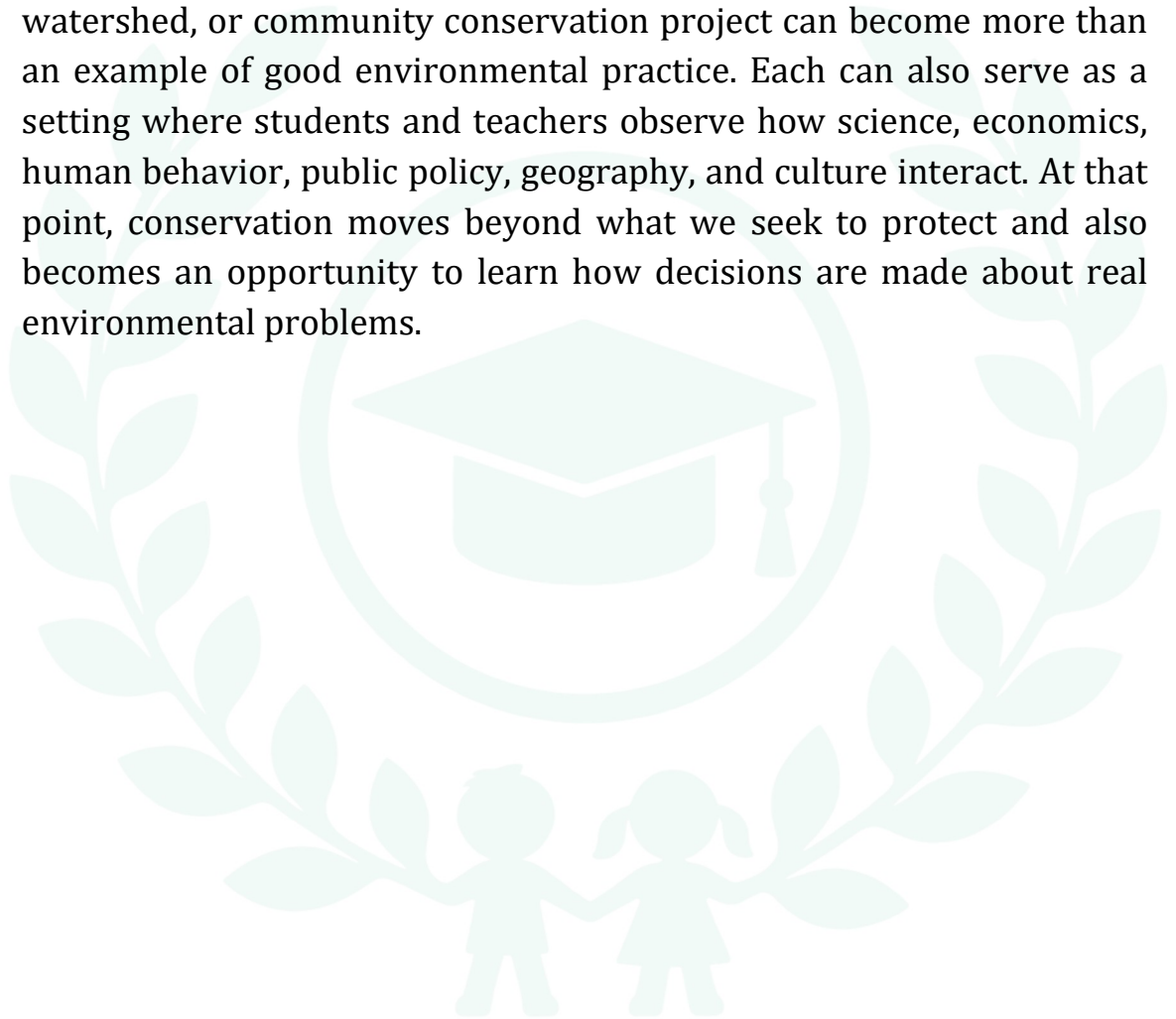
That strategy translates into substantial goals for 2030. These include helping conserve 650 million hectares of land, one million kilometers of rivers, 30 million hectares of lakes and wetlands, and four billion hectares of ocean. The organization also aims to reduce or store the equivalent of three billion metric tons of carbon dioxide annually, support one hundred million people exposed to severe climate risks, and work alongside tens of millions of people whose livelihoods depend directly on healthy ecosystems. These figures are TNC's own targets and reflect the scale at which it seeks to combine conservation, climate, and human well-being.

In Latin America, this work is particularly relevant because of the regional concentration of biodiversity, water resources, forests, production systems, and highly sensitive ecosystems. TNC works in countries such as Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, Guatemala, and Belize, with projects related to the Amazon, Patagonia, watersheds, restoration, sustainable production, rivers, and large-landscape conservation. The region also offers an especially clear example of a principle running through its current work: conserving an ecosystem requires understanding the communities that depend on it, the productive activities that transform it, and the institutions that determine how it can be used.

Its inclusion in this report is especially relevant because of this combination of scientific knowledge and application on the ground. When we analyze biodiversity, forests, oceans, freshwater, restoration,

or ecosystem protection, broad concepts risk becoming abstractions that are difficult to connect with concrete decisions. The work of organizations such as TNC reveals the other half of the problem: what happens when those principles must become real conservation, with limited resources, different interests, involved communities, and ecosystems that rarely respond simply to a single intervention.

For CERLI, this experience is especially valuable from an educational perspective. A protected ecosystem, restored river, managed watershed, or community conservation project can become more than an example of good environmental practice. Each can also serve as a setting where students and teachers observe how science, economics, human behavior, public policy, geography, and culture interact. At that point, conservation moves beyond what we seek to protect and also becomes an opportunity to learn how decisions are made about real environmental problems.



Global Footprint Network

Global Footprint Network is a charitable nonprofit organization founded in 2003 by Mathis Wackernagel and Susan Burns. Its aim is to communicate measurable ecological limits so that governments, organizations, businesses, and citizens can take informed action for sustainability.



In the early 1990s, Wackernagel and William Rees developed the Ecological Footprint concept at the University of British Columbia, initially as part of Wackernagel's doctoral research. Over time, that methodology evolved from an academic tool into one of the most recognizable ways of representing human pressure on natural resources.

Its logic begins by comparing two quantities. On one side, the “Ecological Footprint” estimates a population’s demand on biologically productive areas, primarily through food, fibers, forest products, fishing, infrastructure, and the area needed to absorb certain carbon dioxide emissions. On the other, “biocapacity” represents ecosystems’ capacity to regenerate resources and provide those services. Both variables are expressed in global hectares, a standardized unit that allows comparisons among territories with different levels of productivity.

The comparison identifies an ecological deficit when demand exceeds available biocapacity. At the national scale, that difference can be compensated for through imports, exploitation of domestic ecological

stocks, or carbon emissions that exceed local absorption capacity. At the planetary scale, the situation changes because Earth cannot import resources from another territory. When the global Ecological Footprint exceeds global biocapacity, Global Footprint Network uses the term ecological overshoot to describe that difference.

One of the best-known expressions of this work is Earth Overshoot Day. The initiative began as a collaboration with the New Economics Foundation in 2006 and translates the relationship between Ecological Footprint and biocapacity into a calendar date: the exact day when humanity's cumulative demand exceeds what ecosystems can regenerate over that entire year. In 2026, the organization calculated that date as July 30. To put it in context, Earth Overshoot Day fell on September 23 in 2000, August 15 in 2010, August 18 in 2020, and August 1 in 2025 ¹³.

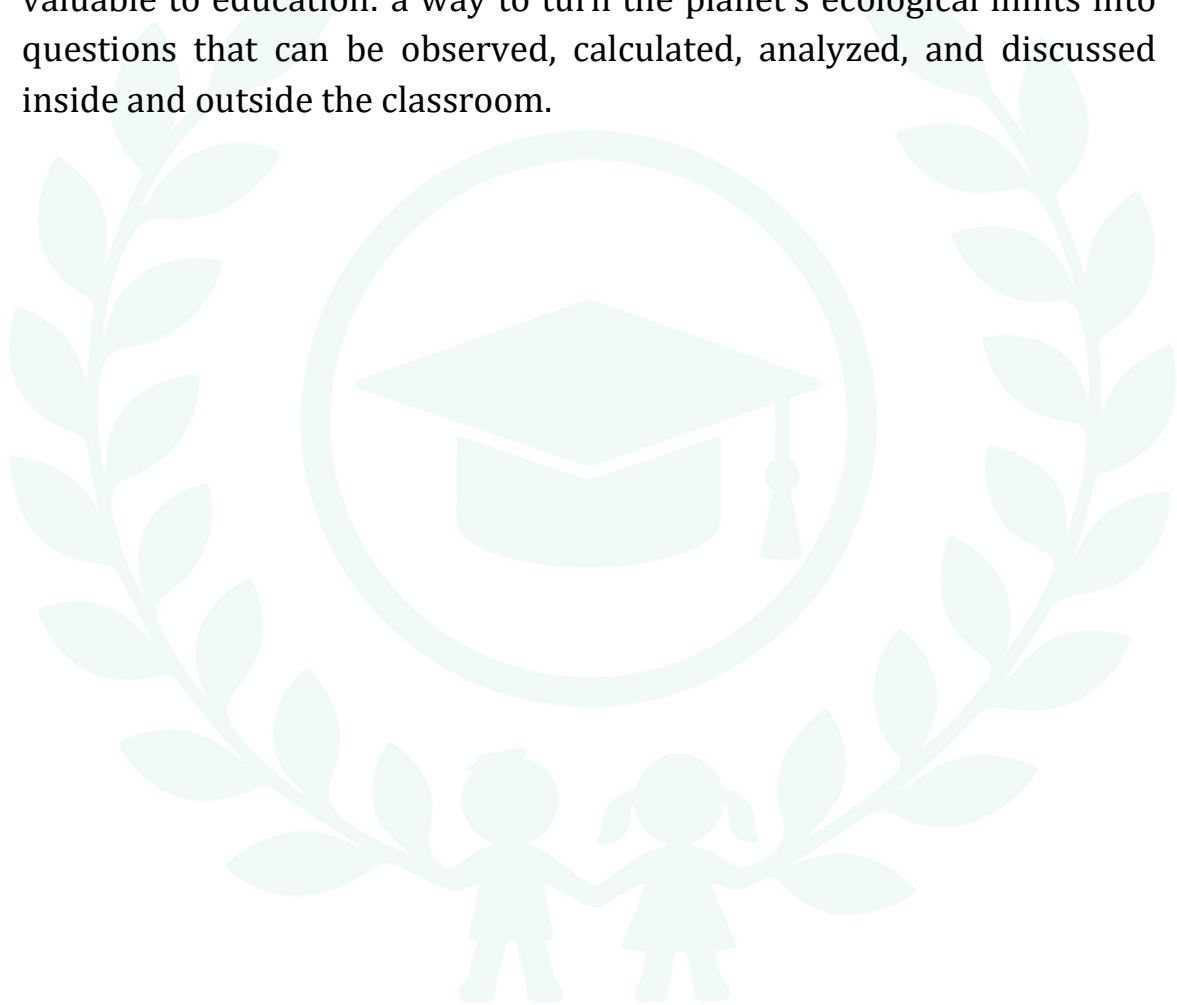
The new 2026 edition also estimated that humanity uses ecological resources and services approximately 73% faster than the planet can regenerate them, which is equivalent to a demand of about 1.73 Earths. That last clarification is especially important for environmental education. An intuitive figure such as "1.73 planets" has enormous power to communicate a complex problem, but its educational value increases when we also understand what it measures, how it was calculated, what assumptions it uses, and what its limits are.

The Ecological Footprint does not aim to combine every possible dimension of environmental impact into a single indicator. Its strength lies in providing a concrete accounting of certain human demands against available regenerative capacity, which can then be complemented by information on biodiversity, pollution, water, climate, and other environmental processes.

¹³ Global Footprint Network recalculates historical Earth Overshoot Day dates when it updates its National Footprint and Biocapacity Accounts, so dates originally published in earlier years may differ from the latest historical series. Although July 24 was initially announced for 2025, the 2026 edition recalculated that date as August 1. Using the methodology and data from this latest edition, July 30, 2026, represents the highest level of ecological overshoot on record.

For CERLI, this approach connects directly with a principle we have defended throughout the report: learning about sustainability also means learning how to measure it. Concepts such as consumption, available resources, regenerative capacity, ecological deficit, and environmental pressure can become research problems in which students must work with real data, compare territories, question indicators, and discuss what information each measurement leaves out.

In this sense, Global Footprint Network offers something especially valuable to education: a way to turn the planet's ecological limits into questions that can be observed, calculated, analyzed, and discussed inside and outside the classroom.



Epilogue

We began this report with a seemingly simple idea: if we want to educate for a sustainable future, we first need to understand what sustainability really means. As we progressed, that question revealed a considerably more complex reality. Climate change, waste, resource consumption, biodiversity loss, and ecosystem transformation are interconnected, but each has different mechanisms, scales, uncertainties, and possible solutions. Trying to reduce all these challenges to a single slogan impoverishes what we aim to teach.

We also discovered that environmental evidence requires some effort to interpret. A figure can be correct yet misleading when presented without context. A campaign can begin with a legitimate concern and use weak arguments to defend it. Two people can recognize exactly the same problem and reasonably disagree about which solution deserves priority. For CERLI, this complexity is not an obstacle to environmental education. On the contrary, it is one of its greatest educational opportunities, because it requires teaching how to investigate, compare, question, and reach conclusions from information that rarely arrives perfectly organized.

The objective we propose for environmental education therefore goes far beyond transmitting a list of desirable habits. We want students to understand why particular recommendations exist, what evidence supports them, what limitations they have, and how they change when we move them from one context to another. Sorting waste, reducing certain types of consumption, protecting an ecosystem, or changing how we use water gains much greater educational value when students can explain what problem they are trying to solve and assess whether their own intervention made any difference.

This perspective also changes the student's role. Faced with environmental problems on a planetary scale, it is easy to convey a sense of smallness and helplessness. An educational project can do exactly the opposite: provide a sufficiently familiar setting in which students can investigate, make mistakes, correct them, measure results, and discover which aspects of a problem can be changed through individual and collective action. The school, its neighborhood, a nearby waterway, the building's energy consumption, or the waste produced each day can become small laboratories for learning to act on a reality that once seemed distant.

The models proposed in these pages begin with that possibility. Active participation, cross-curricular integration, connection to real problems, gradually increasing autonomy, ongoing assessment, and follow-up form a set of elements that must be adapted to each institution. No single method can guarantee that students will adopt particular behaviors for the rest of their lives. We can, however, design experiences that increase opportunities to understand a problem deeply, use knowledge from different areas, test ideas against evidence, and develop tools that can be used again when new challenges arise.

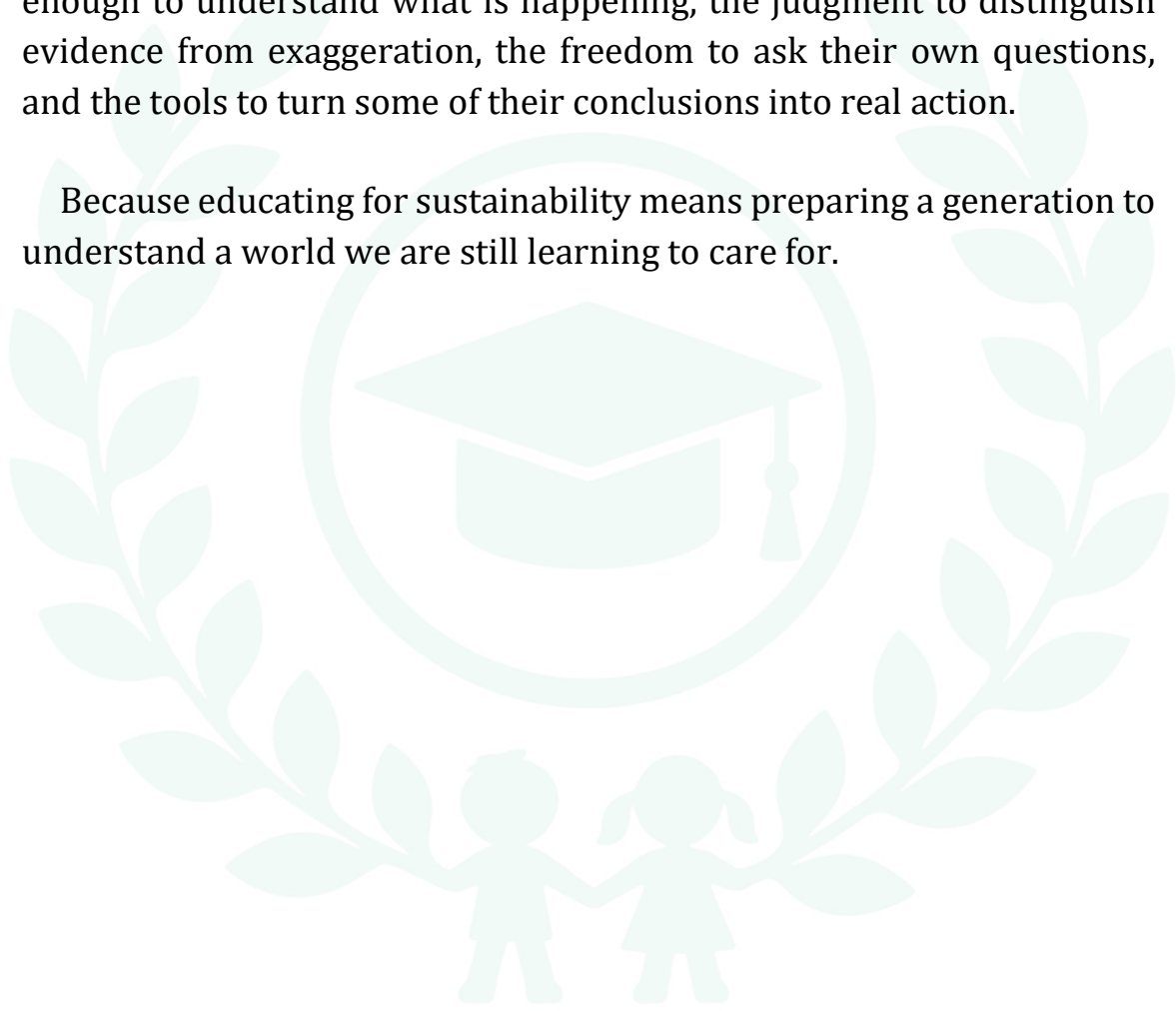
For the same reason, evaluating these initiatives will require more than observing an appealing result at the end of the year. We must ask what was actually implemented, what students learned, what changed within the institution, how much of that change persisted, and which elements could be carried into future experiences. Some projects will work better than others. Others will need to be modified, abandoned, or rebuilt after we discover that our initial hypotheses were incorrect. This capacity to learn from what fails is also part of the model we propose.

No institution will have to travel this path entirely alone. Throughout this report, we have seen how international organizations, environmental organizations, researchers, communities, teachers, and students contribute different perspectives on the same challenge. Partnerships bring those worlds closer, enable the sharing of experiences, provide access to specialized knowledge, and prevent every new initiative from having to start again at the first step. For

CERLI, that cooperation will be fundamental to any serious effort to build environmental education that can also learn from those who have already spent decades working on these problems.

Perhaps that is ultimately the most important idea we can leave in these pages. The sustainable future we talk about so often is still being built, and many of those who will have to make decisions about it are in classrooms today. Our educational responsibility is to offer them something more valuable than ready-made answers: knowledge solid enough to understand what is happening, the judgment to distinguish evidence from exaggeration, the freedom to ask their own questions, and the tools to turn some of their conclusions into real action.

Because educating for sustainability means preparing a generation to understand a world we are still learning to care for.



Bibliography

1. Armstrong McKay, D. I., Staal, A., Abrams, J. F., Winkelmann, R., Sakschewski, B., Loriani, S., Fetzer, I., Cornell, S. E., Rockström, J., & Lenton, T. M. (2022). Exceeding 1.5°C global warming could trigger multiple climate tipping points. *Science*, 377(6611), eabn7950. <https://doi.org/10.1126/science.abn7950> PubMed
2. Asamblea General de las Naciones Unidas. (2002). Decenio de las Naciones Unidas de la Educación para el Desarrollo Sostenible (Resolución A/RES/57/254).
3. Asamblea General de las Naciones Unidas. (2015). Transformar nuestro mundo: La Agenda 2030 para el Desarrollo Sostenible (Resolución A/RES/70/1). <https://sdgs.un.org/es/2030agenda> Department of Economic and Social Affairs
4. Baker, J. A., Bell, M. J., Jackson, L. C., Vallis, G. K., Watson, A. J., & Wood, R. A. (2025). Continued Atlantic overturning circulation even under climate extremes. *Nature*, 638, 987–994. <https://doi.org/10.1038/s41586-024-08544-0> PubMed
5. Baldé, C. P., Kuehr, R., Yamamoto, T., McDonald, R., D'Angelo, E., Althaf, S., Bel, G., Deubzer, O., Fernandez-Cubillo, E., Forti, V., Gray, V., Herat, S., Honda, S., Iattoni, G., Khatriwal, D. S., Luda di Cortemiglia, V., Lobuntsova, Y., Nnorom, I., Pralat, N., & Wagner, M. (2024). The global e-waste monitor 2024. International Telecommunication Union; United Nations Institute for Training and Research. https://www.itu.int/pub/D-GEN-E_WASTE.01-2024 ewastemonitor.info

6. Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84(2), 191–215. <https://doi.org/10.1037/0033-295X.84.2.191> verdi.cs.ucl.ac.uk
7. Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy & Practice*, 5(1), 7–74. <https://doi.org/10.1080/0969595980050102> tandfonline.com
8. Broek, S., & Kaur, A. (2026). Mid-term evaluation of the ESD for 2030 framework, 2021–2024. UNESCO. <https://www.unesco.org/en/articles/mid-term-evaluation-esd-2030-framework-2021-2024> UNESCO
9. Bunge, A. C., Mazac, R., Clark, M., Wood, A., & Gordon, L. (2024). Sustainability benefits of transitioning from current diets to plant-based alternatives or whole-food diets in Sweden. *Nature Communications*, 15, Article 951. <https://doi.org/10.1038/s41467-024-45328-6> Nature Communications
10. Carroll, C., Patterson, M., Wood, S., Booth, A., Rick, J., & Balain, S. (2007). A conceptual framework for implementation fidelity. *Implementation Science*, 2, Article 40. <https://doi.org/10.1186/1748-5908-2-40> Springer Nature Link
11. Chiba, M., Sustarsic, M., Perriton, S., & Edwards, D. B., Jr. (2021). Investigating effective teaching and learning for sustainable development and global citizenship: Implications from a systematic review of the literature. *International Journal of Educational Development*, 81, Article 102337. <https://doi.org/10.1016/j.ijedudev.2020.102337> ScienceDirect
12. Consejo de la Unión Europea. (n.d.). Derecho a reparar productos. <https://www.consilium.europa.eu/es/policies/right-to-repair-products/> Consilium
13. Consejo de la Unión Europea. (2024, May 30). Economía circular: El Consejo da su aprobación definitiva a la Directiva sobre el Derecho a Reparar.

- 14.** Conteh, Y. A., & Miller, L. C. (2026). The impact of fear appeals on individuals' climate change attitudes and behaviors: A meta-analysis. *Journal of Environmental Psychology*, 113, Article 103110. <https://doi.org/10.1016/j.jenvp.2026.103110> ScienceDirect
- 15.** Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Becker, W., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Melo, J., Oom, D., Branco, A., San-Miguel, J., Manca, G., ... Pekar, F. (2024). GHG emissions of all world countries. Publications Office of the European Union. <https://doi.org/10.2760/4002897> edgar.jrc.ec.europa.eu
- 16.** Empresa de Pesquisa Energética. (2024). Balanço energético nacional 2024: Ano base 2023. <https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-2024> epe.gov.br
- 17.** European Commission. (n.d.). Sustainable hunting under the Birds Directive. https://environment.ec.europa.eu/topics/nature-and-biodiversity/birds-directive/sustainable-hunting-under-birds-directive_en Environment
- 18.** Flores, B. M., Montoya, E., Sakschewski, B., Nascimento, N., Staal, A., Betts, R. A., Levis, C., Lapola, D. M., Esquivel-Muelbert, A., Jakovac, C., Nobre, C. A., Oliveira, R. S., Borma, L. S., Nian, D., Boers, N., Hecht, S. B., ter Steege, H., Arieira, J., Lucas, I. L., ... Hirota, M. (2024). Critical transitions in the Amazon forest system. *Nature*, 626, 555–564. <https://doi.org/10.1038/s41586-023-06970-0> PubMed
- 19.** Food and Agriculture Organization of the United Nations. (2020). Global forest resources assessment 2020: Main report. <https://www.fao.org/forest-resources-assessment/past-assessments/fra-2020/> fao.org
- 20.** Food and Agriculture Organization of the United Nations. (2022). FRA 2020 remote sensing survey. <https://www.fao.org/forest-resources-assessment/remote-sensing/remote-sensing-survey/en> fao.org

- 21.** Food and Agriculture Organization of the United Nations. (2023a). Methane emissions in livestock and rice systems: Sources, quantification, mitigation and metrics. <https://openknowledge.fao.org/3/cc7607en/cc7607en.pdf> fao.org
- 22.** Food and Agriculture Organization of the United Nations. (2023b). The world's mangroves 2000–2020. <https://www.fao.org/interactive/remote-sensing-mangroves/en/> fao.org
- 23.** Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410–8415. <https://doi.org/10.1073/pnas.1319030111> PMC
- 24.** Genc, M. (2015). The project-based learning approach in environmental education. *International Research in Geographical and Environmental Education*, 24(2), 105–117. <https://doi.org/10.1080/10382046.2014.993169> tandfonline.com
- 25.** Global Footprint Network. (n.d.-a). Ecological footprint. <https://footprintnetwork.org/our-work/ecological-footprint/> Global Footprint Network
- 26.** Global Footprint Network. (n.d.-b). Our history. <https://footprintnetwork.org/about-us/our-history/> Global Footprint Network
- 27.** Global Footprint Network. (n.d.-c). Past Earth Overshoot Days. Retrieved September 25, 2026, from <https://overshoot.footprintnetwork.org/newsroom/past-earth-overshoot-days/> Global Footprint Network
- 28.** Global Footprint Network. (2026, July 30). Earth Overshoot Day 2026 falls on July 30. <https://overshoot.footprintnetwork.org/newsroom/eod-2026-en/> overshoot.footprintnetwork.org

- 29.** Intergovernmental Panel on Climate Change. (2021). Climate change 2021: The physical science basis. Cambridge University Press. <https://doi.org/10.1017/9781009157896> ipcc.ch
- 30.** Intergovernmental Panel on Climate Change. (2023). Climate change 2023: Synthesis report. <https://doi.org/10.59327/IPCC/AR6-9789291691647> apps.ipcc.ch
- 31.** Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. (2016). The assessment report on pollinators, pollination and food production (S. G. Potts, V. L. Imperatriz-Fonseca, & H. T. Ngo, Eds.). <https://zenodo.org/records/3402857> Zenodo
- 32.** International Energy Agency. (2024). Global EV outlook 2024. <https://www.iea.org/reports/global-ev-outlook-2024> IEA
- 33.** International Energy Agency. (2025). Global EV outlook 2025. <https://www.iea.org/reports/global-ev-outlook-2025> IEA
- 34.** International Union for Conservation of Nature. (2000). IUCN policy statement on sustainable use of wild living resources. <https://portals.iucn.org/library/sites/library/files/documents/Rep-2000-054.pdf> portals.iucn.org
- 35.** Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). What a waste 2.0: A global snapshot of solid waste management to 2050. World Bank. <https://documents.worldbank.org/curated/en/697271544470229584/pdf/132827-PUB-9781464813290.pdf> documents.worldbank.org
- 36.** Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. Prentice-Hall. WorldCat.org
- 37.** Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge University Press. <https://doi.org/10.1017/CBO9780511815355> Cambridge Aspire website

- 38.** Mekonnen, M. M., & Hoekstra, A. Y. (2012). A global assessment of the water footprint of farm animal products. *Ecosystems*, 15(3), 401–415. <https://doi.org/10.1007/s10021-011-9517-8> Springer Nature Link
- 39.** Miao, F., & Holmes, W. (2023). Guidance for generative AI in education and research. UNESCO. <https://www.unesco.org/en/articles/guidance-generative-ai-education-and-research> UNESCO
- 40.** Ministerio de Industria, Energía y Minería. (2024). Balance energético nacional 2023.
- 41.** National Oceanic and Atmospheric Administration, Global Monitoring Laboratory. (2025). The NOAA annual greenhouse gas index (AGGI). <https://gml.noaa.gov/aggi/aggi.html> NOAA Global Monitoring Laboratory
- 42.** National Park Service. (n.d.-a). History of wolf management. <https://www.nps.gov/yell/learn/historyculture/wolf-management.htm> nps.gov
- 43.** National Park Service. (n.d.-b). Wolf ecology. <https://www.nps.gov/yell/learn/nature/wolf.htm> nps.gov
- 44.** Organisation for Economic Co-operation and Development. (2022). Global plastics outlook: Economic drivers, environmental impacts and policy options. OECD Publishing. <https://doi.org/10.1787/de747aef-en> OECD
- 45.** Organización de Estados Iberoamericanos para la Educación, la Ciencia y la Cultura. (2025). Alianzas para la esperanza activa: Educación ante el cambio climático con impacto en Iberoamérica.
- 46.** Piaget, J. (1970). Science of education and the psychology of the child (D. Coltman, Trans.). Orion Press. (Original work published 1969). catalog.library.tamu.edu

- 47.** Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, 360(6392), 987–992. <https://doi.org/10.1126/science.aag0216> PubMed
- 48.** Réseau de Transport d'Électricité. (2024). Bilan électrique 2023. <https://analysesetdonnees.rte-france.com/bilan-electrique-2023/production RTE>
- 49.** Sabarwal, S., Venegas Marin, S., Spivack, M., & Ambasz, D. (2024). Choosing our future: Education for climate action. World Bank. <https://documents1.worldbank.org/curated/en/099082624160037461/pdf/P180005183528c03c1802a1896a79b744ea.pdf>
documents1.worldbank.org
- 50.** Secretariat of the Basel Convention. (n.d.). Illegal traffic: Overview. <https://www.basel.int/implementation/legalmatters/illegaltraffic/overview/tabid/3421/default.aspx> basel.int
- 51.** Storoszczuk Durán, M. (2024). Educación en situaciones de emergencia; catástrofes y refugiados. *The Orvium Education Journal*. <https://www.researchgate.net/publication/387344937> researchgate.net
- 52.** TAGMA. (n.d.-a). Red de escuelas y aulas sustentables. Retrieved September 25, 2026, from <https://somostagma.com/> Educación, Comunidad y Sostenibilidad
- 53.** TAGMA. (n.d.-b). Una escuela sustentable en Uruguay: Jaureguiberry. <https://somostagma.com/una-escuela-sustentable-uruguay/Jaureguiberry – TAGMA>
- 54.** The Nature Conservancy. (n.d.-a). Our history. <https://www.nature.org/en-us/about-us/who-we-are/our-history/> The Nature Conservancy
- 55.** The Nature Conservancy. (n.d.-b). The Nature Conservancy's 2030 goals. <https://www.nature.org/en-us/what-we-do/> nature.org

- 56.** The Nature Conservancy. (n.d.-c). Who we are. Retrieved September 25, 2026, from <https://www.nature.org/en-us/about-us/who-we-are/> The Nature Conservancy
- 57.** UNESCO. (2017). Education for Sustainable Development Goals: Learning objectives. <https://doi.org/10.54675/CGBA9153247444eng.pdf>
- 58.** UNESCO. (2020). Education for sustainable development: A roadmap. <https://www.unesco.org/en/articles/education-sustainable-development-roadmap> UNESCO
- 59.** UNESCO. (2024a). Global education monitoring report 2024/5: Leadership in education—Lead for learning. <https://www.unesco.org/reports/gem-report/en/2024> Global Education Monitoring Report - Reports
- 60.** UNESCO. (2024b). Green school quality standard: Greening every learning environment. <https://www.unesco.org/en/articles/green-school-quality-standard-greening-every-learning-environment> unesco.org
- 61.** UNESCO. (2024c). Greening curriculum guidance: Teaching and learning for climate action. <https://doi.org/10.54675/AOOZ1758> unesdoc.unesco.org
- 62.** United Nations Children’s Fund. (2025). Learning interrupted: Global snapshot of climate-related school disruptions in 2024. <https://www.unicef.org/reports/learning-interrupted-global-snapshot-2024> UNICEF
- 63.** United Nations Environment Programme. (n.d.). Red de Formación Ambiental para América Latina y el Caribe. <https://www.unep.org/es/red-de-formacion-ambiental-para-america-latina-y-el-caribe> UNEP - UN Environment Programme
- 64.** United Nations Environment Programme. (2019). Dark skies, bright future: Overcoming Nigeria’s e-waste epidemic.

<https://www.unep.org/news-and-stories/story/dark-skies-bright-future-overcoming-nigerias-e-waste-epidemic> unep.org

- 65.** United Nations Environment Programme. (2022). Global peatlands assessment: The state of the world's peatlands. <https://globalpeatlands.org/resource-library/global-peatlands-assessment-state-worlds-peatlands-main-report> Global Peatlands Initiative
- 66.** United Nations Environment Programme. (2024). Eight ways to overcome the waste pollution crisis. <https://www.unep.org/news-and-stories/story/eight-ways-overcome-waste-pollution-crisis> UNEP
- 67.** United Nations Environment Programme, & International Solid Waste Association. (2024). Global waste management outlook 2024: Beyond an age of waste—Turning rubbish into a resource. United Nations Environment Programme. <https://doi.org/10.59117/20.500.11822/44939> Turning Rubbish into a Resource
- 68.** United Nations Framework Convention on Climate Change. (n.d.). The Paris Agreement. Retrieved September 25, 2026, from <https://unfccc.int/process-and-meetings/the-paris-agreement> UNFCCC
- 69.** United Nations High Commissioner for Refugees. (2026, July 3). UNHCR warns Lake Chad Basin at tipping point as violence and displacement surge. <https://www.unhcr.org/us/news/briefing-notes/unhcr-warns-lake-chad-basin-tipping-point-violence-and-displacement-surge> UNHCR US
- 70.** U.S. Environmental Protection Agency. (n.d.). Basic information about landfill gas. <https://www.epa.gov/lmop/basic-information-about-landfill-gas> US EPA
- 71.** U.S. Fish and Wildlife Service. (n.d.). Hunting on wildlife refuges 101: Frequently asked questions. <https://www.fws.gov/story/hunting-wildlife-refuges-101-frequently-asked-questions> U.S. Fish & Wildlife Service

- 72.** U.S. Geological Survey. (2018, June 6). Where is Earth's water? <https://www.usgs.gov/water-science-school/science/where-earths-water>
U.S. Geological Survey
- 73.** van de Wetering, J., Leijten, P., Spitzer, J. E., & Thomaes, S. (2022). Does environmental education benefit environmental outcomes in children and adolescents? A meta-analysis. *Journal of Environmental Psychology*, 81, Article 101782. <https://doi.org/10.1016/j.jenvp.2022.101782> research-portal.uu.nl
- 74.** Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Harvard University Press. Discover
- 75.** World Bank. (2022). The climate change and conflict nexus in West Africa: A new approach for operationally relevant vulnerability assessments. <https://documents1.worldbank.org/curated/en/099184003162387055/pdf/P1729410b3a8dd05909a1006b5887fa5d0d.pdf>
documents1.worldbank.org
- 76.** World Health Organization. (2021). Children and digital dumpsites: E-waste exposure and child health. <https://www.who.int/publications/i/item/9789240023901> who.int
- 77.** World Health Organization. (2022). Dietary and inhalation exposure to nano- and microplastic particles and potential implications for human health. <https://www.who.int/publications/i/item/9789240054608> who.int
- 78.** World Meteorological Organization. (2025). WMO global annual to decadal climate update (2025–2029). <https://wmo.int/resources/publication-series/wmo-global-annual-decadal-climate-update/wmo-global-annual-decadal-climate-update-2025-2029> wmo.int
- 79.** Wunderling, N., Sakschewski, B., Rockström, J., Flores, B. M., Hirota, M., & Staal, A. (2026). Deforestation-induced drying lowers Amazon climate

threshold. *Nature*, 654, 114–120. <https://doi.org/10.1038/s41586-026-10456-0> PubMed

- 80.** Zhang, L., & Ma, Y. (2023). A study of the impact of project-based learning on student learning effects: A meta-analysis study. *Frontiers in Psychology*, 14, Article 1202728. <https://doi.org/10.3389/fpsyg.2023.1202728>

