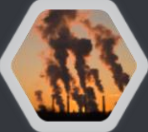

Megatrend 3
Environment &
Resources
Roland Berger

Environment & Resources


1
Climate Change & Pollution


2
Resources: Abundance vs. Scarcity


3
Ecosystems at Risk

Upping global climate change mitigation a must – In the future, water, food, and raw materials face critical issues. Valuable biodiversity is underfunded

Subtrends of megatrend "Environment & Resources"

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Climate Change & Pollution

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Resources: Abundance vs. Scarcity

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Ecosystems at Risk

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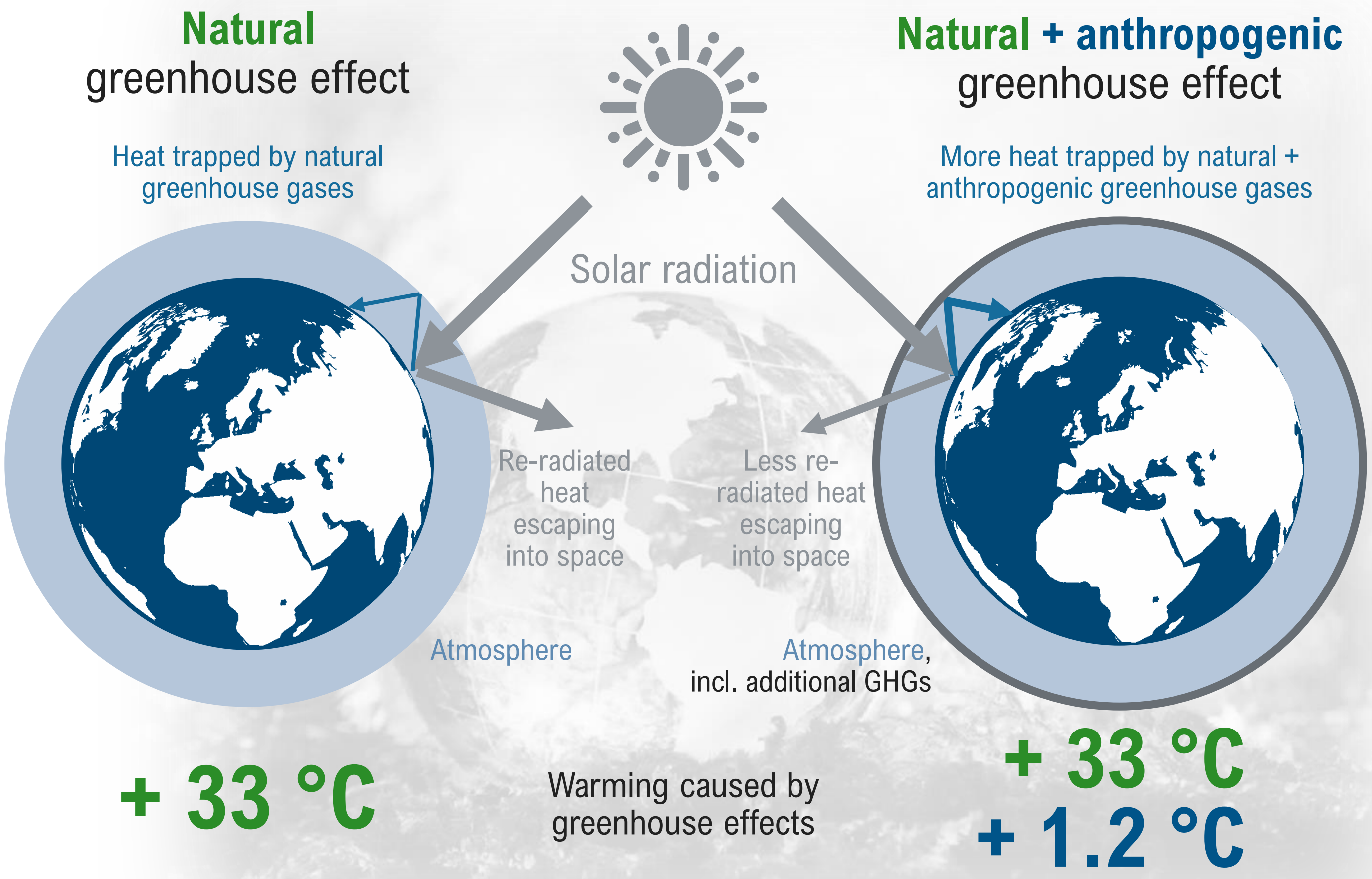
The natural greenhouse effect enables our life on Earth – The anthropogenic greenhouse effect is a burdensome layer

Illustration of the natural and anthropogenic greenhouse effect



Compared to the natural greenhouse effect, the anthropogenic greenhouse effect looks small. But it appeared very fast, so that Earth's natural systems (like ecosystems, ocean currents, jet stream, etc.) and civilization could not adapt in time

> The **greenhouse effect** is a process that **heats the Earth's surface.** When solar radiation reaches the Earth, some of it is re-radiated into space. Some is trapped by greenhouse gases in the atmosphere, warming the Earth

> The **natural greenhouse effect,** caused by water vapor and natural levels of CO_2, methane, nitrous oxide and ozone in the atmosphere, keeps the Earth's temperature about **33 °C warmer** than otherwise (15 °C average surface temperature instead of -18 °C**). Water vapor** accounts for **36-85%** of the overall greenhouse effect, depending on sky and regional conditions

> **Human activities** – particularly activities such as the burning of fossil fuels (coal, oil, and natural gas), agriculture, and land clearing at scale – are **increasing the concentration of greenhouse gases**, in particular of CO_2, methane and nitrous oxide. This is the **anthropogenic greenhouse effect**, causing an additional warming of the Earth of currently 1.2 °C

Sources: NRDC; Real Climate; Niwa; Roland Berger

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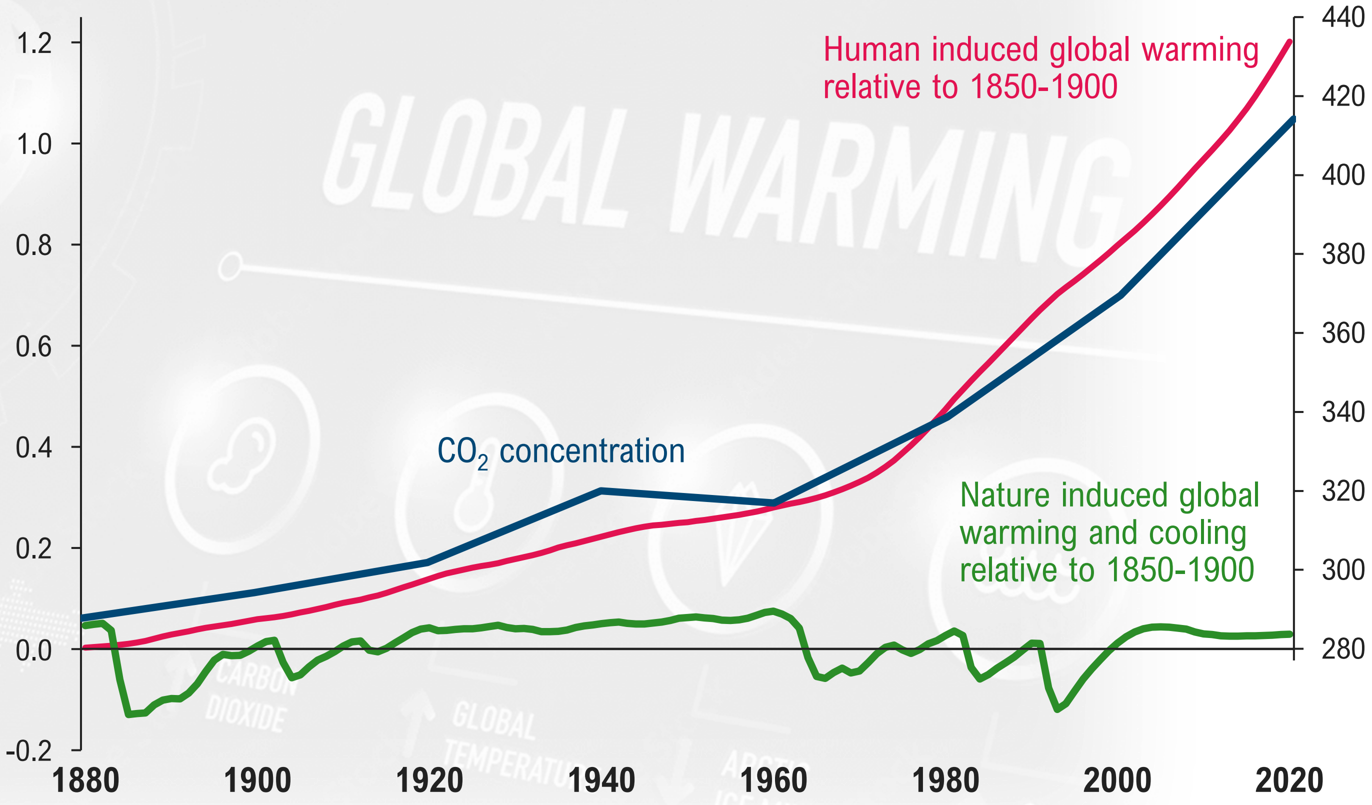
In parallel to the increase of CO_2 concentration, the global average temperature has risen by more than 1°C over the last century

CO_2 / Temperature increase nexus

Global temperature anomalies compared to the average global temperature 1850-1900 [left scale, additional °C] and CO_2 concentration in the atmosphere [right scale, ppm]

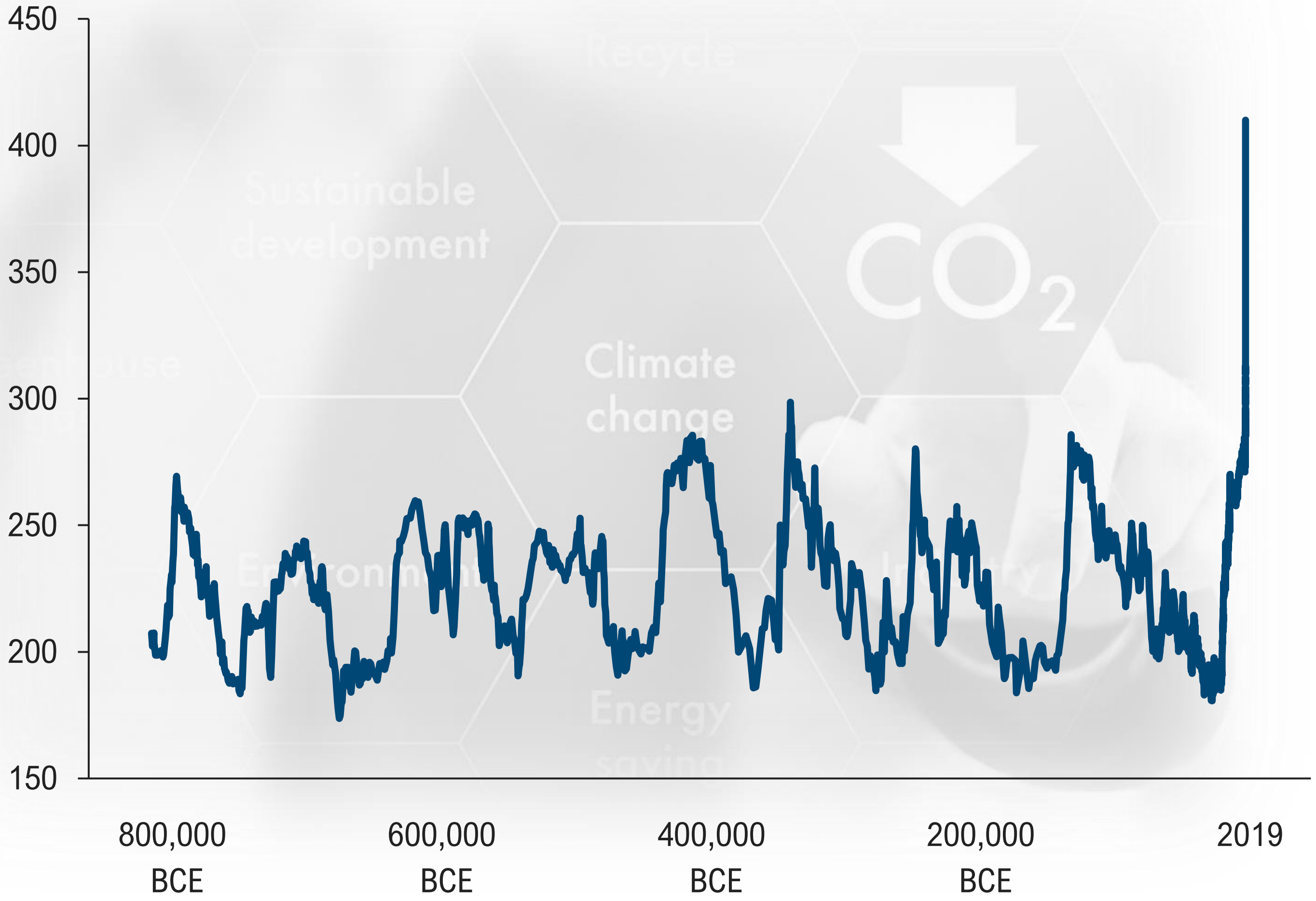


- > Over the last few decades, the global temperature has **risen sharply**, as has the CO_2 concentration in the atmosphere
- > While there are minor nature-induced fluctuations in temperature, e.g. due to volcanic eruptions or changes in solar activity, the **human induced change** is much higher and one-directional: It is **getting warmer**
- > Compared to the period 1850-1900, the human induced global warming is **1.2°C (2020)**
- > A **particular increase** of both the CO_2 concentration in the atmosphere and the human induced warming can be observed **since the 1960s**: Increasing industrialization, economic boom (also in emerging countries) and population growth lead to a rise in global emissions from industry, agriculture, transportation, and households

Sources: Global Warming Index; Roland Berger

CO_2 concentration – the main GHG contributor – has reached its highest level on record at an accelerated rate

Global average long-term atmospheric concentration of CO_2 [ppm]



> The current **concentration levels of CO_2** in the atmosphere are **the highest** for at least 800,000 years. Such long-term trends in CO_2 concentration are **measured** in **preserved air samples** from **ice cores**

> Historic cycles of peak and trough CO_2 concentrations follow **cycles of ice ages** (lower CO_2 concentration) **and warmer interglacial periods** (higher CO_2 concentration). During most of these cycles, CO_2 concentrations did not exceed 300 ppm – **today** they are well **above 400 ppm**

> Even if the global community achieves a **decrease in carbon emissions**, this **will not have an immediate impact** on lowering atmospheric concentrations because CO_2 remains in the atmosphere for a long time – until it is removed by natural processes like absorption through land vegetation, soils and the ocean

> Natural **absorption processes** last from **less than five years to thousands of years**. Thus, even if CO_2 emissions were completely stopped today, we would still be faced with higher CO_2 concentrations for several hundred years

Sources: Our World in Data; NOAA; SIO; Roland Berger

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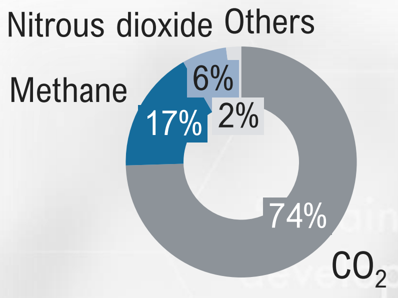
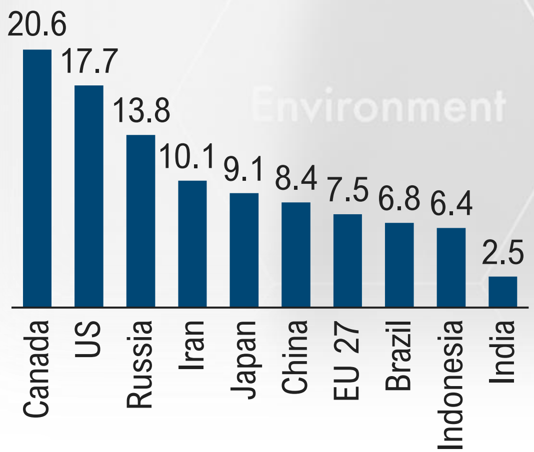
The majority of greenhouse gases emitted are CO_2 – A handful of countries account for a disproportionately large share of global emissions

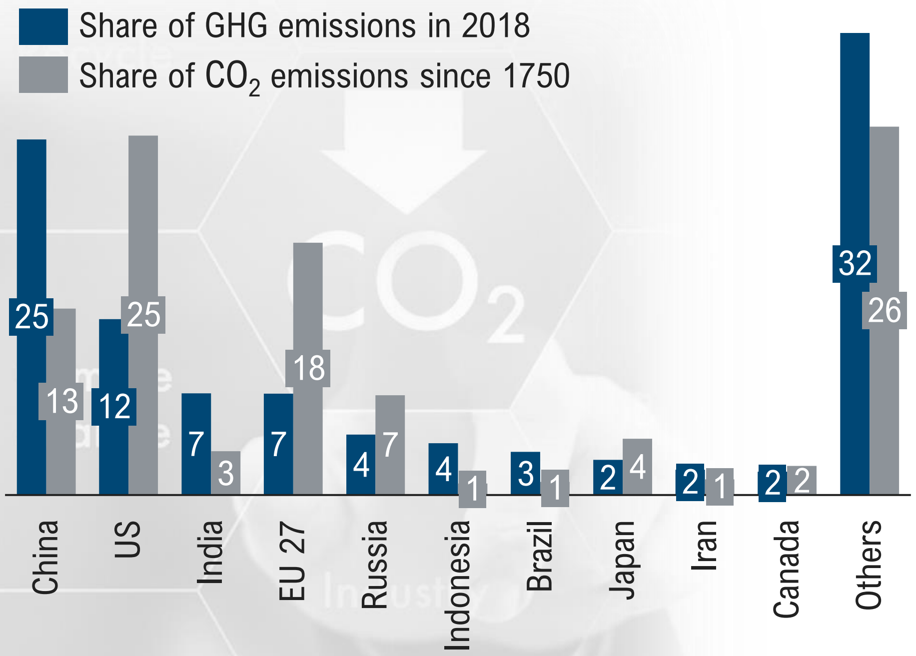
Composition of global GHG emissions 2018[1)]



Per Capita emission of GHG [tCO_2e/c] of the biggest emitters 2018[1)]



Biggest GHG emitters in 2018[1)] and its share of cumulative CO_2 emissions 1750-2018[2)], [%]



Global GHG emissions 2018:

48.9 $GtCO_2e$

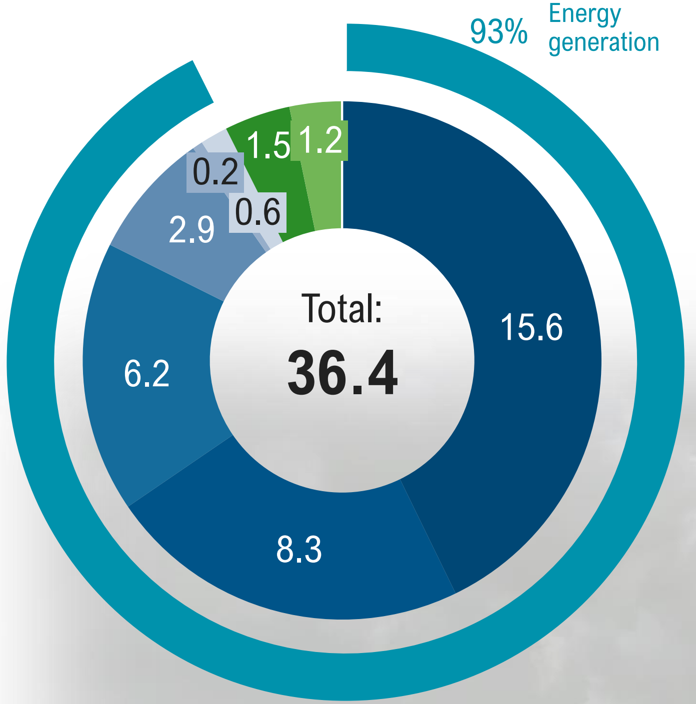
- In **2018**, nearly **49 gigatons of CO_2 equivalents** ($GtCO_2e$) were emitted on a global scale
- The **three dominant greenhouse gases** (carbon dioxide, methane, nitrous oxide) account for the **bulk of the emissions** – amounting to almost **98%**
- **CO_2** is the single most dominant greenhouse gas leading to human-induced climate change – taking up **around 3/4 of the GHG mix**
- In terms of **biggest emitters** by country (in 2018), China shares nearly a quarter, the US half of that (1/8) with the EU and India at around 7% respectively – whereas the 100 **least-emitting countries** contribute **less than 3%** combined
- **Historically** and looking at the cumulative share of CO_2 emissions since 1750, **Western countries** – having industrialized earlier – are the ones that bear the highest share of CO_2 emissions

1) Share of emissions based on all GHGs measured in CO_2 equivalents; 2) Cumulative production-based emissions of CO_2 since 1750, based on territorial emissions, which do not account for emissions embedded in traded goods

Sources: Climate Watch; Our World in Data; ESSD Copernicus; Roland Berger

The three major greenhouse gases show a different sector split – Overall, energy generation drives GHG emissions most

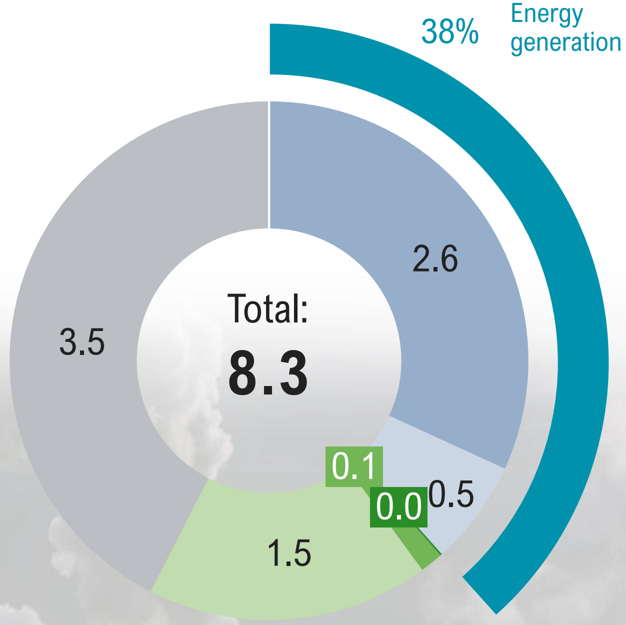
Sectors causing global GHG emissions 2018 [$GtCO_2e$]



Carbon dioxide

1 CO_2 = 1 CO_2e

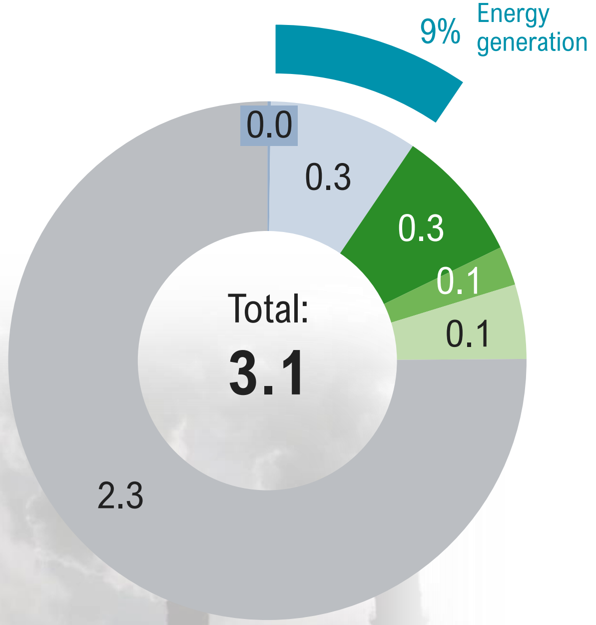
Average lifetime in the atmosphere: n.a.[1)]



Methane

1 CH_4 = 25 CO_2e

Average lifetime in the atmosphere: 12.4 years



Nitrous oxide

1 N_2O = 25 CO_2e

Average lifetime in the atmosphere: 121 years

Electricity/Heat | Transportation | Manufacturing/Construction | Building | Fugitive emissions | Other fuel combustion | Industrial processes | Land-use change and forestry | Waste | Agriculture

1) Singular lifetime measure not available; CO_2 life cycle is different to other GHGs. The carbon in CO_2 cycles between different reservoirs in the atmosphere, ocean, land vegetation, soils and sediments

Sources: Climate Watch; US EPA; Roland Berger

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Tackling climate change has been an international and intergovernmental effort for many decades culminating in the binding 2016 Paris Agreement

Selection of climate change negotiations

- **1972** – United Nations conference on the Human Environment is held
- **1988** – The Intergovernmental Panel on Climate Change (IPCC) is set up
- **1994** – The UNFCCC enters into force
- **1997** – The Kyoto protocol is adopted
- **2001** – The Marrakesh accords take place
- **2005** – The EU's Emissions Trading System (ETS) is launched
- **2005** – The Kyoto protocol enters into force
- **2010** – The Cancun agreements are adopted
- **2015** – The **Paris Agreement** is adopted at COP 21[1)]
- **2016** – The **Paris Agreement** enters into force
- **2019** – The EU pledges to become climate-neutral and adopts the Green New Deal – other countries to follow suit
- **2021** – COP 26 to take place in Glasgow

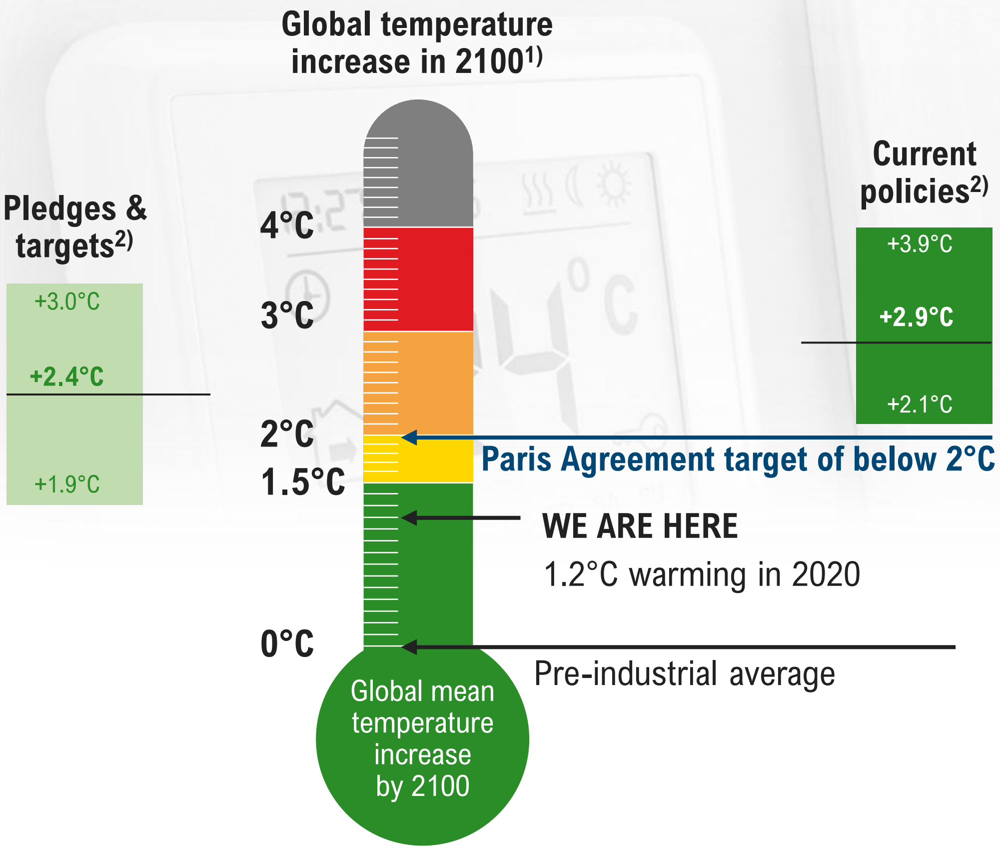
The **Paris Agreement** combating climate change is the first truly universal, legally binding global climate agreement. The goal of the agreement is to hold the rise in global average temperature to **well below 2°C** above pre-industrial levels, while pursuing **efforts to limit the rise to 1.5°C**. The deal aims to ensure that global greenhouse gas **emissions peak as soon as possible** and that emissions and removals are balanced in the second half of this century

1) COP 21 stands for "21st session of the Conference of the Parties", COP is the supreme governing body of an international convention; COP 21: UN Framework Convention on Climate Change

Sources: European Parliament; Roland Berger

The Paris Agreement aims to hold the increase in the global average temperature to well below 2°C compared to pre-industrial levels

Paris Agreement target and status quo of global temperature increase



Is the limit of 2°C enough?

For some time, keeping global warming below 2°C had been regarded as the main benchmark in terms of risk limitation. More recently, **1.5°C is being considered safer** – this requires rapid, far-reaching and **unprecedented changes across all aspects of society**

> **There is no 'Plan B' because we do not have a 'Planet B.' We have to work and galvanize our action."** **Former UN Secretary-General Ban-Ki Moon**

- **191 parties** (190 countries plus the EU) are **signatories to the Paris Agreement,** committed to take on the fight against climate change
- Compared to a **pre-industrial temperature** average, we are already at around **1.2°C** – huge hurdles must be overcome to achieve the **Paris target** of limiting global warming well below **2°C**
- Under **current policies**, a warming of **2.9°C is expected** by 2100. With pledges made so far, a reduction to an average of 2.4°C appears possible
- According to scientists of the International Energy Agency (IEA), **limiting global warming to 1.5°C by 2100** is only possible if the world is **"net zero"** (reg. emissions) **by 2050**

1) Compared to pre-industrial temperature level average; 2) Probability range; 50% probability in bold

Sources: Climate Action Tracker; UNFCCC; IEA; Roland Berger

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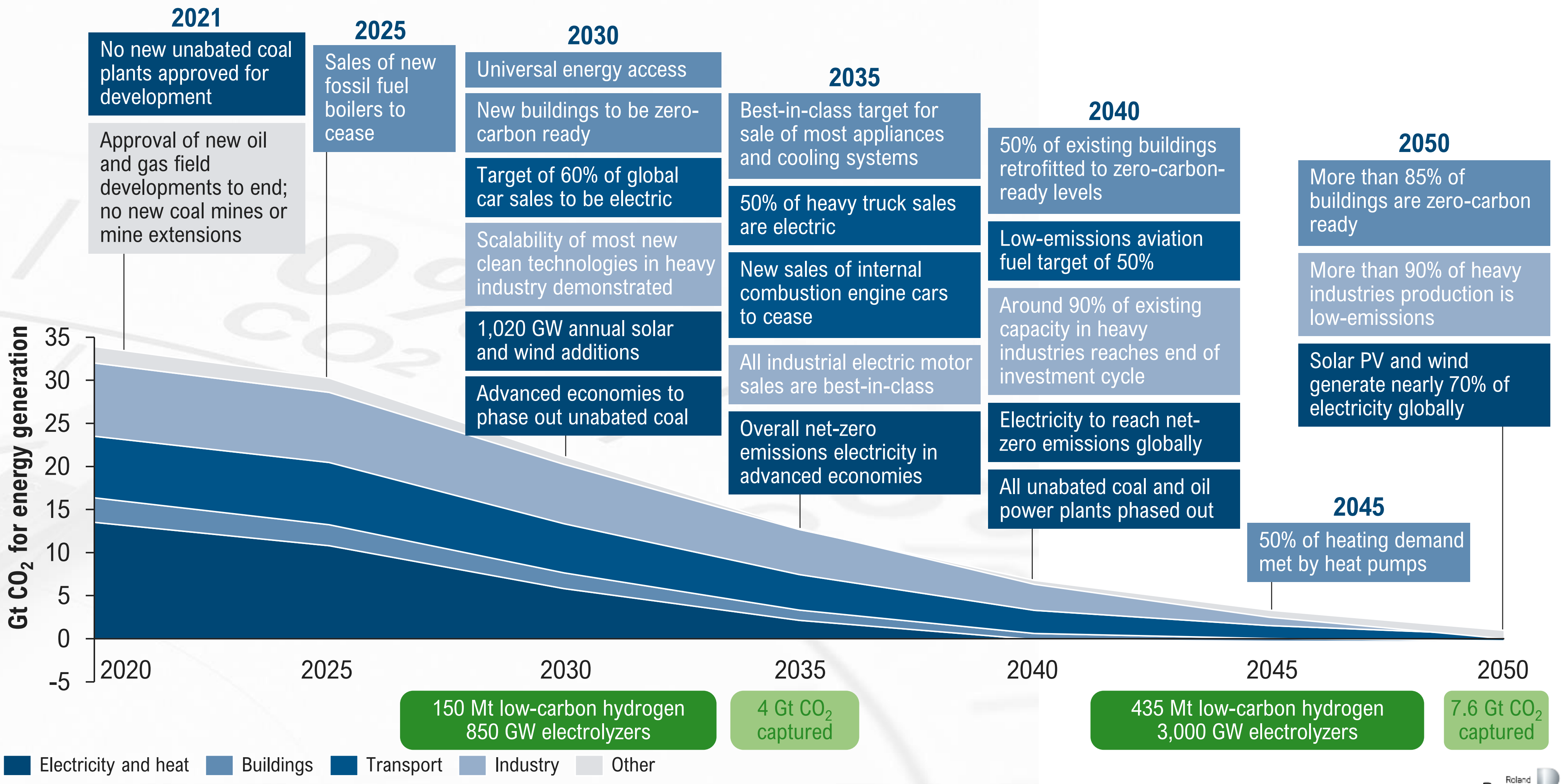
From agreement to an actionable way forward: IEA's Net Zero Emissions (NZE) initiative maps a path to a CO_2-neutral year 2050

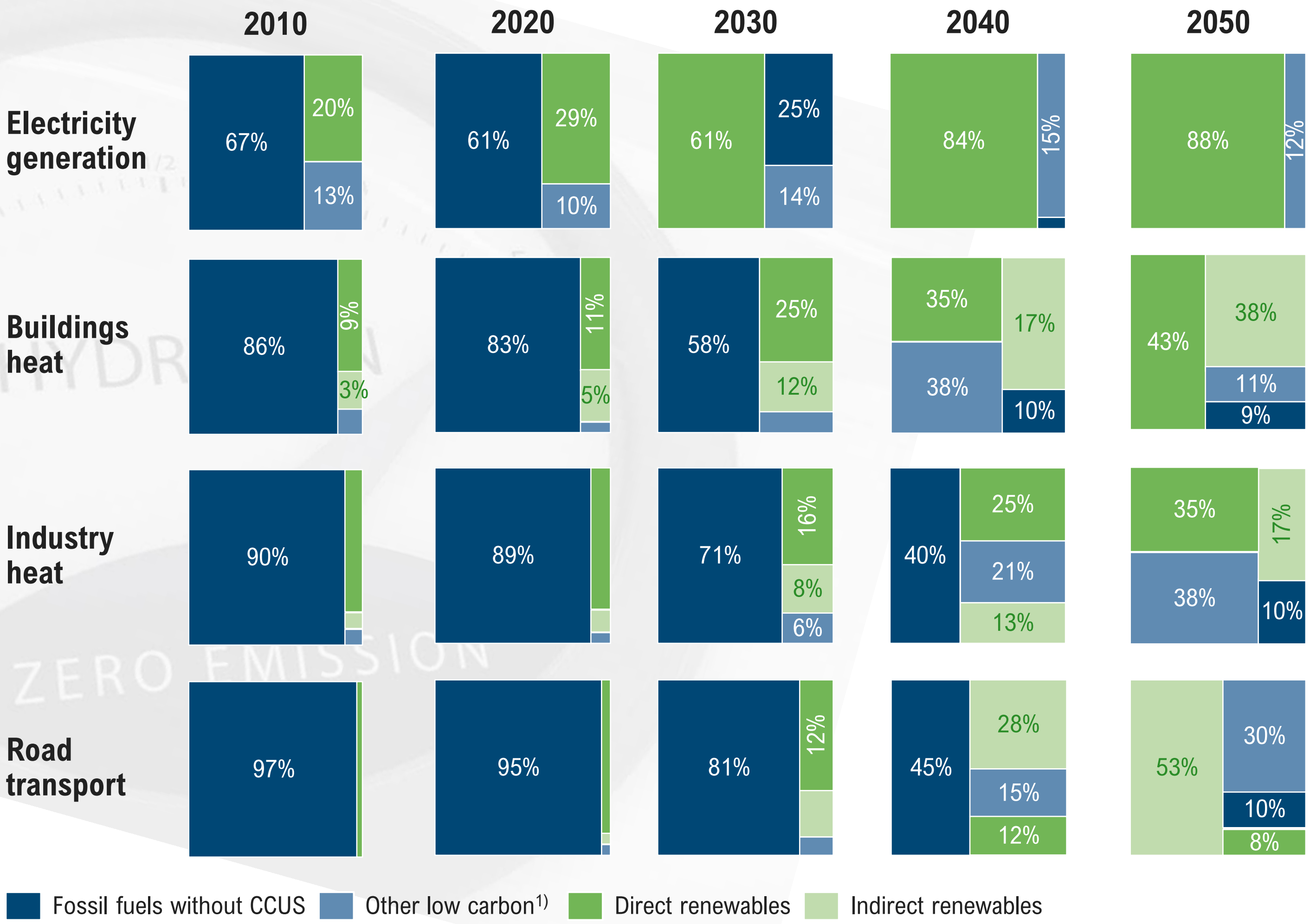
Selected global milestones for policies, infrastructure and technology deployment in the NZE scenario



Sources: IEA; Roland Berger

To reach the goal of net zero emissions by 2050, the role and use of renewable energy needs to increase drastically

Fuel shares in total energy use in selected applications in NZE [%]



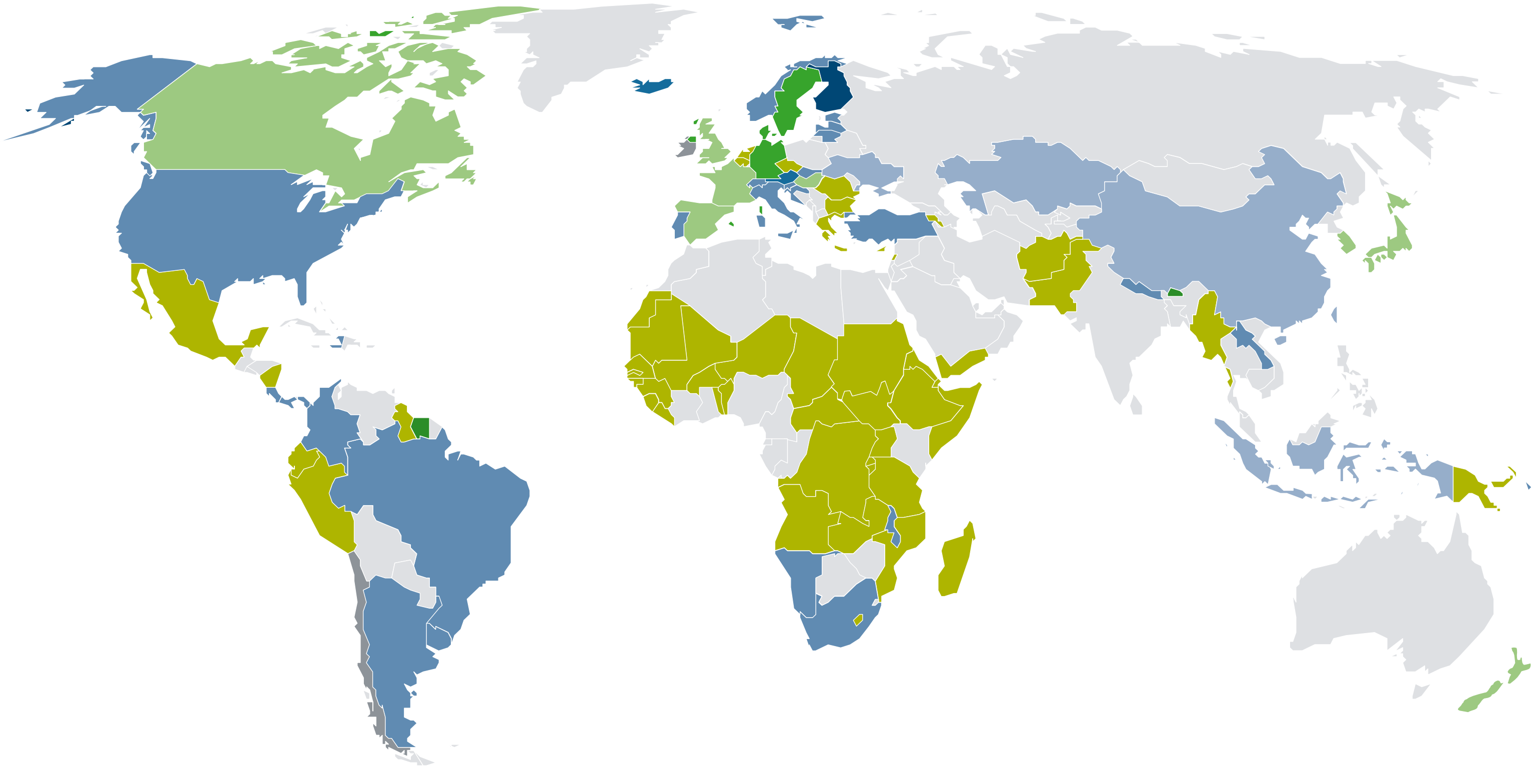
- To become carbon neutral by 2050, today's global energy mix would undergo **drastic changes across various fields of applications**
- On a global scale, renewable energy technologies are pivotal to lowering emissions: **Hydropower has been a leading** low-emission energy source over many decades; the **expansion of wind and solar power** will triple renewable power generation by 2030 and provide an **eightfold boost by 2050** in the NZE roadmap
- Its accomplishment will require **annual additions of wind and solar capacity** to be **five times higher between 2020 and 2050** than the average of the years 2018-2020
- Energy use from renewables differs: **Direct renewables** guarantee a use of energy without the need to transformation into a further form of energy (e.g. biofuels for road transport). The **indirect use of renewables**, however, requires the initial energy form to be transformed into another, as is the case in electric vehicles powered by renewables

1) Other low-carbon refers to nuclear power, facilities equipped with CCUS (carbon capture, usage & storage), and low-carbon hydrogen and hydrogen-based fuels

Sources: IEA; Roland Berger

National laws paving the way to net zero emissions are scarce – 2°C target appears unattainable at present

Global net-zero carbon emission targets as of September 2021



Achieved | In law (2045) | In law (2050) | In policy document (2035)
In policy document (2040) | In policy document (2050) | In policy document (2060) | Proposed legislation (2050)
Target under discussion (2050) | No data

- While the Paris Agreement was signed by 197 countries, treaty **signatories are at very different stages of implementation**: Formal commitments of CO_2 emission reductions enshrined in national law are comparatively scare
- By other measures, progress appears to be at a halfway point: Around **49% of global GDP derives from countries** with an actual or intended **net zero target**
- Either way, climate change efforts must be stepped up: According to the latest **Climate Change Performance Index** (assessing the climate protection performance of those 57 countries that, together with the EU, are responsible for 90% of global CO_2 emissions) **no country is doing enough to keep global warming at bay**

Sources: ECIU; CCPI; Roland Berger

If we do not respond to the threat of global warming, our world will change irreversibly

Climate risks: Impact of 1.5°C versus 2.0°C of global warming

Climate risk

Arctic sea ice

Ice free summers in the Arctic at least **once every 100 years** | Ice free summers in the Arctic at least **once every 10 years**

People

9% of the worlds population or 700 million people will be exposed to extreme heat waves at least once every 20 years | **28% of the world's population or 2 billion people** will be exposed to extreme heat waves at least once every 20 years

Sea level rise

46 million people impacted by sea level rise of **nearly half a metre** till 2100 | **49 million people** impacted by sea level rise of **56 cm** till 2100

Food

Every half degree of warming will steadily lead to lower yields and lower nutritional content in tropical regions

Coral bleaching

70% of the world's coral reefs are lost by 2100 | Virtually **all coral reefs** are lost by 2100

Oceans

Lower risks to marine biodiversity, ecosystems and their ecological functions and services at 1.5°C compared to 2°C

Costs

Lower economic growth at 2°C than at 1.5°C for many countries, esp. low-income countries

Water availability

350 million city dwellers are exposed to severe drought by 2100 | **140 million** urban residents are exposed to severe drought by 2100

Extreme weather events

100% increase in flood risk | **170%** increase in flood risk

Species

6% of insects, **8%** of plants and **4%** of vertebrates will be affected | **18%** of insects, **16%** of plants and **8%** of vertebrates will be affected

Scenarios: **1.5°C** global warming; **2.0°C** global warming

Sources: WWF; Roland Berger

Roland Berger

Rising temperatures are not the only threat to our environment – Various types of pollution are damaging our environment and threaten our health

	Air pollution	Water pollution	Land pollution	Noise pollution	Light pollution
Examples	Fine dust, sulfur dioxide, carbon monoxide, nitrogen oxides, ozone, chemical vapors, pollen, radioactive air pollutants	Waste (particularly plastics) and sewage, bacteria, oil, chemicals, pesticides and herbicides, fertilizer, tire abrasions, metals, drugs	Liquid, solid or sludge waste e.g. open dump or landfill; microplastics in sewage sludge used as fertilizer; pesticides, herbicides, heavy metals	Traffic noise, flight paths, heavy industry, mining, construction sites	Over-illumination of streets/places/buildings/ industrial plants
Selected origins	Fuel combustion for energy production/transportation/ heating etc., non-exhaust vehicle emissions; natural, chemical and nuclear catastrophes	Industry and household sewage, mines, vehicles (e.g., ships/oily water and garbage), agricultural runoff, spillages	Industry, households, mines, agriculture	Vehicles, aviation, industrial plants, mining, construction machinery	Public and private infrastructure
	9 out of 10 people breathe **air** that exceeds WHO air pollution guidelines – air pollution is responsible for 1 in 8 deaths worldwide	The Great Pacific **Ocean** Garbage Patch contains 1.8 trillion pieces of plastic in an area of 1.6 million km^2 – 3x the size of France	Globally, 33% of waste is still openly dumped and approx. 40% goes to **landfills**	#1 cause of the 466 million people globally suffering from disabling hearing loss is mostly work-related **noise** – not age	83% of the world's population live under **light-polluted** skies

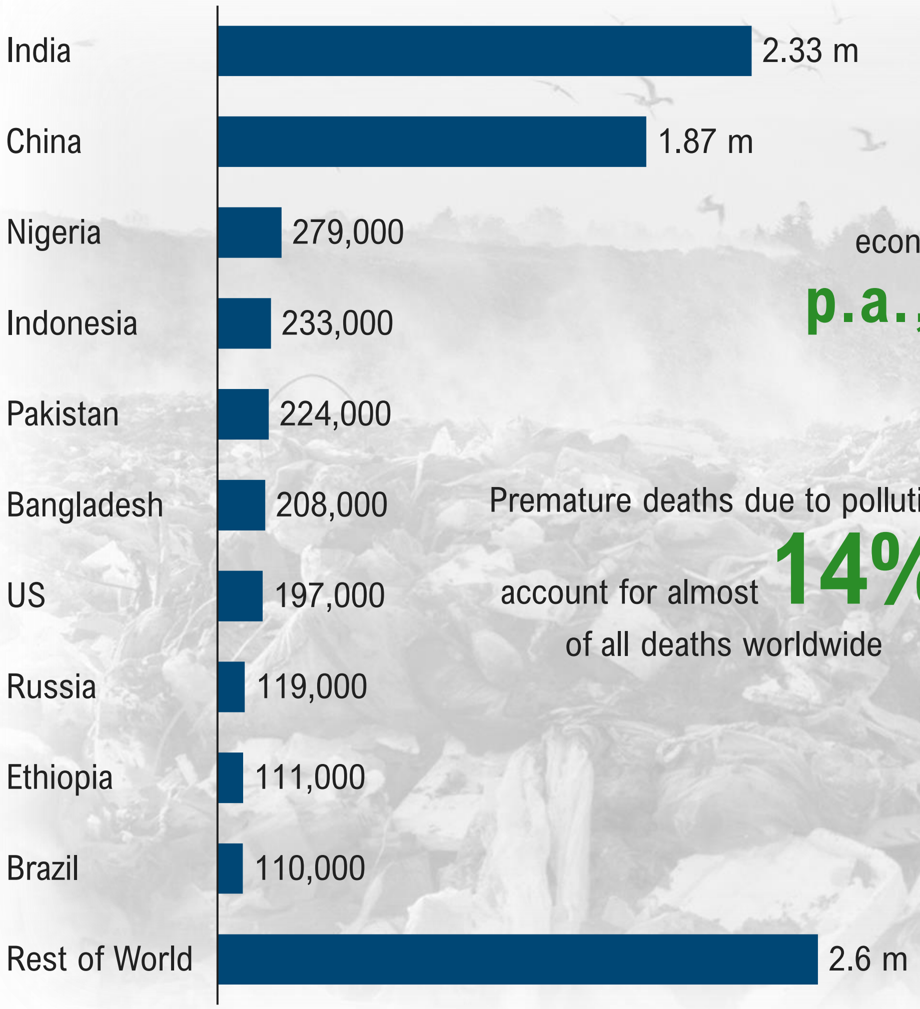
Pollution reduction approaches

- > Ban (more) harmful pollutants
- > Set tighter pollution limits and lower pollution thresholds across all types of pollution
- > Implement emission-free/lower emission energy production and industrial processes
- > Switch to circularity approaches and longer-lasting, more sustainable products
- > Inform and improve better land use, waste and light management practices

Sources: Live Science; WHO; WWF; Ocean Cleanup; World Bank; National Geographic; Roland Berger

Beyond global warming, pollution poses another key environmental threat to human health – Around 8.3 million deaths can be attributed to pollution

Estimated number of premature pollution-related[1)] deaths per year, 2019



Pollution costs the global economy **USD 4.6 trillion p.a.**, equivalent to **6.2%** of the global economic output

Premature deaths due to pollution account for almost **14%** of all deaths worldwide

>90% of pollution related deaths occur in low- and middle-income countries

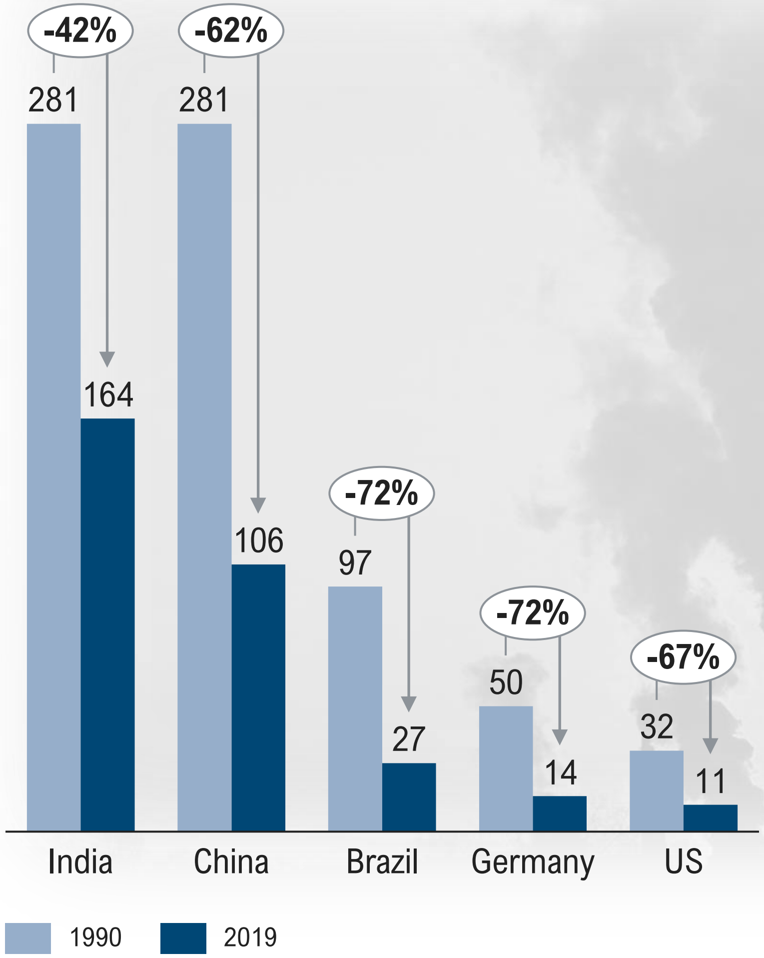
- **Pollution** is considered the world's **most ubiquitous environmental threat** to human health – but also to other living organisms
- Pollution takes on many forms and **combinations**, such as land and water pollution
- Certain types of pollution are more **easily recognizable** than others, depending on severity: **Air pollution** in urban areas can be seen as smog, yet rural areas can also suffer from bad air due to farming practices; **light pollution** can be seen from outer space; **water pollution** can manifest as debris swept up at coastal areas
- Some types, such as air or noise pollution can be measured by a handful of **parameters**, while others (water) face an abundance of metrics from a growing number of relatively **novel pollutants** such as microplastics or pharmaceutical products (hormones, antibiotics)

1) Fatalities after exposure to toxic air, water, soil and chemical pollution

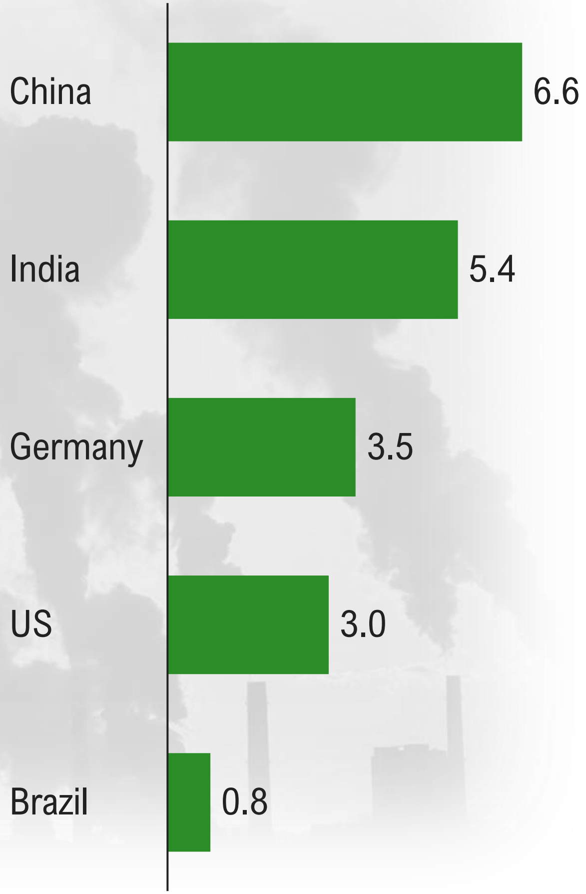
Sources: Global Alliance on Health & Pollution; Roland Berger

Since 1990, deaths attributable to air pollution have declined – However, economic costs remain significant

Age-standardized deaths/100,000 population attributable to air pollution



Economic costs of air pollution as a share of GDP, 2018 [%]

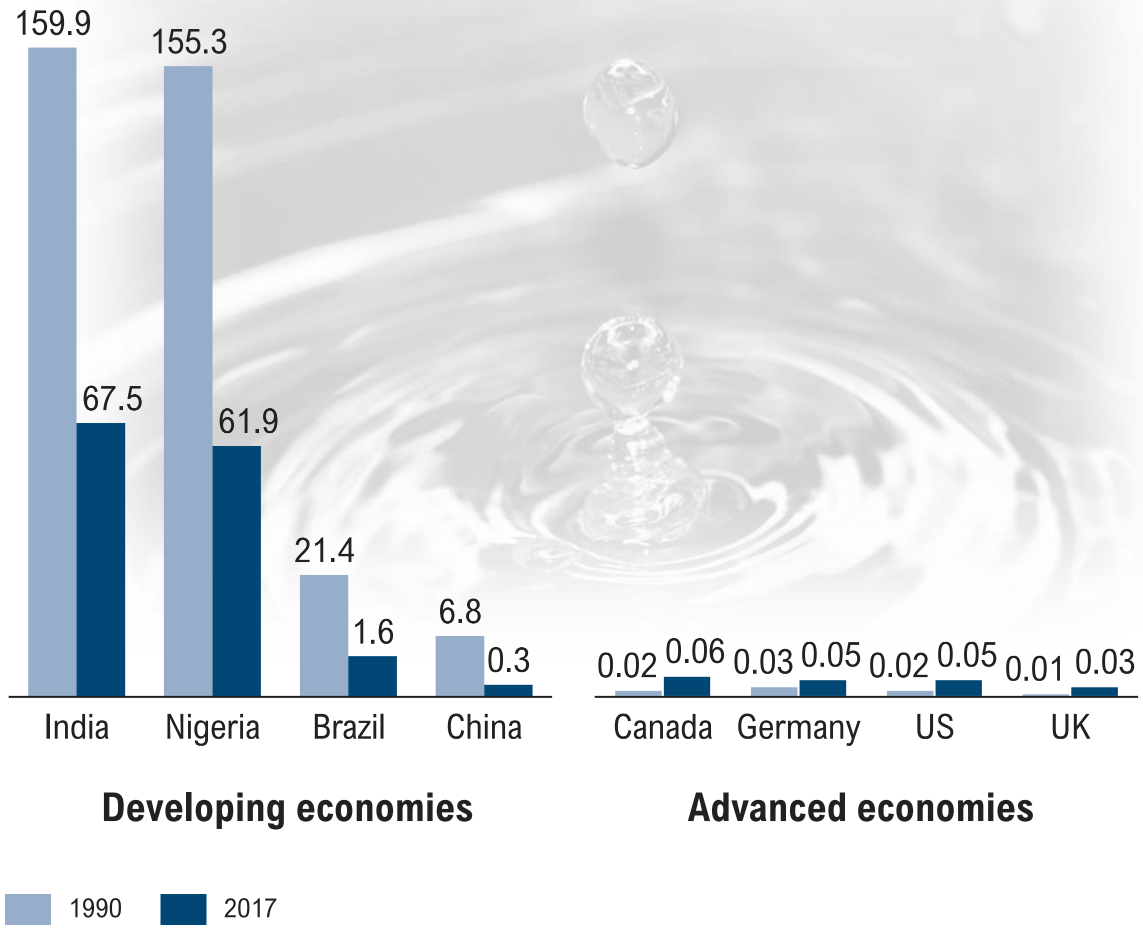


- > **Air pollution** refers to the prevalence of chemicals or compounds in the air that are **not normally present** and that **degrade air quality** or cause adverse changes in quality of life (e.g., damage to the ozone layer or global warming)
- > Although air pollution is displaying an improvement in terms of steadily declining numbers of attributable deaths, **air pollution still shortens lives more than any other external cause** – by 2.2 years (global average per person)
- > Around **91% of the world's population** live in places where **air quality levels exceed WHO limits**
- > **Total costs of air pollution** on a global scale are estimated at around **3.3% of global GDP**, accounting for disabilities from chronic diseases, asthma, preterm births, sick leaves, and deaths

Sources: State of Global Air; CREA; WHO; Roland Berger

While deaths from unsafe water are declining in developing countries, advanced economies observe low level increases – Quality parameters vary

Number of deaths per 100,000 population from unsafe water sources, selected countries



Can the economic cost of bad water quality be determined?

Biochemical oxygen demand[1)]

Polluted water harms economies: Studies found, that in regions where **BOD is high**, **GDP growth** is **lowered by up to 1/3**

Oxidized nitrogen

Nitrates are **lethal for babies**; nitrates **increase childhood stunting** by **11%-19%** and **decrease adult earnings** by **1%-2%**

Salinity

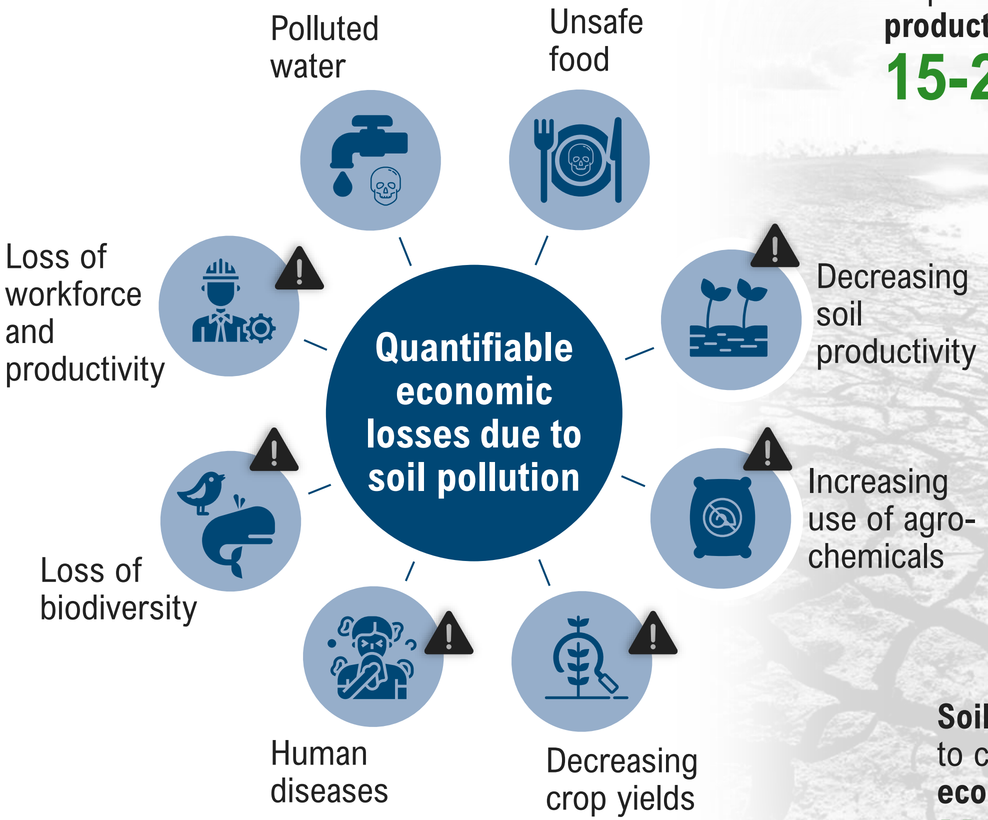
Salts degrades land. Due to saline water, enough **food is lost each year** to feed **>170 million people**, equivalent to the population size of Bangladesh

1) Biochemical oxygen demand (BOD) represents the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic (oxygen is present) conditions at a specified temperature

Sources: IHME; World Bank; Roland Berger

Although soil pollution is often less obvious, food and water contamination endanger human, animal and environmental health

Quantifiable economic losses due to soil pollution



Soil contamination is responsible for **agricultural productivity losses** of **15-25%**

Global annual **pesticide usage** increased by **more than 80%** since 1990

Soil pollution is estimated to cause annual **agricultural economic losses** worth **USD 20 billion** in China

- Soil pollution is defined as the **prevalence of toxic chemicals** (pollutants or contaminants) in soil at concentration levels sufficient to **pose a threat to human health** and/or the **ecosystem**
- The **cost of remediating** polluted soils **is site specific** and **future use dependent**: Cost factors include size of the affected area, remediation depth, pollutant concentration, technology used, civil protection measures, etc.
- There are additional, often overlooked and therefore **underestimated indirect costs** related to soil pollution on the natural world: **Biodiversity losses** and **degradation** of **ecosystems** affect **long-term soil productivity** and **resilience**
- For humans, **illnesses** stemming from unsafe water and food due to pollutions in the soil affect **workforce productivity**

Sources: FAO; Roland Berger

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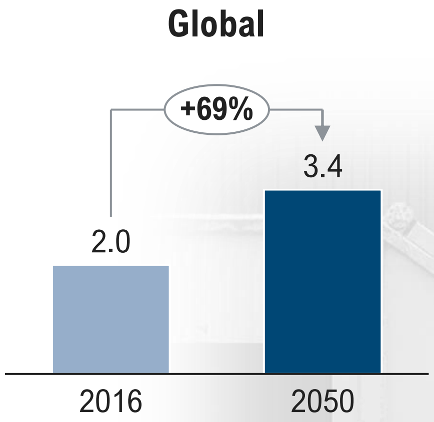
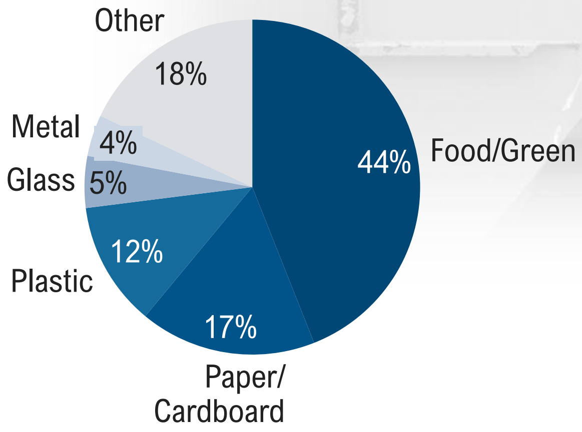
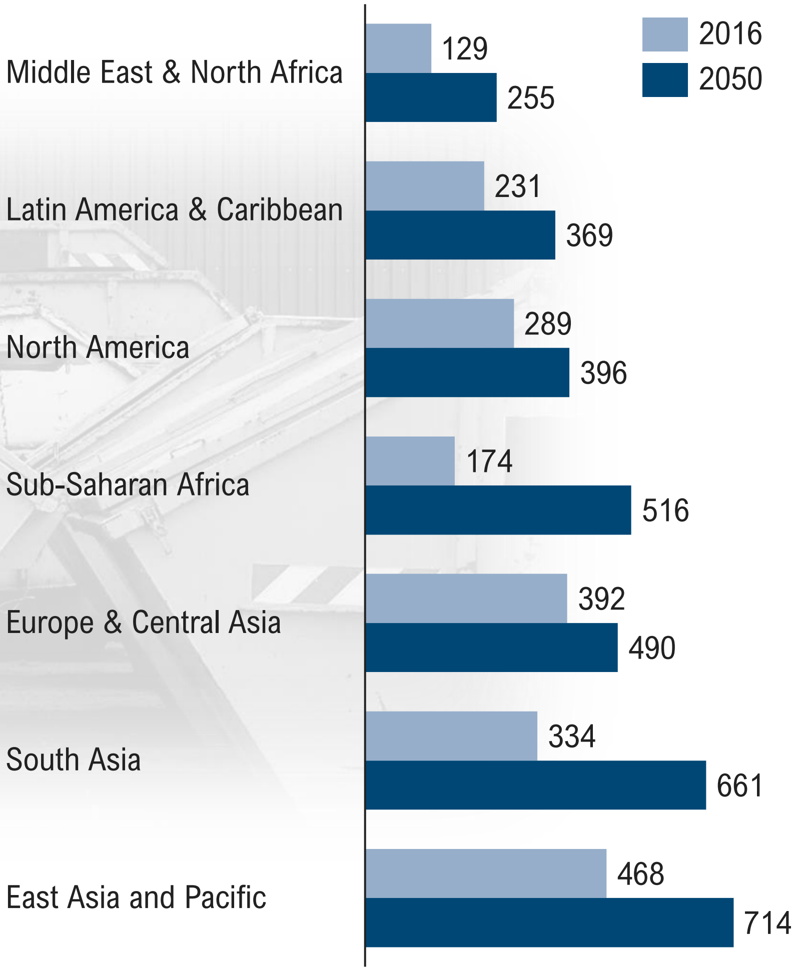
Soil pollution is also linked to waste (mis)management – In addition, waste emits considerable quantities of CO_2, furthering global warming

Annual municipal solid waste, globally and regional [bn. tons]







- In line with a rising global population increasingly living in urban areas is the rise of **municipal solid waste** (MSW) generation; further factors are **related to lifestyle** and easy access to packaged products
- MSW **includes household waste** such as packaging, food scraps, grass cuttings, furniture, clothes, paper and cardboard, household appliances, paint and batteries
- **Improper management** of MSW landfills increases the **potential for soil pollution** from leachate as well as **CO_2 emissions into the atmosphere**
- In uncontrolled MSW landfills, the **contaminants mix leaking** into soil **poses a risk to the environment and human health;** in low-income countries, 90% of waste is mismanaged
- **Food waste**: The **energy** that goes into producing, harvesting, transporting, and packaging of food that is wasted **generates more than 3.3 billion metric tons of CO_2** – if food waste **were a country**, it would be the **world's third largest emitter of GHGs**, behind the U.S. and China

Sources: World Bank, FAO, National Geographic; Roland Berger

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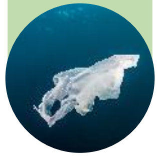
More than 8 billion tons of plastic have been produced over the past 70 years – Today, plastic particles are found almost everywhere

Plastic threatens our environment

… in the **ocean**

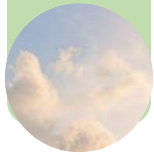


Increasing threat of "plastic islands" e.g. in the Great Pacific Garbage Patch:

> There are **~80.000 tons** of plastic in the northern Pacific ocean, which equals **1.6 million km²** – equivalent to **3x the size of France**

> Plastic trash is found **in the guts** of more than **90% of the world's sea birds** and in more than **half of the world's sea turtles**

… in the **air**



Airborne microplastics threaten our air quality:

> Plastic waste **breaks down** into smaller particles until it becomes **microscopic**, gets **swept up into the atmosphere**, and travels – carried by the jet stream – across continents

> **84%** of atmospheric microplastics come **from roads, 11% from oceans** and **5% from agricultural soil dust**

… on **land**

Microplastics in soils, sediments and freshwater have a long-term, negative effect on our ecosystems:

> Less than **9% of all plastic waste** ever produced has been **recycled**. Roughly **12% was combusted**, while the **rest** (79%) is accumulating in **dumps, landfills or the natural environment**

> Estimates suggest, that **1/3 of all plastic waste** ends up in **soils or freshwater**. Most of it disintegrates into particles smaller than five millimeters

Cumulative plastic production volume, globally
[bn. metric tons]

> **Plastic pollution** has become one of the most **urgent environmental challenges** as the rapidly expanding production of single-use plastic products exceeds the world's ability to manage this kind of waste product

> **400 million tons of plastic** are produced annually – **40% are single-use** products

> The post-war production boom and the development of thousands of new plastic products has changed the modern age to such an extent that **life without plastics** would be **almost unimaginable** in most countries today

> **Today's plastic** is largely **non-biodegradable:** It doesn't rot (like paper or food) and can linger in the environment for hundreds of years

> Research trials using **plastic-eating microbes** are underway in several countries while endeavors to clean up large marine areas have launched innovative techniques such as **artificial coastline** waste traps and in-water **seabins**

Sources: University of California/Geyer R.; Media research; Roland Berger

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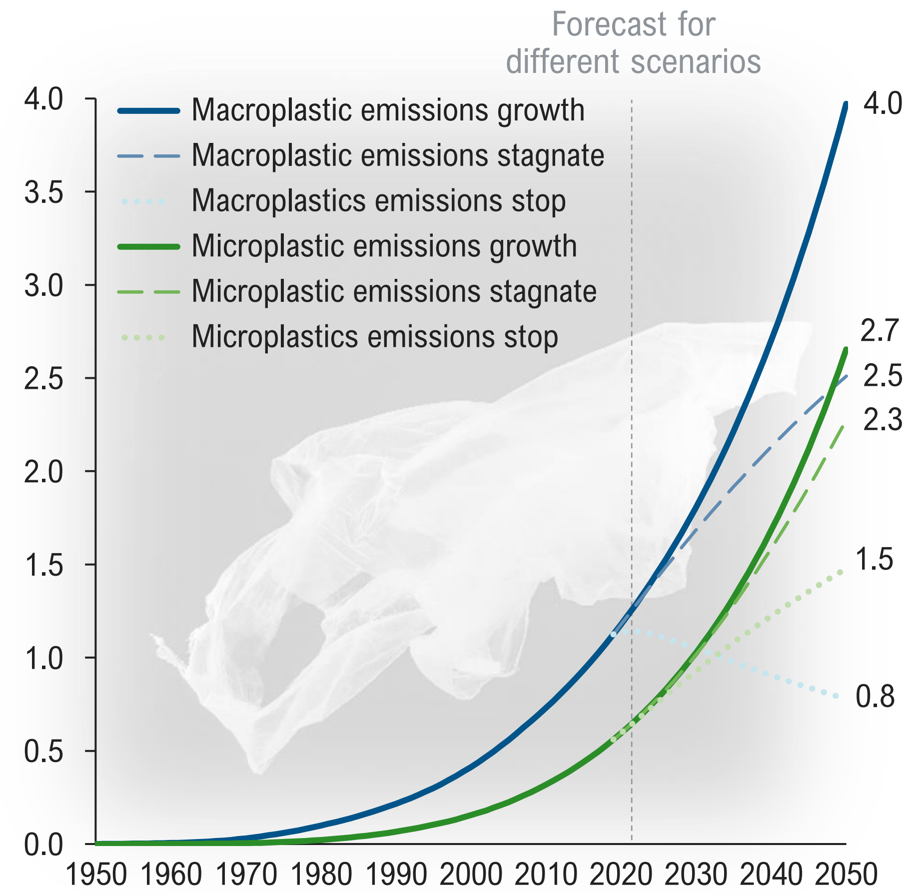
Even if we stopped emitting plastics into the ocean today, plastic particles would persist in our surface waters for many decades

Amount of micro- and macroplastics[1] in the surface ocean & scenarios[2] [million tons]



Breaking the plastic wave could[3] …

… save **government cost** of up to **USD 70 billion**

… save **costs to corporates** of up to **USD 1.3 trillion**

… generate **1 million new jobs**

… **reduce GHG emissions** by **500 million tons of CO_2e**

How to break the plastic wave?

> We must **stop plastic waste entering our waterways** as a matter of urgency: Most of the plastic that pollutes the oceans is due to **poor waste management** practices – particularly in low-to-middle income countries

> Efforts must also be focused on **recapturing and removing existing plastics** from our offshore waters and from shorelines

> Past assumptions postulated that **plastics in the ocean** have a **short lifespan**, quickly degrade into microplastics, and sink to greater depths – however, **this is incorrect**

> Macroplastics can **persist even for decades** – even if we were to **stop emitting plastic waste** into the ocean by now, macroplastics would persist **in our surface waters** for many **decades** to come

> **By 2050**, there could be **more plastic** in the ocean **than fish** (by weight)

> In fact, this is partly because there is a **massive legacy of plastics buried along our shorelines** which would keep re-surfacing and be transported to nearshore regions

> The **level of microplastics** in the oceans will **increase under any scenario** as the existing larger plastics **continue to degrade**. Any additional plastic waste acts as a further contribution

1) Macroplastics are defined as buoyant plastic materials >0.5 cm in diameter, microplastics are buoyant plastic materials <0.5 cm in diameter; 2) The three scenarios are defined as follows: emissions stop – emissions to the oceans stop in 2020; emissions stagnate – emissions stagnate at 2020 emission rates; emissions growth – emissions continue to grow until 2050 in line with historical plastic production rates; 3) According to Pew Trusts "System Change scenario"

Sources: LeBreton; Pew Trusts; Roland Berger

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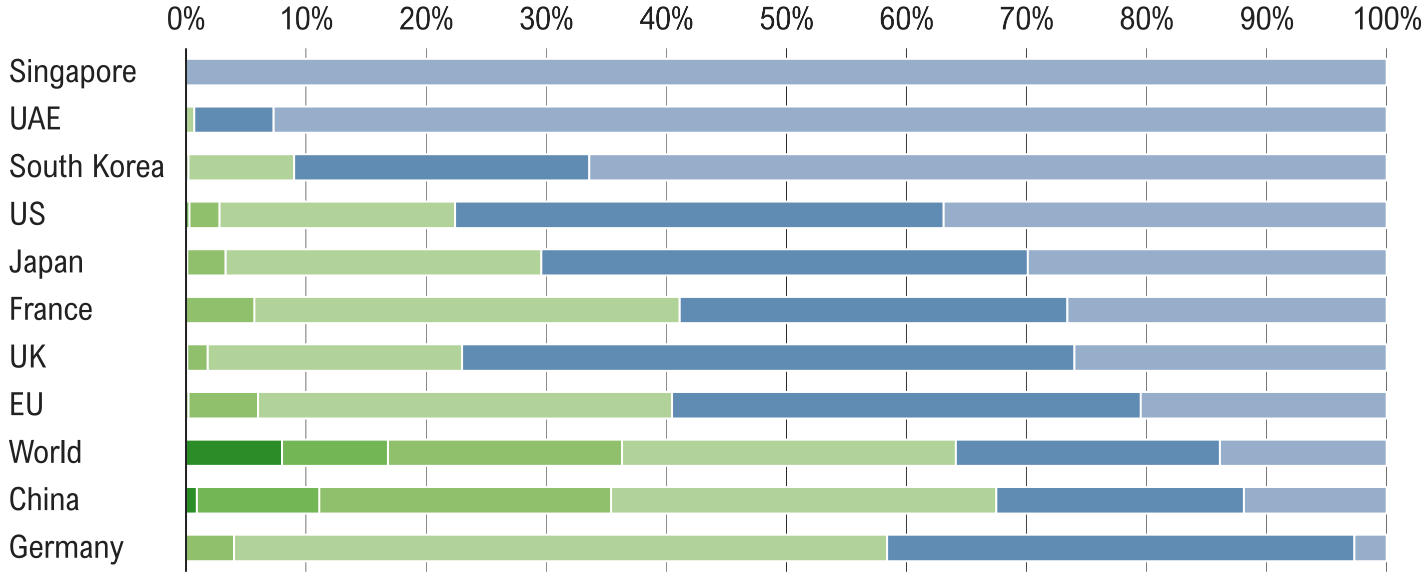
Artificial lights increase night sky luminance, creating artificial skyglow, posing a threat to human health and animal behavior

Share of people exposed to light pollution, selected countries 2016 [%, colors indicate pollution levels in µcd/m²]



Pristine sky	Up to 1% above natural nighttime brightness (<1.7 µcd/m²)
Relatively unpolluted sky at the zenith but degraded toward the horizon	1-8% above natural nighttime brightness (1.7 - 14 µcd/m²)
Polluted sky degraded to the zenith	8-50% above natural nighttime brightness (14 - 87 µcd/m²)
Natural appearance of the sky is lost	From 50% above natural nighttime brightness to the level at which the Milky Way is no longer visible (87 - 688 µcd/m²)
From Milky Way loss to estimated cone stimulation	688 - 3000 µcd/m²
Very high nighttime light intensity	Night adaptation is no longer possible for human eyes (>3000 µcd/m²)

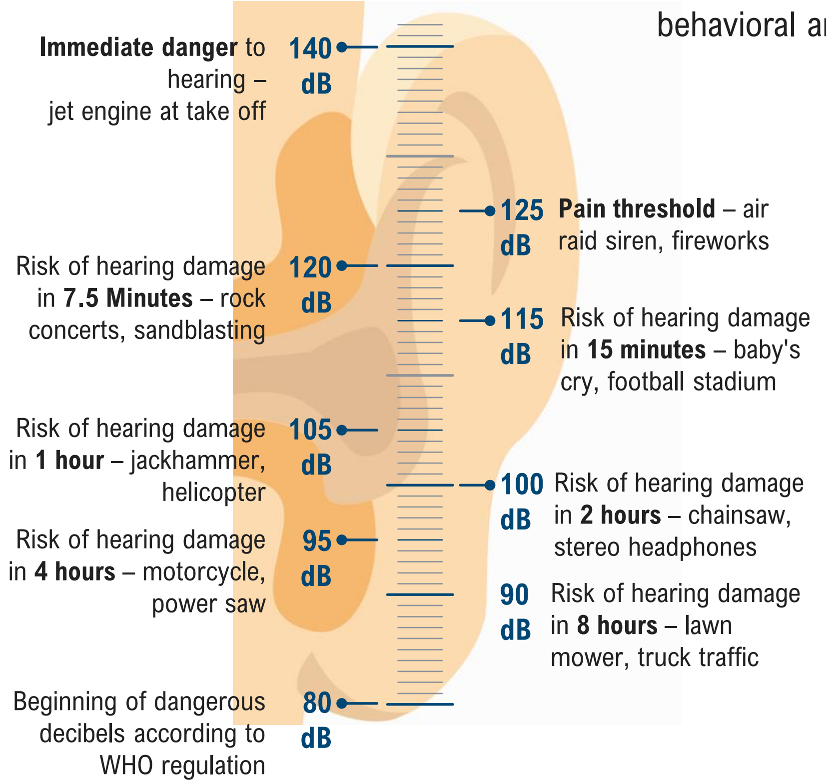
- **Concerns voiced** by the scientific community ranging from ecology, public health, spatial planning to astrophysics **regarding the impact of light pollution are increasing**
- **Artificial sky brightness** is measured against natural nighttime brightness, which is set at 174 µcd/m²
- More than **80% of the world's population lives under skyglow**, meaning exposure to light levels above 14 µcd/m².
- Light pollution, which is the **excessive or inappropriate use of artificial light outdoors**, impacts human health, wildlife behavior, and our ability to observe celestial objects such as stars
- Artificial light can **disrupt natural body rhythms and behavior patterns of humans as well as animals**: Nocturnal light interrupts sleep and upsets circadian rhythms – the internal, twenty-four-hour clock that controls day and night activities and **influences physiological processes** in almost all living organism

Sources: Falchi et al. (Science); NZ Stats; Roland Berger

The invisible danger of noise pollution is all around causing health problems for people and wildlife

Noise pollution / health nexus

Risk of hearing damage at selected decibel levels



An estimated **USD 1 trillion** is lost each year due to failures in adequately addressing hearing loss – this includes genetic and biological but also behavioral and environmental factors

Around **16%** (7-21% across different regions) of hearing loss in adults results from **exposure to excessive noise** in the **workplace** – which is responsible for over 4 million disability adjusted life years (DALYs)

Of persons aged 12-35 years, **50%** are at **risk of hearing loss** due to **exposure** to unsafe levels of sounds in **recreational settings**

> Noise pollution is **any unwanted or disturbing sound** that **affects the health and well-being** of humans – and other living species

> For humans, loud sounds can be encountered in the **workplace**, in the overall **living environment**, or as part of **recreational** activities

> Sounds that **reach 80 decibels (dB) or higher** can **harm a person's ears**. Sound sources that exceed this threshold are, for example, truck traffic (90 dB) and rock concerts (110-120 dB)

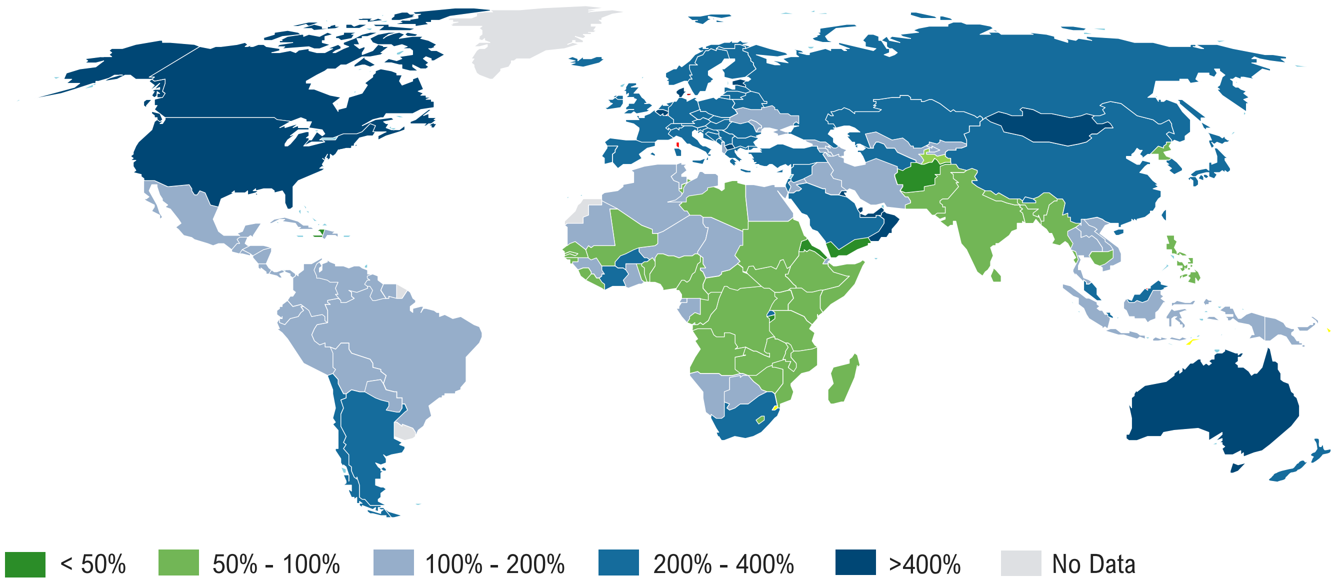
> The most common health problem to do with loud sounds is **Noise Induced Hearing Loss** (NIHL) but also **high blood pressure**, **heart disease**, **sleep disturbances**, and **stress.** These health problems can affect all age groups

> Noise pollution also impacts the **health and well-being of wildlife**: As **animals** use sound for a wide variety of reasons – including to navigate, find food, attract mates, and avoid predators – (human made) noise pollution makes it difficult for them to accomplish these tasks, affecting their ability to reproduce, feed and – ultimately – survive

Sources: ProtectEar; WHO; Roland Berger

Resource sustainability means balancing abundance and scarcity – Our current ecological footprint is exhausting global biocapacity

Countries' ecological footprints relative to average global biocapacity [%]



Ratio of Ecological Footprint relative to Global Biocapacity for selected countries

Qatar[2)]	9.1
US	5.0
Germany	2.9
China	2.3
World	**1.7**
India	0.7
Eritrea[2)]	0.3

> The ratio between a **country's ecological footprint** and global biocapacity (both measured per capita) strongly **correlates with its economic activity**, but also with its population density. Resource consumption is strongly determined by these two factors

> Globally speaking, **humankind's ecological footprint is 1.7 times larger than the Earth's biocapacity**. In other words: To live sustainably, we would need 1.7 earths

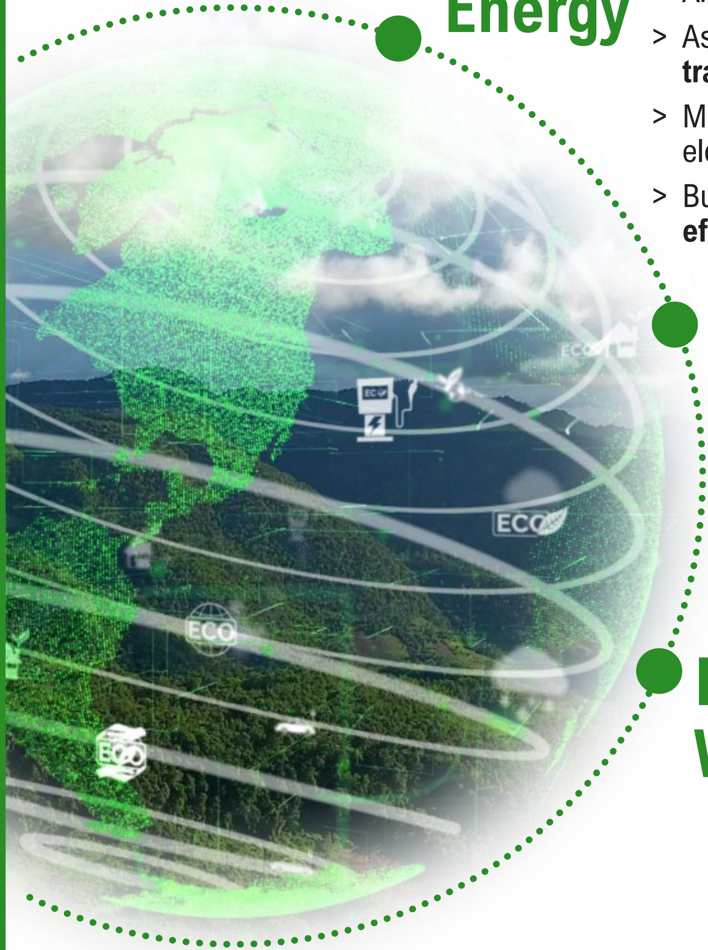
> A fine **balancing act of abundance and scarcity of resources** is called for: Both economic and population growth can be decoupled from the ecological footprint by making use of (unlimited) renewable energy, more efficient production technologies and circular economy processes that reuse materials and combine a sustainable way of living

1) Ecological Footprint and Biocapacity are measured in global hectares (gha) in the categories cropland, grazing land, forest land, fishing ground and built-up land. For the ecological footprint, the carbon footprint is considered in addition 2) Respectively, the two countries represent the highest and lowest ratio globally

Sources: National Intelligence Council; Global Footprint Network; Roland Berger

The world's sustainable development depends on the sustainable provision of energy, raw materials, and food & water

Globally essential resources between abundance and scarcity[1)]



Energy

> All **processes** – in the economy, in transportation, in households and elsewhere – **depend on energy**

> As described in subtrend 1, **current energy generation drives GHG emissions** the most, urging the **need for a transition** to renewables

> Major elements of the energy transition are to **electrify** the global economy, to replace fossil fuels, and to generate electricity from **renewable sources**

> But replacing fossil fuels by renewable energy is not enough. In addition, a considerable **improvement in energy efficiency** is necessary to meet the future energy demand

Raw materials

> **Raw materials,** like metals or minerals, are **limited** and bounded by access and availabilities

> **Global distribution** but also **total raw material reserves determine general availability** – this can change over time

> To **overcome these limitations,** moving away from a 'produce-consume-discard' cycle, **waste itself should be more universally understood as a raw material** – increasingly, it can be recycled, re-processed and re-integrated into production cycles, thus moving from a linear to a circular economy model

Food & Water

> **Access to** life's most basic resources, **food and water, is unevenly distributed** on Earth

> Thanks to continuous efforts, **progress** to improve the situation of the most dependent could be observed over past decades: The global prevalence of **undernourished children** aged 5 years or younger dropped from **28% in 1990 to 13% in 2020**

> Still, too many people are exposed to **famine** around the world. The **goal** should not only be to **feed everyone**, but to do so **in a sustainable way**

> Specifically, this includes **lowering the consumption of water- and land-intensive foods**, and to lower GHG emissions caused by food production

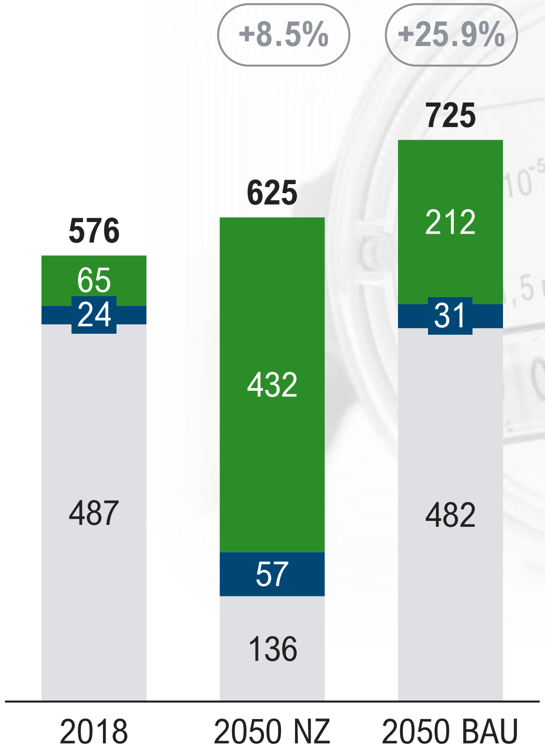
1) Here, resource as term is used in a more general way. For a technical definition, see slide 36

Sources: UN Foundation; Roland Berger

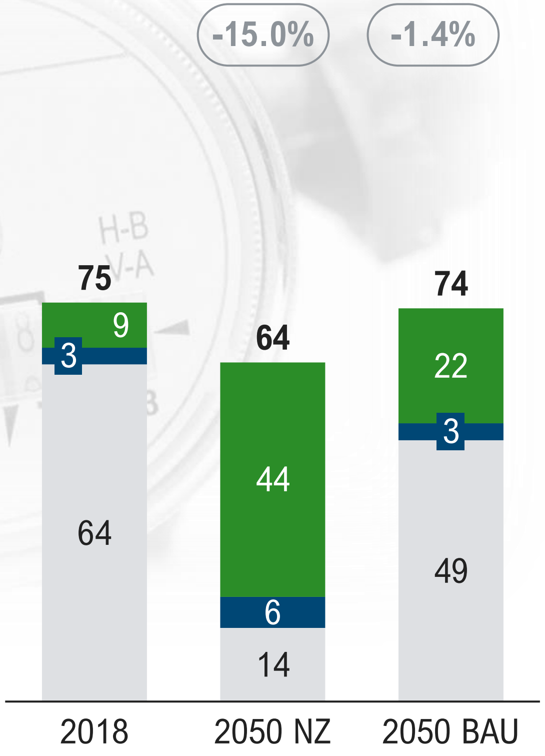
Sustainable energy use is facing a profound ramp-up – Global transformation of energy sources is needed to comply with the Paris Agreement

Evolution of global primary energy demand according to the Paris Agreement (2050 NZ) and to current policies (2050 BAU)[1)]

Total energy consumption [EJ[2)]]



Per capita energy consumption[3)] [GJ[4)]]



Renewable energy sources | Nuclear energy source | Fossil energy sources

- The Paris Agreement infers a **global greenhouse gas budget** that should not be exceeded – in order to keep global warming below 2°C, preferably to 1.5°C. To comply, the transformation to more renewable energy sources must happen
- In bp's **net zero emissions (NZ) scenario** – where global emissions amount to a net of zero by 2050 – **renewable energy sources meet 70% by 2050** (432 EJ)
- Presently, around 11% of global energy consumption stems from renewables – setting forth a profound transformation: Global energy demand would **increase until 2030 and remain constant thereafter.** Additional demand would need to be met by **efficiency gains** in the production, transportation and consumption of energy
- However, current policies do not suggest such a transformational path for the global community. In a **business-as-usual (BAU) scenario**, only 30% by 2050 of total energy demand would be met by renewable energy sources (212 EJ). Additionally, total energy demand would **increase significantly by over 25% until 2050**, compared to 2018

1) NZ (net zero in 2050) refers to a global energy policy compliant with the terms of the Paris Agreement; BAU (business-as-usual) refers to current adopted laws
2) EJ: Exajoule (= 10^{18} Joules) 3) Calculated with data from UN Population Division 4) GJ: Gigajoule (= 10^{9} Joules)
Sources: bp; UN Population Division; Roland Berger

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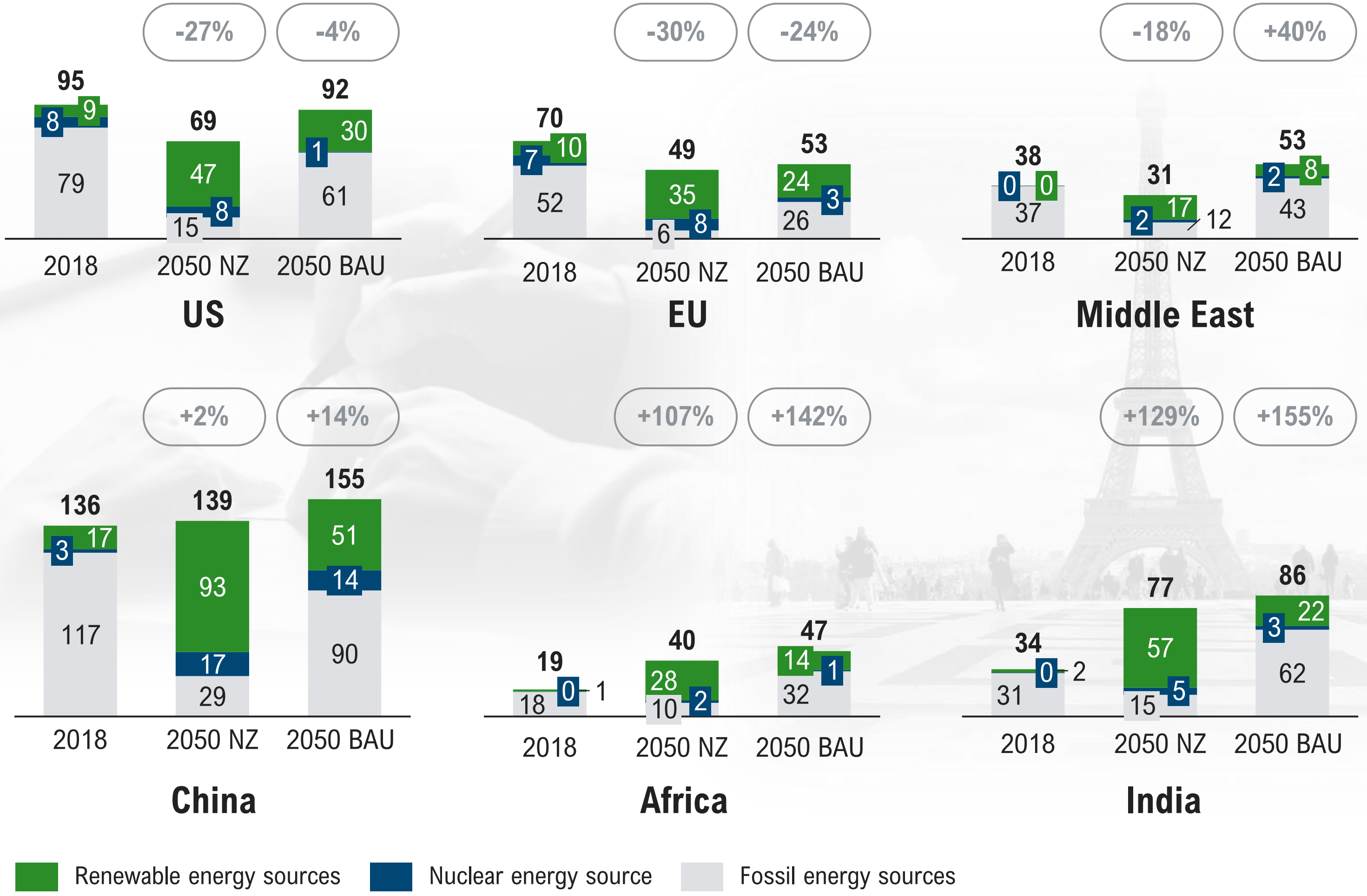
All regions are mirroring this trend – In some regions, efficiency improvements lead to lower overall energy demand

Evolution of primary energy demand according to the Paris Agreement (NZ 2050) and to current policies (BAU 2050) [EJ]



> **Currently, in all regions** worldwide **fossil energy sources dominate the energy mix.** Also, economic activity correlates positively with energy demand. In the US, in 2018 the average per capita demand was around 290 GJ, whereas in China and India, demand equated to 95 GJ and 25 GJ, respectively[1)]

> In the **future, developed countries** with high levels of energy demand will see **demand fall due to energy efficiency increases**

> However, these developments cannot compensate for the **rise in demand stemming from fast growing economies,** such as India and parts of Africa – such countries are expected to double their energy demand under any scenario

> In **bp's net zero (NZ) scenario,** energy efficiency is set to increase more, while **renewables will play a much bigger role** in the energy mix

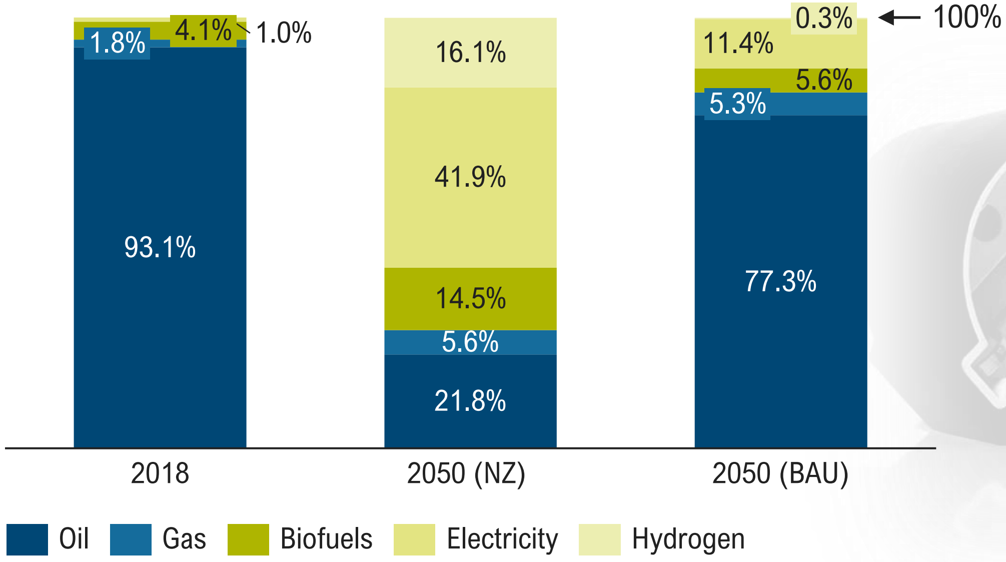
1) Calculated with data from UN Population Division

Sources: bp; UN Population Division; Roland Berger

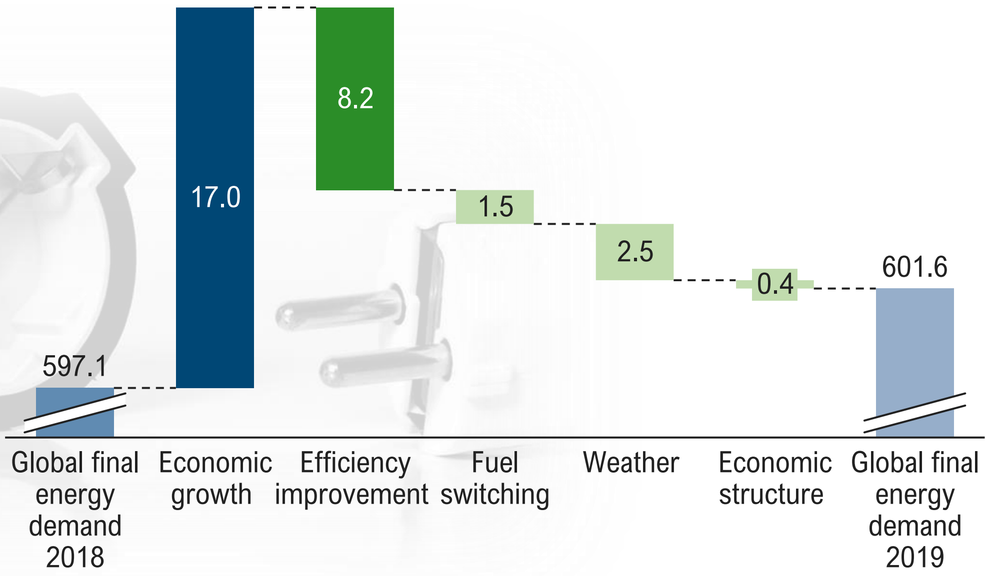
Roland Berger

Transition to more sustainable energy consumption is achieved under two key considerations: Decarbonization and efficiency improvement

Transport sector (illustrative): Global share of final energy consumption by energy carrier and scenario



Change of global energy consumption between 2018 and 2019 [EJ]



Decarbonization

> Decarbonization – a key requirement of the Paris Agreement – is mostly achieved by **switching from fossil energy sources to renewables.** In the case of net zero in 2050, just 1/4 of energy needed by the transport sector will come from carbon emitting energy sources – compared to almost 95% today

> Data from the **transport sector** (above) is shown as an **example** of the extent of the **transformation** required by 2050

Efficiency improvement

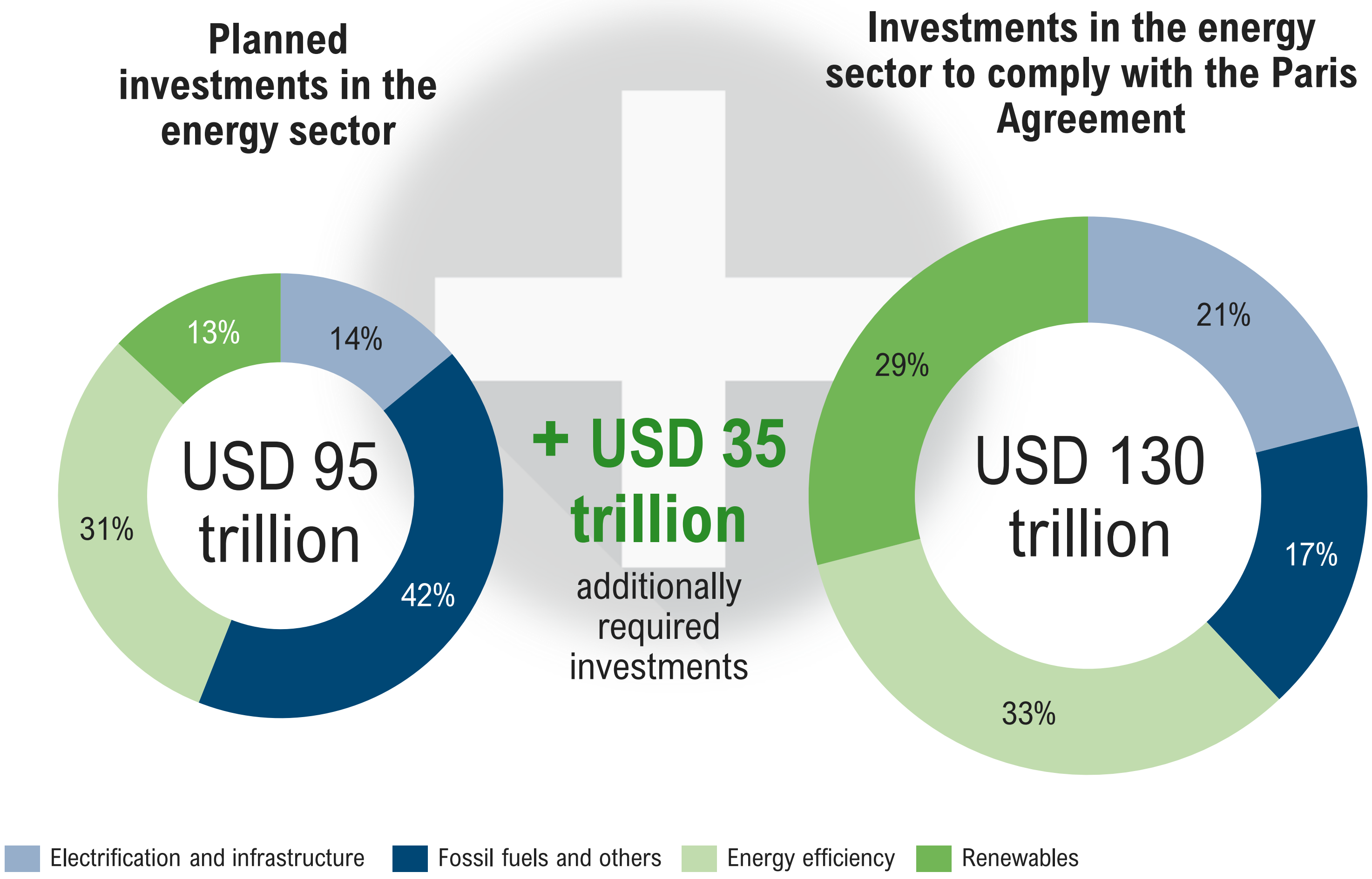
> Efficiency improvement will play a **decisive role** when it comes meeting Paris Agreement targets: In 2019, such reductions played an important part despite the overall increase in energy demand due to economic growth

> Efficiency improvements comprise **technological improvements,** better thermal **insulation in buildings** or **reuse** of materials

Sources: bp; IEA; Roland Berger

To implement energy sector transformations in line with the Paris Agreement, an additional USD 35 trillion need to be invested by 2050 …

Cumulative planned investments and required investment for Paris Agreement target until 2050 in the energy sector

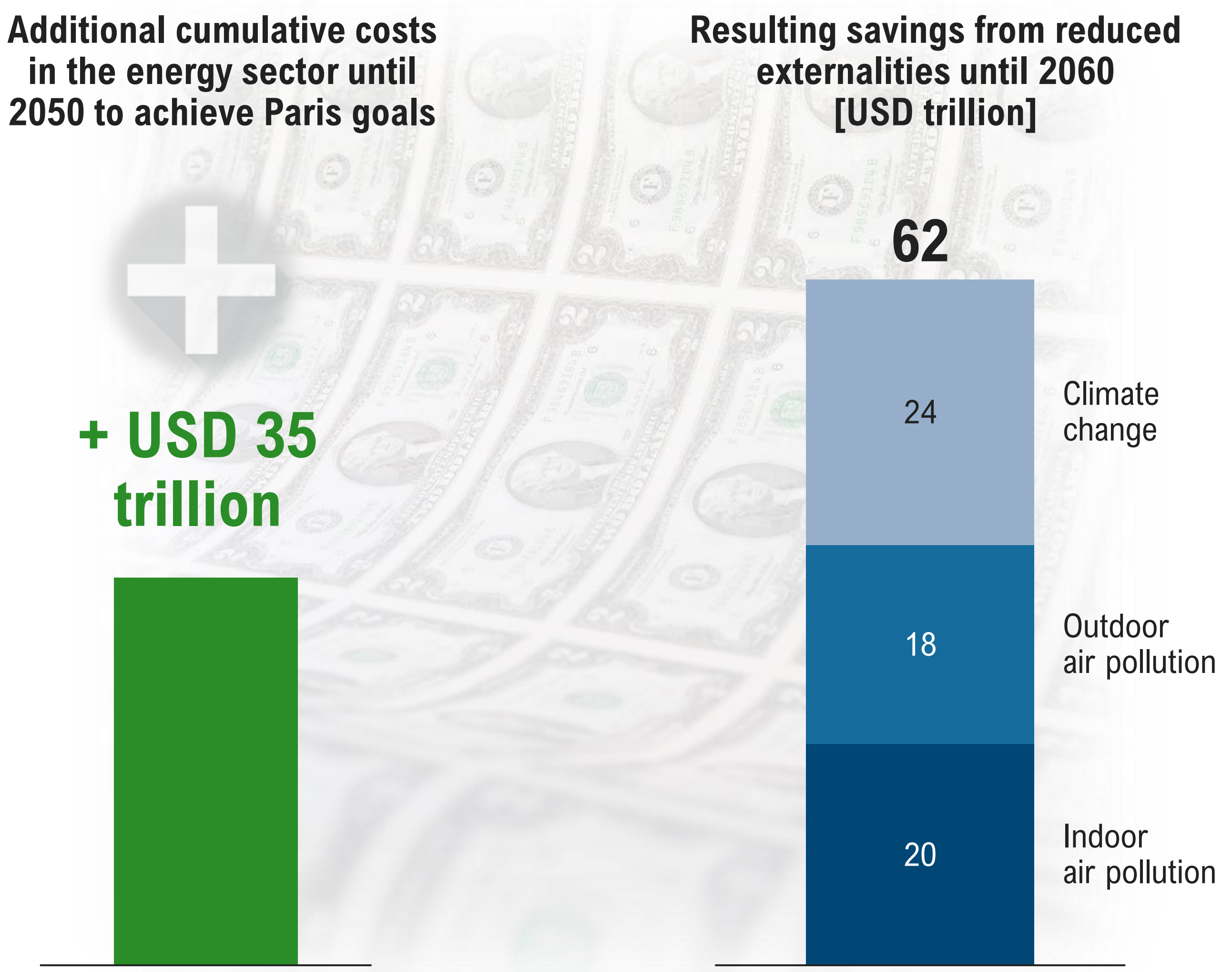


- Between 2014 and 2018, overall **energy sector investments** totaled USD 1.8 trillion. Under a **business-as-usual scenario, more than USD 2.8 trillion annually are planned investments until 2050**. Out of every ten dollars invested in the energy sector, four dollars would (still) flow into fossil energy sources – counteracting Paris Agreement efforts
- **To comply with the agreement,** the energy sector investment portfolio would require promoting increases in energy efficiency and renewable energy sources while lowering the use of fossil energy. As a result, instead of investing USD 2.8 trillion annually, **USD 3.8 trillion need to be invested annually,** bringing the **total of additional global investments** to **USD 35 trillion by 2050** – an amount equal to the combined GDP (2019) of the US and China

Sources: IRENA; World Bank; Roland Berger

… resulting in a payoff of USD 62 trillion to 2060 due to savings from reduced externalities

Investments in a greener energy sector lead to long term savings from reduced externalities

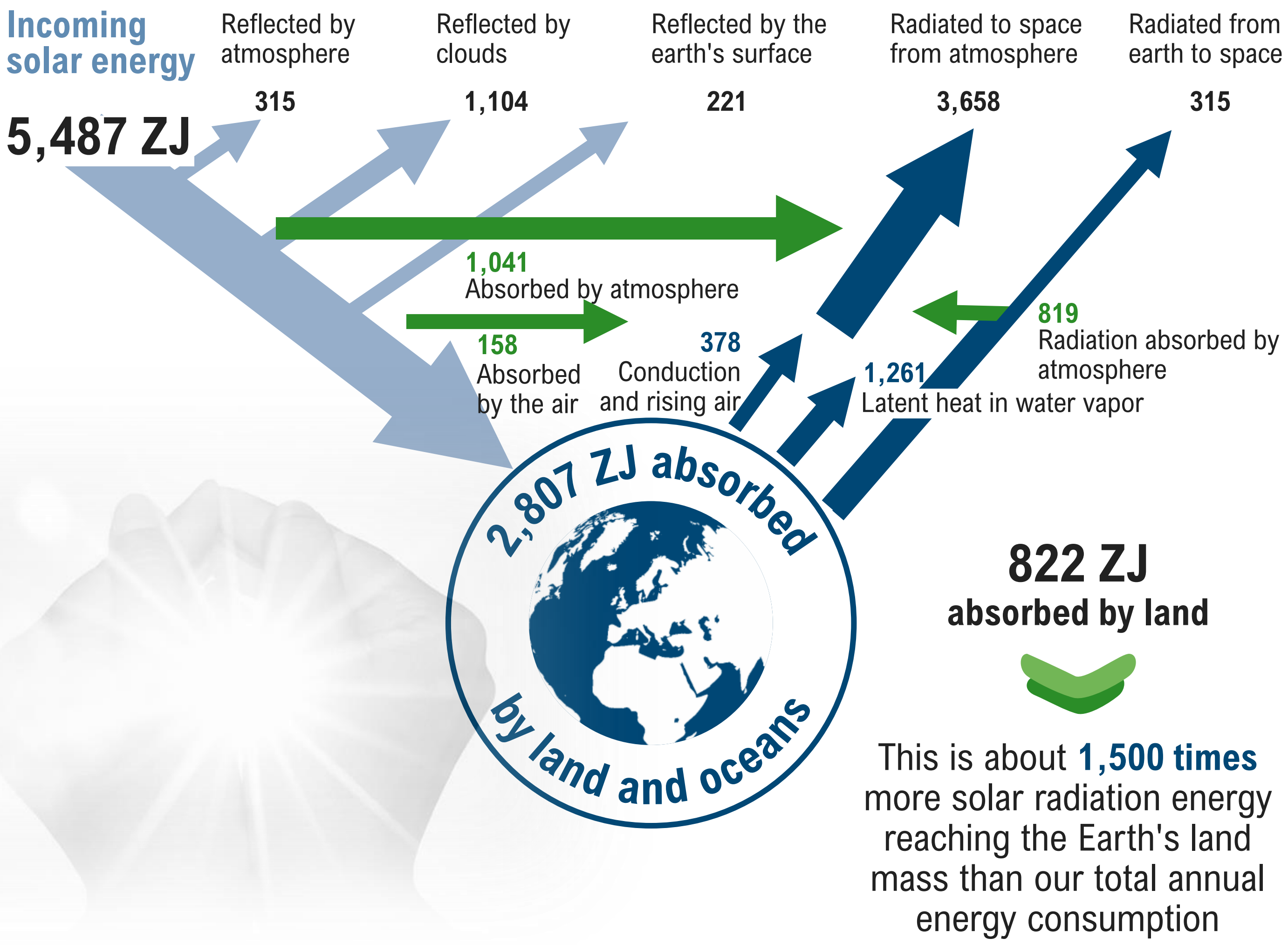


- Considering the **reduced externalities resulting from the transformational change in the energy mix**, the Paris agreement required estimated investment of USD 35 trillions would see a payoff around twice this amount, that is USD 62 trillion until 2060 – getting back around USD 2 for every USD 1 invested
- Meeting the Paris Agreement target in terms of reduced externalities means, for example, that the **intensity** but also the **quantity** of **storms, floods, droughts, and forest fires will be contained** with a lesser need for major adjustments and safety precautions incurring additional costs. **Deaths** resulting from **heat waves** as well as from **air pollution** would be lower
- In fact, **investments would see a payoff just from reduced (indoor and outdoor) air pollution**: Annually, seven million people die prematurely due to air pollution. Moreover, these calculations do not include working population efficiency losses and any additional costs related to the many diseases that are caused by air pollution

Sources: IRENA; IASS Potsdam; Roland Berger

Despite fossil fuel's dominance, the sun is our biggest energy supplier, delivering on land around 1,500 times the Earth's energy consumption

Energy input by solar radiation power per year and its distribution on earth [ZJ]



- **Solar radiation** is the **Earth's main renewable energy source.** Incoming solar energy per year is 5,487 Zeta Joule (ZJ = 10^{21} J); energy stemming from the Earth's interior (geothermal energy) is about 3,500 times smaller, energy from gravitation of moon and sun (driving tidal power) is 35,000 times smaller
- On **Earth's land surface** (29.3% of Earth's total surface), the sun provides 822 ZJ p.a. This is nearly **1,500 times the energy we consume** per year (2020: 556 Exa Joule; EJ = 10^{18} J)
- To meet the **world's energy demand by solar power,** a solar panel spanning 335 km in length and width would be required – equivalent to **1.2%** of the area of the **Sahara Desert**
- **Solar radiation also drives** other renewable energy sources such as **wind** and **water**
- Although renewable energy seems to be available in high abundance, there are **natural limits of use**: For example, on land there are 1,577 EJ **wind energy** p.a. usable in principle. But **only 10% can be sustainably used** – if we use more, the 'global weather machine' would falter

Sources: Smil; Wengemayr (MaxPlanckResearch); BP; Predict/Forbes; Roland Berger

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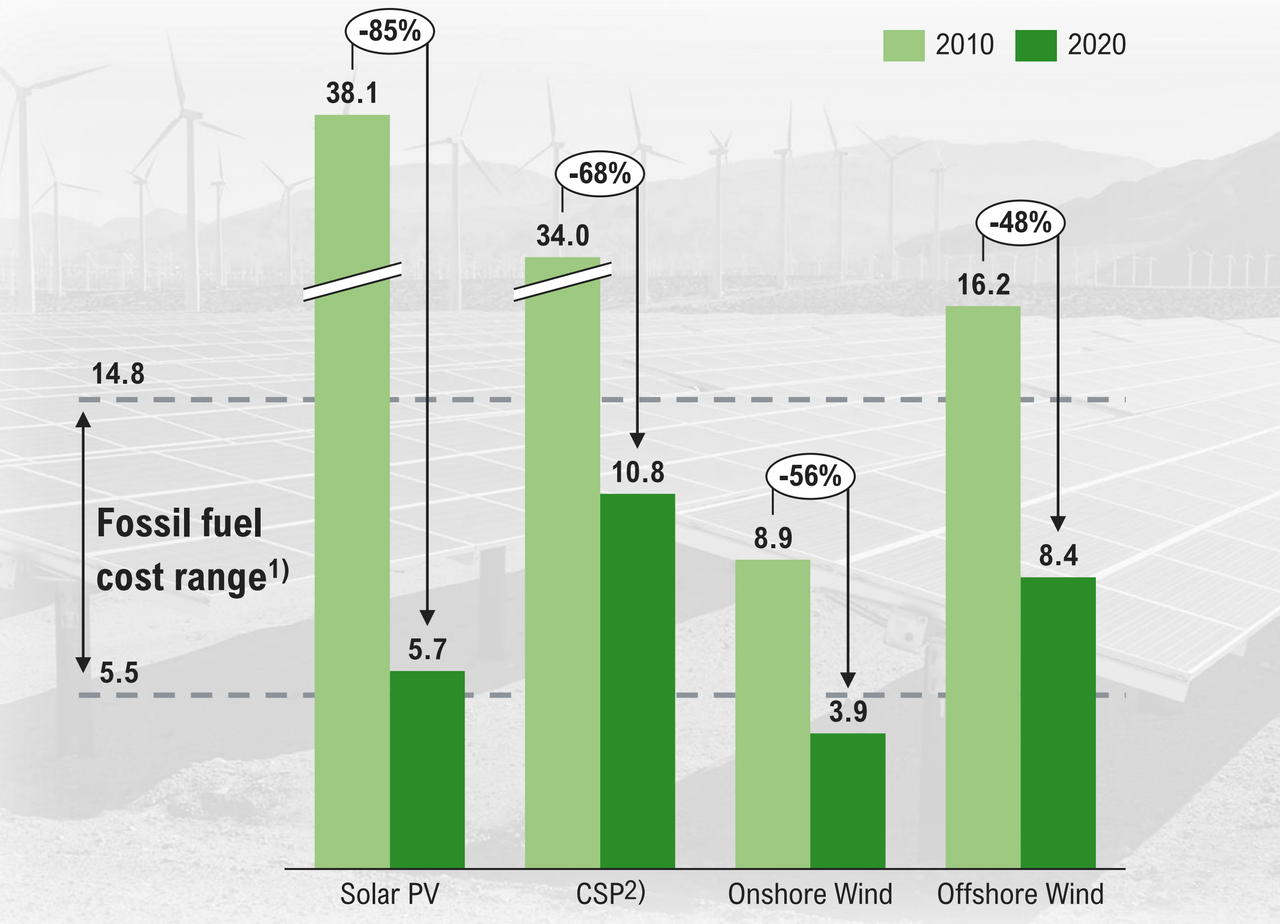
Renewables are now competitive in terms of levelized costs of electricity when compared to fossil fuels

Average levelized cost of electricity generated by renewables for 2010 and 2020 [USD Cent/kWh]



- For a transition from fossil fuels to renewable energy sources to be successful, **respective technologies must be competitive in terms of energy generation costs**
- Over the past decade, the **cost** of the two most significant renewable energy sources, **wind and solar**, **has dropped significantly**
- While historically photovoltaic (PV) systems were not remotely competitive with fossil fuels – being at least twice as expensive – this **situation has changed most notably in solar PV where an 85% reduction in costs** has been observed over the past decade. Compared to the average cost of 7.6 USD Cent/kWh of electricity generation from fossil fuels, the average cost of solar PV generation is now 25% lower
- **Competitiveness heightens the attractiveness of renewable energy sources to investors**, potentially addressing several challenges simultaneously: First, dependency on finite energy sources would ultimately cease. Next, lower renewable energy costs could help to tackle climate change. And lastly, with a well-developed renewable energy grid, an abundant low-cost power supply could meet increasing demand stemming from future economic growth

1) The fossil fuel-fired power generation cost range for the G20 group by country and fuel type is estimated to be between USD 0.055/kWh and USD 0.148/kWh. The lower bound represents new, coal-fired plants in China and is based on IEA, 2020; 2) CSP refers to Concentrating Solar Power;

Sources: IRENA; Roland Berger

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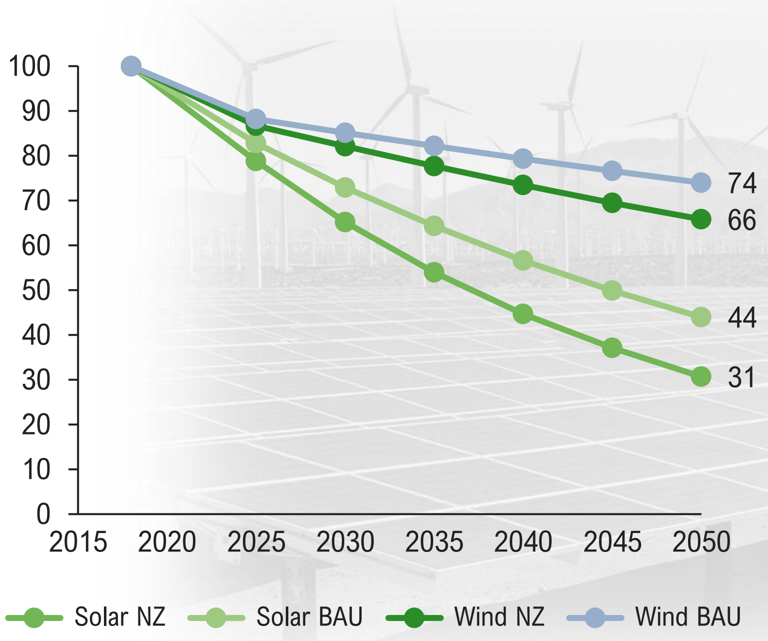
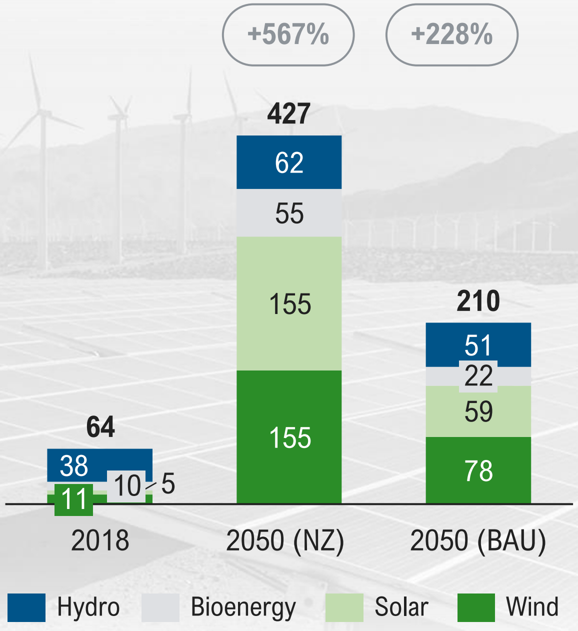
In the future, renewable energy sources, driven by falling prices, will play a greater role in any case – Electricity will power more of the global economy

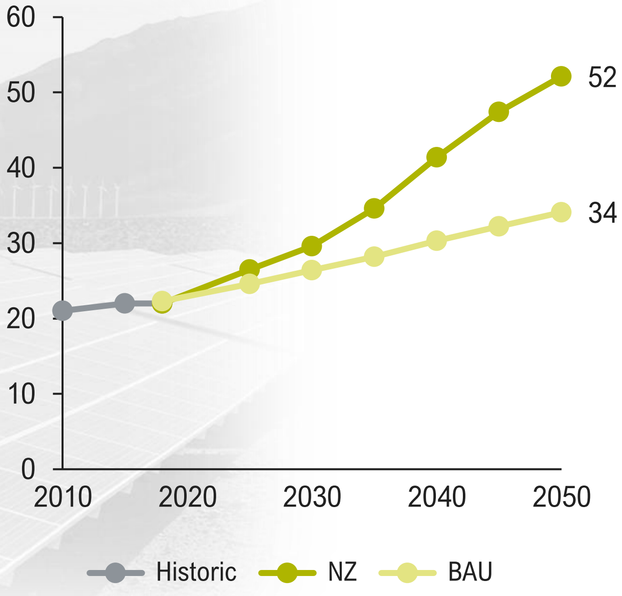
Cost of wind and solar energy by scenario (Index, 2018 = 100)



Global energy consumption of renewables[1)] [EJ]



Share of electricity in global final energy consumption [%]



> Driven by technological progress, increased competition, promotion and scaling, it is expected that energy generation from renewable energy sources will become **even cheaper in the future**. Solar energy, for example and under any scenario, will cost less than half compared to 2018

> In turn, **growth in energy consumption from renewables** appears unstoppable: Under the **business-as-usual (BAU) scenario, this energy consumption** will **double**, while under the **net zero (NZ) emissions scenario** energy it is expected **to increase fivefold**

> As a result, traditional energy sources – such as gas – will play a lesser role. The economy will be decarbonized and increasingly powered by electricity from renewable energy sources

1) Differences of the sums to the numbers on page 26 are due to rounding
Sources: bp; Roland Berger

Roland Berger

Due to the rise of renewables, electricity supply will fluctuate more – New technological solutions are needed to balance the power system

Technologies that help balance the power system for different durations of energy need

	Seconds	Minutes	Hours	Days	Weeks	Seasons
Batteries	Most advantaged	Most advantaged	Most advantaged	Not applicable/expensive	Not applicable/expensive	Not applicable/expensive
Pumped hydro	Less advantaged	Most advantaged	Most advantaged	Not applicable/expensive	Not applicable/expensive	Not applicable/expensive
Demand responses and rescheduling	Less advantaged	Most advantaged	Most advantaged	Less advantaged	Not applicable/expensive	Not applicable/expensive
Hydro with high-capacity reservoirs	Less advantaged	Most advantaged	Most advantaged	Most advantaged	Most advantaged	Most advantaged
Hydrogen	Less advantaged	Less advantaged	Less advantaged	Most advantaged	Most advantaged	Most advantaged
Gas (or coal) with CCUS	Not applicable/expensive	Less advantaged	Less advantaged	Most advantaged	Most advantaged	Most advantaged
Bioenergy with or without CCUS	Not applicable/expensive	Less advantaged	Less advantaged	Most advantaged	Most advantaged	Most advantaged

Most advantaged | Less advantaged | Not applicable/expensive

> The **quality of** a country's **power supply** is measured by **continuity of supply, voltage quality** (stability of voltage level) and **commercial quality** (e.g. response time, compensation in case of failures)

> **Renewable energy sources are dependent** on external circumstances, especially the **weather**, for their energy production. In the absence of the right **conditions** (windless, overcast, etc.) it is not possible to feed (enough) renewable energy into the power grid – the power supply would fail

> In order **to guarantee a stable energy supply** in the coming energy transition, the reliability of various **technological energy storage solutions** is key: In the event of overproduction, these technologies can help **balance the power system** during adverse weather conditions

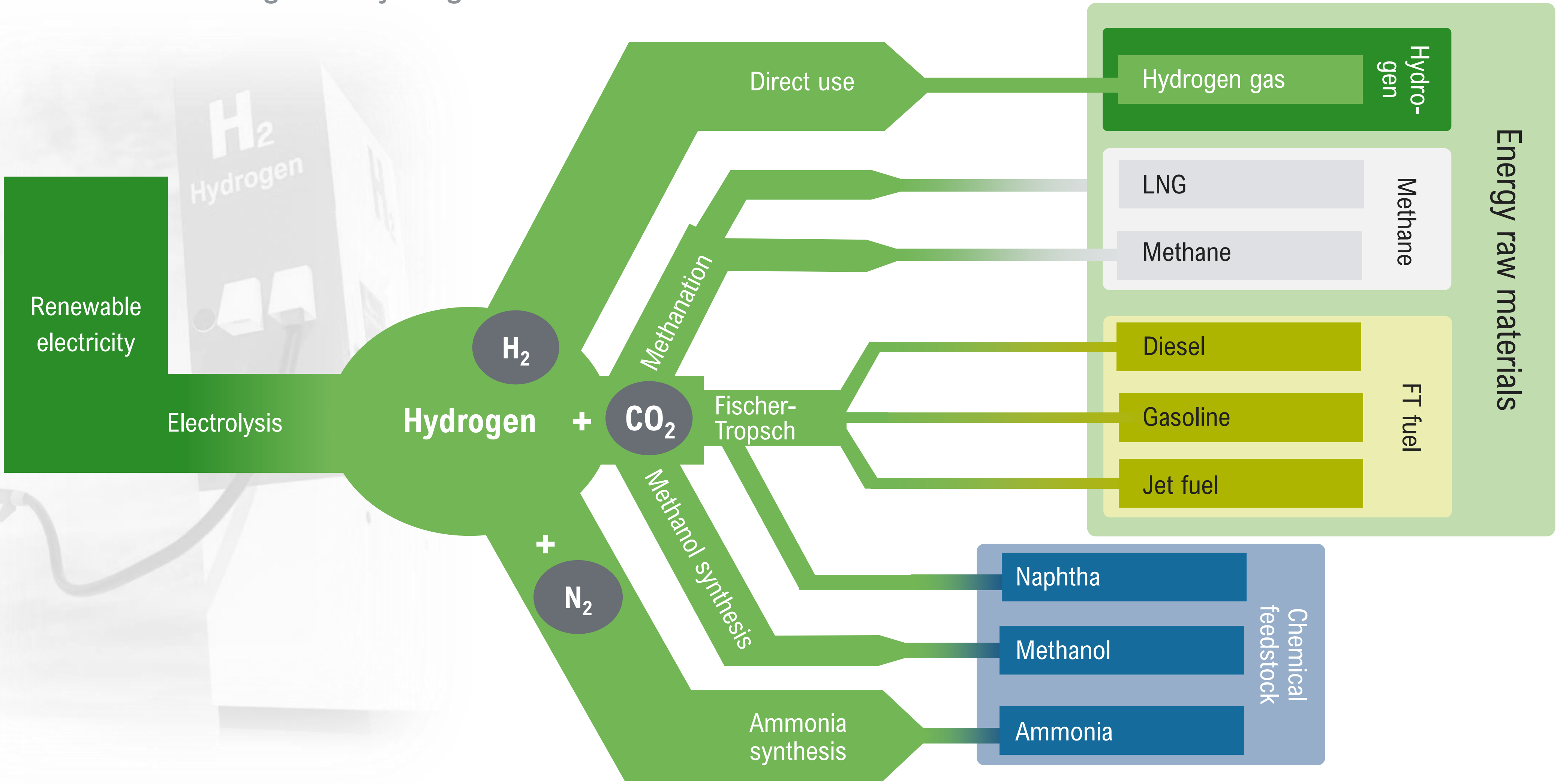
> The optimal choice and use of the technology depends mostly on **economic feasibility**, but also on the technological one

1) CCUS refers to carbon capture, utilization and storage and describes the possibility to store or further process CO2 emitted by energy production

Sources: bp; CEER; Roland Berger

Green hydrogen turns out to be a particularly flexible solution with multiple possible options for further processing and use

Possible uses of green hydrogen



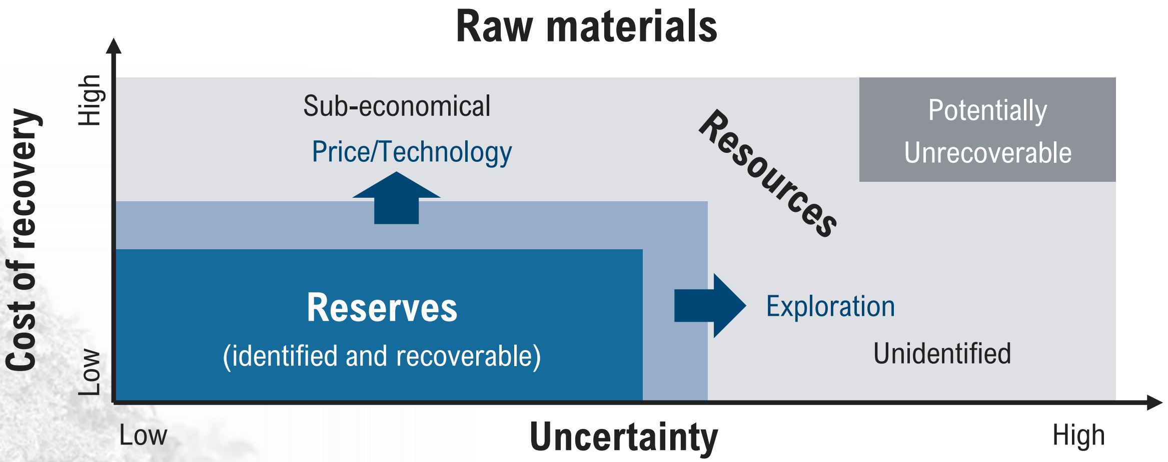
Sources: LUT University; SolarPower Europe; Roland Berger

In the future, the supply of non-energy raw materials will become more important – Finding a balance of finite resources vs abundant use

Raw materials and two approaches of classification

Raw materials

- Energy raw materials
  - > Fossil energy raw materials: coal, oil, natural gas
  - > Renewable energy raw materials: hydrogen
- **Non-energy raw materials**
  - Metal raw materials
    - > Gold
    - > Iron ore
    - > Copper
  - Industrial raw materials
    - > Oil
    - > Salts
    - > Limestone
  - Construction raw materials
    - > Sand
    - > Clay
    - > Cement



- > **Raw materials** are categorized either as **reserves** or **resources**
- > As reserves, the following conditions must be met: Firstly, the **existence** in the respective extraction locations must be **proven** and their **quantity** must be precisely **known**. Secondly, their **extraction must be economically profitable**
- > If at least one of the two conditions is not met, raw materials are not counted as reserves, but as **resources** (their amount in mineral deposits is estimated). However, on further exploration, the level of **certainty** can be increased and thus be newly counted as reserves. The same applies for changes in underlying aspects of **recovery** (higher prices, better technologies) making raw materials exploitation more economically feasible, following which they are counted as reserves

Sources: EU; Transport Geography; Roland Berger

In relation to resources, accessible reserves are quite small – Metal raw materials in particular entail limited availability

Cobalt
Resources: 325 m t
Reserves: 7.1 m t
Mine prod. (2020): 140,000 t
Price (2020): USD 30.000-40,000/t
Substitutes: iron, barium, nickel, cerium, rhodium

Copper
Resources: 3.5 bn t
Reserves: 870 m t
Mine prod. (2020): 20 m t
Price (2020): USD 6,000-8,000/t
Substitutes: aluminum, titanium, optical fiber, plastics

Gold
Resources: 33,000 t
Reserves: 53,000 t
Mine prod. (2020): 3,200 t
Price (2020): USD 1,500-2,000/oz
Substitutes: palladium, platinum, silver

Iron
Resources: 230 bn t
Reserves: 84 bn t
Prod. (2020): 1.2 bn t
Price (2020): USD 100-200/t
Substitutes: none

Lithium
Resources: 86 m t
Reserves: 21 m t
Mine prod. (2020): 82,000 t
Price (2020): USD 400-500/t
Substitutes: calcium, mercury, magnesium, aluminum

Magnesium
Resources: > 12 bn t
Reserves: 7.6 m t
Mine prod. (2020): 26,000 t
Price (2020): ~ USD 2,000/t
Substitutes: alumina, chromite, silica

Platinum Group Metals (PGM)
Resources: 100,000 t
Reserves: 69,000 t
Mine prod. (2020): 380 t
Price (2020): USD 800-1,000/troz[3]
Substitutes: PGM can substitute for another, with losses in efficiency

Rare Earths
Resources: unknown
Reserves: 120 m t REO[1]
Mine prod. (2020): 240,000 t REO
Price (2020): multiple prices
Substitutes: available for many applications but less effective

Silver
Resources: unknown
Reserves: 0.5 bn t
Mine prod. (2020): 20 m t
Price (2020): USD 15-25 troz
Substitutes: stainless steel, aluminum, rhodium

Zinc
Resources: 1.9 bn t
Reserves: 250 m t
Mine prod. (2020): 12 m t
Price (2020): USD 2,000-2,500/t
Substitutes: aluminum, cadmium, magnesium, plastics

Phosphate
Resources: 300 bn t
Reserves: 71 bn t
Mine prod. (2020): 223 m t
Price (2020): ~ USD 80/t
Substitutes: none

Cement
Resources: shortages unlikely
Clinker capacity: 3.7 bn t
Cement prod. (2020): 4.1 bn t
Price (2020): ~ USD 120/t
Substitutes: fly ash, ground granulated blast furnace slag

Coal
Resources: 19.9 trillion t
Reserves: 1.1 trillion t
Mine prod. (2020): 7.7 bn t
Price (2020): USD 42-83/t
Substitutes: oil, natural gas, renewable energy

Natural Gas
Resources: 631 trillion m^3
Reserves: 188.1 trillion m^3
Extraction (2020): 3.9 trillion m^3
Price (2020): USD 1.5-4/mmBtu[2]
Substitutes: oil, coal, renewable energy

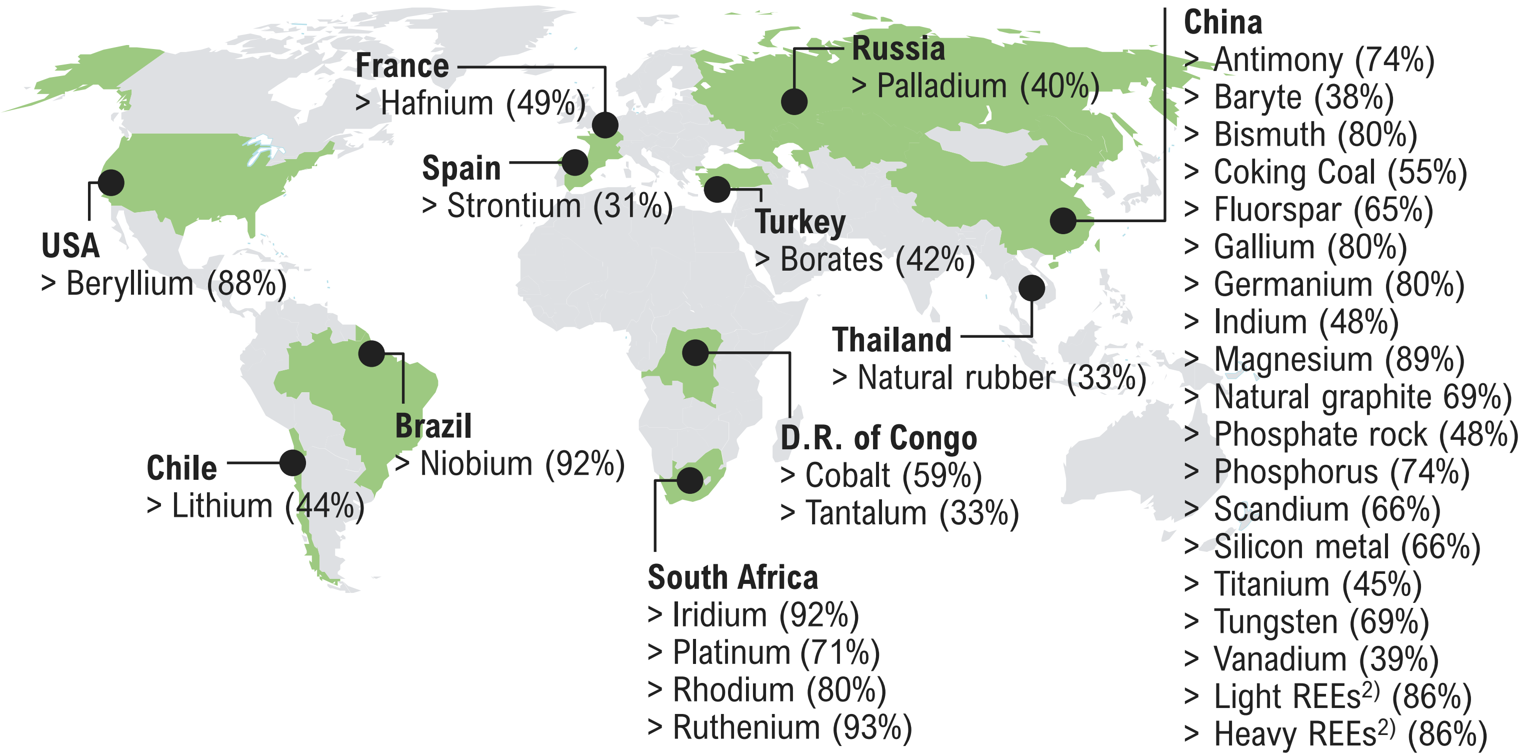
Oil
Resources: 502 bn t
Reserves: 244.4 bn t
Extraction (2020): 4.2 bn t
Price (2020): ~ USD 40/barrel
Substitutes: natural gas, coal, renewable energy, Bio-gas

Metal raw material | Chemical raw material | Construction raw material | Energy raw material

1) REO: Rare-earth oxide; 2) mmBtu: million British thermal unit corresponds to ~ 28,3 m^3 natural gas at defined temperature and pressure 3) troz: troy ounce; 1 troz = 31.1g
Sources: BGR; USGS; bp; Roland Berger

China is the dominant supplier of a long list of raw materials critical to our economy

An EU analysis: Countries accounting for largest share of global supply of critical raw materials (CRM) 2020[1)] [%]



Selected CRMs and examples of end-use

Beryllium: electronic and telecommunications equipment; Germanium: infrared optics; Hafnium: superalloy; Niobium: magnets; Rhodium: auto catalyst; Phosphate rock: mineral fertilizer; Tantalum: capacitors; Tungsten: tools

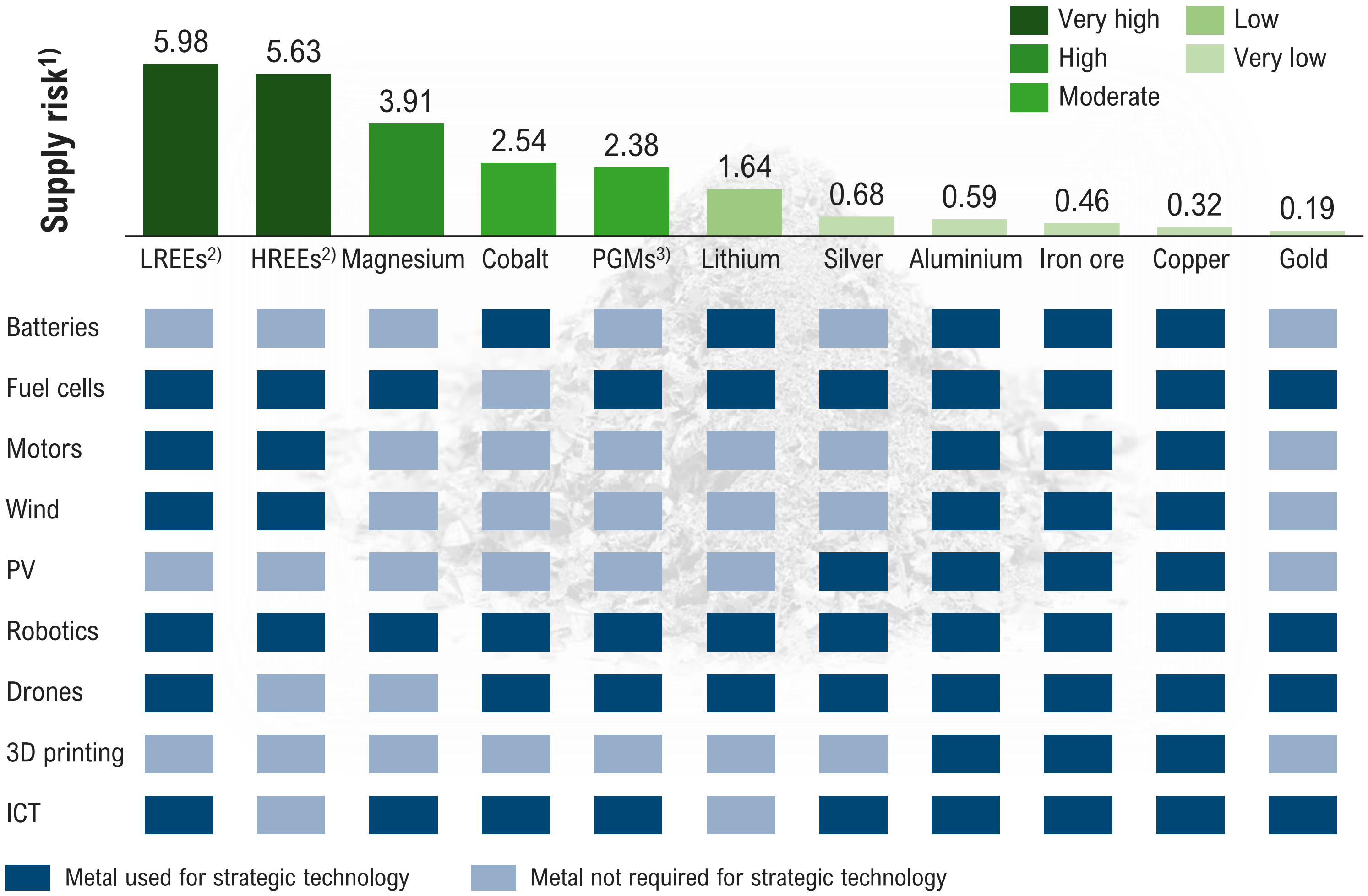
The EU analysis concerning CRMs

- Since 2011 the **EU reports on the global supply of raw materials**
- The **2020 (fourth) assessment covers 80+ raw materials** with a view to these being critical – or not – for the EU
- The EU defines a raw material as critical when its **economic importance** and its **supply risk** is **high**
- At present, the EU identified **30 raw materials or** raw material **groups as critical**

1) Percentage shares refer to the study "Report on critical raw materials for the EU" (2020), European Commission 2) REEs: Rare Earths Elements
Sources: European Commission; Roland Berger

Particularly crucial are rare-earth elements that are difficult to substitute, yet essential for important and upcoming strategic technologies

Supply risk index of selected metal raw materials and their use for strategic technologies



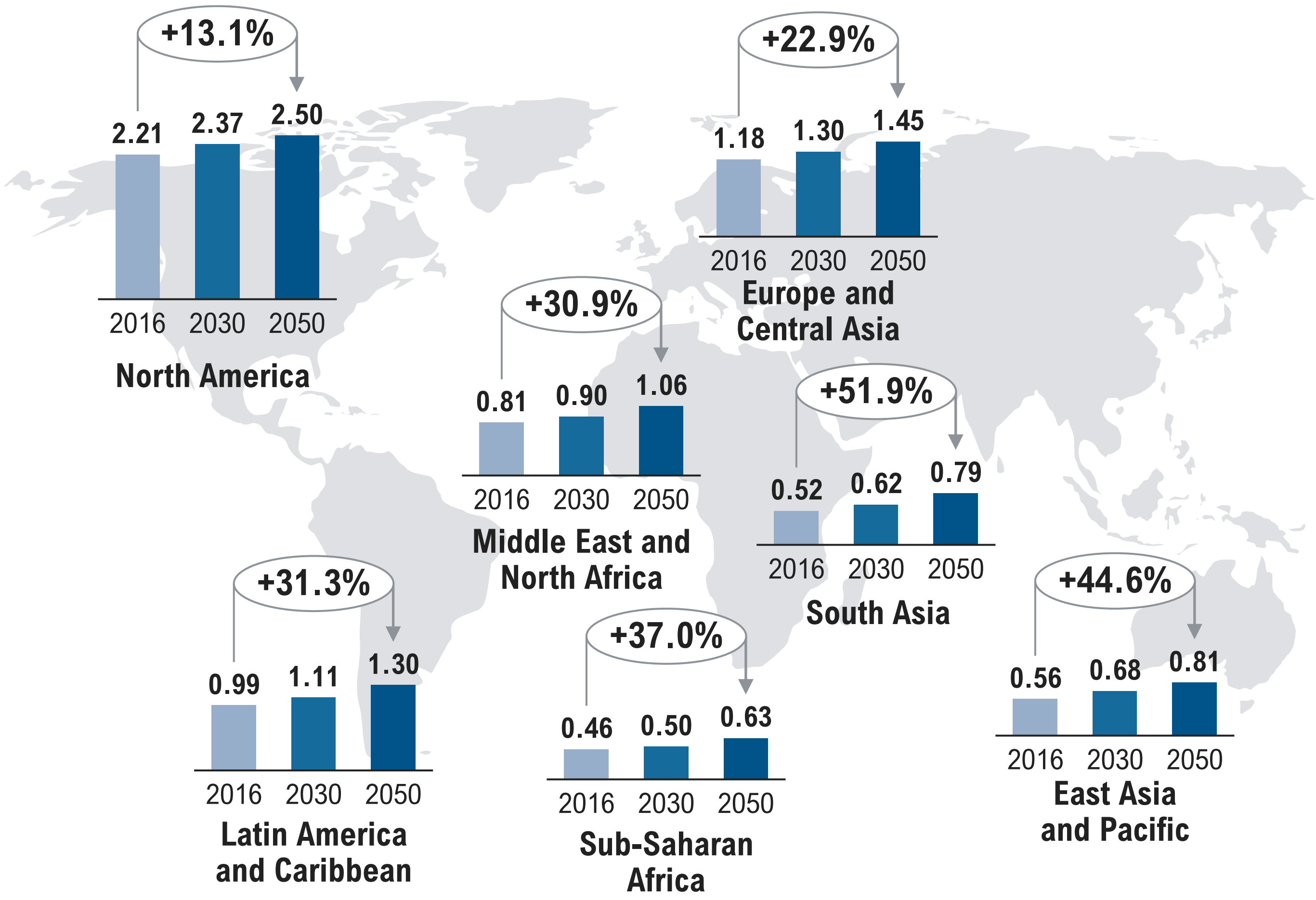
- In coming years, the EU sees **very high supply risk** issues for two types of metals, both are groups of **rare-earth elements:** LREEs (e.g. cerium, samarium) and HREEs (e.g. ytterbium, thulium)
- **Demand** for **rare-earth elements** used in permanent magnets for electric vehicles, digital technologies or wind turbines could **increase tenfold by 2050**
- By **2050**, the EU will require around **60 times more lithium**, essential for e-mobility, and **15 times more cobalt**, used in electric car batteries. However, their supply is less risky because reserves are spread across several countries, are sufficiently available or can be replaced by other sufficiently available metals, albeit under efficiency losses

1) The Supply Risk Index (0-6) considers the global supply risk, the European domestic supply, criticality factors, import reliance, substitution and recycling of the respective raw material;
2) LREE: Light rare-earth elements; HREE: Heavy rare-earth elements; 3) PGM: Platinum group metal

Sources: European Commission; Roland Berger

Although we are faced with potential raw material scarcities, unabated trends in waste generation hold due to linear economy processes

Daily waste generation 2016-2050 [kg/capita]

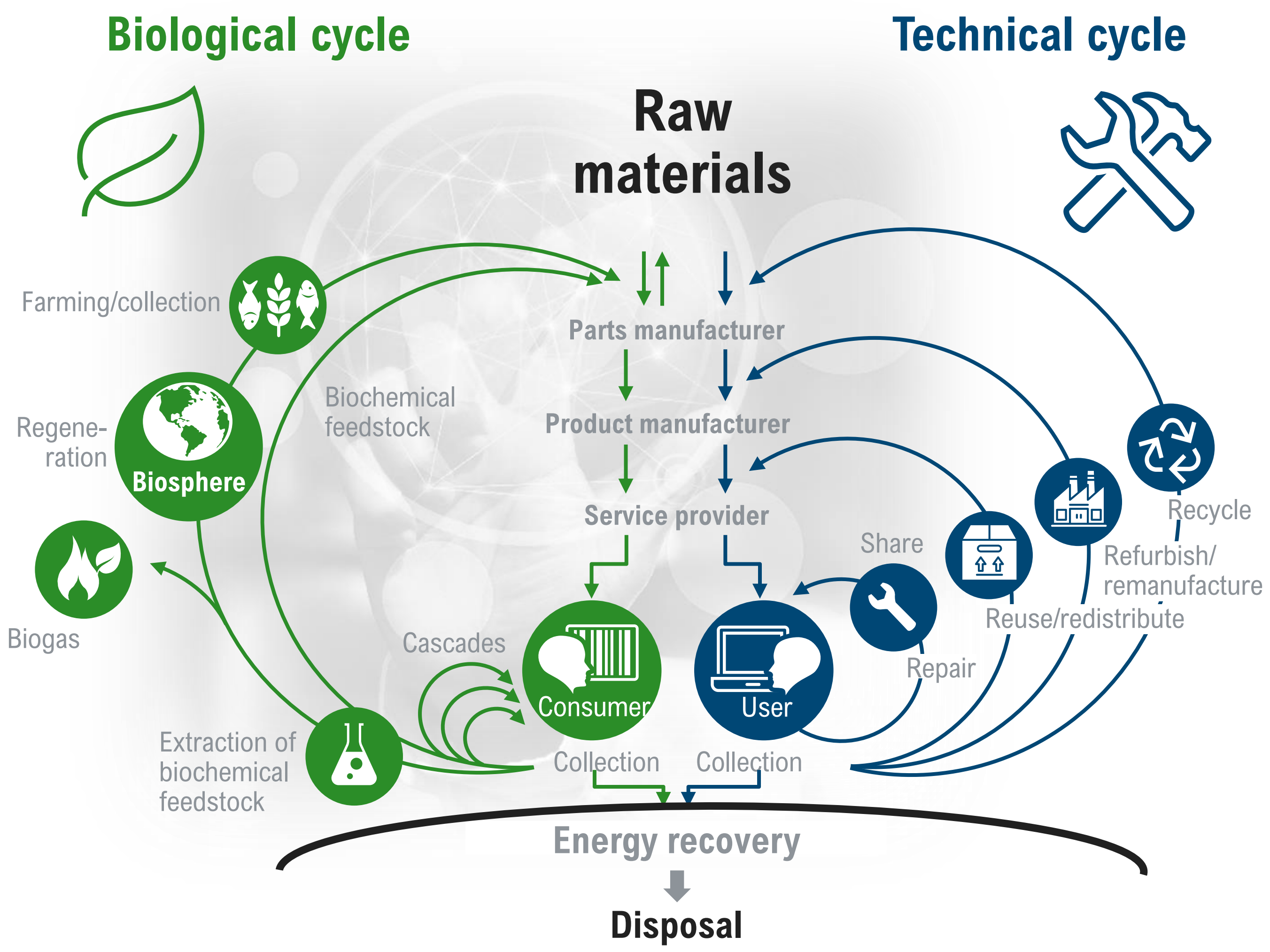


- On the one hand, we are faced with a potential **scarcity of raw materials**, on the other hand, we produce **waste in abundance**. At the heart of this lies the way – having evolved over decades if not centuries – we have designed our production processes and how we conduct our economic activities: It's a mostly **linear economy**
- Along with **global production** as well as **consumption patterns**, our waste is rising; the motto is often "buy, consume, throw away"
- Unsurprisingly, **most waste is generated in economically strong countries**. In North America, for example, more than 2.2 kg of waste are generated per person per day, while in lesser developed regions it is a fraction, for example in Sub-Saharan Africa it is around one fifth of that
- This trend appears unabated: **Waste generation is increasing worldwide**, most strongly in those regions of the world that can expect the greatest economic **growth** in the future, such as South Asia with an annual future growth of 1.2% in waste generation. Nonetheless, economically developed regions will remain the number one waste producers

Sources: World Bank; Roland Berger

Circular – not linear – economy concept promises a more regenerative, less wasteful economic system, more independent of scarce resources

Circular economy concept

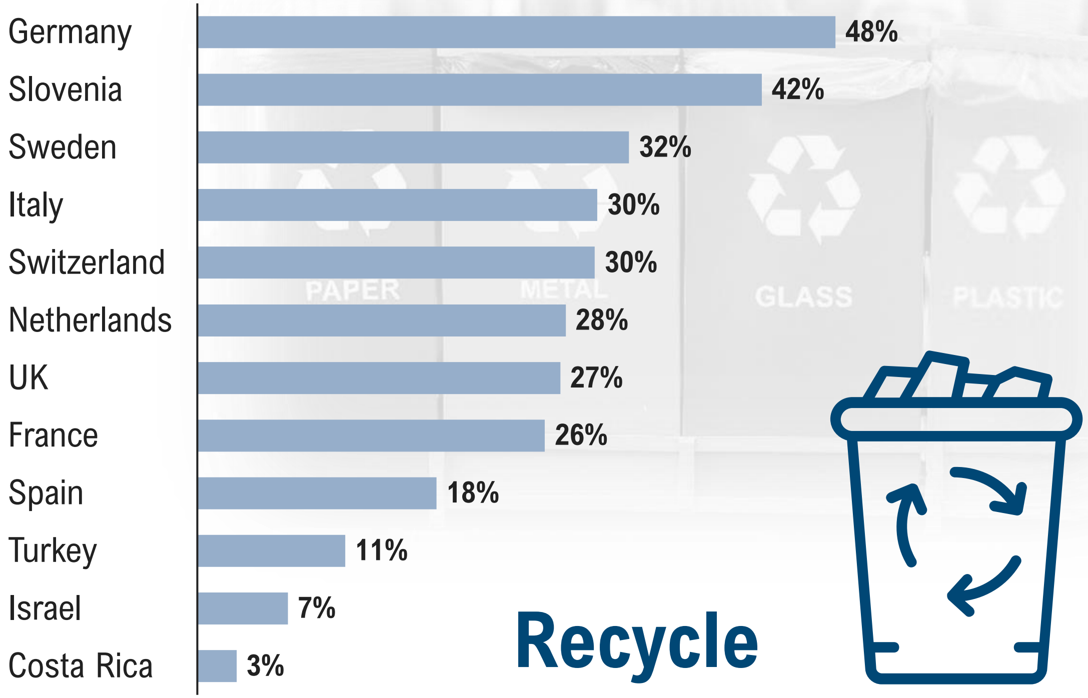


- > **Circular economy** describes a regenerative economic system and aims to **minimize resource input as well as waste and emission production.** These objectives derive from the need for maximum efficiency in the use of potentially finite global resources
- > The circular economy concept consists of two cycles, that, if complied with, can lead to a **sustainable economy both in terms of resources use as well as biocapacity**. However, the model represents an idealistic system that requires **profound change in production processes** and **consumer behavior**
- > **Biological cycles** are solely concerned with the **management of renewable resources** and can only affect the consumer side in a circular economy. This implies that, fossil fuels no longer have a place in a circular concept
- > **Technical cycles** involve the **management of finite resources** that are extracted and used in multiple economic cycles and processes. This is mainly achieved by reuse, repair and remanufacturing, but also by recycling

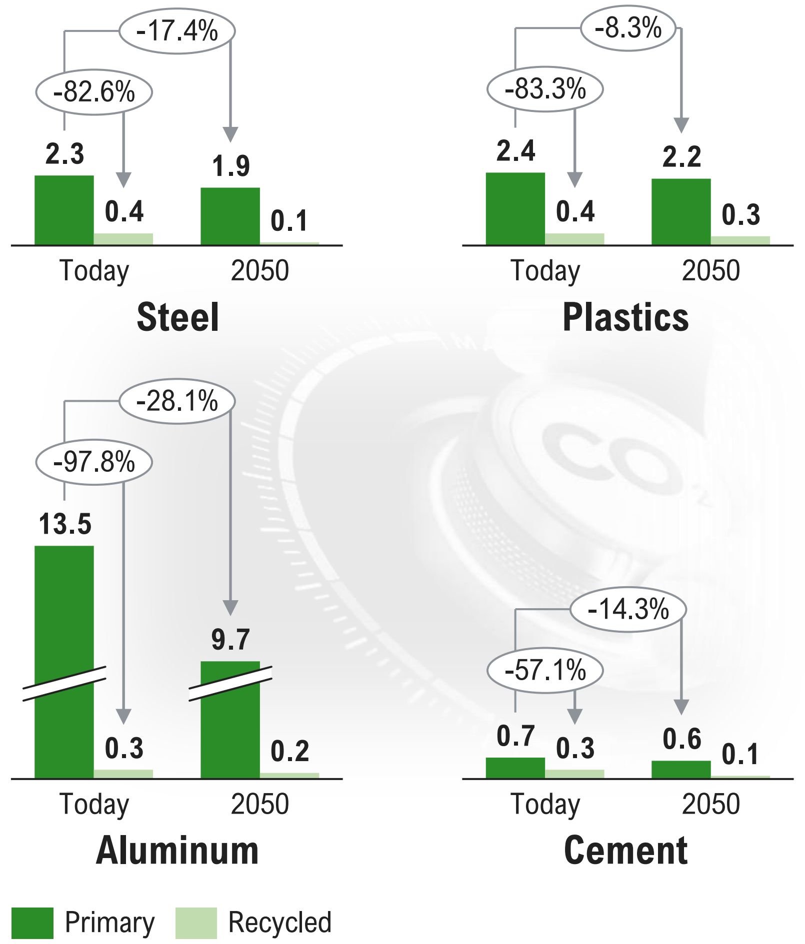
Sources: Ellen MacArthur Foundation; Roland Berger

The use of recycled materials helps abate CO_2 emissions already today, more so than advances in production processes by 2050

Share of waste being recycled, 2019 [%]



CO_2-emissions during production process, primary vs. recycled [t CO_2/ t product]



- **Recycling** as a circular economy component generally receives the most attention, as recycled materials mostly have a clear **market value**; they can also be used for a **variety of purposes and processes**, thus closing the circular economy loop in the **most flexible** way
- Recycling is also one of the key steps in **climate change mitigation**: Use of recycled inputs in production processes would **save more emissions now than future advances in production technology by 2050**
- **Refurbishing**, **reusing** and **repairing** would additionally contribute to a more sustainable economy

Source: OECD; Material Economics, Roland Berger

CO_2 collection and reuse is one example of applied circular economy principles – Storage of CO_2 is a necessity due to its abundance

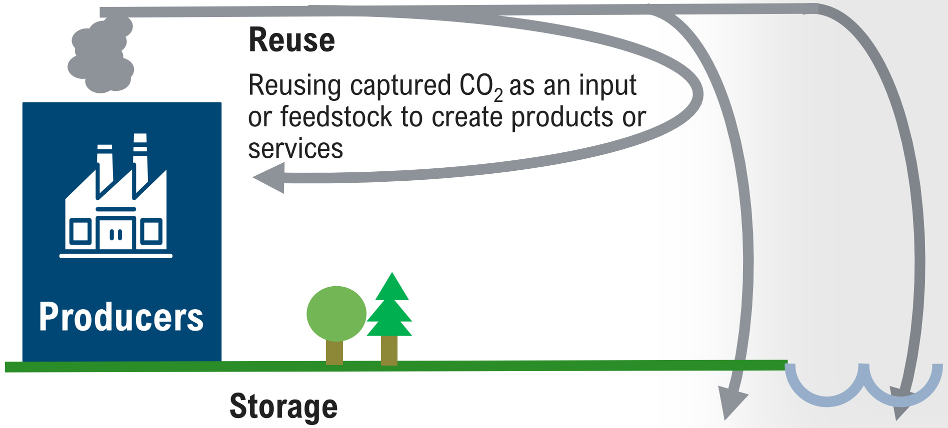
Further use of CO_2

Capture

Capturing CO_2 from fossil fuel or biomass-fueled power stations, industry facilities, or directly from the air

Transport

Moving compressed CO_2 by ship or pipeline from the point of capture to the point of use or storage



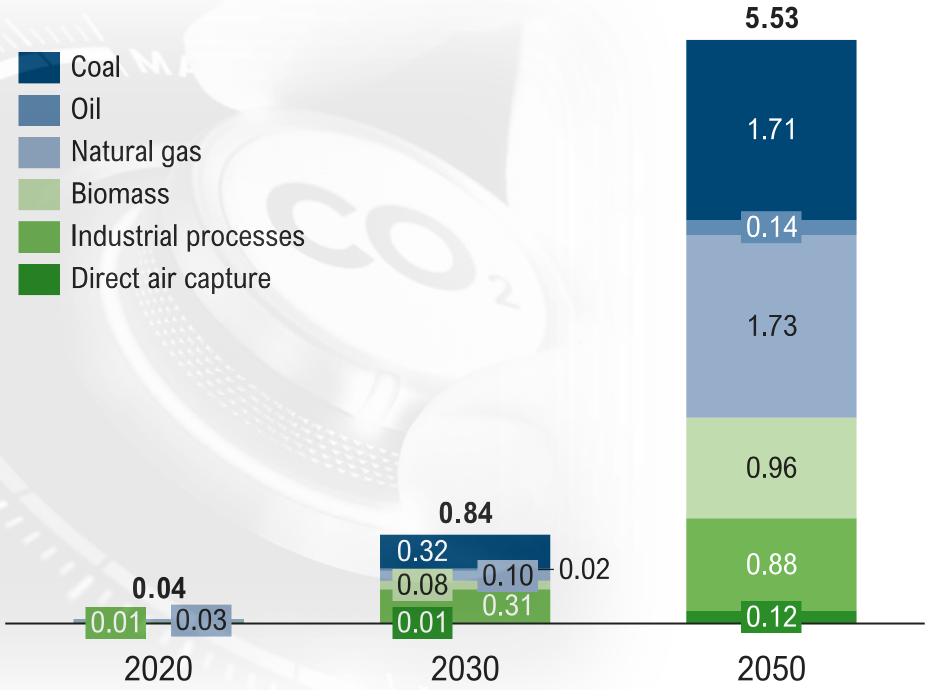
Reuse

Reusing captured CO_2 as an input or feedstock to create products or services

Storage

Permanently storing CO_2 in underground geological formations, onshore and offshore

Carbon capture [Gt CO_2] by producers under IEA Sustainable Development Scenario[1)]



> At present, most CO_2 emissions are released into the air. However, there are several ways to capture, store and/or use CO_2. By the **second half of this century, carbon capture,** for example at source in energy generation, **will play a significant role** in helping to make the global economy climate-neutral

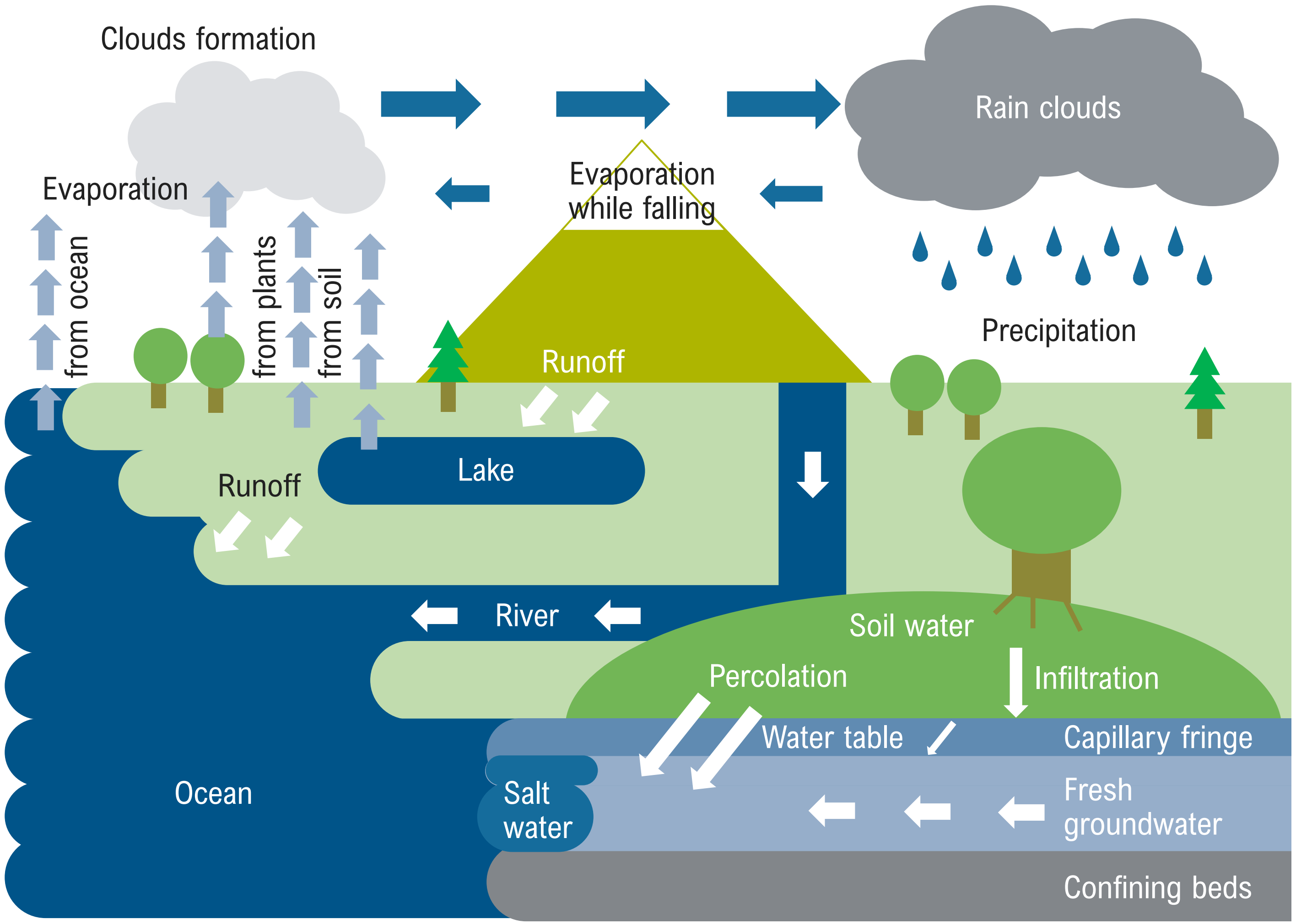
> **Reusing captured CO_2 as a feedstock** opens many possibilities, for example in the production of **climate-neutral fuels**

1) IEA Sustainable Development Scenario assumes that global net zero emission target is met in 2070

Sources: IEA; Roland Berger

The water cycle serves as a natural model akin to a circular economy – Water is collected, purified, recycled and redistributed after use

The hydrological cycle

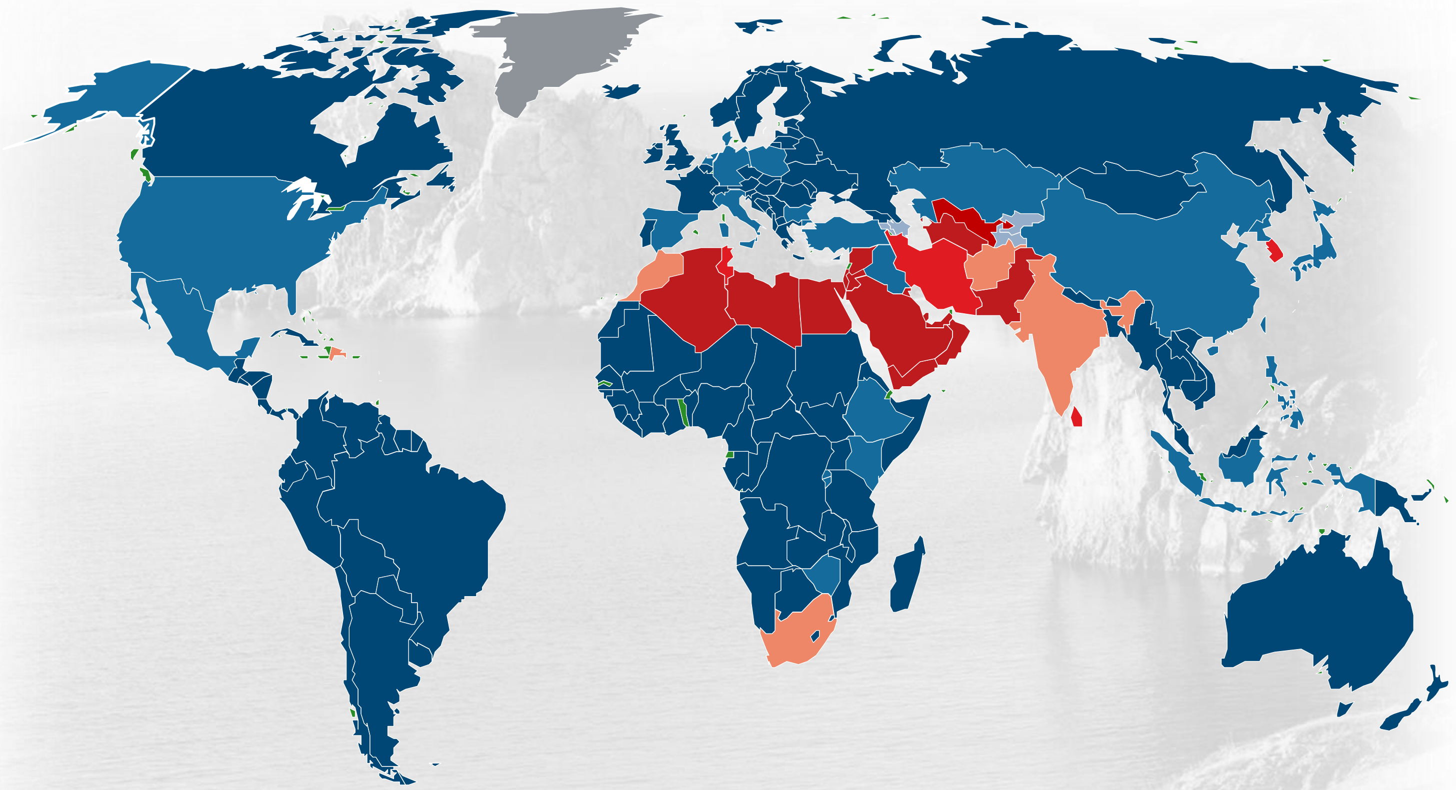


- The **hydrological cycle is the natural counterpart to the circular economy** model; it describes the various, continuous stages of the movement of water
- Water is **naturally recycled** as it evaporates from the oceans into the atmosphere and, ultimately, through precipitation, back to the oceans overland and underground
- Depending on **climate**, **temperature** and **weather conditions** as well as **human interference**, the amount of water available in individual bodies of water (rivers, lakes, water tables etc.) varies
- The water cycle can be profoundly **disrupted** by **excessive withdrawal of water** that is not returned, for example, in agriculture in arid regions; a further **disruption** stems from **sealed surfaces**, found especially in **urban** areas, where rainwater is prevented from passing through soil back into the water cycle
- Disrupting the water cycle, especially considering climate change, poses any number of **risks to humans and nature** – ranging from **drought** to **flooding**

Sources: FAO; Roland Berger

However, disturbing the water cycle leads to water stress with irreversible consequences – Sensibility depends on initial humidity of region of concern

Levels of water stress: Freshwater withdrawal as a proportion of available freshwater resources, 2018



No stress: 0-25% | Low stress: >25-50% | Medium stress: >50-75%

High stress. >75-100% | Critical stress: >100% | No data

> The **level of water stress** is defined as the proportion of **total freshwater withdrawal** by all major sectors (agricultural, industrial, municipal) in relation to **total renewable freshwater resources** after considering environmental flow requirements. Glaciers, lakes and rivers as well as groundwater are all considered as freshwater

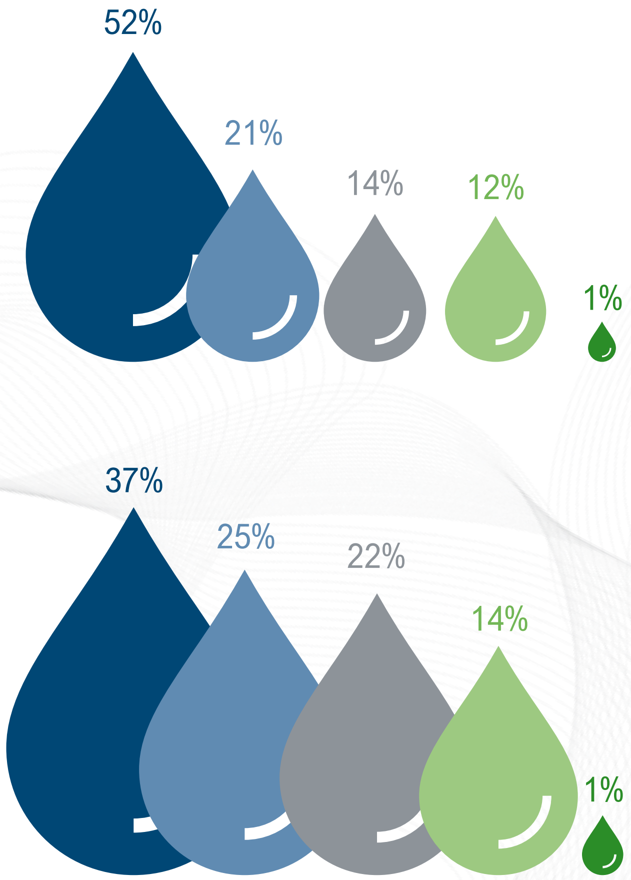
> Several **factor combinations can cause water stress**: For example, an arid region that is not affected by human freshwater withdrawals would not be considered as "stressed", but "arid". However, it is also true that arid regions, e.g. the Saharan region, are more likely to experience water stress

> A region or country that experiences **long-term water stress is likely to see a lasting, irreversible disruption of the water cycle**. As a result, economic livelihoods are under threat, as is human health, especially in poorer regions of the world

Sources: FAO; Roland Berger

The demand for water is expected to grow significantly toward 2050 – Higher efficiency and further levers could mitigate growth

Global water demand 2020[1)] vs. 2050 [km³]



Irrigation | Electricity | Manufacturing | Domestic | Livestock

2020
4,325 km³

+26%

2050
5,467 km³

Water:
Main drivers of demand

> Population growth
> GDP growth
> Growing prosperity
> Urbanization
> Sectoral change

Water:
Main levers for a sustainable water resource management

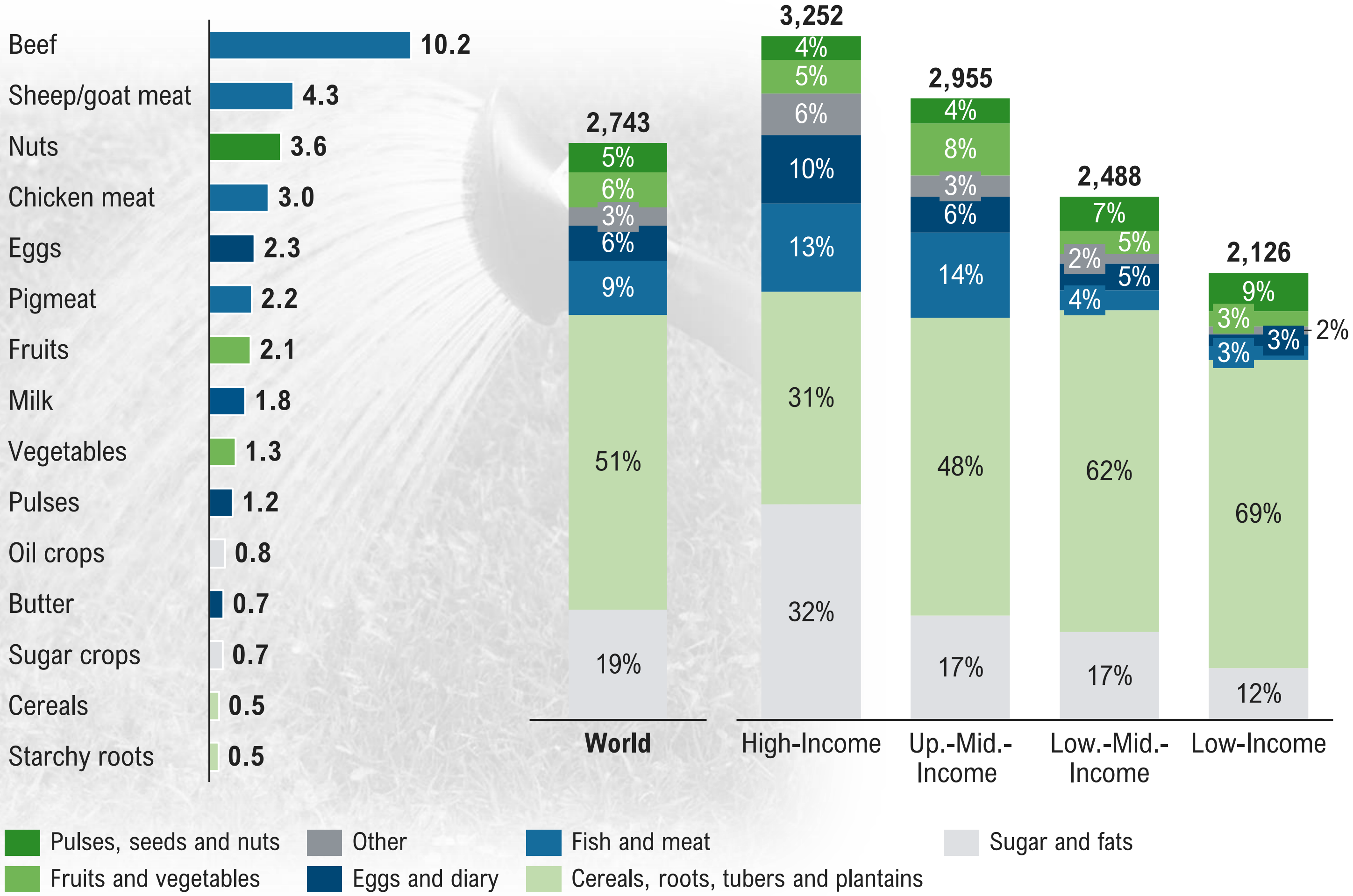
> Incentivize water use efficiency
> Invest in innovative water storage
> Reconsider water allocation mechanisms
> Mitigate water related disasters
> Improve wastewater treatment/reduce run-off
> Accelerate water supply and sanitation in developing countries
> Improve coherent water governance

1) Values for 2020: Linear extrapolations with 2000 and 2050 values; 2) BRIICS: Brazil, Russia, India, Indonesia, China, South Africa; 3) RoW: Rest of the world
Sources: OECD; Roland Berger

Water is essential for food production – Water requirements per kilocalorie differ fundamentally depending on food category

Water requirement of production [l/kcal]

Daily dietary intake, world and country groups by income, 2017 [kcal/capita]



- **Water extraction and food production** are closely **intertwined.** Producing water-intensive food carries disadvantages, especially in arid regions where there is a shortage of water and a shortage of food
- Most notably, **meat products** fall under the category of **water-intensive products**, as do other animal products such as eggs and dairy. **Tree nuts** (almonds, pistachios, walnuts, cashews) are some of the most **water-intensive crops** grown today
- Dietary intake is deeply dependent on a country's **standard of living**. High-income countries can supply a **calorie intake** of more than 3,200 kcal, whereas low-income countries can only supply two thirds of that
- **Meat consumption is related to income,** too – hence the resulting water consumption. While in high-income countries, fish and meat take up a large amount in terms of calorie intake, in poorer countries, these foods are almost negligible

Sources: Unesco-IHE; FAO; Roland Berger

To meet the future demand for food in a sustainable manner, three gaps need to be closed until 2050 …

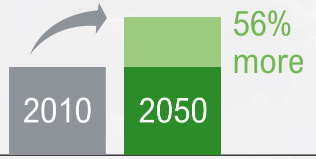
Global food demand 2010[1)] vs. 2050 [km³]

Food
Main drivers of demand

> Population growth
> Growing prosperity leading to a shift in diets

Three gaps that must be closed to achieve a sustainable food future in 2050: To meet the higher demand for food in 2050 we need (compared to 2010) …

… **56% more** crop calories to be produced …

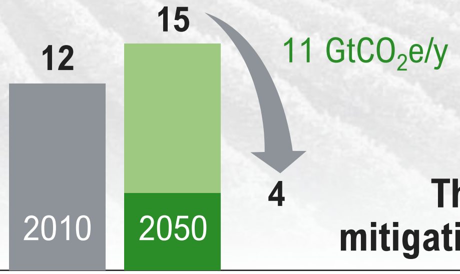


The food gap

… which requires **593 m ha more** agricultural land …

The land gap

… resulting in an amount of 15 $GtCO_2e/y$ GHG emissions from agriculture and land-use in 2050. This is **11 $GtCO_2e/y$** higher than the amount to comply with the 2°C Paris goal



The GHG mitigation gap

Food
Main levers to close the gaps

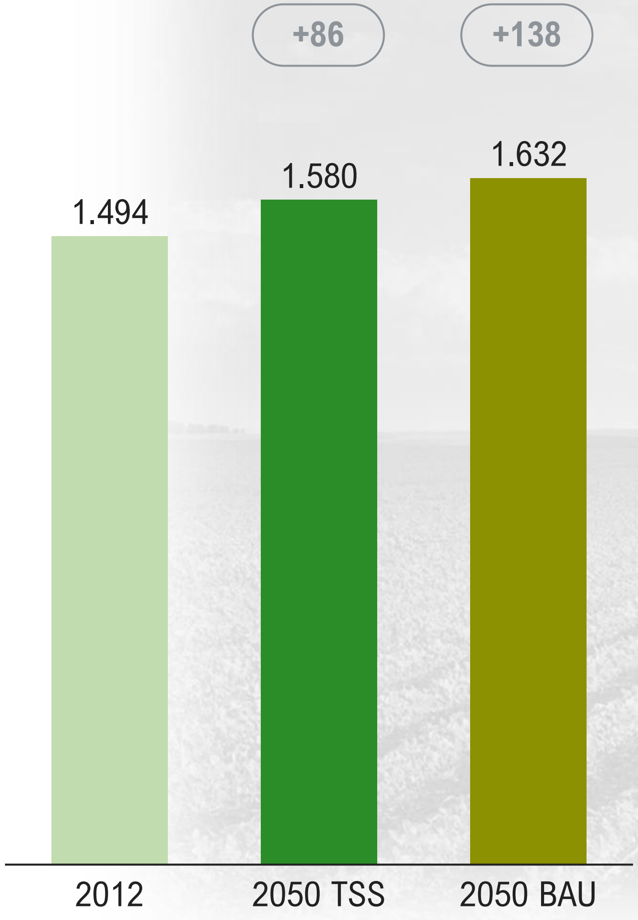
> Raise productivity
> Manage demand
> Link agricultural intensification to natural ecosystems protection
> Moderate ruminant meat consumption
> Target reforestation and peatland restoration
> Require production-related climate mitigation
> Spur technological innovation

1) With current rate of productivity gains, emissions from agriculture and land-use change will increase to 15 $GtCO_2e$ per year in 2050
Sources: World Resources Institute; Roland Berger

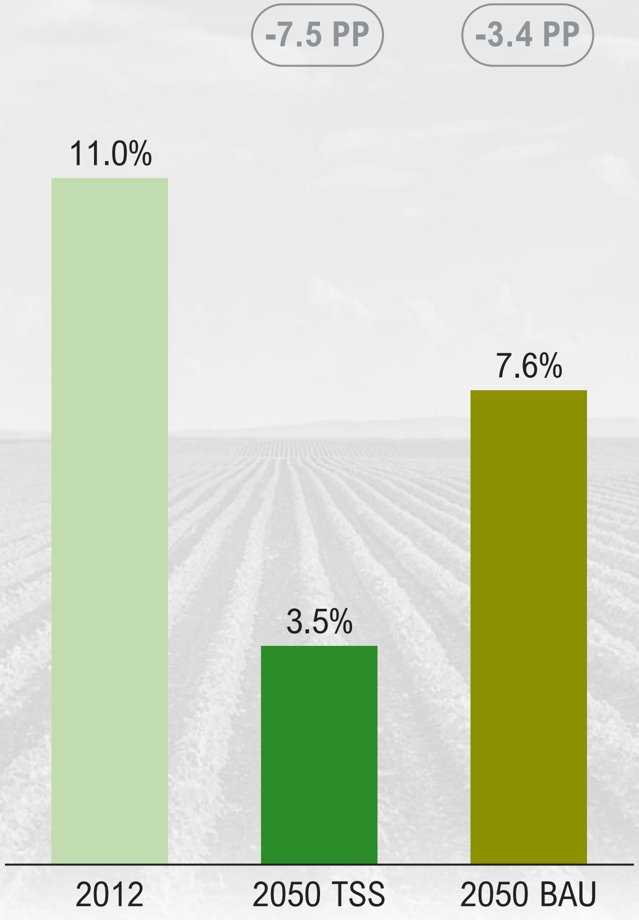
Roland Berger

… however, closing all three gaps at once will be challenging – More action is needed to feed the global population

Arable land worldwide [Mio. ha]



Global prevalence of under-nourishment [% of population]



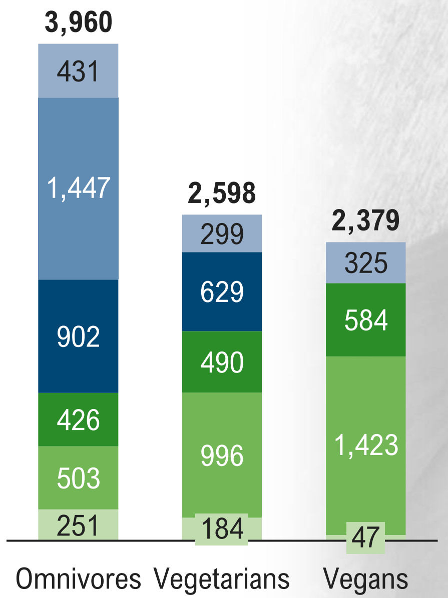
- To **reconcile social, economic and ecological needs** appears to be one of the most **challenging tasks**. However, the goals should not be considered as mutually exclusive, but should be attained as **complementary goals**
- The so-called "Towards Sustainability Scenario" (TSS[1)]) aims to comply with the requirements of all three goals, yet it excludes eradicating hunger globally; prevalence of undernourishment is expected to decrease by 7.5 percentage points by 2050 under the TSS scenario
- Fewer people would suffer from hunger if essential parameters were changed. A **fair distribution** could be achieved by having **less meat consumption** in richer countries. A further efficient way to reduce global hunger is by **minimizing food waste:** Today, the amount of food wasted during production or thrown away annually equates to the amount needed to nutritionally sustain 3 billion people

1) TSS: Towards-sustainability-scenario refers to meeting the climate target, a globally fairer distribution of income, and a more sustainable agriculture; BAU: Business-as-usual scenario refers to a continuation of current policies

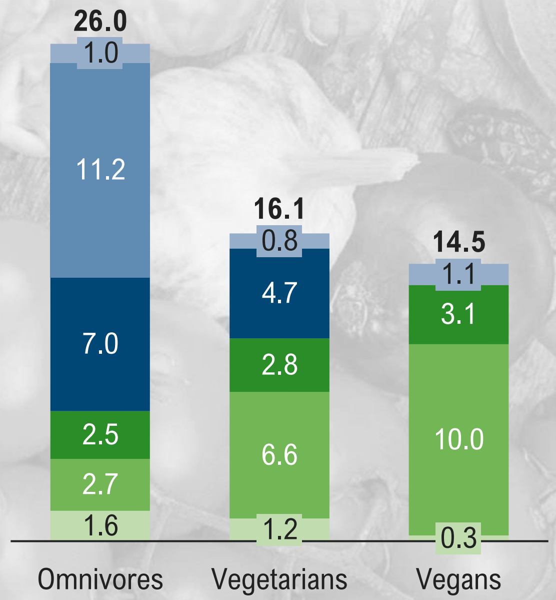
Sources: FAO; Roland Berger

Moving away from an omnivore diet, options to meet 2050 food demand include plant-based and cell-based meat as resource-saving alternatives

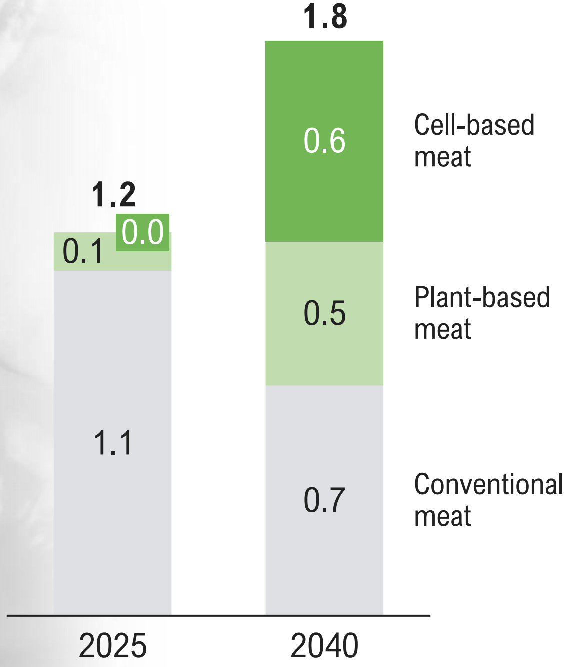
Daily carbon footprint[1)] [g CO_2e]



Daily ecological footprint[1)] [global m²/d]



Global market size for meat and meat substitutes [USD trillion]



Drinks | Other animal-based foods | Other vegetable-based foods
Meat and fish | Cereals and their derivatives | Sweets and desserts

> In order to **conserve scarce resources** and at the same time **reduce global hunger** even further by 2050, greater **emphasis** should be placed on **alternative** (meat-less) **diets** such as vegetarian and vegan diets, both having a lower carbon footprint and a smaller impact on resources

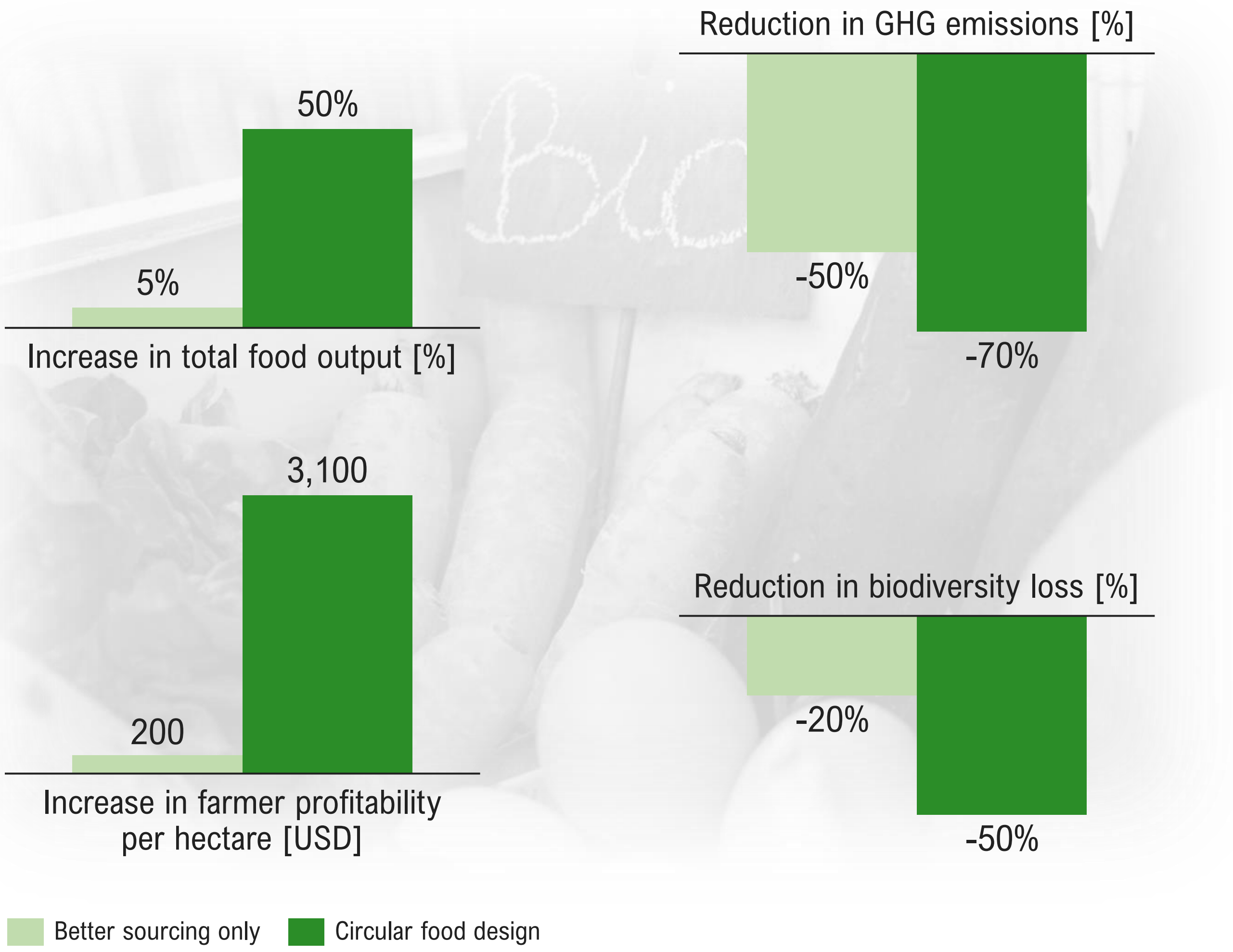
> Under scarcity of resources constraints, **plant-based meat substitutes**, but also laboratory-grown **cell-based meat**, will play an increasing role in future years

1) Volunteers were recruited for a previous observational multi-center study, enrolled across four centers in Italy. A total of 153 healthy adults (aged 18–60 years), recruited according to their self-reported habitual diets, completed the study: 51 omnivores, 51 ovo-lacto-vegetarians, 51 vegans

Sources: Nature; Meat Atlas Report; Roland Berger

Circular design principles applied to food sectors provide a further way to close the three gaps while also reducing the impact on biodiversity

Average effects of a sustainable and circular design for food[1)2)]

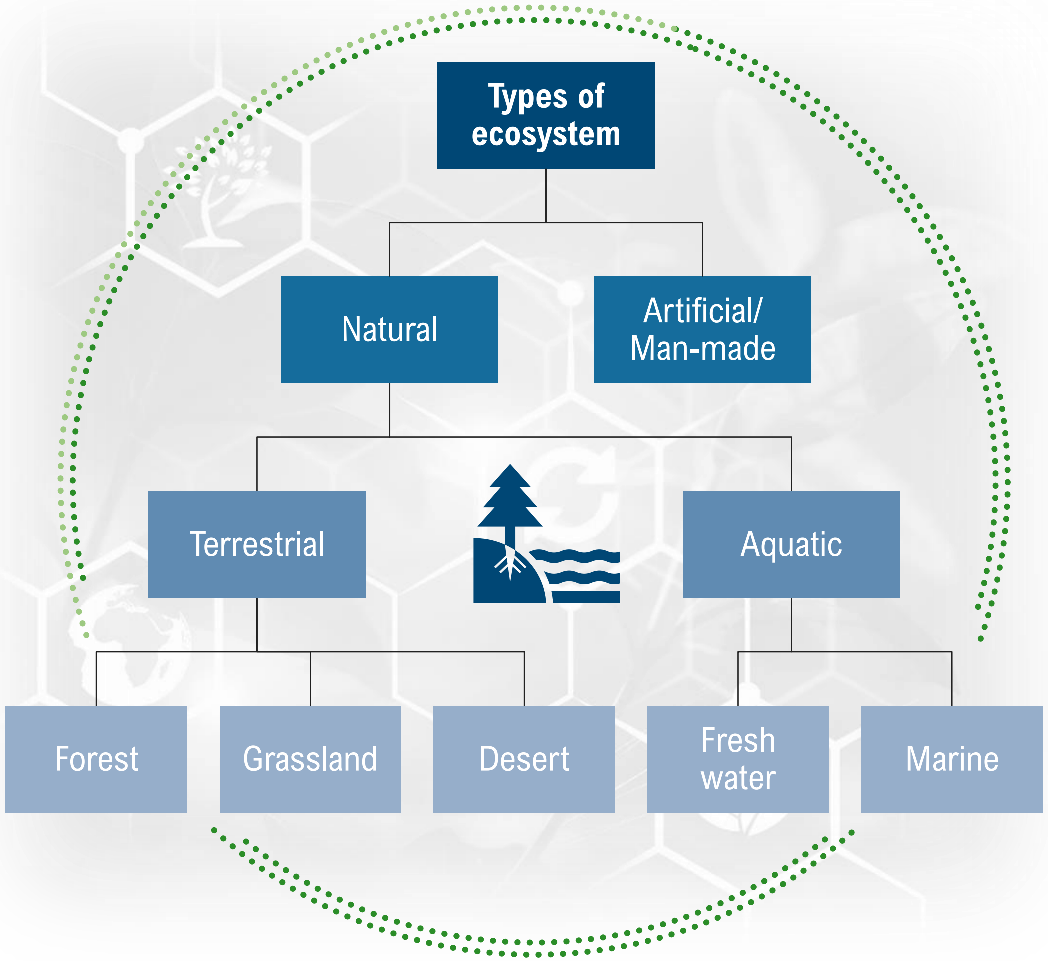


- **Sustainable** farming practices underpin multiple environmental goals – applying **circular economy ideas** to **agricultural and food production sectors** sets free **further potential**; the extent of implementation determines not only the increase of food output and profitability, but also the reduction of GHGs and biodiversity loss
- In this way, the **circular food design concept combines different aspects of sustainability**, each of them already having a profound effect on food supply and the environment. For example, **upcycling** the global harvest of cascara (coffee cherry husk, a coffee bean byproduct) **as an ingredient** (flour) – rather than leaving it to decompose – could save GHGs equal to 730,000 return flights from London to New York
- Following circular food design principles brings increased profitability due to development in other areas and sectors, such as sustainable packaging
- To further **stabilize soils** around the world, crop farming should be **diversified further** as presently just four crops (wheat, rice, corn and potatoes) provide almost 60% of the calories consumed globally
- In this way, **circular design for food** combines a diverse, upcycled and regenerative production of food with a **lower impact for biodiversity**

1) For three modelled ingredients (per harvest for wheat and potatoes, and per year for diary) in the UK and EU;
2) A sustainable design for food includes, but is not limited to, healthy and stable soils, improved local biodiversity, and improved air and water quality
Sources: Ellen MacArthur Foundation; Roland Berger

Ecosystems comprise our ambient environment – The surface of the Earth is a series of connected ecosystems threatened by human activity

Classification of ecosystems

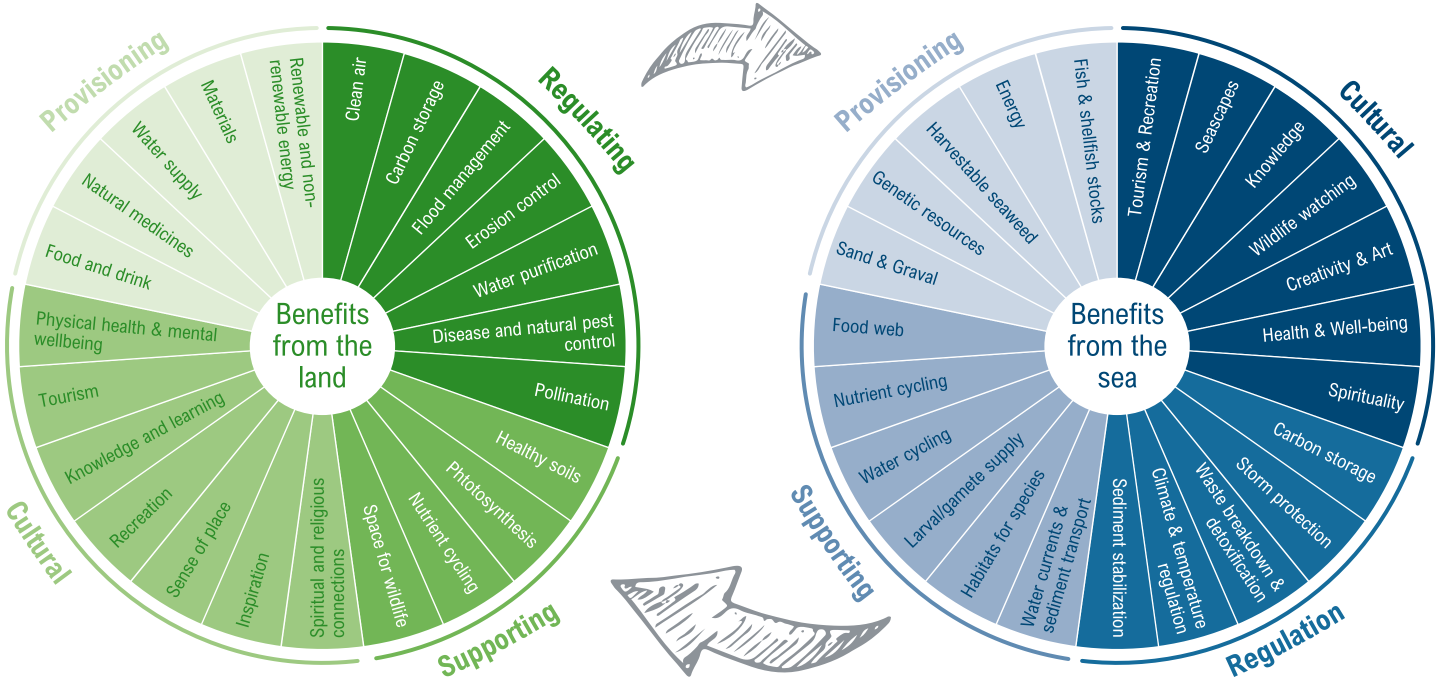


- An **ecosystem** is the **systematic interaction of a set of** living (biotic i.e. animals, plants, and other tiny organisms) and non-living (abiotic i.e. rocks) components of an area engaging within a particular **habitat**; a **habitat** is specific to a **species** or population of organisms – its main components are **shelter**, **water**, **food** and **space**
- Covering around **71% of the planet's surface area**, **aquatic ecosystems** are the Earth's biggest ecosystem: **Aquatic ecosystems** broadly comprise **marine** (saltwater) **and freshwater environments** such as wetlands, watersheds, fisheries (coastal), freshwater lakes, estuaries, mangroves, coral reefs and the ocean
- **Terrestrial ecosystems** cover the remainder (around **29%**): Key categories of terrestrial ecosystems include **deserts, grasslands, and forests**
- Any number of ecosystems and habitats make up a **biome**: A **biome covers a wider physical area than an ecosystem or habitat** and has a relatively large 'geographical zone' defined mainly by its **climate** (**precipitation** and **temperature**). The same biome (e.g. tundra, tropical rainforest) may reoccur in several other locations around the world that share similar conditions. Because biomes are largely shaped by climate, **if the climate changes so does the biome**
- **Ecosystems** differ enormously depending on **a range of factors** other than climate, namely underlying geology, soil status, nutrients, plant and animal life, hydrology, etc. – all **prone to human-made activity and manipulation**

Sources: National Geographic; Dasgupta Review; Roland Berger

What's at stake? Ecosystem services are the benefits humans derive from nature – Over half of the world's GDP is dependent on nature's services

Terrestrial and aquatic ecosystem services – Illustrative



> **Over half of the world's GDP is moderately to highly dependent on ecosystem services and biodiversity,** such as through pollination, soil health, water quality and provision of natural resources
>
> **World Economic Forum**

- Ecosystem services are understood as the **benefits people obtain from nature** – the direct and indirect contributions provided for human wellbeing and quality of life
- Ecosystem services include basic services – **provisioning services** like the delivery of food, fresh water, wood, fuel, fiber, and medicine – and services that are equally critical but less tangible and more complex to quantify: **Regulating services** like carbon sequestration, pollination, and erosion control; **cultural services** like recreation, ecotourism, and educational values; and **supporting services** such as nutrient and water cycling
- Humanity depends on natural capital assets and ecosystem services: WEF research shows that **USD 44 trillion of economic value generation** – more than half of total global GDP – **is moderately or highly dependent on nature and its services**, and therefore directly exposed to risks from nature loss

Sources: Nature Agency Scotland; WEF; Roland Berger

Multiple pressures affect the state of global biodiversity, its species and ecosystems

Pressures on ecosystems services

Population	Consumption	Resources			**Causal factors**
Agriculture & forestry	Fishing & hunting	Urban & industry	Water use	Energy & transport	**Indirect drivers**
Land/sea use change	Direct exploitation	Invasive alien species	Pollution	Climate change	**Direct pressures on biodiversity & ecosystems**
Terrestrial	Marine	Freshwater	Species		**Biodiversity impact**
Provisioning services	Regulating services	Supporting services	Cultural services		**Ecosystem services**

- **Biodiversity** (biological diversity) is **fundamental to a healthy planet and to human well-being,** regulating environmental processes, including filtering pollutants, sequestering carbon, regulating ocean acidification, protecting soil quality, providing pollination and pest control, and hazard reduction
- Due to multiple **direct and indirect pressures** – and despite long-standing local, national and international environmental protection efforts – **biodiversity is deteriorating worldwide**
- Chief causes are **land and sea use changes** and (over)**exploitation**, **pollution**, **invasive alien species**, and **climate change**
- These five direct stressors result from an array of **underlying causes** across major sectors which are, in turn, linked to and driven by human population dynamics and societal behaviors, production and consumption patterns, resource use and overall governance

Sources: WWF; IPBES; Roland Berger

Environment & Resources

1 Climate Change & Pollution

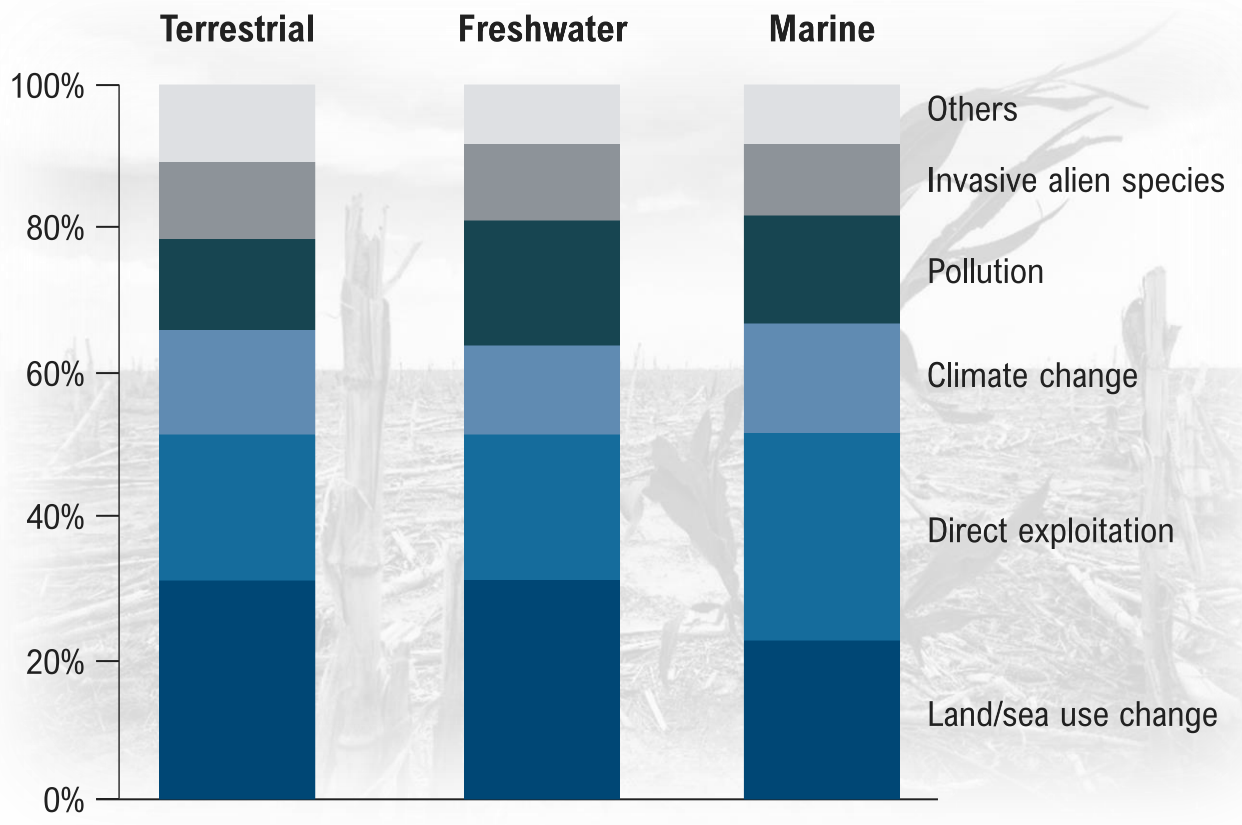
2 Resources: Abundance vs. Scarcity

3 Ecosystems at Risk

Changes in land/sea use and direct exploitation account for more than 50% of the global impact on ecosystems – Climate change an additional driver

Climate change and pollution are additional drivers for biodiversity loss (see subtrend 1)

Relative global impact of direct drivers[1)]



- **Direct drivers** (natural and anthropogenic) are drivers that **unequivocally influence biodiversity and ecosystem processes**
- **Natural drivers** cannot be influenced by human activity; these includes volcanic eruptions, earthquakes, tsunamis or tropical cyclones, for example
- **Anthropogenic drivers**, resulting from human decisions and activity, include habitat conversion, e.g., degradation of land and aquatic habitats, deforestation and afforestation, exploitation of wild populations, **climate change**, **pollution of soil, water and air**, and species introductions. Some of these drivers, such as pollution, can have negative impacts on nature; others, as in the case of habitat restoration, or the introduction of a natural enemy to combat invasive species, can have positive effects
- According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), **land- and sea-use change and direct exploitation account for more than 50% of the global impact on land and aquatic ecosystems** – but each driver is dominant in certain ecosystem contexts

1) The color bands represent the relative global impact of direct drivers on terrestrial, freshwater and marine nature, as estimated from a global systematic review of studies published since 2005
Sources: IPBES; Roland Berger

Across ecosystems and species, human activity continues to severely erode the world's ecological foundations and biological diversity

Illustrative findings to ecosystem and biodiversity damage

> **Human actions have already severely altered around 3/4 of the land surface and 2/3 of the ocean area** IPBES

Aquatic ecosystems

- **At least 55% of ocean area** is covered by industrial fishing
- **33% of fish stocks** are overfished
- **50% of the world's coral reef system** has been destroyed

Terrestrial ecosystems

- **More than 85% of wetlands** have been lost
- **1/3 of the world's topsoil** has been degraded
- **32% of the world's forest area** has been destroyed
- The **Amazon has lost 17% of its size** in the past 50 years

Species

- **83% population decline across freshwater species** since 1970
- **60% population decline across vertebrate species** since 1970
- **41% of know insect species** have declined in the past decades
- **Around 25% of assessed plant and animal species are threatened** by human actions, with a million species facing extinction, many within decades

Sources: WEF; IPBES; Roland Berger

Biodiversity Intactness Index is an indicator of biodiversity loss under human pressures – Improvements require a sustainability lens

Biodiversity Intactness Index (BII) of selected countries in 2020[1)] [0-100%]; BII changes to 2050 under a middle-of-the-road scenario (SSP2) and a sustainable scenario (SSP1) [percentage points (PP)]

Country	2020BII[1)]	Change to 2050 under SSP2[1)]	Change to 2050 under SSP1[2)]
Papua New Guinea	100%	➡ 0 PP	➡ 0 PP
Canada	92%	⬇ -1 PP	➡ 0 PP
Finland	88%	⬇ -11 PP	⬇ -8 PP
Brazil	80%	⬇ -2 PP	➡ 0 PP
Japan	79%	⬇ -1 PP	➡ 0 PP
Indonesia	73%	⬇ -2 PP	⬆ +1 PP
Australia	71%	➡ 0 PP	⬆ +1 PP
US	67%	➡ 0 PP	⬆ +1 PP
China	67%	➡ 0 PP	⬆ +2 PP
Germany	61%	⬇ -1 PP	⬆ +5 PP
India	57%	⬇ -3 PP	➡ 0 PP
Ireland	56%	⬆ +7 PP	⬆ +8 PP
South Africa	55%	➡ 0 PP	⬆ +1 PP
UK	54%	⬆ +2 PP	⬆ +3 PP
Nigeria	52%	⬇ -2 PP	➡ 0 PP

>90% – Safe limit: Threshold for areas to have **enough biodiversity** to be a **resilient** and **functioning ecosystem**

Globally, biodiversity intactness is measured at 75%

<30%, depleted biodiversity to an extent of what is **needed for** a **functioning ecosystem**

> **Biodiversity intactness** is defined as the modeled average abundance of originally present (i.e. pre-modern times) species, relative to their abundance in an intact ecosystem after land use change or human impacts

> In other words, the **Biodiversity Intactness Index (BII) estimates how much of an area's natural biodiversity remains**

> **At country** level, it can be used to **show how terrestrial biodiversity has fared under pressures from humanity** nationally

> The BII concept also helps to demonstrate **plausible improvement to 2050 under sustainability development aspects (sustainable scenario)** – or not, as is the case in the middle-of-the road scenario

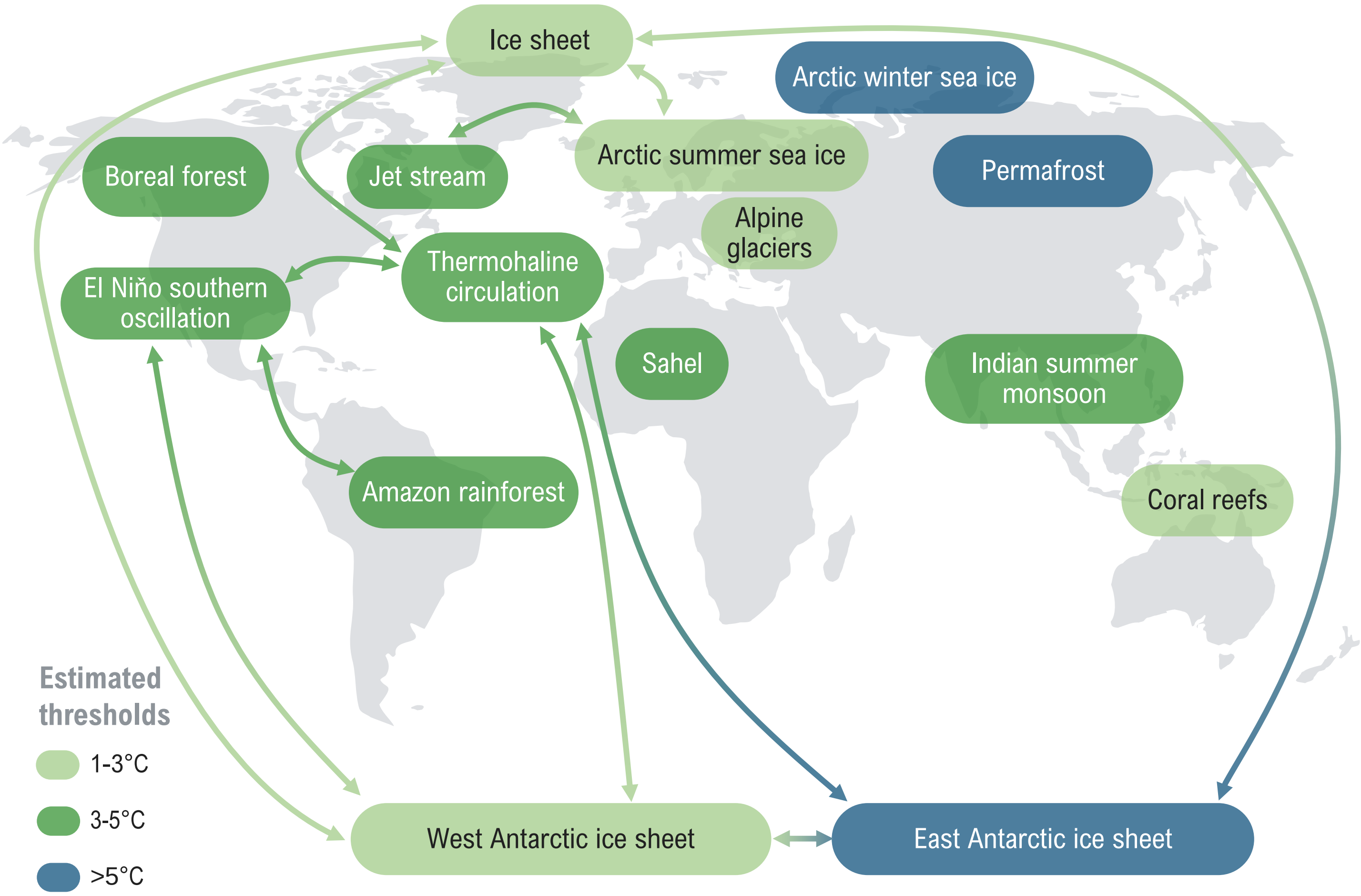
> The underlying database is the largest and most geographically and taxonomically representative of spatial comparisons of biodiversity collated to date – including around **54,000 species** of birds, mammals, plants, fungi and insects **across 26,000 locations**

> **All major organizations** concerned with environmental issues (e.g. UN, CBD, IPBES) have **adopted the BII as a core ecological indicator**

1) Based on a "middle-of-the-road" scenario (SSP2); 2) Based on a "sustainable development" scenario (SSP1) in 2050
Sources: Natural History Museum; Roland Berger

Global warming is pushing the Earth's major components near or over their thresholds – A number of tipping points have been assessed

Potential tipping elements and cascades according to estimated thresholds (tipping points) in global average surface temperature[1)]



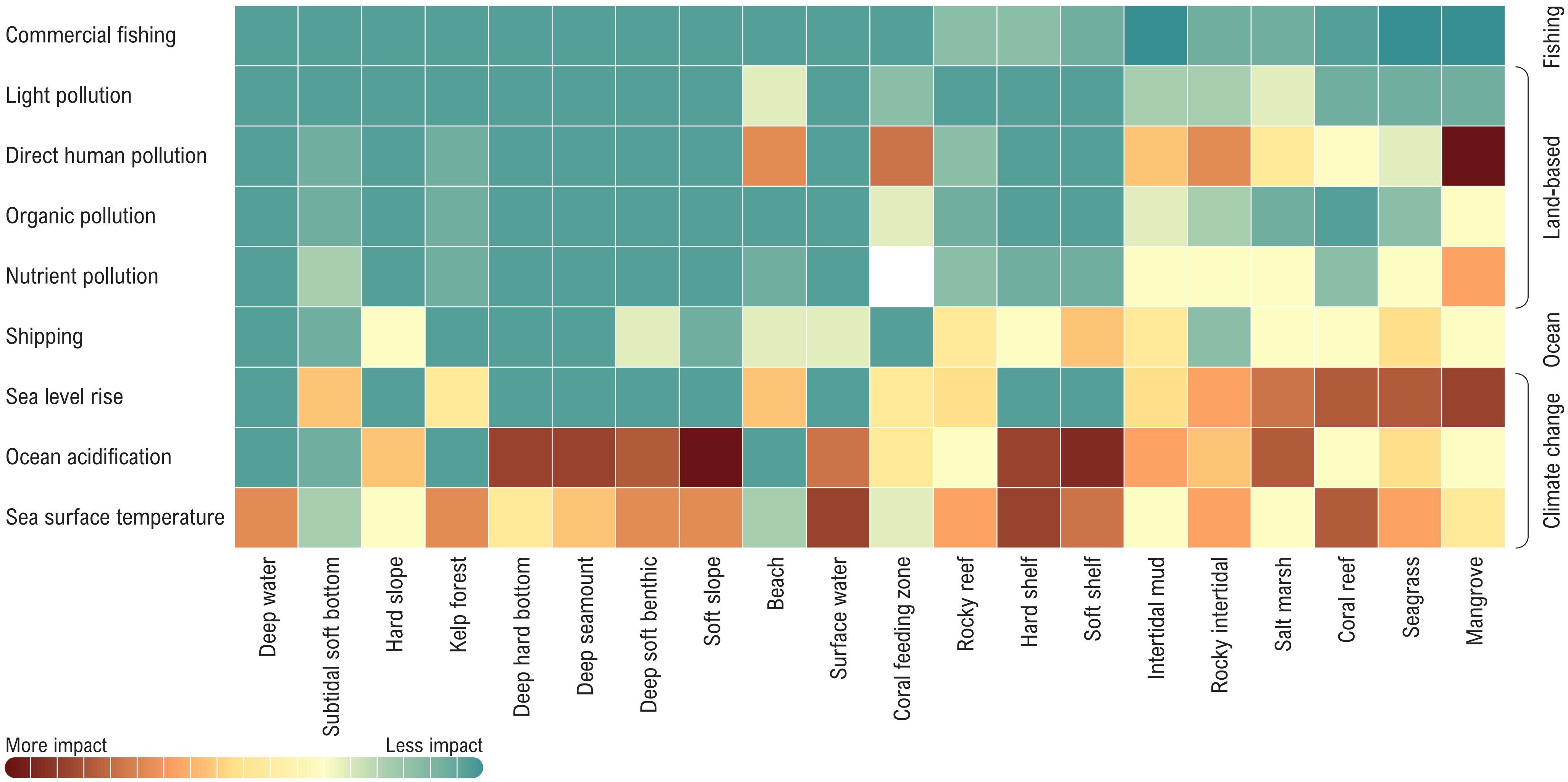
- > **Tipping elements** are large-scale, relevant **components of the Earth's system**, which are characterized by a threshold behavior
- > There are three groups of tipping elements: **Ice masses** (e.g. Arctic sea ice melting), **oceanic** and **atmospheric circulations** (e.g. that of the Atlantic ocean), and **large-scale ecosystems** (i.e. biosphere components such as coral reefs)
- > Large-scale discontinuities in the climate system have a **temperature change threshold** – a **tipping point**; once tipped, transition (abrupt or gradual) can continue without further forcing
- > **Tipping points vary:** For example, coral reefs are more susceptible to rising temperatures than the Amazon rainforest
- > Information from most recent IPCC reports suggests that **tipping points could be exceeded even between 1 and 2°C of warming** – not at 5°C as was previously thought
- > Climate scientist have identified over a dozen possible tipping points in relation to climate change and note that **cascading effects** might be common

1) Tipping point in degrees Celsius above the average pre-industrial temperature (pre-1850); colors according to estimated thresholds; arrows show potential interactions among tipping elements

Sources: Steffen et al./PNAS; EEA; PIK; Nature; Roland Berger

Oceans are threatened from sea- and land-based human activities – 59% of marine ecosystems are under cumulative pressures

Different marine environments and their exposure to and impact of a range of human activity pressures



Sources: Nature; Roland Berger

Ocean ecosystem services include the production of at least half the oxygen we breathe; Ocean economy GVA to reach USD 3 trillion by 2030

Global value added and jobs in the ocean economy in 2030 [constant 2010 USD]

	2010		2030
GVA	1.5 trillion	✖ 2.0	3 trillion
Jobs	31 million	✖ 1.3	40 million

Overview of industry-specific value added in the ocean economy [constant 2010 USD billions]

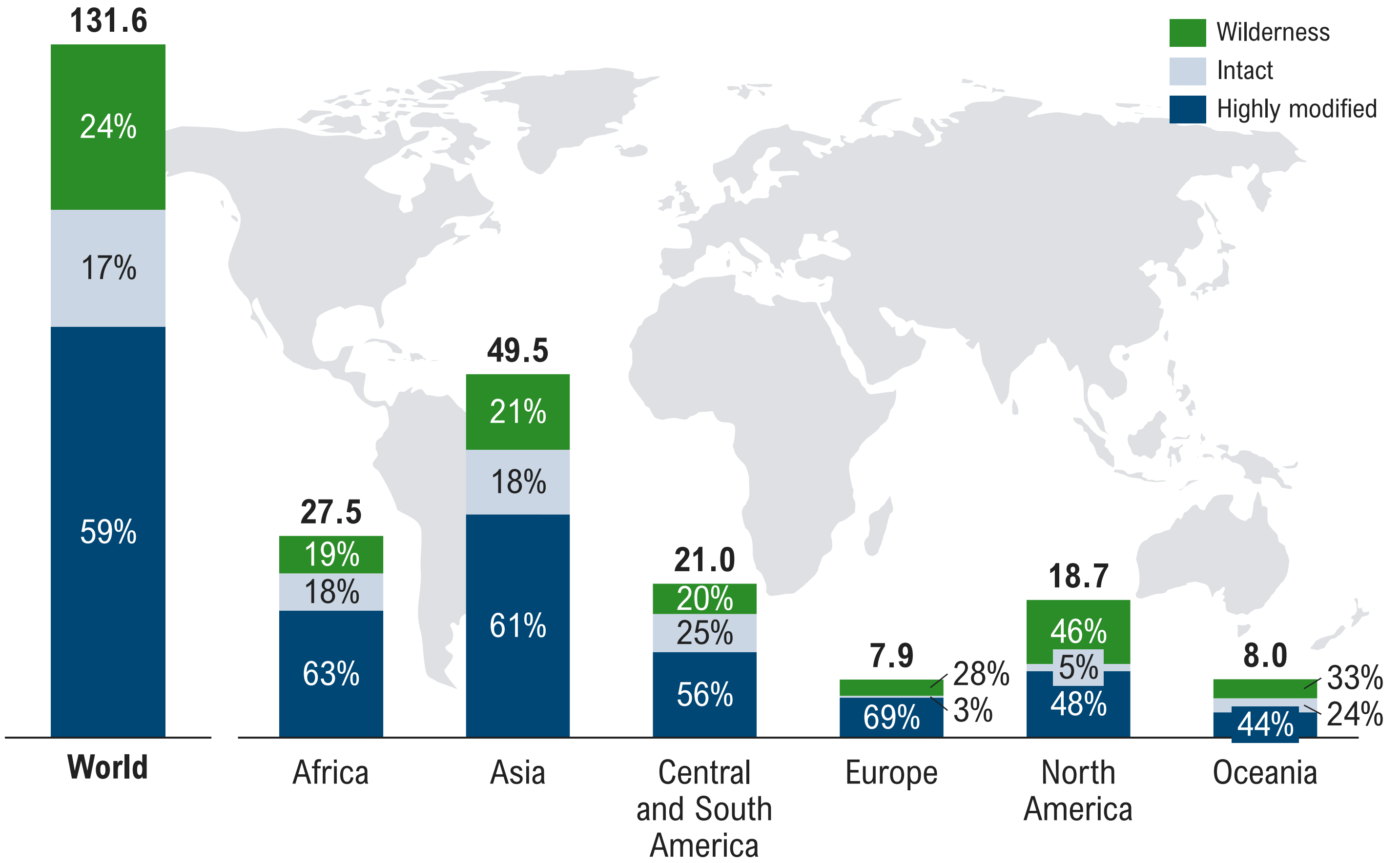
Industry	2010	2030
Maritime and coastal tourism	390	777
Offshore oil and gas	504	636
Port activities	193	473
Maritime equipment	168	300
Fish processing	79	266
Offshore wind	3	230
Water transport	83	118
Shipbuilding and repair	58	103
Industrial capture fisheries	21	47
Industrial marine aquaculture	4	11

- > Ocean ecosystem services: The ocean produces at least **half the oxygen we breathe (50-80%)** and **absorbs more than a quarter (>25%) of the anthropogenic emissions of carbon dioxide (CO_2)** and around **93% of the added heat** arising from human-driven changes to the atmosphere
- > Ocean economy value: Prior to the COVID-19 pandemic, **OECD projected a doubling of the ocean economy from 2010 to 2030, to reach USD 3 trillion and employ 40 million people**
- > The ocean economy spans **multiple sectors** – including oil and gas, fishing, aquaculture, shipping, ports, tourism, offshore wind energy, and marine biotechnology – and is growing rapidly

Sources: OECD; EarthSky; Ocean-Climate; Roland Berger

The state of our land areas is highly modified: Almost 60% of the Earth's terrestrial area is under moderate to intense human pressure

Share of anthropogenic disturbances and total surface on continents[1)] [%, Mio. km^2]



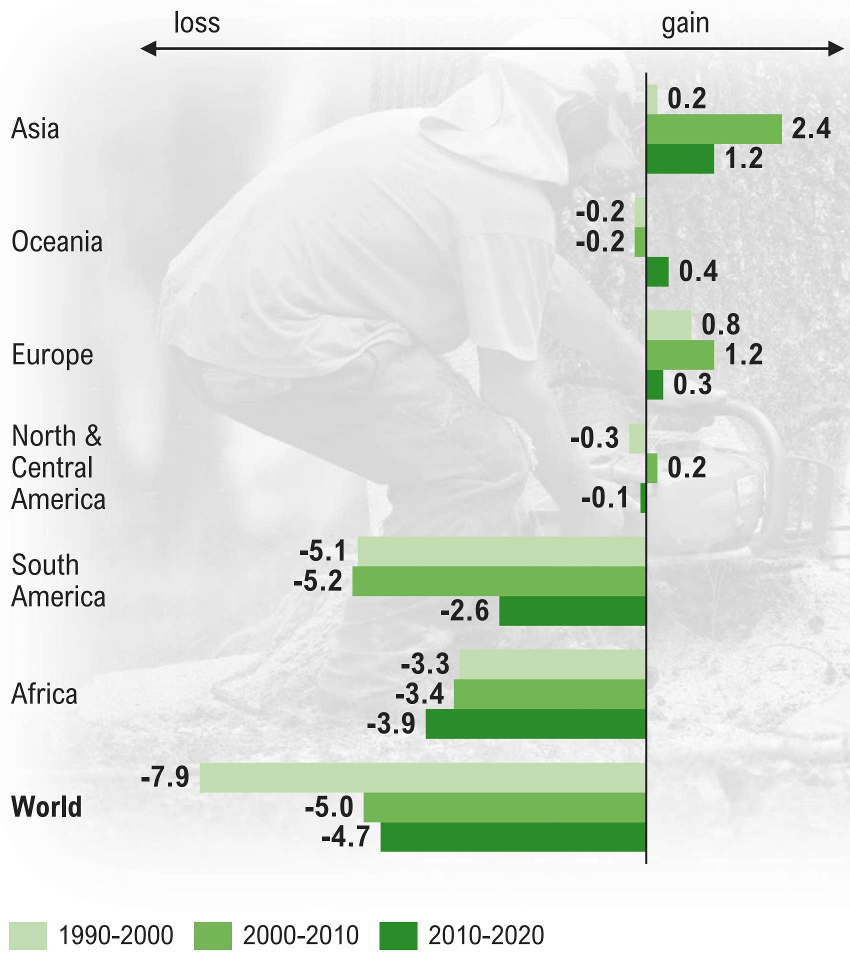
- Based on data from recent surveys, **less than half (41.6%) of the Earth's surface was intact or wilderness**, i.e. with a human footprint below the threshold to being highly modified (≥4) – meaning it was assessed as being **ecologically intact**
- However, this includes mostly **wilderness** (24%). Other **ecologically intact areas** (17%) include areas with low density **transitory human populations**, for example, as well as low intensity grazing pastures
- The remaining area **(59%)** – with a human footprint of ≥4 – was under **moderate or intense human pressure** and is therefore regarded as **highly modified**
- This highly modified area encompasses **over half the area of 11 of Earth's 14 biomes**
- The ≥4 **threshold** has been found to be **robust** from a **species conservation perspective** because, once surpassed, species extinction risk increases dramatically, and several **ecosystem processes are altered**

1) Human Footprint: Study uses a human footprint threshold of <4 (on a 0–50 scale) to identify where land is considered ecologically intact (below the threshold) or highly modified and thus ecologically degraded (equal to or above the threshold). Areas below this threshold are ecosystems that may be subject to some level of human pressure, but still contain most of their natural habitat and maintain their ecological processes

Sources: One Earth/Brooke; Roland Berger

Although the global annual net rate of forest loss has eased, the sheer scale of deforestation in Africa and South America is an ongoing threat ...

Annual forest area net change by decade and region (1990-2020) [Mio. ha p.a.]



Deforestation projections from 2010 to 2030 (selective)

	Amazon	Greater Mekong	Borneo	Cerrado	Congo Basin
Projected loss of forest [Mio. ha]	23-48	15-30	22	15	12
Livestock	Primary cause of forest loss	Not a cause of forest loss	Not a cause of forest loss	Primary cause of forest loss	Less important cause of forest loss
Large-scale agriculture	Primary cause of forest loss	Primary cause of forest loss	Primary cause of forest loss	Primary cause of forest loss	Secondary cause of forest loss
Small-scale agriculture colonization	Primary cause of forest loss	Secondary cause of forest loss	Secondary cause of forest loss	Not a cause of forest loss	Primary cause of forest loss
Unsustainable logging	Less important cause of forest loss	Secondary cause of forest loss	Secondary cause of forest loss	Not a cause of forest loss	Secondary cause of forest loss
Pulp plantations	Not a cause of forest loss	Secondary cause of forest loss	Secondary cause of forest loss	Not a cause of forest loss	Not a cause of forest loss
Fires	Secondary cause of forest loss	Not a cause of forest loss	Secondary cause of forest loss	Not a cause of forest loss	Not a cause of forest loss
Charcoal and fuelwood	Not a cause of forest loss	Less important cause of forest loss	Not a cause of forest loss	Less important cause of forest loss	Primary cause of forest loss
Mining	Secondary cause of forest loss	Not a cause of forest loss	Not a cause of forest loss	Less important cause of forest loss	Secondary cause of forest loss
Hydroelectric power	Primary cause of forest loss	Less important cause of forest loss	Less important cause of forest loss	Secondary cause of forest loss	Secondary cause of forest loss
Infrastructure	Primary cause of forest loss	Less important cause of forest loss	Secondary cause of forest loss	Less important cause of forest loss	Not a cause of forest loss

Primary cause of forest loss | Secondary cause of forest loss | Less important cause of forest loss | Not a cause of forest loss

Sources: FAO; WWF; Roland Berger

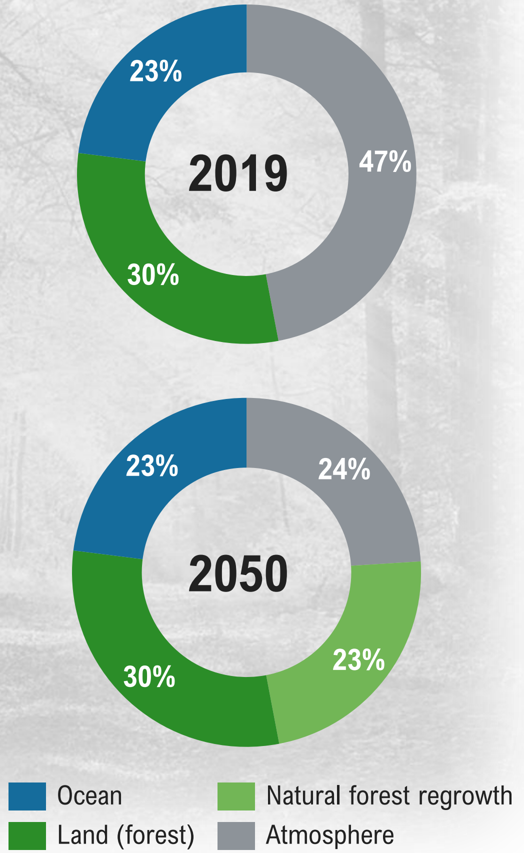
… to sustain the global forest ecosystem as a carbon sink – twice the size of annual US carbon emission – as well as its natural reforestation potential

Forest ecosystem services – Forest ecosystem value

USD 16.2 trillion is the estimated **value of ecosystem services** provided by forests in 2018

The formal forest sector account for estimated **45 million jobs**, generating **labor income** of **USD 580 bn** per year in 2018

Share of CO_2 emissions absorbed by forests in 2019 and potential impact of natural forest regrowth until 2050[1)]



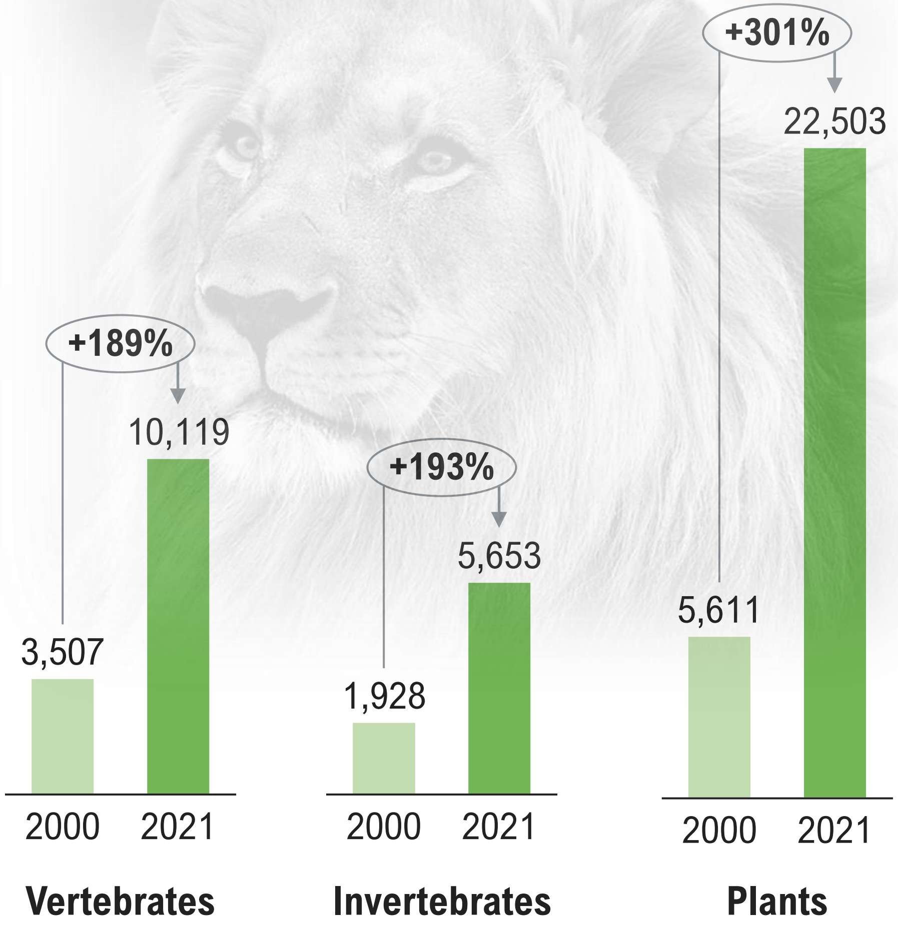
- **Humans' benefit** are reliant on what nature provides; this includes **terrestrial ecosystems such as forests**
- In terms of **biodiversity**, the world's forests contain **60,000 different tree species**, 80 percent of amphibian species, 75 percent of bird species, and 68 percent of the world's mammal species
- According to the FAO, around **30% of CO_2 emissions are absorbed by forests,** around 23% by the oceans. The remainder is absorbed by the atmosphere
- Through actions that **encourage natural forest regrowth until 2050, a 23%** increase in the absorptions of CO_2 emissions by such areas could be achieved (as 31% of the carbon is stored in the biomass and 69% in the soil) while helping to increase biological diversity across all species
- Reforestation is not a silver bullet: Proper selection of tree species and locations is critical – if not, it can do more harm than good. It is more important to **protect existing, natural forests and natural regrowth**

1) Bases on ground and Earth observation data to map annual forest-related greenhouse gas emissions and removals globally for the period 2001–2019

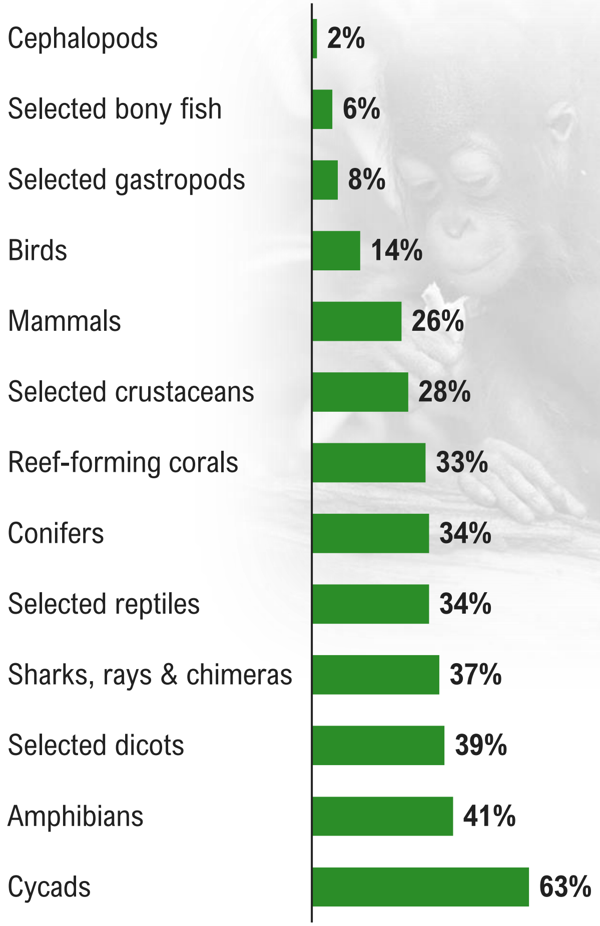
Sources: FAO; UN; UNEP; WRI

Over the last two decades the number of species classified as threatened has strongly increased …

Threatened species 2000 and 2021



Share of species (selective) classified as threatened 2021 [%]

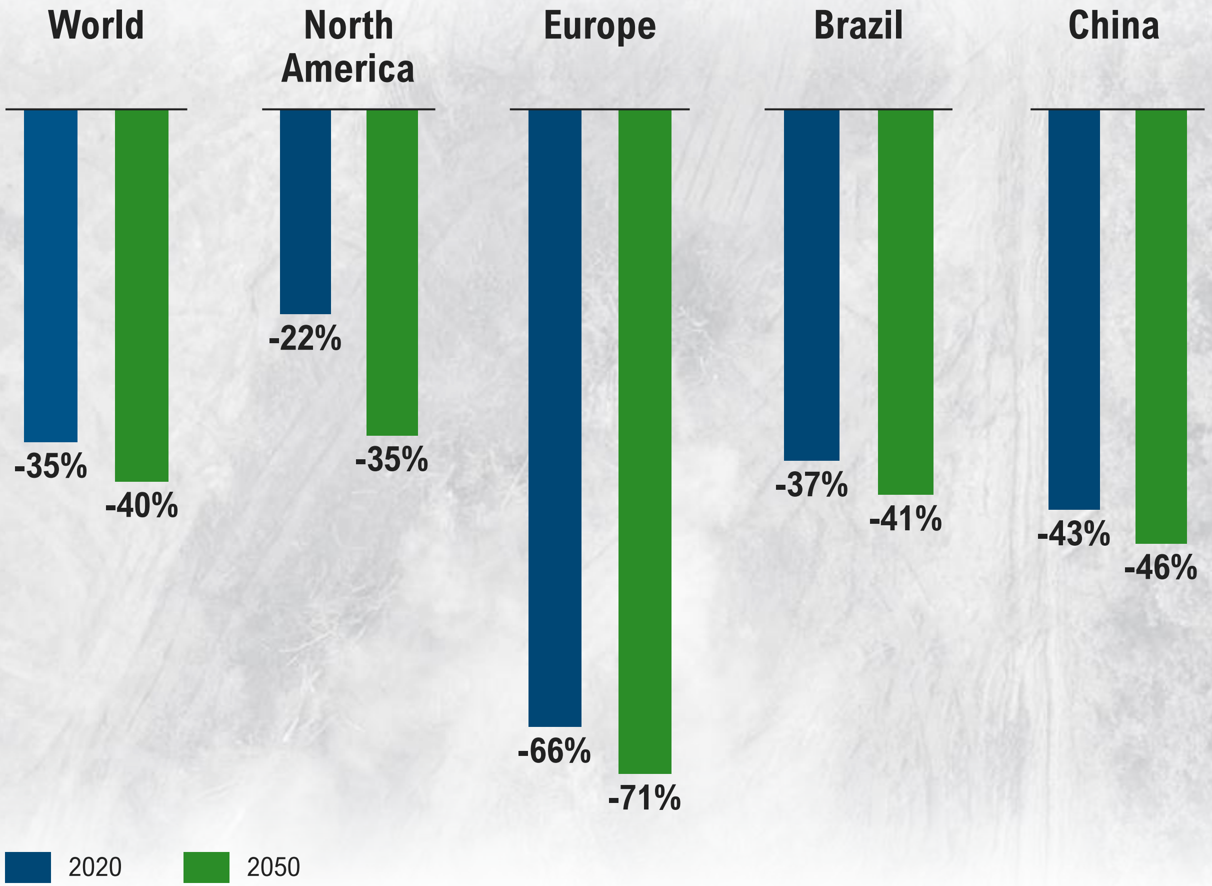


- The International Union for Conservation of Nature's **(IUCN) Red List** is the most acknowledged source to inform about the status and development of the global extinction of species
- In the **last two decades** the number of **species threatened** by extinction has **significantly increased**
- According to the IUCN, **1/4 of species are at risk of extinction**
- Caveat: The **IUCN list is under constant revision,** not least due to the discovery of new species; taxonomy changes and reassessments cause a variation in total numbers assessed year-on-year

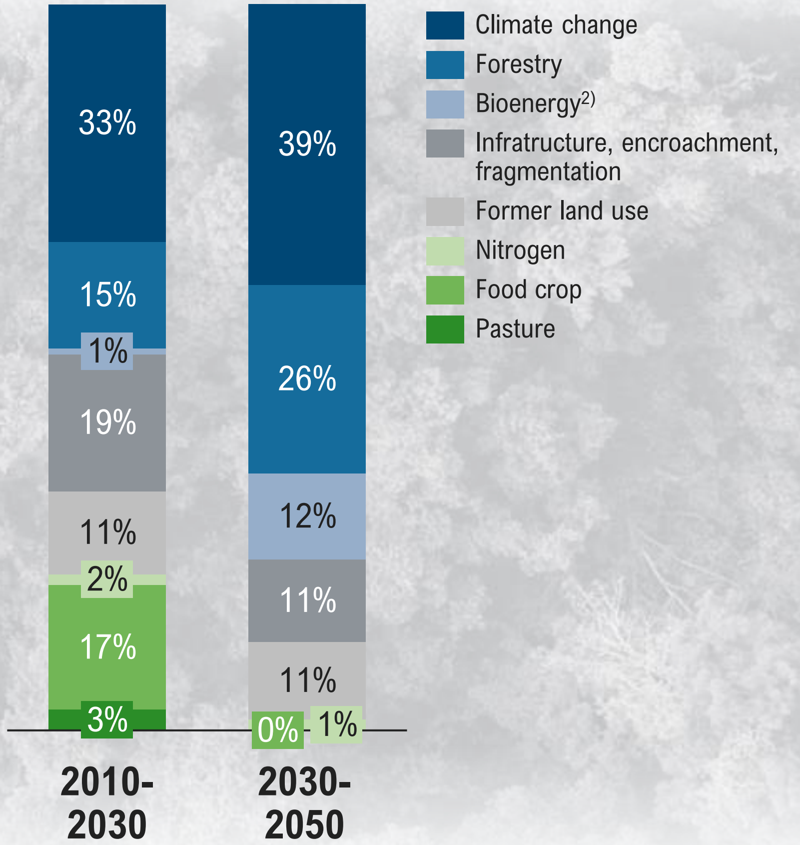
Source: IUCN; Dasgupta Review

… and biodiversity is expected to decline further in the future – The need to tackle rising pressures is high

Terrestrial mean species[1] abundance loss 2020 and 2050 for selected regions and countries[2] [% loss compared to pristine ecosystem]



Relative share of pressures to additional terrestrial biodiversity loss 2010-2050[2] [%]



1) Species account for all living organisms
2) According to the Baseline scenario of the OECD, which includes steady GDP growth and a strong ongoing use of fossil fuels
Sources: OECD; Roland Berger

Sustainable biodiversity is a 'must have' – For our planet but also for our economy – Animal world offers highly valuable services

Value of biodiversity for a sustainable and economically sound planet

USD 1 trillion

- Methods to quantify the economic value of biodiversity are complex yet important

Two **illustrative examples**:

- **Great whales** sequester 33 tons CO_2 on average over their lifetime. Together with other economic effects such as fishery enhancement, ecotourism and phytoplankton productivity **(capturing 37 bn. tons CO_2 p.a.)** the IMF puts the average value of a great whale at more than USD 2 m, and the value for the **current stock of great whales at over USD 1 trillion**
- More than 75% of global food crops are dependent on **insect pollinators**, thus contributing 35% of global food production. According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) the **annual value** of global crop output **at risk** due to **pollinator loss** is estimated at **USD 235-577 billion**

USD 235 - 577 billion p.a.

Sources: UN; WEF; IMF; Roland Berger

Rewilding is a more recent, progressive strategy aiming for long-term resilience in nature – Ultimately without regular human intervention

Since 2020, the Global Rewilding Alliance is partnered with the UN's Decade of Ecosystem Restoration to 2030

Global Rewilding Alliance – Terrestrial & Marine (101 members and growing)

> To restore stability to our planet, we must restore its biodiversity, the very thing that we've removed, it's the only way out of this crisis we've created – **we must rewild the world**
>
> **Sir David Attenborough**

- **Protect the best – rewild the rest:** The Global Rewilding Alliance brings together 100+ organizations from over 70 countries, now also in partnership with the UN and its agenda of the Decade on Ecosystem Restoration to 2030
- **Let nature lead:** All **rewilding** is also restoration, but not all restoration is rewilding – **rewilding aims for resilience in nature without human intervention**
- **Restoration,** on the other hand, refers to a **wide spectrum of activities such as reforestation,** erosion control, removal of non-native species, etc. – all efforts often requiring regular human intervention
- **Work at nature's scale: Initiatives** include efforts to **reintroduce wolves** to Yellowstone**, jaguars** to the marshlands of Argentina and **beavers** to the British Isles; restore free-roaming **bison herds** on the Great Plains of North America and parts of Europe; **restore tigers** to the forests of India; designate **new marine national parks** in the South Atlantic Ocean; bring back missing **megafauna** to wildlife conservancies in southern Africa; replenish the Scottish **forests**, and many more

Sources: Global Rewilding Alliance; Roland Berger

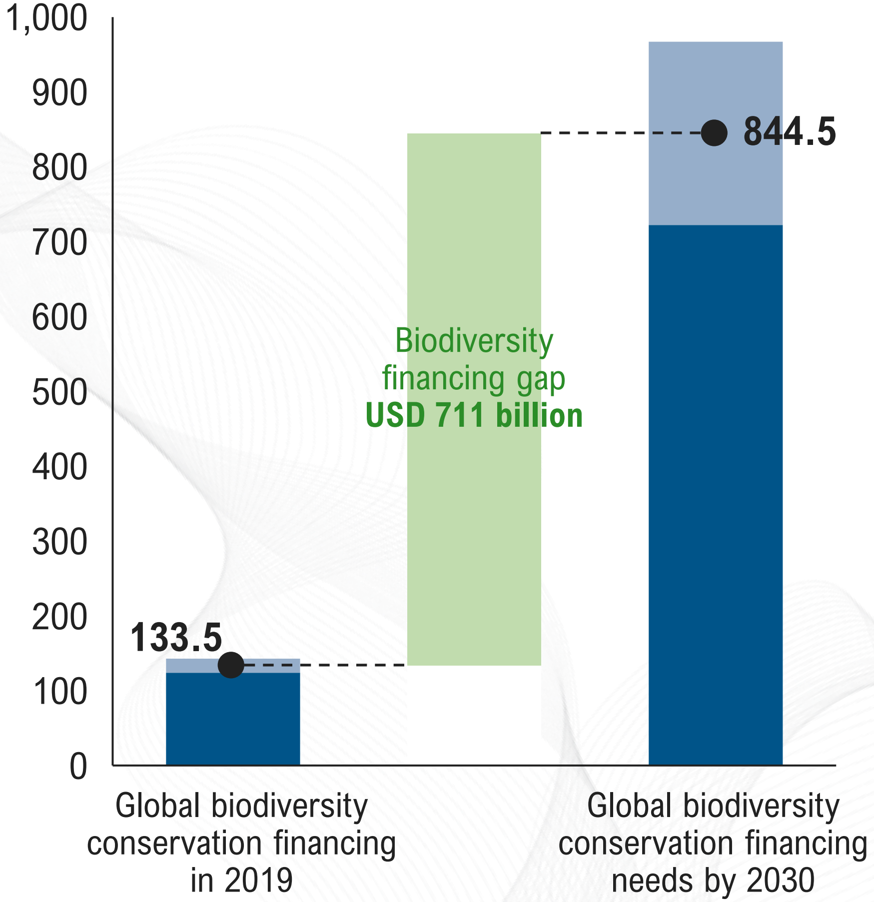
Less than 1% of annual global GDP could close the USD 711 billion annual biodiversity funding gap and conserve the planet's environment

Global biodiversity conservation financing vs. global biodiversity conservation needs [USD bn.]

Current biodiversity financing flows

> In 2019, the total **global** annual flow of funds toward **biodiversity protection** amounted to approx. **USD 124-143 billion p.a.**

> Meanwhile, annual **governmental expenditures on activities harmful to biodiversity** in the form of agricultural, forestry, and fisheries subsidies – USD 274-542 billion p.a. in 2019 – are **two to four times higher than annual capital flows toward biodiversity conservation**



Lower limit | Upper limit | ● Middle point

Future biodiversity spending needs and levers

> We need to spend **USD 722-967 billion p.a.** to **halt the decline** in global biodiversity between now and 2030

> This leaves an estimated global **biodiversity financing gap of USD 598-824 billion p.a.** – roughly equal to just under one percent of annual global GDP

Sources: Paulson Institute/Cornell/Nature Conservancy; OECD

Roland Berger

Environment & Resources

1 Climate Change & Pollution

2 Resources: Abundance vs. Scarcity

3 Ecosystems at Risk

Environmental and ecosystems protection have been on the global agenda for many decades – Efforts are intensifying to halt and revert nature loss

Timeline of major environmental and biodiversity milestones

1948: International Union for the Conservation of Nature **IUCN**

1961: **WWF**

1969: **Greenpeace**

1972: UN conference on Human Environment, Stockholm – **UNEP** founded

1992: UN Rio Earth Summit

1993: "Biodiversity Convention" Convention on Biological Diversity (**CBD**) treaty

1995: World Business Council for Sustainable Development **WBCSD**

2000: The UN's Millennium Development Goals to 2015 incl. goal 7: **Environmental sustainability**

2001: Millennium Summit & global **Millennium Ecosystems Assessment** 2004, findings presented in 2005

2005: **Group** on **Earth Observations** (**GEO**) / Biodiversity Observation Network – nature data network

2007: G8 environment ministers + 5 main newly industrialized countries meet in Potsdam

2010: First report of the Economics of Ecosystems and Biodiversity (**TEEB**) initiative

2010: UN International Year of Biodiversity

2010: Aichi Biodiversity Targets 2011-2020

2012: **IPBES** (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services); **latest global assessment published in 2019**

2015: UN **Sustainable Development Goals 2030**, including multiple environmental goals

2019: **G7 Metz Charter** on Biodiversity

2020: UN Biodiversity Summit: 70 world leaders **pledge to reverse nature loss by 2030**

2020: "**Nature-positive to 2030**" – Global goal for nature[1)]

2021: **Dasgupta** Review – The Economics of Biodiversity

2021: G7 leaders – **2030** Nature Compact

2021: **COP 15 meeting** to the Convention on Biological Diversity (CBD), **part 1 (virtual)**

2021–2030: UN **Decade of Ecosystem Restoration**

2022: **CBD / Aichi Vision 2050** – a post-2020 global biodiversity framework – draft to be finalized at **COP 15** meeting, **part 2**, in Kunming, April/May 2022[2)]

1) Proposed by a select group of internationally renowned scientists and ecology leaders 2) COP 15 to adopt a post-2020 global biodiversity framework as a steppingstone towards the Aichi 2050 Vision of 'Living in harmony with nature'

Source: Roland Berger

Time to pivot: Not only 'net zero' but also 'nature positive' – G7 2030 Nature Compact commits to paradigm shift needed for integrated crises actions

A new worldview: Climate and biodiversity crises are interdependent

G7 2030 Nature Compact

"We, the G7 Leaders, commit to the global mission to halt and reverse biodiversity loss by 2030. We will act now. Through this Compact, we commit to supporting global consensus and to taking bold action for delivery of ambitious outcomes for nature in 2021 at the Convention on Biological Diversity (CBD) COP 15 in Kunming and United Nations Framework Convention on Climate Change (UNFCCC) COP 26 in Glasgow in particular.

Climate change is one key driver of biodiversity loss, and protecting, conserving and restoring biodiversity is crucial to addressing climate change. Ahead of COP 15 (Kunming) and COP 26 (Glasgow), as we embark upon this pivotal decade, **we commit to tackle these interdependent and mutually reinforcing crises in an integrated manner,** thereby contributing to the achievement of the Sustainable Development Goals and a green, inclusive and resilient recovery from COVID-19.

Global system-wide change is required: our world must not only become net zero, but also nature positive, for the benefit of both people and the planet, with a focus on promoting sustainable and inclusive development. Nature, and the biodiversity that underpins it, ultimately sustains our economies, livelihoods and well-being – our decisions must take into account the true value of the goods and services we derive from it. The lives and livelihoods of today's youth and future generations rely on this."

G7 leaders, Cornwall, June 2021

Sources: G7 Summit; Roland Berger

Roadmap to 2030 and beyond: CBD proposes a framework for a post-2020 global biodiversity agenda and for managing nature in the coming decades

A New Global Framework for Managing Nature Through 2030

The **Convention on Biological Diversity (CBD)** draft framework currently comprises **21 targets** and **10 milestones** proposed for 2030; this is to inform the forthcoming, so-called **Aichi Vision 2050**: Living in harmony with nature

Key targets include:

> Ensure that **at least 30% globally of land areas and of sea areas**, especially areas of particular importance for biodiversity and its contributions to people, **are conserved** through effectively and equitably managed, ecologically representative and **well-connected systems of protected areas** and other effective area-based **conservation measures** and integrated into the wider landscapes and seascapes

> **Prevent or reduce the rate of introduction and establishment of invasive alien species by 50%,** and control or eradicate such species to eliminate or reduce their impacts

> **Reduce nutrients lost to the environment by at least 1/2, pesticides by at 2/3,** and **eliminate discharge of plastic waste**

> Use **ecosystem-based approaches to contribute to mitigation and adaptation to climate change**, contributing **at least 10 GtCO_2e per year to mitigation**; and ensure that all mitigation and adaptation efforts avoid negative impacts on biodiversity

> Redirect, repurpose, reform or **eliminate incentives harmful for biodiversity** in a just and equitable way, **reducing them by at least USD 500 billion per year**

> **Increase financial resources from all sources**, including new, additional and effective financial resources, increasing by at least USD 10 billion per year international financial flows to developing countries, leveraging private finance, and increasing domestic resource mobilization, taking into account national biodiversity finance planning

Sources: CBD Convention on Biological Diversity; Roland Berger

Long view: Tackling biodiversity loss and climate change as interconnected risks could yield over USD 10 trillion in business opportunities annually

15 transitional actions across 3 socio-economic systems

Energy and extractives

- Circular and resource efficient models
- Nature-positive metals and minerals extraction
- Sustainable materials supply chains
- Nature-positive energy transition

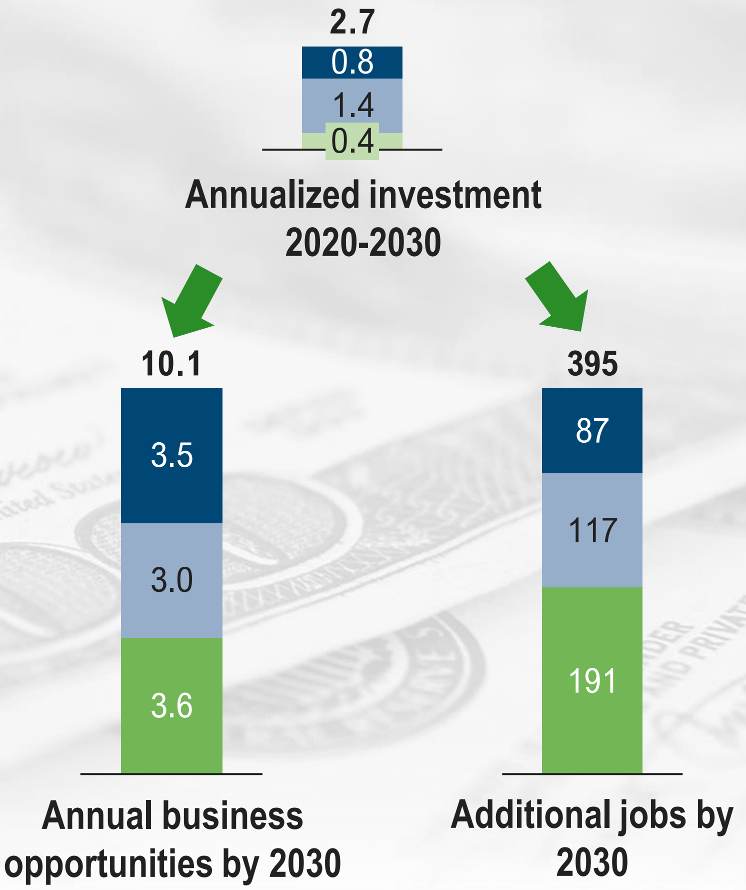
Infrastructure and the built environment

- Densification of the urban environment
- Nature-positive build environment design
- Planet-compatible urban utilities
- Nature as infrastructure
- Nature-positive connecting infrastructure

Food, land and ocean use

- Ecosystem restoration and avoided expansion
- Productive and regenerative agriculture
- Healthy and productive ocean
- Sustainable management of forests
- Planet-compatible consumption
- Transparent and sustainable supply chains

Annualized investment [USD trillion], annual business opportunities [USD trillion] and additional jobs [million] by system



- Combatting climate change by decarbonizing the economy is important but other **direct drivers of biodiversity loss must be tackled**:
- According to estimates from the World Economic Forum (WEF), **three economic systems are responsible for nearly 80% of nature loss**, namely energy and extractive sectors, food, land and ocean use, and infrastructure
- Transforming these large systems along 15 transitional actions is necessary not just for nature's sake but to meet the **growing demands of stakeholders** for businesses to **lead in a nature-conscious manner**
- It is expected that such a transformed, **nature-positive economy can unlock USD 10 trillion** of annual business opportunities and **create 395 million jobs by 2030**

Sources: WEF; Roland Berger

Environment & Resources

1 Climate Change & Pollution

2 Resources: Abundance vs. Scarcity

3 Ecosystems at Risk

Climate change is causing the greatest economic transformation this century – Tomorrow's winning side is shaped by bold actions

Actions recommended for companies across all sectors to proactively steer their future

Align your business with the new competitiveness paradigm

- Across most sectors, **business will change**, be it through the direct and indirect effects of the climate emergency, regulatory changes, or new trends in consumption. This transformation presents an **opportunity** for companies to **gain competitive advantage**. Companies that act **proactively now**, will **not face surprises from trends** looming on the horizon
- Companies can tackle the transformation by **assessing its impact** on their business model and **evaluate the extent** to which they are exposed to external pressure. At the outset, companies must first **create transparency** about their own climate impact in terms of emissions and assess how this **can influence costs, products and processes** in the near future
- In order to successfully manage the transformation, companies should **define realistic goals** along **solid timelines** and based on these, **formulate a strategy** for achieving the targets
- **Customer perception** of sustainable products and services **has sharpened** dramatically in recent years. The younger generation in particular attaches **great importance to sustainability** aspects. **Tomorrow's customer base** requires acting today. Embrace **climate change as an opportunity** now to become the **new champion** in your industry tomorrow

Source: Roland Berger

1 Climate Change & Pollution

2 Resources: Abundance vs. Scarcity

3 Ecosystems at Risk

It is becoming clear that our future resources mix will be different from the one we have been used to for decades

Actions recommended for companies across all sectors to proactively steer their future

Businesses should evolve linear production inputs towards circular production principles

- Given future environmental restrictions and potential threats of increased scarcity of raw materials, firms that **implement circular production** principles now will **be less affected by shocks** stemming from restrictions or supply risks – this also applies to energy resources
- Companies should also evaluate their **energy sources**. In addition to **intensifying the use of renewable energy**, potential raw materials and energetic **savings** under circular approaches should be **quantified**
- Being a **leading company** in our respective sector in terms of **circular production processes** is an **advantage** that yields new markets and thus **potential for profit**. Unless the **current paradigm is changed**, elevated prices and volatility in markets could threaten profit margins and economic development
- To secure a future where **sustainability meets demand**, a **global shift** from a "take-make-dispose" economy **to a restorative circular economy** is a must

Source: Roland Berger

Being net zero is not equal to zero CO_2 emissions – Use all technological and natural possibilities to offset emitted CO_2 elsewhere

Actions recommended for companies across all sectors to proactively steer their future

Think emissions reversal by means of carbon capture & recycling and reforestation

- Combined with the previously described **need for circular thinking** in terms of processes and inputs, there is an opportunity to reuse captured CO_2 elsewhere. If the demand for carbon capturing solutions increases, the scaling up of processes will reducing currently high levels of cost
- Ongoing and future research into innovative CO_2 technologies brings opportunities to save, store or reuse CO_2 more efficiently. Recycled CO_2 can be **used in other areas** such as **construction materials, chemicals,** and **fuels**
- In addition, further **natural ways** to reduce the carbon footprint should be considered: **Re-naturalization of forest** as well as the **support** of similar **vital carbon sink** ecosystems, such as **mangroves** and **wetlands**, ensures an important contribution that yields more than mere carbon offsetting: Protecting such ecosystems supports critical species **conservation** and **biodiversity**

Source: Roland Berger

To establish a long-term globally sustainable economy, a nature positive view must play its part

Actions recommended for companies across all sectors to proactively steer their future

Ecosystems must be protected to yield continued future benefits

- Understanding our deep reliance on nature's services, makes **nature conservation** essential **for future economic development,** and reveals new **market** and **investment opportunities –**not only strengthening companies' flexibility today but also for future generations
- **Acting now** leads to **several beneficial advantages**: Investing and implementing technologies that **reduce the pressure on ecosystems** captures a **leadership premium**. As the public discourse increasingly focuses on measures to protect biodiversity and ecosystems, **consumer awareness** increases leading to more demand **for sustainable, nature-positive products and services**
- Reducing pressure on biodiversity and protecting ecosystems does not just imply **better standards of living**. **Reduction of pollution** of any kind is a logical outcome of nature conservation, leading to a **healthier, more a productive workforce**. **Investments in technologies** that mitigate, reduce or upcycle environmental threats help leverage an **underestimated value** for the economy, environment and society

Source: Roland Berger

Environment & Resources

1
Climate Change & Pollution

2
Resources: Abundance vs. Scarcity

3
Ecosystems at Risk

Main sources

Megatrend "Environment & Resources"

> **Climate Watch:** Historical GHG emissions. https://www.climatewatchdata.org/ghg-emissions
> **United Nations Framework Convention on Climate Change (UNFCCC):** The Paris Agreement. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
> **Climate Action Tracker:** The CAT Thermometer. https://climateactiontracker.org/global/cat-thermometer/
> **International Energy Agency (IEA)**: Net zero by 2050. https://www.iea.org/reports/net-zero-by-2050
> **The Intergovernmental Panel on Climate Change (IPCC):** Sixth Assessment Report, Climate Change 2021. https://www.ipcc.ch/assessment-report/ar6/
> **World Health Organization:** Air pollution and WHO air pollution levels. https://www.who.int/health-topics/air-pollution
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> **bp:** Energy Outlook 2020. https://www.bp.com/en/global/corporate/energy-economics/energy-outlook.html
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> **International Union for Conservation of Nature (ICUN):** The ICUN Red List of Threatened Species. https://www.iucnredlist.org/
> **The Intergovernmental Policy Platform on Biodiversity and Ecosystem Services (IPBES):** Global Assessment Report on Biodiversity and Ecosystem Services. https://ipbes.net/global-assessment
> **Convention on Biological Diversity (CBD) – COP 15:** Post-2020 Global Biodiversity Framework. https://www.cbd.int/conferences/post2020
> **World Wide Fund for Nature (WWF):** Living planet. https://www.wwf.org.uk/living-planet-report
> **Dasgupta Review:** The Economics of Biodiversity. https://www.gov.uk/government/publications/final-report-the-economics-of-biodiversity-the-dasgupta-review

Further reading

Roland Berger
Think:Act
Sustain and Survive

Source: Roland Berger

Authors

Dr. Christian Krys

Senior Expert

Roland Berger Institute

+49 (211) 4389-2917

christian.krys@rolandberger.com

Dr. David Born

Manager

Roland Berger Institute

+49 (69) 29924-6500

david.born@rolandberger.com

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