ENERGY TRANSITION

IMPACT VISION



SHIFT

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FOREWORD

SHIFT Invest's mission is to fight climate change, biodiversity loss and natural resource depletion. SHIFT invests in four high burden sectors: Food & Agriculture (F&A), Energy, Mobility & Logistics and Green Industries. In this document, we share our impact vision for Energy. Transitioning to a net-zero energy system is essential to mitigate climate change, and to ensure affordable and secure energy for everyone.

The purpose of this document is **to outline key drivers of negative impact along the value chain on the one hand, and solutions** that have been shown to have the **greatest magnitude and importance**, collated from key academic institutions, interest groups, and (non)governmental organisations[1] on the other hand. Exact numbers vary between sources (e.g. the GHG emissions associated with agriculture) depending on the methodology and scope used by the source. The goal is not to provide the most accurate assessment of various impact and mitigation potentials, but to demonstrate the relative importance and magnitude of each.

This strategy is by no means exhaustive as the problems posed to nature by the Energy sector are complex, interconnected, and also dependent on action taken in the public sector and international arena.





1. For example, the Intergovernmental Panel on Climate Change (IPCC), Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), European Environmental Agency (EEA), Food and Agriculture Organisation (FAO), World Wildlife Fund (WWF), Ellen MacArthur Foundation (EMF).

EXECUTIVE SUMMARY

ENERGY TRANSITION

The impact challenge in Energy

- Fossil fuels have historically been at the heart of economic development but are also the main driver of GHG emissions and climate change.
- There is much room for improvement, and challenges are likely to grow due to global economic growth and because the mitigation potential of many sectors depends on sustainable energy.
- The EU's energy transition policies aim to cut emissions 55% by 2030 through cleaner energy, efficiency, and carbon pricing, but progress is hindered by continued fossil fuel investment, import dependence for key technologies, and insufficient national measures and social support to fully align with the 1.5°C goal.
- Besides industry and transport, buildings account for a substantial share of fossil fuel energy and GHG emissions globally, with a high degree of inefficiency.
- There are a few critical raw materials that are key for low-emissions energy technologies but face high scarcity risks. Water is also an essential resource for electricity and heat production and sources like biomass and hydropower can have a high water-footprint. Energy also have significant impacts on water resources through thermal and chemical pollution.
- The fossil energy system is an important source of air pollution that is damaging to biodiversity, but the net zero emissions energy system will also have a significantly larger land and water-footprint and cause increased impacts related to mining.

SHIFT impact view on the required transition

- Mitigation is challenging due to the lifetime and state of existing energy assets and infrastructure, prioritization of energy security, and geophysical factors.
- The net zero energy system will revolve mainly around wind and solar energy sources, supplemented where feasible by other renewables like geothermal. It entails widespread electrification, substantially more efficient energy use, alternative energy carriers, and greater integration between parts of the energy system. Future innovation is especially important for batteries, hydrogen, DACS, and stimulating behavioral change.
- Mitigation efforts are also necessary to mitigate the trade-offs for natural resources and biodiversity of the net zero energy system. This includes reducing critical metal use through substitution, improving circular design and improving recycling technologies, and establishing nature-inclusive and/or land efficient solar and wind systems. Biomass should be avoided as an energy source where possible.



SHIFT IMPACT VISION FOR ENERGY TRANSITION

SHIFT's mission is to mitigate climate change, biodiversity loss and resource depletion in energy, by investing in:

Generation

Innovative technologies to accelerate renewable energy production: technological advancements will enable an increase in renewable energy generation and thus contribute to the reduction of GHG emissions

Distribution

Innovations for electric grid management: the grid has become a bottleneck as it cannot keep up with the rapid expansion of wind and solar and was not designed to cater to intermittency. Innovations are thus crucial to the energy transition

Small & medium-scale storage solutions: energy storage enables a more resilient and flexible energy system with higher levels of energy security and further integration of locally produced energy



Usage

Residential, commercial and industrial energy management and energy efficiency technologies: energy management and efficiency technologies optimize energy usage resulting in a lower overall energy demand, thereby saving GHG emissions

Recycling

Innovations that lead to circular design, improved recyclability and reduced critical metal use in the net-zero energy system: to minimize the depletion of important natural resources that are heavily used in the Energy transition



…to avoid and reduce adverse impacts, and improve positive ones and restore the balance between nature and society

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01 SETTING THE STAGE



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WHY INVESTING IN ENERGY MATTERS

THE ENERGY SECTOR HAS A NEGATIVE IMPACT ON MANY AT-RISK PLANETARY BOUNDARIES

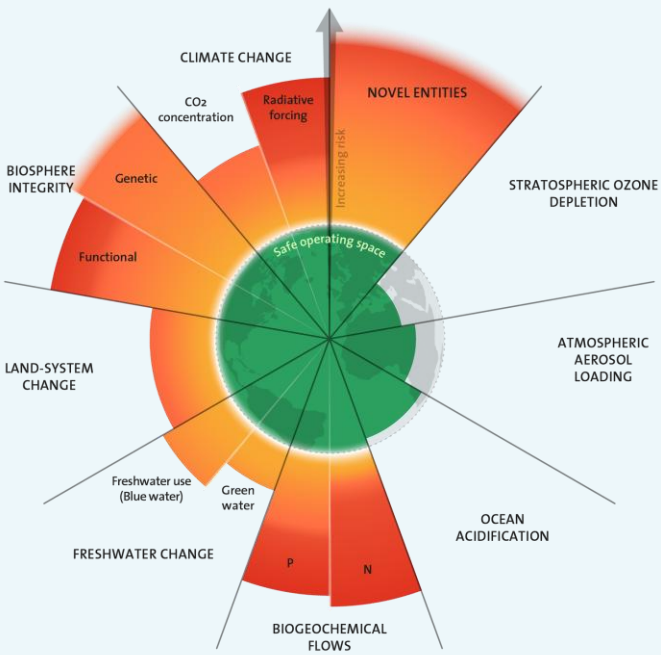
Fossil fuels have been at the heart of economic development[1]: coal-based steam powered the industrial revolution in the 18th and 19th centuries, and electricity and the internal combustion engine shaped the 20th. Energy provides heat to warm our homes and power our industries, the electricity that lights our buildings and powers our appliances, fuel and fertilizers for the agricultural revolution, and the motive power to transport ourselves and our goods. The benefits have been enormous.

However, this fossil fuel combustion, which has dominated the energy sector, releases significant amounts of greenhouse gases that drive climate change. It also has an impact on many other planetary boundaries, shown below, including biosphere integrity and land system change (both mainly via bioenergy), and freshwater use (nuclear, hydro). The energy sector's scale and influence make it a primary target for environmental mitigation. It is likely that the energy transition will involve some degree of burden shifting from GHGs to land-system change[2].

There is much room for progress as the world is highly energy inefficient: It is estimated that the world is about 10% exergy efficient[3], with big sectoral variations. A reasonable estimate is that in theory, the world only needs about 5% of the energy that it uses to provide the comforts we need.

This is not to mention that sustainability transitions across all sectors of the economy will require increased electrification. This, combined with overall economic growth, is certain to increase the impact of the energy sector on the environment if no mitigating actions are taken. Fortunately, there are a variety of possible solutions to these problems, ranging from renewable energy technologies to CO_2 removal. Through the adoption of these sustainable practices, the sector has more potential than most others to contribute to a more sustainable future.

The planetary boundaries framework[4]



1. Grubb (2014); 2. Stranddorf et al. (2023); 3. Energy is converted to other forms. Some types of energy can do more useful work than others. This is measured in terms of exergy efficiency (primary energy in fuels versus useful work extracted); primary energy in fuels versus useful work extracted); 4. Rockstrom et al. (2023);

POLICY LANDSCAPE - OUTLINE

THE EU HAS A VARIETY OF STRATEGIES AND POLICIES FOR THE ENERGY TRANSITION[1]

IT IS COVERED BY 'FIT FOR 55', 'REPOWEREU', 'EMISSION TRADING SCHEME', 'EFFORT SHARING REGULATION', AND OTHER LEGISLATIVE FRAMEWORKS.

Around 75% of the EU's total GHG emissions are from energy consumption, so energy-related regulation is the core of the EU's climate policy. Combined, the adoption of most of the regulations proposed in the Fit for 55 package and RePowerEU plan **would cut emissions by 51-57% below 1990 GHG emissions by 2030** (excluding land use)**,** which aligns with **the EU's target of at least 55% reduction[2].**

This reduction is achieved via various regulatory levers. Some noteworthy examples:

- **EU Emissions Trading Scheme (ETS) leverages carbon pricing to reduce GHG emissions**
  The **emissions reduction target** has been strengthened from 43% to **62% below 2005 levels,** which covers emissions from electricity, industry and has been expanded to include sectors like maritime and road transport;

- **Effort Sharing Regulation (ESR) governs emissions outside ETS sectors with national targets per sector**
  The emissions reduction targets of the **Effort Sharing Regulation** have increased from 30% to **40% below 2005 levels,** which applies to sectors like buildings, (non-ETS) transport, waste, and agriculture;

- **Renewable Energy Directive (RED) aims to change the energy mix to cleaner sources**
  The EU has strengthened its 2030 **renewable energy share target from 32% to 42.5%,** but aims for 45% of final energy consumption,

- **Energy Efficiency Directive**
  includes the target that final energy consumption should not exceed **763 Mtoe by 2030[3]**



Along with the major policy changes, the EU has also **simplified permitting procedures** for investments in renewable energy, batteries, and electricity grid development.

1. Climate Action Tracker (2025); 2. Note: member states still need to adopt policies implementing these targets.; 3. Entails a reduction in energy consumption for member states of on average 1.5% p.a. between 2024-2030, or reducing final energy use by 11.7% compared to projected 2030 levels from the 2020 reference scenario;

POLICY LANDSCAPE – SHORTCOMINGS

…HOWEVER, SOME KEY FACTORS UNDERMINE ENERGY AMBITIONS AND PROGRESS

While ambition is high, Climate Action Tracker[1] finds a **significant gap in policies** needed to fully reach or exceed the 55% target, mainly because member state plans (the 2023–2025 National Energy and Climate Plans) show insufficient concrete measures to realise or exceed this target. This means **the EU's trajectory does not limit warming to 1.5°C.** Other key weaknesses highlighted in the report include:

- **Continued investments in new fossil fuel infrastructure**, especially LNG terminals and fossil gas pipelines, risk carbon lock-in (or stranded assets) and generally undermine the EU's decarbonization efforts. Instead of definitively phasing out gas by 2035, the EU is expanding infrastructure and creating overcapacity. This sends mixed signals and undermines decarbonization goals.
- In the case of majority of **key low-carbon energy technologies**, especially solar panels, wind turbines, and batteries, the EU is to a large degree **dependent on imports** from other countries. This has the potential to exacerbate already existing bottlenecks if trade flows are interrupted. The adoption of the **Net Zero Industry Act**, which sets the goal of covering at least 40% of selected low carbon technologies with domestic manufacturing, is an important step but policy support and implementation must be much stronger to overcome existing supply chain vulnerabilities.
- The EU and its member states need to ensure that households, especially those potentially affected by **energy poverty**, are supported in their decarbonization efforts. The creation of the Social Climate Fund, mitigates this challenge to some degree, but assessments show it may not be enough to finance the necessary transition in the buildings sector (e.g. mandatory minimum energy performance standards under the proposed revisions to the Energy Performance of Buildings Directive (EPBD)), risking uneven social outcomes.

1. Climate Action Tracker (2025);

BARRIERS TO CHANGE

THE ENERGY TRANSITION IS EXTRA CHALLENGING DUE TO THE LEGACY OF EXISTING INFRA, ENERGY SECURITY CONCERNS AND GEOPHYSICAL CONSTRAINTS

Lifetime of existing assets & infra

A notable barrier is the weight of emissions likely to be created by existing and currently planned fossil infrastructure[1]. Given the **long lifetimes of the physical assets, institutions, laws and regulations that make up the energy system**, they can greatly influence the rate of transformation and lock societies into carbon-intensive lifestyles and practices for many decades[2].

For instance, the current state of the existing **grid infrastructure** limits the integration and expansion of DERs, which requires grid expansion, energy storage, and demand response solutions. The new energy system also makes existing guidelines **for power system planning** obsolete (e.g. that specific generation types are needed for baseload, intermediate load, and peak load to follow and meet demand).

This also includes "social infrastructure" such as the skills of the current (energy) workforce.

Energy security

The ability to access **reliable and affordable** energy resources continues to shape (inter)national energy policy. Energy security is often prioritized over climate and other environmental concerns. Fossil fuel **subsidies** have historically been used for this purpose, but these have proven to be regressive in most cases. Energy security concerns have historically led to a continued reliance on domestic coal production and consumption. Energy security's importance also means that **geopolitical structures and trade dynamics** have been established around fossil fuel industries, posing an additional barrier to the transition away from these.

There are also energy security concerns associated with **renewable energy technologies**. The supply chain for these is currently **strongly concentrated in just a few key regions** (e.g. China's share in all the manufacturing stages of solar panels exceeds 80%[4]), meaning that the transition is highly vulnerable to supply shocks due to, a.o. geopolitical developments[5].

Geophysical constraints

Aside from those already mentioned, like land-use, water, and scarce raw materials, there are also other geophysical constraints that make the energy transition challenging:

Geological resources: e.g., CCUS has a high theoretical geologic storage potential but most capacity is in saline aquifers where there is minimal pre-existing infrastructure or data, suboptimal subsurface pressure, and they are not situated near CO_2 sources.

Physical climate change: climate change will impact many low-carbon energy technologies by altering hydropower production, bioenergy, thermal power plant efficiencies, demand for heating and cooling, and directly impact power system infrastructure[3].

1. IPCC WGIII CH6 (2022); 2. Scenario evidence suggests that without carbon capture, the worldwide fleet of coal and gas power plants would need to retire about 23 and 17 yrs earlier than expected lifetimes to meet emissions targets (IPCC). Fortunately, unit cost reductions have increased the economic attractiveness of the low-emission energy sector transition to such an extent that maintaining emission-intensive systems may, in some regions and sectors, be more expensive than transitioning to low-carbon systems (Dunne et al., 2022); 3. Overall, climate change is not expected to affect wind and solar resources to the extent that it would compromise their ability to reduce emissions; 4. IEA (2022); 5. See also IRENA (2023).

ENERGY AND SHIFT'S MISSION

INVESTING IN SOLUTIONS TO THREE CHALLENGES AS PART OF SHIFT'S MISSION



The majority of energy comes from fossil sources (coal, oil and gas), and CO_2 is the fundamental product of burning fossil fuels. With concentrations already at levels not seen for millions of years, it continues to accumulate in the atmosphere and constitutes the main adverse impact of our energy system on the environment today.



The fossil energy system is an important source of air pollution, driven mainly by nitrogen oxides (NO_X) and sulphur dioxide (SO_2) emissions from e.g. coal.

The land and water-use footprint of the net zero emissions energy system is significantly larger than before and puts more direct pressure on ecosystems (as opposed to the more indirect pressure associated with GHG emissions from fossil sources via climate change). NZE technologies will increase demand for mined minerals, with associated adverse impacts like pollution.



Water is essential for electricity and heat production and energy sources like biomass and hydropower can have a very high water footprint. Energy also has significant impacts on water resources through thermal and chemical pollution.

There are a few critical raw materials that are finite or naturally regenerated at a rate that is too low to be considered "renewable". These raw materials are crucial for the renewable energy transition and accelerating technological innovation cycles have led to increasing demand for these highly sought after metals and minerals.

Energy has an important impact on all of SHIFT's impact domains. As such, these are all included in the scope of this impact vision document.

As with our other impact vision documents, it is also the case here that mitigation measures can address multiple impact drivers. There can be both synergies and trade-offs in mitigation measures. However, climate change mitigation measures such as the expansion of solar and wind energy are considered a given as these are crucial and unmissable to avoid catastrophic climate change. As such, it will be important to alleviate their impact on natural resources and biodiversity where possible, but the latter two domains should not be a reason to step away from these technologies as a whole.

1. Poore & Nemecek (2018);

02 ENERGY AND CLIMATE CHANGE



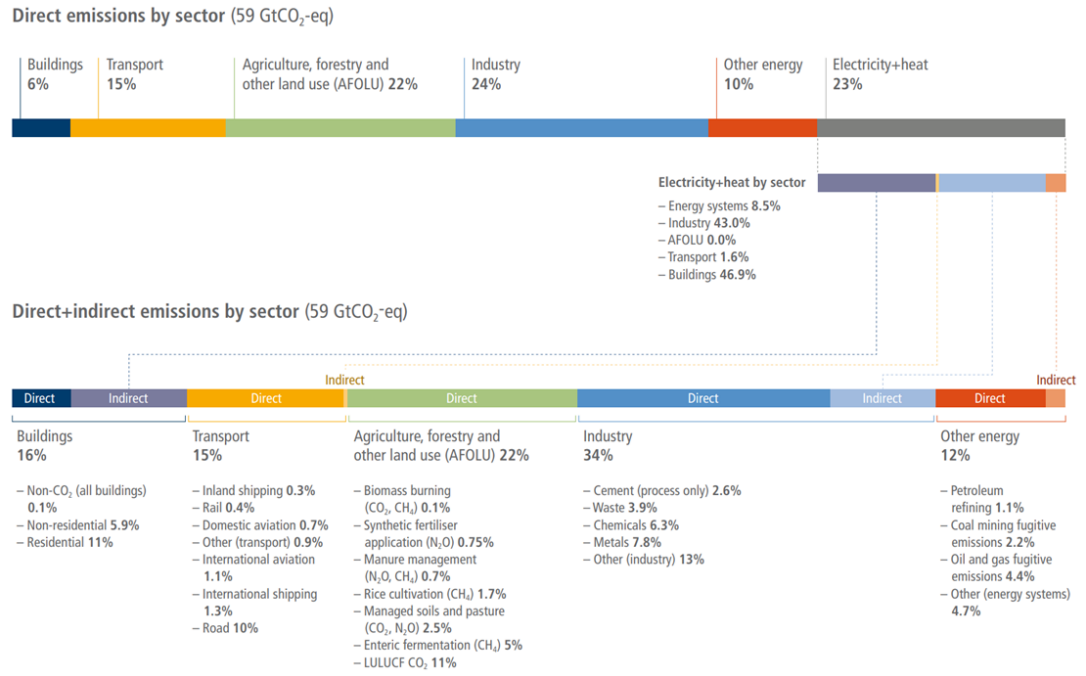
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GHG EMISSIONS IN ENERGY

ENERGY IS THE LARGEST GLOBAL SOURCE OF GHG EMISSIONS

THE ENERGY SECTOR IS RESPONSIBLE FOR 20GT CO_2 SPREAD ACROSS VARIOUS END USES[1]

Graph shows total anthropogenic direct and indirect GHG emissions in 2019, by sector and subsector. Direct emissions are Scope 1, and indirect refers to the reallocation of emissions from electricity and heat to the sector of final use.



GLOBAL ENERGY SECTOR EMISSION TRENDS

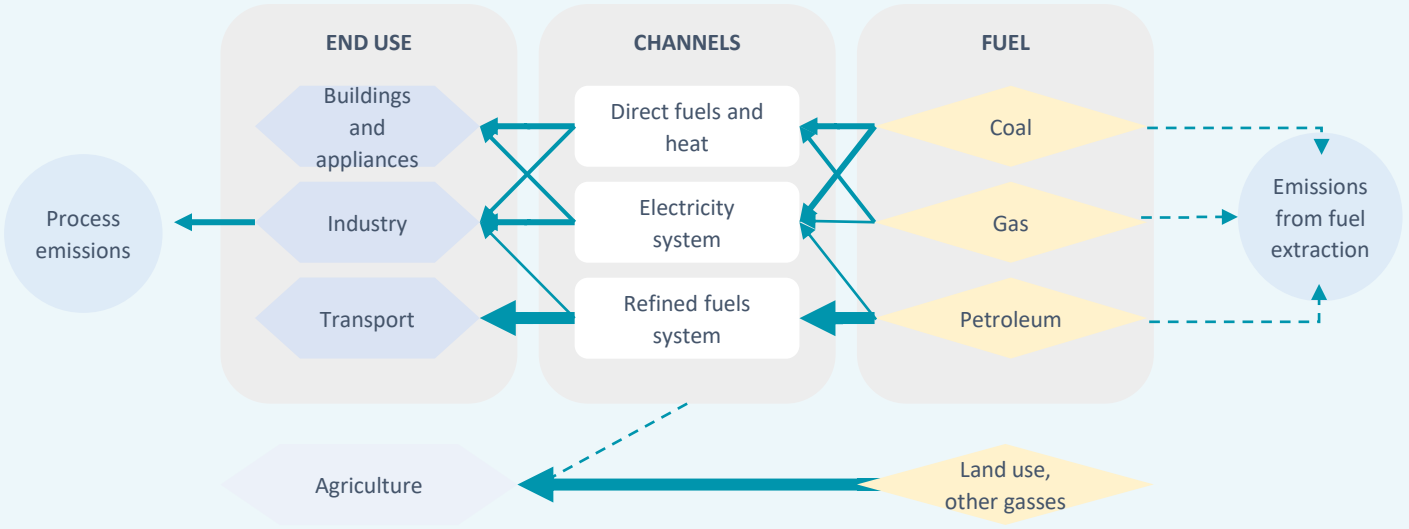
- Beyond electricity and heat, when accounting for primary energy use in other sectors (industry, transport, buildings), estimates suggest the proportion of global GHG emissions attributed to energy exceeds 70%[2].
- Global energy systems emissions growth has slowed down in recent years, but global oil and gas use is still growing, and the sector remains the single largest contributor to global GHG emissions.
- Most of the emissions from electricity and heat generation are due to energy use in industry and in buildings, making these sectors prominent targets for mitigation.
- Growth in emissions from energy systems closely tracks rising GDP per capita globally, affirming a mutual relationship between economic growth and demand for energy and electricity.
- The key driver for slowing the growth of energy sector emissions has been declining energy intensities (2% less energy per unit of GDP was used globally between 2010-2019).
- Since 2007, Europe's carbon intensity improvements have been driven by the steady expansion of renewables in the share of electricity generation.
- Generally, the use of natural gas for electricity production is growing strongly in most countries and has contributed to the largest increase in global fossil CO_2 emissions in recent years. Furthermore, gas brings the risk of increased methane (CH_4) emissions from fugitive sources, as well as large cumulative emissions over the lifetime of new gas power plants

Image from IPCC report (2022) 1. IPCC(2022), via direct emissions and energy use; 2. Our World in Data (2020)

GHG EMISSIONS AND THE ENERGY SYSTEM

THE ENERGY SYSTEM IS DRIVEN BY THREE MAIN END USES: BUILDINGS, INDUSTRY AND TRANSPORT

ENERGY & EMISSION FLOWS IN THE ENERGY SYSTEM[1]



BUILDINGS AND APPLIANCES

- Buildings and appliances account for a large proportion of fossil energy and emissions globally.
- The scale of unnecessary energy use is biggest in buildings, and in the supply of low-grade heat required for heating, cooling, and cooking.
- Space heating and cooling together often account for >50% of energy consumption in both commercial and domestic buildings, but the latter use significantly more hot water. The share of electricity consuming activities is greater in commercial buildings than in residential (e.g. lighting accounts for 10% of domestic energy use, vs 20% on commercial premises).
- The biggest technical challenge in buildings currently comes from the explosion of electrical appliances, which has pushed electricity demand.

INDUSTRIES

- Globally, industry dominates coal use (incl. generation for industrial electricity consumption).
- Half of industrial energy consumption and a larger share of emissions come from just four sectors: iron & steel, cement, non-ferrous metals (mainly aluminum), and chemicals (incl. petrochemicals).

See SHIFT Industries impact vision

TRANSPORT

- Transport accounts for over 2/3rds of global oil consumption. Oil is a highly convenient transport fuel, making it difficult to find alternatives.
- Road accounts for a significant majority of energy use and emissions, followed by aviation, shipping and rail.

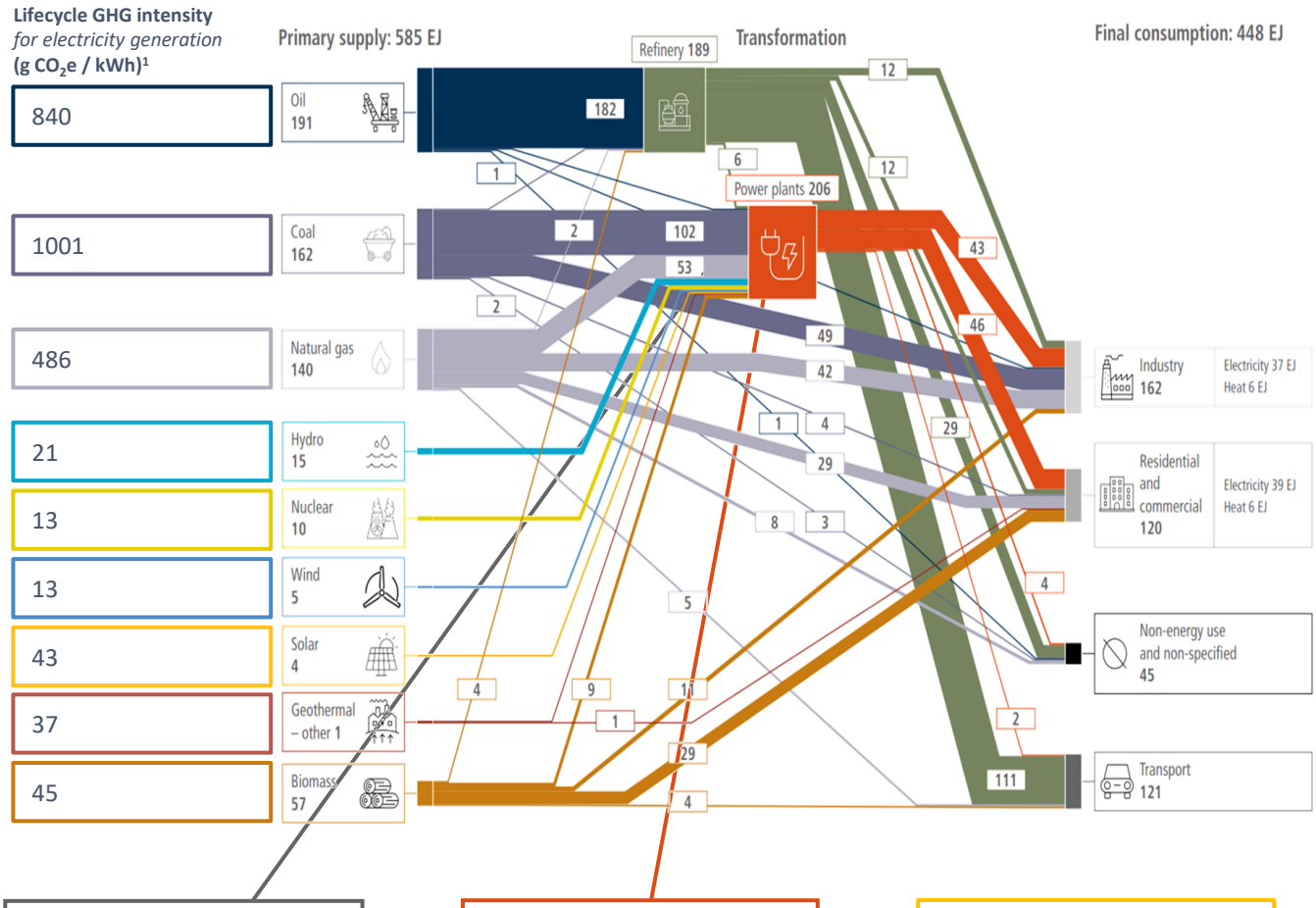
See SHIFT Mobility impact vision

1. Diagram adapted from Grubb (2014)

EMISSIONS OF DIFFERENT ENERGY SOURCES

ENERGY SUPPLY AND EMISSIONS ARE DRIVEN BY COAL, OIL AND NATURAL GAS

Global energy use (2019)



Energy is also lost in transmission. The World Bank estimates that 8% of global electricity output is lost in power transmission and distribution[3]. This represents up to 500 Mt CO_2 p.a..[4]

The electricity mix and therefore emissions intensity of electricity differs per country (overview). In the EU, in 2022, the emission intensity of electricity was 225 g CO_2e/kWh.[2]

Not shown: energy storage

Lifecycle GHG intensity
for electricity storage
(g CO_2e / kWh)[1]

Hydropower = 7.4
Li-ion battery = 33
Hydrogen fuel cell = 38

1. Wind is landbased and offshore, nuclear is light water reactor only. Data from NREL (2021), who compiled this from various sources ranging from the 2011 IPCC report to a 2021 paper. The value shown is the median value of the total of four life cycle phases (one-time upstream (e.g., materials acquisition and plant construction), ongoing combustion (where applicable), ongoing noncombustion (e.g., operation and maintenance), and one-time downstream (e.g., plant decommissioning and disposal/recycling)). Geothermal has a relatively higher emissionfactor when used for electricity generation, but it is one of the least carbon intensive sources of direct heat; 2. Climate Action Tracker (2023), note that the scope used for this emission factor may be different from the GHG intensities shown on the left; 3. World Bank (2014); 4. IPCC

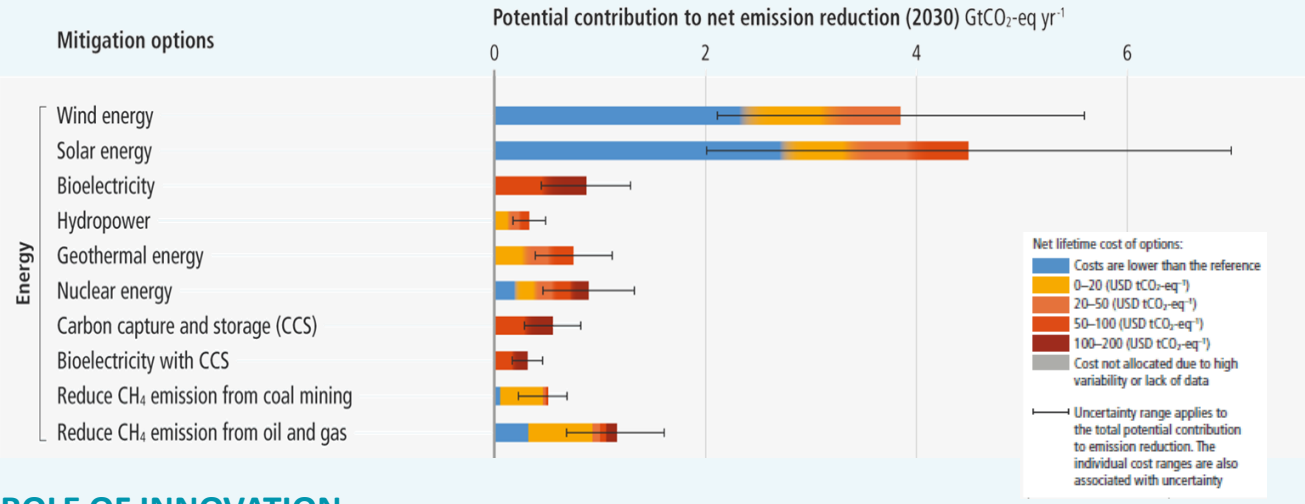
CLIMATE CHANGE MITIGATION IN ENERGY

RENEWABLE ENERGY, ELECTRIFICATION AND ALTERNATIVE ENERGY CARRIERS ARE THE CORE PILLARS OF THE ENERGY TRANSITION

CHARACTERISTICS OF THE ENERGY TRANSITION

Reaching net zero by 2050 requires both the further rapid deployment of available technologies as well as widespread use of technologies that are not on the market yet. Key characteristics of our decarbonized energy system include[1]:

- Electricity systems that produce no CO_2 or remove it from the atmosphere (low carbon sources produce 93-97% of global electricity by 2050)
- Widespread electrification, including light-duty transport, heating and cooking (electricity should supply 48-58% of final energy in 2050)
- Substantially lower fossil fuel use and more efficient energy use
- Alternative energy carriers: hydrogen, bioenergy, ammonia (because some applications like aviation are not amenable to electrification)[3]
- Greater integration between parts of the energy system
- CO_2 removal to offset residual emissions



ROLE OF INNOVATION

Innovation is crucial to achieving net zero emissions because, while most emission reductions by 2030 come from existing technologies, nearly half of the reductions needed by 2050 will rely on technologies still in development[2]. Key areas for innovation include advanced high-energy-density batteries, hydrogen electrolysers and carriers, and direct air capture and storage, which together enable ~5% of emission cuts between 2030 and 2050. These technologies must be supported by major new infrastructure such as CO_2 transport pipelines and hydrogen distribution networks. Alongside technological advances, behavioural changes like reducing energy waste, lowering indoor temperatures, and moderating driving speeds also play an essential role.

1. IPCC (2022); 2. IEA (2021) Net Zero Emissions by 2050 pathway; 3. As a general rule, across all sectors, it is more efficient to use electricity directly to avoid large conversion losses from other carriers like hydrogen. However, these do provide time and space option value to electricity produced using variable clean sources, e.g., for use as hydrogen, as stored future electricity, or as an industrial feedstock. They also involve a symbiotic range of general purpose technologies (electric motors, heat pumps, batteries, electrolysis, fuel cells) that have different applications across sectors but cumulative economies of innovation and production scale benefits.

03 ENERGY AND NATURAL RESOURCES



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NATURAL RESOURCES AND ENERGY TRANSITION

CRITICAL COMPONENTS FOR RENEWABLES FACE MATERIAL SCARCITY

There are a few critical raw materials that are regenerated at a rate that is too low to be considered renewable or are finite. These raw materials are crucial for the energy transition, and accelerating innovation has skyrocketed demand for these metals and minerals[1].

By 2050, more than 80% of electricity in the EU is expected to come from renewable energy sources, with electricity providing half of the final energy demand in the EU. Many technologies are used to convert the renewable resources into electricity (e.g. wind turbines and solar panels), store this energy (e.g. in rechargeable batteries), improve the manufacturing processes (e.g. through robotics and 3D-printing) and facilitate the conversion and transmission of the electricity via smart grids (e.g. using digital technologies). The shift to low-carbon energy systems will thus imply significant changes in raw materials requirements. A foresight-based assessment of critical raw materials in the EU context finds that **light and heavy rare earth elements have the highest supply risk**[2].

For example:

- Some critical REEs such as neodymium, dysprosium and praseodymium, are key ingredients of permanent magnets used in high-performance wind turbines. Recycling rates for these metals are below 1%[3].
- Critical raw materials such as borates, gallium, germanium, indium and silicon metal are needed in solar PV, robotics and digital technologies. Batteries employ CRMs such as cobalt and natural graphite, which are also required in 3D-printing and digital technologies. Platinum is used as a catalyst in fuel cells and in digital applications, for example for hard disk drives.

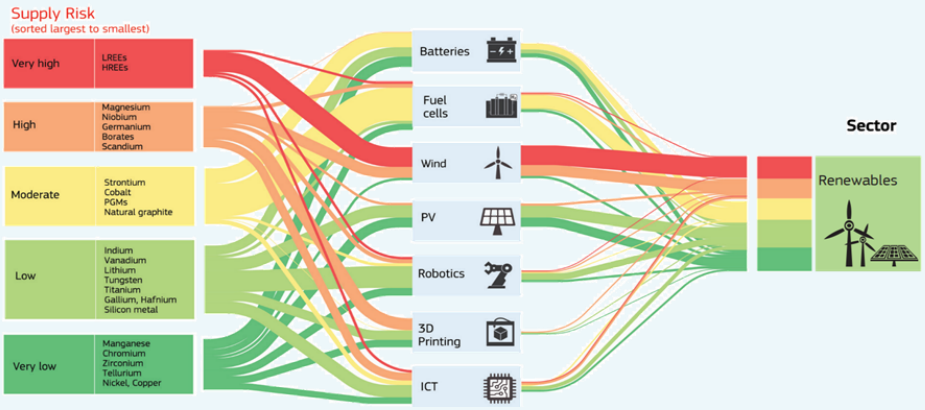


Figure 48. List of critical and non-critical raw materials used for renewables ranked by their 2020 supply risk

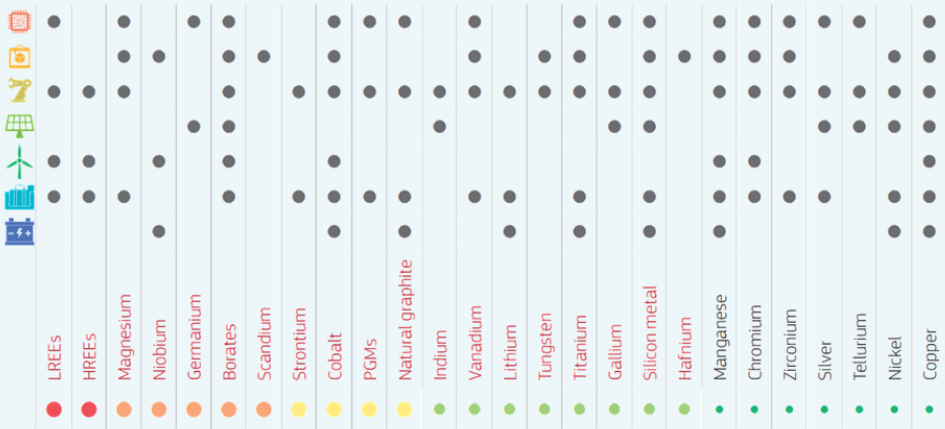


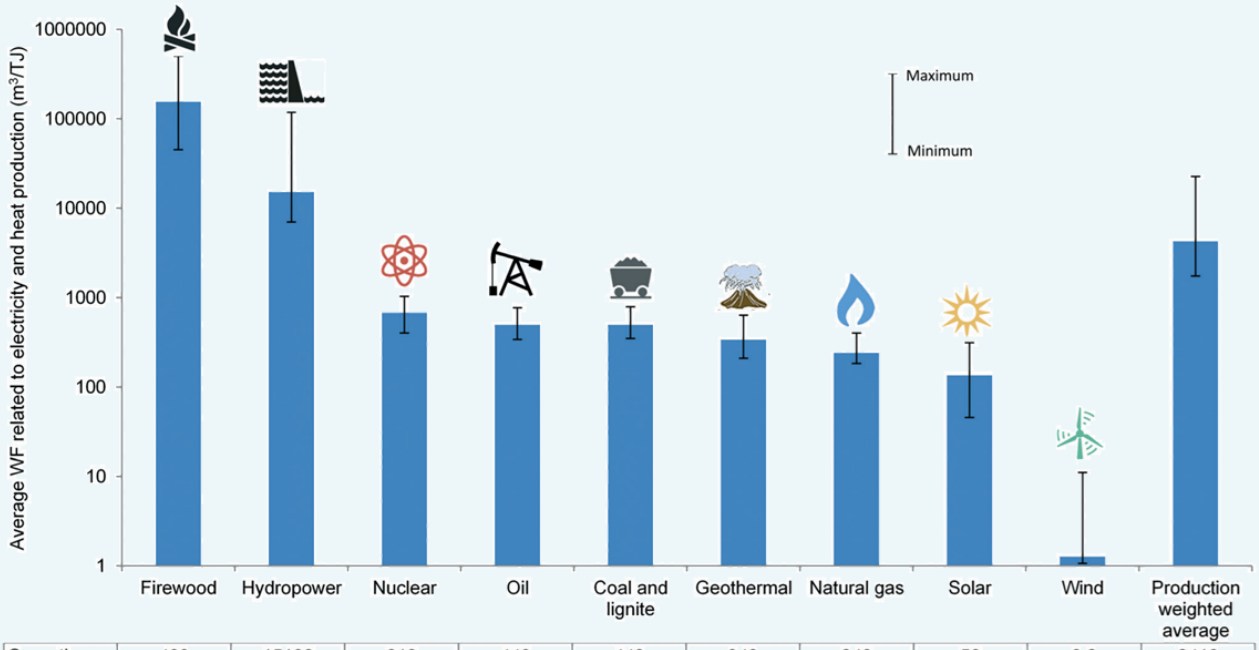
Diagram from European Commission (2020) 1. European Commission (2020); REE = rare earth elements; L/H REE = light/heavy rare earth elements; 2. Supply risk takes into account geopolitical factors that contribute to scarcity. 3. Metabolic (2018)

NATURAL RESOURCES AND THE ENERGY TRANSITION

ENERGY REQUIRES SIGNIFICANT VOLUMES OF FRESH WATER AND POLLUTES WATER RESOURCES

Energy production requires significant volumes of fresh water and has significant impacts on water resources through thermal and chemical pollution[1]. Energy's dependence on water availability also makes it vulnerable to water scarcity.

- The global consumptive water footprint (WF)[2] of electricity and heat is estimated to be **378 billion m^3 per year**,[4] with the weighted average WF of electricity and heat being **4241 m^3 / TJ_e**.
- As shown on below, renewable energy sources **wind** (0.2–12 m^3 / TJ_e), **solar** PV (6–303 m^3 TJ_e) and **geothermal** energy (7–759 m^3 / TJ_e) have the **smallest WFs**.
- **Biomass** (50 000–500 000 m^3 / TJ_e) and **hydropower** (300–850 000 m^3 / TJ_e) have the **largest WFs**.
- **Europe has the largest WF** (22% of total), followed by China (15%), LATAM (14%), USA & Canada (12%), and India (9%)[1].
- Generally, the WF of energy is **dominated by operations** (57%) and fuel supply (43%), while the WF of construction is negligible[1].
- **Electricity production contributes the vast majority** to the total WF (90%), with heat being responsible for only 10%[1]. When fuels such as coal, lignite and uranium, or materials for construction, such as copper, are mined, this generally comes along with **water pollution**, causing a **grey WF[3]**. Power plants also release different chemicals and thermal loads to fresh water.



Operation	400	15100	610	440	440	340	240	50	0.2	2410
Construction	0.4	0.3	0.3	1.1	1.1	2.1	1.1	90	1.1	1.0
Fuel supply	156000	0	68	55	54	0	6	0	0	1830

Note that the scale is logarithmic. The ranges shown reflect minimum and maximum values per energy source. The values in the table represent the WF (m^3/TJ) for the three main stages of the electricity and heat production chain.

Image from Mekonen et al. (2016) 1. Mekonen et al. (2016); 2. Consumptive WF = the sum of green (rain) and blue (ground and surface) water footprints. 3. These numbers do not include the grey water footprint and therefore underestimates the WF of electricity and heat.; 4. e.g., that of agriculture ranges between 5,900-8,500 billion m^3 per year (80% green, 11% blue, and 9% grey).

04 ENERGY AND BIODIVERSITY



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BIODIVERSITY AND THE ENERGY TRANSITION

THE LOCATION OF POWER INFRASTRUCTURE AND MINING OF NECESSARY METALS ARE IMPORTANT FOR BIODIVERSITY IMPACT

The location of power infrastructure is a key factor in determining its impacts on biodiversity, and careful planning and siting of power plants, transmission lines, and other infrastructure can help minimize negative impacts. Generally, renewable energy sources such as wind and solar power have lower impacts on biodiversity than fossil fuel-based power generation, but they can still have negative effects if they are not properly sited and managed[1]. The impact of the energy value chain on biodiversity is expected to grow due to increased mining for key metals and in case bioenergy, BECCS, or hydropower grow in the energy mix/transition.

As a core driver of GHG emissions and **climate change**, the energy sector is responsible for climate-driven impacts on biodiversity loss, such as habitat destruction, the alteration of species ranges, and changes in the timing of biological events such as migration and reproduction[2].

The production, transport, and use of fossil fuels also results in the **pollution** of air, water, and soil, leading to adverse impacts on ecosystems and species. Technologies and infrastructure required for the decarbonized energy system will also drive an increase in the production of many metals, creating greater **mining-related threats** for biodiversity[3]:

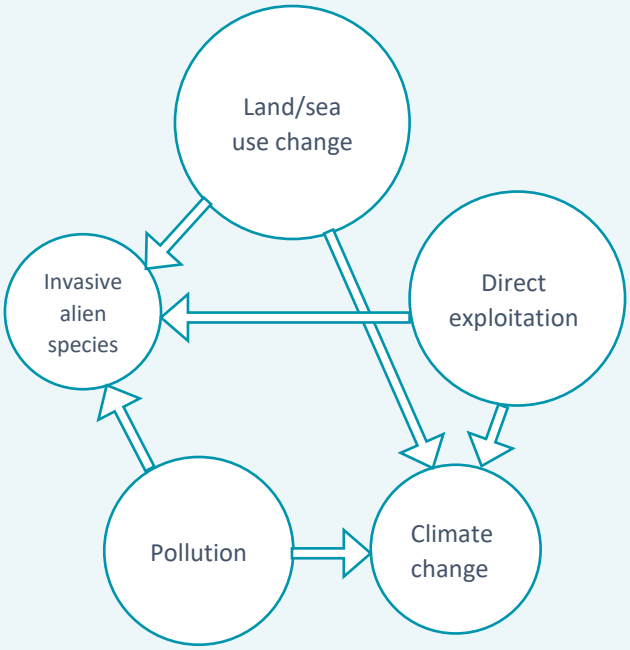
- Surface mining occupies under 1% of global land area but negatively affects vast areas as a driver of land-cover change, pollution of surface and ground water, and air quality degradation[2].
- Deposits are often within zones with **high biodiversity** (e.g., bauxite from Indonesia/Brazil and cobalt from the DRC). The pre-processing of these materials also has further adverse impacts by for instance increasing the bioavailability of mercury and other metals.

Land use change and fragmentation **(see next page)**

Hierarchy of direct drivers of biodiversity loss (***not sector specific***)[4]

Size of the circle is representative of the relative size of the impact driver (i.e., land/sea use change has the biggest adverse impact on biodiversity).

Arrows linking pairs of drivers show the dominance difference between them.



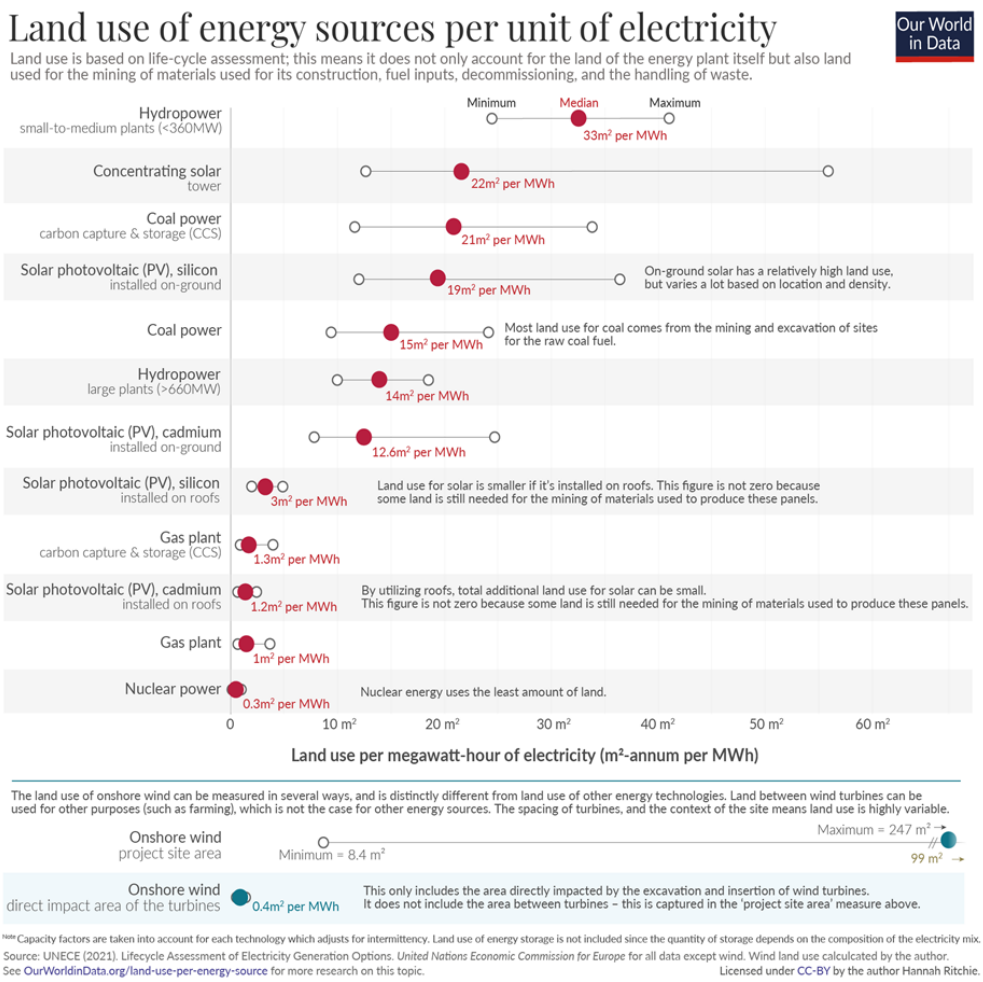
1. Holland et al. (2019); 2. IPBES (2019); 3. Sonter et al. (2020); 4. Adapted from Jaureguiberry et al. (2022);

BIODIVERSITY AND THE ENERGY TRANSITION

LAND USE IS AN IMPORTANT ENERGY-RELATED DRIVER OF BIODIVERSITY LOSS

Land use change and fragmentation is an important energy-related driver of biodiversity loss. The impact of land use can vary significantly depending on where energy sources are built, and what the alternative uses of that land are (e.g. energy sources expanding into natural habitats are far worse than a solar farm in an ecologically unproductive desert).

- **There are significant differences in the land use footprint of different electricity sources[1]:** where nuclear energy is the most land-efficient source, needing 18-27x less land per MWh than on-ground solar PV, and CSP and hydropower the least efficient.
- **There are also significant differences within a single energy technology type:** land use also depends largely on the specific materials used, how the technology is deployed, and the local context. For example, solar panels from cadmium use less energy and materials than silicon panels, and therefore use less land per unit. It also matters whether you mount panels on rooftops vs the ground and the spacing of the panels.
- **Wind should be considered differently regarding land use:** offshore wind uses marine rather than land area, and in many cases, land used for onshore wind can still be used for other purposes like farming (similarly to solar PV). As such, the land use impact can be highly variable.



1. Ritchie (2022), Note - the assessment only considers key sources of electricity – since oil is predominantly used for transport, it's not included

MITIGATING BIODIVERSITY LOSS AND NATURAL RESOURCE DEPLETION

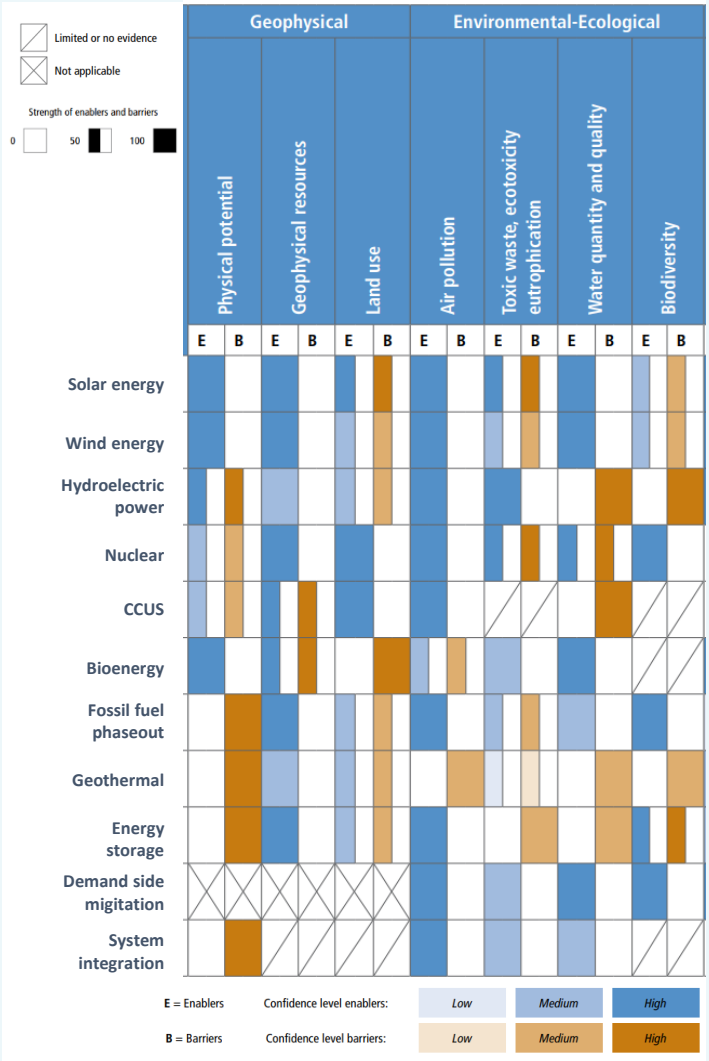
A NATURE INCLUSIVE AND RESOURCE-LIGHT ENERGY SYSTEM

The energy transition and its net-zero emissions technologies are necessary to avoid catastrophic climate change. In many ways, the transition from fossil fuels to renewable energy sources will also improve non-climatic impacts (co-benefits) to nature such as air pollution. However, some renewable energy sources are preferable to others when wider impacts are considered.

KEY MITIGANTS

- **Reduce critical metal use through substitution**
  There are alternatives to the strategic minerals currently used to support a low-carbon transition. Wind turbines can be manufactured without permanent magnets to reduce the need for strategic minerals (albeit with higher production costs and lower efficiency). Alternatives to silicon, such as thin films, can be used to produce PVs (but can contain other potentially critical metals like tellurium, cadmium, and gallium). Alternatives to lithium-ion batteries, such as sodium-ion batteries, are becoming more practical and feasible.
- **Improve circular design and increase recycling efforts**
  It will be important to improve the lifetime, modularity, recovery, recycling of these materials to reduce overall demand and improve resource efficiency.
- **Establish nature-inclusive energy infrastructure where possible**
  Conventional solar power is worse than fossil gas when it comes to land use. It is therefore important to establish nature-inclusive PV systems, or ones that make more effective use of land by combining or co-siting multiple functions (e.g. agrivoltaic systems).

Extent that environmental factors enable (E) or inhibit (B) the deployment of mitigation options in energy systems



- **Avoid bio- and hydropower where possible**
  From a water and nature perspective, **biomass and conventional hydropower should be avoided** as energy sources where possible, and especially in areas facing high water stress.

Source: IPCC (CH6)

CONTACT US

QUESTIONS, COMMENTS OR WANT TO CONNECT?



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I'm a startup with an innovative solution to a problem highlighted in this report.
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TURNING INVESTMENTS INTO IMPACT