



MASTER IN ENTREPRENEURSHIP  
INNOVATION MANAGEMENT  
IN COLLABORATION WITH **MIT SLOAN**

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**MIT** MANAGEMENT  
SLOAN SCHOOL



UNIVERSITÀ DEGLI STUDI DI NAPOLI  
**PARTHENOPE**

MASTER MEIM 2022-2023

# Green Management

ENVIRONMENTAL IMPACT OF ENERGY SYSTEMS

A cura del prof. Simona Di Fraia

Ricercatrice del Dipartimento di Ingegneria dell'Università degli Studi di Napoli Parthenope

# Why green management?

<https://www.worldometers.info/>



Adopted by all United Nations Member States in 2015 to achieve social, economic and environmental sustainability

# About me

Assistant Professor at Parthenope University:

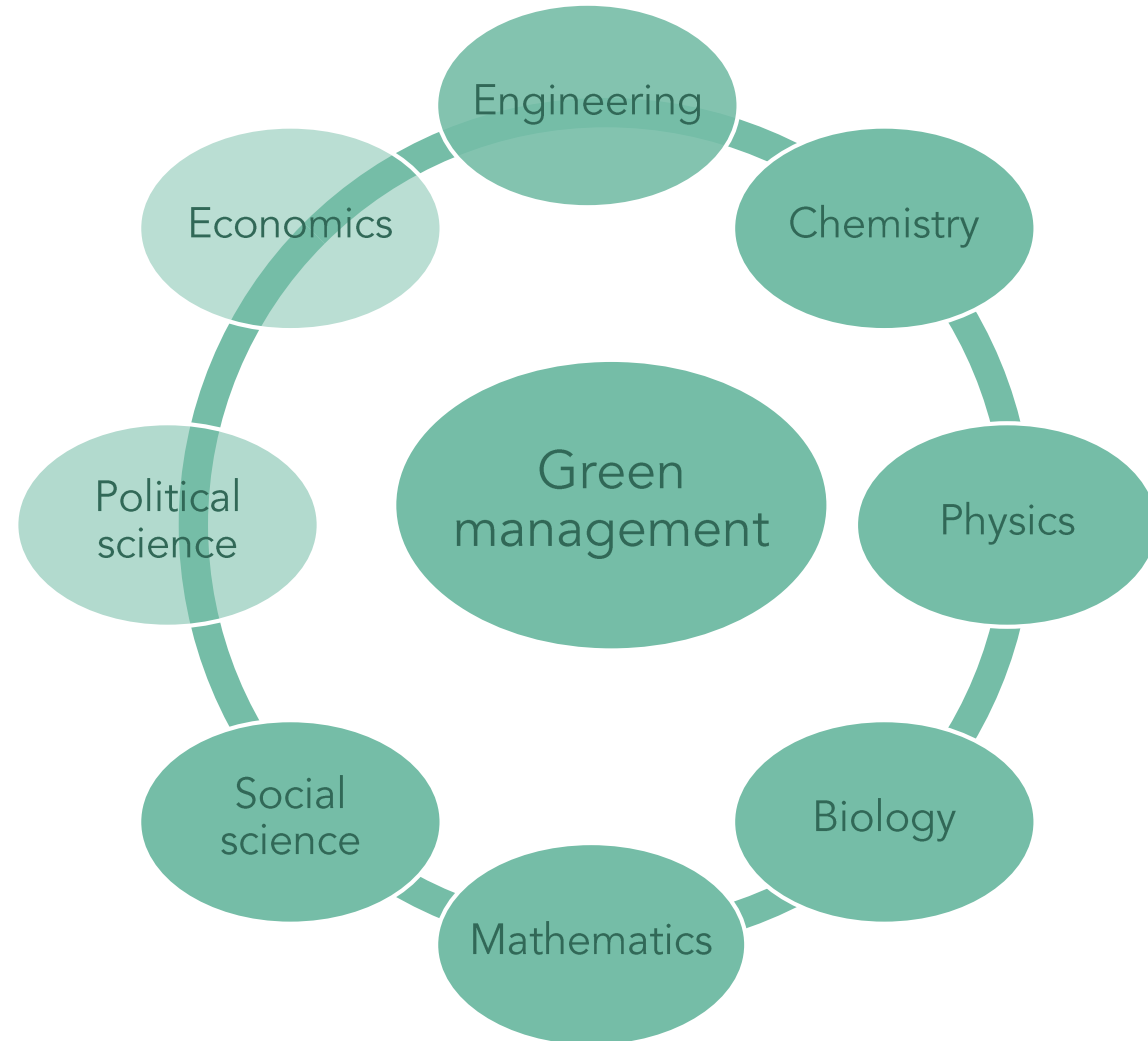
- Energy recovery from residual biomass
- Energy efficiency in wastewater and sludge treatment
- Energy systems based on renewables
- Heat and mass transfer in porous media for energy applications

PhD in Energy Science and Engineering

Master degree in Environmental engineering

# What about you?

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...  
...



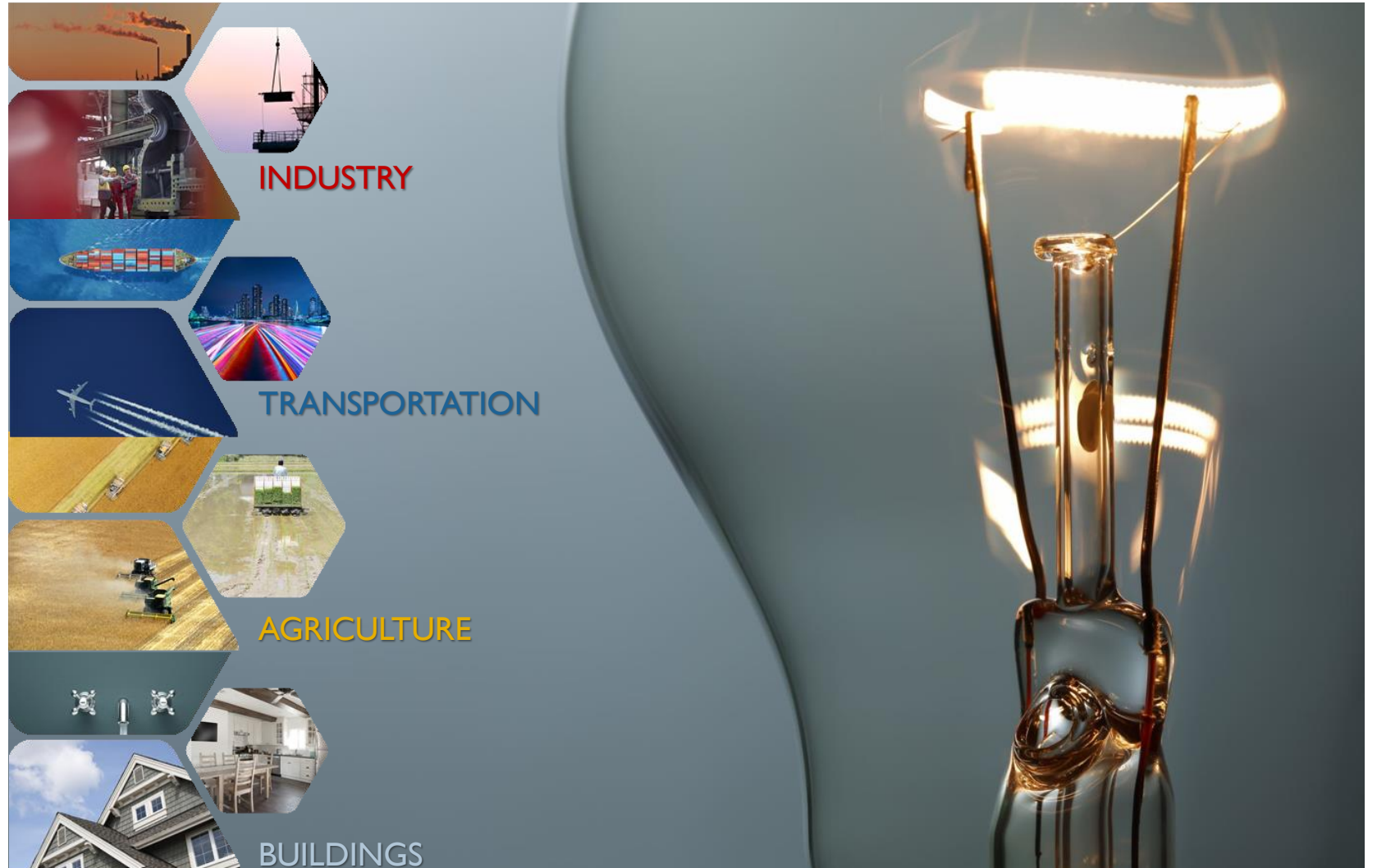
# Summary

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# Introduction





# Introduction

Energy producing systems presently in use across the world can be classified into three main categories:

- fossil fuels
- nuclear power
- renewables



# Introduction

## Environmental pollution

Energy and environment  
are closely related.

Environmental pollution is  
defined as the addition of  
any substance or any form  
of energy to the  
environment at a rate faster  
than it can be dispersed,  
diluted, decomposed,  
recycled, or stored in some  
harmless form.



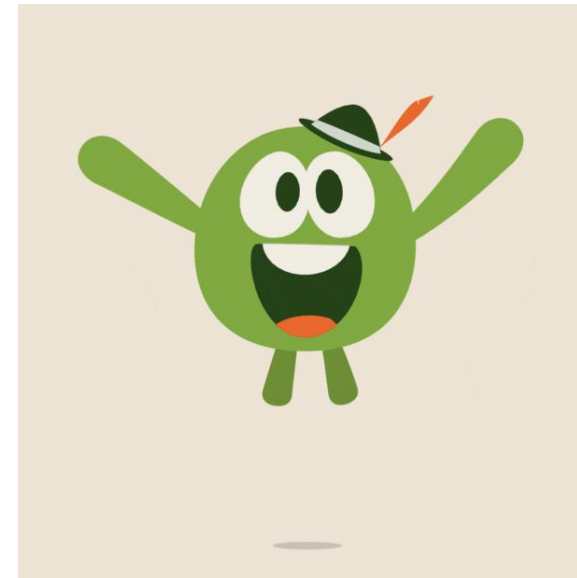
<http://www.napolicittasolidale.it/portal/primo-piano/8658-anno-%E2%80%9Cnero%E2%80%9D-per-lo-smog-in-campania-%E2%80%9Cmaglia-nera%E2%80%9D-dalla-citt%C3%A0-metropolitana-di-napoli.html>



<https://edizionenapoli.it/2021/07/17/mare-in-campania-17-punti-fortemente-inquinanti-ecco-quali-sono/>



<https://commons.wikimedia.org/wiki/File:Soil-pollution.jpg>



<https://giphy.com/gifs/wetransfer-3ov9k4dawRrTNyVE3K>

# Introduction

## Environmental pollution

Energy and environment are closely related.

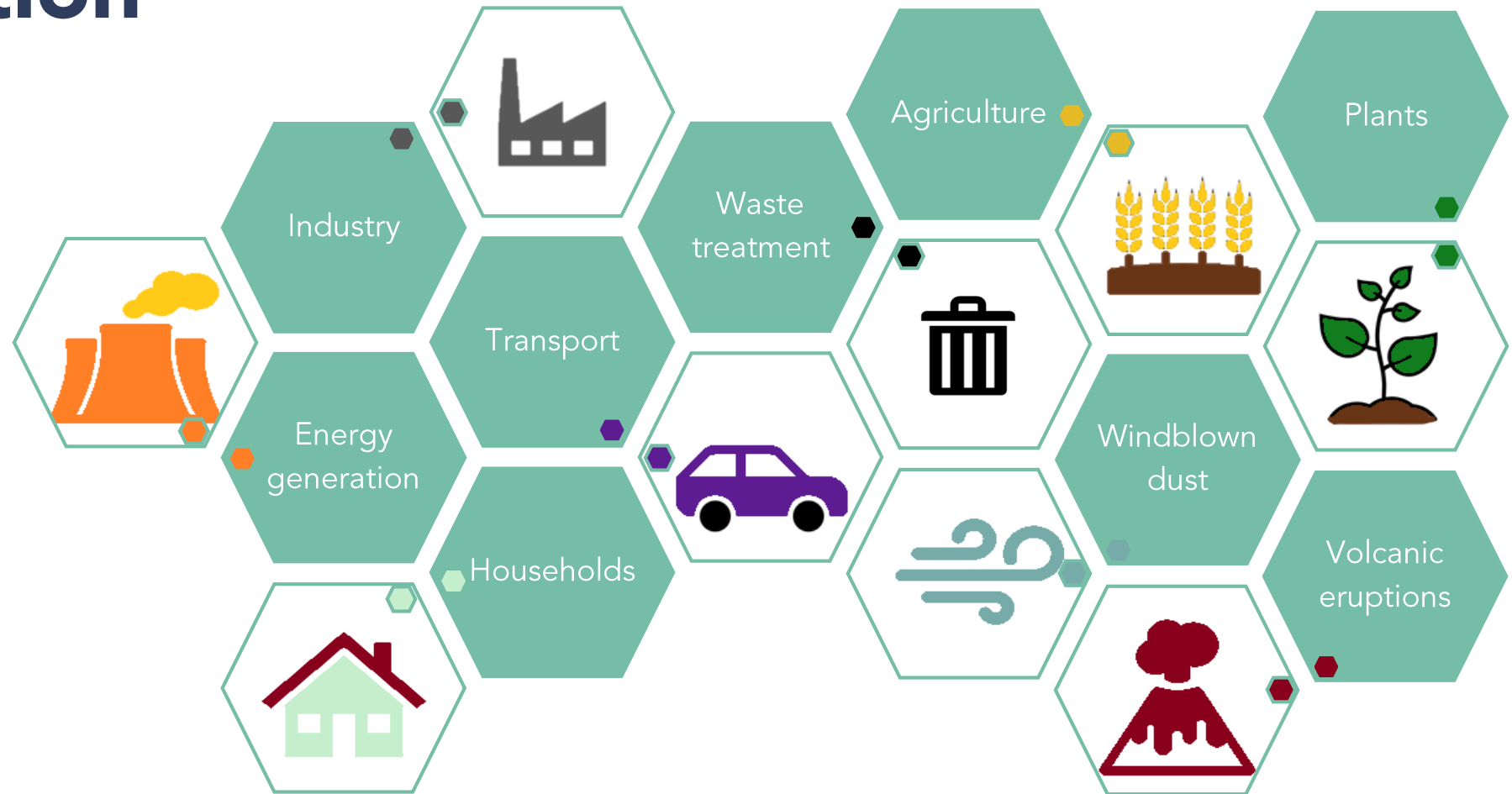
Environmental pollution is defined as the addition of any substance or any form of energy to the environment at a rate faster than it can be dispersed, diluted, decomposed, recycled, or stored in some harmless form.



# Introduction

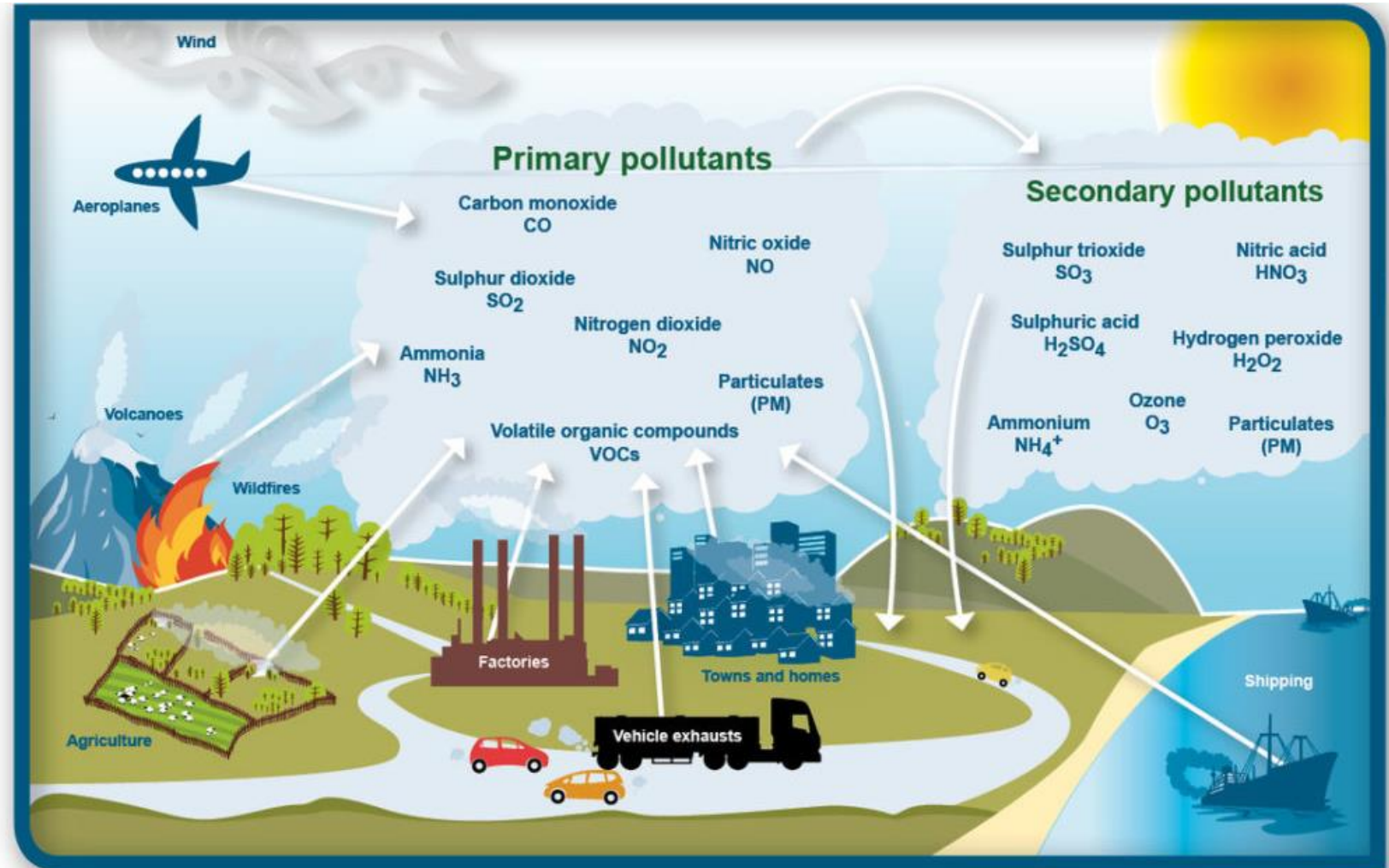
## Air pollution

Contamination of indoor or outdoor environment by any chemical, physical or biological agent that modifies its natural characteristics.



# Introduction

Air pollution



# Introduction

## Air pollution

An air quality index (AQI) is used by government agencies to communicate to the public how polluted the air currently is or how polluted it is forecast to become.

Website	Pollutants	Standard
<a href="https://waqi.info">https://waqi.info</a>	PM 2.5, PM10 It provides information about weather conditions (temperature, pressure, humidity, rain, wind)	US EPA AQI standard
<a href="https://www.iqair.com/earth">https://www.iqair.com/earth</a>	PM 2.5, PM10 It provides information about wind	US EPA AQI standard
<a href="https://www.breezometer.com/">https://www.breezometer.com/</a>	It shows the instantaneous main pollutants	Different standards

# Introduction

## Water pollution

Water pollution is the contamination of water sources by substances which make the water unusable for drinking, cooking, cleaning, swimming, and other activities.

Pictures from:

<https://connectforwater.org/tag/h2o-facts/>

[https://commons.wikimedia.org/wiki/File:Water\\_pollution\\_0025.jpg](https://commons.wikimedia.org/wiki/File:Water_pollution_0025.jpg)

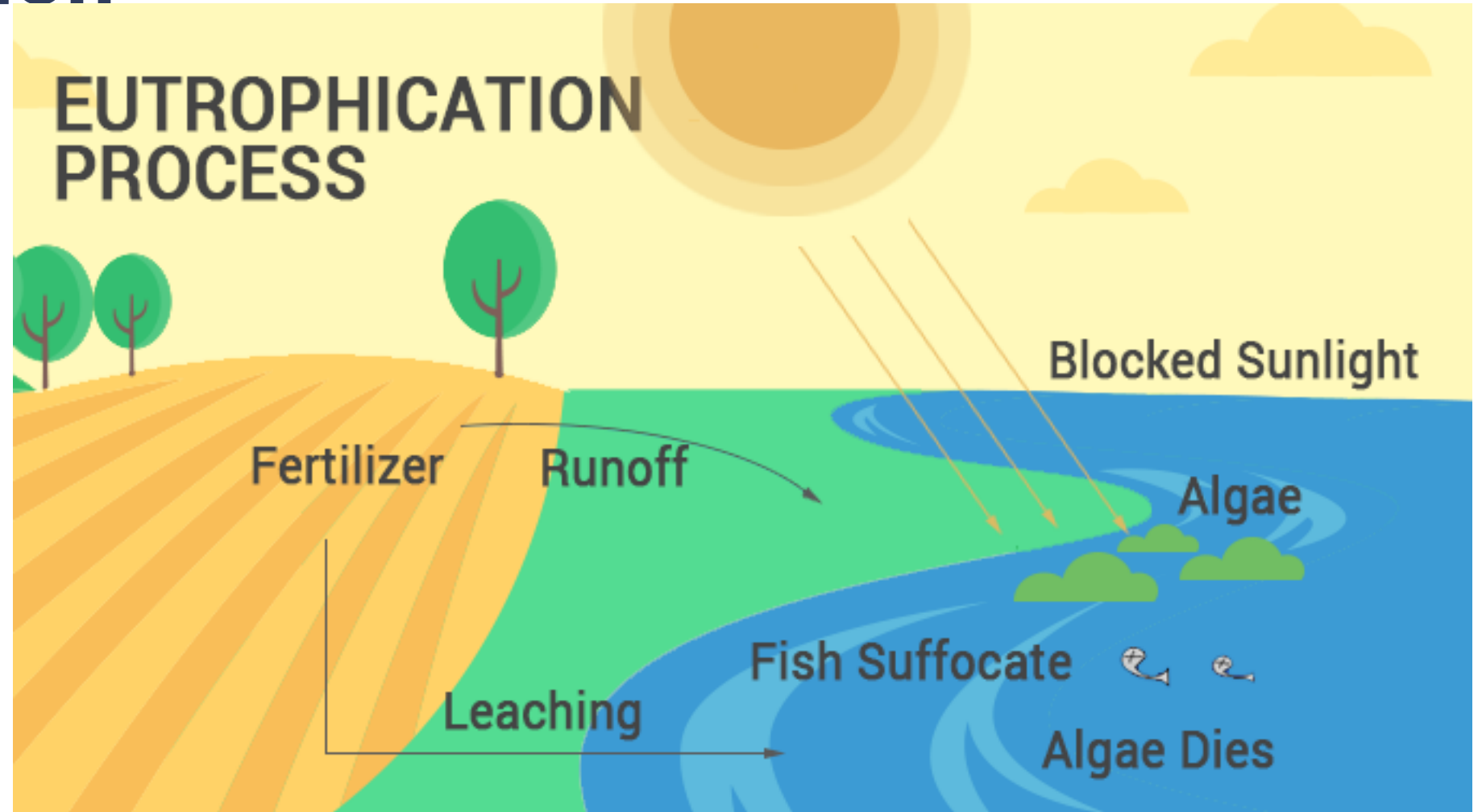
[https://commons.wikimedia.org/wiki/File:Water\\_pollution\\_due\\_to\\_domestic\\_garbage\\_at\\_RK\\_Beach\\_01.jpg](https://commons.wikimedia.org/wiki/File:Water_pollution_due_to_domestic_garbage_at_RK_Beach_01.jpg)

<https://www.iaea.org/newscenter/news/science-and-partnerships-key-to-tackling-marine-plastic-pollution-iaea-at-un-ocean-conference>



# Introduction

Water pollution





# Introduction

## Water pollution

In addition to agriculture, sources of water pollution include:

- industrial waste
- marine dumping
- solid wastes, wastewater, and sewage
- oil leaks and oil spills
- greenhouse gases.

Pictures from:

<https://connectforwater.org/tag/h2o-facts/>

[https://commons.wikimedia.org/wiki/File:Water\\_pollution\\_0025.jpg](https://commons.wikimedia.org/wiki/File:Water_pollution_0025.jpg)

[https://commons.wikimedia.org/wiki/File:Water\\_pollution\\_due\\_to\\_domestic\\_garbage\\_at\\_RK\\_Beach\\_01.jpg](https://commons.wikimedia.org/wiki/File:Water_pollution_due_to_domestic_garbage_at_RK_Beach_01.jpg)

<https://www.iaea.org/newscenter/news/science-and-partnerships-key-to-tackling-marine-plastic-pollution-iaea-at-un-ocean-conference>



# Introduction

## Land pollution

Impacts on land are generally due to man-made causes and naturally occurring causes.

Anthropogenic soil pollution causes:

- accidental leaks of chemicals;
- foundry activities
- manufacturing processes
- mining activities
- construction activities
- agricultural activities
- transportation activities
- waste disposal.



Pictures from:

<https://safestart.com/news/first-line-defense-against-chemical-spills/>

<https://it.wikipedia.org/wiki/Fonderia#/media/File:Castingiron.jpg>

[https://commons.wikimedia.org/wiki/File:Togo\\_phosphates\\_mining.jpg](https://commons.wikimedia.org/wiki/File:Togo_phosphates_mining.jpg)

<https://commons.wikimedia.org/wiki/File:2021-05-21-Construction-work-Benrodestrasse-foto3.jpg>

[https://commons.wikimedia.org/wiki/File:Agriculture\\_in\\_Vietnam\\_with\\_farmers.jpg](https://commons.wikimedia.org/wiki/File:Agriculture_in_Vietnam_with_farmers.jpg)

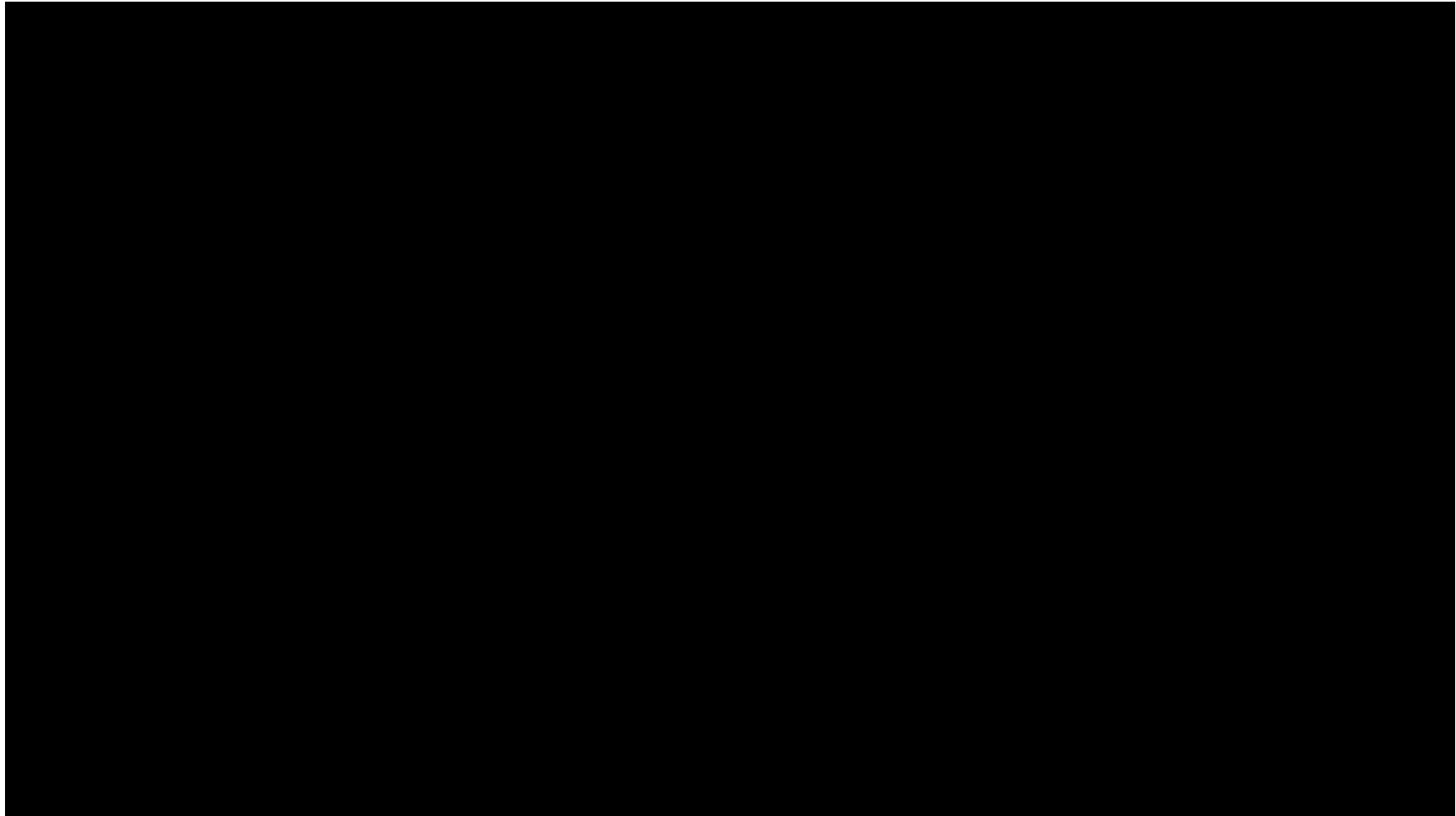
[https://commons.wikimedia.org/wiki/File:Disposal\\_of\\_solid\\_waste\\_in\\_the\\_city\\_%286908383519%29.jpg](https://commons.wikimedia.org/wiki/File:Disposal_of_solid_waste_in_the_city_%286908383519%29.jpg)

# Introduction

## Land pollution

Soil permeability influences land pollution.

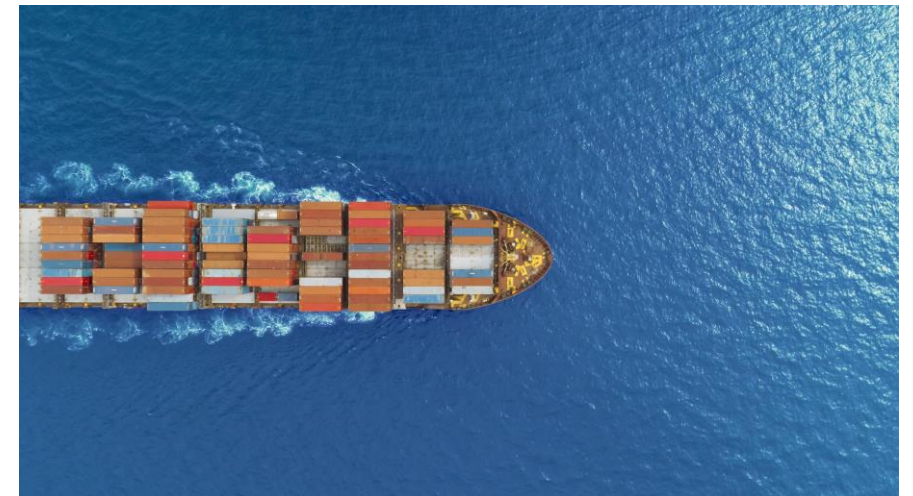
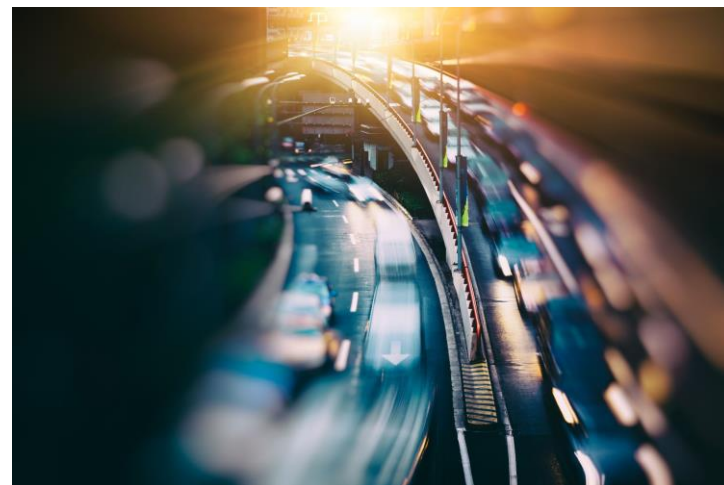
The greater the permeability, the greater the risks from land pollution.



# Introduction

## Noise pollution

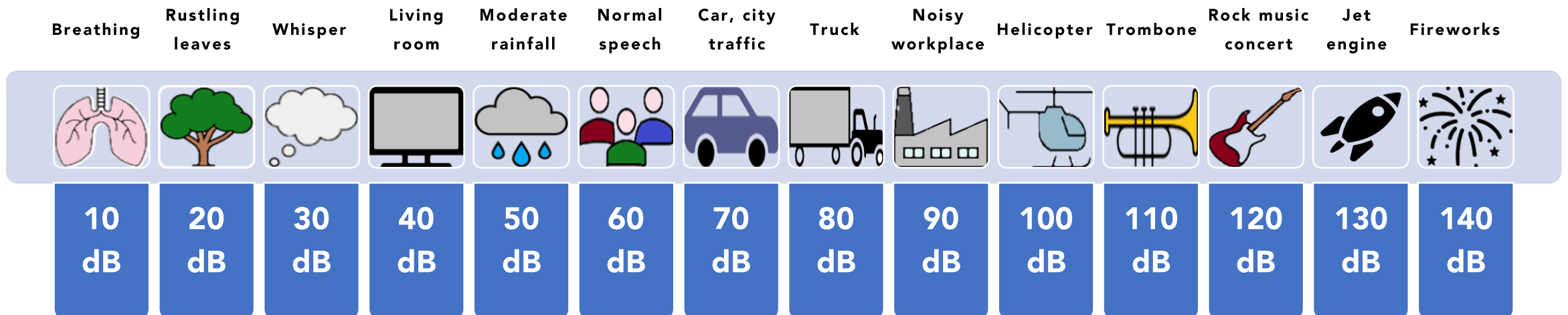
Noise pollution is caused by machines and engines pretty much associated with the industry, as well as the noise of transportation systems.



# Introduction

## Noise pollution

Sound is measured in decibels. The normal audible frequency range is approximately 20 Hz–20 kHz.



# Introduction

## Noise pollution

Health problems caused by exposure to loud noise.

Impacts on the health and well-being of wildlife (both on land and under water).



# Introduction

## Visual pollution

Many do not know about visual pollution and that is why it is becoming more frequent to have contact with it and its effects.

Due to the excessive amount of elements contained in these indoor or outdoor environments.

Light pollution is an example.



# Introduction

## Visual pollution

For human beings, it generates visual problems, distraction and psychological stress.

Fauna and flora can be affected with migration of species as consequence.

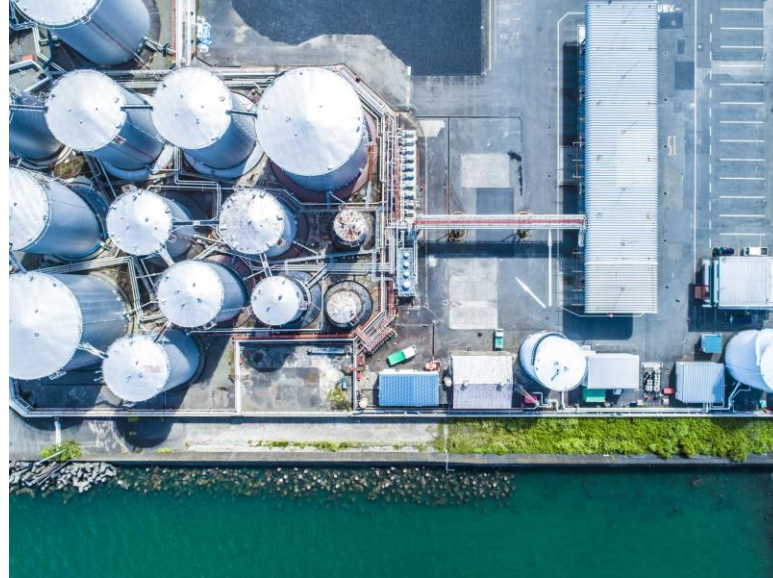




# Introduction

## Thermal pollution

Thermal pollution is the rise or fall in the temperature of a natural body of water caused by human influence.

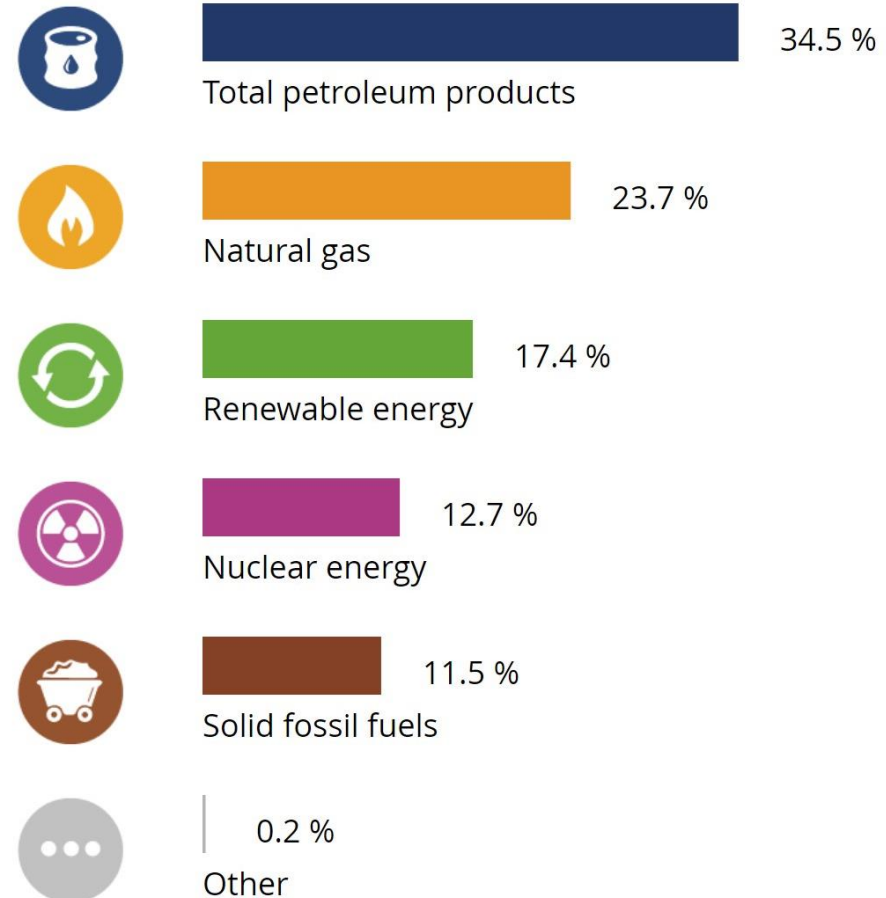


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# Fossil fuels

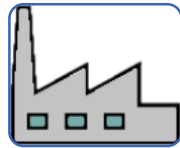
## Energy mix for the European Union



# Fossil fuels



Land



Air



Water



Noise

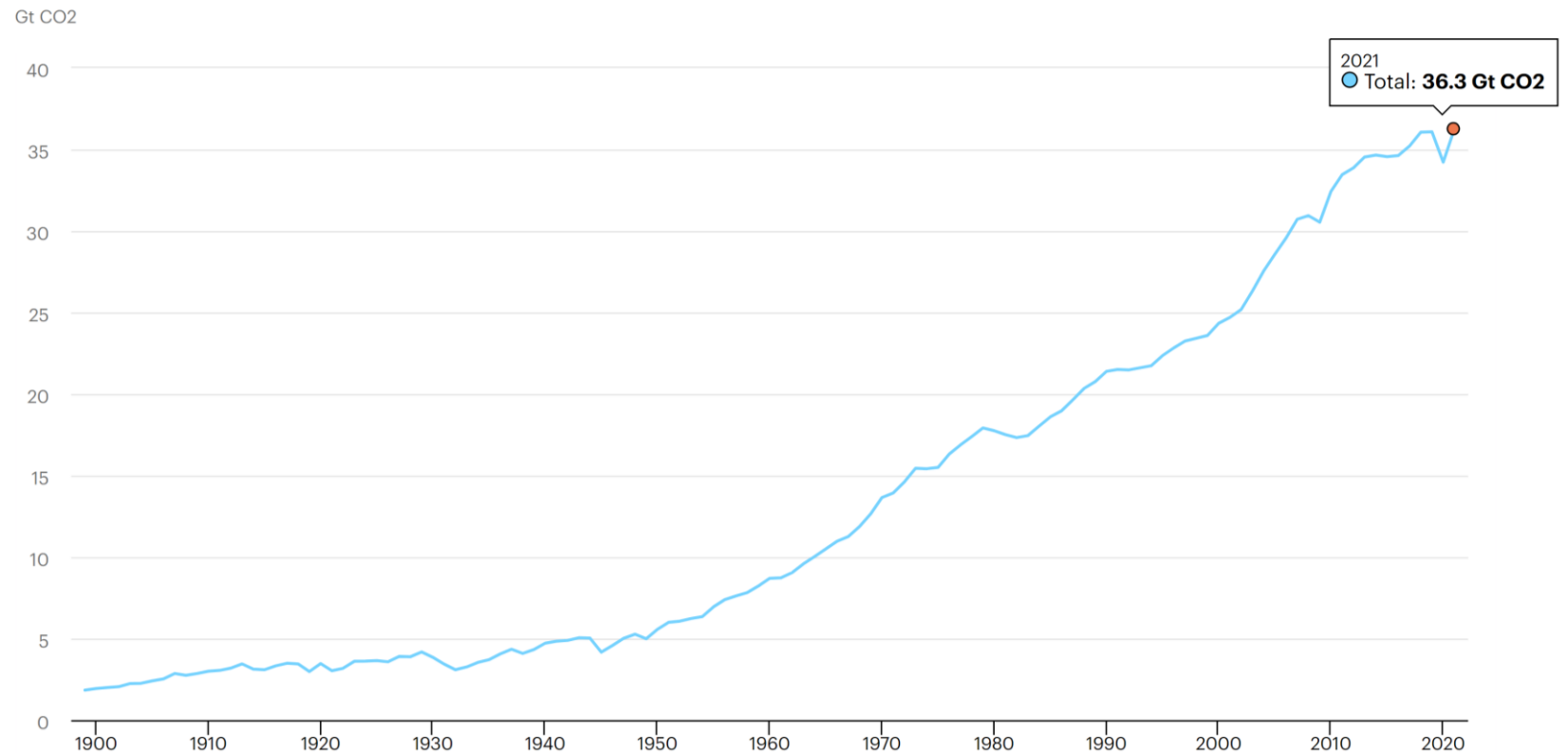


Visual

# Fossil fuels

## Air pollution

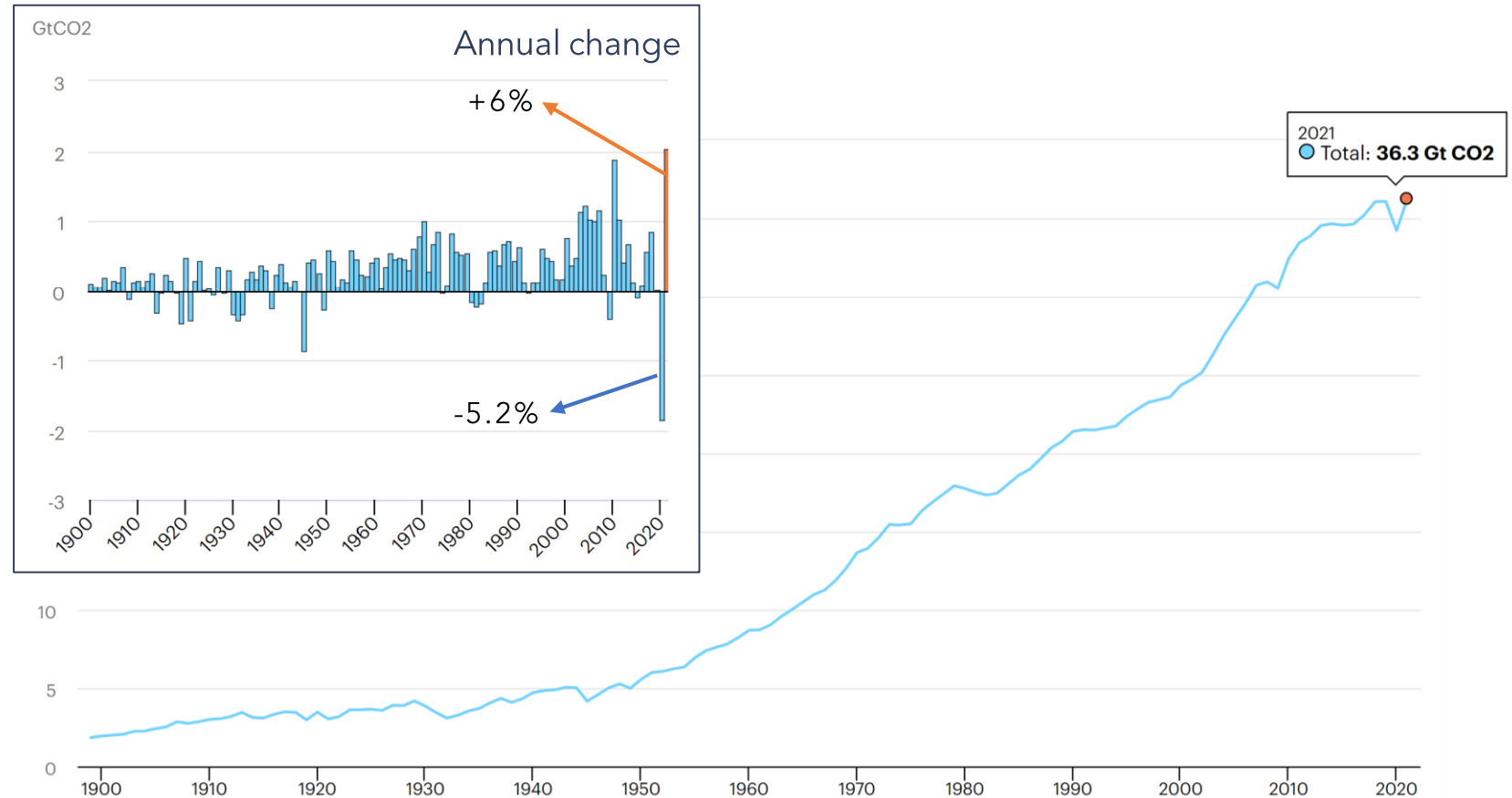
CO<sub>2</sub> emissions from energy combustion and industrial processes, 1900-2021



# Fossil fuels

Air pollution

CO<sub>2</sub> emissions from energy combustion and industrial processes, 1900-2021



IEA, CO<sub>2</sub> emissions from energy combustion and industrial processes, 1900-2021, IEA, Paris <https://www.iea.org/data-and-statistics/charts/co2-emissions-from-energy-combustion-and-industrial-processes-1900-2021>

# Fossil fuels

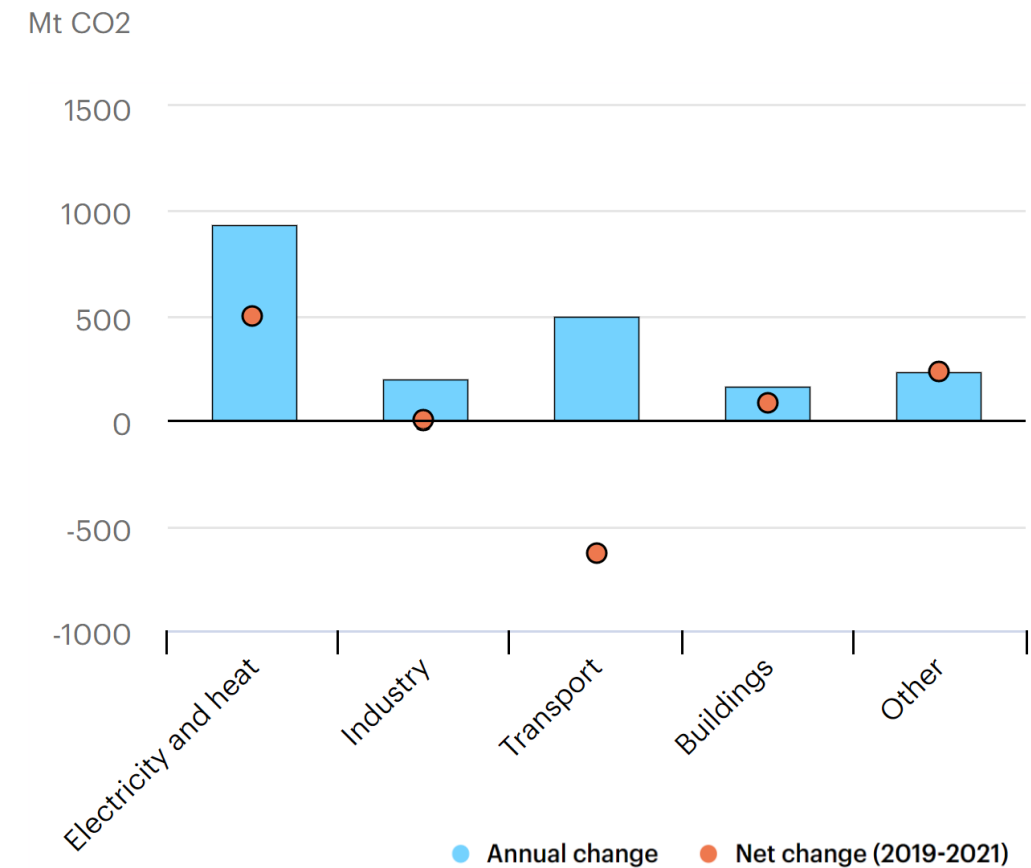
## Air pollution

### Annual change in CO<sub>2</sub> emissions by sector, 2021

A 6% increase from 2020 pushed emissions to 36.3 Gt, in line with the jump in global economic output of 5.9%.

The biggest increase in CO<sub>2</sub> emissions by sector in 2021 took place in electricity and heat production, where they jumped by more than 900 Mt.

IEA, Annual change in CO<sub>2</sub> emissions by sector, 2021, IEA, Paris <https://www.iea.org/data-and-statistics/charts/annual-change-in-co2-emissions-by-sector-2021>



# Fossil fuels

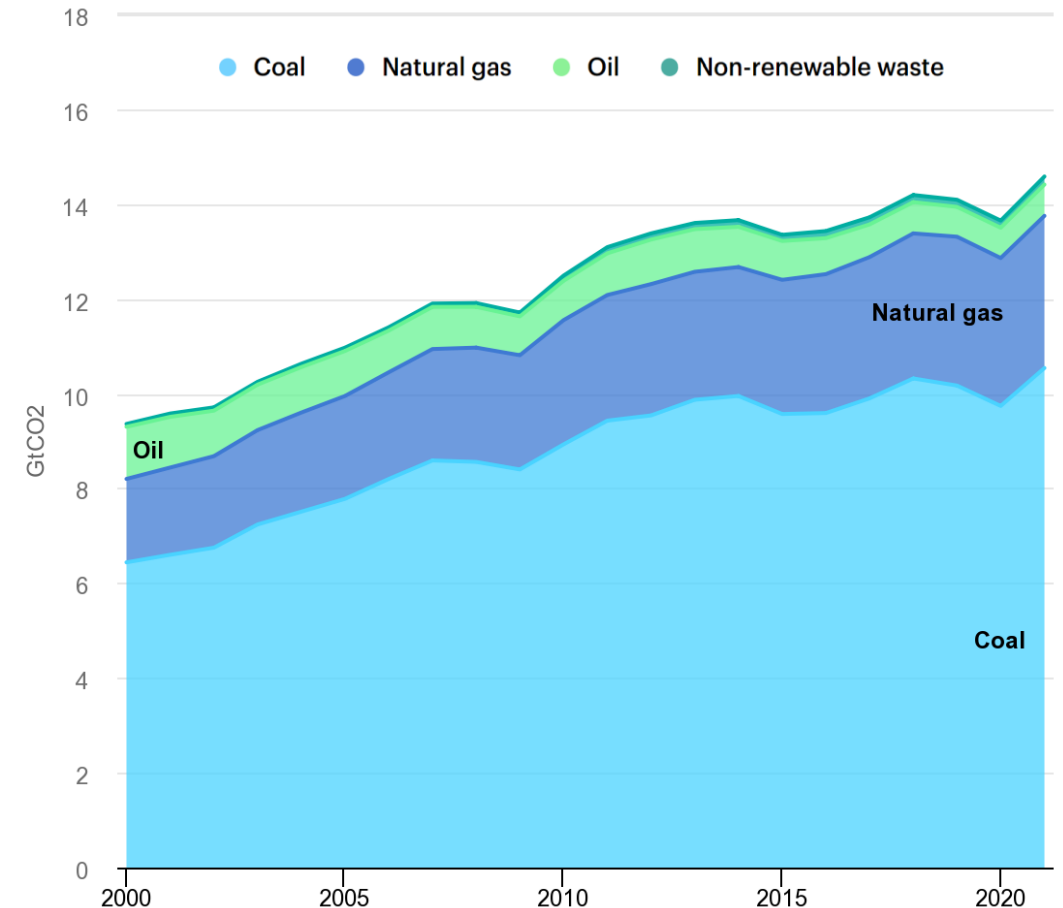
## Air pollution

### CO<sub>2</sub> emissions from electricity and heat production by fuel, 2000-2021

Despite the rebound in coal use, renewable energy sources and nuclear power provided a higher share of global electricity generation than coal in 2021.

Without increasing output from renewables and nuclear power, the rise in global CO<sub>2</sub> emissions in 2021 would have been 220 Mt higher.

IEA, Annual change in CO<sub>2</sub> emissions by sector, 2021, IEA, Paris <https://www.iea.org/data-and-statistics/charts/annual-change-in-co2-emissions-by-sector-2021>





# Fossil fuels

Air pollution

Targets for reducing greenhouse  
gas emissions

Key targets for  
2020

- 20% cut in greenhouse gas emissions (from 1990 levels)
- 20% of EU energy from renewables (more than double the 2010 level of 9.8%, with a 10% share of renewables in the transport sector)
- 20% improvement in energy efficiency

Key targets for  
2030

- At least 40% cuts in greenhouse gas emissions (from 1990 levels)
- At least 32% share for renewable energy
- At least 32.5% improvement in energy efficiency

By 2050

- The EU aims to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions. This objective is at the heart of the European Green Deal and in line with the EU's commitment to global climate action under the Paris Agreement.

# Fossil fuels

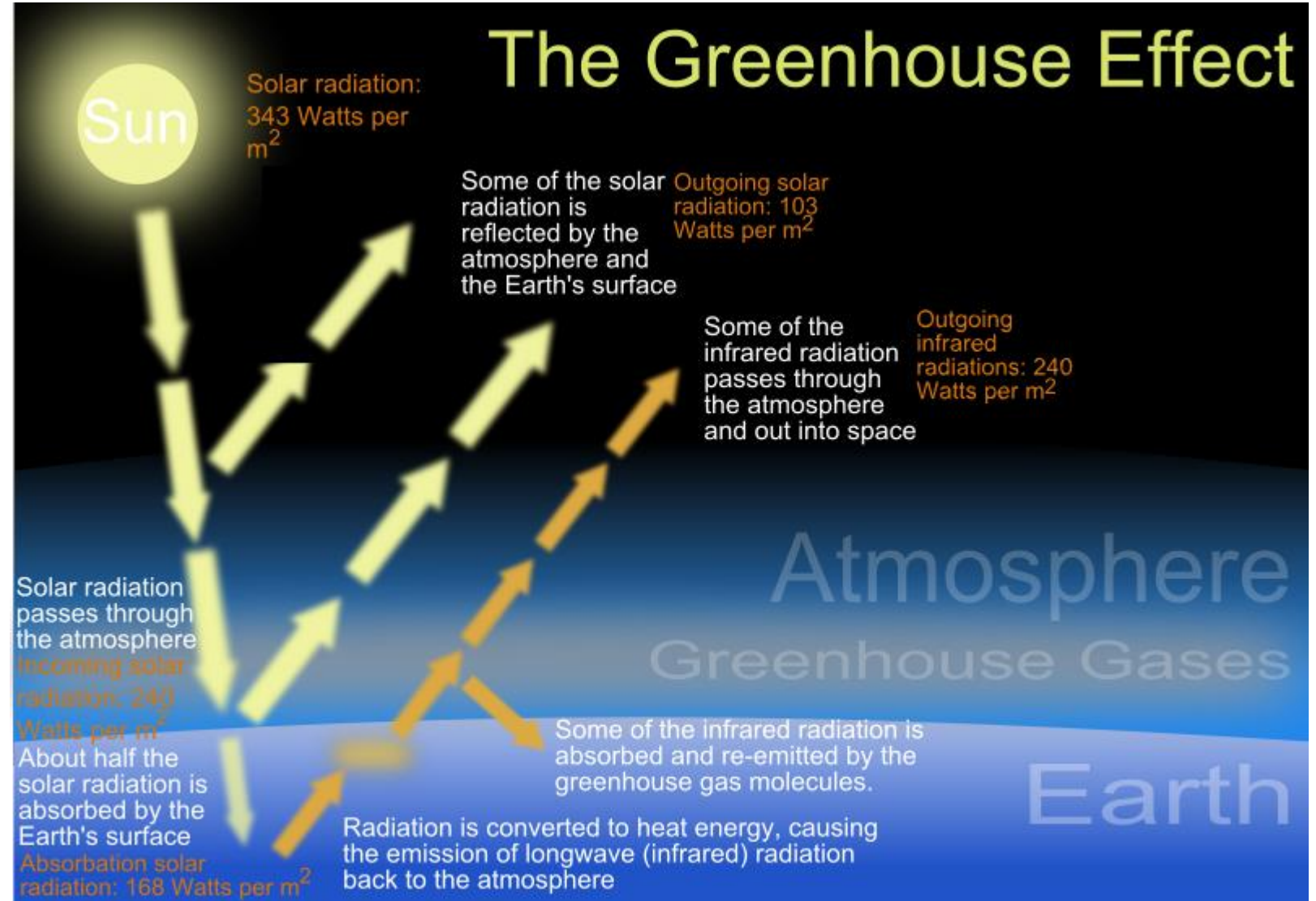
Air pollution

Greenhouse effect

The greenhouse effect helps trap heat from the sun.

People's activities are increasing the amount of heat-trapping greenhouse gases in the atmosphere, causing the earth to warm up.

[https://commons.wikimedia.org/wiki/File:The\\_green\\_house\\_effect.svg](https://commons.wikimedia.org/wiki/File:The_green_house_effect.svg)

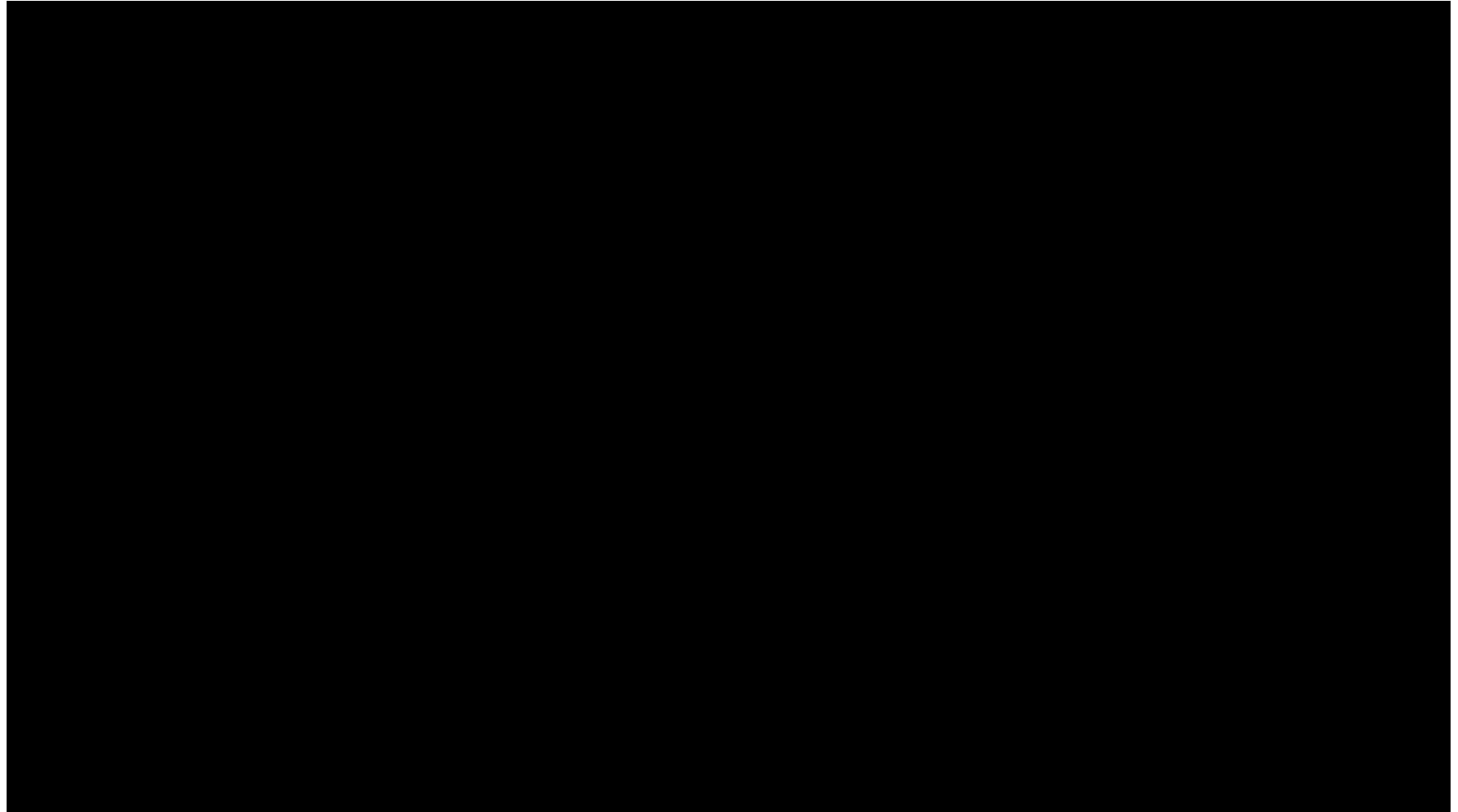


# Fossil fuels

Air pollution

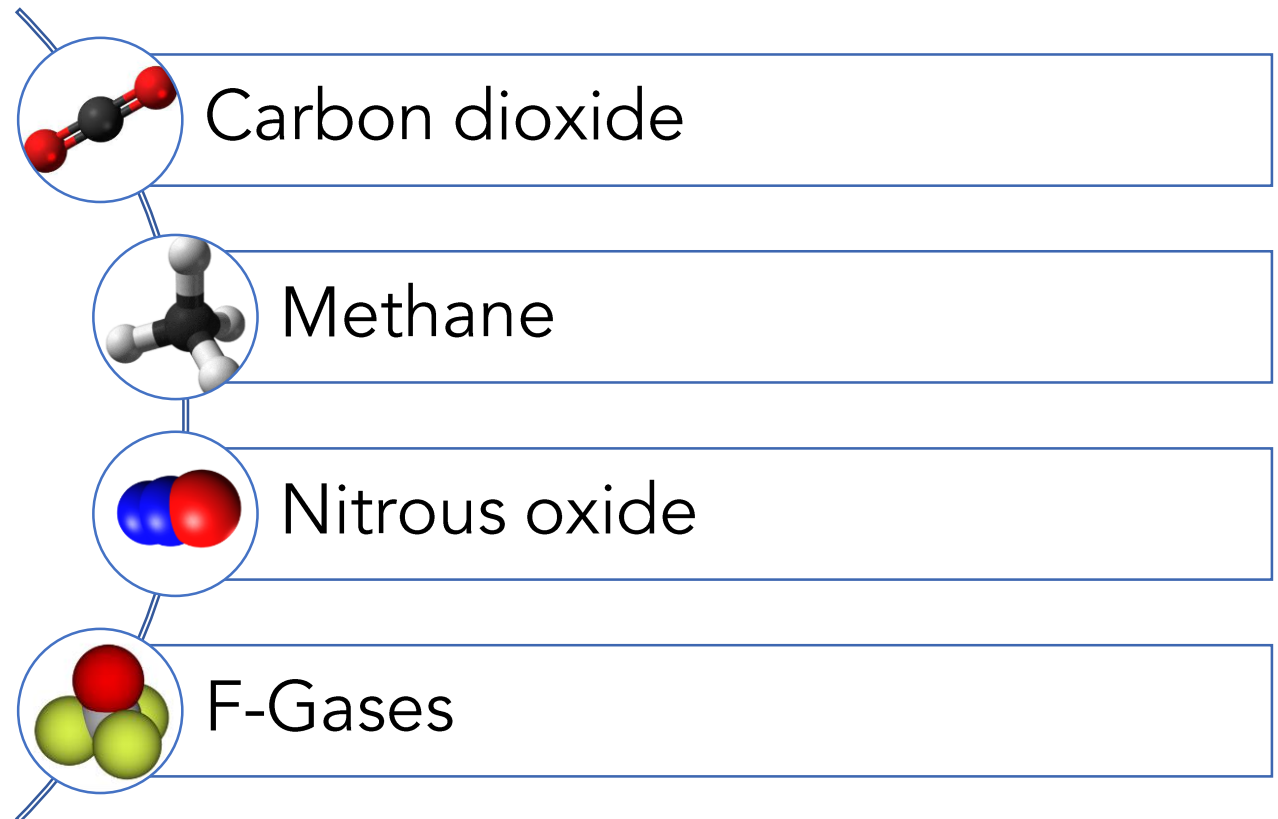
Greenhouse effect:  
the carbon cycle

<https://youtu.be/IWEvBLIUa2E>



# Fossil fuels

Key greenhouse gases

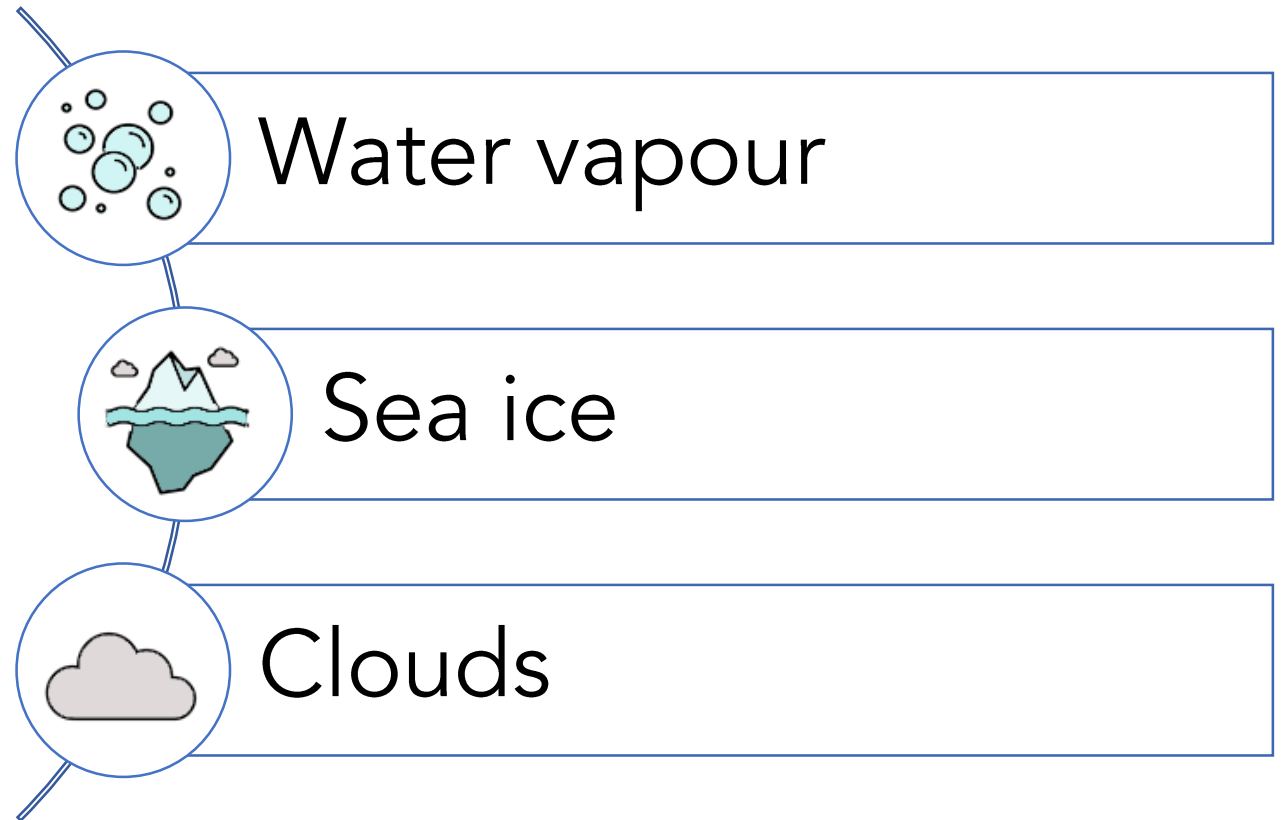


*Pictures from: [https://commons.wikimedia.org/wiki/File:Carbon\\_dioxide\\_3D\\_ball.png](https://commons.wikimedia.org/wiki/File:Carbon_dioxide_3D_ball.png)  
<https://freesvg.org/methane-molecule-3d>  
[https://commons.wikimedia.org/wiki/File:Nitrous\\_oxide-3D-vdW.png](https://commons.wikimedia.org/wiki/File:Nitrous_oxide-3D-vdW.png)  
<https://commons.wikimedia.org/wiki/File:Vanadium%28V%29-oxytrifluoride-3D-vdW.png>*

# Fossil fuels

Climate feedback

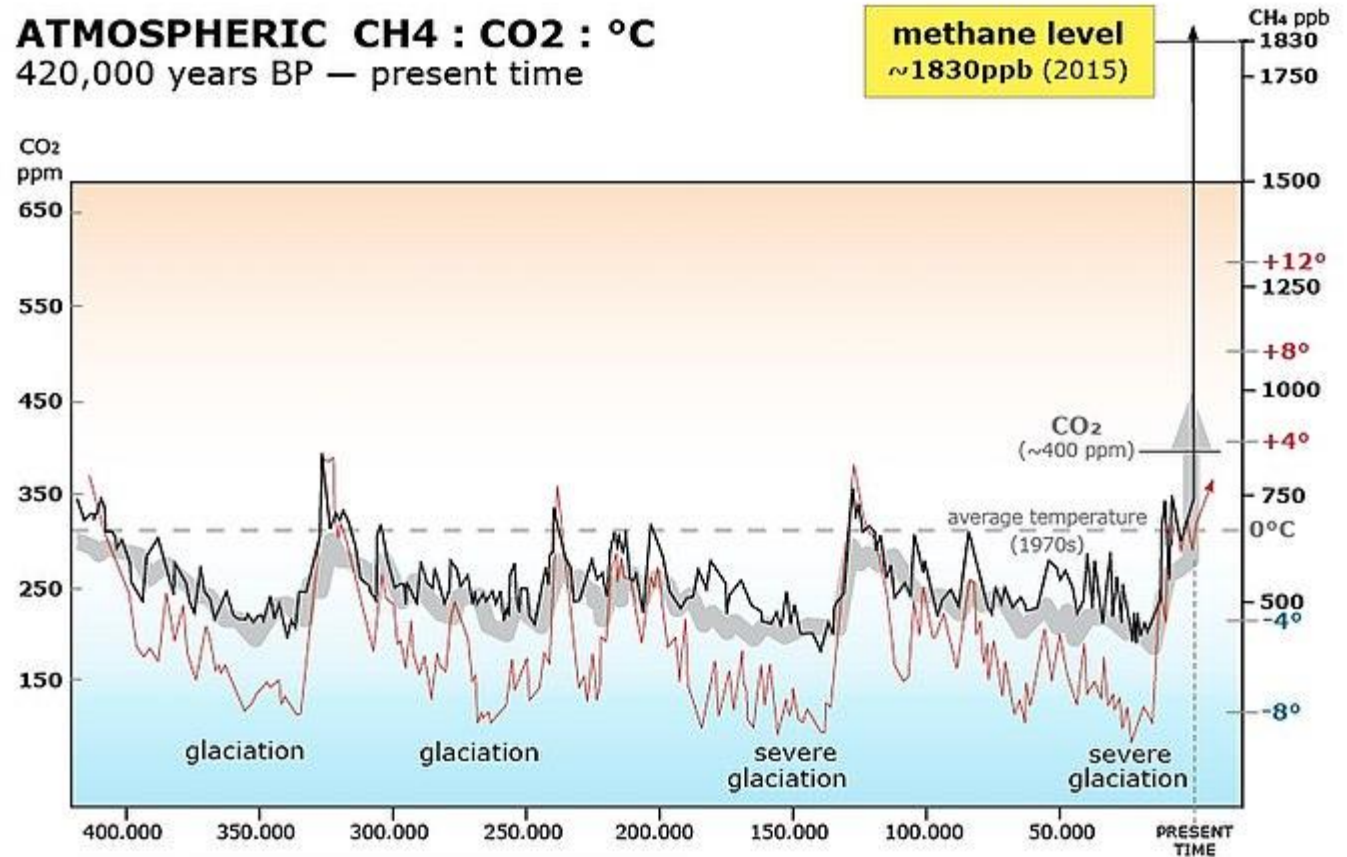
<https://climatekids.nasa.gov/time-machine/>



# Fossil fuels

Climate feedback

**ATMOSPHERIC CH<sub>4</sub> : CO<sub>2</sub> : °C**  
420,000 years BP — present time



Temperature variation from present shown in °C  
 Methane (CH<sub>4</sub>) parts per billion (ppb by volume)  
 Carbon dioxide (CO<sub>2</sub>) parts per million (ppm/v)

Based on Antarctic and Greenland ice-core data, and atmospheric data from Cape Grim, Tasmania. Vostok ice core data: Petit et al, Nature (No.399, 1999) Law Dome ice core data: Etheridge et al., Journal of Geophysical Research (1996) Cape Grim Station data: CSIRO Atmospheric Research and Bureau of Meteorology °C between 160,000 and 420,000 years BP from IPCC.

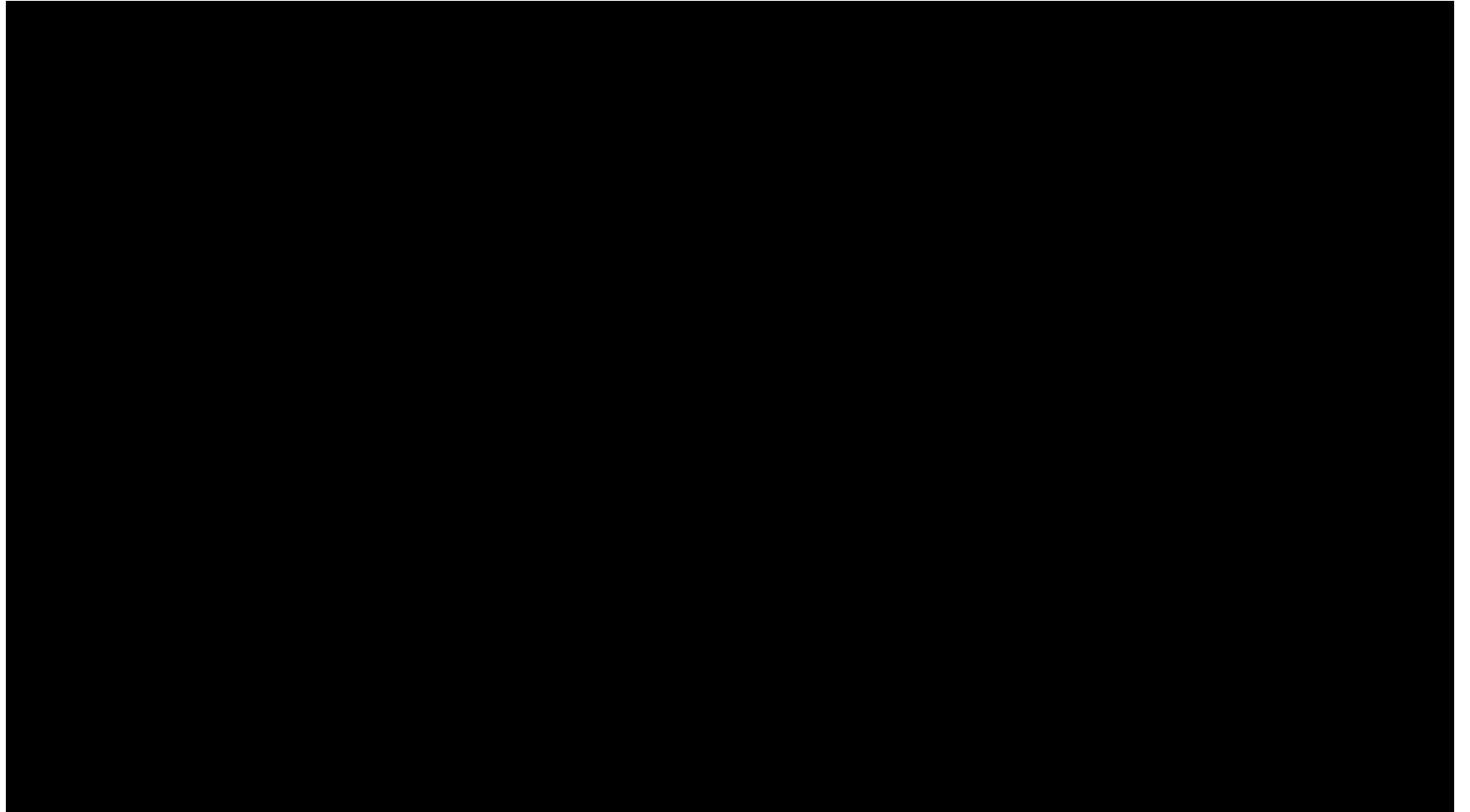
REG MORRISON, <http://regmorrison.edublogs.org/articles/>

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Picture from:  
[https://commons.wikimedia.org/wiki/File:Graph\\_CO2\\_CH4\\_and\\_Temperature\\_Graph\\_in\\_English\\_15\\_June\\_2015\\_by\\_Reg\\_Morrison.jpg](https://commons.wikimedia.org/wiki/File:Graph_CO2_CH4_and_Temperature_Graph_in_English_15_June_2015_by_Reg_Morrison.jpg)

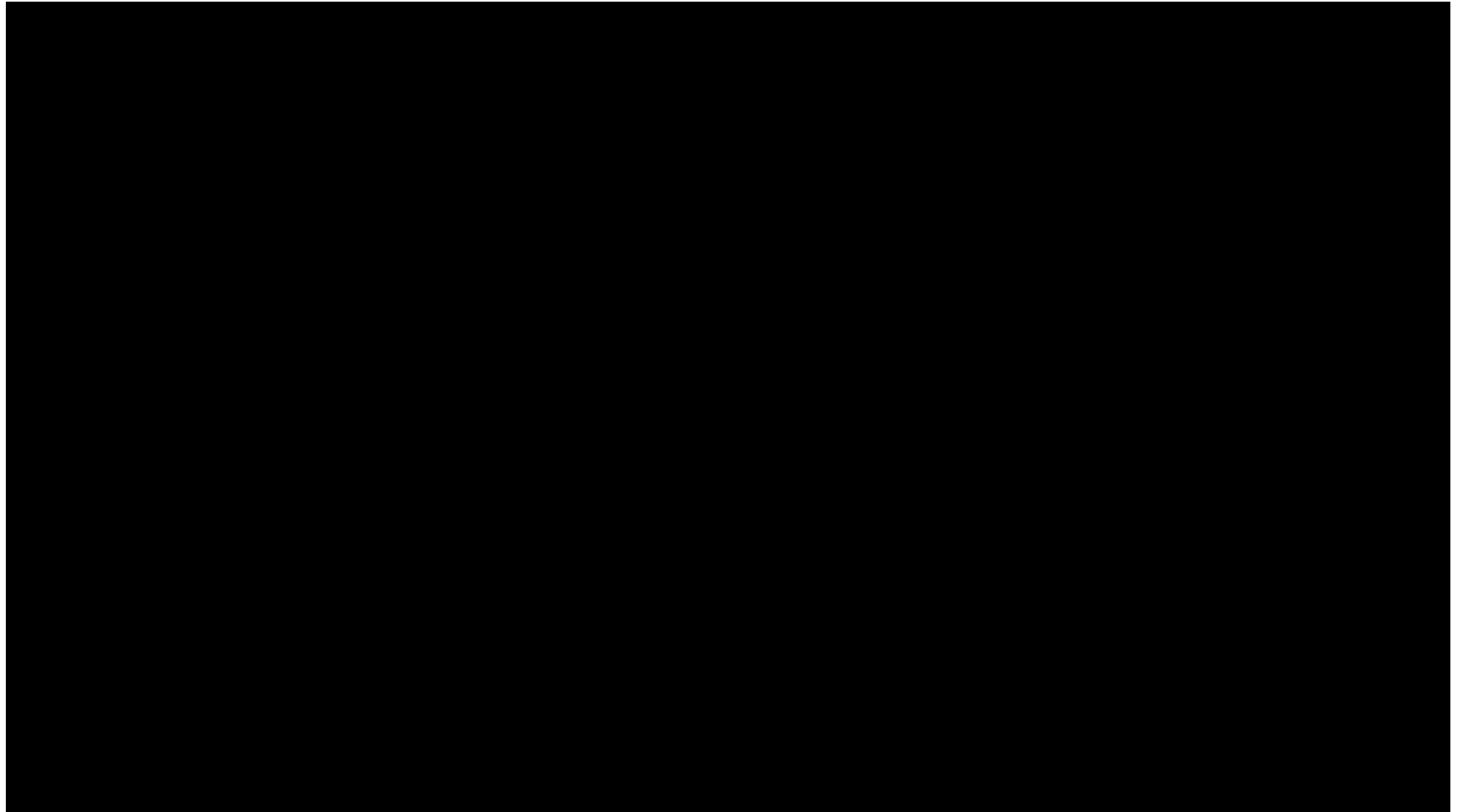
# Fossil fuels

Climate change:  
different opinions



# Fossil fuels

Climate change:  
different opinions





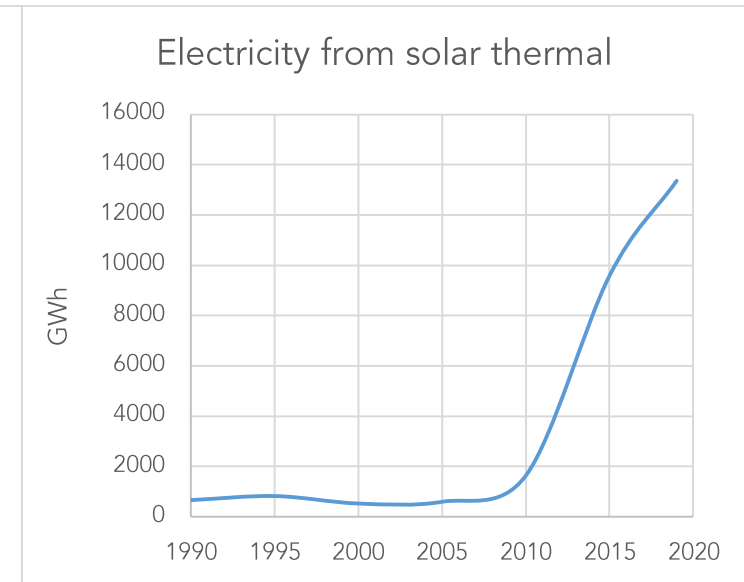
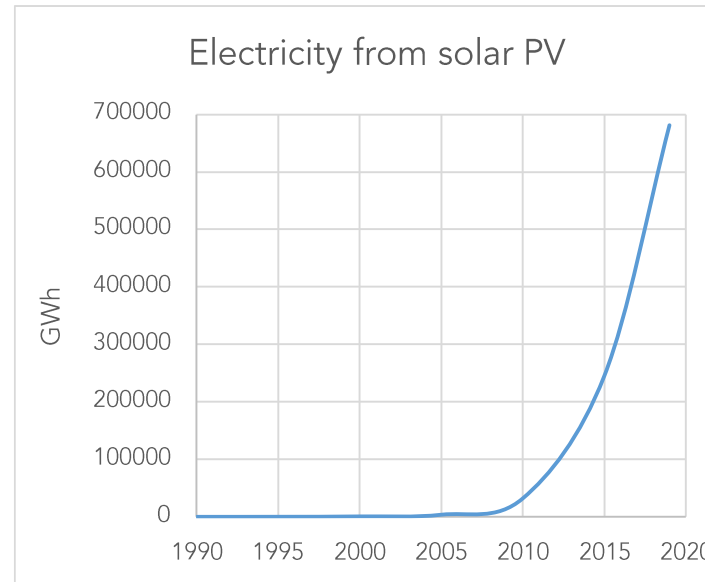
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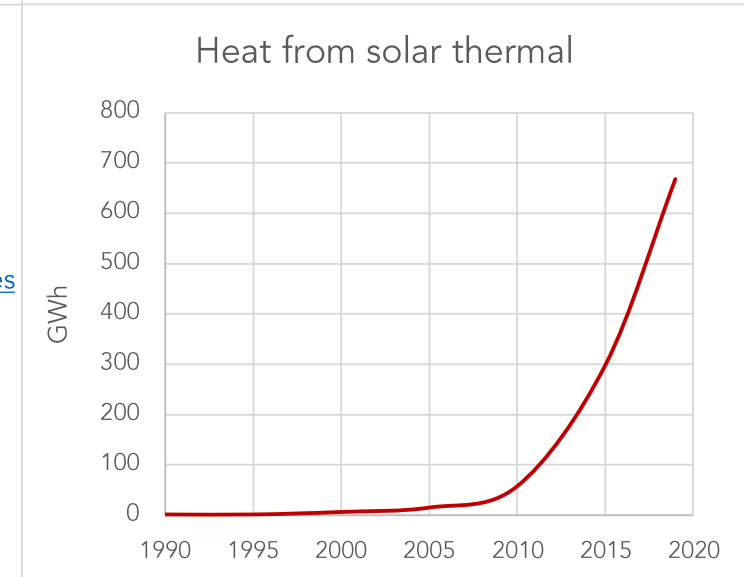
# Renewables

## Solar energy

Solar energy is attracting more and more to reduce the environmental impact of energy generation.



<https://www.iea.org/fuels-and-technologies/renewables>

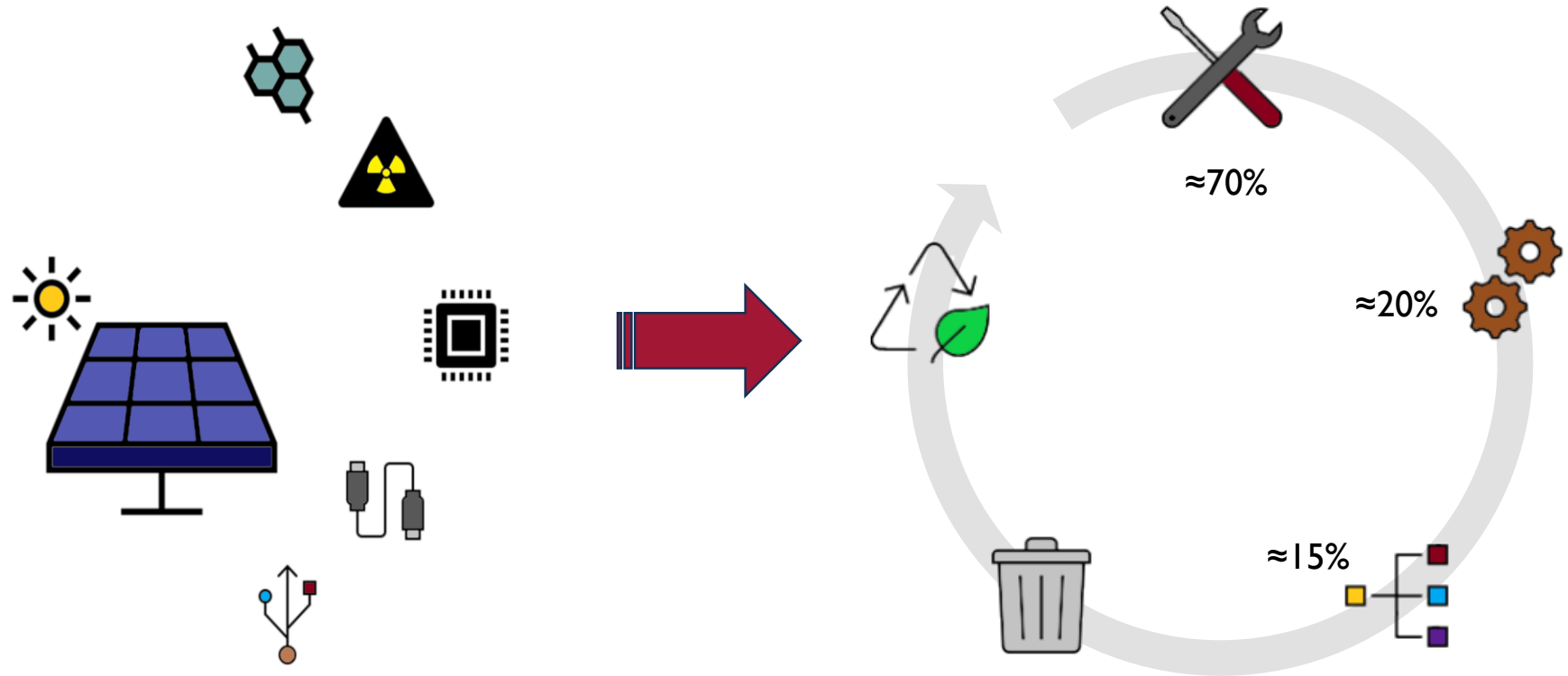


# Renewables

## Solar energy

PV setup consists of several parts, i.e. cells, electrical and mechanical components.

The fabrication of different components of the PV system involves the use of different chemicals and hazardous material.

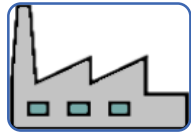


# Renewables

Solar energy



Land



Air



Hazardous materials



Water



Noise



Visual

# Renewables

## Solar energy

Solar power systems have a very high energy land-use intensity compared to other energy technologies.

The construction phase usually contributes to the major environmental impact on the land and habitat.

Shortening the distance between the rows of PV modules or installing the modules in occupied spaces can lower land use and raise land efficiency.

Land use can be also reduced by employing floating PV or hybrid systems.



[https://commons.wikimedia.org/wiki/File:At\\_work\\_on\\_the\\_solar\\_array.\\_%289474823276%29.jpg](https://commons.wikimedia.org/wiki/File:At_work_on_the_solar_array._%289474823276%29.jpg)  
<https://commons.wikimedia.org/wiki/File:Solar-Car-Park-PV-Structures.jpg>  
[https://commons.wikimedia.org/wiki/File:Floating\\_PV\\_system\\_Far\\_Niente\\_Winery\\_California\\_2018.jpg](https://commons.wikimedia.org/wiki/File:Floating_PV_system_Far_Niente_Winery_California_2018.jpg)

# Renewables

## Solar energy

Manufacturing is responsible for the largest share of emissions.

Eventual cut of plants to avert shading effects reduces sequestration rate of CO<sub>2</sub> by vegetation.

PV impact may be reduced by improving the performance, increasing lifespan, increasing irradiance, using renewable energy mixes and thin-film or cadmium selenide quantum dot PVs.



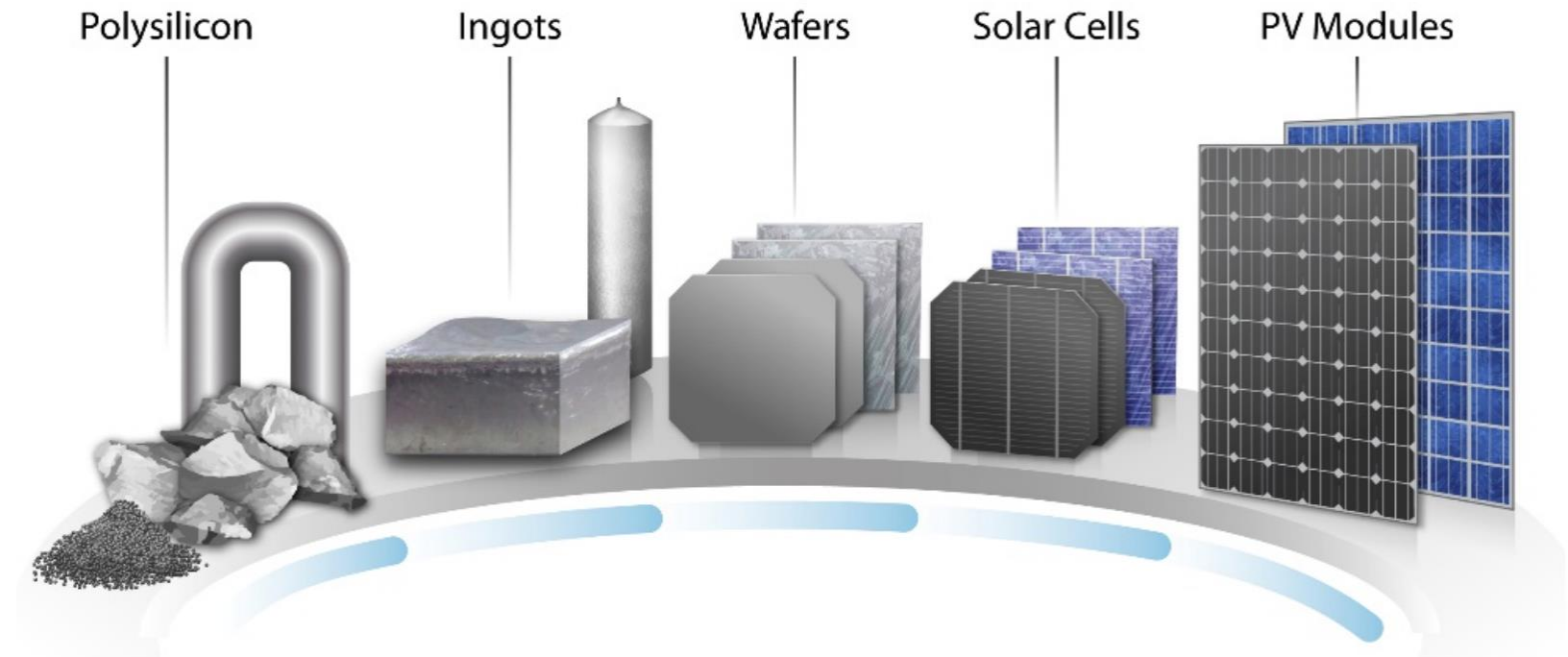
# Renewables

## Solar energy

PV cells' manufacturing requires the use of:

- several raw materials, i.e. silicon, cadmium, tellurium, copper, selenium, and gallium;
- numerous chemicals and solvents.

Thus, recycling of PV waste and disposed PV modules is crucial.



Picture from: Woodhouse, Michael. Brittany Smith, Ashwin Ramdas, and Robert Margolis. 2019. Crystalline Silicon Photovoltaic Module Manufacturing Costs and Sustainable Pricing: 1H 2018 Benchmark and Cost Reduction Roadmap. Golden, CO: National Renewable Energy Laboratory.  
<https://www.nrel.gov/docs/fy19osti/72134.pdf>

# Renewables

## Solar energy

Manufacturing and recycling processes are characterized by a significant water consumption (higher than during operation).

Water consumption is critical mainly for countries exposed by severe water shortage.

However, compared to other conventional and renewable energy type of technologies PV would be the best option for conserving water supply.

Picture from: [https://commons.wikimedia.org/wiki/File:Matrice\\_nettoyage.jpg](https://commons.wikimedia.org/wiki/File:Matrice_nettoyage.jpg)





# Renewables

## Solar energy

Noise impact may be relevant during the construction phase, whereas it is insignificant during operation.

One novel design is the use of PV systems as noise barriers.



Picture from:

[https://commons.wikimedia.org/wiki/File:Autobahn\\_L%C3%A4rmschutzwall\\_T%C3%B6ging\\_am\\_Inn.JPG](https://commons.wikimedia.org/wiki/File:Autobahn_L%C3%A4rmschutzwall_T%C3%B6ging_am_Inn.JPG)

# Renewables

## Solar energy

Visual impact depends on the area of installation.

The negative impact can be minimized by:

- mounting PV panels on the rooftop and building facades
- placing the PV facilities in regions far away from residential areas such as desert regions.

Picture from:

[https://commons.wikimedia.org/wiki/File:BAPV\\_solar-facade.JPG](https://commons.wikimedia.org/wiki/File:BAPV_solar-facade.JPG)

<https://www.pv-magazine.com/2021/11/03/pv-system-design-for-low-cost-hot-water-production/>

[https://commons.wikimedia.org/wiki/File:PikiWiki\\_Israel\\_75640\\_pv\\_site.jpg](https://commons.wikimedia.org/wiki/File:PikiWiki_Israel_75640_pv_site.jpg)

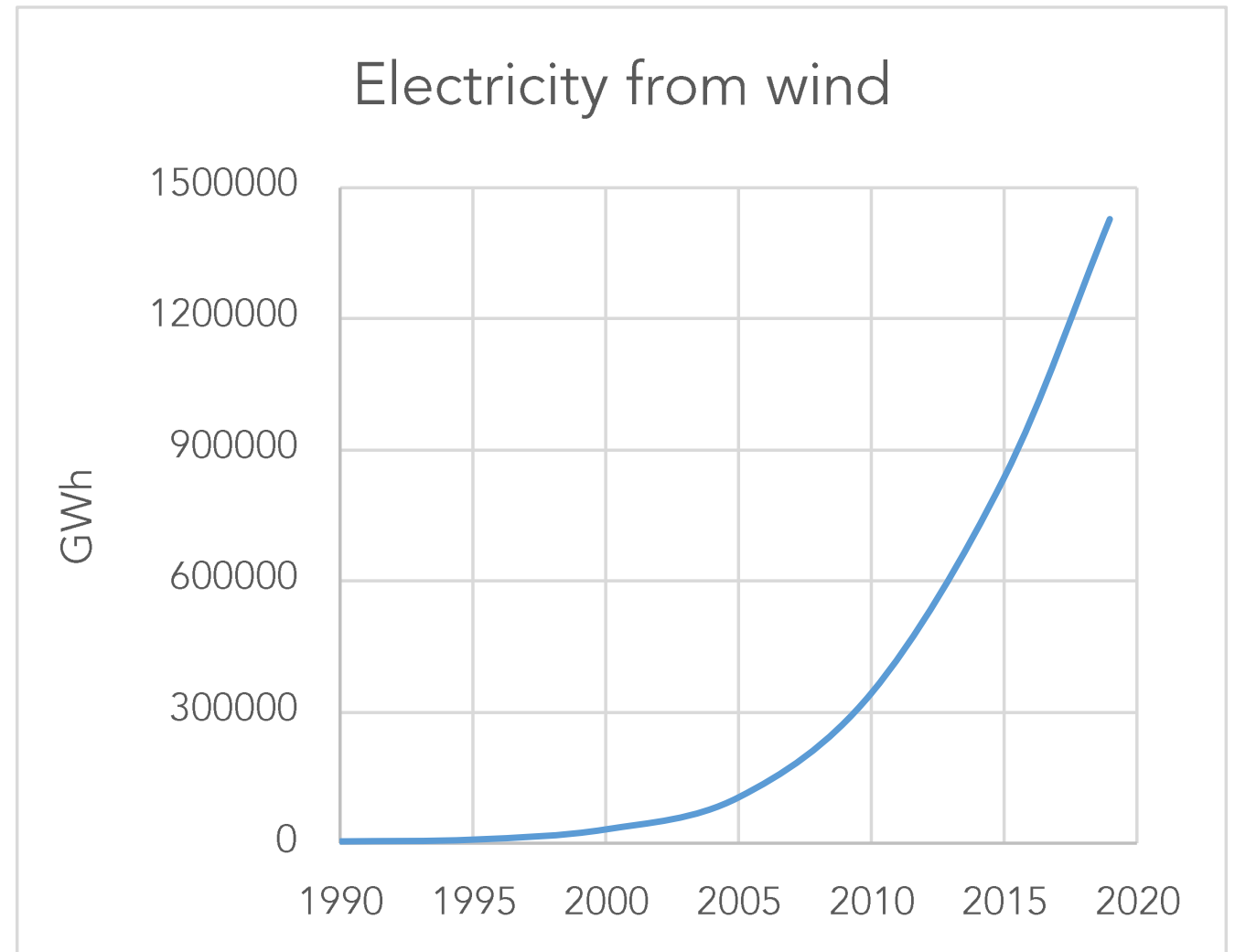


# Renewables

## Wind energy

Throughout the history of the progress of wind power, there has been a clear correlation between the oil price and the demand for wind energy.

<https://www.iea.org/fuels-and-technologies/renewables>

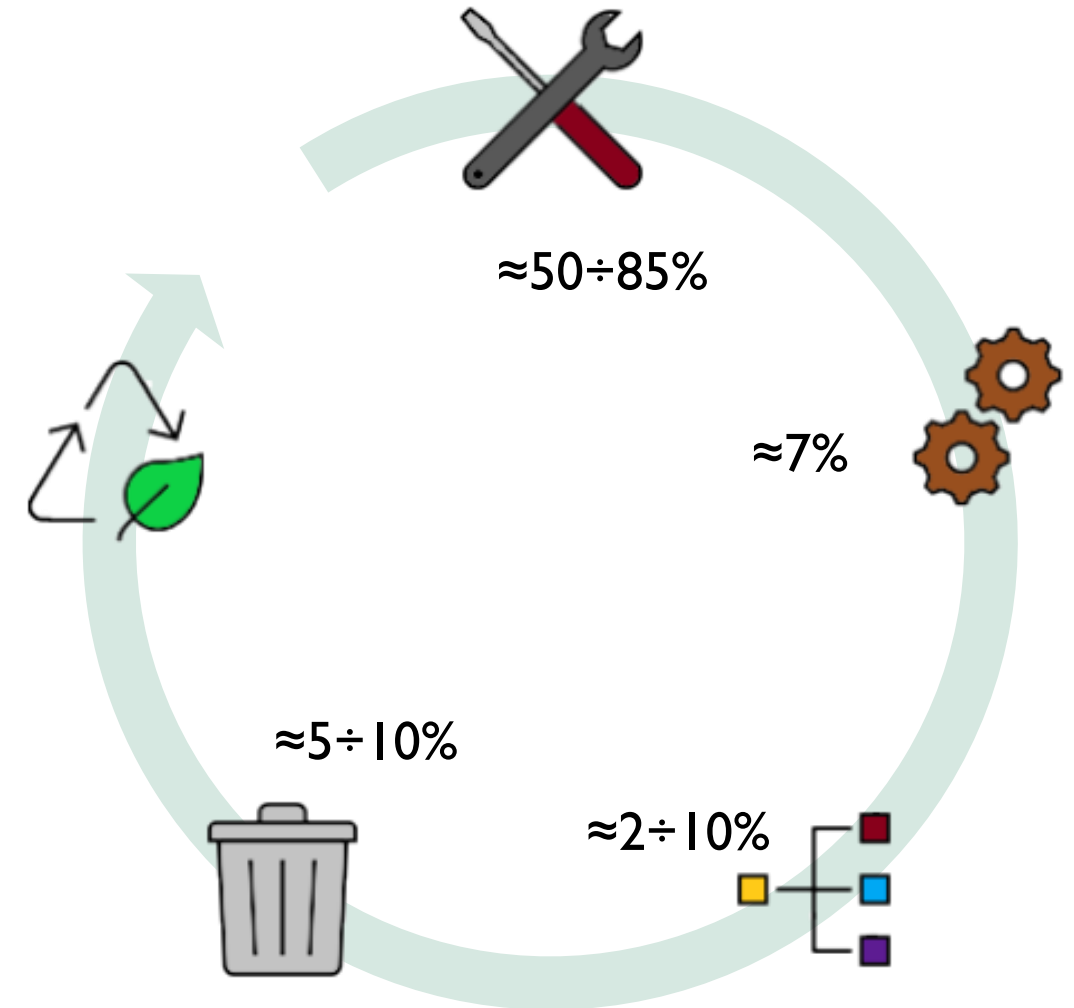


# Renewables

## Wind energy

Conventional wind turbines are generally considered “zero-emission” during operation.

However, there are environmental hazards associated with their manufacturing and disposal processes.



Data from:

Gkantou, M., Rebelo, C., & Baniotopoulos, C. (2020). Life cycle assessment of tall onshore hybrid steel wind turbine towers. *Energies*, 13(15), 3950.

Arvesen, A., & Hertwich, E. G. (2012). Assessing the life cycle environmental impacts of wind power: A review of present knowledge and research needs. *Renewable and sustainable energy reviews*, 16(8), 5994-6006.

# Renewables

Wind energy



Noise impact



Visual impact



Fauna



Climatic conditions



Land use

# Renewables

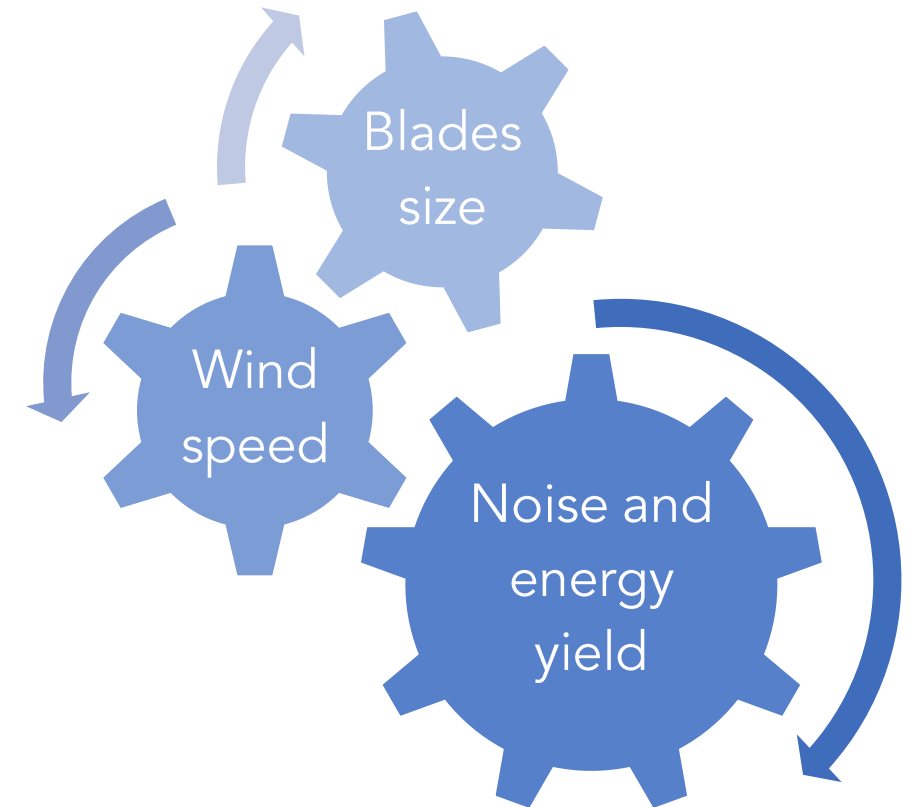
## Wind energy

### Mechanical noise

- It is caused by rotating machinery.
- It is affected by normal wear and tear, poor component designs, or lack of preventative maintenance.
- It can be alleviated by incorporating sound insulation.
- Actually it has virtually disappeared in the newer designed rotors.

### Aerodynamic noise

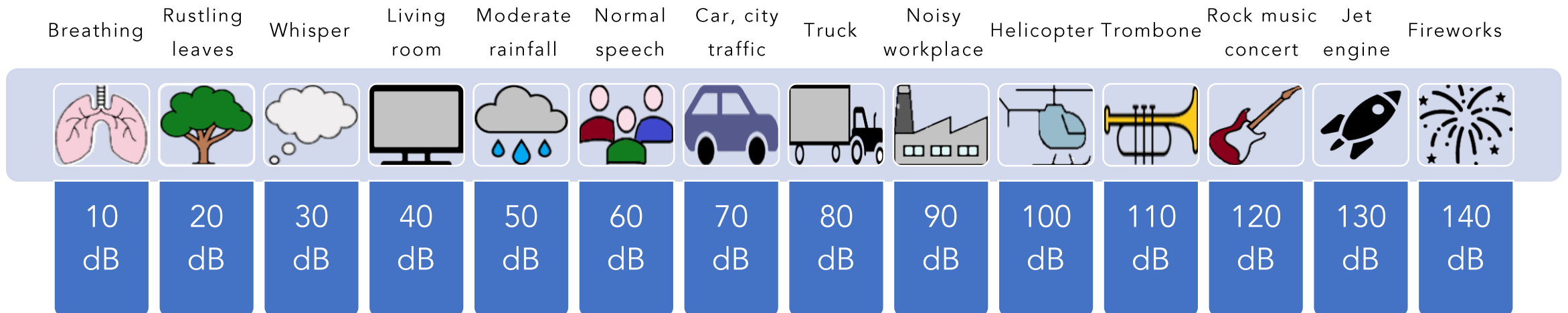
- It is the swishing sound emitted as the blades pass the tower.
- It can create headaches, hearing loss, and sleep disorders. It may even hamper the vestibular system.
- The intensity is higher near the base of the wind turbine.
- For blade noise, lower blade tip speed results in lower noise levels.



# Renewables

## Wind energy

Wind farms are always located where the wind speed is higher than average, and the background noise of the wind tends to cover any sounds that might be produced by operating wind turbines.

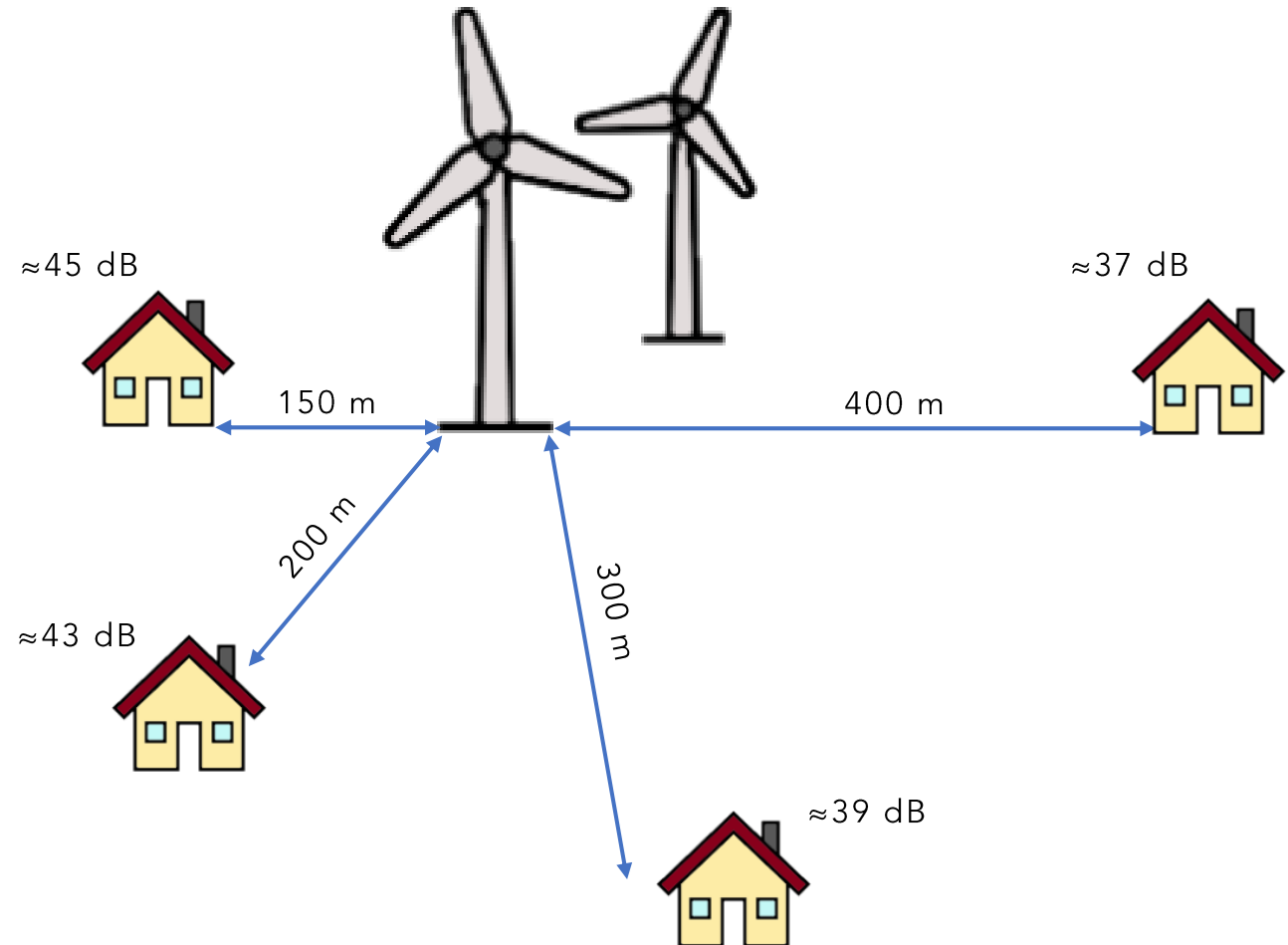


# Renewables

## Wind energy

Noise pollution decreases as the distance from the turbine decreases.

It is affected by background noise and wind velocity.





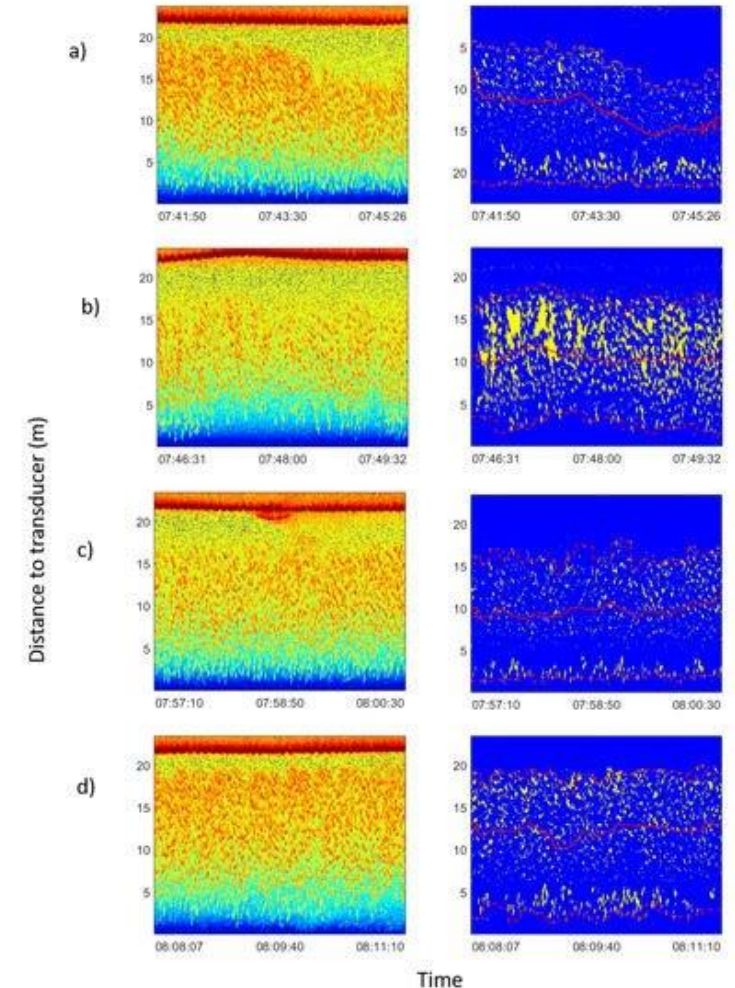
# Renewables

## Wind energy

Noise can be reduced by using:

- upwind turbines;
- variable-speed turbines;
- direct-drive machines, with no gearbox or high-speed mechanical components;
- prediction models and software tools to predict emissions.

Pictures from:  
[https://commons.wikimedia.org/wiki/File:Gearbox\\_-\\_Rotor\\_Shaft\\_and\\_Disk\\_Brake\\_Assembly\\_for\\_Turbine\\_No\\_11\\_-\\_geograph.org.uk\\_-\\_785216.jpg](https://commons.wikimedia.org/wiki/File:Gearbox_-_Rotor_Shaft_and_Disk_Brake_Assembly_for_Turbine_No_11_-_geograph.org.uk_-_785216.jpg)  
 Puig-Pons, V., Soliveres, E., Pérez-Arjona, I., Espinosa, V., Poveda-Martínez, P., Ramis-Soriano, J., ... & Santaella, E. (2021). Monitoring of caged bluefin tuna reactions to ship and offshore wind farm operational noises. *Sensors*, 21(21), 6998.

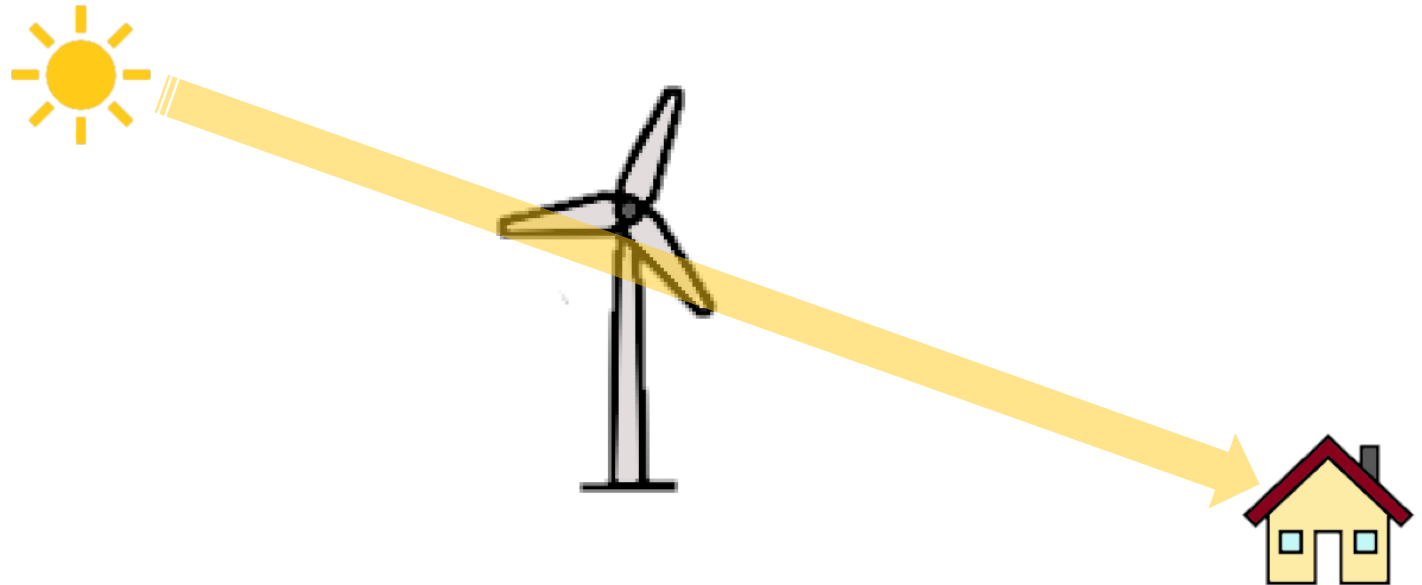


# Renewables

## Wind energy

Visual effects vary with:

- color contrast
- size
- distance from the home
- flashing shadows.



# Renewables

## Wind energy

Birds can be injured or killed when they collide with the blades of a wind turbine.

Moreover, lights near the wind farm attract nearby birds which increases the chance of collision



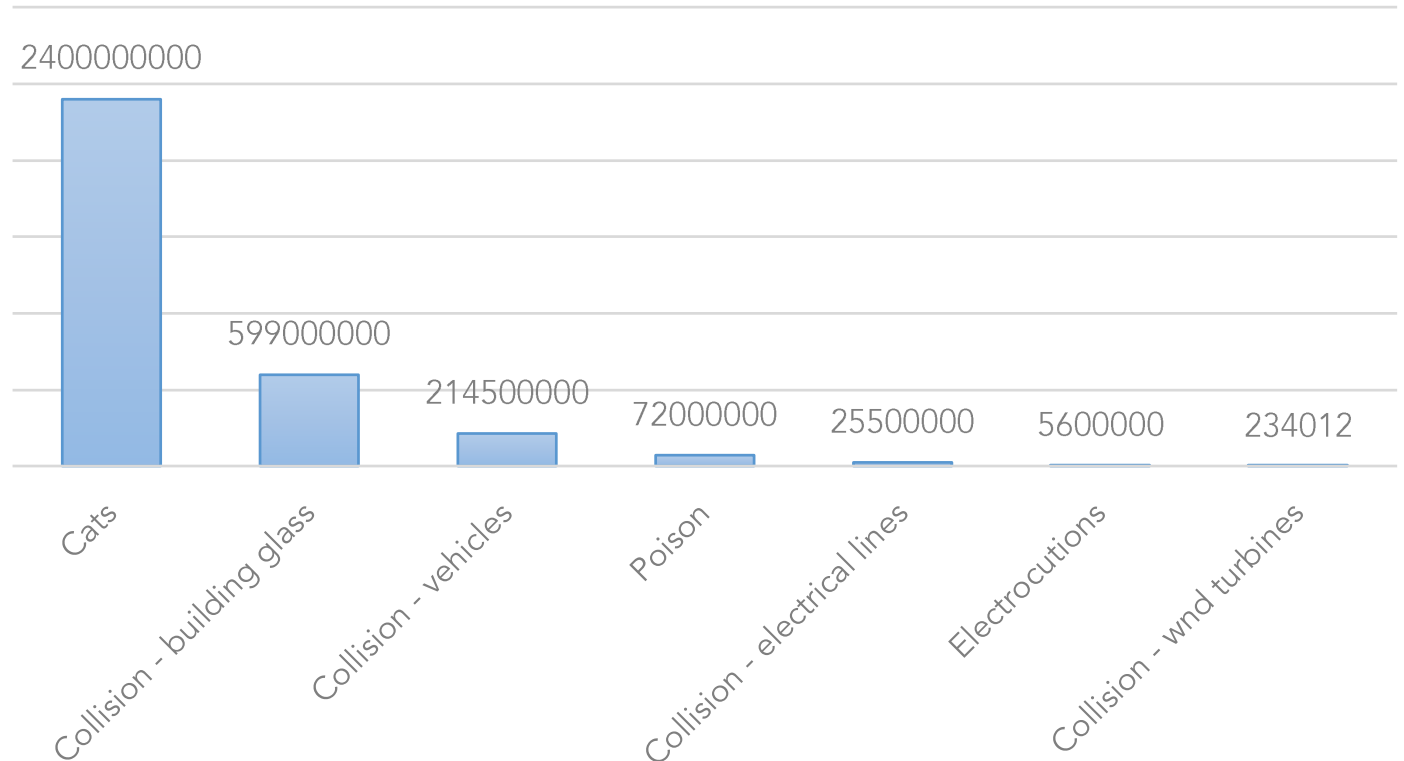
# Renewables

## Wind energy

Birds can be injured or killed when they collide with the blades of a wind turbine.

Moreover, lights near the wind farm attract nearby birds which increases the chance of collision

Annual estimated birds mortality in U.S.



# Renewables

## Wind energy

The impact on the natural ecosystems is a significant issue.

Noise during construction process hampers the breeding process.

Off-shore WTs can also harm marine bird lives.

Pictures from:  
[https://commons.wikimedia.org/wiki/File:Demoiselle\\_cranes\\_flying\\_past\\_wind\\_turbines,\\_Gujarat.jpg](https://commons.wikimedia.org/wiki/File:Demoiselle_cranes_flying_past_wind_turbines,_Gujarat.jpg)  
[https://commons.wikimedia.org/wiki/File:Alpha\\_Ventus\\_Windmills.JPG](https://commons.wikimedia.org/wiki/File:Alpha_Ventus_Windmills.JPG)



# Renewables

## Wind energy

Effects on:

- the kinetic energy of local winds;
- direction of the high-speed wind near the ground and consequently on local moisture evaporation.



# Renewables

## Wind energy

Development of wind energy farms causes soil erosion and deforestation.

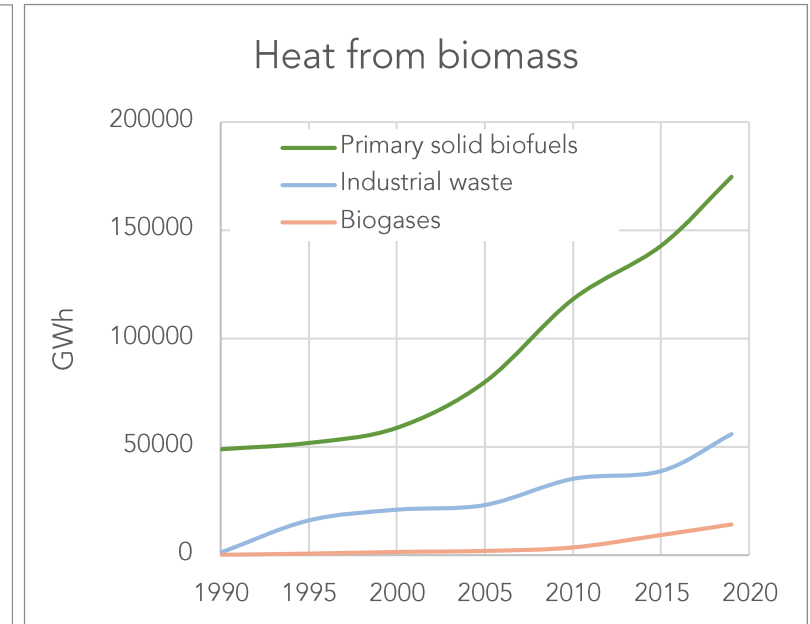
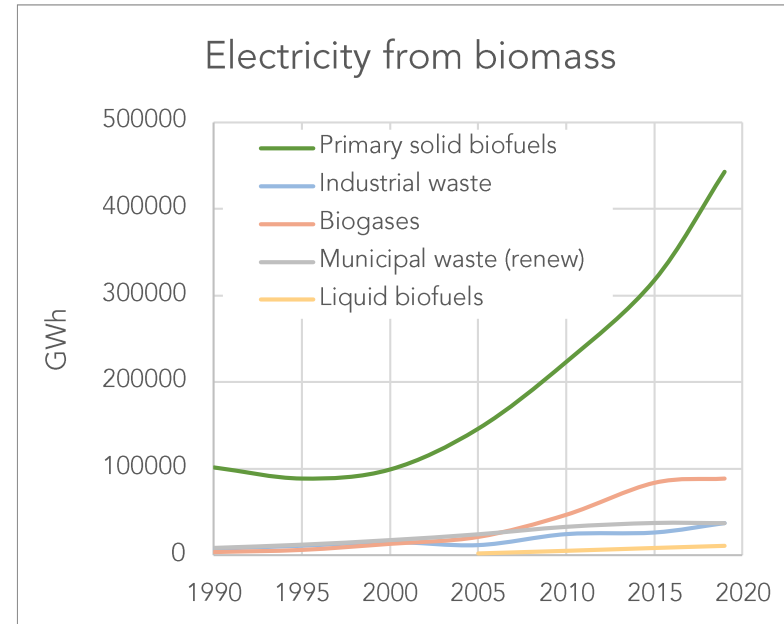
Several activities, such as the excavation of foundations, roads, and projected lands during the construction of the wind energy farm, affect the local biological system.



# Renewables

## Bioenergy

Biomass is one of the oldest sources of energy.



<https://www.iea.org/fuels-and-technologies/renewables>



# Renewables

## Bioenergy

Biomass is one of the oldest sources of energy.



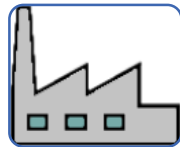
Land



Water



Fauna and flora



Air

<https://www.iea.org/fuels-and-technologies/renewables>

# Renewables

## Bioenergy

In case of dedicated biomass:

- eventual deforestation;
- high soil erosion rate;
- competition with food production.

To mitigate the adverse effects:

- use of marginal lands;
- waste, residues, aquatic biomass.



Pictures from:

<https://www.publicdomainpictures.net/it/view-image.php?image=296121&picture=la-deforestazione>

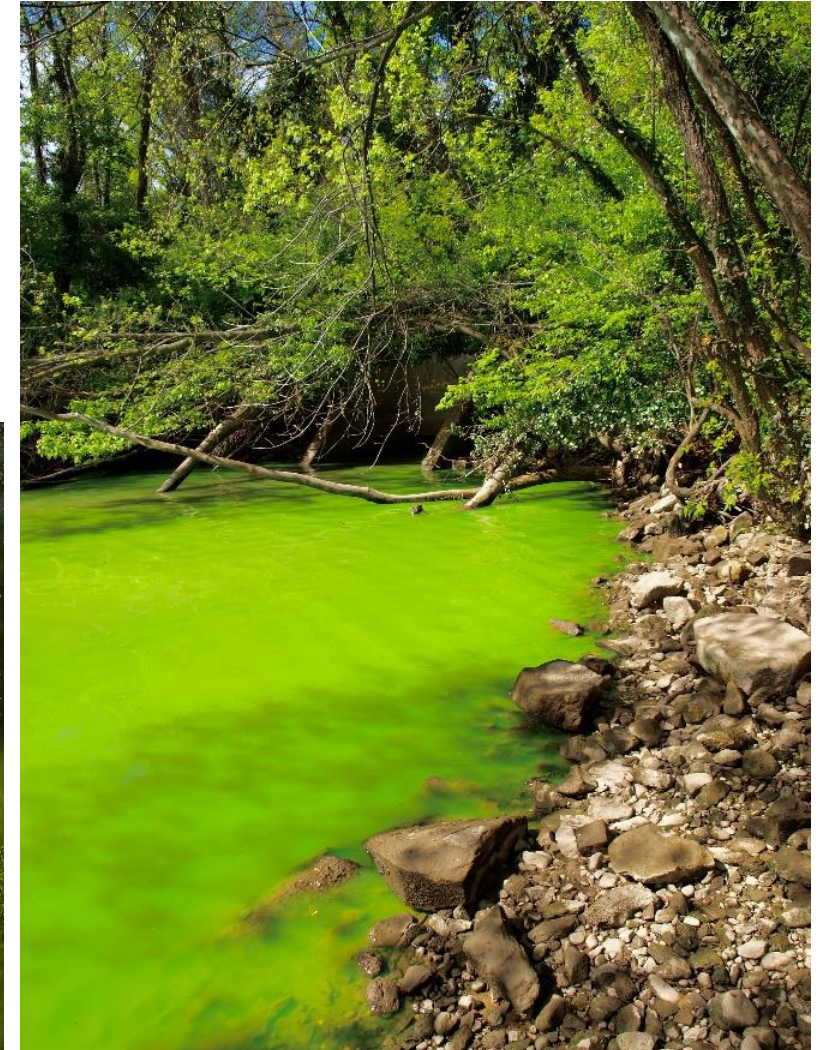
<https://pxhere.com/en/photo/1107629>

# Renewables

## Bioenergy

Water requirements are comparable to other electricity plants: approximately  $75 \div 200$  l per MWh of energy.

Risk of eutrophication.



# Renewables

## Bioenergy

Problems for wildlife due to the destruction of habitats and nutrients or food resources.

The impact on biodiversity depends on:

- the initial land use condition;
- the type of bioenergy production system;
- the landscape configuration.

[Pictures from:](https://zestip.com/role-of-ipr-in-bio-diversity/)

<https://zestip.com/role-of-ipr-in-bio-diversity/>



# Renewables

## Bioenergy

The most common pollutant emissions are:

- carbon monoxide;
- sulfur dioxide;
- nitrogen oxide.

In some instances, the biomass burned can emit more pollution than fossil fuels.

Pictures from:

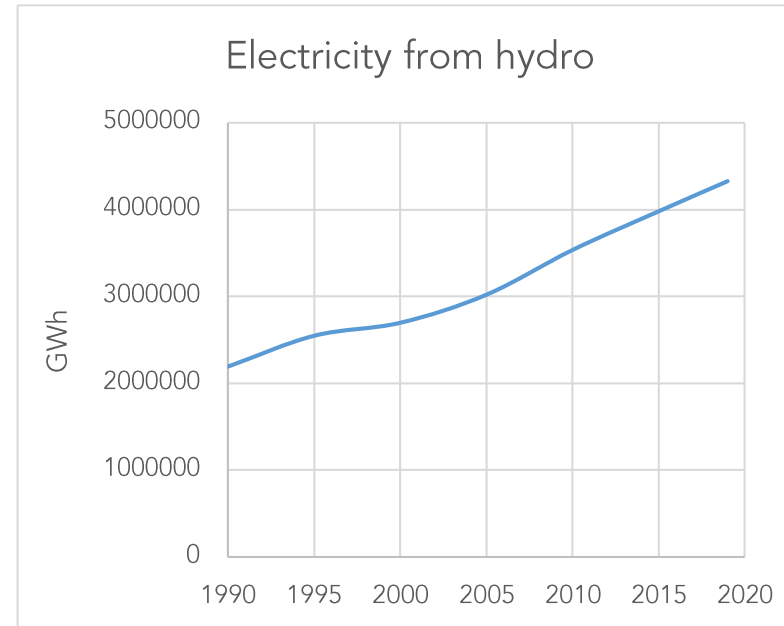
<https://zestip.com/role-of-ipr-in-bio-diversity/>



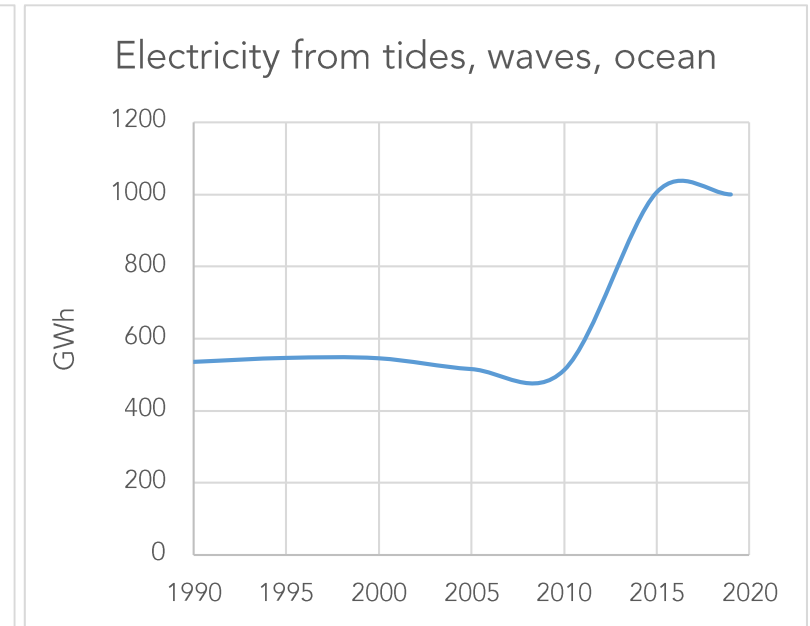
# Renewables

## Water based

Hydroelectric energy or hydropower, tidal energy, wave energy, and ocean thermal energy conversion can be defined as water-based energy systems.



Hydropower provides the largest power generation globally compared to other renewable technologies.



Although still at the research and development stage and not yet commercially available, tides, waves and currents can be used to produce electricity.

# Renewables

## Water based

Land usage is influenced by geographical conditions.

It can cause destruction of cultivable lands, archeological sites, wildlife habitats, and forests.

Pictures from:

[https://commons.wikimedia.org/wiki/File:PresadeElAtazar\\_-\\_01.jpg](https://commons.wikimedia.org/wiki/File:PresadeElAtazar_-_01.jpg)

[https://commons.wikimedia.org/wiki/File:Dam\\_sel.jpg](https://commons.wikimedia.org/wiki/File:Dam_sel.jpg)

[https://commons.wikimedia.org/wiki/File:Diga\\_comelico\\_2.jpg](https://commons.wikimedia.org/wiki/File:Diga_comelico_2.jpg)

[https://commons.wikimedia.org/wiki/File:Diga\\_di\\_Alanno\\_2016.jpg](https://commons.wikimedia.org/wiki/File:Diga_di_Alanno_2016.jpg)



# Renewables

## Water based

Stagnant nature of reservoir water may cause:

- eutrophication
- an increase in water evaporation rate
- decrease of the oxygen level.

Pictures from:

[https://commons.wikimedia.org/wiki/File:River\\_algae\\_Sichuan.jpg](https://commons.wikimedia.org/wiki/File:River_algae_Sichuan.jpg)

[https://it.wikipedia.org/wiki/File:Diga\\_Furore.jpg](https://it.wikipedia.org/wiki/File:Diga_Furore.jpg)

[https://commons.wikimedia.org/wiki/File:Diga\\_del\\_truzzo.jpg](https://commons.wikimedia.org/wiki/File:Diga_del_truzzo.jpg)





# Renewables

## Hydropower

Barriers or dams of hydro power plants affect:

- the migration process of fish
- the temperature and flow of water
- the chemical properties of the water.

Consequently most indigenous plants and animals will experience negative impacts.

Pictures from:

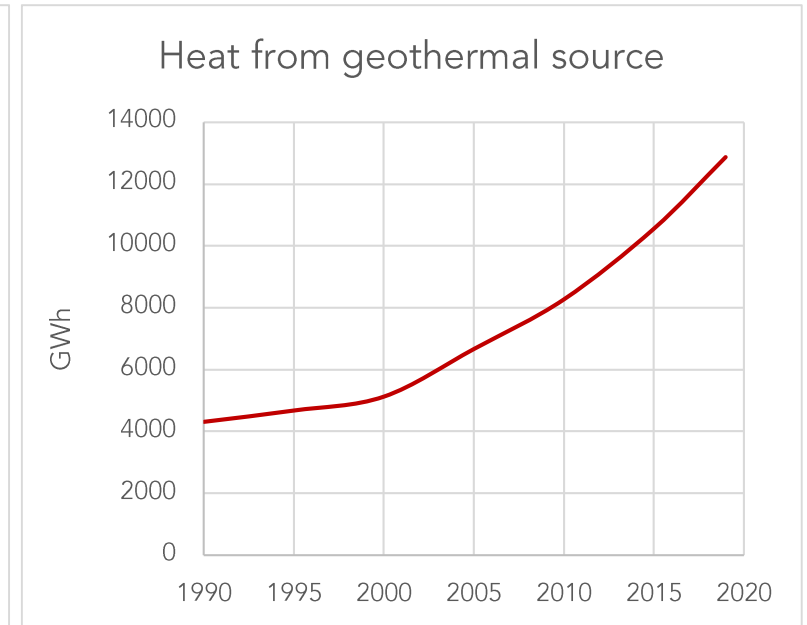
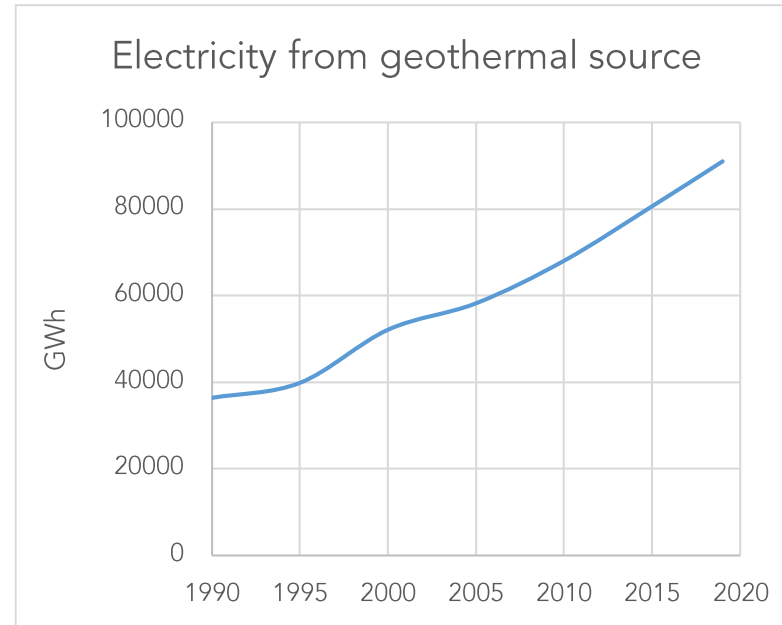
[https://commons.wikimedia.org/wiki/File:John\\_Day\\_Dam\\_fish\\_ladder.jpg](https://commons.wikimedia.org/wiki/File:John_Day_Dam_fish_ladder.jpg)

[https://it.wikipedia.org/wiki/Passaggio\\_per\\_pesci#/media/File:Fischtreppe\\_Isar\\_bei\\_Pullach.jpg](https://it.wikipedia.org/wiki/Passaggio_per_pesci#/media/File:Fischtreppe_Isar_bei_Pullach.jpg)



# Renewables

Geothermal source



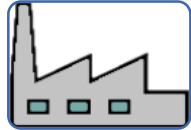
<https://www.iea.org/fuels-and-technologies/renewables>

# Renewables

Geothermal source



Water



Air



Land



Noise



Visual

# Renewables

## Geothermal source

Water impact is related to:

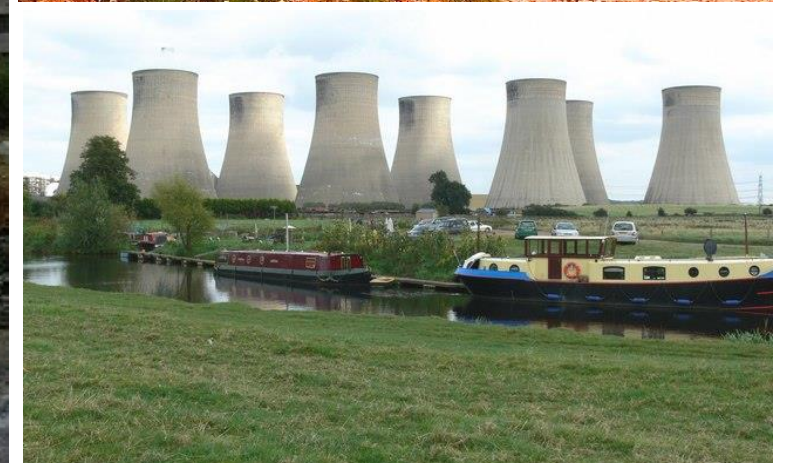
- withdrawal of large quantities of geothermal fluid
- drilling wells activities
- discharge of heat
- groundwater level change and pollution.

Pictures from:

[https://commons.wikimedia.org/wiki/File:Rig\\_drilling\\_known\\_locally\\_as\\_Borewell\\_for\\_Water\\_well\\_drilling\\_in\\_operation\\_in\\_India.jpg](https://commons.wikimedia.org/wiki/File:Rig_drilling_known_locally_as_Borewell_for_Water_well_drilling_in_operation_in_India.jpg)

[https://commons.wikimedia.org/wiki/File:Eight\\_cooling\\_towers\\_-\\_geograph.org.uk\\_-\\_556733.jpg](https://commons.wikimedia.org/wiki/File:Eight_cooling_towers_-_geograph.org.uk_-_556733.jpg)

[https://commons.wikimedia.org/wiki/File:Geothermal\\_steam\\_rich\\_rock\\_gorges.jpg](https://commons.wikimedia.org/wiki/File:Geothermal_steam_rich_rock_gorges.jpg)



# Renewables

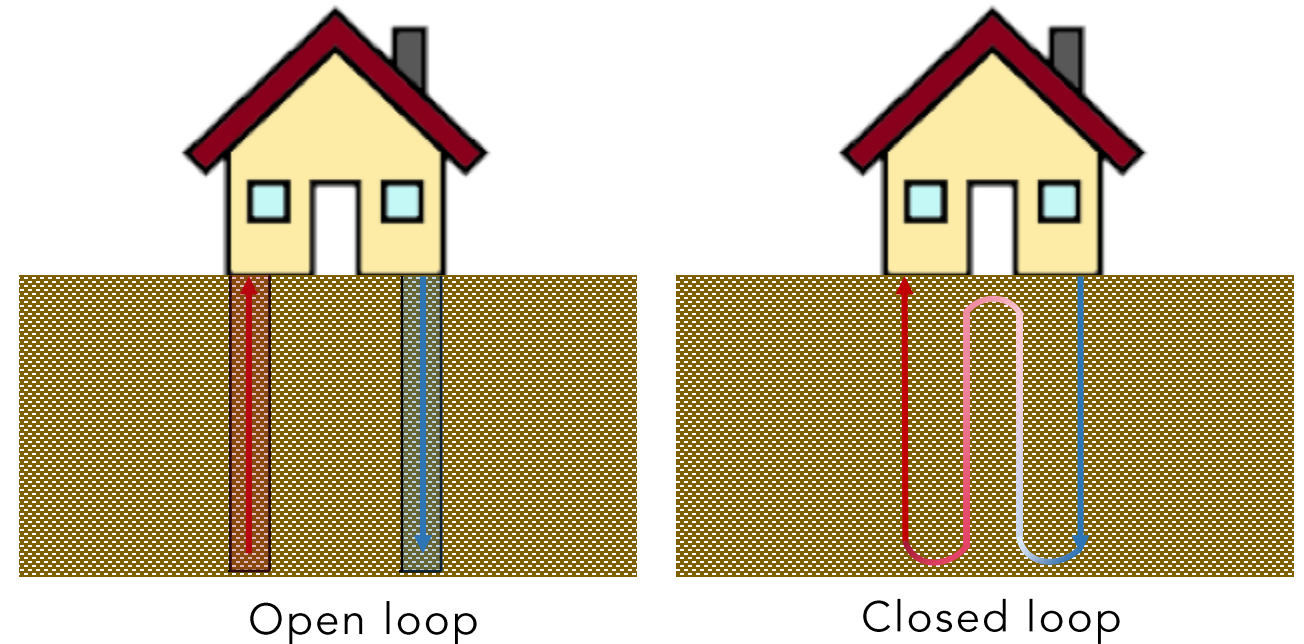
## Geothermal source

Air emissions are affected by the plant configuration.

Carbon dioxide is the main greenhouse gas emission from geothermal power plants.

Emissions of  $H_2S$  can significantly vary according to individual fields.

Geothermal gases may contain ammonia, mercury in trace amounts, boron vapour and hydrocarbons such as methane.



# Renewables

## Geothermal source

Land occupation depends on the properties of the geothermal source, the plant layout and capacity, the type of cooling system, the locations of wells, pipelines, the substation and auxiliary building.

Other effects on ground are:

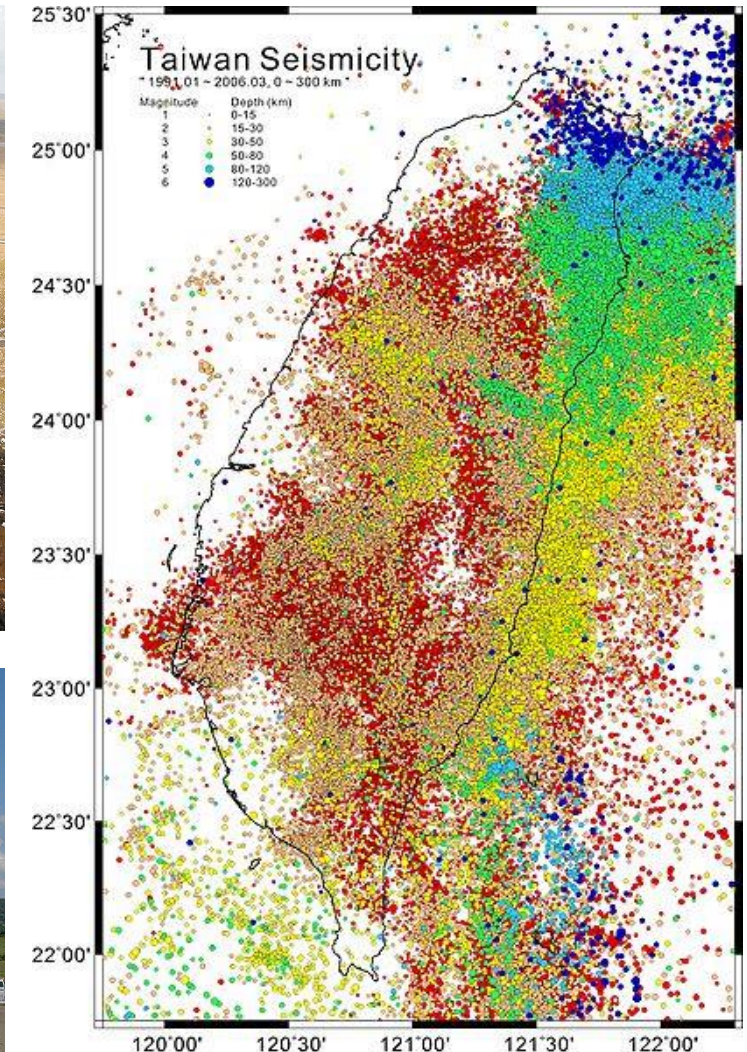
- subsidence
- induced seismicity.

Pictures from:

[https://commons.wikimedia.org/wiki/File:The\\_Hellishei%C3%B0i\\_Geothermal\\_Power\\_Plant,\\_2018,\\_Iceland.jpg](https://commons.wikimedia.org/wiki/File:The_Hellishei%C3%B0i_Geothermal_Power_Plant,_2018,_Iceland.jpg)

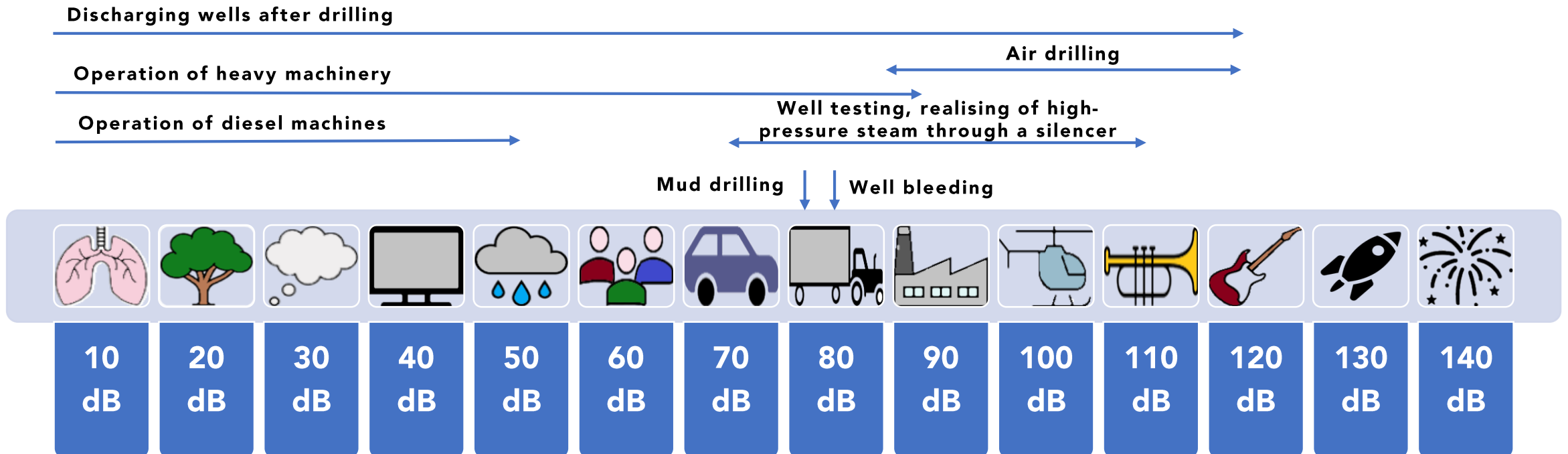
[https://commons.wikimedia.org/wiki/File:Vale\\_Seccolo\\_Geothermal\\_Power\\_Plant.jpg](https://commons.wikimedia.org/wiki/File:Vale_Seccolo_Geothermal_Power_Plant.jpg)

[https://commons.wikimedia.org/wiki/File:Taiwan\\_seismicity.jpg](https://commons.wikimedia.org/wiki/File:Taiwan_seismicity.jpg)



# Renewables

## Geothermal source



Data from:  
Bošnjaković, M., Stojkov, M., & Jurjević, M. (2019). Environmental impact of geothermal power plants. *Tehnički vjesnik*, 26(5), 1515-1522.

# Renewables

## Geothermal source

Visual impact is significant during construction of the plant.

The impact is high when geothermal source is located close to naturalistic attractions.

Pictures from:

[https://commons.wikimedia.org/wiki/File:Rig\\_drilling\\_known\\_locally\\_as\\_Borewell\\_for\\_Water\\_well\\_drilling\\_in\\_operation\\_in\\_India.jpg](https://commons.wikimedia.org/wiki/File:Rig_drilling_known_locally_as_Borewell_for_Water_well_drilling_in_operation_in_India.jpg)

[https://commons.wikimedia.org/wiki/File:Krafla\\_geothermal\\_power\\_station\\_wiki.jpg](https://commons.wikimedia.org/wiki/File:Krafla_geothermal_power_station_wiki.jpg)

[https://commons.wikimedia.org/wiki/File:Hellisheidi\\_Geothermal\\_Power\\_Plant.png](https://commons.wikimedia.org/wiki/File:Hellisheidi_Geothermal_Power_Plant.png)

