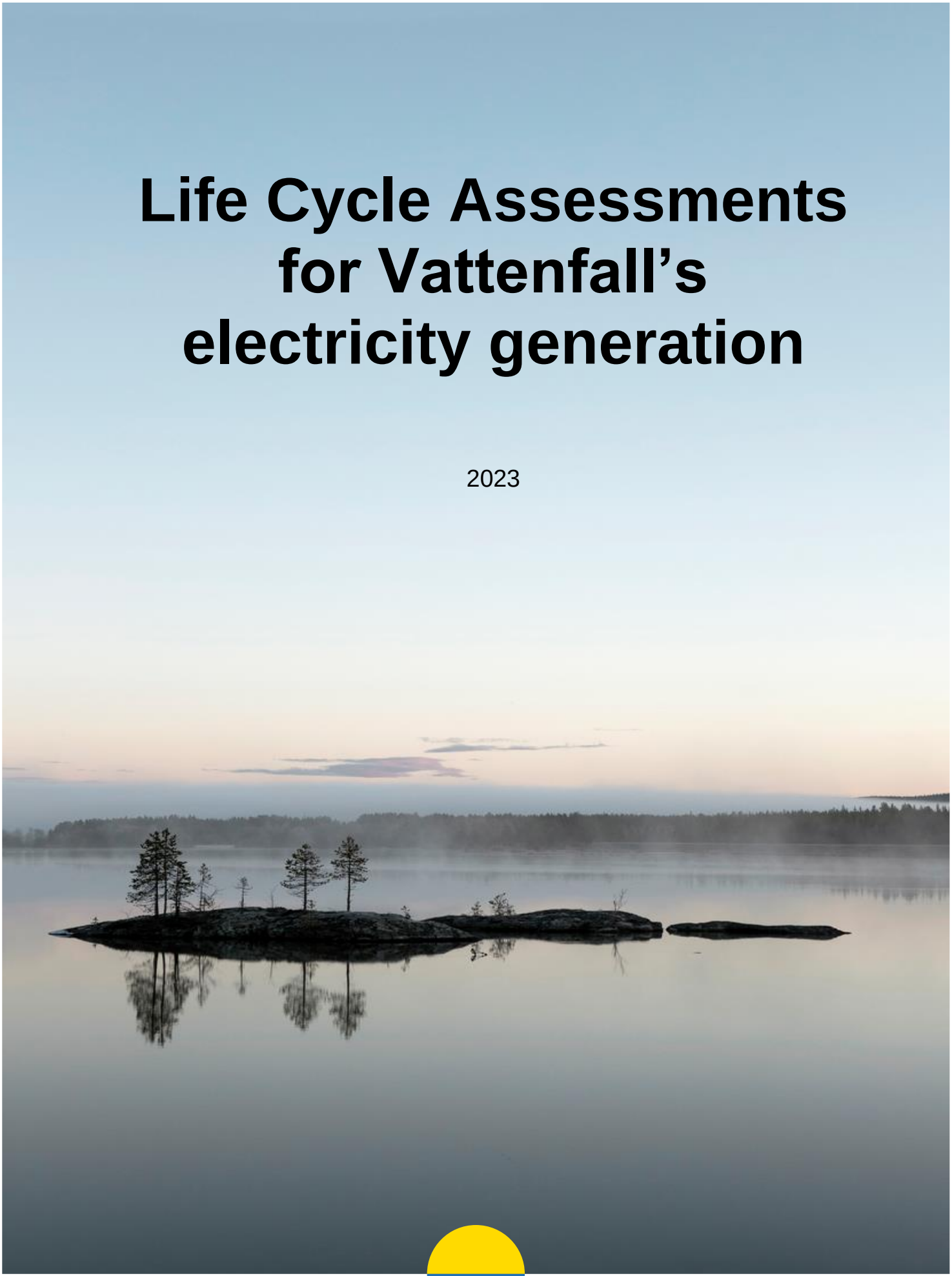
Life Cycle Assessments for Vattenfall's electricity generation

2023



VATTENFALL

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Lifecycle Assessments

An important tool for evaluating environmental impacts

Vattenfall has been working with Lifecycle Assessments (LCA) to evaluate and map the environmental impact of electricity generation activities in a full value chain perspective since the early 1990s. The LCA approach helps us to identify where environmental impacts arise and which measures must be applied to reduce them. The results are, for example, used for decision making in setting supplier requirements and to provide information to customers. Based on our LCAs we develop Environmental Product Declarations (EPDs) for our own electricity production. These EPDs are Type III Declarations[1] complying with the ISO 14025 standard. Environmental information on the life cycle of a product is quantified to enable comparisons between products fulfilling the same function. The EPDs are third party verified and updated at least every fifth year.

We publish EPDs for wind, nuclear, and hydro power in the EPD® International system. Emissions, material flows and waste flows from construction, operation and decommissioning of both power plants and the distribution grid are included. For climate impact, fossil, biogenic and land use and land use change (LULUC) emissions are included[2]. See Figure 1 for more details on the different life cycle phases and their scope. In addition to the LCA of environmental impact, the EPD includes a land use and biodiversity assessment. For nuclear, there is also an environmental risk assessment. For more information about the EPD system, go to environdec.com

Life cycle phase	Explanation
Upstream	Production of oils, chemicals and fuels for operation of the power plants. *Nuclear: Production of nuclear fuel (from mines to fabrication).
Core	Operation of the power plants, incineration or deposit of operational waste. *Hydro: emissions of oil to water and ground.
Core - infrastructure	Construction, reinvestments and decommissioning of the power plants. *Hydro: Emissions from land inundated by reservoirs.
Downstream	Operation of electricity networks, i.e. emissions from inspection trips, production and emissions of oils. Extra generation in power plants to compensate for losses in the distribution system
Downstream - infrastructure	Construction and decommissioning of the transmission grids and distribution networks.

Figure 1. Life cycle phases in the EPD. For further read, see Vattenfalls' EPDs at environdec.com

Characteristics of LCA methodology

To ensure both accuracy and comparability of the LCA results, system boundaries are set. These determine what is included or excluded from different life stages.

THE SCOPE The result you get from an LCA depends on what system boundaries are used in the assessment. All life cycle stages, from cradle to grave, should be included to get a full picture of a product's environmental impact. For electricity production that includes raw material extraction, fuel production, construction, operation, demolition and waste treatment of the power plants.

FUNCTIONAL UNIT The functional unit is used in LCAs to present the environmental impact in specific values. For example as CO_2e/kWh generated electricity, in which case *1 kWh generated electricity* is the functional unit. It enables comparison of electricity from different producers. The functional unit in product declarations must be relevant for the customer so the functional unit in our EPD is *1 kWh electricity delivered to an industrial customer at the regional grid*. But, it's also possible to see the impact for 1 kWh net electricity (electricity sent to grid) in the EPD results.

[1] Type III Declaration: environmental declaration providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information.

[2] Biogenic emissions are GHG emission from combustion of biomass. LULUC emission originates from changes in the defined carbon stocks caused by land use and land use changes, e.g. when forest is being cut down to make place for a power plant.

Environmental impact of different energy sources

Regardless of the energy source, generating and distributing electricity impacts the environment.

Figure 2 shows a comparison of the climate impact from different energy sources from a life cycle perspective. The data is based on Vattenfall's LCA assessments and information from IPCC's Assessmernt Report 5 (2018). The results show that all non-fossil energy sources have significantly lower impact compared to fossil energy sources.

In Figure 3, the lifecycle of electricity generation is shown. The main sources of greenhouse gas (GHG) emissions in fossil free energy generation are linked to emissions upstream in the value chain, typically from material production and construction of the sites. Conversely, the main sources of emissions in fossil based energy generation comes from direct combustion.

As the proportion of renewable power generation in the energy mix is increasing, so is the need for a life cycle perspective when evaluating environmental performance.

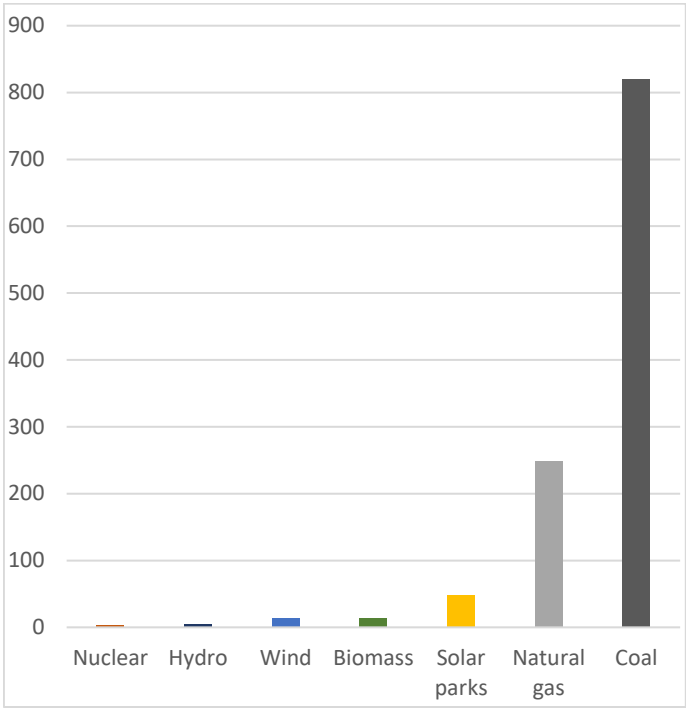


Figure 2: Life cycle GHG emissions [gC_2e/kWh] from electricity generation from different energy sources. Nuclear, Hydro and Wind power results are from Vattenfall's EPDs and include fossil-, land use- and biogenic emissions. Biomass and natural gas emissions are based on internal LCAs. For biomass this includes fossil emissions from pellets and chips and for natural gas it is based on Vattenfall's combined heat and power plant Marzahn, commissioned in 2020. For solar parks and coal power, life cycle greenhouse gas emissions median values from IPCC 2018 were used.

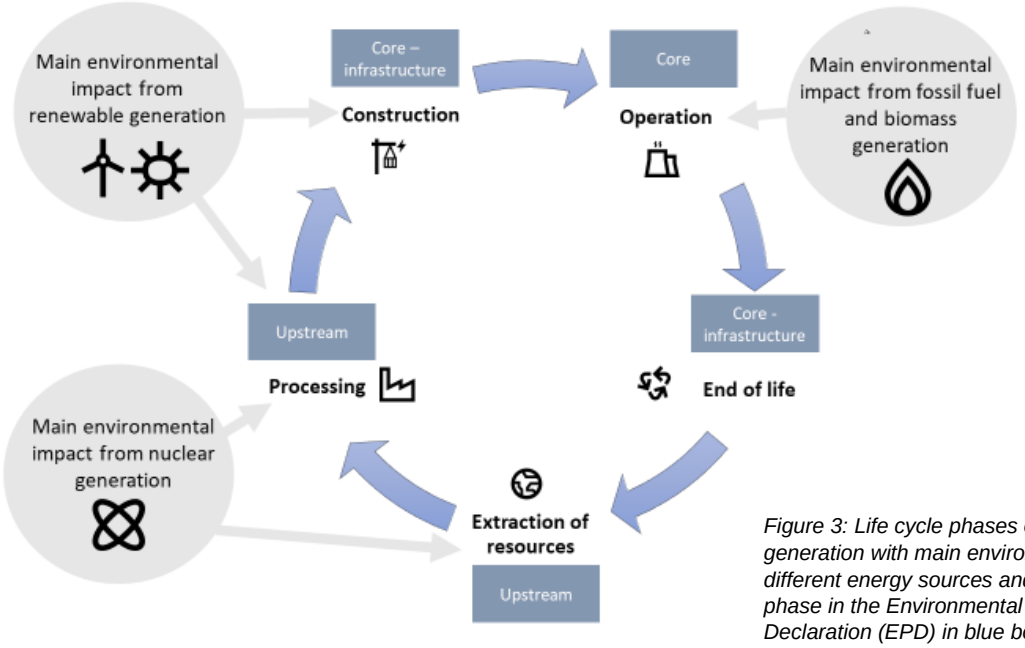


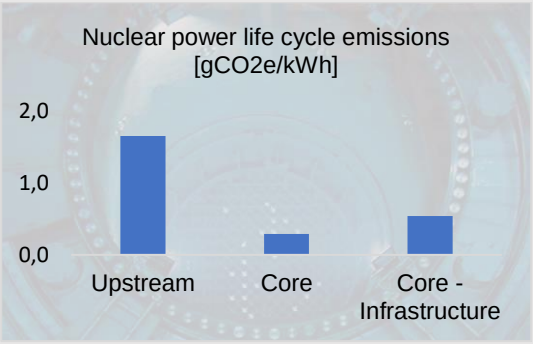
Figure 3: Life cycle phases of electricity generation with main environmental impact of different energy sources and corresponding phase in the Environmental Product Declaration (EPD) in blue boxes.

Nuclear power

Climate change impact

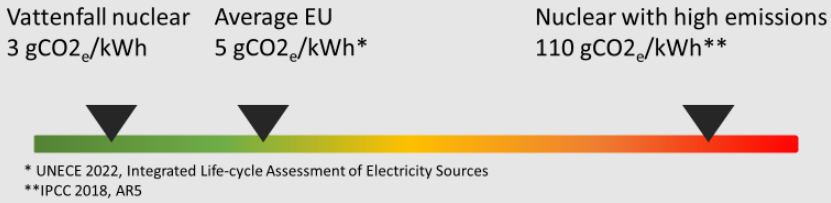
The results of our EPD show that our nuclear power plants have a global warming potential of approximately 3 gCO_2e/kWh generated electricity. The majority of these GHG emissions are linked to fuel production, which is a part of upstream processes. Test runs of backup power, production of chemicals and transportation of radioactive waste are the main contributors to the emissions from the operation stage of the nuclear power plant's lifecycle. These are however small compared to upstream emissions.

Vattenfall's nuclear power has lower emissions than other producers. This is explained by the detailed data collection process at Vattenfall and that many of our suppliers use non-fossil energy. GHG emissions from nuclear remain low and stable, but a small decrease has been noted in recent years as the electricity mix in our supply chain has become less CO_2 intense. This is due to decreased use of fossil fuels in the electricity mix, particularly in Europe. Additionally, as the number of LCAs performed globally rises, the accuracy of the data has also gone up, improving the quality of the results.



Variation in GHG emission levels of nuclear power

Since Vattenfall uses suppliers with fossil free energy, the emissions are lower compared to other producers. Further, uranium is mainly sourced from underground mines which sees lower emissions when compared with open pit mining. Other factors impacting the emission levels are ore grade and fuel fabrication.



Other sustainability aspects

Vattenfall screens and approves all nuclear fuel suppliers before they deliver to make sure quality, environment, working conditions, human rights and local community impact is given proper consideration.

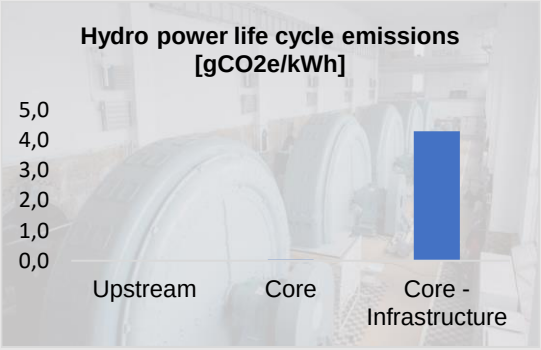
In the EPD of electricity from Vattenfall's nuclear power plants, a risk inventory is included to complement the lifecycle assessment. Environmental risks in the nuclear fuel chain have low probability according to acceptance criteria set by the regulatory body[3]. See chapter 4.4 in the complete EPD® Report on environdec.com for more information.

[3] The *regulatory body* refers to international bodies and national authorities regulating nuclear operations

Hydropower

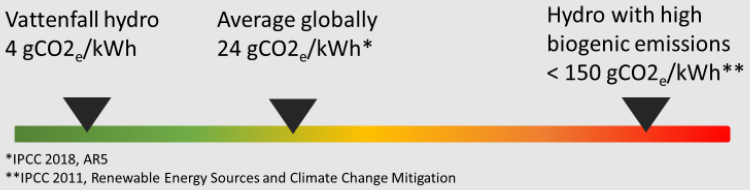
Climate change impact

Vattenfall's operation of hydropower plants have a global warming potential of 4 gCO_2e/kWh generated electricity. These emissions mostly derive from construction and reinvestment phases, particularly from the production of steel and concrete. When hydropower was established it resulted in establishment of reservoirs and the flooded soil containing organic carbon compounds formed greenhouse gases. These emissions were mainly released in the first few decades after the Nordic hydropower was built. Methane emissions from flooding are not included in our LCA's since the mechanisms are unclear and emissions are difficult to quantify. Most emissions from hydropower globally arise from flooded land, particularly in tropical areas where emission can be extremely high. The warm climate and heavy vegetation leads to more carbon compounds and nutrients in the flooded soil, and hence more greenhouse gas formation.



A big range of hydropower life cycle GHG emissions

Vattenfall's hydropower plants are located in the Nordic countries. The emissions from flooded land are therefore rather small because of the cold climate and less vegetation. Another contributing factor to low emission levels is the high efficiency of the Nordic hydropower – lowering emission per produced kWh.



Other sustainability aspects

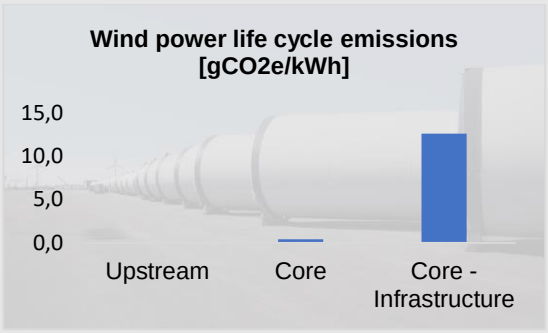
Hydropower impacts the river's ecology by inducing a change in its hydrologic characteristics. For example, natural flooding of surrounding land is reduced and barriers created by the power plants can impact fish migration. Swedish hydropower production will be equipped to meet modern environmental permit conditions over the years 2020-2040. Vattenfall is undertaking several initiatives to reduce the negative effects on ecosystems and biodiversity caused by hydropower. For example, by building fish ladders and removing fish migration obstacles, Vattenfall is reducing disruption to fish migration. By protecting valuable nature through these initiatives, and investing in R&D, we are championing sustainable solutions for the future. Read more about our various biodiversity projects in all business areas in our biodiversity brochure.

Wind power

Climate change impact

Upstream processes for both offshore and onshore wind power contribute to most of the emissions. The production of steel, concrete and composites are the main emission drivers. Roughly half of the GHG emissions come from the production of steel for the turbines.

Vattenfall's wind power have a global warming potential of 13 gCO_2e/kWh generated electricity, calculated as an average across the whole of Vattenfall's wind portfolio. This includes both onshore and offshore wind farms, old ones as well as new ones. The LCA includes: upstream processes (production of auxiliary substances); construction and dismantling of the wind farms; electricity generation by the wind farms; changing of components and inspection trips. In the construction phase, usage of concrete for foundations, heavy transports, site infrastructure and deforestation is included.



Rapid growth of wind power is happening

Driven by society's need to tackle climate change, renewable energy generation continues to grow and over the past two decades associated costs have fallen dramatically. Today, wind and solar are cost competitive and fast to build compared to other energy sources. Wind power alone provided 14% of European generation in 2020. In order to meet the increased power demand between 2020 and 2050, wind power will play a crucial role in the energy mix as it is cheap, fast to build and can provide power at scale.

Other sustainability aspects

Vattenfall is committed to promoting a circular economy and reducing environmental impact throughout the product's life cycle. In 2021 Vattenfall set a target to recycle 100% of the wind turbine blades by 2030. 85% of a Vattenfall wind turbines is already recycled and with the target for the blades, the remaining 15% are also captured. In 2023 Vattenfall and BASF will install Siemens Gamesa's RecyclableBlades at the Hollandse Kust Zuid offshore wind farm. The blades are made with a new type of resin which makes it easier to reclaim the different blade components.

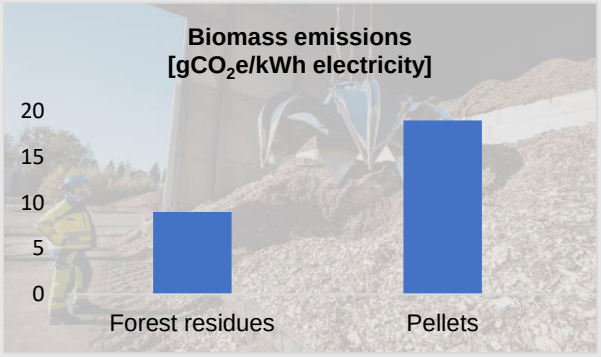
Wind farms, both onshore and offshore, impact biodiversity. Vattenfall is engaged in many different projects that enhance biodiversity locally at our different sites. These range from biodiversity research programs to small scale measures. Example projects include piling noise reduction with "air bubble-curtains"; strategic turbine shut down to avoid bird collisions; and nature inclusive design where the offshore foundations become artificial reefs. Read more about our various biodiversity projects in all business areas in our biodiversity brochure and read about bird and bat research within offshore wind power here.

Biomass

Climate change impact

Biomass is a renewable energy source and can be anything from fast-growing energy crops to agricultural or forestry residues. The combustion of biomass in power production results in GHG emissions. However, the emissions are not considered to contribute to global warming, as the biomass binds carbon dioxide by photosynthesis during its growth and new trees/crops are replanted. The production of wood chips and biomass pellets/briquettes, on the other hand, does give rise to GHG emissions of various types. The emissions occur primarily during the transportation and processing phases, but also from forestry or agriculture, depending on the origin of the fuel.

Vattenfall's power from biomass has been estimated to emit around 14 gCO2e/kWh generated electricity. We believe that woody biomass and residual wood that meets robust sustainability criteria can and should make a positive contribution to the energy transition and climate change mitigation by replacing fossil fuels.



Other sustainability aspects

In order to ensure that biomass for energy leads to a meaningful CO_2 reduction, cultivation, production and transport must be controlled and sustainable. Vattenfall sources biomass from sustainable sources, e.g., certified producers or sourced from smaller local suppliers. We mainly use residual wood[4], processing residues from industries like furniture production and recycled waste wood which comes in the form of chips. Some wood also originates from land non suitable for agricultural in Germany, then this includes wood from short-rotation plantations with fast-growing tree species. Our biomass sourcing is continuously monitored to ensure the biomass we use is environmentally and socially sustainable.

[4] Residual wood are rest products from the forest industry, i.e. branches and top parts of the trees that would otherwise have been discarded

Solar power

Climate change impact

Solar power has low GHG emissions during its life cycle and plays an important role in decarbonization. This is clear when compared to coal power, which result in 24 times more emissions than solar parks. The environmental impacts mainly occur during the construction phase where production of the photovoltaic cell and its components is the main contributor to emissions (80%).

The geographic location, latitude, hours of sun and the angle towards the sun has a large impact on how much electricity the PV can deliver and thus the climate impact per generated kWh.

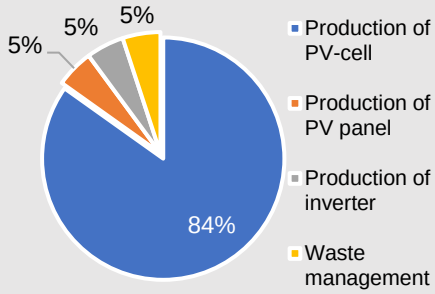
Large-scale solar farms will play a pivotal role in transforming Europe's energy system. Vattenfall's portfolio is growing, most notably in Germany and in the Netherlands where large solar farms can be operated subsidy free.

LCAs for Vattenfall's solar power

Vattenfall offers solar power to their customers through brokers in cooperation with solar power producers in Europe. An LCA was performed for the locations of solar power generation; Italy, Belgium and Sweden, resulting in 26 – 44 gCO_2e/kWh.

In 2016 an LCA on the solar energy offerings to household and business customers was performed (see results in pie chart to the right). The LCA revealed that Vattenfall's PV panels to customers emitted 66 gCO_2e/kWh of generated electricity. This number is likely to have decreased since technology developments have led to better efficiencies for PV panels – lowering lifecycle emissions.

PV, B2C, lifecycle emissions [%] of 66 gCO_2e/kWh in total



Fast developing technology in beginning of its innovation

In recent years, a lot has happened regarding solar panels as the technology has seen a huge growth. The technology itself has improved and become more efficient, the life time has been extended, resources needed for production has been reduced and prices have fallen dramatically. In scenarios modelled by the International Energy Agency in 2022, renewables led by solar PV and wind are set to dominate global capacity additions. These renewable energy sources are estimated to account for 75-80% of all new capacity to 2050. This development has also led to decreased environmental impact, which will keep decreasing as the technology develops further. Research show that for every doubling of installed photovoltaic capacity, GHG emissions decrease by 17 % and 24 %, for poly- and monocrystalline based photovoltaic systems, respectively.

Other sustainability aspects

Solar panels can be integrated in agricultural lands and help preserve the land for food production and improve ecological conditions. In the Netherlands Vattenfall is constructing a solar park where solar panels are combined with cultivation. Read more about this and other biodiversity projects in all business areas in our biodiversity brochure. New technologies often mean entering into new geographies and new supply chains which bring new and different risks. As part of our efforts aiming for sustainable supply chains, a rigorous selection of our suppliers is conducted which is based upon a mix of dialogues, screening, assessments and audits in order to minimise the risks for poor working environments and forced labour.

Application of LCA in the business

LCAs are used in several different ways at Vattenfall. Here follows some examples:

Cutting GHG emissions by 25 % in onshore wind farm construction

In order to reduce the overall environmental impact of the construction phase of the Dutch onshore wind farm Nieuwe Hemweg, completed in 2021, an Environmental Cost Indicator (ECI) was included in the procurement process. The ECI is a method based on LCA, which combines a range of environmental impacts of a project and calculates the cost of mitigation. Suppliers were asked to describe how they would reduce this ECI value using their design, machinery, transport, work and material improvements. The method resulted in a significant GHG emission reduction of 25 % compared to business-as-usual, to similar costs. Vattenfall is currently developing and testing sustainability award criteria in other countries to work on a sustainable supply chain together with its suppliers.

Climate smarter concrete developed for hydro power

Our EPD results have highlighted concrete usage as a main contributor to GHG emissions in our hydro power operations. Therefore, Vattenfall has developed a climate-smarter hydropower concrete with less cement content that can reduce carbon emissions by around a quarter. The first major structures were built in 2021, at Lilla Edet hydro power station in Göta älv (Sweden).

Site specific LCAs pinpointing decreasing climate impact for modern wind farms

Blakliden Fäbodberget, is an onshore wind farm with 84 turbines located in northern Sweden. It went into commercial production in spring 2022 and the annual production of just over 1 billion kWh equals the consumption of around 220,000 Swedish households. A specific LCA was conducted for this wind farm and the overall emissions during the next 30 years are estimated to be as low as 8 gCO_2e/ kWh. This is significantly lower than the current wind power portfolio footprint of 13 gCO2e/kWh. This is the result of taller turbines with a longer life span than previously and a clear environmental focus on transportation and conscious choice of materials.

Inform strategic decision on phasing out fossil fuels

In 2018 an LCA was conducted for our state of the art Combined Heat and Power Plant (CHP) Marzahn in Germany which is a modern and efficient gas power plant commissioned in 2020. It helps balance fluctuations from feeding renewable energy into the electricity grid. The carbon footprint is about a third compared to coal power – making gas, in this case, an efficient transition energy source.

Strategic decisions and commitments

Thanks to our work with LCAs we know that, today, the main emission drivers in Vattenfall's supply chain are extraction and production of raw materials such as concrete, steel and other metals. Transportation in the supply chain also represents a significant share of emissions. In order to decrease these emissions, Vattenfall has joined First Movers Coalition and committed to purchase low carbon products and technologies. For example, we have committed to have at least 10 % of our purchased steel by 2030 being produced based on breakthrough technologies like the Hybrit fossil free steel.