ELECTRIFICATION

Achieving climate goals means reducing greenhouse gas emissions from all energy sectors. Deep decarbonization of heating, transport, and industry can be achieved by substituting fossil fuels with emission-free alternatives. Since the main emission-free energy technologies generate electricity, it seems inevitable that the other energy sectors must be largely electrified. At the same time, electrification of energy brings new alternatives for managing the variability of wind power and solar PV in a cost-effective manner.

How to decarbonise all final energy demand?

Fossil fuel used in the other energy sectors can be replaced either directly with electricity or indirectly through synthetic fuels made with electricity (Figure 1). There are also other alternatives, like producing heat directly from nuclear reactors, geothermal wells or from solar thermal absorbers, as well as using bioenergy directly for heating and transport. However, they may have limitations due to resource, usability or geographical constraints.

Direct electrification technologies include resistance heaters, heat pumps and electric vehicles. In addition, there are solutions for mainly industrial applications, such as electric arc furnaces.

Indirect electrification often starts with electrolysers that produce hydrogen using electricity. Hydrogen can then be used in fuel cells to convert the energy back to electricity or it can be burned to produce heat. Hydrogen can also be used to make more complicated synthetic fuels and other molecules.

Because of losses in the conversion phases, indirect electrification is an expensive route and usually comes into question only when other options are exhausted. One important option is to replace existing fuels used in existing infrastructure - these would include natural gas and gasoline.

Space heating and domestic hot water can utilize both direct and indirect electrification. Heat pumps have the best efficiency and are likely to be the major electrification route, but they can be complemented by resistance heaters, heat storages and synthetic fuels to increase flexibility.

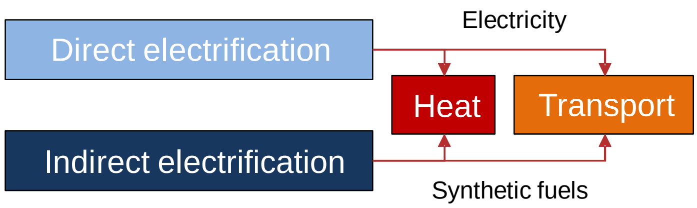

Figure 1. *Direct electrification is defined as replacing fossil-based end-use technologies with electric end-use technologies. Indirect electrification is defined as the substitution of fossil fuels through electricity-based synthetic fuels.*

In the transport sector, the bulk of electrification is likely to be through electric vehicles. However, it is not an option in all cases (e.g. aviation) and it is likely to be supplemented by synthetic fuels as well as fuel cell vehicles.

Emissions from the industrial sector are divided into energy-related and process-related emissions. Energy-related emissions mostly result from the use of heat at different temperature levels. Heat pumps are usually the cheapest option for low temperature levels, but they can be supplemented by resistance heaters and heat storages. High temperature levels can also be achieved with direct conversion from electricity - using resistance heaters, electric arc furnaces, and induction furnaces, for example. When burning of fuels is necessary, indirect electrification has advantages. Finally, the reduction of process-related emissions requires specific solutions (e.g. in cement making and reducing oxygen from metals).

Is there sufficient potential for wind and solar to cover the additional electricity demand?

De-carbonization through electrification only works if enough emission-free electricity is available. This raises the question whether the potential of wind and solar energy is sufficient to cover the increased electricity consumption due to electrification.

In all European countries, the potential for wind and solar energy is significantly higher than the required electrical energy consumption after electrification. However, there are regions where the realizable potential for wind and solar energy is quite limited and energy imports are likely to be important.

What is the effect of increased direct electrification on short and long-term flexibility in the energy system?

In the short term, adding inflexible electrical loads can increase system costs and impede the integration of larger shares of (future) wind and solar energy. On the other hand, if the new loads are flexible, this will enable more cost-efficient integration of larger wind and solar energy shares. Indirect electrification can often be flexible. For example, hydrogen electrolysers can be shut down at high electricity prices. Furthermore, indirect electrification options pose an opportunity for seasonal energy storage.

In the long term, the energy system is likely to adapt to the increasing variability of power generation. Electrification can become an important source of flexibility. However, inflexible electric devices can be cheaper to buy and lifetimes for energy devices are typically long, in the range of 15 to 60 years. Consequently, if flexibility is not currently profitable, we could see inflexible electrification that can become a problem later. In addition, both flexible and inflexible electrification may require notable grid reinforcements.

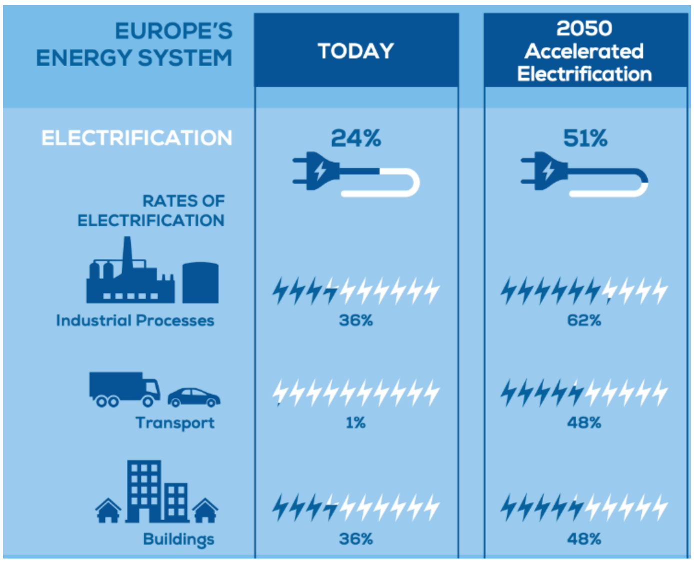

Figure 2. Rate of electrification today and in a future scenario. (Source: WindEurope).

How is electrification proceeding?

Electrification is already happening, and the climate targets foresee more electrification (Figure 2).

In the past, low electricity prices in countries such as France, Norway or Sweden resulted in a higher share of electrical appliances in heating and/or transport compared to traditionally fossil-based systems such as Germany or Italy. These examples show that the willingness to electrify depends, amongst others, on the electrification costs.

Cheaper electricity or more expensive fuels can speed up the electrification. Fossil fuels will become more expensive when the cost of emitting CO_2 goes up. This can accelerate electrification where the cost of equipment is low like heating. On the other hand, for electric vehicles, the cost of batteries is more decisive than the cost of fuels.

Associated publications

- WindEurope. **Breaking new ground**. https://windeurope.org/about-wind/reports/breaking-new-ground/
- ESIG (2019). **Toward 100% Renewable Energy Pathways: Key Research Needs**. https://www.esig.energy/esig-101/
- Guminski, A.; Böing F.; Murmann, A.; von Roon, S. (2019). **System effects on high demand-side electrification rates: A scenario analysis for Germany in 2030.** WIREs Energy and Environment, 8, e327. https://doi.org/10.1002/wene.327
- Ruhnau, O.; Bannik, S.; Otten, S.; Praktiknjo, A.; Robinius, M. (2019). **Direct or indirect electrification? A review of heat generation and road transport decarbonisation scenarios for Germany 2050.** Energy, 166, 989–999. https://doi.org/10.1016/j.energy.2018.10.114

More information

This Fact Sheet draws from the work of IEA Wind Task 25, a research collaboration among 18 countries. The vision in the start of this network was to provide information to facilitate the highest economically feasible wind energy share within electricity power systems worldwide. IEA Wind Task 25 has since broadened its focus to analyze and further develop the methodology to assess the impact of wind and solar power on power and energy systems.

See our website at
https://community.ieawind.org/task25

See also other fact sheets

Storage and Wind Power Fact Sheet
Balancing Power Systems with Wind Power Fact Sheet
Capacity Value of Wind Power Fact Sheet
Wind Integration Issues Fact Sheet