
## Electricity-based fuels: the future of PtX

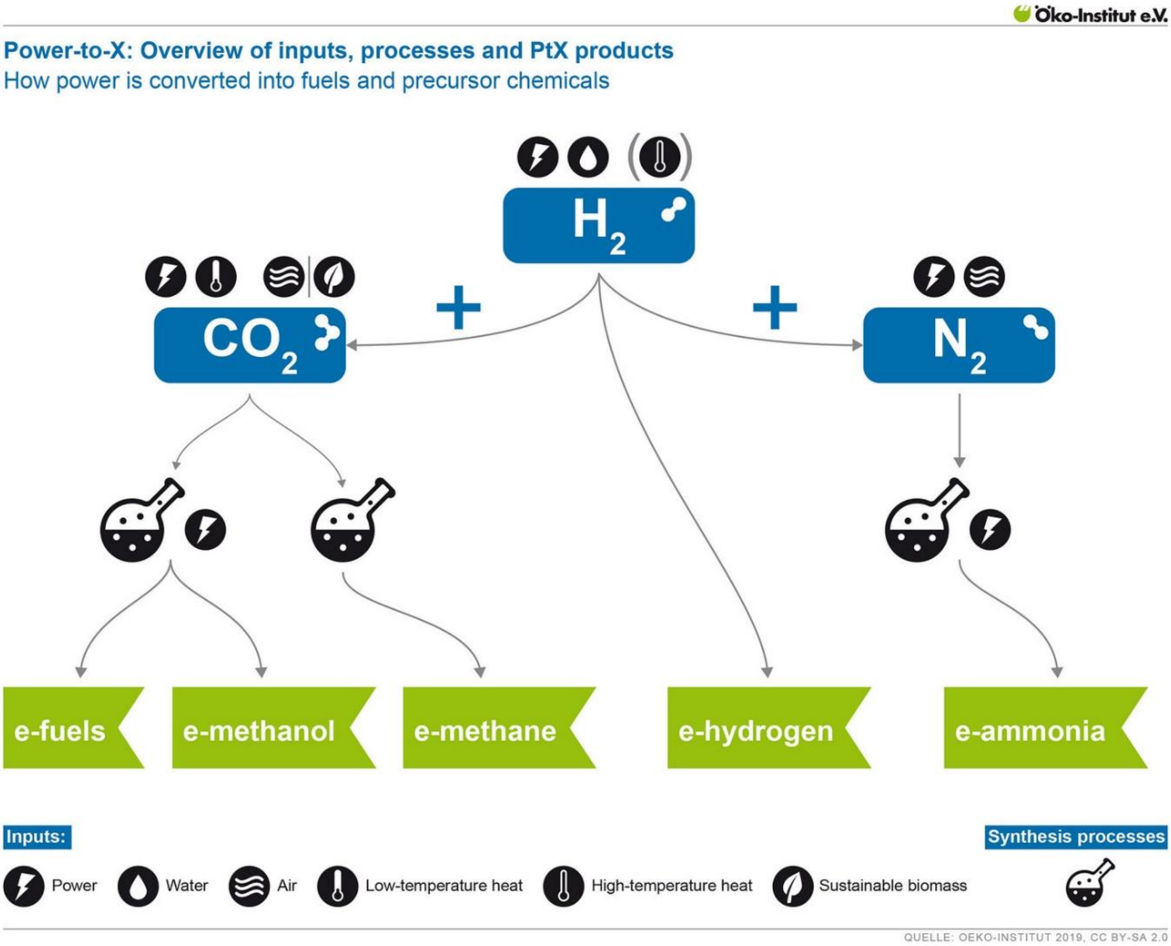
Materials produced from electricity – known as power-to-X (PtX) – are often hailed as the universal solution as we move towards an emissions-free future, with claims that they facilitate carbon-neutral applications wherever climate change mitigation efforts are still faltering – in mobility, in buildings, in energy-intensive industry. But is it really that simple?

Look more closely at electricity-based fuels and it quickly becomes apparent that not all PtX materials are sustainable – quite the contrary. If they are currently produced in Germany without any regulation of their sustainability, their emissions are in fact much higher than emissions from natural gas or diesel. For PtX materials to contribute to climate change mitigation, clear sustainability criteria are required.

### PtX production

PtX production is a complex process. First, **water** is converted into hydrogen using electricity in a process known as electrolysis. The hydrogen can be used directly in various applications. Before being stored or distributed, however, it must be compressed or liquefied, which requires additional energy inputs. As the next step, the hydrogen can be processed into gaseous or liquid fuels (e.g. methane) or e-fuels (e.g. synthetic kerosene and diesel), in which case carbon dioxide ($CO_2$) is also required.

**Figure:** **Overview of inputs, processes and PtX products**



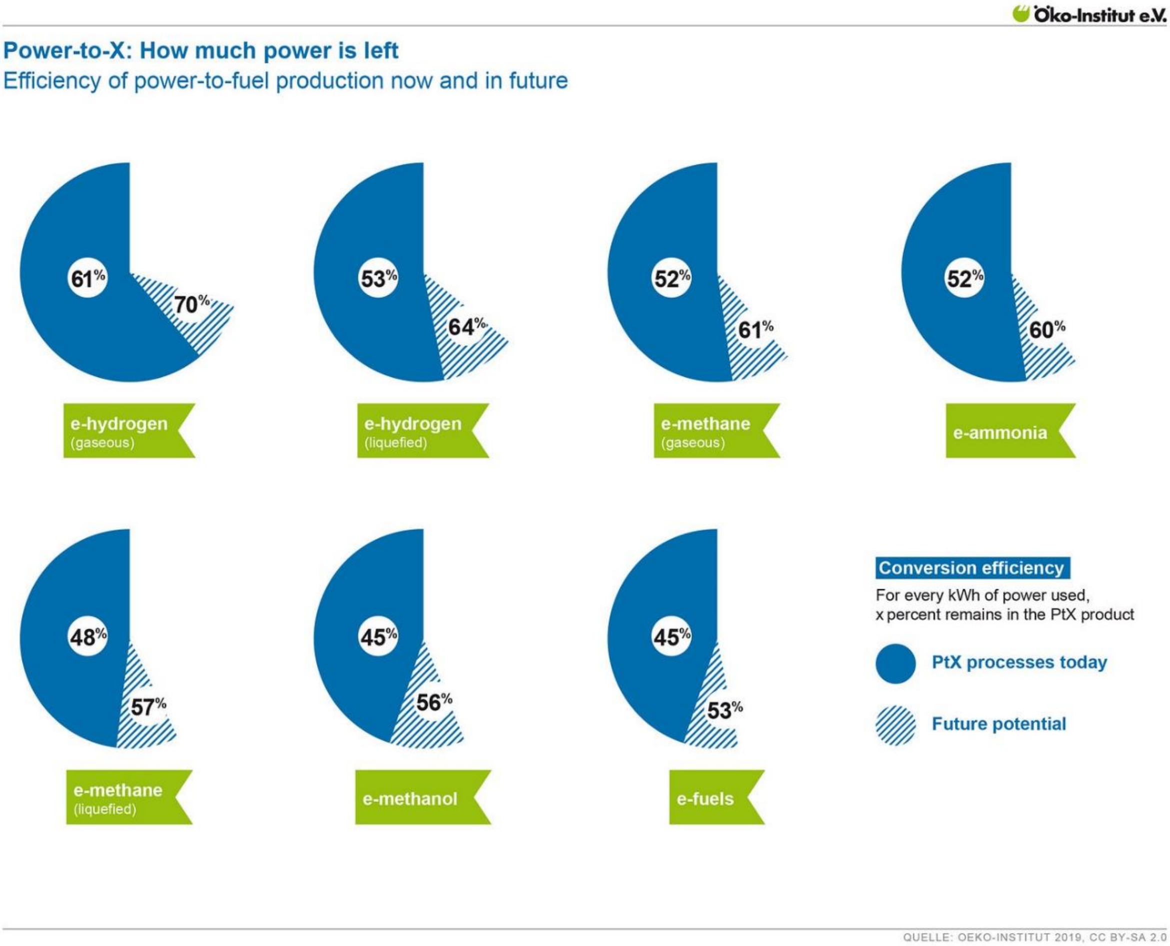

Source: Oeko-Institut

## PtX: conversion losses limit efficiency

Calculations by the Oeko-Institut show that direct electricity use is far more efficient in comparison to the use of electricity for PtX production. Why? Because of conversion losses. With the current state of technology, after production and storage, the energy content of gaseous hydrogen relative to the energy content of the electricity input is only around 61 per cent; for gaseous methane, it is 52 per cent, falling to just 45 per cent for e-fuels.

The outlook for the future is slightly more promising: energy efficiency in the production of gaseous or liquid energy carriers from electricity is set to increase. The Oeko-Institut anticipates a conversion potential of 70 per cent for gaseous hydrogen, 61 per cent for gaseous methane and 53 per cent for e-fuels. Even so, direct electricity use remains the more efficient option.

**Figure: Power-to-X: how much power is left**

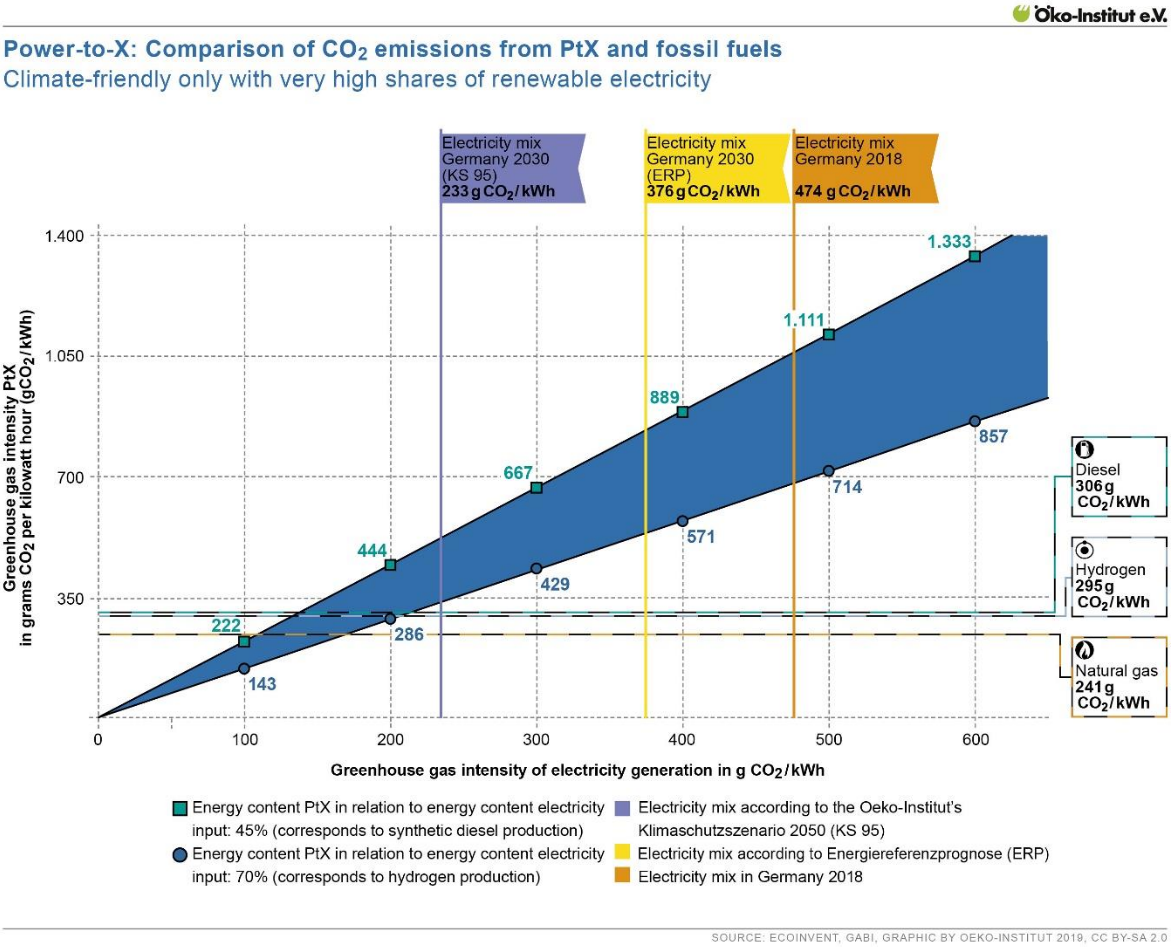



Source: Oeko-Institut

## Protecting the climate: sustainability criteria for PtX

In the Oeko-Institut's view, PtX materials have potential to help protect the climate, but only if certain conditions are met. From a climate perspective, it is only worth converting electricity into PtX materials if at least 75 per cent of the electricity input comes from renewable sources. Otherwise, the greenhouse gas emissions are even higher than emissions from natural gas or oil. Diesel combustion, for example, emits 306 g $CO_2$ per kilowatt hour (kWh); the figure for natural gas is 241 g $CO_2$/kWh. In Germany's electricity mix (2018), which produces 474 g $CO_2$ per kilowatt hour (kWh), the $CO_2$ intensity of PtX ranges from 700 to 1,100 g $CO_2$/kWh, depending on the efficiencies of the conversion processes. The renewables-generated electricity required to produce PtX materials consequently needs to come from additional sources. Renewables capacity must therefore be expanded if PtX materials are to contribute to climate change mitigation.

**Figure: Comparison of $CO_2$ emissions from PtX and fossil fuels**




Source: Oeko-Institut

Furthermore, for electricity-based materials to have a positive climate protection effect, the $CO_2$ required for their production must be captured from the air or from sustainable biomass use – the only sources of $CO_2$ that do not produce greenhouse gas emissions. In theory, the $CO_2$ inputs could come from fossil fuel-based industrial processes. However, this increases the risk that industry's emission reductions will slow down. These $CO_2$ emissions could then acquire value as an input for PtX production, potentially creating negative incentives and adversely impacting on emissions trading.

Various projects under way at the Oeko-Institut investigate the production and sustainability of PtX materials. One example is a study entitled "The significance of electricity-based materials for climate protection in Germany", established within the framework of the ENSURE – New Energy Network Structures for the Energy Transition project funded by the German Federal Ministry of Education and Research (BMBF). Another is an impulse paper entitled "Not to be taken for granted: climate protection and sustainability through PtX" produced on behalf of BUND (Friends of the Earth Germany).

## Power-to-X: costs and imports

Producing PtX materials is a high-cost undertaking. The Oeko-Institut estimates that even with optimised processes and efficiency increases, they are still likely to be more expensive than their fossil counterparts over the long term. Furthermore, the additional renewable energies required will absorb not only resources but also land. Renewables expansion already frequently encounters opposition in Germany, which is why it is slowing down. For that reason, many electricity-based materials are likely to be imported from other countries in future, partly because the costs of producing PtX in Europe are higher than in North Africa, Australia, Chile and the Middle East, for example.

Timely consultations with possible supplier countries are therefore essential, as is the establishment of an appropriate infrastructure for the hydrogen sector. In the Oeko-Institut's view, the adoption of uniform sustainability criteria – based on European import standards or international certificates, for example – is a further requirement.

## Meaningful use? PtX in the transport sector

In future, PtX materials may have a meaningful role to play in aviation and shipping, in high-temperature applications in industry and in long-term electricity storage solutions. According to Oeko-Institut projections, a near-carbon-neutral energy system in 2050 is likely to require several hundred terawatt hours of PtX.

By contrast, the researchers are sceptical about the use of hydrogen or hydrogen-based synthetic fuels (e-fuels) in road transport. Avoidance and a modal shift, along with efficiency increases and electrification of propulsion systems, already offer potential to reduce transport emissions by more than 80 per cent. Electric vehicles are roughly two and a half times more efficient than vehicles with combustion engines. If the losses incurred in the production of e-fuels are factored in as well, the direct use of electricity consumes up to five times less power for the same journey compared with e-fuels.

Kurzstudie über den Stand des Wissens und die mögliche Bedeutung von E-Fuels für den Klimaschutz im Verkehrssektor [Current knowledge and the possible significance of e-fuels for climate protection in the transport sector]: Short study by the Oeko-Institut on behalf of Climate Alliance Germany

In larger vehicles too, electric propulsion is the better alternative to hydrogen or e-fuels due to its much higher efficiency rates. For example, in a diesel truck powered by synthetic fuel, around 80 per cent of the energy from the electricity input is lost in conversion. The figure for a fuel cell truck powered by renewable hydrogen is roughly 70 per cent. For e-trucks powered by batteries or overhead cables, the rate of loss is much lower: conversion losses in these vehicles are below 30 per cent, with overall efficiency of 73 per cent.

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