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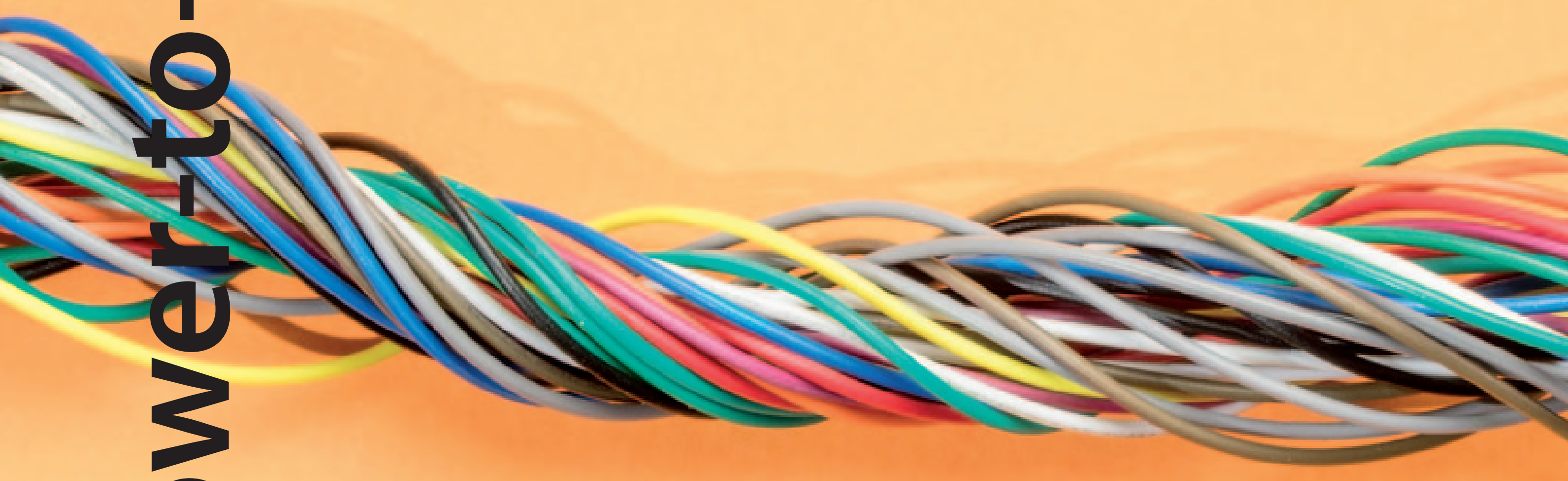
Sustainable reading from the Oeko-Institut



Power-to-X

Why do we need PtX?

Opportunity or risk? Interview with Dr Joachim Fünfgelt

Not a universal solution

Jan Peter Schemmel
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Remember Desertec? At the start of the new millennium, someone in Germany came up with the bright idea of harnessing the abundant sunshine in North Africa to generate electricity in vast solar energy systems and transferring it to Europe via long-distance power lines. The idea met with an enthusiastic response. There was one problem, however – there was too much input from German desk-jockeys and not enough dialogue with the countries concerned.

Hydrogen, as a key product in power-to-X value chains, will play an important role in our future energy supply. However, it will only be genuinely green if it is produced using additional renewable energies. It is already clear that these additional renewables will not be available in sufficient quantities here in Germany and that large amounts of hydrogen will have to be imported. Having been a development professional for many years, I firmly believe that hydrogen production should be consistently aligned with and contribute to the exporting countries' sustainable development, that our cooperation should be based on transparency, and that every new collaboration should consider the needs of the country concerned. In the interview in this issue of eco@work, Dr Joachim Fünfgelt from Bread for the World offers some exciting insights on this topic.

At the same time, we need to recognise that PtX materials are not a universal solution for a emissions-free future. It is more efficient, and more cost-effective, to use renewables-generated electricity directly than via the detour of hydrogen. Hydrogen should therefore be used – in a purposeful and carefully considered manner – only when there are no other climate-friendly options available, for example in aviation and energy-intensive industry.

Too many ifs and buts, you think? Then let me conclude by emphasising that electricity-based fuels are, of course, intriguing products that can provide powerful support for the energy transition. The enthusiastic response that these innovations may encounter here in Germany can boost our shared willingness to progress towards a sustainable future as an industrialised country. If this enthusiasm is combined with recognition of the realities and with economies of scale in PtX production, we will be on the right path.

Yours,
Jan Peter Schemmel

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"There are practical as well as ethical issues at stake"

The Oeko-Institut predicts that in a near-carbon-neutral energy system in 2050, several hundred terawatt hours of PtX will be required. If this involves the use of green hydrogen produced using renewable energies, Germany's own capacity is likely to be insufficient and large-scale imports will be required from other countries, e.g. in North Africa or the Middle East. But how can Germany ensure that hydrogen production in these countries is genuinely sustainable from both an environmental and a social perspective? We put this question to Dr Joachim Fünfgelt, Energy Policy Advisor at Bread for the World.

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Dr Fünfgelt, is exporting hydrogen an opportunity or a risk for countries of the Global South?
It is both. The risk is that Germany will want to build capacity fast and that countries with potential to produce hydrogen will want to start generating revenue as quickly as possible. But establishing sustainable hydrogen partnerships is a long process that requires participants to invest time in exploring ethical as well as practical issues. And to involve local communities – that's really important. Of course, there are potential benefits for these communities as well, in terms of local wealth generation, jobs, development of local renewables and better access to energy.

What are the ongoing risks?
Hydrogen production can worsen water scarcity and harm the environment; resource extraction is a factor here. A further risk is that it will slow down the expansion of renewable energies for local use. Priority must be given to supporting the countries in achieving a 100 per cent renewable energy supply first, before giving any thought to exports. And of course, there is the risk of illegal landgrabbing; this can occur if land that should be used to grow food for local communities is turned over to hydrogen production instead.

In that case, should green hydrogen be imported at all?
Yes, certainly, but it is important to proceed with caution. We are in favour of restricting the use of hydrogen. That means only using it where there is no alternative – in aviation, for example – and relying on other solutions as well, such as more energy efficiency or sufficiency measures.

What can be done to mitigate the negative impacts?
When analysing the potential in these countries, it is essential to consider their renewables expansion pathway and corresponding demand. We also believe it is vital to consult and involve the local community. In addition, it is important to define sustainability criteria early on and to discuss them with local civil society.

What benefits are afforded by dialogue with the local community?
Through this dialogue, we gain a better understanding of the local situation and what local communities need if they are to benefit from domestic hydrogen production.

What can be done to ensure that local people's needs are met?
Regulatory measures are required here. In competitive tendering, for example, local companies should be given preference. And it should be mandatory for energy partnerships to develop the local energy infrastructure.

What is your view of the German Hydrogen Strategy, which earmarks two billion euros for the development of international partnerships?
First and foremost, the emphasis on green hydrogen is extremely gratifying and very welcome. As a development agency, we think it is important to focus on the African continent. It is noteworthy in that context that the strategy clearly states that hydrogen production must be guided by local needs. So a priority now is to keep a very close eye on whether this actually happens.

Do you have any criticisms of the strategy?
One point of criticism is the very high estimate of import demand. Our concern is that our own energy hunger, rather than the local energy transition and energy supply in the countries concerned, will be the priority. So the German Hydrogen Strategy needs to be embedded in much more rapid expansion of renewable energies and a reduction of energy demand through efficiency and sufficiency measures.

Thank you for talking to eco@work.
The interviewer was Christiane Weihe.

Power to fuel

What does the future hold for PtX?

Green hydrogen
is produced using 100 per cent renewables-generated electricity.

Grey hydrogen
is produced using fossil hydrocarbons, releasing CO_2 into the atmosphere.

Blue hydrogen
is produced using fossil hydrocarbons, but with a carbon capture and storage (CCS) system, avoiding CO_2 emissions.

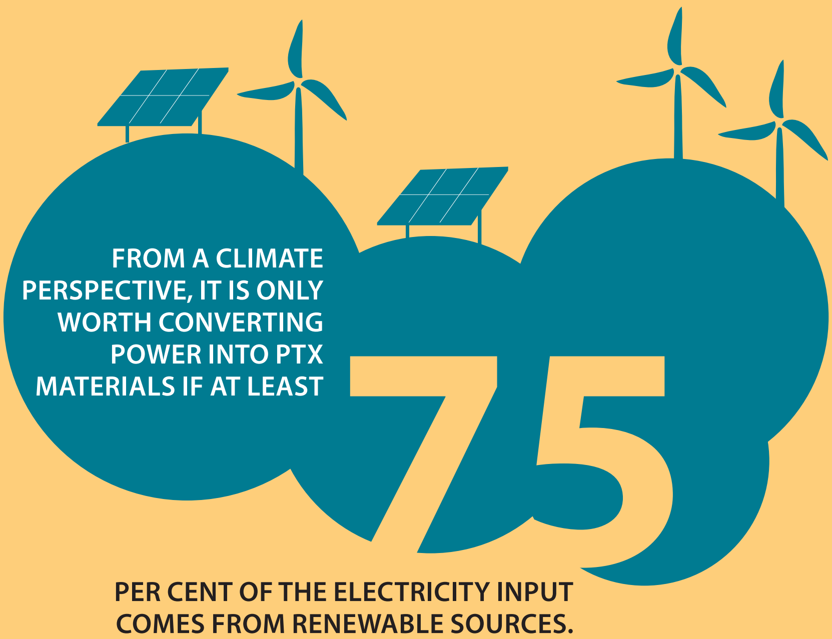
Turquoise hydrogen
is produced via the thermal splitting of methane. This produces solid carbon rather than CO_2.

Use gas and fuel with a clear conscience? Power-to-X materials – PtX for short – seemingly make air travel possible with no awkward questions about sustainability. This is because the production of PtX materials is based on (renewables-generated) electricity. However, this does not necessarily mean that they are sustainable or that their broad-scale use is appropriate. To be genuinely sustainable, PtX materials must be based on additional renewable energy sources – and much of this energy input is lost during production. So where can PtX materials be usefully deployed, and what role might they play in mitigating climate change in future? Studies by the Oeko-Institut aim to answer these questions.

"There are different interpretations of what PtX actually means," says Christoph Heinemann, a Senior Researcher in the Oeko-Institut's Energy and Climate Division. "Indeed, heat pumps are sometimes classed as PtX technology because they convert power into heat. But when we talk about PtX materials, we generally mean gaseous or liquid substances that are produced with the aid of electricity." And this production is a complex procedure. As the first step in all PtX production, water is converted into hydrogen using electricity in a process known as electrolysis. The hydrogen can be used directly; before being stored or distributed, however, it must be compressed or liquefied, which requires additional energy inputs. "And as the next step, the hydrogen can be processed into other gaseous or liquid fuels, such as methane, or e-fuels like synthetic kerosene and diesel. In that case, carbon dioxide is additionally required to produce these hydrocarbons."

HOW SIGNIFICANT IS PTX?

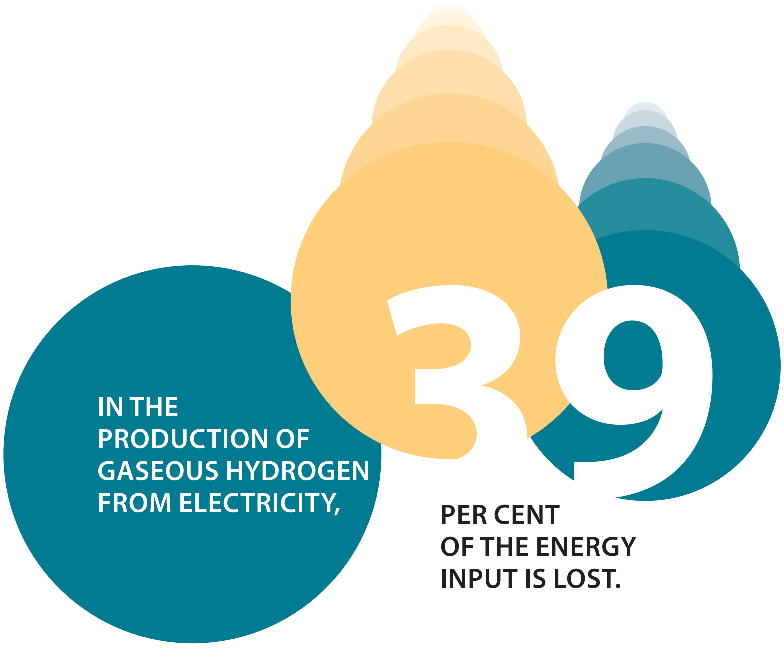
"PtX materials may well have a meaningful role to play in certain sectors such as aviation, shipping and industry," says Christoph Heinemann. "In fact, the use of PtX materials can probably help to protect the climate from 2030 onwards – provided that certain conditions are met." In the study "The significance of electricity-based materials for climate protection in Germany", the Oeko-Institut looks at current knowledge about power-based fuels and turns the spotlight on their production, use and costs. The study was conducted 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). In the study, the researchers show that from a climate perspective, it is only worth converting electricity into PtX materials if at least 75 per cent of this electricity input comes from renewable sources. "Otherwise, the greenhouse gas emissions are even higher than emissions from fossil fuels, i.e. coal, oil or natural gas," Christoph Heinemann explains. 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 efficiency of the conversion processes involved.



ADDITIONAL CAPACITY

As Christoph Heinemann emphasises, the green electricity required to produce PtX materials must come from additional sources, which requires an expansion of capacity. "If additional renewable energies are used, PtX production can be almost climate-neutral. However, this will require substantial resource inputs, as well as a considerable amount of land. In Germany, it is already proving difficult to generate public acceptance of the renewables expansion that is needed even without widespread use of PtX." The energy expert therefore thinks it is likely that electricity-based materials will in future be imported in large quantities from other countries, partly because the costs of producing hydrogen are higher in Europe than in North Africa, Australia, Chile or the Middle East, for example. "Costs are influenced by a variety of factors," he says. "For instance, they are lower at sites with optimal conditions for power generation from renewables. And transport costs are only really a major factor in relation to hydrogen."

In 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), the Oeko-Institut also makes it clear that for PtX to have a positive climate impact, 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 industrial processes," says Christoph Heinemann. "However, there is then a risk that industry's emission reductions will slow down. These CO_2 emissions could then acquire value as a raw material, potentially creating negative incentives and adversely impacting on emissions trading."



In the study conducted within the framework of the ENSURE project, the Oeko-Institut also reveals the high costs of producing PtX materials. Even with optimised processes and efficiency increases, they are still likely to be more expensive than their fossil counterparts over the long term, according to the study. "So before using electricity-based fuels, other more cost-effective steps should be taken first: more energy efficiency and other measures to reduce energy demand, such as insulation of buildings," says Christoph Heinemann. "Direct electricity use is also far more efficient because of the conversion losses associated with PtX production." 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. Efficiency in the production of gaseous or liquid electricity-based fuels is likely to increase in future: the Oeko-Institut is predicting 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. "PtX materials should be used primarily in sectors where direct electricity use is difficult or impossible – in aviation or high-temperature industrial applications, for example," the scientist says. They may also have a meaningful role to play in steel production or in long-term electricity storage. The chemical industry also uses hydrogen to produce ammonia, methanol and ethyls, for example.

NO SIMPLE SOLUTIONS

Given the numerous challenges, the Oeko-Institut's energy expert believes it is essential, in any discussion of PtX, to approach the topic with an open mind, to make realistic assessments of these fuels' potential and always to be willing to reappraise one's position. "Looking at the climate scenarios, it is clear that moving forward without PtX will be difficult," he says. "In a near-carbon-neutral energy system in 2050, we are likely to require several hundred terawatt hours of PtX. So for that reason, not least, we will keep the issue of PtX under critical review here at the Oeko-Institut, with a particular focus on the sustainability dimension." There is still a great deal of controversy over the future role of hydrogen and electricity-based fuels. "Our analyses are also intended to ensure that this is an objective debate," says Christoph Heinemann.

Another factor of importance for sustainable, future-focused PtX use is consistent and timely political control that takes account of the costs and technical challenges associated with PtX materials, assesses them transparently and derives future-proof solutions on this basis. The National Hydrogen Strategy, adopted in June 2020, and the appointment of a National Hydrogen Council – whose members include Dr Felix Christian Matthes from the Oeko-Institut – are key steps in this direction. The German government plans to invest a total of nine billion euros in boosting the hydrogen market and promoting initial applications in industry, for example.

From the Oeko-Institut's perspective, however, PtX should only be promoted if there is certainty from the outset that they will genuinely reduce greenhouse gas emissions. "Given that the use of PtX is likely to rely heavily on imports in future, timely consultations with potential supplier countries are essential, as is the establishment of an appropriate infrastructure," says Christoph Heinemann. "Adoption of uniform sustainability criteria – based on European import standards or international certificates, for example – is a further key requirement." The fact is that if we want to use PtX, we must do our utmost to ensure that they are as sustainable as possible and genuinely reduce carbon emissions.

Christiane Weihe

Christoph Heinemann studied Geography, Political Economy and Business Management. A Senior Researcher in the Oeko-Institut's Energy and Climate Division, his areas of expertise include innovative power products, modelling of the future energy system and the integration of renewable energies.
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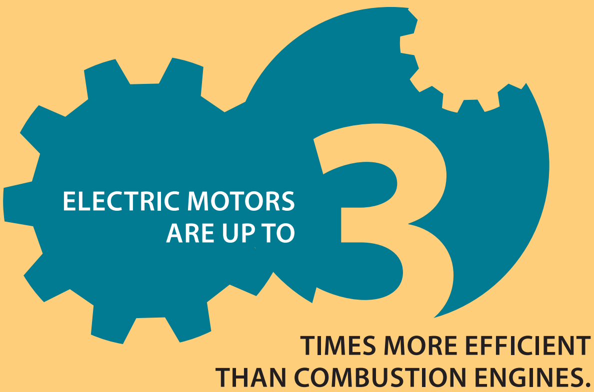
Not the first choice

Electricity-based fuels in the transport sector

Back in the mid 1990s, Daimler-Benz set out to develop a hydrogen car in its drive towards an eco-friendly future. More than 20 years on, vehicles powered by hydrogen or synthetic hydrogen-based fuels – known as e-fuels – are a rarity on German roads. Liquid fossil-based fuels such as diesel and petrol dominate the transport sector, while electromobility is proving to be an efficient alternative to hydrogen fuel cells. What role can e-fuels play in future? Where can electricity-based fuels be meaningfully deployed, and how soon? The Oeko-Institut is working to find answers to these questions.

When it comes to protecting the climate, the German transport sector certainly needs to up its game. Its target is to be near-climate-neutral by 2050, yet its 2019 emissions were still on a par with the 1990 level, at just over 163 million tonnes of CO_2e. How worthwhile is it to rely on e-fuels to bridge the gap? In theory, electricity-based fuels can reduce transport emissions if they are produced in accordance with clear sustainability criteria – using additional renewable energies, for example (*for more details, see "Power to fuel – What does the future hold for PtX?" on p. 4*).



But this would be a very costly approach. "Achieving more climate change mitigation in the transport sector largely on the basis of e-fuels is the most expensive option," says Peter Kasten, a Senior Researcher at the Oeko-Institut. "For that reason, other approaches should be explored first." This means traffic avoidance and a modal shift, with more walking, cycling and public transport use. Increasing the efficiency of existing drive systems and more e-mobility should also be priorities, according to the Oeko-Institut. "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," says Peter Kasten. "What's more, 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." In a short study entitled "Current knowledge and the possible significance of e-fuels for climate protection in the transport sector", produced by the Oeko-Institut on behalf of Climate Alliance Germany, he outlines the challenges associated with e-fuel production and compares them with other climate change mitigation measures in the transport sector.

LOW EFFICIENCIES

In larger vehicles as well as passenger cars, 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," Peter Kasten explains. "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." What's more, the transition towards e-mobility – unlike electricity-based fuels – is already well under way. "The technology is more advanced and e-mobility is becoming increasingly affordable. And we have already seen many vehicle manufacturers pulling out of hydrogen technology altogether," says Peter Kasten. "It's also important to ensure that policy incentives for e-fuels do not undermine the development of battery electric mobility." From the Oeko-Institut's perspective, however, this does not mean that there is no place for electricity-based fuels in the transport sector. "The technology is especially suitable for aviation and shipping, so policy-makers should provide incentives to ensure that fuels are developed specifically for these sectors."

AT LEAST

10

YEARS FOR E-FUELS TO BE PRODUCED BY INDUSTRY AT SCALE.

AT LEAST 10 YEARS

There is another reason why electricity-based fuels are not suitable to support a rapid energy transition: although decades have passed since hydrogen vehicles first made an appearance, many experts believe that industrial production of electricity-based fuels at scale lies many years in the future. "We are probably looking at a minimum of 10 years," says Peter Kasten. "A figure of around 30 petajoules per annum is seen as technically feasible for Germany by 2030 – in an ideal scenario." By comparison, Germany's transport sector – including shipping and aviation – used 2,800 petajoules of fuel in 2018, with road transport accounting for the major share, i.e. around 2,300 petajoules.

So why the delay in producing sustainable e-fuels at scale? One factor is the additional renewable energies required: the pace of renewable energy system expansion is limited. These 30 petajoules would require an additional 15-18 terawatt hours of power. Although industrial production is unlikely to take place here, a glance at Germany is instructive: producing this amount of extra power would require the construction of an additional 610 offshore or up to 2,900 onshore wind turbines – over and above the expansion that is already planned. "In the medium term, for climate-friendly production of e-fuels, you also have to use CO_2 that is captured from the atmosphere, which is currently very expensive and only possible in micro-scale and pilot plants," Peter Kasten explains. "If you use CO_2 from other sources – such as fossil-based industrial processes – the sectors concerned no longer have any incentive to cut their CO_2 emissions. That means that the production of e-fuels can indirectly increase emissions in other sectors and substantially reduce the potential for climate change mitigation."

An industrial-scale production plant would also require planning, consultations and the development of a transport infrastructure. And not least, it would need investors. However, the investment climate is beset with uncertainty at present, as the EU's recast Renewable Energy Directive (RED II) is still in the process of being transposed into German law. "The criteria for calculating the greenhouse gas balance and the supply of electricity for producing e-fuels have not yet been established. The standards that must be met by production plants if their e-fuels are to qualify for classification and support as sustainable fuels will not be available until 2021," says Peter Kasten. "Given that a large-scale PtX production plant will require several billion euros in investment, financial backers are likely to be reluctant to come forward until then." The Oeko-Institut is advising the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety on the transposition of RED II. "It's an exciting and important task – because this legislation will determine how these fuels reach the German market," says Peter Kasten. And it will also shape the future of hydrogen in the transport sector more than two decades after Daimler first announced its hydrogen car production – suspended since mid-2020.

Christiane Weihe

Peter Kasten's research focuses on sustainable mobility. A Senior Researcher in the Resources and Transport Division, he works on topics such as alternative mobility strategies, sector coupling of energy and transport, and CO_2 avoidance in transport at the EU level.
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