Power-to-X
Technologies for Sectoral Integration
The Paris Agreement sets a clear goal for politicians and society: in order to limit the rise in temperature to a maximum of two degrees Celsius by the end of the 21st century, greenhouse gas emissions must be drastically reduced by 2050. The aim is to achieve a high degree of climate neutrality in all sectors without endangering social peace and prosperity in Europe. In the European Union a long-term strategy for a prosperous, modern, competitive and climate-neutral Europe in 2050 is currently being discussed. For 2030 the EU-wide targets and policy objectives are already set: Cutting at least 40 per cent of the greenhouse gas emissions (from 1990 levels), increasing the share of renewables to at least 32 per cent and improving the energy efficiency by at least 32.5 per cent.

Overall, however, the European Union still has a long way to go before the energy transition can be deemed a success. Storage is a major challenge: the largest natural energy sources for renewable electricity — solar and wind power — depend on the weather. The non-weather-dependent resources (geothermal energy, hydroelectric power, tides, and renewable raw materials) are not evenly and sufficiently available in all European countries to guarantee continuous electricity generation. In order to survive times with little wind or sunshine in which no energy is produced for several days or even weeks, previously generated solar and wind power must be stored. In order to guarantee a stable power supply based on renewable sources in Germany, a controllable power plant capacity of up to 130 gigawatts must be available in 2050. If these power plants are to be operated in a climate-neutral manner, there are no alternatives to gas-fired power plants that run on synthetically produced methane. Like hydrogen, methane can also be added to natural gas from fossil sources during the ramp-up phase, thus contributing to a rapid reduction in greenhouse gas emissions.

Another major challenge to be mastered to ensure the success of the energy transition is the heavy dependence on fossil fuels within many sectors, in particular the transport sector. The switch to battery electric drives is an interesting option for passenger cars and is currently being pursued intensively. For growing road freight transport, shipping and aviation, however, electrical energy storage is not an alternative that could completely replace internal combustion engines and gas turbines by 2050. Independence from mineral oil-based fuels can only be achieved with P2X fuels. When such eFuels are burned, only the amount of carbon dioxide that was previously chemically bound during production is released.

The proportion of fossil fuels in the heat sector has also been very high so far. Heat is required not only for heating in buildings, but also for many industrial processes, such as metal production and processing. It differs from the heat used in buildings in that it must be continuously available and reaches very high temperatures of several hundred degrees. Interruptions to the heat supply can result in serious damage or even complete destruction of the production facilities. Nowadays, industrial process heat is usually generated by burning natural gas — a process that could be completely and safely substituted for synthetically produced gas.
Synthetic gas and liquid P2X eFuels have one thing in common: the infrastructure based on fossil fuels can continue to be used for transport and refuelling. In addition, as research projects have shown, they can be mixed with almost any proportion of fossil fuels and thus contribute to a rapid reduction in greenhouse gas emissions.

Climate-neutral gas also guarantees a reliable power supply. Hence, P2X technologies are key to the success of the energy transition.

**Daily share of renewable energies in net public electricity generation in Germany, year 2018**

Source: Fraunhofer Institute for Solar Energy Systems
P2X – Energy storage for the future

Electricity is always available: To charge the smartphone or to keep a complete production line running. But storing electrons in one place so that they can be recalled later, requires a few tricks. Chemical storages, which can be produced in a climate neutral manner from hydrogen and carbon with the aid of renewable electricity, have a particularly high energy density. These technology paths are referred to as „Power-to-X“ or P2X for short. What they have in common is that at the beginning of the reaction chain there is always electricity generated from renewable sources („power“) from which gaseous or liquid energy sources („X“) are produced.

P2X is therefore ideally suited for sector coupling. Regardless of the end product, almost all P2X processes use regenerative electricity to produce hydrogen from pure water in the first step. The energy carrier hydrogen can be used in many ways: Either it is used in fuel cells to generate electricity at the time and place where it is consumed. It can also be burned directly within the engine. Both methods produce no waste product other than water.

A significantly higher energy density can be achieved if the hydrogen is enriched with carbon. The simplest technically usable hydrocarbon is CH₄, also known as methane, which is the main component of natural gas. The methanisation of hydrogen is based on a known chemical process („hydrogen shift reaction“), which is used to produce hydrogen from fossil natural gas. If the process is reversed, carbon dioxide is required as the starting material. This can come either from industrial processes such as steel or cement production, in which carbon dioxide is unavoidably produced as a waste product – it is then climate-neutral carbon recycling. Carbon dioxide can also be extracted directly from the air using carbon capture processes, which leads to a reduction in the CO₂ concentration in the atmosphere. Synthetically produced methane is suitable for use in both internal combustion engines and gas turbines. In the latter, the mechanical energy generated can be used to drive a generator to generate electricity.

The energy density can be further increased by producing liquid instead of gaseous energy carriers on the basis of hydrogen produced by regenerative means. The variety of suitable processes for these „power-to-liquid“ technologies is as large as the number of starting materials. Liquid P2X energy carriers can be very well transported and distributed within the existing energy infrastructure. Due to their high energy density, they are particularly suitable for mobile applications such as aircraft turbines or ship engines.
P2X processes can be used not only for the production of energy sources but in the future, they will replace the mineral oil-based raw materials needed in the chemical industry, like in the production of plastics.

Generally applied to all P2X processes: with increasing volumetric energy density, the energy required for production also increases, while at the same time the costs for storage and transport decrease. P2X is therefore especially useful where long-term storage or high mobility requirements represent a higher value than maximum efficiency in direct energy conversion.
P2X – Jobs and competitiveness

The energy transition represents a great opportunity for the export-oriented European mechanical and plant engineering industry. The full implementation of the Paris agreement requires the worldwide introduction of new technologies for energy conversion, increased energy efficiency, and storage. The more than 3,200 VDMA member companies see themselves as suppliers to the energy system transition process. The Association’s member companies are leaders in the development and manufacture of power generation systems. Last but not least, ships, aircraft, and mobile machinery all over the world are equipped with energy-efficient drives, which are developed and produced in Europe.

A study by Frontier Economics concluded in 2018 that the global demand for P2X fuels could reach 20,000 terawatt hours in 2050. This would correspond to a value added of 2,000 billion euros per year. In order to produce this amount of energy, a plant capacity with a nominal output of up to 8,000 gigawatts would be required. However, Europe cannot cover this energy demand on the basis of renewable energy alone. On the one hand, the sun and wind are only available at fluctuating times, and on the other hand, land consumption would be too high. In some scenarios, this leads to P2X fuel production being shifted to countries with constantly high solar or wind supply. This would be a further market segment for the mechanical and plant engineering companies act as equipment suppliers in which they would have to hold their own in global competition.

European plant manufacturers are already among the world’s most efficient suppliers of the process technologies required for this. Currently, every fifth electrolysis plant sold worldwide comes from Germany. Germany currently has a world market share of 16 percent in the plant components required for the subsequent chemical processes. According to the study, the construction of P2X production facilities could create up to 470,000 jobs in the German economy – regardless of where they are put into operation.

However, the mechanical and plant engineering industry is not only a supplier for the mineral oil and chemical industries worldwide, but is also dependent on a functioning energy supply. For instance, against the background of the imminent phase-out of nuclear energy and the phase-out of coal announced for 2038 in Germany, it is essential to begin to create structures that guarantee a secure supply of electricity and heat. P2X technologies have a key role to play in this respect, if climate neutrality is to be achieved to a large extent by 2050. It should be noted that large-scale plants and power stations have life cycles of several decades. Targeted investments can therefore only be made if the course for the post-fossil age is set at an early stage. One advantage for the acceptance of P2X technologies among the population is that the existing infrastructure can be used for distribution.
The mechanical and plant engineering industry is already an important employer today: VDMA member companies alone employ more than one million people in socially secured jobs in Germany. The prerequisite for this is success on the world markets, where machines and systems score points with technological progress and high productivity. So that European companies can participate in the emerging market for P2X technologies, it is therefore necessary to develop Europe into a leading market of these technologies. For P2X, climate protection and economic competitiveness go hand in hand.

How much Power-to-X systems can achieve which could be in operation worldwide by 2050

2,000 billion euros could be the value added globally by power-to-X fuels

8,000 GW are provided by the plants, that could operate globally in 2050

Around 470,000 jobs could be created in the German economy alone through the installation of Power-to-X plants.

Source: Frontier Economics, IW