The Key Power-to-Heat Technologies for the European Energy Transition

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Abstract

Power-to-heat (P2H) technologies offer great potential for the European energy transition. This article identifies the vital P2H technologies to use in households and industries in future sustainable energy systems.

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Power-to-heat (P2H) is a set of cost-effective technologies that offer many opportunities and advantages for the energy transition. P2H can use electricity from renewables, which may otherwise be curtailed, for the heating sector and provide additional flexibility to the electricity market [1]. By using renewable electricity for heating purposes, this helps to replace fossil fuels and protect the climate. Converting electricity into heat can also help keep power grids stable. This is because P2H technologies, when combined with thermal energy storage, can be used to preferentially absorb renewable-based electricity whenever a considerable amount of it is available. Many P2H technologies with different technology readiness levels exist to date. This article discusses the major P2H technologies expected to play a crucial role in the European energy transition. We have identified heat pumps, electric boilers, and electric resistance heaters as the most promising P2H technologies. Combining two or more of the technologies mentioned above is known as a mixed heating system. In addition, combined heat and power (CHP) plants can play a vital role in bridging the power and heat sectors.

The *heat pump* is a vital P2H technology that produces heating energy and, if required, hot water for single-family homes, apartment buildings, or even industries. Its distinguishing feature, however, is its method of heat extraction because, unlike most other heating systems, the heat pump does not have to burn any material to produce heat. Instead, it extracts the heat from the environment and harnesses it for our purposes, using very little electricity. This makes heat pumps particularly economically attractive and environmentally friendly. The way the heat pump works is often described as the "principle of the inverted refrigerator." Although there are specific differences in detail depending on the design of the heat pump, the basic principle is always the same: the heat pump extracts part of the stored thermal energy from its heat source (air, earth, or water) with the help of an evaporating refrigerant. In Europe, the heat pump is already on course for growth and on its way to becoming the most popular P2H technology. Heat pumps are beneficial because of their improved efficiency, lower energy price, simple installation, lower maintenance requirements, and higher safety standards compared to other heaters. According to the European Heat Pump Association, heat pump sales have achieved on average 12% growth per annum in the last six years [2]. High-temperature heat pumps are becoming more prevalent in industries, with food, paper, and chemical industries showing the highest potentials [3].

Photo: A new generation industrial heat pump. Source: TNO

The *electric boiler* is another popular P2H application often used in utility-related processes to generate hot water and steam. Electric boilers are generally categorized into two types: electrical resistance boilers and electrode boilers. The electric resistance boiler is connected at low voltage, while the electrode boiler is connected at medium voltage. Electrode boilers are popular in industrial applications for producing highly heated steam for industrial processes. Electric boilers are compact, affordable, and easy to install. In addition, they do not require a chimney or fuel supply. They

require little maintenance and are quick and easy to install. Mobile use is possible in many cases without any problems, which is a clear advantage of electric boilers. In the last ten years, electric boiler usage increased by 86% in EU-27 and the UK [4].

Electric resistance heaters are our next choice as a P2H technology, including two different types: direct electric heating and electric storage heating. Direct electric heating gives off the heat directly to the heated room. The advantage of these heaters is that their installation is relatively inexpensive compared to central heating. However, their operating costs are comparatively higher. There are various direct electric heaters: electrically heated radiators, mobile fan heaters, electric floor heaters, etc. On the other hand, electric storage heaters heat their integrated heat storage during so-called off-peak times, which can be used as needed at a later time. It is a flexible P2H option as it can reduce the peak demand by storing heat at low energy price times.

Mixed heating systems generally refer to heat pumps coupled with an electric boiler or electric resistance heater. It can be a promising alternative in terms of flexibility but needs higher investment costs than the individual P2H technologies. In district heating systems, electric boilers are sometimes combined with CHPs to create hybrid systems. Hybrid systems can help improve overall system flexibility compared to single P2H-based systems.

CHPs consume fuel to produce both power and heat, and therefore can be a crucial technology to bridge the gap between these sectors. A recent study showed that the CHP share in total electricity generation increases with rising renewable shares [5]. CHPs offer high efficiency, reduced operational cost, decreased air pollution, higher reliability, improved power quality, flexibility and greater productivity. According to the JRC policy report, the conversion of existing power plants to CHPs will increase the overall efficiency of the European energy system, which is otherwise limited to 50% [6].

P2H systems fed by renewable energy are expected to contribute significantly to the European energy transition. P2H opens up new possibilities for using renewable energies for the heating market. However, economic viability would have to be ensured to exploit the potential of P2H fully. P2H could then be used on a larger scale to decarbonize the heating sector.

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