# HP4Drying Project Successfully Concluded

***The transnational project «Energetic and Environmental Optimisation of Drying Processes by Integration of Heat Pumps», or HP4Drying for short, was successfully concluded on 30 June 2016 after more than two years' research work. In addition to PFI, two research groups from the University of Gent and five other German research organisations representing a wide range of industrial sectors participated in the project. The project was concerned with the integration of heat pumps into drying systems for digestate and sewage sludge, spices and medicinal plants, bricks, wood, textiles, and laundries. Successful coupling of two drying processes with a heat pump was demonstrated by PFI at Pirmasens-Winzeln Energy Park.***

## Project Goal

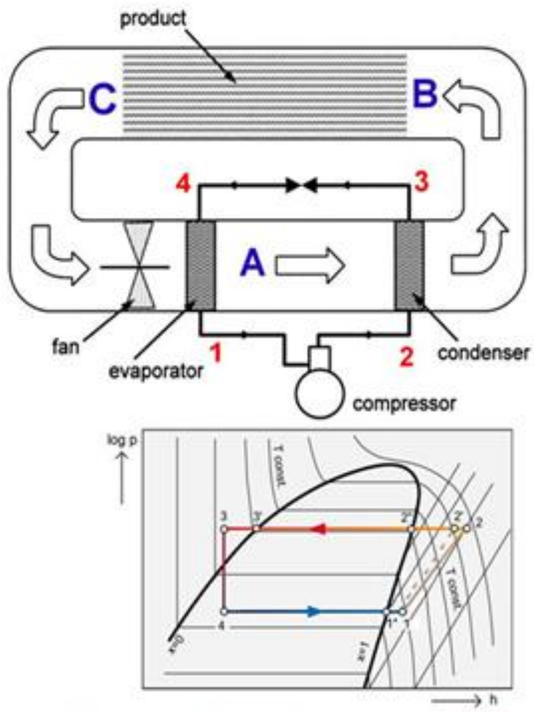
The main goal of the project was the integration of heat pumps (HP) into industrial drying processes, in order to optimise them energetically and ecologically. The main focus was on convection dryers because they are the most commonly used and because they more readily facilitate the integration of heat pumps. In the course of the project, simulations, demonstrations, and case studies were undertaken at various industrial locations.

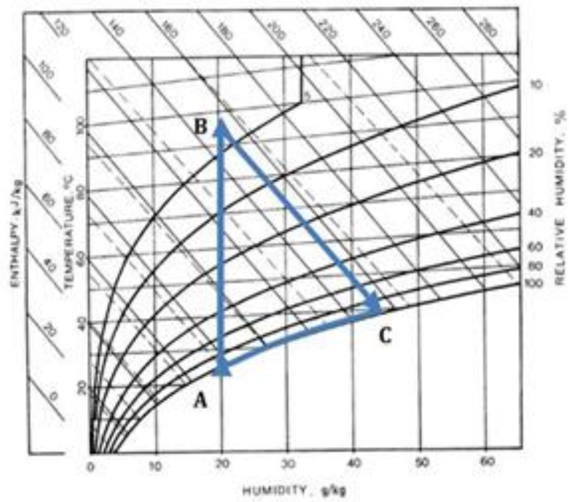
## Industrial Applications

Drying is a key component of many production processes. The results of this cross-sectoral project therefore serve the interests of a wide range of industries. The project consortium was made up of research institutes with many years of experience in HP and/or drying technologies and SMEs from different industries with a practical knowledge of specific production methods and the relevant technical, economic, and ecological requirements. The German research organisations covered drying processes in the timber, textile, and brickmaking industries as well and drying in laundries and in the case of agricultural products. Further industrial sectors were covered by participating companies in the Flemish User Group.

## Function of a Heat Pump Dryer

Heat pumps can save energy by extracting thermal energy at one place and transferring it at a higher usable level to another place. As in the case of household heat pump clothes dryers, the technology can also be used in industrial dryers. These are referred to as closed drying systems because the air used for drying can be reused for the same purpose after the moisture taken up from the material to be dried has been precipitated by cooling. The energy extracted from the moist air on cooling can in turn be used to reheat the now dry but cool air. Figure 1 is a schematic drawing of a simple closed heat pump dryer. Apart from saving energy, closed HP dryers have the additional advantage that they can reduce emissions and odour nuisance. Instead of moist waste air they discharge liquid water.




Mollier diagram: Stawreberg, L., Energy Efficiency Improvements of Tumble Dryers (2011)

Figure drying cycle: Carrington, C. G. Heat Pump and Dehumidification Drying. Chapter 10 (pp 249-273) in Food Drying Science and Technology: Microbiology, Chemistry, Applications. DEStech Publications Inc (2007).

***Figure 1: Schematic depiction of a heat pump dryer and plots of drying cycles (Mollier diagram and log p-h diagram)***

**Project Work at PFI's Energy Park**

Each of the research organisations participating in this project studied the integration of heat pumps for a specific sector of industry. PFI focussed on the drying of digestate and sewage sludge. Given a water content of more than 90 %, the drying of digestate is of considerable interest because of the possible reduction of storage capacity and of the logistical burden associated with digestate. The situation is similar with sewage sludge, which has to be dewatered and dried prior to thermal disposal.

In the context of this project, PFI examined digestate management at Pirmasens-Winzeln Energy Park and developed a pilot plant. A thermeco2 heat pump with a heating capacity of 50 kW was installed to cool the biogas from the fermenter from 36 °C to 20 °C (and thus dry the gas for use in the combined heat and power generation plant) and to raise this thermal energy to a temperature level of 50 °C in order to heat the external air for the dryer. The heat pump thus coupled two drying processes, that of the biogas and that of the digestate. The aim was to achieve a coefficient of performance (COP) of >3 on the basis of the electricity/gas price ratio valid at the time. This indicates how many kilowatts of useful thermal energy can be generated per kilowatt of electric power. The pilot plant was designed as an open dryer, meaning that external air was warmed for the drying process and then discharged into the atmosphere. The pilot also has a screw press separator (SPS) for dewatering of the digestate. The dryer module, originally intended for concentration of the separation liquid, was refitted for drying of the separated solids. Figure 2 shows a schematic diagram of the pilot plant.

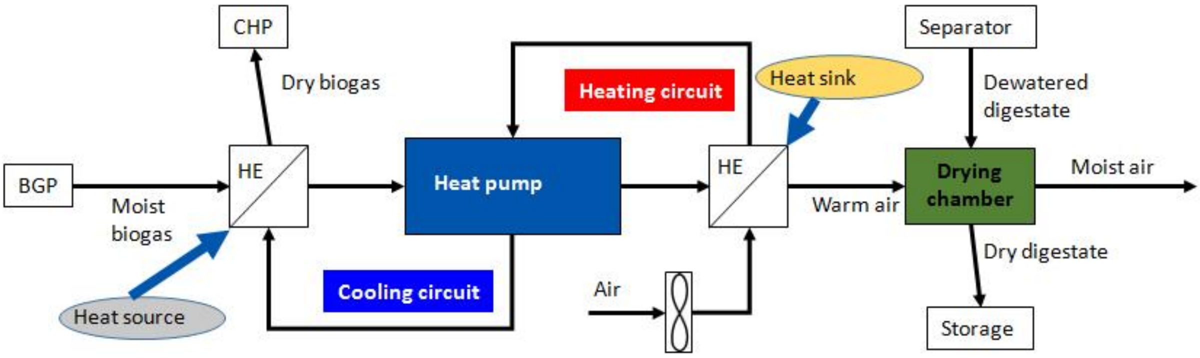



***Figure 2: Schematic depiction of pilot plant. The heat pump couples the biogas dryer as heat source with the digestate dryer as heat sink. HE = heat exchanger, BGP = biogas plant, CHP = combined heat and power generation plant***

Using this system, the biogas could be dried with a cooling capacity of about 30 kW. The dryer had a heating capacity of 50 kW. The heat pump required some 16 kW of electric power. This yields a COP of 4.83 for the overall system. Thus each kilowatt of electricity afforded 4.83 kilowatts of useful thermal energy.

Figure 3 shows an extended schematic diagram of the pilot plant with relevant measured values.

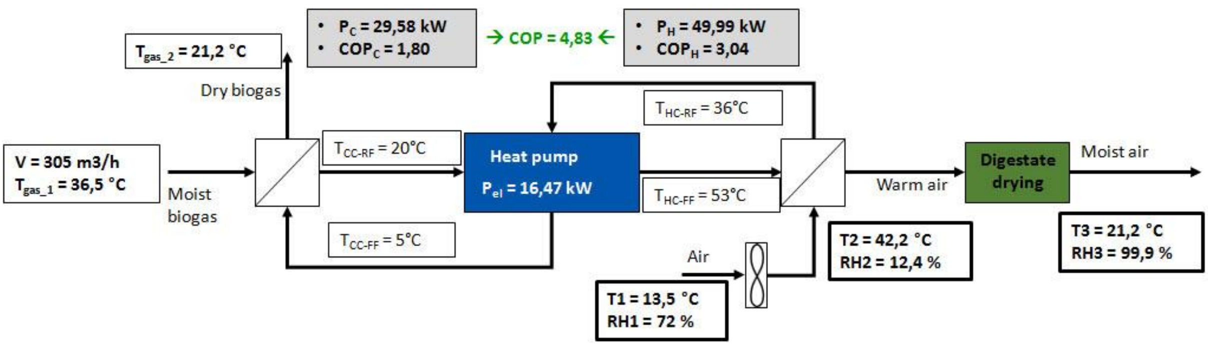



***Figure 3: Schematic depiction of pilot plant with measured values for the individual material flows. HC = heating cycle, CC = cooling circuit, RF = return flow, FF = forward flow, RH = relative humidity, T = temperature, V = volume flow, P = performance, C = cooling, H = heating,***
***COP = coefficient of performance***

It could be demonstrated with the aid of this system how a heat pump can be used in biogas and biorefinery applications for energy-saving coupling of cooling and heating processes with a favourable COP. There are future plans to study the coupling of other processes at Pirmasens-Winzeln Energy Park.

**Conclusions Draw from the Overall Project**

Furthermore, simulations and demonstrations (on a laboratory and pilot scale) have demonstrated the possibility of considerable potential energy savings through the integration of heat pumps. Case studies, particularly those undertaken by UGent in Flanders, did not always show the same energy savings. The main reason for this discrepancy is seen in the high operating temperatures (180 to >220 °C) of some of the drying processes investigated, which are beyond the reach of currently available heat pumps.

The current mode of heat recovery by means of heat exchangers between exhaust air from the dryer and the supply of fresh air requires a high temperature lift in the case of open dryers. This leads to a low COP, which in some cases is lower than the current price ratio between electricity and gas. The gas price in particular fell dramatically in the course of the project, meaning that the use of electrically driven heat pumps is hard to justify.

Thermally driven heat pumps with minimal current consumption were considered as a possible way of countering this problem. Appropriately adapted heat transformers (type II absorption heat pumps) are rarely available on the market. And the available temperature levels are also too low for such heat pumps.

Another type of thermally operated heat pump investigated was the (classical) compressor heat pump driven directly by an internal combustion engine or a gas turbine. Although this technology still has only a modest market presence, it certainly led to the most promising results.

In Flanders heat pumps are in intense competition with combined heat and power generation, which is heavily subsidised in that region by CHP certificates. Also with regard to investment, CHP often comes out on the winning side.

Since the dryers investigated in the case studies were not closed systems, it was not possible to demonstrate all the advantages of the integration of heat pumps. As a result, none of the applications examined has been implemented industrially in the short term. However, the results of the project were regarded by the participating users as very useful in view of the expected energy turnaround with higher taxation of carbon dioxide and strongly fluctuating electricity prices. Moreover, closed drying units are being considered in connection with future investment decisions.

**Presentation of the Project Results to an International Audience**

The 4th International Symposium on Waste Heat Valorization in Industrial Processes held in the Belgian city of Kortrijk on 23 and 24 May, 2016, provided an opportunity to publicise the activities of

PFI. In connection with the CORNET Project HP4Drying, interest was focused on the applications of heat pumps in drying processes. Dr. Michael Müller, Project Manager of the Biotechnology and Microbiology Department, presented a paper on the digestate management system at PFI's Energy Park (click here for a pdf download). Over 90 attendees from science and industry participated in the symposium, including energy consultants, system providers, as well as representatives of universities and manufacturing industry.

The energy-saving possibilities presented attracted avid interest and met with broad acceptance. Overall the event met with a very positive response.

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We also wish to take this opportunity to express our gratitude to companies from the biogas, brick, textile, and timber industries as well as companies from the spice and medicinal plant, laundry, heat pump, and mechanical engineering sectors for their active support of this project.

Thanks are also due to the project partners for their valuable cooperation.

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The complete final report is available in English from the participating research organisations.

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