Abstract

The electrification of final uses refers to the process of substituting fossil-based technologies with electricity-driven ones to exploit the renewable energy source (RES) production to decrease the CO_2 and pollutant emissions. Is a complete switch to electricity the right solution? What are the real benefits of this solution today? And what will they be in a future dominated by renewable energy sources? The first major synergy between the electricity and heat sectors is found in district heating systems. Simulations of different solutions for lowering the temperature in heat grids have been carried out to show that the interaction with heat pumps does not always seem to improve these two indices. In fact, the developed simulation, decreasing temperature (towards 60°C) in already built networks seems to have the potential to reduce energy losses and consumption while maintaining the indoor temperature in an acceptable range. Indeed, if the building is well insulated and/or new construction, 60 °C can be even too much. For this reason, the booster heat pump can play a major role in keeping the temperature level of the network ring lower (towards 45-50°C) and boost up the temperature just where it is needed. From the simulated cases, this can be an effective solution, but it presents a drawback. In fact, the solution with HP presents higher primary energy consumption (about 30%) and higher carbon dioxide emissions (in a range of 140 to 227 tCO_2 more) with respect to the 60°C cases. But this outcome may be related to the usage of average coefficients (primary energy factor and CO_2-factor) which can be no longer valid in a time of strong energy transition. The actual consumption data of different real heat pump installations were matched with hourly energy production data for 10 different European countries. The actual HP consumption mix is compared with the annual generation mix of each country to assess the extent to which an hourly analysis differs from an annual average and whether the additional data requirements are justified by the more accurate results that can be obtained. The results do not provide any particular differences from the averages under the working hypothesis (about 5-6% difference),

although some peaks do ring alarm bells for the near future: likely, the average values will no longer be representative of reality in a short time, as the share of renewable energies increases rapidly. Then, according to IEA estimates, cooling will be the most energy-intensive sector by 2050. Countries with hot, humid, and summery climates all year round are equipping themselves with air conditioning and cooling systems at an exponential rate. This leads to high loads on the electricity grid and higher emissions of refrigerant gases, which affect the greenhouse effect and are generally harmful to the environment. Adsorption refrigeration systems can offer some advantages to limiting energy consumption and improving the management of high humidity in summer in equatorial climates. The ReCognition project (H2020-LC -SC3-2018) has developed and integrated renewable technologies to improve the energy efficiency of buildings and local energy consumption. In this dissertation, the development of a prototype for cooling (HySun) based on adsorption is reported. The main objective of HySun is to improve efficiency compared to traditional compression cycles and to work with multiple sources and multiple energy vectors to generate cooling power and drive the regeneration cycle. This system has been designed and implemented. First, a coating technique has been implemented and tested to verify the performance of coating which has been found to be lower than the pure material, but still with a large possibility to improve. Moreover, a simulation code was developed to understand HySun behaviour and the dependencies of the variables. A parametric analysis and a dynamic simulation show the possibilities of the system as well as some disadvantages that must be considered in the real operation of the prototype. Temperature levels, such as the one used in the developed simulation, allow the integration of several renewable energy technologies for the adsorption and regeneration phases, which is important from the point of view of increasing renewable penetration. The developed simulations present important results as the HySun prototype seems to outperform the market compression cycle. In fact, the estimate COP varies between 2.85 and 5.2, which are peak values for commercial units. One of the major drawbacks of this type of system is that, given the non-linear behaviour of the adsorbent material, precise and targeted control must be envisaged to ensure a constant and stable cooled airflow. In summary, this dissertation shows that choices in heating, cooling and mobility could have a major impact on the electricity sector. Cooperation between traditional heating and electrification could provide stable and profitable results. Special attention needs to be paid to cooling, which is expected to be the ruler of electricity consumption in the near future. Adsorption systems, like HySun, can be fundamental to increase the efficiency of the whole sector.