Chapter 33
Integration of Renewable Energy in Refrigerated Warehouses

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ABSTRACT

Refrigerated warehouses are large energy consumers and account for a significant portion of the global energy demand. Nevertheless the opportunity for integration of renewable resources in the energy supply of large cold storage facilities is very often unjustifiably neglected, whereas the employment of renewable energy for many other industrial and comfort applications is actively promoted and explored. In that context, the purpose of this chapter is to bridge the existing gap by raising the public awareness of stakeholders, researchers, practicing engineers and policy makers about the availability of a number of smart engineering solutions and control strategies to exploit renewables of different nature (solar, wind, geothermal, biogas, etc.) in the food storage sector, as well as by calling the readers' attention to the specialised knowledge in the matter, which has been published so far.

INTRODUCTION

On 5 June 2014 the UN Secretary-General launched the "UN Decade of Sustainable Energy for All", urging leaders from around the world to "deliver new and expanded commitments and partnerships that will transform the global energy landscape" ("UN Secretary-General", 2014). Increasing the integration of renewable energy sources (RES) in the global energy supply chain is one of the key aspects of sustainable development. Hence, one of the goals of the Sustainable Energy for All (SE4ALL) initiative is doubling the share of renewable energy in the global energy mix by 2030. As the International Energy Agency (2007) states, renewable sources are "essential contributors to the energy supply portfolio as they contribute to world energy supply security, reducing dependency on fossil fuel resources, and provide opportunities for mitigating greenhouse gases".

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According to Coulomb (2006) and the International Institute of Refrigeration (2007, 2015), refrigeration (including air-conditioning) currently accounts for about 17% of worldwide electricity use, while over 80% of the global warming impact of refrigeration systems is due to this electricity use. Industrial refrigeration, comprising over 550 million m^3 of cold storage space worldwide (International Institute of Refrigeration, 2015), is a major consumer of about 8% of the electrical power on a global scale (consistent with the circumstance that approximately 40% of the global food output require refrigeration). In the context of sustainable development, designing or retrofitting of a cold store refrigeration plant should consider the possibility of using RES to provide at least a portion of the required energy input.

Although there are a number of RES-assisted technologies for different refrigeration applications, many of these tools are still at rudimentary stages of development, either not commercially viable or only applicable for relatively small-scale systems. However, integration of RES in refrigerated food storage facilities might provide a cost-efficient way of: (i) reducing electricity consumption from the grid, and/or (ii) shifting refrigeration loads from peak to low consumption periods, thereby contributing to the overall balance of the power supply system and minimizing the environmental footprint of the cold store. While many of the today's engineering solutions are not yet cost efficient by themselves, various governmental policies in support of renewable energy developments and integration are carried out around the world, which can substantially enhance the economic feasibility of RES-powered installations.

The objective of this chapter is to familiarise the readers with: (i) state-of-the-art RES-based technologies applicable to refrigeration systems, including their technical and economic performance, (ii) different strategies to integrate these technologies in the energy supply of refrigerated warehouses in an efficient way, (iii) practical examples, pilot projects and on-going research involving RES utilization for cold storage facilities, and (iv) government incentives which can facilitate investment in RES projects. The material is primarily intended to serve as guidance for cold store operators and refrigeration stakeholders, who are still unaware of the latest RES technologies and the opportunities to employ them in the food refrigeration industry. As the chapter has no ambition to analyse in-depth any of the concerned technologies, the readers are advised to examine additional literature in order to gain more comprehensive knowledge on the particular topics of interest (e.g., see the list of references as a starting point).

BACKGROUND

Integration of renewables in the energy supply of cold storage facilities can be accomplished in a variety of ways, as illustrated in Figure 1. Solar photovoltaic cells and wind turbines can be used for on-site power generation, while solar thermal collectors, geothermal sources and biogas combustion can serve as a heat source for thermally driven refrigeration systems. In addition, thermal sources can be used to drive cogeneration or trigeneration systems, thereby simultaneously producing electricity, heating and refrigerating output. Thermal energy storage for heat and cold accumulation can be integrated in the system to shift energy supply and/or demand as to permit better overall utilization of renewable energy. Provided that proper interaction is established between the cold store operator and the electric utility, on-site RES-generated power can be fed to the utility grid, which permits to sell excessive energy at attractive prices (especially in the presence of convenient government policies). The latter and the inclusion of thermal energy storage can overcome a major inconvenience of many RES technologies, i.e. the intermittent energy supply due to the fluctuating availability of the energy resource.