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Life Cycle Assessment Applied to Supermarket Refrigeration System: Effects of Location and Choice of Architecture

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Abstract : Taking into consideration all the life cycle of a product is now an important step in the eco-design of a product or a technology. Life cycle assessment (LCA) is a standard tool to evaluate the environmental impacts of a system or a process. Despite the improvement in refrigerant regulation through protocols, the environmental damage of refrigeration systems remains important and needs to be improved. In this paper, the environmental impacts of refrigeration systems in a typical supermarket are compared using the LCA methodology under different conditions. The system is used to provide cold at two levels of temperature: medium and low temperature during a life period of 15 years. The most commonly used architectures of supermarket cold production systems are investigated: centralized direct expansion systems and indirect systems using a secondary loop to transport the cold. The variation of power needed during seasonal changes and during the daily opening/closure periods of the supermarket are considered. R134a as the primary refrigerant fluid and two types of secondary fluids are considered. The composition of each system and the leakage rate of the refrigerant through its life cycle are taken from the literature and industrial data. Twelve scenarios are examined. They are based on the variation of three parameters, 1. location: France (Paris), Spain (Toledo) and Sweden (Stockholm), 2. different sources of electric consumption: photovoltaic panels and low voltage electric network and 3. architecture: direct and indirect refrigeration systems. OpenLCA, SimaPro softwares, and different impact assessment methods were compared; CML method is used to evaluate the midpoint environmental indicators. This study highlights the significant contribution of electric consumption in environmental damages compared to the impacts of refrigerant leakage. The secondary loop allows lowering the refrigerant amount in the primary loop which results in a decrease in the climate change indicators compared to the centralized direct systems. However, an exhaustive cost evaluation (CAPEX and OPEX) of both systems shows more important costs related to the indirect systems. A significant difference between the countries has been noticed, mostly due to the difference in electric production. In Spain, using photovoltaic panels helps to reduce efficiently the environmental impacts and the related costs. This scenario is the best alternative compared to the other scenarios. Sweden is a country with less environmental impacts. For both France and Sweden, the use of photovoltaic panels does not bring a significant difference, due to a less sunlight exposition than in Spain. Alternative solutions exist to reduce the impact of refrigerating systems, and a brief introduction is presented.

Keywords : eco-design, industrial engineering, LCA, refrigeration system
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