Energy use and indoor environment in new and existing dwellings in Arctic climates - DTU Orbit (22/08/2019)

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Buildings in Arctic climates require large amounts of heat to provide their occupants with a comfortable indoor environment. In recent years the intention to conserve energy has caused buildings in the Arctic (and worldwide) to become more insulated and airtight. The natural infiltration of buildings is being reduced to avoid heat loss and unpleasant air drafts, often without proper compensation. Many studies have shown that living in insufficiently ventilated spaces increases the risk for asthma and allergy symptoms. However, the indoor environment in Arctic dwellings has seldom been investigated. For energy and indoor environmental reasons it is advisable that new airtight buildings be equipped with mechanical ventilation systems with heat recovery. Nevertheless, these systems when exposed to the Arctic winter climate face the risk of frost formation, which may put the ventilation system out of order for long periods or potentially damage it. The main objectives of the work described in this thesis have been: A) to provide new knowledge about optimal operation and performance of low energy technologies in the Arctic and B) to map the indoor environmental quality in dwellings in the Arctic. The first part of this thesis provides an overview of three case studies undertaken in newly built residential buildings in Greenland and Alaska. It was found that ventilation systems in these buildings are either under or oversized which has a significant negative effect on their indoor air quality or energy use respectively. One of the evaluated buildings in Greenland had ventilation units that were not equipped with the frost protection and as a result, serious ice buildups appeared inside the heat exchangers. The prototype heat exchanger developed at the Technical University of Denmark and installed in the Low Energy House in Sisimiut had experienced an unnoticed malfunction for the first 3 years of operation. However, after repairing the heat exchanger it was capable of continuous operation without freezing and reached an average thermal effectiveness of 69 %. In Alaska, three out of four ventilation systems studied in new homes used recirculation as a method of frost protection. This strategy allowed a continuous operation of the ventilation system; however, the fresh air supply was reduced significantly during winter months. The second part of the thesis presents a cross sectional study on indoor air quality performed in Sisimiut, Greenland. A questionnaire as part of the study found that over 30 % of respondents experience cold discomfort during winter months (i.e. cold floors, cold draft or too low indoor temperature), 35 % of the respondents reported frequent condensation on windows. Despite the cool summers 40 % of the respondents complained about summer overheating. It was also found that 34 % of the respondents smoke inside their homes. Additionally it was revealed that ventilation equipment is typically limited to fresh air openings on walls, mechanical exhausts from bathrooms (present in 63 % of the dwellings) and kitchen range hoods (installed in 82 % of the dwellings). Presence of balanced mechanical ventilation was not reported by any of the respondents. The questionnaire study was followed by summer and winter measurements in bedrooms of 79 dwellings selected among dwellings inhabited by the questionnaire respondents. The winter measurements indicate that 73 % of the monitored bedrooms experienced average additional moisture higher than 2.5 g/kg or average night CO2 concentration above 1000 ppm and 59 % of bedrooms had experienced both. This indicates that the majority of the monitored bedrooms were insufficiently ventilated. The problems with poor ventilation were more severe in newer buildings (build after 1990) due to tighter envelopes and unchanged ventilation strategies. In conclusion, it is possible to provide dwellings in the Arctic with good indoor environment. However, this is largely dependent on the design of buildings and their ventilation systems. The ventilation should not rely on simple wall openings as they prove to be inefficient in providing continuous air change at a sufficient rate without creating thermal discomfort.

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