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Perceived indoor environment in social housing with different ventilation principles

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ABSTRACT

The need for renovation and energy retrofitting of Danish social housing from the 1960s and 1970s is substantial. Such energy retrofits often include the installation of mechanical ventilation systems with heat recovery to fulfil the current standards for energy efficiency. These systems typically ensure a more constant and higher ventilation rate than previous systems. Therefore, there is potential for residents to perceive a higher air quality and a reduction in problems due to condensation on cold surfaces and mould growth after retrofits. The purpose of the present study was to evaluate if this potential is realised for residents in social housing complexes. A questionnaire survey was performed among residents in dwellings with ventilation categorised within one of the five ventilation principles: natural ventilation, bathroom fan, exhaust fans in the kitchen and bath, decentralized balanced mechanical ventilation and centralized balanced mechanical ventilation. Compared with residents without balanced mechanical ventilation, residents having such systems perceived less often problems with unpleasant odour from their own apartment and less visible mould, but more often perceived the air as dry. Residents with decentralized mechanical ventilation tended to experience more often problems with noise from their ventilation system. However, results show that nuisance are avoidable with correctly designed decentralized ventilation.

INTRODUCTION

There is an urgent need for renovation and energy retrofitting of existing buildings in Europe. Reducing the energy consumption is necessary for reaching the ambitious targets of an increased coverage by renewable energy in our energy supply system (European Commission 2016; Danish Government 2014). In Denmark, this challenge has initiated a long line of building projects, with the common aim to increase renovation rates and improve renovation strategies. One of these projects was REBUS (Renovating Buildings Sustainably, 2021). The REBUS project sought to advance comprehensive renovation of the social housing sector. Approximately 60% of the 600,000 Danish homes in social housing were built before 1979 and thus before the requirements for the energy requirements of buildings were seriously tightened in the Danish Building Regulations (Danish Government 2014). Behind the project is a dedicated partnership representing all parts of the value chain ranging from end users (residents and social housing associations) through project developers and manufacturers to knowledge institutions. The REBUS project has an overall target for renovation works to reach a minimum of 50% energy savings, 30% reduction of resources and 20% increment in productivity.

Energy retrofits of Danish social housing built in the 1960s and 1970s often include installation of a balanced mechanical ventilation system with heat recovery in order to fulfil the present energy requirements of the Building Regulations.

Ventilation in existing and not recently retrofitted Danish dwellings, are based on natural ventilation often combined with a simple exhaust fan, and do not live up to requirements defined in the present Building Regulations. In one study, 57% of the 500 measured dwellings had a lower ventilation rate than the minimum required ventilation rate of 0.5 h^{-1} (Bekö et al., 2010). Adding mechanical ventilation that fulfils the ventilation requirements of the Building Regulations will likely lead to a more constant and higher ventilation rate. There is therefore a potential for the residents to experience an improved perceived air quality and fewer problems related to water condensation on cold surfaces and mould growth. In addition, extensive retrofitting typically also includes a number of other building improvements, e.g. insulation of walls and roof, and replacement of old windows with new low energy windows, leading to better perceived thermal and acoustic conditions (Almeida, M. et al., 2017). There are indications suggesting that if done correctly, there is a potential for a win-win situation, where energy is saved, while an improved perceived air quality, thermal comfort and acoustic comfort is achieved (Knudsen, 2017; Knudsen and Jensen, 2015; Thomsen et al., 2016).

The purpose of the present study was to evaluate how residents in social housing complexes with different ventilation principles including retrofitted centralised or decentralised balanced mechanical ventilation and more traditional solutions, like natural ventilation or simple exhaust fans, perceive the indoor environment.

METHODS

A questionnaire survey was conducted among the residents of 40 Danish social housing departments from the two housing associations Himmerland Building Association and Frederikshavn Building Association during December 2019 and January 2020. Some of the housing departments (48% of the participating residents' apartments) had undergone renovation and energy retrofits within the last few years, which included the installation of balanced mechanical ventilation systems with heat recovery or simpler solutions with exhaust fans in kitchen and bath. Besides the retrofits of the ventilation systems, the different housing departments had undergone various further renovation measures that may have an impact on the indoor environment. These included for example additional insulation of the facades, roof and floors, as well as replacement of windows with low-energy windows.

The design of the ventilation solutions varied between the different housing departments and dwellings. For the analysis, it was therefore decided to categorise the different systems within one of five ventilation principles (percentage distribution in parentheses):

- Centralized balanced mechanical ventilation (12%), i.e. one air handling unit (AHU) provides ventilation of several apartments via a network of ducts
- Decentralized balanced mechanical ventilation (13 %), i.e. one AHU provides ventilation of one apartment
- Exhaust fans in the kitchen and bath (48%)
- Bathroom fan (11%), i.e. one exhaust fan in the bathroom
- Natural ventilation (16%), i.e. no mechanical ventilation

Within the REBUS project, a questionnaire for evaluating the perceived indoor environment was developed (Knudsen et al., 2019). The intention with the questionnaire was to reveal how satisfied the residents were with the indoor environment in general and identify which indoor environmental problems they experienced within the four main categories: acoustic, atmospheric, thermal and visual indoor environment. It was aimed at making the questionnaire easy to understand and possible to complete in a maximum of 10 minutes. Therefore, technical terms such as "room acoustics" and "reverberation time" were avoided and easy-to-understand terms, such as "temperature conditions in your home", "the air in your home", "noise conditions in your home" and "lighting conditions in your home" were used. Each of these main categories were divided into more detailed questions about indoor environmental conditions, which are known to pose problems in dwellings. The questionnaire also contained a number of open questions allowing the residents to describe in their own words the indoor environmental problems they face.

The questionnaire was distributed in various ways (flyers, e-mails and posters) to 4707 homes, from which 573 (271 from Himmerland Building Association and 302 from Frederikshavn Building Association) responded, corresponding to a response rate of 12%.

RESULTS AND DISCUSSION

There was a tendency for residents in dwellings with centralised or decentralised balanced mechanical ventilation to less often experience problems with unpleasant odours from their own dwellings than residents with other ventilation principles, especially among residents in Frederikshavn Building Association (Figure 1).

On the other hand, some residents with balanced mechanical ventilation in Himmerland Building Association experienced problems with unpleasant odours (related to tobacco smoke and cooking) from neighbouring dwellings (Figure 2). This may be related to differences in air pressure between adjacent dwellings, which can cause air to be transferred between dwellings through leaks. If no attempt is made to seal each dwelling, extensive renovations with balanced mechanical ventilation pose demand on the correct balancing of ventilation systems in different dwellings, in order to prevent that difference in pressure cause transfer of air between dwellings.

Residents with balanced mechanical ventilation experienced more often problems with the perception of dry air (Figure 3). This tendency has also been observed in new dwellings with mechanical ventilation, which meet the requirements for ventilation as specified in building regulations (Jensen et. Al., 2018). The reason for this observation, especially pronounced during winter months, should be further investigated.

Fewer residents with balanced mechanical ventilation experienced visible mould or mildew in their dwellings (Figure 4). Increased ventilation rate likely contributed to the dwellings being less damp. Indeed, the residents in dwellings with balanced mechanical ventilation experienced condensation on the inside of the window panes less often compared with residents with other ventilation principles (Figure 5).

There was a tendency towards more frequent problems with noise from technical installations among residents in dwellings with decentralized balanced mechanical ventilation, especially in Himmerland Building Association (Figure 6). The results indicate that the level of noise nuisance may depend on the ventilation principle for mechanical ventilation. However, results also indicate, as 69% of the residents in Frederikshavn Building Association experience problems with noise less often that once a month, that with the right design, it is possible to

establish decentralized ventilation that does not annoy residents. Further investigations are recommended to determine the causes of elevated noise levels with decentralised mechanical ventilation e.g. lack of silencers, ducts diameters, mounting. There is a need for continued focus on the commissioning of new balanced mechanical ventilation systems to make sure that they are designed, installed and operated correctly, in order to achieve both the intended low energy consumption and an acceptable indoor environment.

CONCLUSIONS

Compared to residents with other ventilation solutions, residents in dwellings with balanced mechanical ventilation system, centralised or decentralised, experienced:

- less often problems with unpleasant odour from their own dwelling
- less often the presence of visible mould
- more often problems with the perception of dry air

Compared to residents with centralised balanced ventilation solutions, residents with decentralized balanced mechanical ventilation experienced more often problems with noise from their ventilation system.

The study shows that there is a need to clarify:

- the specific reasons for noise nuisance in some dwellings with balanced mechanical ventilation systems
- the potential transfer of air between dwellings and its prevention
- the importance of commissioning/checking the design, installation and operation of ventilation systems in retrofitted social housing
- the reasons for the perception of dry air

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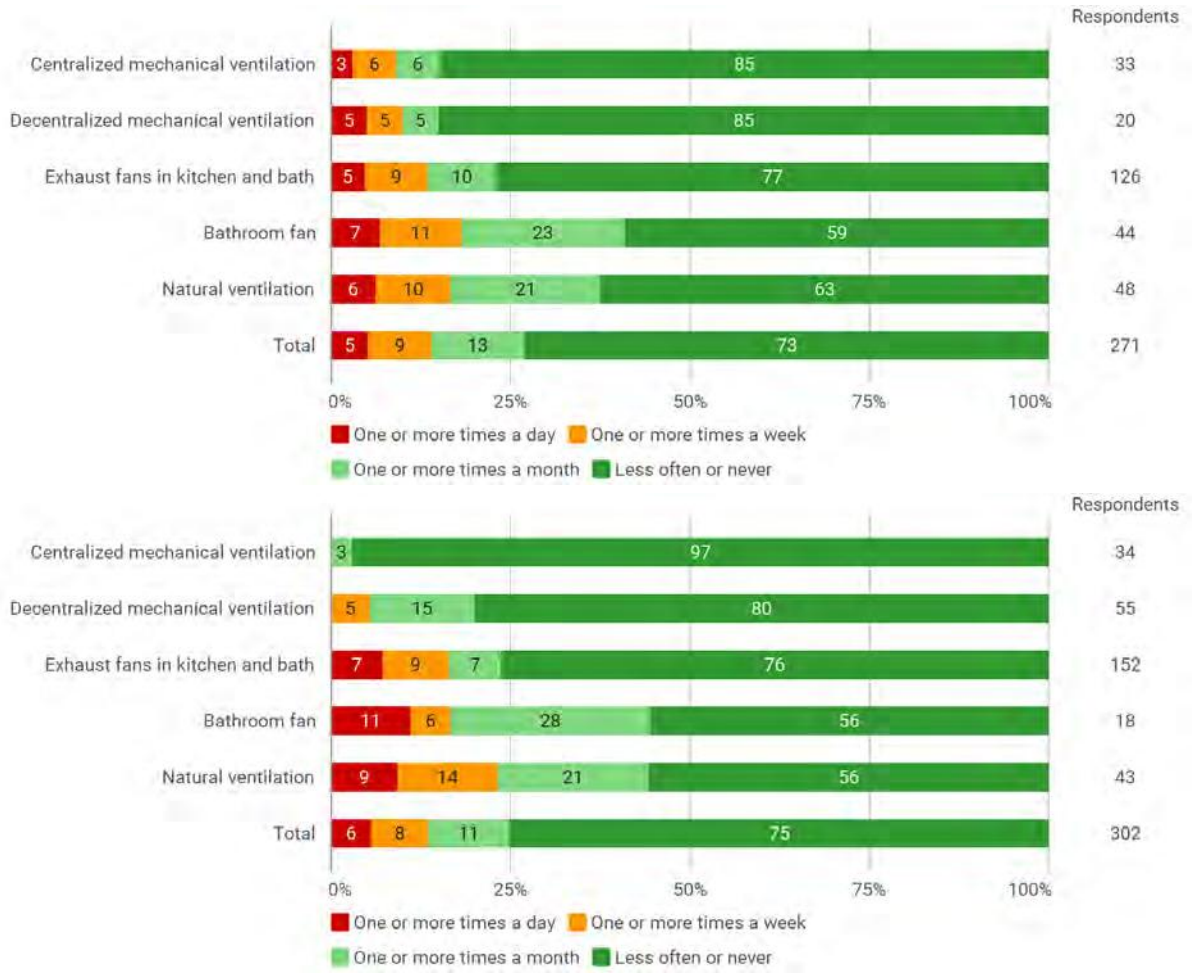

Figure 1. The answers to the question "How often do you perceive problems with unpleasant smell from your own apartment?" for residents with different ventilation solutions in Himmerland Building Association (top) and Frederikshavn Building Association (bottom).

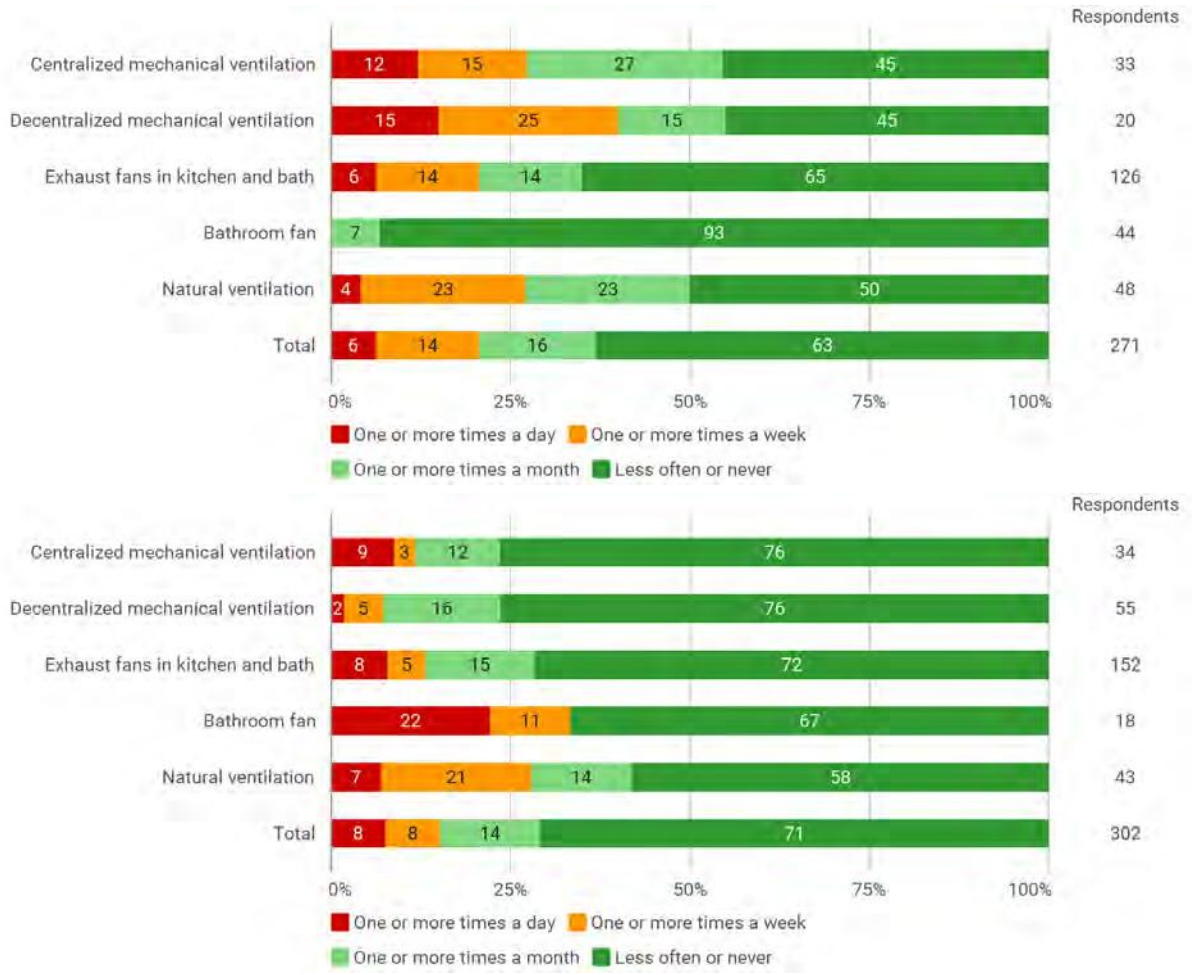

Figure 2. The answers to the question "How often do you perceive problems with unpleasant smell from other apartment?" for residents with different ventilation solutions in Himmerland Building Association (top) and Frederikshavn Building Association (bottom) .

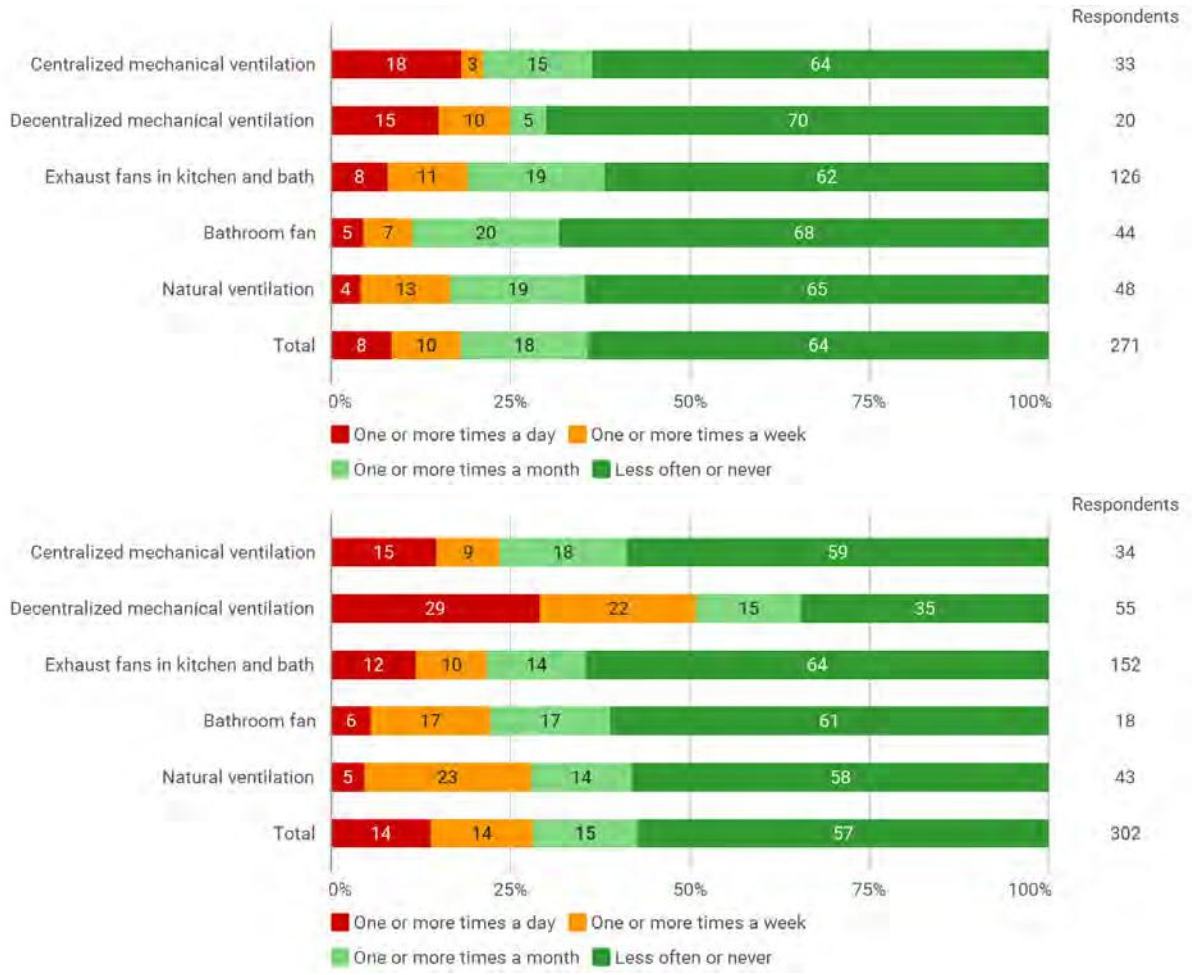

Figure 3. The answers to the question "How often do you perceive problems with dry air?" for residents with different ventilation solutions in Himmerland Building Association (top) and Frederikshavn Building Association (bottom).

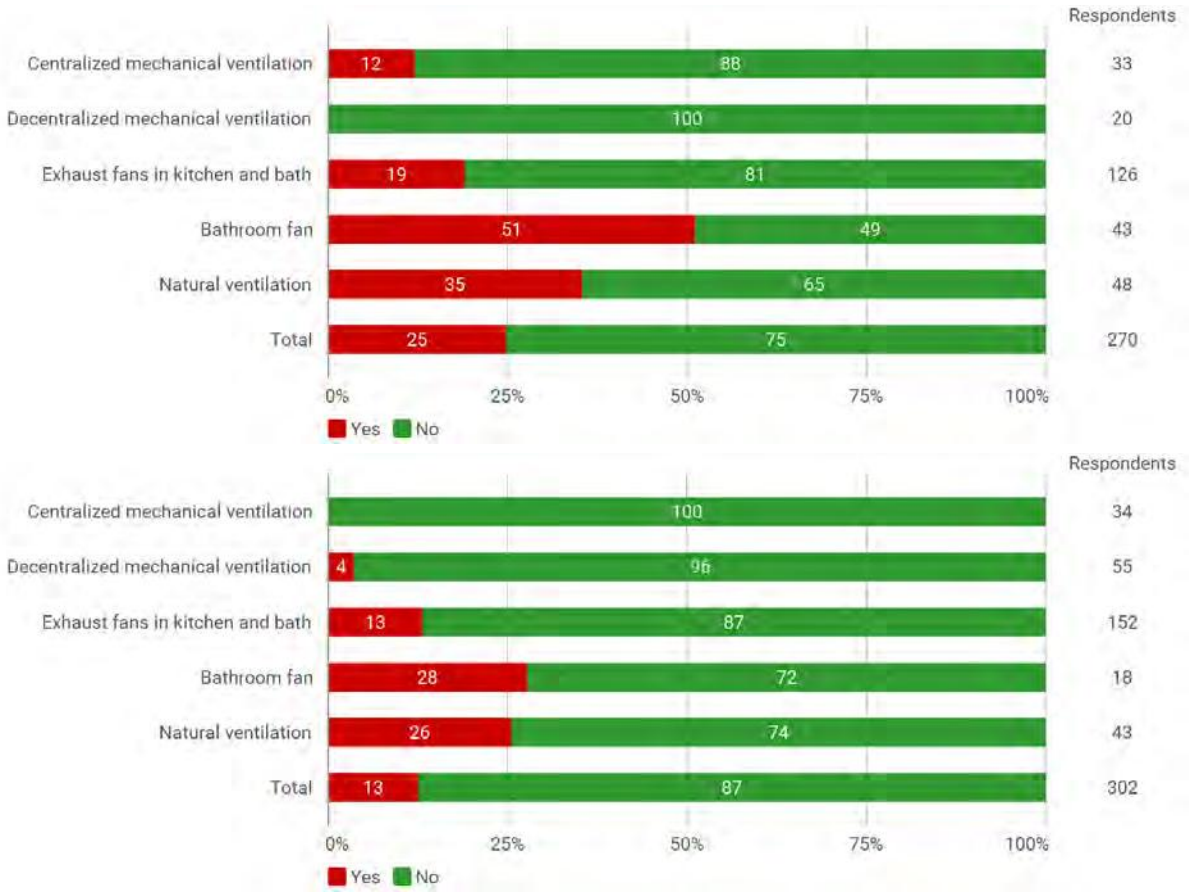

Figure 4. The answers to the question " Is there visible mould or mildew in your home?" for residents with different ventilation solutions in Himmerland Building Association (top) and Frederikshavn Building Association (bottom).

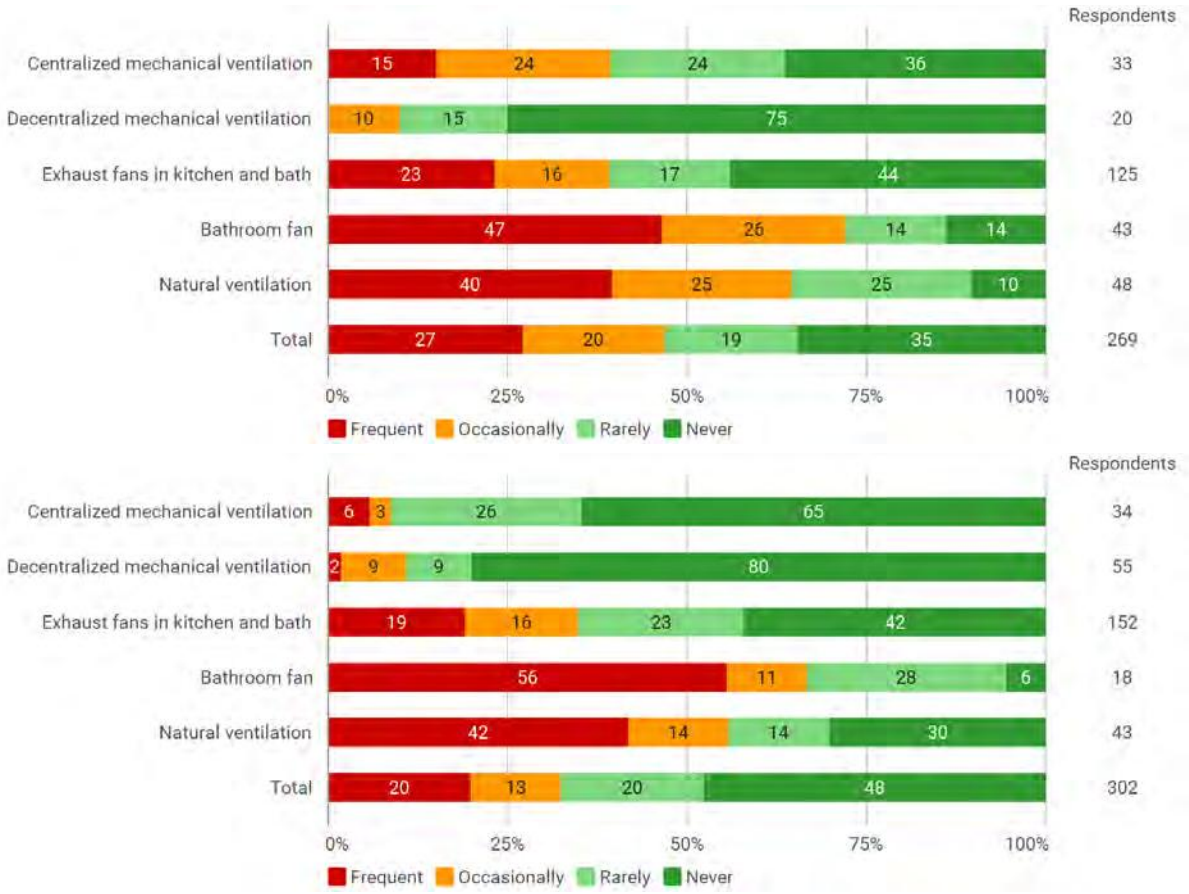

Figure 5. The answers to the question "How often do you perceive condensation on the INSIDE of the windows?" for residents with different ventilation solutions in Himmerland Building Association (top) and Frederikshavn Building Association (bottom).

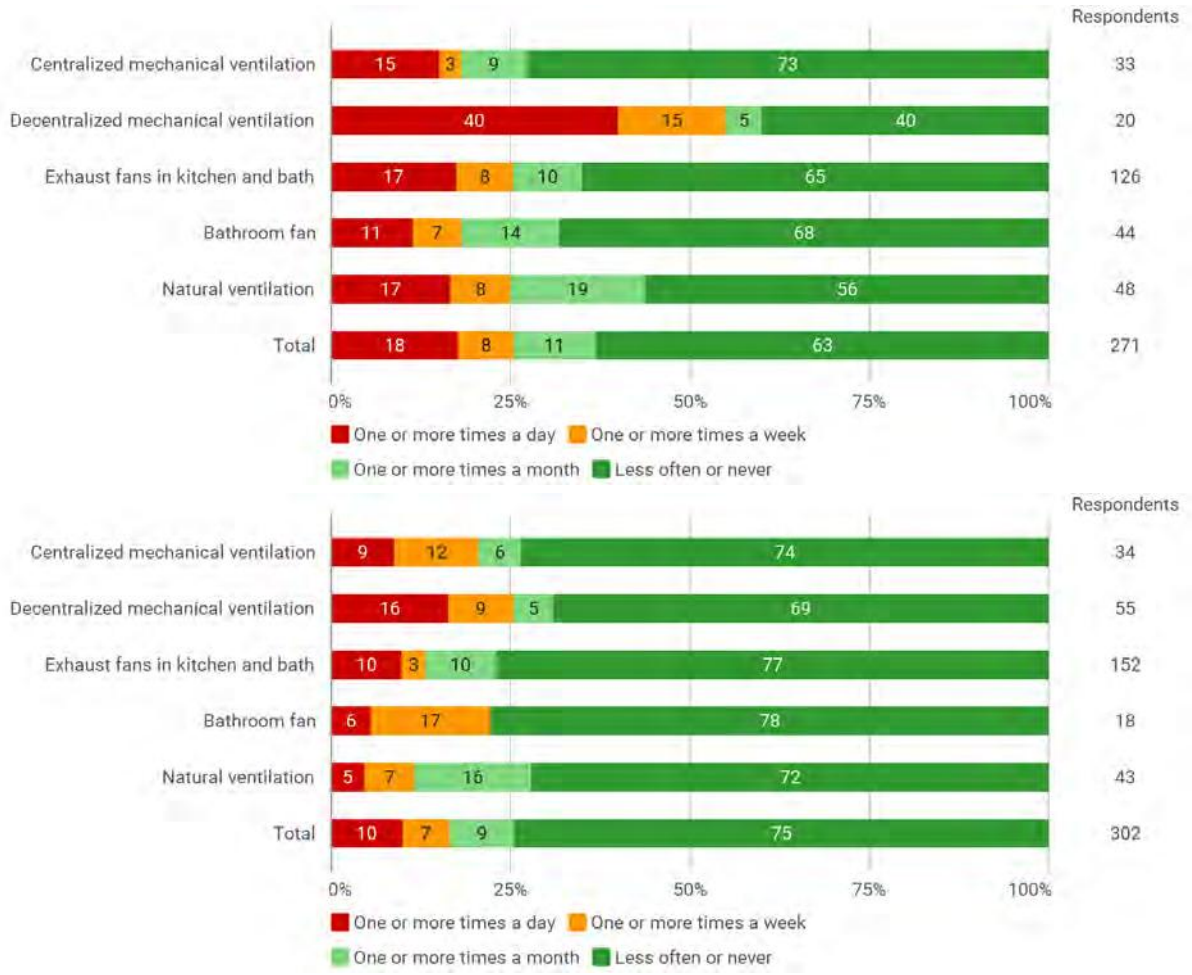

Figure 6. The answers to the question "How often do you perceive problems with noise from technical installations?" for residents with different ventilation solutions in Himmerland Building Association (top) and Frederikshavn Building Association (bottom).