Cool Down Güssing: Sustainable Cooling Concepts for Existing Buildings using the Example of the Municipality of Güssing

Robert Pratter, Christian Doczekal, Ernst Reiterer

(DI Robert Pratter, 4ward Energy Research GmbH, 8020 Graz, Reininghausstraße 13A, robert.pratter@4wardenergy.at)
(DI(FH) DI Christian Doczecal, Güssing Energy Technologies GmbH, 7540 Güssing, Wiener Straße 49, c.doczekal@get.ac.at)
(Ing. DI (FH), Ernst Reiterer, Reiterer & Scherling GmbH, 8230 Hartberg, Ressavarstraße 64, ernst.reiterer@reiterer-scherling.at)

1 ABSTRACT

Within the Cool-down Güssing project, measures for sustainable cooling of existing buildings were investigated. While in new buildings the heat input can be reduced by intelligent construction and passive cooling measures can be integrated relatively easily by installing surface cooling system (e.g. concrete core activation), the situation in existing buildings is much more difficult. Nevertheless, with suitable measures, sustainable cooling, or at least a significant reduction of the residual cooling demand, can be achieved. It has been shown that there is no universal solution for all different types of existing buildings. For example, different measures are suitable for large production halls of companies compared to private households. Therefore, the buildings were divided into several categories, like private households, companies and public buildings.

Different types of night ventilation have shown good potential for public building and companies to reduce room temperatures by at least a few degrees. This can be done either by means of decentralized ventilation units or automatic window openers, or by intelligent control of existing infrastructure such as fire ventilation systems which is especially suitable for production halls. Especially for public buildings, financing is often a major challenge, so that suitable financing models must be found. In addition, the heat input should be reduced as far as possible. This can be achieved by external shading and by reducing internal loads. Proper user behavior should also not be underestimated. The remaining electricity demand should be covered as far as possible with electricity from renewable generation. If the installation of an own photovoltaic system (PV) is not possible, energy communities offer the possibility to purchase local renewable electricity at favorable conditions.

Keywords: public buildings, companies, private households, existing buildings, sustainable cooling

2 INTRODUCTION

In Austria, as well as in many other countries, there has been a massive increase of hot days. The number of days above 30 °C has doubled to tripled in recent decades.[GeoSphere Austria, 2022] What used to be a record a few years ago has become average now. In connection with the rising temperatures, the energy demand for cooling has also increased steadily in the recent years. This is problematic, as the operation of conventional cooling devices is very energy-intensive and can thus contribute to a further advance of the climate change. Moreover, due to (currently) high electricity prices, the operation of such cooling systems can cause significant costs. While in new buildings the heat input can be reduced by intelligent construction and passive cooling measures, which can be integrated relatively easily by installing surface cooling system (e.g. concrete core activation), the situation in existing buildings is much more difficult. Surface cooling respectively surface heating systems can only be retrofitted at great constructional and financial expense as part of a comprehensive renovation. To enable climate-friendly cooling in these buildings, therefore, not only new technologies are needed, but also new and, above all, holistic approaches that combine different measures and evaluate their suitability for the use in existing buildings.

Therefore, the Cool-down Güssing project[1] investigates different measures based on nine pilot buildings. The pilot buildings are composed of companies, private households and public buildings in order to take into account a broad cross-section of different requirements and initial situations. The cooling should be carried out as sustainable as possible. In the first step, this means reducing the required cooling energy as much as possible. Various measures to reduce the heat input (insulation, sun protection films, installation of external shading elements, construction of canopies, etc.) were investigated and their suitability for the use in existing buildings was evaluated. Furthermore, the potential for intelligent (night) ventilation was investigated, that the cooler air during the night hours can be used to lower the temperature in the interior spaces. Only if the

[1] https://smartcities.at/projects/cool-down-guessing/

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use of passive cooling technologies is not (economically) possible or the required cooling capacity cannot be achieved with them, the use of active cooling technologies was examined. If this was the case, the energy demand should at least be supplied with renewable electricity. Especially photovoltaic systems are very well suited to supply cooling devices due to their simultaneity with the occurring cooling demand. In addition to the installation of own photovoltaic systems on the roof of the pilot buildings, renewable energy communities offer stakeholders without photovoltaic systems the opportunity to obtain renewable electricity locally at advantageous conditions in order to operate their cooling equipment. Furthermore, this offers the possibility to use additionally available photovoltaic electricity within the energy community for other purposes. These measures were combined with an extensive stakeholder involvement for demand assessment, awareness raising and training for an optimal user behavior.

The right choice of measures always depends on the individual circumstances. No company, public institution or private household is exactly the same as another. Therefore, general valid solutions are difficult. However, it could be shown that there are many similarities, especially within the respective building categories, where recommendations for measures could be derived from.

3 PUBLIC BUILDINGS

3.1 General conditions

Public buildings are often characterized by large glass surfaces, such as large window fronts or glass-covered staircases. A shading or cooling concept was usually not considered, especially in buildings constructed in the second half of the twentieth century. Although this creates a pleasantly bright indoor climate, many of these buildings are now affected by overheating in summer due to rising temperatures. An example of this is the BORG in Güssing, which is one of the pilot buildings. Already in early summer, temperatures beyond 30°C were measured in some classrooms, which have a negative impact on the students' ability to concentrate.

A second characteristic of public buildings is the difficulty to finance cooling measures. The necessary budget is usually only available to a very limited extent or, in some cases, not at all. Depending on the type of public buildings, there are different stakeholders, which often have a very limited radius of action. Significant changes to buildings often involve a high planning effort, as various committees have to be passed through. Depending on the owner of the building, the responsible parties can be found at the municipal, state or federal level. As a result, this type of building requires particularly cost-effective solutions, both in terms of investment and operation. In the rarest of cases, those responsible for the individual buildings are in a position to implement extensive cooling measures on their own. Therefore, an overriding strategy is required that promotes or finances cooling measures in schools and other public buildings. Otherwise, the implementation of an extensive cooling concept will rarely succeed.

3.2 Recommendations for public buildings

In the case of public buildings, measures to reduce solar radiation and intelligent night ventilation concepts have proved particularly suitable. Although the installation of a central cooling system would be desirable, it is usually beyond the financial scope. The operation of decentralized cooling units causes high operating costs, which in turn burden the budget. In addition, the air conditioning units used are not optimal from an ecological point of view. It is therefore advisable, if not already done, to install external shading options for the window surfaces. In most public buildings, the rooms are used during the day. So, there is nothing to be said against operating the shading manually. However, consistent and early shading is important. If rooms are used only occasionally, a time control can help to carry out the shading. Sun protection films also offer another possibility to minimize solar radiation without completely darkening the rooms. Removable solar protection films also make it possible to take them off in winter to avoid negative effects in terms of heating requirements.

With intelligent night ventilation, the cooler night temperature can be used to cool the building during the night hours, so that temperature peaks during the day can be reduced or at least postponed. Either decentralized ventilation units installed in the respective rooms or automatic window openers are suitable for this purpose.

Automatic window openers can be easily retrofitted to many windows and are cheaper to purchase than decentralized ventilation units. Windows are opened automatically in the summer months as soon as the outside air temperature drops below the temperature inside the building. Rain sensors enable the windows to be closed automatically in case of bad weather. An additional timer control also makes it possible to lock the automatic window openers for certain times to reduce the potential risk of injury from trapped fingers. This can be particularly relevant for schools or kindergartens. Basically, a distinction is made between window openers that tilt the window and those that open the window completely. The wider windows are opened, the higher the air exchange and thus the cooling effect. However, since public buildings are usually not used during the night hours, burglar protection must be taken into account in this regard. Automatic window openers are therefore particularly suitable for higher floors. Optimal are rooms that have windows on several sides or concepts that combine several rooms by means of wall openings or open doors. Another issue are animals such as birds or bats that can get into the building when the windows are open, setting off alarms. Meshes mounted in front of the windows can remedy this, but also reduce the air exchange rate.

Decentralized ventilation units are more expensive to purchase and have, albeit slightly, higher operating costs. On the other hand, the windows remain closed and all the problems associated with open windows are eliminated. In addition, they offer the advantage of providing controlled ventilation during the day, depending on the CO2 content, thus ensuring that there is no higher heat input than absolutely necessary during the ventilation process. In winter, these ventilation units can also be used to reduce heating costs through integrated heat recovery. Furthermore, it is often possible to retrofit cooling modules in case they are needed later on.

3.3 Example: BORG Güssing

This pilot building houses the BORG and the ECOLE HLW Güssing. The students and teachers suffer from far too high temperatures in the classrooms as early as May. Although the building has external blinds, they are not sufficient as a stand-alone measure to prevent overheating in summer. The classrooms on the south and east sides of the building are particularly affected. A glass roof also causes additional heating of the stairwell.

Measurements have shown that 30 degrees and more are not uncommon. It has also been shown that even during comparatively cool nights, temperatures in the classrooms cool only slightly, as can be seen in Fig 1. While outside air temperatures drop below 13 degrees during the night, indoor temperatures do not drop below 25 degrees. It was therefore decided to equip two of the particularly affected classrooms with decentralized ventilation units for night ventilation. Automatic window openers have not be an option in this case because there is a heating plant in the immediate vicinity, from which a stronger dust input must be assumed in unfavorable wind conditions.

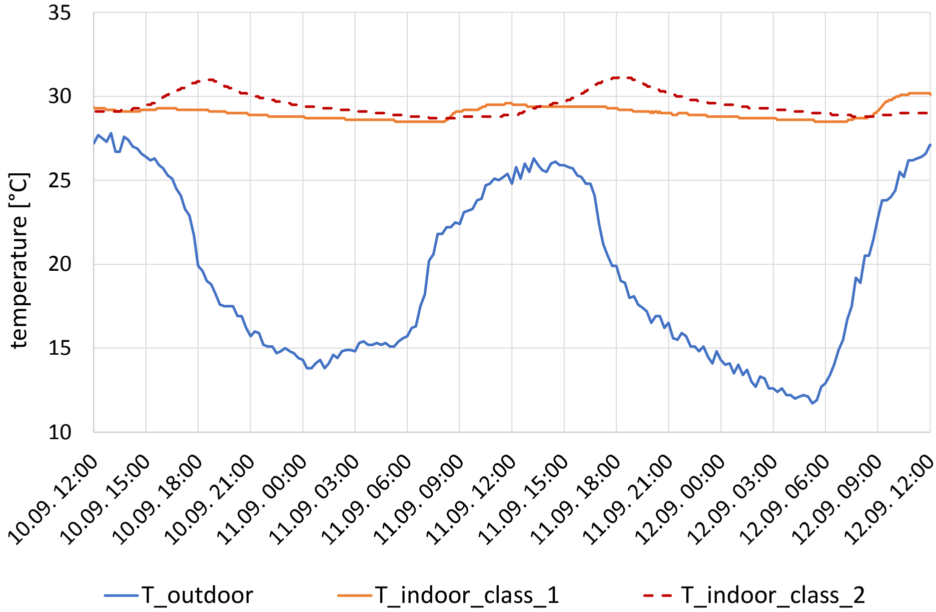

Fig. 1: Temperature profile in the school building measured in the year 2020.

The units will be installed in the summer of 2023. It is assumed that there will be a significant reduction in room temperatures during the night hours, which should result in a much more pleasant indoor climate, at least in the mornings. In addition, an outdoor class (see Fig. 2) has been installed to escape the hot classroom on particularly hot afternoons.

Fig. 2: Picture of the outdoor class of the BORG Güssing

The financing of the cooling units was achieved by sponsoring from an executing company, as this would not have been possible from the school's budget alone. Within the framework of the project, further financing models were developed (crowdfunding, leasing, events), on the basis of which schools can generate further income for cooling measures. However, the integration of a comprehensive cooling concept is only possible through the provision of financial resources and subsidies from a higher authority (in this case the Bundesimobiliengesellschaft). Such measures are urgently needed and should be rolled out nationwide, as the BORG Güssing is by no means an isolated case.

4 COMPANIES

4.1 General conditions and recommendations for companies

Companies were divided into office areas and production halls, as these are subject to very different requirements. In the case of office areas, parallels can be found with public buildings, although the financial constraints are usually less pronounced. The first step is to minimize solar heat gain. External shading options and solar protection films are suitable for this purpose. The installation of canopies can also reduce solar radiation. Optimally, these are combined with photovoltaic systems so that renewable electricity can be generated at the same time to operate cooling equipment. Cooling can also be provided by night ventilation, as described in chapter 3. In addition, roofs of commercial buildings are usually well suited for the installation of PV systems, so that, if necessary, the power supply of conventional air conditioning units can be covered with local renewable electricity.

The cooling of production halls is usually a major challenge if it has to be achieved at reasonable cost. As shown in chapter 4.2 on the example of the Guttomat company, the control of the already installed fire ventilation for night ventilation has proven to be a cost-effective measure, with which the temperatures in the halls could be significantly reduced overnight. How quickly the halls warm up again during the day depends on the structure of the building and its use, but in many cases the time of severe overheating can be postponed by at least a few hours. If possible, an earlier start to work in the summer months can also be considered to take advantage of the cool morning hours. Another option for cooling production halls is adiabatic cooling. Adiabatic cooling is based on the evaporation process. The water evaporates in the air as the air stream passes over the water. The air cools down because the thermal energy required for this is extracted from the air. The advantages lie in the relatively low energy input and low maintenance requirements. The performance depends on the outside air temperature and the humidity. Humid air is more difficult to cool than dry one. Nevertheless, the cooling capacity is significantly higher than the cooling capacity of night ventilation, especially at high outdoor air temperatures during nighttime, but adiabatic cooling also involves significantly higher investment costs.

In addition, it is advisable to take a look at the internal loads. In many cases there are devices that emit heat. Often this heat input can be reduced by suitable insulation measures or by targeted heat dissipation.

4.2 Example: Guttomat[2]

Guttomat is a production company for overhead, sectional, tilt-up and industrial doors. Overheating occurs in the summer months due to the structural conditions and large windows in the production halls as a result of direct solar radiation as well as heat input via the roof surfaces. In this case the existing fire ventilation system (smoke and heat extraction) was adopted to be used for natural ventilation. The fire ventilation system at Guttomat consists of louvre and hood ventilators. In addition to the fire ventilation function the system is designed to provide natural ventilation by utilizing the thermal load within a building as a function of pressure or temperature difference. Based on a test operation, the potential of night ventilation could be confirmed. An example of this is shown in Fig. 3.

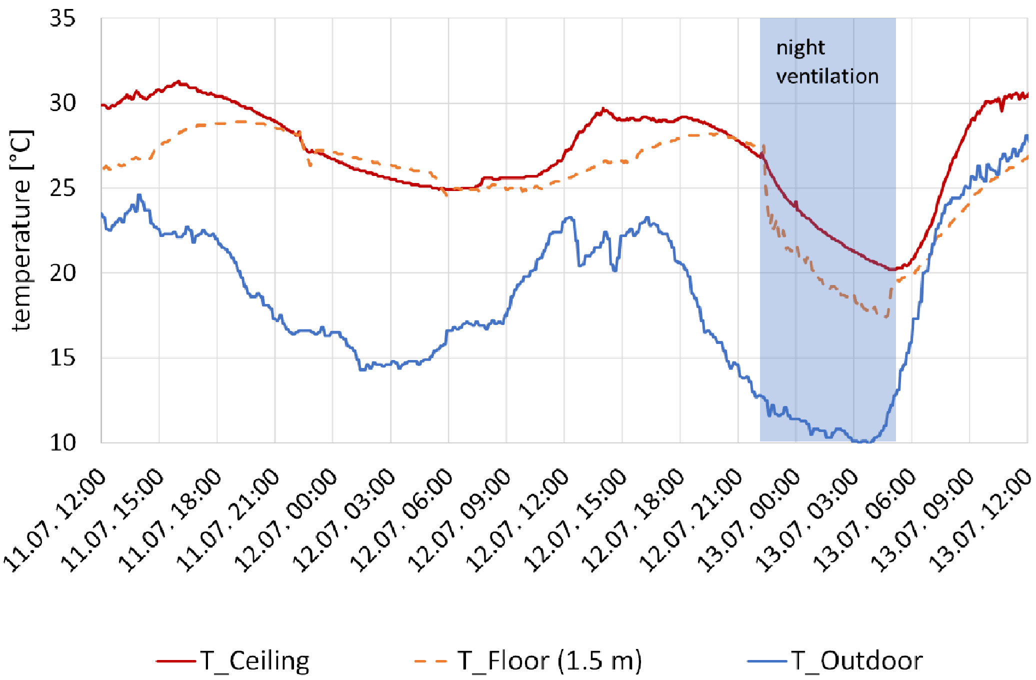

Fig. 3: Effects of the night ventilation test by using the fire ventilation system.

In this case, night ventilation was activated by means of a fire ventilation system on the 13th of July at 10 pm. It can be seen that an immediate reduction of the inside air temperature, especially the one near the floor was dedicated. The temperature drops continuously until the night ventilation was stopped at about 4 o'clock due to precipitation in order to avoid moisture ingress. Despite the early termination of the night ventilation, significantly lower temperatures could be reached in the morning hours than for example on the 12th of July where no night ventilation was carried. It has to be mentioned, that the outside air temperature on the 13th of July was lower than on the 12th of July which might have an additional beneficial effect on the indoor temperatures on the 13th of July, but nevertheless the effects of the night ventilation test are shown clearly. According to the employees who are in this area, the night ventilation brought a noticeable improvement especially in the morning hours. After that, a renewed heating of the hall occurred, but the time of overheating could be postponed for several hours. This solution was preferred to adiabatic cooling because of the significantly lower investment costs.

5 PRIVATE HOUSEHOLDS

Private households differ from other building types in terms of hours of presence. Solutions for automatic night ventilation, which are advantageous for public buildings and companies, are usually not needed for private households, as the occupants are usually at home during the cool night hours and can carry out the ventilation manually. If this is not the case, such solutions are of course an option. Furthermore, private

[2] https://www.guttomat.at/

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households in the Cool-down Güssing project were divided into single- and multi-party residential buildings. Depending on ownership and dedication, different options are available to residents.
If single-family homes are heated with a heat pump, or if a heating system replacement is imminent, it makes sense to use the heat pump for cooling in the summer months. Ground source heat pumps are particularly well suited for cooling, as the cooling circuit can be used for passive cooling in summer (i.e. without operating the heat pump itself). In the case of air-source heat pumps the heat pump can be operated as a chiller. This requires a higher energy input, but especially in combination with a PV system, it is still a comparatively effective solution. If no heat pump is available, ground heat exchangers with air flow can be used to precondition the supply air in combination with a ventilation unit.
In multi-apartment buildings, the individual residents usually have only limited options available to them. In most cases, a conventional air-conditioning split unit is the only possibility to realize cooling. Tenant power models, i.e. common PV systems installed on the roof of multi-party apartment buildings, as well as participation in an energy community offer possibilities to supply them with local renewable electricity.
Proper user behavior should also not be underestimated. Ventilation procedures should be carried out as shock ventilation. The windows should not remain open longer than necessary. CO_2-sensors can help determine the correct ventilation time. Windows should be shaded in good time with external shading measures. Before leaving the house or apartment, it is recommented to shade all windows where a direct exposure to sunlight may occur. Automated systems, such as Smart Home, can support this but are not mandatory.

6 CONCLUSION

The installation of sustainable and at the same time affordable cooling solutions in existing buildings is a major challenge if no comprehensive renovation will be carried out. The installation of conventional air conditioning split units is often the much simpler solution. Nevertheless, with suitable measures, sustainable cooling, or at least a significant reduction of the residual cooling demand, a cooling effect can be achieved. In public buildings, which usually have a particularly limited budget, automatic window openers and decentralized ventilation units have proven to be particularly suitable. These are characterized by low investment and low operating costs. In this case, the cool night air is used to cool the classrooms during the night hours. The performance of night ventilation is limited by the outside air temperature, but in many cases it helps to improve the situation significantly and to postpone overheating at least for a few hours. In production halls, the cool night air can also be used for cooling. For this purpose, the fire ventilation system, which is installed in many cases anyway, can be used. Another option is the installation of an adiabatic cooling system. In addition, internal loads should be identified and reduced. In the case of private houses or apartments, automatic night ventilation is usually not expedient, since people are usually present during the night hours and can carry out night ventilation manually. For houses, the combination of cooling with the heating system is a good option. Especially geothermal heat pumps are well suited for this purpose. Air-source heat pumps can also be used for cooling, although in this case the energy rate is higher. A combination with a PV system is a good way to cover the electricity demand with own renewable electricity and to reduce the operating costs. In apartments, where often only the installation of a conventional split air conditioner is possible, the electricity consumption can be covered by a common PV system on the roof of the apartment building (tenant electricity model) or by joining a renewable energy community with local renewable electricity at more favorable conditions.

These solutions should always be combined with measures to reduce solar gain, e.g. in the form of external shading measures. During the day, ventilation should only be as much as necessary and should be carried out as shock ventilation.

7 REFERENCES

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