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Relative Humidity, RH (%), a Problem or Not in Swedish Buildings

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Abstract

In 1972, the oil producing countries implemented an oil embargo on a number of states, including Sweden. During this period, oil was an important raw material for Sweden. The oil accounted for nearly 40% of Sweden's total energy supply and was an extremely important source of heating for the Swedish building stock. Subsequently, restrictions from Swedish authorities have been introduced into how energy can be used. The purpose of these restrictions is to reduce energy consumption and a part of this is that new requirements have been introduced on how buildings should be designed. The changes have had negative consequences as people, who live in these types of buildings, claim that they suffer from health problems, which are referred to as "building related illness". The purpose of this project is to examine how the structural changes regarding air exchange and windows carried out after the oil embargo in 1972, have affected the climate and environment in Swedish buildings. The aim is to investigate whether there are links between these changes and assertions about building-related illness. From an energy point of view, windows are a delicate building component and the project includes studying the effect of using an external roller shutter. Furthermore, the project aims to investigate how the environment and climate in Swedish buildings are experienced at the user level and how authorities assess the scope and effect of the measures they have implemented. The results show that unhealthily low levels of the relative humidity generally prevail in the Swedish housing stock and that the changes in the construction carried out after the oil embargo in 1972, regarding air exchange systems and window designs, reinforce the problem. With regard to various design alternatives, it is necessary in Sweden to consider the prevailing climate and environmental conditions and that the energy efficiency of the buildings is good.

Keywords

Hygiene and Health, Indoor Air Quality, Indoor Humidity, Indoor Temperature

1. Introduction

In 1972, the oil producing countries implemented an oil embargo on a number of states, including Sweden. During this period, oil was an important raw material for Sweden. The oil accounted for nearly 40% of Sweden's total energy supply and was an extremely important source of heating for the Swedish building stock. Subsequently, restrictions from Swedish authorities have been introduced into how energy can be used. The purpose of these restrictions is to reduce energy consumption and a part of this is that new requirements have been introduced on how buildings should be designed [1]. These requirements have meant that the construction industry has undergone an extensive process of change, which means that buildings have a higher degree of insulation and are significantly denser than before. Examples of designs that are installed are technical systems to try to ensure good air-exchange efficiency between the air outside and the air inside and that the previous two-glass window designs have been replaced with three-glass structures. The changes have had negative consequences as people, who live in these types of buildings, claim that they suffer from health problems, which are referred to as "building related illness". These health problems are considered to be derived from the fact that there are deficiencies in the technical constructions of buildings. The symptoms that affected people refer to are nonspecific and usually present in the population such as dry skin, dry mucous membranes, redness, mental fatigue, headache, respiratory infections, cough, hoarseness, itching, nausea and dizziness [2]. Despite several decades of extensive research and efforts, it has not been possible to confirm that this link exists between the health problems mentioned on the one hand and the deficiencies in the technical status of the buildings on the other. The authorities have set limit values for indoor environments regarding climate and emissions, with the aim of preventing illness [3]. However, in the field of building-related illness, the authorities consider those limit levels being too high in this context. Instead a working model, supported by industry players, has been developed. The model is based on a theory and measurement methods on building-related illness, but there is no confirmed scientific hypothesis to support this model [4]. Examples of basic defects in the model used are the following:

- There is no delimitation from emissions and disturbances that arise from the activities carried out in the building.
- There is no required demarcation from unhealthy emissions transmitted from other environments outside the building concerned.

The model is more a form of template which in different contexts may be needed to accompany a society. However, in this context, the model has fundamental flaws, which means that investigations that are conducted become incomplete and when analyzing the problems a complete picture of the problem is not obtained [5]-[15]. In order to deal with this type of problem, it is important that there are measurable parameters available that are relevant to the context. One parameter that can be determined to be important in how the environment and climate are experienced indoors, is the temperature. The temperature, in turn, affects the relative humidity (RH) which, for human well-being, has an optimal zone in the range 40% - 60%, see **Figure 1** [16]. Examples of issues that should be explored in more detail are what levels normally prevail in residential environments regarding temperature and the relative humidity, how these vary, both in a building as a whole and in an individual room. In addition, it should be more thoroughly clarified how these parameters vary over time, not least given the seasonal variations that occur in Sweden.

The purpose of this project is as follows:

- By means of physical measurements, examine how the structural changes regarding air exchange and windows carried out after the oil embargo in 1972 have affected the climate and environment in Swedish buildings. The aim is to investigate whether there are links between these changes and assertions about building-related illness. From an energy point of view, windows are a delicate building component and the project includes studying the effect of using an external roller shutter.
- Furthermore, the project aims to investigate how the environment and climate in Swedish buildings are experienced at the user level and how authorities assess the scope and effect of the measures they have implemented.

2. Measurement Method

The activities in the buildings included in this project are schools, offices and housing, that is, the categories of buildings that are often affected by the so-called building-related illness. The climate parameters in the indoor environment that are measured are air temperature and the relative humidity, which are compared with the outdoor air which gives level to the indoor environment. The measurements are carried out in buildings with different designs regarding air exchange and windows. The measuring instrument used in this project is Testo 175-H1, a data logger that measures the temperature in degrees Celsius, (˚C), in the range from minus 20˚C up to plus 70˚C, and measures the relative humidity, RH (%), in the interval 0% - 100%. Storage capacity comprises up to one million measurement values and each instrument is set to a storage frequency, with registration every four hours. For this project, the following structural engineering constructions are tested

1) Two different systems for air circulation between outdoor and indoor air are compared. One design with a natural draft system, which was standard before 1972, as well as a design with mechanical systems introduced after 1972.

2) Two different window designs are compared, one with two glass (two-glass systems) standard before 1972 and one with three glass (three-glass systems) introduced after 1972.

3) An exterior roller shutter is applied to a window frame with a two-glass system, see **Figure 2**, [17] which is compared to an equivalent window frame in the same room without this shutter.

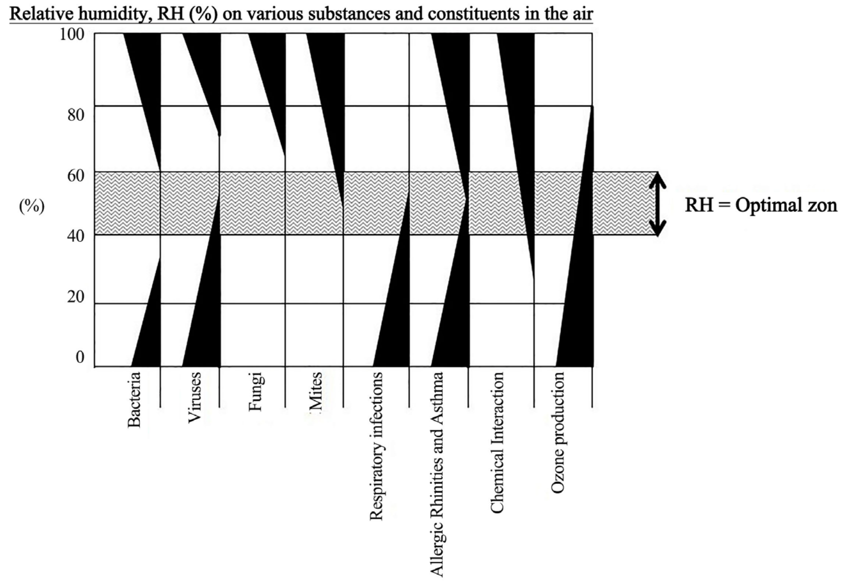

Figure 1. The effect of relative humidity, on biological and chemical factors, is graphically summarized above. The optimum zone is in the range between 40% - 60% relative humidity to minimize the negative health effects of common air pollutants [16].

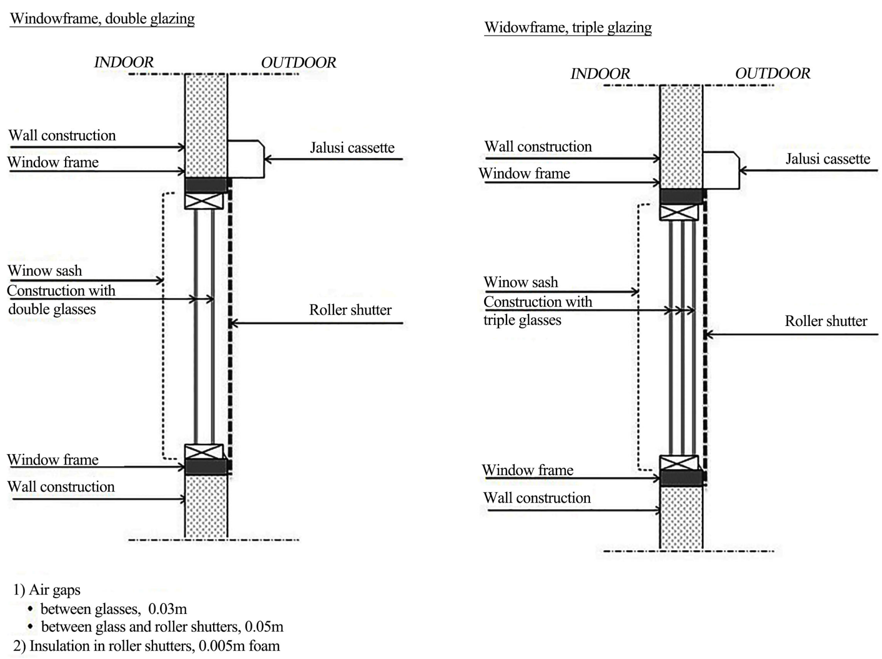

Figure 2. Principle sketch of Swedish window construction [17] as substrate calculation heat transmission coefficient (U) and transmission loss (E).

The purpose of the physical measurement effort is to investigate whether differences in the indoor environment can be identified between the different technical constructions. The measurements comprise three steps:

1) The measurements in twelve buildings are carried out in six geographically different locations, two buildings in each location Alvesta, Stockholm, Filipstad, Söderhamn, Robertsfors and Arvidsjaur, with a distribution so that Sweden's

three climate zones are covered [18]. In Alvesta it is an apartment and an office, in Stockholm it is an apartment and a school, in Filipstad it is two schools, in Söderhamn it is two schools, in Robertsfors it is two schools and in Arvidsjaur it is an office and a school.

2) The two buildings at each location consist of a building with natural draft and a building with a mechanical system. The aim of these measurements is to compare whether differences can be identified between the two air exchange systems. The measurements were carried out during the period January to March 2016.

3) In a room in a dwelling with two different window designs, measurements are made in a window frame with two-glass system and in a window frame with three-glass system. The measuring instruments are placed in the respective window frames as well as an instrument inside the room as a reference for comparing the climate conditions inside the room in relation to the two window frames. The measurements were carried out during a longer period, from July 2016 to May 2019. The purpose is to study how the climate varies, both in different places in the room and partly between the two window systems as well as during the different seasons. The basis for the climatic conditions indoors is the climate that exists outside the building and therefore instruments are also placed in the outdoor environment outside the building.

4) Measurements are carried out in a room with two windows, both windows with the same design "two-glass system", where one window surface including the window frame is provided with an external roller shutter. The aim of this study is to investigate whether positive climate effects can be achieved with the help of blinds. The measurement period covers from July 2018 to May 2019. The window frame with the shutter has the shutter coverage throughout the measurement period.

The study of the shutters design is supplemented with calculation of heat resistance and energy performance and how these parameters vary for the two window designs, two- and three-glass systems, respectively. This is done using calculation formulas and in this project the following two parameters are studied:

1) *The heat transfer coefficient*, is denoted by U and indicates how well a building or building component insulates. The unit for the heat transfer coefficient is W/m², ˚C. The lower the value the better the insulation.

2) *Transmission losses*, denoted by E, are the heat/energy that "leaks" from a building or part of a building. The transmission loss unit is Wh. The lower the value the better the performance.

The formulas below are used: [19]

$$R_{\text{layer}} = \delta/\lambda$$

$$R_{\text{sum}} = 0.17 + R_{\text{layer1}} + R_{\text{layer2}} + \dots + R_{\text{n}}$$

$$U = 1/R_{\text{sum}}$$

$$P = U \cdot A\,(t_i - \text{DUT})$$

$$E = U \cdot A \cdot G$$

EXPLANATION/INTERPRETATION

R: Thermal resistance

δ: The thickness of the layer [m]

λ: The thermal conductivity of the material [W/m, ˚C], a table value

U: Heat transfer coefficient [W/m^2, ˚C]

P: The transmission loss, the effect [W]

A: The surface through which the heat is conducted [m^2]

t_i: Designable outdoor temperature [˚C], a table value

DUT: Designable temperature inside [˚C], a table value

E: The transmission loss, energy [Wh]

G: Number of degree hours at the location, a table value [˚C, h]

A basic sketch of the designs, with and without roller shutters, on which the calculation is based, is presented in **Figure 2**. For the calculation of the E parameter, a living space of 100 m^2 is studied and geographically three different locations in Sweden are studied; Kiruna, Stockholm and Malmö, which geographically encompass all of Sweden's three climate zones [18]. In the project, a survey is conducted, comprising 1200 respondents with the aim of examining how the environment and climate are perceived in the Swedish building stock. A literature study examines how the Swedish authorities themselves assess the extent of building-related illness and how they assess the effects of the changes they have implemented to address the problem. The tools used for conducting the literature study are the databases at the Royal Institute of Technology in Stockholm, searching through the Google search engine, reviewing the relevant authorities' websites via the internet and, if necessary, direct contact with the authorities for clarification on various issues.

3. Results

The basis of the climate in a building, in terms of temperature and relative humidity, is the level that prevails outside the building. The outdoor levels in Stockholm for the period from July 2016 to May 2019 are shown in the graphs, **Figure 3** and **Figure 4**. Stockholm is located in Sweden's climate zone 2 [18] and the results show that the temperature drops during the winter, in order to be higher during the summer and the opposite is true for the relative humidity. The measurement results in the building at the same location and during the same measurement period show that even indoors the climate varies at different places in the room, see **Figure 5** temperature and **Figure 6** the relative humidity. The variations are not in the order of magnitude outdoors and generally for each parameter, the temperature inside the room is at the levels prescribed by the authorities, from 20˚C and up to 24˚C [20]. Occasionally, the levels in the window frames are in some contexts more extreme due to shorter temporary climate changes such as directly affecting solar radiation and window weathering in winter time (see **Figure 5**). With regard to the relative humidity there are no limit values, but as shown in **Figure 1**, the level should be between 40% and 60%. However, the level falls below this level, during most time of the period, shown in Figure 6. Levels above 40% occur during the summer periods, in order to fall sharply again in the autumn with the lowest levels during the winter season.

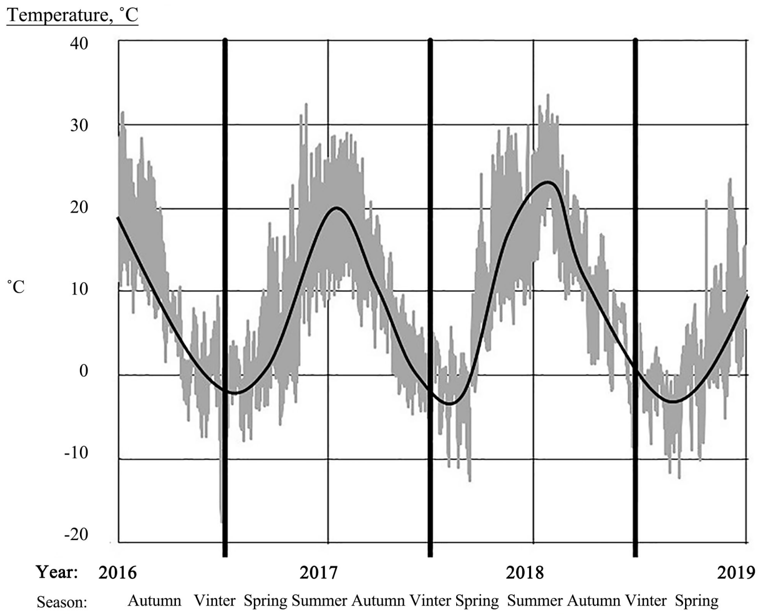

Figure 3. The outdoor climate, temperature in ℃, outside the building where the physical measurements were carried out in this project, see Figure 5 and Figure 6. The measurement period is from July 2016 to May 2019. Please note that the climate variation outside is strong. The gray graph shows the range of the measuring instrument and a marking with a black line is made to clarify the direction of the climate variation.

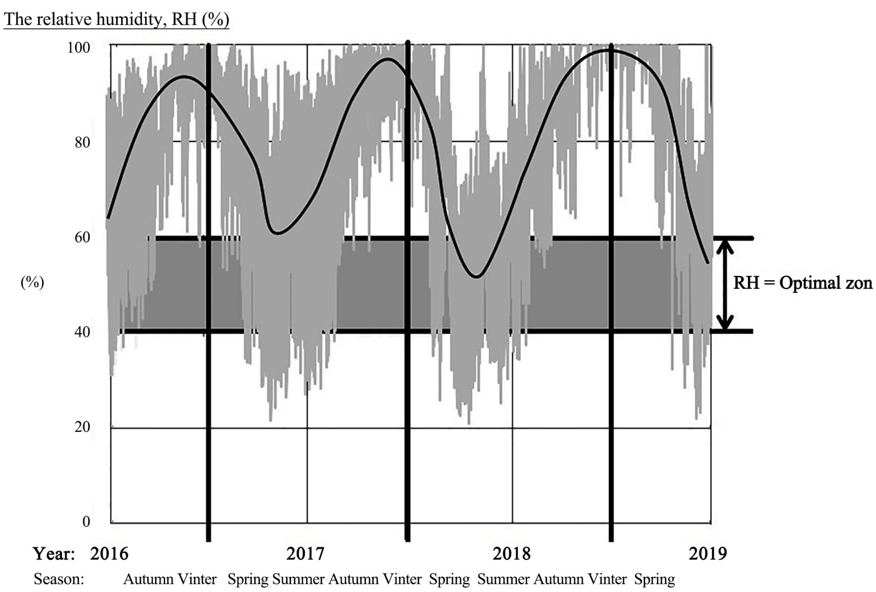

Figure 4. The outdoor climate, the relative humidity (RH), in %, outside the building where the physical measurements were carried out in this project, see Figure 5 and Figure 6. The measurement period is from July 2016 to May 2019. Please note that the climate variation outside is strong. The gray graph shows the range of the measuring instrument and a marking with a black line is made to clarify the direction of the climate variation.

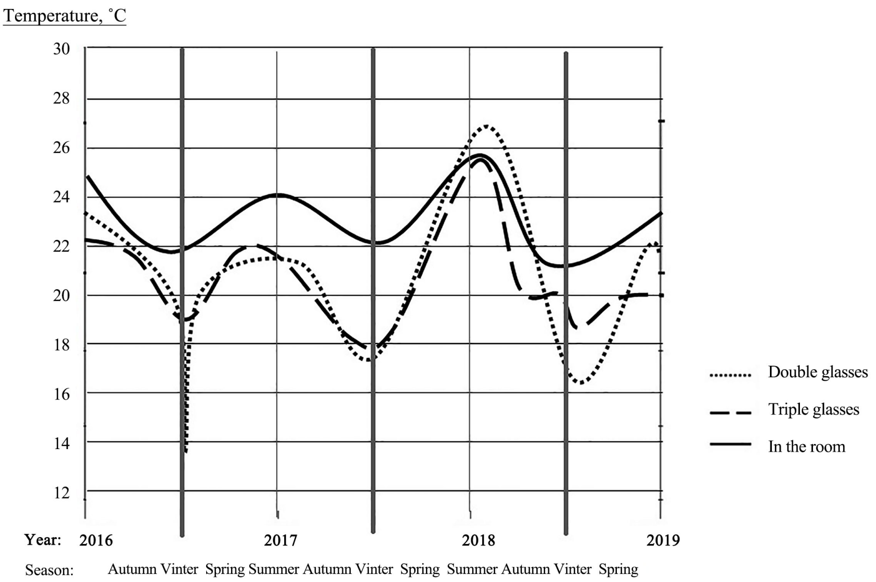

Figure 5. The diagram shows the average of air temperature, in ℃, for each week. The diagram compares in one room, the temperature in two window frames, a frame with two-glass window and a frame with three-glass window and inside the room. The measurement period is from July 2016 to May 2019.

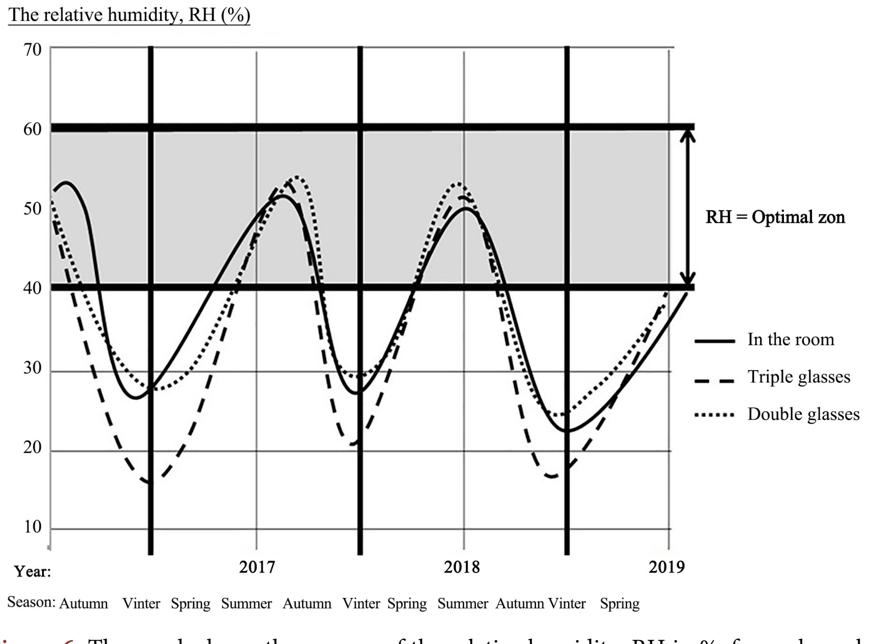

Figure 6. The graph shows the average of the relative humidity, RH in %, for each week. The diagram compares in one room, the RH level in two window frames, a frame with two-glass windows and a frame with three-glass windows and inside the room. The measurement period is from July 2016 to May 2019.

Regarding the measurement results indoors, it can be noted that the mean level of relative humidity over the entire measurement period is below 40% in the room and in both window frames above 40%. If a more detailed study is conducted over this entire measurement period, more detailed differences will be revealed. The variation indoors is caused by the fluctuations in the relative humidity that occurs outdoors and it is difficult to fully compensate for these fluctuations through technical designs. The results in the window frames show that it is colder next to the windows during the winter season than in the other parts of the room, and this especially during the short and intense cold season that prevailed during the winter season 2016-2017. The temperature inside the room is even, varying between 21˚C and 25˚C. In the window frames it varies more strongly, between 19˚C and 26˚C in the three-glass system and in the two-glass system between 14˚C and 28˚C. The relative humidity varies between 25% and 50% inside the room, in the window frames with the triple-glass system between 18% and 52% and between 25% and 55% in the window frame with the two-glass system. Identifiable differences can be found in the space between the three measurement sites. When compared, the two window frames reach the lowest level in the window frame with triple-glass system. If we make a comparison with regard to the outside temperature graph in **Figure 3**, it can be seen that its curve contour corresponds well with the curve contours for the relative humidity inside, see the graphs in **Figure 6**. This is explained by the lower the temperature, the less moisture the air contains [21]. This means that during the winter months, when lower temperatures prevail, the air contains less moisture. As the outdoor air, when taken into the building, is heated to the temperature prevailing in the building, the moisture content of the indoor air is further reduced [22].

The measurement performance, which compares the various air exchange systems, natural draft systems and mechanical systems, shows that the average relative humidity is significantly below 40% see **Figure 7** and **Table 1**. The measurement period January-March is a delicate part of the year. The outside temperature is regularly below 0˚C, with the result that the level of relative humidity is generally low indoors, see **Figure 6**. The problems with the relative humidity are most extensive in the buildings with mechanically controlled air exchange where levels below 10% are measured. This can be compared with the lowest levels in the buildings with natural draft where the level is 18%, see **Table 1**. In summary, the relative humidity indoors is low during a predominant part of the year in the Swedish building stock and is thus a source of the complaints that are being addressed regarding building-related illness see **Figure 1**, **Figure 6** and **Figure 7** and **Table 1**. The relationship is confirmed by the survey study conducted where:

- 70% of respondents report problems with dry air
- 78% of respondents report problems with both unev.en and uncomfortable air temperature.
- 38% of respondents experience health problems in some buildings.
- 46% of respondents report concerns about being affected by health problems by staying in a particular building.

The survey results are presented in **Figure 8**. For many decades, the Swedish authorities have been trying to address the problems of building-related illness. The first major government inquiry was presented in 1989 [23]. Right from the

Table 1. The relative humidity, RH (%).

A BUILDING WITH	NATURAL DRAFT	MECHANICAL VENTILATION
The average value		
1) SÖDRA GÖTALAND	32	23
2) ÖSTRA SVEALAND	35	25
3) VÄSTRA SVEALAND	31	22
4) SÖDRA NORRLAND	29	22
5) NORDÖSTRA NORRLAND	28	21
6) NORDVÄSTRA NORRLAND	26	19
The lowest value		
1) SÖDRA GÖTALAND	21	11
2) ÖSTRA SVEALAND	25	15
3) VÄSTRA SVEALAND	19	9
4) SÖDRA NORRLAND	20	9
5) NORDÖSTRA NORRLAND	18	12
6) NORDVÄSTRA NORRLAND	16	8
The highest value		
1) SÖDRA GÖTALAND	45	35
2) ÖSTRA SVEALAND	44	39
3) VÄSTRA SVEALAND	44	32
4) SÖDRA NORRLAND	41	31
5) NORDÖSTRA NORRLAND	39	34
6) NORDVÄSTRA NORRLAND	42	31

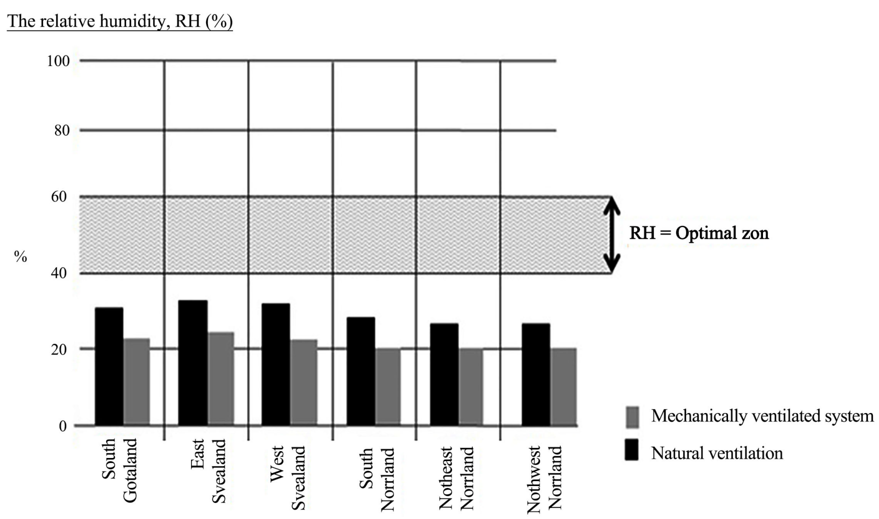

Figure 7. The diagram shows the average of the relative humidity, RH, in %, in twelve buildings, 2 at each location. One building with air exchange through natural draft and the other building with air exchange that is mechanically controlled.

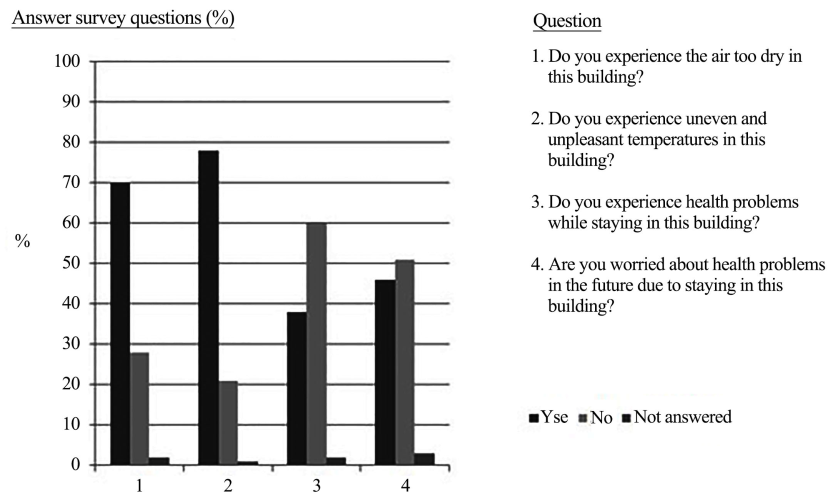

Figure 8. Results from a survey of 1200 respondents and how they experience the climate and building-related illness in Swedish buildings.

beginning there was a one-sided focus on the construction of buildings, a form of management that lacks evidence, but is still used. The authorities made it more or less official at a conference held in 1992 [24]. A ritual management method has been created, and now new directives from the authorities, with the aim of addressing the prevailing health problems, regularly reduce energy consumption and create conditions for better management of resources in accordance with Swedish environmental policy. The Swedish Parliament has defined Swedish environmental policy in so-called generational goals with the following wording: "*The overall goal of environmental policy is to hand over to the next generation a society where the major environmental problems are solved, without causing increased environmental and health problems outside Sweden's borders*" [25] [26]. In 1994, the Prime Minister of Sweden at that time clarified the importance of acting in environmental work and pointed out that the major environmental problems must be addressed by 2020 [27]. In 2018, the responsible authority announced, in its annual assessment, that the environmental goal regarding building-related illness will not be achieved within this time period [28]. Reported figures from the authority revealed that between 2009 and 2017, the problems related to building-related illness increased, from covering 1.2 million people [29] to exceeding 1.4 million people [2]. In fact, there has been an increase in numbers. n a direct follow-up of a preschool that was demolished and a new building constructed in accordance with the ritual working model [4], the staff announces that the problems remain and this despite a resource consumption of more than SEK 45.5 million. The responsible authorities have nothing further to disclose in the case, but inform those affected that what has been done is done [30] [31].

In the comparison between the window frame with and without the roller shutter, the measurement results show that a more even temperature is achieved in the window frame which is equipped with an external roller shutter, see **Figure 9**. Regarding the relative humidity, differences can be identified, but no conclusion can be drawn from these measurement data, see Figure 10. With regard to heat resistance (U) and transmission loss (E) the calculations show significant advantages found by using roller shutters, see Figure 11 and Figure 12 and Table 2 and Table 3. It is noteworthy that it is more advantageous to supplement two-glass systems with roller shutters than to install the triple glass system alone. The measurement results in this study show that there are connections between the new constructions installed in buildings and the building-related illness. With regard to the designs studied in this project, the following should be clarified:

- The air exchange systems installed after 1972 have had a negative impact on the indoor environment, see Figure 7 and Table 1.
- With regard to the window designs, it is evident that climatic differences are identified, between the two and three glass systems, see Figure 5 and Figure 6 and between the window surfaces with and without roller shutters regarding the temperature, see Figure 9. The scope of problems related to building-related illness is increasing. Reported figures from authorities range from the level of 1.2 million people to 1.4 million between 2009 and 2017 [2] [29]. The results, from the survey study included in this project, confirm this development, see Figure 8.
- From the energy point of view, the calculations show that an external roller shutter covering the window surface produces significant effects on the heat transfer coefficient (U), see Figure 11 and Table 2 and the transmission loss (E), see Figure 12 and Table 3.

Table 2. The transmission loss, E, (kWh) for different window designs, formula $E = U \times A \times (DUT - t_i)$.

	U	A	DUT - ti	E
WINDOW DESIGN			*Table value*	
			Kiruna	
Two-glass	2.90	100	190,000	55,100
Two-glass + roller shutter	1.89	100	190,000	28,310
Three-glass	1.49	100	190,000	35,910
Three-glass + roller shutter	1.18	100	190,000	22,420
			Stockholm	
Two-glass	2.90	100	117,000	33,930
Two-glass + roller shutter	1.89	100	117,000	17,433
Three-glass	1.49	100	117,000	22,113
Three-glass + roller shutter	1.18	100	117,000	13,806
			Malmö	
Two-glass	2.90	100	105,000	30,450
Two-glass + roller shutter	1.89	100	105,000	15,645
Three-glass	1.49	100	105,000	19,845
Three-glass + roller shutter	1.18	100	105,000	12,390

Table 3. The relative humidity and air temperature, the average value per month in a room in a dwelling and outside during the period August 2018 to February 2019. The room is equipped with two equivalent window designs, where one window surface is provided with exterior roller shutters and the other without roller shutters. Constructions see Figure 2.

The relative humidity, average monthly											
Year	2018						2019				
Month	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	March	Apr	May
Without r.s.*	55.00	51.67	52.44	42.18	36.10	33.78	26.74	30.33	29.79	28.03	31.79
With r.s.*	54.50	51.10	50.40	45.34	37.61	32.34	28.19	29.68	29.05	26.38	32.13
Outdoors	59.88	72.16	82.19	88.32	96.75	98.90	97.36	92.85	86.64	84.66	73.74
The temperature, average monthly											
Year	2018						2019				
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	Apr	May
Without r.s.*	26.90	24.28	20.51	20.20	20.45	17.72	18.28	19.01	19.55	21.36	20.72
With r.s.*	25.80	24.15	20.86	20.93	21.14	19.88	18.89	19.98	20.76	22.72	22.13
Outdoors	25.01	19.03	13.23	7.76	3.70	0.03	−2.97	0.73	1.95	6.69	7.16

* r.s. = Roller shutters.

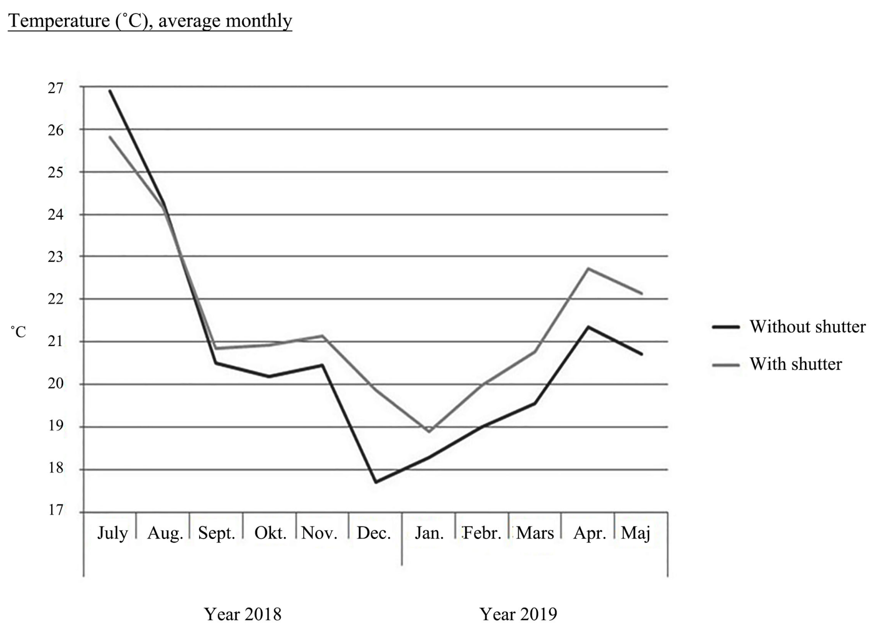

Figure 9. The average value of the temperature for each month from August 2018 to May 2019. Measurement sites in a Swedish residential building and in the air outside this building. The measurement sites in the building comprise a room, with a measurement space in a window frame with two-glass system, which is externally provided with a roller shutter and a measuring place in a window frame with two-glass system without the external roller shutter. Window constructions see Figure 2.

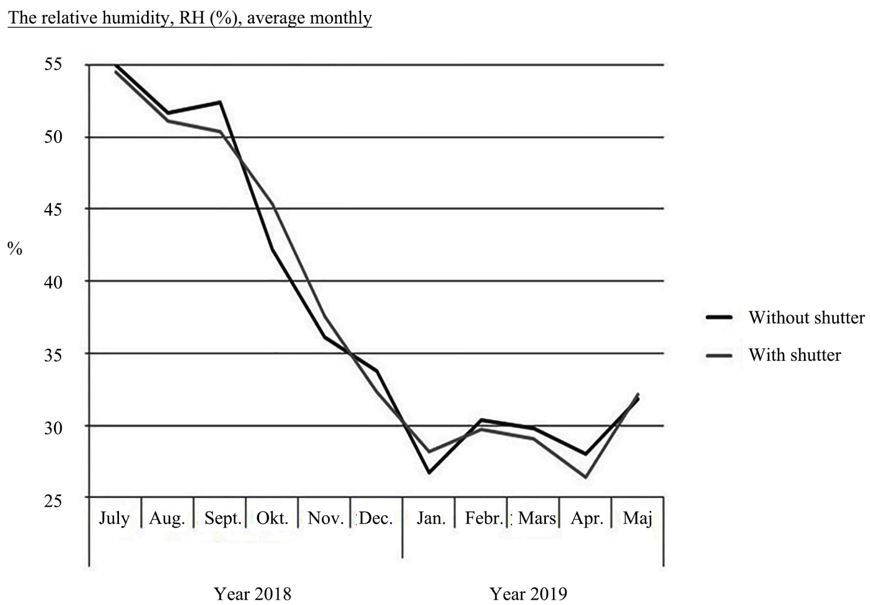

Figure 10. The average value of the relative humidity for the respective month from August 2018 to May 2019. Measurement sites in a Swedish residential building and in the air outside this building. The measurement sites in the building comprise a room, with a measurement space in a window frame with two-glass system, which is externally provided with roller shutters and a measuring place in a window frame with two-glass system without the external roller shutter. Window constructions see **Figure 2**.

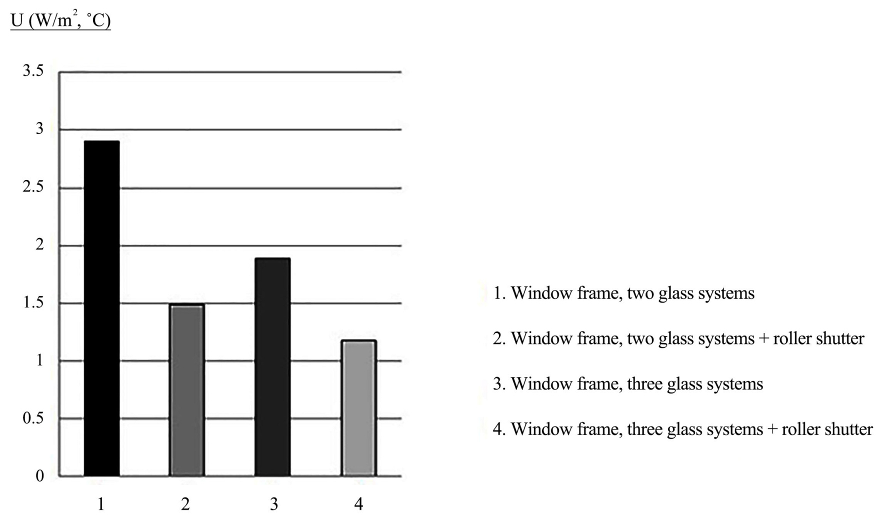

Figure 11. The diagram shows the calculation of the heat transfer coefficient, U, [W/m^2, ℃] with the construction in **Figure 2** as the basis.

It can be noted that the directives issued by the authorities, regarding the ritual model used in structural engineering environmental problems, are not based on substantiated evidence. Instead, their decisions have been based on statements from people who the authorities consider to be particularly competent. This means that the authorities have allowed non-evidence-based material to control the area with the problem of building-related illness [31].

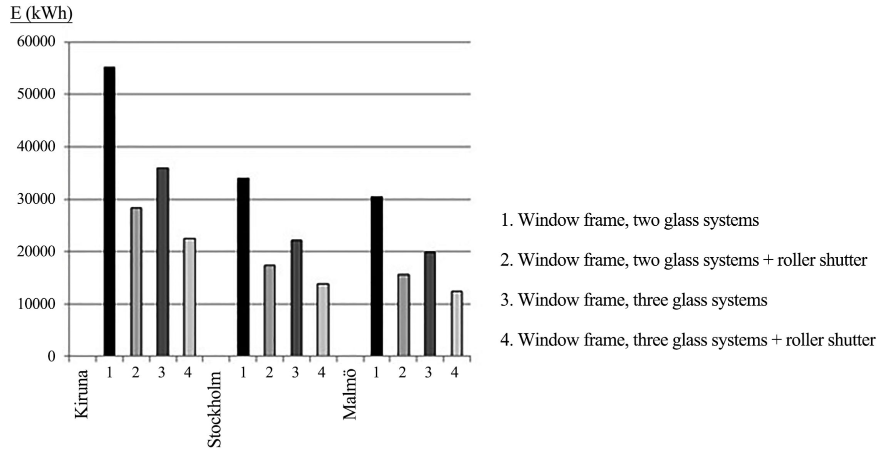

Figure 12. The diagram shows the calculation of the transmission loss - energy, E, [Wh] with the construction described in **Figure 2** as a basis. The calculation is done at three locations; Kiruna, Stockholm and Malmö.

4. Conclusion

It can be noted that many people who reside in Swedish buildings experience problems with the environment and the climate that prevails there. The results of the measurements carried out in this project show that there are extensive problems and the authorities' own follow-up efforts indicate major problems and that the problems even increase [2] [29], despite the fact that extensive resources are both allocated and implemented to remedy the problems. The question should instead be if there are shortcomings in the model used. An identifiable parameter that is not properly considered and managed is the relative humidity of the indoor environment, which is a factor affecting human health, see **Figure 1**. This study has, through physical measurements, identified that this is a source of building-related illness. The results show that unhealthily low levels generally prevail in the Swedish housing stock and that the changes in the construction carried out after the oil embargo in 1972, regarding air exchange systems and window designs, reinforce the problem see **Figure 6**, **Figure 7** and **Table 1**. With regard to various design alternatives, it is necessary in Sweden to consider the prevailing climate and environmental conditions and that the energy efficiency of the buildings is good. This project has shown that there are alternatives to the designs currently proposed. As far as window surfaces are concerned, these are, from an energy point of view, a sensitive part of the building and there is much to be gained from strengthening this part of the building. In the housing stock, there is also a temporary need for the residents to provide the window surfaces with protection for transparency, create a darkening and sound insulation. Are these needs compatible with the needs of climate and energy efficiency? This project has shown that there are alternatives to today's system. A system that is used in many countries, but which in Sweden in a housing context is a fairly unknown concept, is the external roller shutters that have been studied in this project. This roller shutter strengthens from an energy and heat resistance perspective, the design and gives positive effects in terms of climate and energy consumption see **Figure 11**, **Figure 12** and **Table 2** and **Table 3**. Further positive effects are that the mechanical air exchange can be reduced and that the need for energy and resource-intensive technical systems need not be as extensive. An example is if roller shutters are combined with two-glass systems, this gives better air exchange than the three-glass system. At the same time, better energy performance and heat resistance are achieved than using what is currently recommended, three-glass systems, see **Figure 11** and **Figure 12** and **Table 2**.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Energianvändning och energitillförsel, Swedish Energy Agency (2015) Documentation to the Energy Commission. http://www.energikommissionen.se http://www.energikommissionen.se/app/uploads/2015/12/Underlagsrapport-till-Energikommissionen_anv%C3%A4ndning-och-tillf%C3%B6rsel_Energimyndigheten.pdf

[2] Carlsson, J. and Stenius, U. (2017) Environmental Health Report. Public Health Agency of Sweden, Solna. (In Swedish) https://www.folkhalsomyndigheten.se/publicerat-material/publikationsarkiv/m/miljohalsorapport-2017

[3] Swedish Work Environment Authority, Occupational-Exposure-Limit-Values, AFS 2018:1, Regulation. https://www.av.se/globalassets/filer/publikationer/foreskrifter/hygieniska-gransvarden-afs-2018-1.pdf

[4] Swesiac-Modellen (2019) Swedish Chapter of International Society of Indoor Air Quality and Climate. (In Swedish) http://swesiaq.se/swesiaq-modellen-2.html

[5] Myc-Tech AB (2014) The Town Hall, Falu Municipality, Socialcare Administrations, Survey Report 2014-11-25. (In Swedish)

[6] Thörn, Å. (1999) The Emergence and Preservation of Sick Building Syndrome, Karolinska Institutet. Department of Public Health Sciences, Division of Social Medicine, Stockholm.

[7] Brauer, C. (2005) The Sick Building Syndrome Revisited. Department of Occupational Medicine, Copenhagen University Hospital, Glostrup.

[8] Stridh, G. (2003) Should We Measure the Chemistry beneath the Floor Coverage and, If So, How Do We Interpret the Results? (Skall vi mäta kemin under golvbeläggningar och hur tolkar vi i så fall mätresultaten?) Indoor Climate Örebro, Örebro University Hospital, 102-108. (In Swedish)

[9] Alsmo, T. (1994) A Study with Questionnaires and Particle Measurements (En studie med enkäter och partikel-mätningar). Division of Construction Management, Royal Institute of Technology, Stockholm. (In Swedish)

[10] Alsmo, T. and Holmberg, S. (2007) Sick Buildings or Not: Indoor Air Quality and Health Problems in Schools. *Indoor and Built Environment*, **16**, 548-555. https://doi.org/10.1177/1420326X07084414

[11] Alsmo, T. and Holmberg, S. (2010) A Study of Sources of Airborne Pollutants and Poor Hygiene in Schools. *Indoor and Built Environment*, **19**, 298-304. https://doi.org/10.1177/1420326X09342678

[12] Alsmo, T. and Alsmo, C. (2013) A Study of Hygiene in Swedish Schools and Pre-Schools Sources of Air Pollution. *Journal of Environmental Protection*, **4**, 1349-1359. https://doi.org/10.4236/jep.2013.412156

[13] Alsmo, T. and Alsmo, C. (2014) Ventilation and Relative Humidity in Swedish Buildings. *Journal of Environmental Protection*, **5**, 1022-1036. https://doi.org/10.4236/jep.2014.511102

[14] Alsmo, T. and Alsmo, C. (2016) A Comparison of Relative Humidity between Two Swedish Buildings with Different Ventilation Solutions. *Journal of Environmental Protection*, **7**, Article ID: 66551. https://doi.org/10.4236/jep.2016.76078

[15] Alsmo, T. (2016) Indoor Air Environment—Hygienic Factors and Limits. *Journal of Environmental Protection*, **7**, 1730-1744. http://www.scirp.org/journal/jep https://doi.org/10.4236/jep.2016.712140

[16] Arundel, A.V., Sterling, E.M., Biggin, J.H. and Sterling, T.D. (1986) Indirect Health Effects of Relative Humidity in Indoor Environments. *Environmental Health Perspectives*, **65**, 351-356. https://doi.org/10.2307/3430203

[17] Assembly Instructions, Inwido, Elitfönster, Vetlanda Sweden. (In Swedish) https://www.elitfonster.se/globalassets/fonsterguide/dokument/handbocker/montage/monteringsanvisningar_inwido.pdf

[18] Sveriges Klimat. Swedish Meteorological and Hydrological Institute. https://www.smhi.se/kunskapsbanken/klimat/sveriges-klimat-1.6867

[19] Sjelvgren, A. (2012) Handbook for Energy Management in Accordance with the Swedish Housing Agency's Building Rules. 2nd Edition, Boverket, Publikationsservice, Karlskrona, 26. (In Swedish) https://www.boverket.se/globalassets/publikationer/dokument/2012/handbok-for-energihushallning-enligt-boverkets-byggregler.pdf

[20] The Public Health Agency of Sweden (2019). https://www.folkhalsomyndigheten.se/publicerat-material/publikationsarkiv/f/fohmfs-201417

[21] Molliers-Diagram (2019). http://mollierdiagram.com/Mollier_diagram_pro_software.php

[22] Wikipedia. Steam Content. (In Swedish) https://sv.wikipedia.org/wiki/%C3%85nghalt

[23] State Public Investigations, SOU 1989:78 (1989) Prevention of Allergy Hypersensitivity: Measures, Information and Education, Research. Expert Appendix, Descriptions of Allergy/Hypersensitivity: Medical and Environmental Medical Knowledge Compilations. (In Swedish) https://lagen.nu/sou/1989:78

[24] Anderson, K. and Blomquist, G. (1992) Can You Get Sick from Smells, Mold and Bacteria in the House? Seminar in Umeå, the Swedish Council for Construction Research, Sankt. (In Swedish)

[25] The Generational Goal. Swedish Environmental Protection Agency. https://www.swedishepa.se/Environmental-objectives-and-cooperation/Swedens-environmental-objectives/The-generational-goal

[26] The Environmental Targets. Swedish Environmental Protection Agency. https://www.miljomal.se/Miljomalen

[27] Berg, G. and Svärdh, J. (1997) Environmental Management Guide—Step by Step

towards ISO 14000 Och EMAS. (In Swedish)

[28] Swedish Environmental Protection Agency (2018) Environmental Targets—Annual Follow-Up of Sweden's National Environmental Targets. (In Swedish) https://www.miljomal.se/Global/24_las_mer/rapporter/malansvariga_myndigheter/2018/au2018.pdf

[29] Emenius, G. and Svartengren, M. (2009) Environmental Report 2009. Socialstyrelsen och Karolinska institutet. https://ki.se/sites/default/files/mhr2009_0.pdf

[30] Von Sydow, C. (2011) Program Work Regarding Investment Regarding Skogsgläntan's Preschool. (In Swedish)

[31] Danderyd Municipality (2019) Personal Communication 30 April 2019 with Staff at Skogsgläntan's Preschool in Danderyd Municipality, Sweden.