PASSIVE HOUSES IN AUSTRIA - SUSTAINABILITY MONITORING OF STUDENTS' HOSTEL MOLKEREISTRASSE, VIENNA

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Summary

Austria has a diversified know-how concerning sustainable buildings and the highest rate of passive houses per resident. The students' hostel Molkereistrasse in Vienna was the largest passive house worldwide, when it was opened in Sept. 2005. The facility performance evaluation gave evidence for an extremely high user satisfaction and a very good energy performance and climate protection performance concerning space heating and hot water generation. Further measurements for the improvement of the energy performance and the user satisfaction have been derived from the monitoring project. Future realizations of students' hostels can benefit from studying the successful pilot project in Vienna. And an additional attention should be laid to reduce the energy consumption for hot water generation and for electrical appliances.

1. Sustainable buildings in Austria

Austria has been a pioneer in the realization of eco-friendly and energy efficient houses and has accumulated substantial practical know how concerning passive houses, solar heating systems, and biomass energy production systems (Treberspurg + Smutny, 2005). Currently, it can claim twice as many sustainable settlements per resident as Germany (Wolpensinger, 2008). The following figure shows the development of passive houses in Austria. A passive house is designed to be heated with less than 15 kWh useful energy per treated floor area and year. Austria has the highest number of passive houses per resident worldwide with 200 objects per 1 Mio. residents in the end of 2006 (Lang, 2008). In the last three years, the cumulated total floor area has doubled each year.

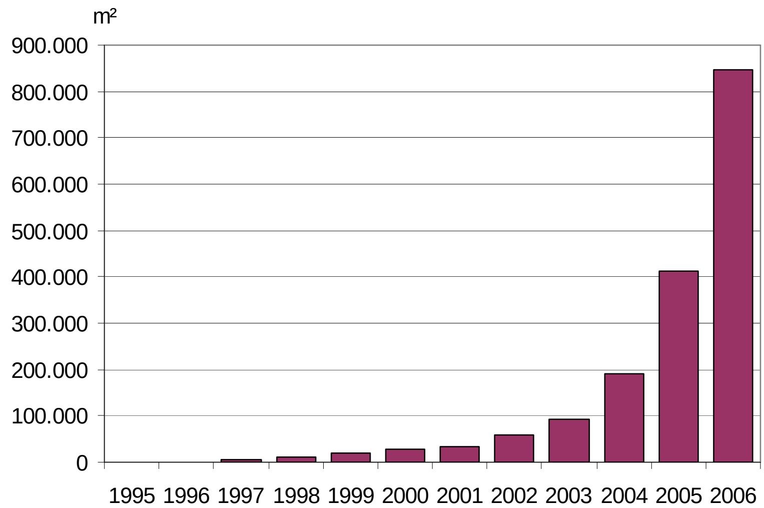


Figure 1: Accumulated total usable floor area [m²] of existing passive houses in Austria (Lang, 2008)

1.1 Presentation of specific passive houses

Approx. 45 % of the documented usable floor area of passive houses is provided by apartment houses, 22 % by one-family and two-family houses and 33 % by other buildings (Lang, 2008). The following pictures provide an overview on selected Austrian passive houses.

Figure 2: Housing estates in passive house standard. From left to right: Mühlweg-Vienna (Source: Bruno Klomfar, Dietrich I Untertrifaller Architects), EBS-solarCity-Linz (Source: Treberspurg & Partner Architects, EBS Linz,), Roschégasse-Vienna (Source: Treberspurg&Partner Architects)

Figure 3: Office buildings in passive house standard. From left to right: SOL4, Mödling (Source: Thomas Kirschner, SOL4), Adobe-Passive-House Tattendorf (Source: Meingast, natur&lehm, Reinberg Architects), Christophorushaus, Stadl-Paura (Source: BBM)

Figure 4: Special buildings in passive house standard. From left to right: S-house (Wimmer, 2005) (Source: GrAt, Schleicher Architects), Gemeindezentrum Ludesch (Source: Gebhard Bertsch, Hermann Kaufmann Architects), Schiestl House alpine refuge at Hochschwab 2154 m above see level (Source: Treberspurg & Partner Architects, pos Architects)

Figure 5: Buildings with thermal retrofit measures that meet the passive house standard. Left: Housing estate Makartstrasse-Linz (Source: Robert Freund, Arch+More Architects), Right: School Schwanenstadt (Source: PAUAT Architects)

A passive house can be designed in different ways. Austrian passive houses have been built in light-frame timber construction, in massive timber construction, and in massive construction with concrete or bricks. There are also some examples of thermal retrofit of existing buildings into passive houses. The renovation of

Makartstrasse, a 50 unit housing estate in Linz, used a super-insulated passive solar façade with integrated decentralized ventilation systems. This resulted in 90 percent savings in heating energy and operational costs. It is obvious, that Austria currently has a lot of diversified planning expertise in the field of passive houses which can be a valuable resource for foreign architects, building engineers, and planners of building services.

1.2 Sustainable energy supply

Austria currently has the highest rate of installed solar collectors per resident in Europe besides Cyprus and Greece (Weiss et al., 2007). The total area of installed solar collectors is 3.3 million m² and is increasing by approximately 0.3 million m² per year (Faninger 2007). To grasp these figures they are compared with the situation in Australia. Even with Austria's much smaller population (8.3 Mio. versus 20.7 Mio. in 2007) and less solar radiation, the annual sales as well as the total installed capacity of glazed solar collector area are about 43 % higher than in Australia (Weiss et al., 2007). This is also an important factor for the economy: More jobs are generated by the solar thermal energy industry than by the Austrian ski producers.

Table 1 Solar heat markets in Austria and Australia according to IEA (Weiss et al., 2007)

Solar Heat Worldwide	Collector Yield 2005 [GWh/a]		Total capacity installed at the end of 2005 [MW_{th}]		Annual installed capacity 2005 [MW_{th}]	
	Hot water, space heating	Total (incl. pools)	Glazed collectors	All collectors	Glazed collectors	All collectors
Austria	860	995	1690	2106	163	168
Australia	701	1971	1192	3605	114	385

Solar thermal energy concepts have been optimized by simulation with TRNSYS and successfully tested in practice. Online monitoring of solar systems has proved to be valuable for owners and occupants, providing safeguards against failure and malfunction and helping to adjust the control settings and thereby increase solar gains. Experience and planning competence are available especially for large volume houses – housing estates, office buildings, hotels, and business/industrial facilities.

Biomass is also an important energy source for heating. About 43 percent of the land area in Austria is forested. Biomass resources are used from forestry, agriculture, and the food industry and timber industries. Since biomass heating has been continuously supported, the regional economy has been strengthened. Meanwhile, Austria is one of the technology leaders in the production of boilers for split logs, wood chips, and pellets.

1.3 Success factors for the realization of sustainable building in Austria

Austria has an effective housing subsidy scheme. High income taxes (30–40 percent) enable several steering mechanisms. About 1.3 percent of the gross domestic product is used for housing subsidies. This stabilizes the building industry and has positive impact on social integration, the overall quality of buildings, and especially the ecological building performance. In early 2006, the housing subsidy scheme in the federal state Vorarlberg was revised. Passive House Standards are now mandatory for subsidized housing estates. As of October 1, 2006, a solar heating system is mandatory for subsidized housing estates in the federal state Styria.

Building laws with mandatory values for thermal insulation. Thermal resistance limits for the building envelope have been increased several times during recent decades and will be further decreased.

A law banning nuclear power plants (Atomsperrgesetz, BGBl. Nr. 676/1978). The use of nuclear power as an energy supply was prohibited after a plebiscite in 1978. This has been an early success on the road to a sustainable energy supply.

Initiatives of individuals had a relevant impact on the development of green buildings. The passive house movement started in the federal state Vorarlberg because of the commitment of individuals. Vorarlberg still has the highest density of passive houses. In the federal state Styria the use of solar collectors has started in the 70ies. Individuals who provided guidance in building the first solar collectors for private homes formed the AEE INTEC, now one of the leading R&D companies for solar heating systems. Meanwhile, individual housing developers who build each new housing estate with a solar thermal system tend to build passive housing estates only.

Funding of research and development: The R&D-impulse-program "Building of Tomorrow" of the Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT) on "technologies for sustainable development" (at:sd) has a focus on sustainable buildings and has supported approximately 200 projects (Paula+Bauer, 2005). Core projects are innovative building and reconstruction concepts and their realization.

Several demonstration buildings already draw international interest, e.g. the S-house that has been presented on SB05 in Tokyo (Wimmer, 2005).

2. Passive house students' hostel Molkereistrasse in Vienna

2.1 Building concept

The building was planned by Baumschlager Eberle P.ARC architects and Team GMI passive house engineers. At the time of completion in September 2005 it was the largest passive house worldwide with a gross floor area of 10 527 m² - this corresponds to a treated floor area of 7 715 m² according to the calculation by PHPP (PHI, 2007). The building holds 280 beds in 133 apartments on seven floors.

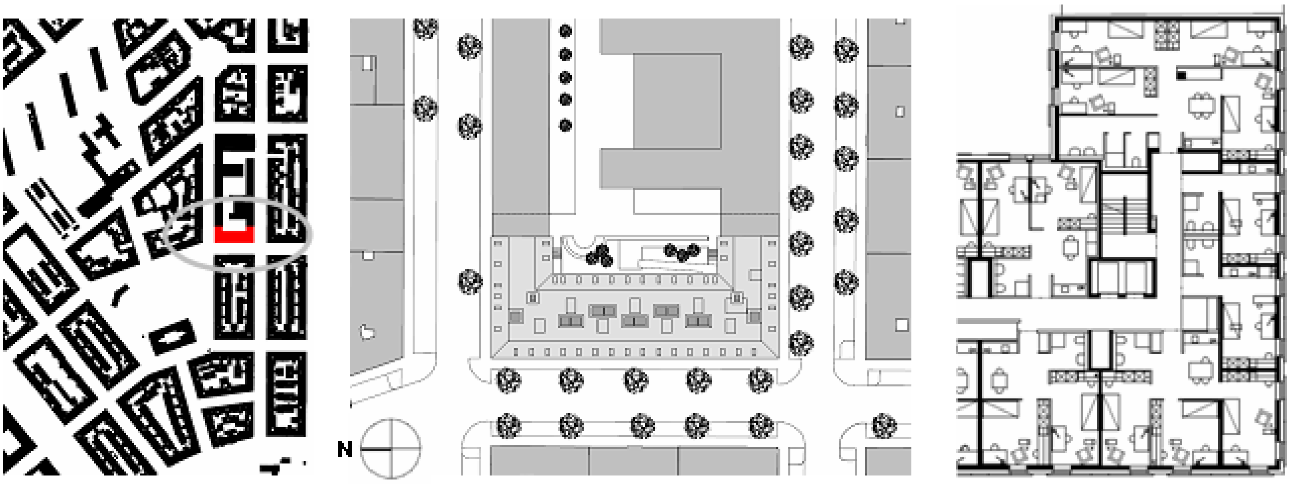


Figure 6: Site plan and floor plan of Students' Hostel Molkereistrasse. Source: Baumschlager Eberle P.ARC

The architects realized several innovative components within the strict financial regulations of the subsidy scheme. Each student has a single room with approx. 14 m² useable floor space and high quality interior equipment (wooden parquet floor, television sets, internet connection, etc.). The brass shadings act as attractive and varying structure for the façade. The shadings are manually operated and can provide a high thermal comfort during heat waves. Due to the high compactness of the building - 18 m depth of building wing -, central corridors are provided with a sophisticated daylight concept. Seven light wells have been optimized by simulation and supply daylight throughout seven floor levels.

The building has an active heating system - supplied with district heating - with mini-radiators in each room that are located above the doors near the supply air opening. Space heating and ventilation are thus separate systems with the advantage that the temperature can be regulated individually for each room by a room thermostat. A window contact automatically switches the thermostat to the lowest level (16 °C) if the windows are opened or tilted.

The distribution of warm water is done by one pipe system instead of a two pipe system (closed circuit). This concept reduces the pipeline length and therefore reduces thermal losses by more than 50 % compared to closed circuit system with the same insulation level.

The controlled ventilation with fresh air is done by small decentral ventilation units - one unit per two apartments. About 30 m³/h air is supplied per person. During cold periods with exterior temperature below 0 °C the air flow is reduced to 20 m³/h to avoid low air humidity. The fresh air is pre-heated or pre-cooled by ground-coupled heat exchangers.

2.2 Facility performance evaluation

Since February 2007 the energy consumption and user satisfaction have been measured. The first research period was analyzed and interpreted in the end of March 2008 (Smutny+Treberspurg, 2008), (Treberspurg et al., 2008). The survey is planned to go on until end of 2009. The aim of this study was to gain experience for future building projects and to improve the ecological and social performance if possible and necessary. The research project examined the actual energy consumption and the wellbeing of the occupants by means of a post-occupancy-evaluation (POE).

The survey concerned the comfort of ventilation, heating and noise and also included the associated needs and requirements of the occupants. Preliminary evaluation results showed good marks for the thermal comfort and the wellbeing of the occupants. More than 80 % of the occupants felt comfortable in the hostel.

The preliminary results were used to intensify the information on special topics (e.g. heating regulation, shading panels, window ventilation, building manual, etc.) that have been appeared to be unclear. A detailed analysis of the user satisfaction is planned to be carried out in the second investigation period. A comparison of 26 Viennese students' hostels showed that the general user satisfaction in the Molkereistrasse is very high. Only one hostel - the recently renovated Albert-Schweizer-Haus - showed better marks, but had a much lower rate of return of the questionnaires (15 %) compared to Molkereistrasse (66 %).

Heat meters and electric meters with electronically data transfer (M-Bus system) have been installed to investigate the site energy for space heating, water heating and ventilating. The site energy is the amount of energy that the user pays to the energy supplier. The calculation of useful energy for heating was done by determining the energy losses of heat distribution with the detailed information of the building services consultant Team GMI. These energy losses accounted for approx. 8 kWh/($m^{2}\cdot a$) per gross floor area (GFA).

Useful energy consumption for heating was further converted according to actual climate and actual room temperature with the purpose of comparing it with the planned heating energy demand under standard reference conditions for temperature. The median of the indoor air temperature of 20 rooms was 23.2 °C (standard deviation 1.7 K), putting the transmission and ventilation losses 22 % higher than under design conditions of 20 °C.

The following figure shows the savings of useful heating energy and interrelated operational costs and greenhouse gas emissions compared to conventional Viennese housing estates of the same size with district heating supply. The referenced value is based on the actual heating energy consumption of a high amount of buildings and has been determined by (Hofbauer, 1998). The medium value of 50 kWh/($m^{2}\cdot a$) is related to dwellings with more than 10 apartments that have been built about the year 2000. This is already a relatively good energy performance compared to older housing estates (80 kWh/($m^{2}\cdot a$); built in 1980) or compared to conventional single family houses (70-100 kWh/($m^{2}\cdot a$); built in 2000). Nevertheless, the successfully realized passive house concept showed to reduce this value by approximately factor five to a level of 11 kWh/($m^{2}\cdot a$) per gross floor area. This corresponds to approximately 15 kWh/($m^{2}\cdot a$) per treated floor area which is the limiting value according to the passive house concept.

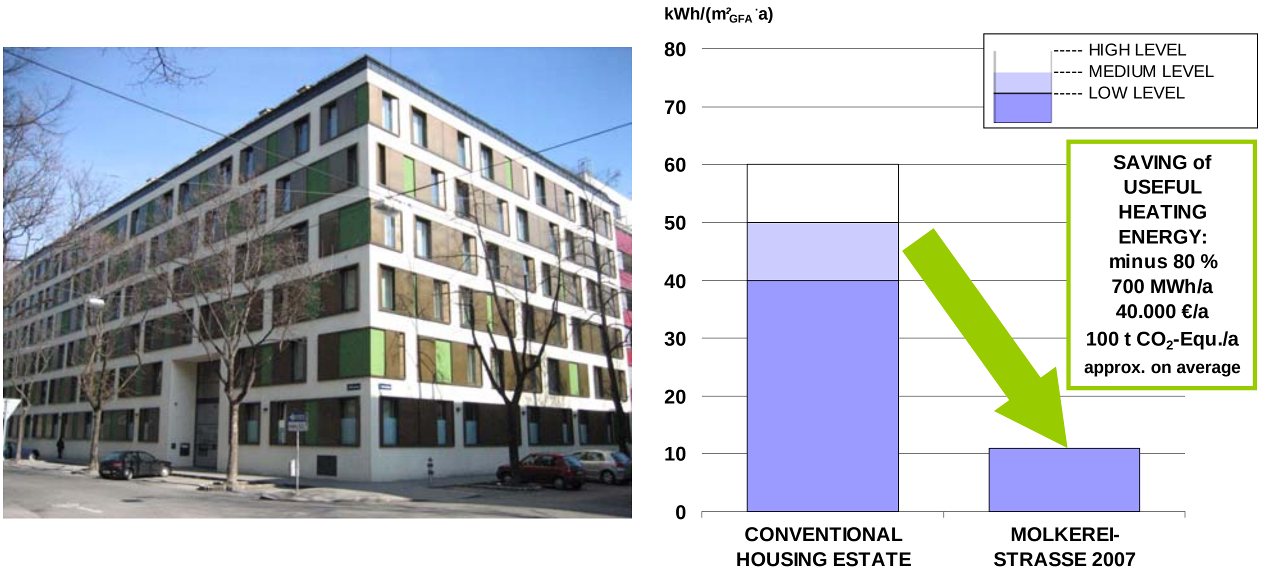
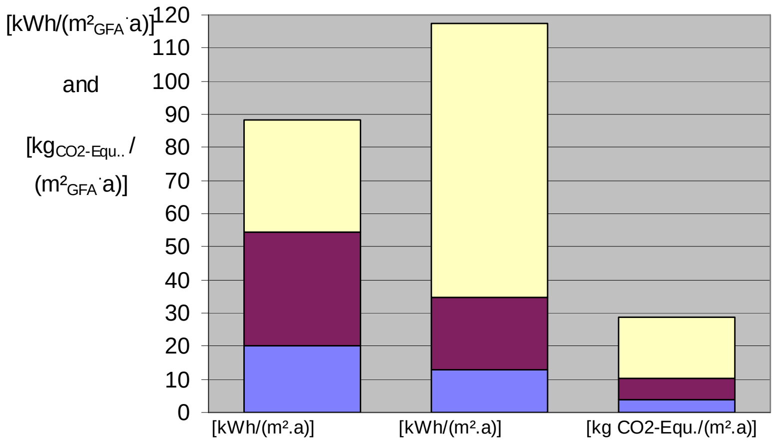


Figure 7: Useful energy consumption for space heating per gross floor area (GFA) under standard reference conditions for temperature. Passive house hostel Molkereistrasse compared to conventional Viennese housing estates built in approximately the year 2000. Foto: Roman Smutny

The second criterion for passive houses concerns the total energy consumption including electricity for household appliances, indicated by the non-renewable primary energy input (PEI_{nr}) with a limiting value of 120 kWh/($m^{2}\cdot a$) per treated floor area, calculated with factors from the GEMIS-database. GEMIS includes the total life-cycle in its calculation of impacts - i.e. fuel delivery, materials used for construction, waste treatment, and transports/auxiliaries. With the primary energy factor for the Viennese electricity supply including imports - 2.43 kWh/kWh which equals approximately the average value for Europe according to GEMIS 4.42 (UBA-AT, 2007) - the primary energy consumption of the hostel is 160 kWh/($m^{2}\cdot a$) per treated floor area. Measurements have been derived from the monitoring to reduce this value under the limiting value for passive houses in the following years.

The following figure shows the total site energy consumption (EC) per gross floor area, which has been assessed by the total non-renewable primary energy consumption (PEI_{nr}) and the total greenhouse gas emissions (GHG) using the corresponding factors for Viennese energy supply including imports (UBA-AT, 2007). The total values for these three energy services are 88 kWh/($m^{2}\cdot a$) EC, 117 kWh/($m^{2}\cdot a$) PEI_{nr} and 29 kg/(m²·a) of CO_2-Equivalents GHG. Please note that these values can not be compared to the passive house criteria, because of the different reference floor area. By the way, there is no criterion for GHG in the passive house concept.



	[kWh/(m².a)] EC	[kWh/(m².a)] PEInr	[kg CO2-Equ./(m².a)] GHG
Electrical Energy, total	34	83	18,1
District heating, Hot water	34	22	6,6
District heating, Space heating	20	13	3,8

Figure 8: Site energy consumption (EC), non-renewable primary energy consumption (PEI_{nr}) and greenhouse gas emissions (GHG) for space heating (not standardized), hot water and electrical appliances per gross floor area (GFA) and year. Medium values of the period 09.2005 - 08.2007.

The analysis of the total energy consumption showed the importance of hot water generation for the overall performance, which was underestimated in the planning stage. The design value for water heating (25 litres with 60 °C per person and day as an ordinary value for conventional housing estates) is approximately half of the actual consumption value. The comparison with four other students' hostels (see *Figure 9* and (Engelmann et al., 2008)) surprisingly showed that the hostel in Molkereistrasse had the lowest value.

The analysis of the primary energy input and the greenhouse gas emissions showed the importance of electricity consumption for the overall performance. Electricity consumption causes 71 % of the total PEI_{nr} and 62 % of the total GHG.

2.3 Comparison with other Viennese students' hostels

In order to evaluate the energy performance and climate protection performance of the hostel in Molkereistrasse, three other Viennese students' hostels have been analysed that had been built in the period 1996 to 2005 and are also supplied with district heating. It is important to keep in mind that a direct comparison of the ecological performance of different buildings has only a limited significance due to methodological frameworks. According to the ISO standards for life cycle assessment (ISO 14040 - 14043) the same functional unit has to be used for comparisons of products or processes. The functional unit of buildings should respect the benefit and comfort of the apartments and therefore has to take into account the quality of the building services and equipment as well as the overall quality of the indoor environment. The passive house concept aims at optimising the thermal and hygrical comfort, the air quality and the daylight quality. For that reason it can be assumed, that the indoor environment in the hostel Molkereistrasse has a higher benefit for the students than in the other hostels, which has been verified by the survey of 26 students' hostels in Vienna. Furthermore the hostel Molkereistrasse offers single rooms only with television sets and internet connection, which is not the fact for the other hostels. Nevertheless, the useful floor area has been preferred as functional unit of the comparison due to practical reasons. The difference in the benefit is expressed qualitatively in addition and has to be kept in mind for the interpretation of the results.

The following figures show the comparison of the energy performance and climate protection performance of four Viennese students' hostels per useful floor area (UFA).

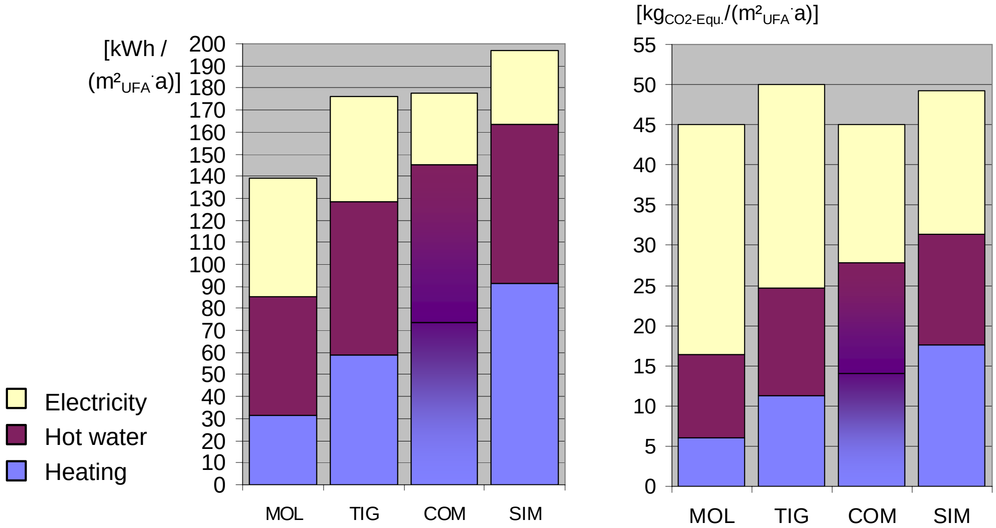


Figure 9: Total site energy consumption (left chart) and greenhouse gas emissions (right chart, factors for Viennese energy supply including imports). Space heating (not standardized), hot water generation and electrical appliances per useful floor area (UFA) and year. Four Viennese students' hostels Molkereistrasse built in 2005 (MOL), Tigergasse built in 2000 (TIG), Comeniusgasse built in 1996 (COM) and Simmeringer Hauptstrasse built in 2005 (SIM). All supplied with district heating. Medium values of the period 09.2005 - 08.2007.

Remark: For the interpretation of the results it is important to take into account the higher benefit of the passive house Molkereistrasse (MOL) concerning thermal comfort, hygrical comfort, air quality, daylight quality, summerly comfort, available TV-Sets, available internet connection, other qualities of the building services and equipment.

The oldest of the four hostels (Comeniusgasse, built in 1996) had the lowest electricity consumption The comparative values of Tigergasse and Simmeringer Hauptstrasse were approximately 50 % higher and of Molkereistrasse approximately 100 % higher. In the survey of the user satisfaction the hostel Comeniusgasse was on 25th position of 26 investigated Viennese hostels. This result can also be referred to the very low building services and equipment quality that causes low electricity consumption. The greenhouse gas emissions (GHG) are dominated by the electricity consumption due to a higher GHG-Factor (533 kg/MWh) compared to district heating (192 kg/MWh) according to GEMIS-Austria (UBA-AT, 2007).

The added value of the hostel Molkereistrasse compared to the hostel Simmeringer Hauptstrasse - with the most similar benefit and quality per usable floor area - is a saving of the total energy consumption of approx. 60 kWh/(m^2_{UFA}·a) - minus 29 % - and a saving of GHG-Emissions of 4.2 kg/(m^2_{UFA}·a) - minus 9 %. With the assumption of the same useful floor area (6 687 m²) the annual savings of district heating amount 520 MWh (78 kWh/(m^2_{UFA}·a)) which corresponds to 34 000 € (5.1 €/(m^2_{UFA}·a) and 100 t CO_2-Equivalents (15 kg/(m^2_{UFA}·a)).

3. Conclusions

The passive house students' hostel Molkereistrasse offers a very good energy performance and climate change performance regarding space heating and hot water generation. The user satisfaction is extremely high. Savings in operational costs for space heating and hot water generation amount approximately 34 000 € per year.

An appropriate design value for water heating in students' hostels is 50 litres with 60 °C per person and day, which corresponds to a low value for hotels with shower (Recknagel et al., 1997). The hostel in Molkereistrasse had the lowest energy consumption for hot water compared with 4 other hostels, which is likely to be caused by the efficient hot water distribution (one-pipe-distribution).

The results of a direct comparison of the ecological performance of passive houses with other buildings have only a limited significance due to a different benefit and comfort of the apartments. The benefit of passive houses is higher (or should be higher if designed and built accurately) regarding thermal comfort, hygrical comfort, daylight comfort, summerly comfort, air quality and larger useable floor area (because of less lost area for radiators and more comfortable area beside windows).

Recommendations are derived to improve the energy performance and the user satisfaction in the students' hostel Molkereistrasse. The consumption of electric energy can be reduced by energy efficient equipment, by a more frequent change of filters in the ventilation units, by a reduction of the ventilation in summer season and other measurements.

For the realization of sustainable students' hostels the passive house concept should be implemented comprehensively including concepts to reduce the consumption of energy for hot water generation and electrical energy, e.g. photovoltaic, energy efficient household appliances and lighting and others.

The passive house concept has proven to be effective to reduce the energy consumption and the fossil energy carriers for space heating and hot water generation. However, it is difficult to reduce the electricity consumption due to increasing comfort requirements regarding electrical equipment (e.g. tumbler, internet usage) and due to more powerful technical equipment (e.g. computer, larger TV-Sets, etc.). An increasing electricity demand has to be avoided to avert new power plants and to protect the climate. Therefore space heating and hot water generation should minimize electrical energy consumption and concepts to reduce electricity should be intensified and promoted.

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