- Detailed Professional Report -

In the first research year, a comparative investigation of two different building energy calculation methods was performed. The calculation procedures were analysed provided by TRNSYS and WinWatt tool through the modelling of a family house heating system with a widely used condensation gas boiler in one case and with an increasingly popular air-to-water heat pump in the other. With TRNSYS 18 computer tool a dynamic simulation energy model was developed, while the WinWatt software calculates by standard analytical heat transfer equations according to the Hungarian implementation of EPBD (Decree No. 7/2006). The results were compared with each other and validated with experimental energy consumption data. Using the 3 years measured consumption data (in 2015: 33,971; in 2016: 34,356 and in 2017: 33,653 kWh/m2a) given by the investor, the result shows that the difference between the measured consumption data and simulated date by TRNSYS is only 1,11% and by WinWatt is 12,51%. By this way the difference between the real consumption data and calculated data based on Hungarian building energy decree (Ministerial Decree TNM 7/2006) is quite high. WinWatt calculated a greater value for the annual specific energy consumption in case of both heating systems: for the gas boiler heating system, the calculation result of WinWatt was 87,789 kWh/m2/a and the calculation result of TRNSYS was 75,98 kWh/m2/a. In the case of the heat pump system, the difference between the two values is smaller: the calculation result for the annual specific heating energy consumption was 38,475 kWh/m2/a with the software using the calculation method provisioned by the Hungarian Decree and 33,82 kWh/m2/a with the software performing the dynamic simulation. In the case of heat pump systems, the difference is smaller and the energy consumption values themselves are smaller as well. The difference between the data obtained with the calculation method provisioned by the Hungarian decree and the data obtained using TRNSYS can also be attributed to several factors. The difference in the annual specific primary energy consumption can mostly be attributed to the fact that the weather data used by the two calculation methods are different. During the model developing the by TRNSYS, the weather data file published by Meteonorm was used, which was prepared using the measurements of the Budapest-Pestszentlőrinc meteorological station. Meteonorm's TMY (typical meteorological year dataset) is based on the results of decades of measurements using the data of GEBA (Global Energy Balance Archive) from between 1991 and 2018 as starting points, while the Decree is based on meteorological data measured between 1901 and 1930 from the last century. The major findings obtained from this work are summarized as follows:

1. Comparing the energy consumption values obtained using TRNSYS 18 working with dynamic simulation and the ones obtained using WinWatt working as provisioned Decree 7/2006 TNM, it can be stated these values are lower in case of TRNSYS.
2. Using the dynamic simulation, 87.9% lower annual specific primary energy consumption was obtained in case of the heat pump heating system and a 86.55% lower value in case of the boiler system.
3. The more accurate calculations of the dynamic simulation may have contributed to the difference, but in my opinion, the most important reason for the lower energy consumption is that the two calculation methods used different weather data.
4. TRNSYS calculated with a 10% lower degree-day based on the temperature data of the recent decades. Based on my calculations considering the current electricity and natural gas prices, the air/water heat pump heating system is not as cost efficient as the boiler heating system; however, the former provides higher levels of comfort, because with the usage of heat pump not only heating, but also cooling in summer season can be provided.

The student assistants, supervised by me, worked also hard in the research and submitted their research work to the Conference of Scientific Students' Associations ("TDK") that was organized on the 19th of November in 2018 at the Budapest University of Technology and Economics. Two students, working on the same research project, gave placement in our faculty with the under mentioned data:

Name of the MSc. students: Dénes Ábrahám, Brúnó Zoltán Kóródi
Title of the „TDK" research work: Energetic investigation of heat pump systems by dynamic simulation
Placed II. in Building Service Engineering Section

In the second research year, investigation of the energy recovery potentials in ventilation systems under different climatic conditions was performed. The well-known heating degree day from the literature was updated using the weather data of cities with different climates from the past 40 years. As the novelty of the research with the developed procedure drawn up in the study, the energetic possibilities of heat recovery under various climate and operating conditions may be investigated in more detail and more realistically than with the methods and available information of current engineering practices. To achieve this long-term and high definition weather data of several cities are processed in order to evaluate the possibilities of heat recovery on a daily and annual

basis. Analysed cities were selected on the basis of diversity of their climates, within the possibilities offered by the Wolfram Alpha database. The major findings obtained from this work are summarized as follows. From among all cities, Belem is outstanding, where heat recovery during the cooling period exceeds the annual amount experienced in all other cities. The least amount of energy can be saved in Sydney, while the amount of savings are not negligible. The energetic similarity shows between Sydney, Szeged, Buenos Aires, Cairo, Dakar and perhaps even Barcelona and Nanchang, with a similar magnitude of recoverable energy amounts during the heating and cooling seasons. Similarly, Tehran, Versailles, Portland, Dublin, Budapest, Odessa, Toronto and Oslo can be ranked together, where the expected recoverable heat amount during the heating season significantly exceeds that during the cooling season. In the case of Miami, Doha, Mumbai and Belem the opposite applies, yet expected heat recovery is significant in these cities during the cooling season. The above findings apply to a constant 22 [°C] temperature and 50 [%] relative humidity condition of exhaust air. In the evaluation program these are represented in the function of the enthalpy of exhaust air, which parameter can later be substituted by any arbitrary ambient, or indoor parameter. Accordingly, the generated curves can be universally applied for calculations under any static, or dynamically changing conditions of exhaust air. The exploitation of this opportunity shall also be the subject of future research work. Using the developed method, a large number of auxiliary tables have been generated on the basis of weather data, which may be utilized in the course of design work and which allow for estimation of the expected realizable energy saving of ventilation equipment in any given month, during any time interval of operation in the function of the temperature and relative humidity of exhaust air, with a given expectation – applied decile curve.

Supervising the student assistant in the topic, named Máté Panyi has submitted his research work to the Conference of Scientific Students' Associations ("TDK") that was organized on the 12th of November in 2019 at the Budapest University of Technology and Economics. Title of his „TDK" research work: Energetic investigation of heat recovery ventilation system. He won the III. placement in Building Services and Process Engineering Section.

During the third research year, energetic investigation of air-conditioning system used in commercial sector was performed. The object of the research work was to develop a thermal simulation model that can be used to investigate the thermal parameters of the refrigerant systems (with ON-OFF and PID control) used in cooling chambers. Moreover the model was further developed which takes into account also the types of compressors, feeder and control units used commonly in practice for energetic investigations. Using the measured energy consumption data obtained by experimental tests during the previous phase of this research work, the validation of the developed energy simulation model by MatLab R2016a could be also achieved with good agreement. MatLab software seemed to be the most appropriate tool for numerical investigations on the energy consumption of refrigeration systems used in commercial cold stores and transient behavior of the indoor air temperature of the cold store, cooling energy performance and consumed energy to the goods stored in cold store. 2 Based on the national and international research studies and regulations it is particularly significant to develop simulation models to enable the energetic investigation of air-conditioning systems in more detail and more realistically than with the recent methods provide in the current engineering practice. My aim was to improve the energy conscious refrigeration system designing, and develop the current calculation procedures and completing design data. To achieve this, object of this research was to work out simulation procedure to determine the energy consumption of refrigeration systems used in commercial sectors with more detail method and more realistically results than provided the recent standards and regulations. By this way the aim of the recent research work was to support also the building service engineers and designers to make more exact energy certifications for buildings. In this study the investigation of thermal and energetic properties of PID and ON-OFF controlled refrigeration systems was conducted considering also the transient effect of the placed product. Using the measured energy consumption data obtained by experimental tests during the previous phase of this research work, the validation of the developed energy simulation model by MatLab R2016a could be also achieved with good agreement. The result of the transient investigation of 5 [kg] goods, placed in the chamber, showed that it takes almost 4 hours to cool down the goods from the initial temperature of 27 [°C] to around 1 [°C] and the energy consumption is 17,996 kWh with PID and 19,068 kWh with ON/OFF controlled refrigeration systems. Investigating the energy and as well as the economic impacts of the two systems under transient conditions, the cooling of 5 [kg] goods in 4 hours resulted 1,072 kWh (5,62 %) energy saving and 0,08672 EUR saving, considering the national industrial consumer energy price (0,0809 EUR/kWh), with the PID controlled system compared to the ON/OFF controlled system. The developed simulation model enables the investigation of the thermal behaviors and energy consumption of a designed cold store for building service engineers. Using the model the effect of the control system on the energy consumption and on the cooling rate can be also investigated which can influence also the quality of the stored goods. The developed simulation model is suitable to investigate the energy consumption and thermal behaviors only the refrigeration systems that are operated with ON-OFF or PID controller device.

Totally 21 pieces of publications were made in the topic during the research term financially supported by the National Research, Development and Innovation Office of Hungary [grant number NKFIH PD_18 127907], Budapest, Hungary. From this there are 10 pieces of international peer-reviewed scientific journal papers found in Web of Science database (WoS) from which 7 pieces have impact factors (IF). Furthermore, there are 8 pieces of published national peer-reviewed scientific journal papers and finally 3 pieces of peer-reviewed scientific papers that were published at international scientific conferences.

Publications/years

I. Year

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[2] Kassai Miklós: Családi ház energetikai vizsgálata dinamikus szimulációval, Magyar Épületgépészet, LXVIII. évfolyam, 2019/4. szám, HU ISSN 1215-9913, pp. 1-6. (2019)

[3] Miklos Kassai: Recovering Heat from Condenser Unit Produced Refrigerant System in Food Processing Facility. Periodica Polytechnica, Mechanical Engineering, ISSN: 0324-6051 pp. 1-10. DOI: 10.3311/PPme.14044, (**WoS; SJR: Q3**) (2019)

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II. Year

[6] Miklos Kassai, Energy Performance Investigation of a Direct Expansion Ventilation Cooling System with a Heat Wheel. **Energies**, vol. 12(22), 4267, pp. 1-16, DOI: 10.3390/en12224267 (**IF=2.707**) (**WoS: Q2; SJR: Q1**).

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III. Year

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International Journal of Green Energy, Vol.: 18., Issue: 4., pp. 390-401., DOI: https://doi.org/10.1080/15435075.2020.1865365, (**IF=1.338**) (**WoS: Q4; Scopus, SJR: Q3**), (2021).

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