Study of heat loss: Ramirent rental modules

Kristjan Edula¹

¹Ramirent Modular Factory AS, 75306 Lehmja, Harju County, Estonia

Abstract. Ramirent Modular Factory (RMF) has conducted the study in cooperation with Tallinn University of Technology to measure heat loss and calculate estimated energy consumption and monthly energy cost of common Ramirent rental modules. The need for the study emerged from Ramirent's rental customers who have requested more environmentally friendly modules. This research was initiated to prove the theoretical assumption that the 2 wooden modules included in the study, which were produced by Ramirent Modular Factory, have lower heat loss and lower monthly energy costs per m², compared to the steel modules. There were 6 different modules included in the study, 2 steel modules with mineral wool insulation, 2 steel modules with polyurethane insulation and 2 wooden modules with mineral wool insulation. The energy consumption was measured between 21.12.2018 -15.05.2019. Exterior and interior climate of the modules was measured during the research. The conclusion is that 2 wooden modules produced by RMF are most energy efficient and have remarkably lower heat loss per m² than other modules included in the research. The calculated heat loss of a wooden module was in correlation with the energy consumption measurements. The real measured energy consumption of the steel modules was higher than calculated values. Future studies of heat loss are needed to eliminate disturbing factors and considering the use of ventilation aggregate with heat exchanger vs. direct forced air extraction, while maintaining healthy interior climate requirements.

1 Introduction

This study was commissioned by Ramirent Baltic AS and conducted by Nearly Zero Energy Buildings Research Group from Tallinn University of Technology.

The purpose of the study is to compare how modules produced by Ramirent Modular Factory compare to other module types and to measure the actual energy use of the modules under controlled conditions over a longer period.

2 Methods

2.1 The modules

In total, heat loss of six common rental modules used in Ramirent Baltic and Finland was measured at Jüri, Ramirent Modular Factory. Modules No.1 (FFA) and No.6 (SHAA, Fig. 1) are wooden modules, produced by Ramirent Modular Factory, all other modules are steel modules. The modules' specifications are shown in Tables 1 through 3. All the modules were placed in similar climatic conditions. Ventilation openings were sealed as the purpose was to investigate the heat loss of the enclosure structures.

Fig. 1. Module No.6, SHAA

* Kristjan Edula: kristjan.edula@ramirent.ee

Table 1. Modules specification.

	Module	External dimensions, mm (LxWxH)	Heated Floor Area, m ²	Built (year)
1.	FFA	7226 x 3442 x 3000	21.4	2018
2.	PU100	6055 x 2435 x 2591	13.1	2018
3.	MW100	6055 x 2435 x 2591	13.1	2018
4.	MW60	6055 x 2435 x 2591	13.1	2017
5.	PU60	7180 x 3290 x 3000	20.5	2008
6.	SHAA	8474 x 2924 x 3000	20.5	2019

Table 2. Modules insulation. MW- mineral wool, RW- rock wool, PU- polyurethane foam

	Module	Floor, mm	Exterior Wall, mm	Roof, mm
1.	FFA	MW150	MW130	MW200
2.	PU100	PU100	PU100	PU140
3.	MW100	MW100	MW100	PU140
4.	MW60	MW100	MW60	MW100
5.	PU60	PU100	PU60	PU100
6.	SHAA	RW150	MW45+ RW120	MW50+ RW170

Table 3. Thermal Conductivity of the Module's Envelope Structures W/(m²·K)

	Module	Floor	Ext. Wall	Roof	Win-dow	Door
1.	FFA	0.24	0.26	0.21	1.29	1.80*
2.	PU100	0.20	0.20	0.15	1.10	1.80
3.	MW100	0.36	0.35	0.15	1.10	1.90
4.	MW60	0.36	0.57	0.36	1.10	1.90
5.	PU60	0.20	0.20	0.15	1.10	1.80
6.	SHAA	0.18	0.22	0.18	0.98	1.80*

*Exact value is unknown, estimated value is used in calculations

2.2 Measurements

Indoor air and floor surface temperatures of each module were measured, with a data logger Hobo U12-013 Temp/RH/Ext/Ext, Fig. 2.

Outdoor temperature was measured from one module's north facade. Fig.3.

Before the sensors were installed, the sensors were benchmarked and the results differed only $\pm 0,1$ C, Graph 3.

The whole measurement period lasted 13.12.2018 – 17.07.2019.

Electricity consumption was measured with additional electricity meter installed in each module and an electricity meter in the electrical cabinet, Fig.4. All electric convector heaters were directly connected to the same measuring circuit.

The energy use of the modules was measured over two periods of time:

In the wintertime: 21.12.2018 – 11.04.2019;

In the springtime: 11.04.2019 – 15.5.2019.

Fig. 2. Measuring set-up, Module No.2, PU100

Fig. 3. Measurement of Outdoor Temperature and Humidity

Fig. 4. Measurement of Electricity Consumption Using a Separate Meter (on the left) and a Electricity Meter (on the right) in the Electrical Cabinet

3 Results

3.1. Comparison of measured and calculated heat loss

Spring heat loss is lower than in winter (Fig. 5), because of the free heat of the sun reduces the need for heating.

Fig. 5. Heat Loss per m² of Heated Area

At module 1, the measured heat loss (as it is) in the winter corresponds exactly to the calculated heat loss (how it should be). For modules 2, 3, 4, the calculated heat loss is much better than the result measured. This indicates a higher heat loss in practice. The reasons for increased heat loss may be:

- quality of installation of insulation,
- the declared thermal transmittance is not correctly calculated,
- in practice, greater heat loss through thermal bridges,
- in practice, greater heat loss due to higher air leakage,

After analyses of the results it came out that starting from spring some modules got more sun exposure than the others.

3.2. Electricity cost

The cost of heating per m² of Module No.1 FFA is remarkably lower than compared to other modules, Fig.6.

Fig. 6. Electricity Cost for room heating per Module & per m² in February

In the Fig. 6 the average electricity for room heating price per kWh is taken from data provided by Eurostat (Statistical Office of the European Union). The average electricity price per kWh in this study is set at 0.14 €.

3.3. Comparison of floor and room temperatures

The average floor temperature of module No.1 FFA was more than 1.8 degrees higher compared to other modules, Fig. 7.

Fig. 7. Average Floor Temperature in February

4 Results

In this study, the indoor climate of the modules was measured for the period of 13.12.2018-17.07.2019 and the energy use for the period 21.12.2018-15.05.2019. In addition to the measurements, the calculated heat loss of the modules was compared with the measurement result.

Based on results of the measurement, modules FFA and SHAA are the most energy efficient.

The calculated heat loss of Module FFA corresponds to the measurement results.

The actual measured heat loss of the modules PU100, MW100 and MW60 is greater than it should be based on computational analysis.

The outcome of the study is affected by various factors. The FFA and MW100 module got partially more sun exposure than other modules. The exterior doors on PU100, MW100 and PU60 modules were not fully airtight (it was discovered in the end of the measurement period), due to bent door blades or wore out rubber door seals. Based on these factors the results could deviate up to 10%.

Future studies of heat loss are needed to eliminate the factors described above. Considering the use of ventilation aggregate with heat exchanger vs. direct forced air extraction, while maintaining healthy interior climate requirements.

References

1. T. Kalamees, E. Arumägi, 2019. Heat loss study of wooden modules (2019)