HEAT ENGINEERING

GENERATION OF A TYPICAL METEOROLOGICAL YEAR FOR ALŪKSNE, LATVIA

Mārtiņš Ruduks
Latvia University of Agriculture, Department of Architecture and Building
Email: martins.ruduks@inbox.lv
Arturs Lešinskis
Riga Technical University, Institute of Heat, Gas and Water Technology
Email: Arturs.Lesinskis@rtu.lv

ABSTRACT

Meteorological conditions vary significantly from year to year. For this reason, there is a need to create a typical meteorological year (TMY) data model, to represent the long term weather conditions over a year. TMY data is one of the main sources for successful building energy simulations. Two different typical meteorological data models were generated and compared: TMY and TMY-2. Both models where created by analysing every 3-hour weather data for a 30-year period (1984–2013) in Alūksne, Latvia, provided by the Latvian Environment Geology and Meteorology Centre (LEGMC). TMY model was created using statistical approach, but to create second model - TMY-2, 30 year average data were applied. In the TMY model creation representative typical meteorological months (TMM) were selected. TMM for each of the 12 calendar months were selected by choosing the one with the smallest deviation from the long-term average weather data. The 12 TMMs, selected from the different years, were used to create a TMY for Alūksne. The data gathered from TMY and TMY-2 models where compared with the climate data from the Latvian Cabinet of Ministers regulation No. 379, Regulations Regarding Latvian Building Code LBN 003-01. Average monthly temperature values in LBN 003-01 were lower than the TMY and TMY-2 values. TMY selection process should include the most recent meteorological observations and should be periodically renewed to reflect the long term climate change.

Key words: Typical meteorological year; climate change, building energy simulations

INTRODUCTION

In Latvian legislation long-term climate data are reflected in the Latvian Building Code (LBN) 003-01 „Būvklimatoloģija" (23.08.2001, Riga), where various climatic indicators are shown that represents the climatic situation in the territory of Latvia, providing information about the average monthly and yearly meteorological parameters. But this information is not sufficient to fully describe the region's climatic conditions, because there is a necessity to define the daily and hourly meteorological data values.

The need of such meteorological data worldwide led to the development of methodologies for generating the typical meteorological year (TMY). TMY is data set that contains a sequence of 8 760 hourly values of chosen meteorological quantities. The requirement of TMY is that it has to correspond to an average year (Skeiker, 2004). TMY provides hourly climatic parameter values, enabling one to use these parameters for heating, ventilation and air conditioning (HVAC) device management and capacity optimisation.

Creation of the TMY was introduced in 1978 by Hall et al. (Hall et al., 1978). For a network of stations in the United States, a representative database consisting of weather data was created. Hall's method has been used to successfully generate TMYs for a number of locations across the globe (Chan et al., 2006; Guggenberger et al., 2013; Hall et al., 1978; Jiang, 2010; Kalogirou, 2003; Lee et al., 2010; Skeiker, 2007; Skeiker, 2004; Yang, et al., 2007; Zang et al., 2012; Zariņš, 2001; Zhang, 2006).

Figure 1. Location of Alūksne

LBN 003-01 describes climate parameters for ten cities in Latvia. These parameters have been calculated using data from 1961-1990. The aim of this research is to generate a representative climate database for one of these cities – Alūksne, by employing the method that has been proposed by Hall et al. (Hall et al., 1978) and adapted in Latvia by Zariņš (Zariņš, 2001). Generation of The TMY of Alūksne would provide hourly climate data that LBN 003-01 does not provide.
Geographical data for Alūksne: latitude 57°26' N; longitude 27°02' E; on a relatively flat surface, elevated 193 m above sea level, located 160 km from the Gulf of Riga (Fig.1).Average temperature is 4.5 °C.
The TMY is generated by using the available weather data obtained from the station of Alūksne by the Latvian Environment Geology and Meteorology Centre (LEGMC), covering the period from 1984–2013. LEGMAC database provides 3-hour weather data values for temperature and relative humidity.
This is the first time in Latvia when 30 year weather data have been used to create a TMY.

MATERIALS AND METHODS

The TMY models where created applying two different TMY creation methods. TMY model was created by using method that was described by Hall et al. (Hall et al., 1978) and adapted in Latvia by Zariņš (Zariņš, 2001). The second TMY model – TMY-2 was created by applying the average meteorological year method (Skeiker, 2007). The TMY model consists of weather data that have been observed in one of the 30 year periods. This method includes temperature peaks that can be used to determine the appropriate power for HVAC systems. The TMY-2 model consists of the averaged 30 year weather data, this method does not show the temperature peaks, but it shows the most precise average monthly temperatures. The TMY-2 model is best used for calculating average long-term building energy consumptions for HVAC systems.

TMY creation

Climate data for TMY creation were obtained from the LEGMC database from 1984–2013. LEGMC provides climate data with 3 hour intervals, but TMY needs hourly climate data. The necessary data for TMY were calculated by linear interpolation.
In February there may be 28 or 29 days, and it is not possible to compare years with a different count of days, e.g. the 29th day. February was excluded from the TMY creation. The rest of the days where rearranged in ascending order starting with the first hour of January till the last hour of December (8 760 values).

For each month the temperature distribution was calculated – how many hours per month each of the temperatures (in the range from –35 °C to 35 °C) was observed. This procedure was used for each month of the 30 year period. Each month can be included in the TMY, but before it is determined it is called a candidate month.
Adapted Halls TMY creation method (Hall et al., 1978) tries to find the most typical month – typical meteorological month (TMM), for each of the 12 months (January–December), from the observed time period (1984–2013).
To determine the TMM for each of the 12 calendar months, each month's temperature distribution was compared with the temperature distribution from a 30 year period. The sum of the square error (SSE) parameter was used (equation 1) to compere months. When all 30 year SSE values were compared the month that had the lowest value of SSE (equation 2) was chosen as the TMM and was included in the TMY. This action was applied for all 12 calendar months.

$$SSE = \sum_{i=1}^{n} (x_i - \bar{x}_i)^2 \tag{1}$$

where x_i - temperature distribution value in a candidate month;
$\bar{x}_i$ - temperature distribution value from 30 year average data

$$SSE = \sum_{i=1}^{n} (x_i - \bar{x}_i)^2 \to \min \tag{2}$$

where x_i - temperature distribution value in a candidate month;
$\bar{x}_i$ - temperature distribution value from 30 year average data

All the TMMs were combined and TMY was generated, but as TMM where from different years and there was mismatch of values at the connecting point of two TMM. Last 6 hours of the preceding month and the first 6 hours of the following month were smoothened by replacing them with the average values.
The TMY model includes temperature and relative humidity values, temperature values are selected as described, but relative humidity values for the TMY are determined according to the selected TMM. Relative humidity values are smoothened at the connecting point of two TMM like with the temperature.

TMY-2 creation

The TMY-2 model was created with average meteorological year method (Skeiker, 2007). In this method the same climate data were used as it was in

TMY model creation. And they were arranged starting from the first hour of January till the last hour of December. Each of the TMY-2 model 8 760 temperature and relative humidity values was calculated by averaging this value from 30 year data.

RESULTS AND DISCUSSIONS

TMY was created combining TMMs that are determined based on their ability to follow the long term distribution. Selected month/year combinations from which the TMY was created are shown in Fig. 2. Two months (November, and December) were selected from one year (1989), but other months were selected from different years. This displays that TMMs are selected from all ranges of the observed period.

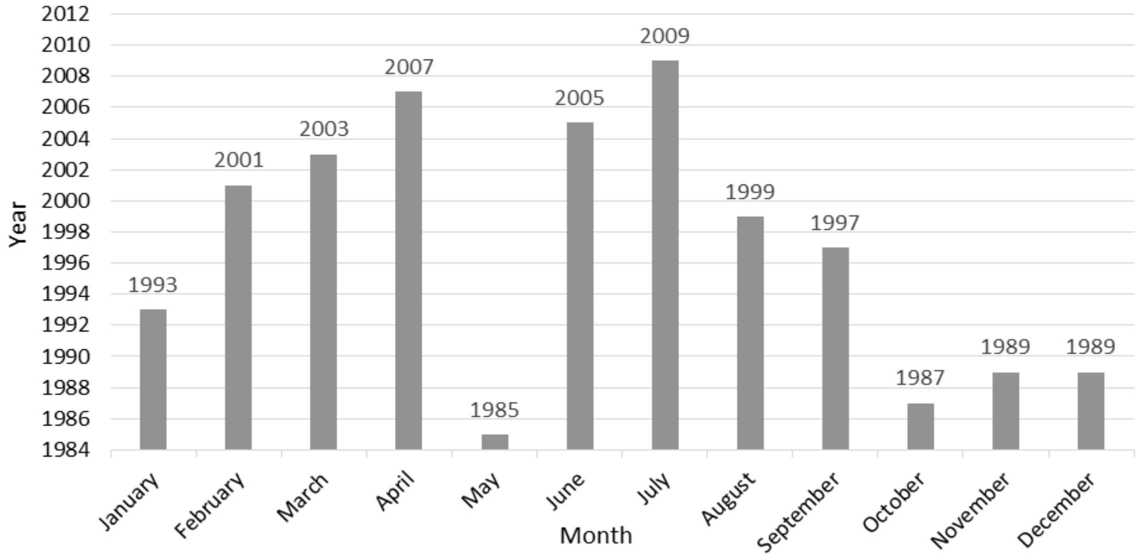

Figure 2. The Month/Year combinations for the composition of TMY

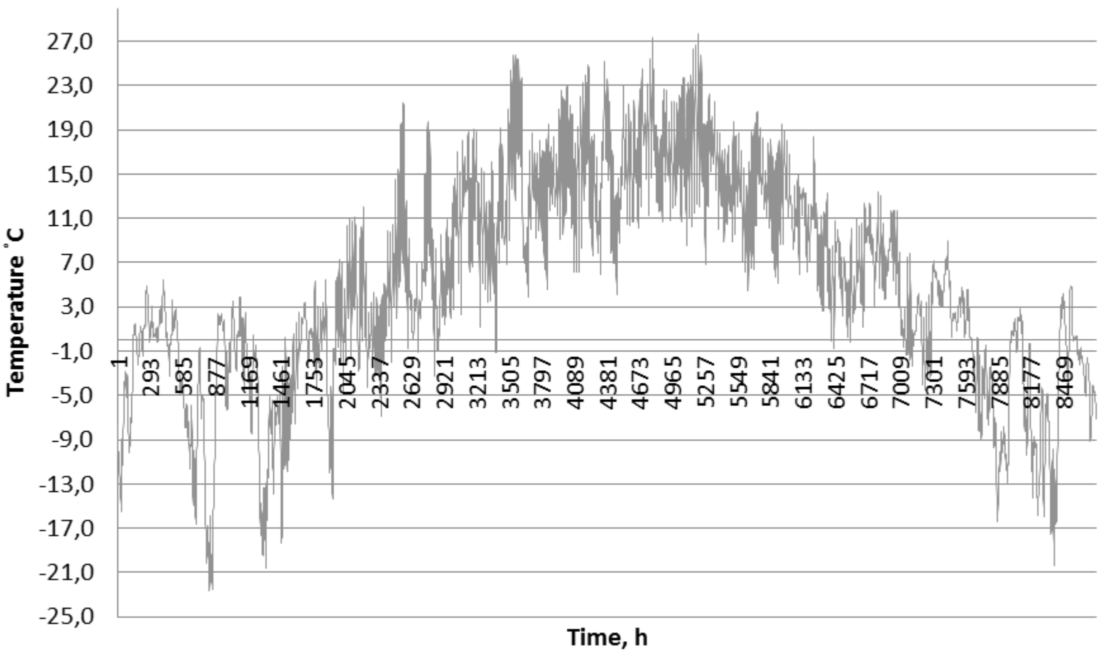

Figure 3. Temperature fluctuation in TMY

After TMMs were connected and the TMY was created, temperature fluctuation (Fig. 3), temperature distribution (Fig. 5), relative humidity fluctuation (Fig. 4) and relative humidity distribution (Fig. 6) was displayed.

When TMY and TMY-2 temperature distribution values are compared with the 30 year average data (long term data) (Fig. 5), TMY shows good agreement with the long term data. TMY value deviation from long term data is a maximum 100 hours per year at 3 °C, but TMY-2 deviation at –5 °C is more than 470 hours per year. The difference between TMY and TMY-2 models can be explained by the fact that TMY-2 is made averaging climate data and it does not contain the maximum and minimum temperature values.

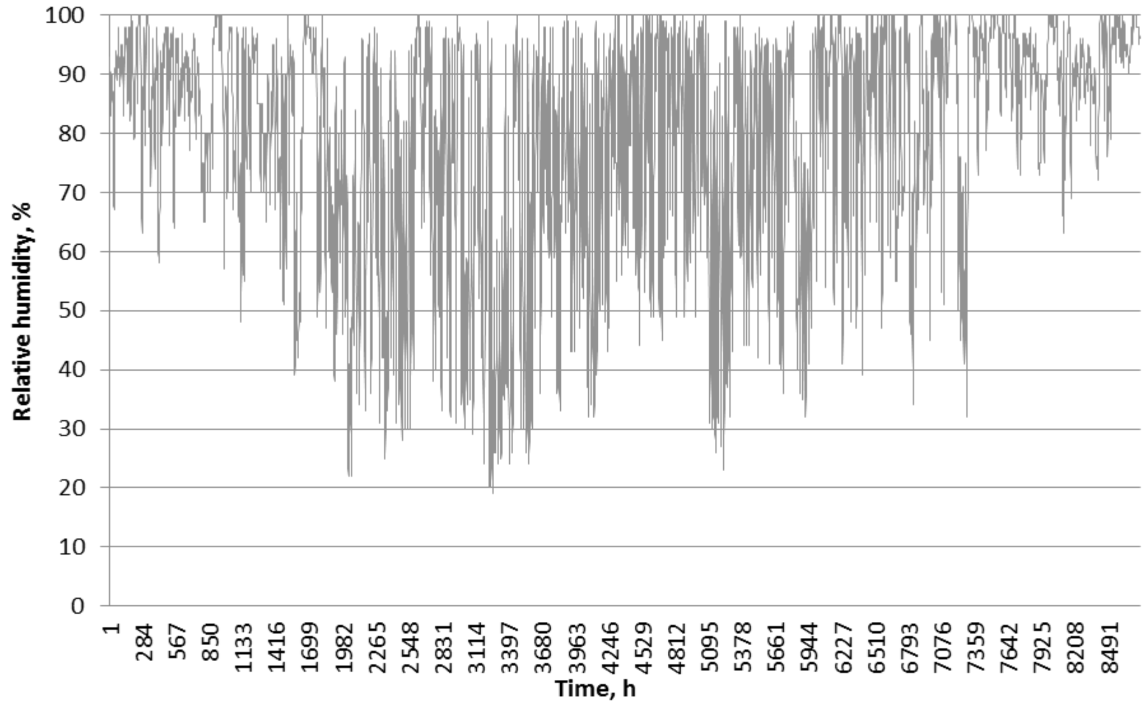

Figure 4. Relative humidity fluctuation in TMY

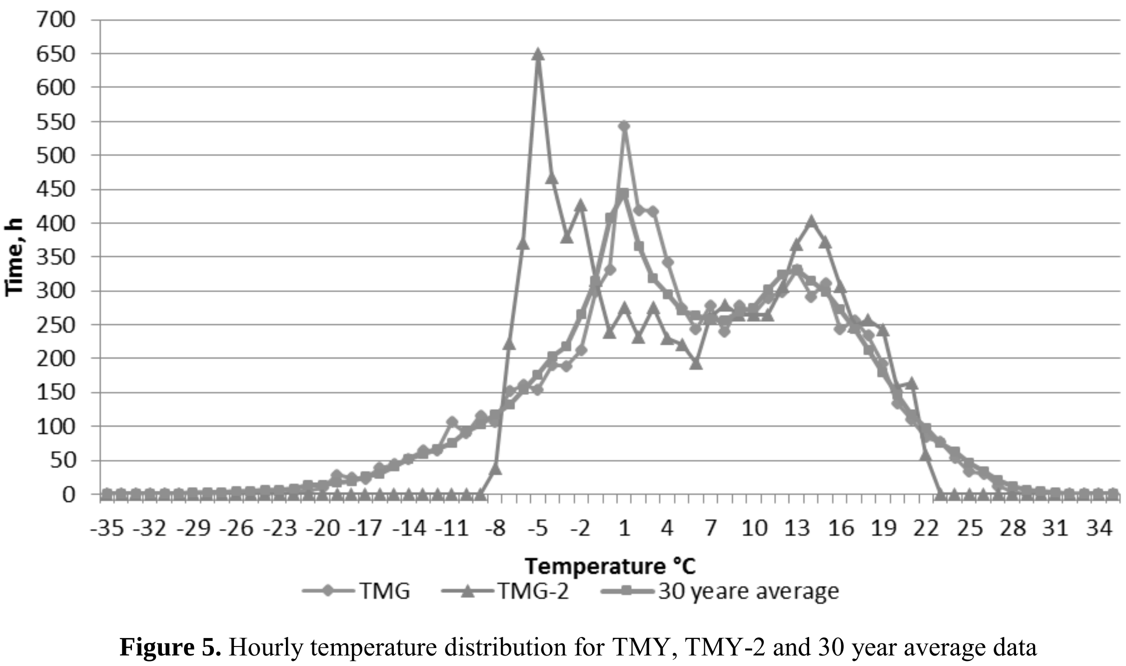

Figure 5. Hourly temperature distribution for TMY, TMY-2 and 30 year average data

One of the most important results that can be obtained from the TMY are shown in Fig. 7 and 8. These figures show how many hours per year each temperature and content of moisture combination can be observed. The most typical content of moisture and temperature combination in the TMY model is 4g/kg at 2 °C, respectively. This combination can be observed for 352 hours. These results can be used for HVAC system analysis and building energy simulations. The data from Fig. 7 gives ability to calculate how long it will be necesery to use heating and cooling devices for buildings in this region, and choose the optimal capacity for these devices.

The TMY-2 most typical content of moisture and temperature combination is 2g/kg at –5 °C (Fig. 8), respectively. This combination can be observed for 629 hours.

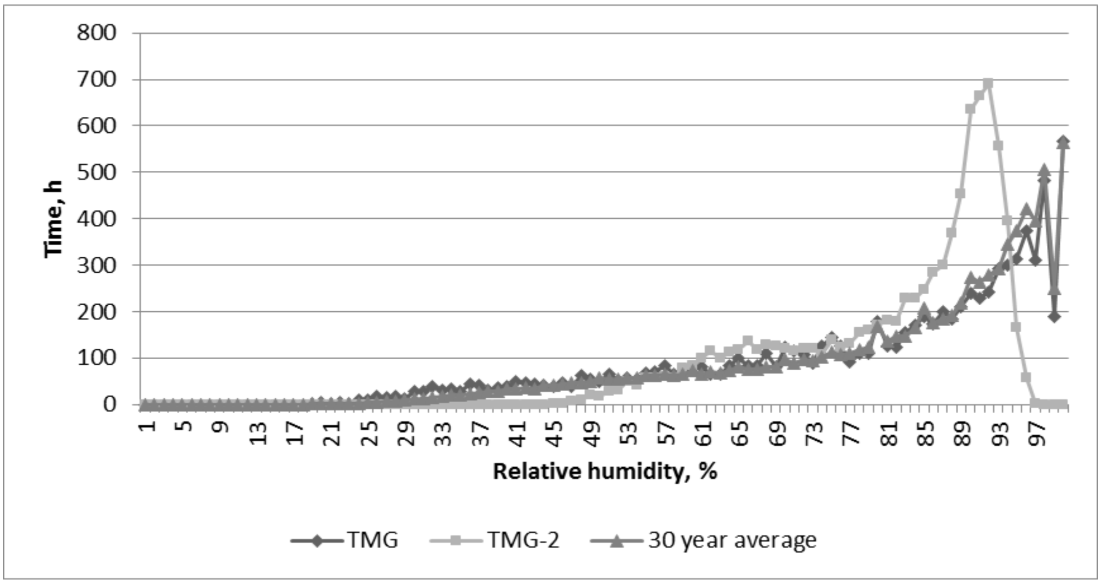

Figure 6. Relative humidity distribution for TMY, TMY-2 and 30 year average data

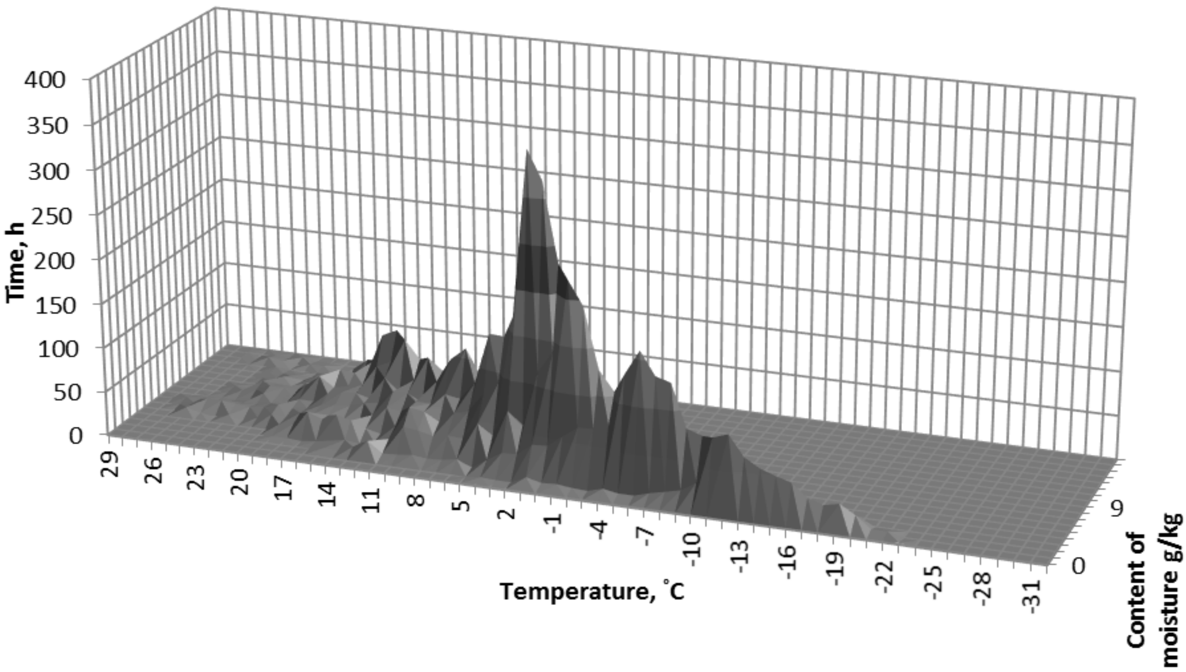

Figure 7. Combination of temperature and content of moisture for TMY

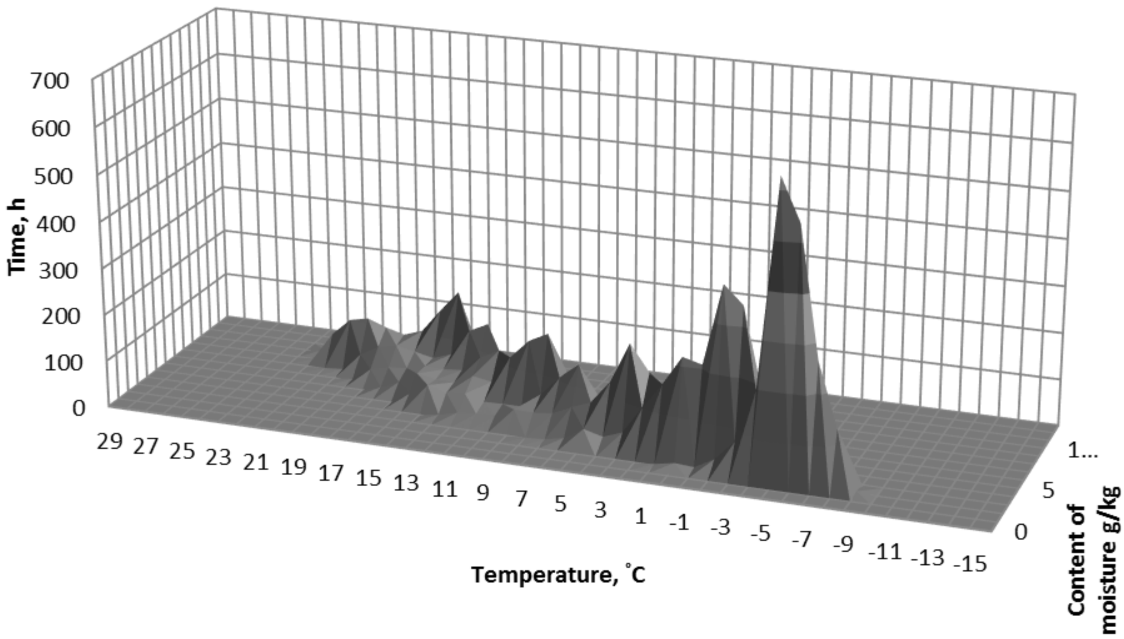

Figure 8. Combination of temperature and content of moisture for TMY-2

Table 1

Average monthly temperature values (°C)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul
30 year average	–5.4	–6.0	–1.5	5.4	11.3	14.9	17.3
TMY	–2.8	–6.2	–1.1	4.8	11.6	14.3	16.7
TMY-2	–5.4	–6.0	–1.5	5.4	11.3	14.9	17.3
LBN 003-01	–7.6	–6.8	–2.5	4.0	11.0	14.8	16.1
Month	Aug	Sep	Oct	Nov	Dec	Average	
30 year average	15.7	10.8	5.4	–0.2	–4.0	5.3	
TMY	15.4	9.7	4.8	–1.3	–4.6	5.2	
TMY-2	15.7	10.8	5.4	–0.2	–4.0	5.3	
LBN 003-01	15.0	10.2	5.2	–0.4	–4.9	4.5	

The TMY and TMY-2 average year temperature value difference is 0.1 °C, but the differences of the LBN 003-01 value are 0.7 and 0.8 °C, respectively (Table 1). The difference of the LBN 003-01 values can be explained by the fact that they were obtained from 1961–1990, but the TMY and TMY-2 values were obtained from 1984–2013. Climate change can be a factor for the difference.

The TMT and TMY-2 average year relative humidity value difference is 2 % (Table 2), but the difference of the LBN 003-01 value for the TMY and TMY-2 is 1%.

Comparing TMY, TMY-2, the long term average and LBN 003-01 values (Table 3) the LBN 003-01 has the longest duration of a heating period, the lowest average temperature in a heating period and also it has the most number of degree days.

Comparing the results in table 1 with the results that were obtained by Zariņš (Zariņš, 2001) for the city of Riga, they show a similar tendency that the average monthly temperatures in LBN 003-01 are lower than the TMY values. The results can be explained by the fact that data in LBN 003-01 were obtained from 1961–1990, but for the TMY from 1984–2013. Due to global changes the average monthly temperatures have risen.

Table 2

Average monthly relative humidity value (%) comparison from January till December

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
30 year average	90	86	78	68	68	74	76	80	84	87	91	91	81
TMY	89	84	72	69	60	73	81	72	81	81	93	92	79
TMY-2	90	86	78	68	68	74	76	80	84	87	91	91	81
LBN 003-01	87	84	78	71	68	71	75	79	84	87	90	90	80

Table 3

Summary of climate parameters

Parameter	TMY	TMY-2	30 year average	LBN 003-01
Maximum temperature, °C	27.7	21.9	32.2	31.1
Minimum temperature, °C	–22.6	–8.8	–33.2	–32.7
Duration of heating period, days	200	205	-	214
Average temperature in heating period, °C	–1.4	–1.1	-	–1.9
Number of degree days	3 887	3 913	-	4 259

CONCLUSIONS

The aim of this research was to generate a TMY for Alūksne and it was generated based on the most recent 30 year (1984–2013) climate data. The generation of TMY is very useful for optimal HVAC system design and building energy simulations. TMY provides a reliable database for engineers who are engaged in design, installation and maintenance of HVAC systems. With data provided by TMY it is possible to make building energy simulations and make calculations to determine the necessary power for devices.

The compared TMY and TMY-2 model values with LBN 003-01values showed a deviation of some weather parameters that can be explained with climate changes. These differences show that there is a need for TMY creation and the newest possible climate data should be used. In this paper TMY has been created for one city in Latvia, but the results suggest that research needs to be continued, and TMY models need to be generated for all 10 cities that are described in the LBN 003-01.

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