GENERATION OF A TEST REFERENCE YEAR FOR LIEPĀJA, LATVIA

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Abstract
Actual and reliable meteorological data are necessary for building performance analysis. Since meteorological conditions vary significantly from year to year, there is a need to create a test reference year (TRY), to represent the long-term weather conditions over a year. In this paper TRY data model was generated by analyzing every 3-hour weather data for a 30-year period (1984 – 2013) in Liepāja, Latvia, provided by the Latvian Environment Geology and Meteorology Centre (LEGMC). TRY model was generated according to standard LVS EN ISO 15927-4. The generated TRY contains from typical months that are included in TRY from a number of different years. The data gathered from TRY was compared with the climate data from the Latvian Cabinet of Ministers regulation No. 379, Regulations Regarding Latvian Building Code LBN 003-15. Average monthly temperature values in LBN 003-15 were lower than the TRY values that indicate on climate changes in this location. The results of this study may be used in building energy simulations and heating-cooling load calculations for selected region. TRY selection process should include the latest meteorological observations and should be periodically renewed to reflect the long-term climate change.
Key words: test reference year; climate analysis, climate change.

Introduction

In Latvian legislation long-term climate data is reflected in the Latvian Building Code (LBN) 003-15 'Būvklimatoloģija' (Construction climatology), Cabinet of Ministers, 2015 (Ministru kabinets, 2015), where various climatic indicators that represent the climatic situation in the territory of Latvia, providing information about the average monthly and yearly meteorological parameters are shown. But this information is not enough to fully describe the region's climatic conditions, because there is a necessity to define every day and every hour meteorological data values.

The need of such meteorological data worldwide led to the development of methodologies for generating the typical reference year (TRY) in the USA known as a typical meteorological year (TMY) (Hall *et al.*, 1978). TRY is a data set that contains a sequence of 8760 hourly values of chosen meteorological quantities. The requirement of TRY is that it has to correspond to an average year (Skeiker, 2004). TRY provides hourly climatic parameter values, enabling to use these parameters for heating, ventilation and air conditioning (HVAC) device management and capacity optimization. One of the most important tasks to optimize these devices is to choose correct and precise outdoor air temperature that can be determined with TRY model (Gaujēna *et al.*, 2015).

Creation of TRY 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 TRYs for a number of locations across the globe (Chan *et al.*, 2006; Guggenberger, Elemore, & Crow, 2013; Hall *et al.*, 1978; Jiang, 2010; Kalogirou, 2003; Lee, Yoo, & Levermore, 2010; Skeiker, 2004; Skeiker, 2007; Yang, Lam, & Liu, 2007; Zang, Hu, & Biang, 2012; Zariņš, 2001).

LBN 003-15 describes climate parameters for ten cities of Latvia. These parameters have been calculated using data from 1961 – 1990 (Ministru kabinets, 2015). The aim of this research was to generate a representative climate database for one of these cities – Liepāja, by employing the method according to standard LVS EN ISO 15927-4 (Latvijas Valsts Standarts, 2005). Generation of TRY of Liepāja would provide hourly climate data that LBN 003-15 does not provide.

Geographical data for Liepāja: latitude 56°28'31,35" N; longitude 21°01'14,36" E; on relatively flat surface, elevated 3,71 m (LAS-2000,5) above sea level. It is located 195 km from the capital city of Latvia – Rīga (Figure 1). Average year temperature is 6.7 °C.

Figure 1. Location of Liepāja in Latvia.

The TRY is generated using the available weather data obtained from the station of Liepāja by the

Latvian Environment Geology and Meteorology Centre (LEGMC), covering the period from 1984 – 2013. LEGMAC database provides 3-hour weather data values for the temperature and relative humidity. As TRY consists of every hour values, the necessary values are interpolated.

In the region, there are only two studies that use LVS EN ISO 15927-4 standard with 30-year weather data: it is Estonian TRY (Kalamees & Kurnitski, 2006) and TRY for Alūksne (Ruduks & Lešinskis, 2015). The aim of this research is to generate TRY for Liepāja with most recent 30-year (1984 – 2013) climate data.

Materials and Methods

In this study, the ISO 15927-4 (Latvia State Standard, 2005) (Latvijas Valsts Standarts, 2005) method was used to construct the TRY. The primary selection was made on the basis of dry-bulb air temperature, cloud coverage (ISO 15927-4 suggested using direct normal solar irradiance, but this parameter is not available for this station, so it was replaced with cloud coverage), and relative humidity. The wind speed was used for secondary selection. To guarantee that the selected year represents the Liepāja climate as completely as possible, 30-year weather data were applied.

Climate data for TRY creation were obtained from LEGMC database from 1984 – 2013. LEGMC provides climate data with 3 hour interval, but TRY needs an hourly climate data. The necessary data for TRY were calculated by linear interpolation.

In February, there may be 28 or 29 days, and it is not possible to compare years with different count of days; thus, 29 February was excluded from TMY creation. The rest of the days were rearranged in ascending order starting with the first hour of January till the last hour of December (8760 values).

For each climatic parameter p (dry-bulb temperature, cloud coverage and relative humidity), daily means $\overline{p}$ are calculated. For each calendar month m, the cumulative distribution function $\Phi_{p,m,i}$ of daily means over all the years in the data set is calculated using equation (1):

$$\Phi_{p,m,i} = \frac{K_i}{N+1} \tag{1}$$

where K_i – rank order of the i-th value of the daily means within that calendar month in the whole data set;
N – number of days in any calendar month in the whole data set.

For each year y of the data set, the cumulative distribution function $F_{p,y,m,i}$ of the daily means within each calendar month is calculated using equation (2):

$$F_{p,y,m,i} = \frac{J_i}{n+1} \tag{2}$$

where J_i – rank order of the i-th value of the daily means within that calendar month and that year;
n – number of days in an individual month.

For each calendar month m the Finkelstein–Schafer statistic for parameter p, $FS_{p,y,m}$ for each year y of the data set is calculated using equation (3):

$$FS_{p,y,m} = \sum_{i=1}^{n} \left| F_{p,y,m,i} - \Phi_{p,m,i} \right|. \tag{3}$$

To normalize $FS_{p,y,m}$ for months of varying lengths, the results of equation (3) are divided by the number of days of the month (28, 30 or 31). For each calendar month individual months are ranked from the multiyear record in order of increasing value of $FS_{p,y,m}$. Monthly average $FS_{p,y,m}$ values of climate parameters dry-bulb air temperature, cloud coverage and relative humidity are added together and the same months of all years are ranked in the order of the increasing value of $FS_{p,y,m}$. From each calendar month, three candidate months with the lowest total ranking are selected. The monthly deviation of the wind speed of the three months is compared with the corresponding multi-year mean of calendar months. The month with the lowest deviation in wind speed is selected as the best month for inclusion in the TRY.

After the selection of the twelve calendar months for TRY, the months should be joined together. The first and the last eight hours of each month are adjusted by interpolation to ensure a smooth transition when months are joined to form a TRY. The adjustment also includes the last eight hours of December and the first eight hours of January, so that the test reference year can be used repeatedly in simulations (Latvia State Standard, 2005) (Latvijas Valsts Standarts, 2005).

Heating degree days (HDD)

HDD is a parameter used in the HVAC industry to estimate heating and cooling energy requirements. HDD can be calculated using equation (4) (Buyukalaca, Bulut, & Yilmaz, 2001):

$$HDD = \sum_{days} (T_b - T_m) \tag{4}$$

where T_b - base temperature (18 °C);
T_m - outdoor temperature (at duration of heating period);
$\sum_{days}$ - duration of heating period.

Results and Discussion

TRY was created combining months from different years based on their ability to follow the criteria described in materials and methods. Selected month/year combinations from which the TRY was created are shown in Figure 2. Two months (June and November) were selected from the year 2005, and two months (April and August) from 2011, but other months were selected from different years. That displays that months were selected from all range of the observed period.

After selected months (Figure 2) were connected and TRY was created, temperature fluctuation (Figure 3), temperature distribution (Figure 5), relative humidity fluctuation (Figure 4) and wind speed distribution (Figure 6) were displayed. Results show similar tendencies with data from Estonian TRY (Kalamees & Kurnitski, 2006) and TRY for Alūksne (Ruduks & Lešinskis, 2015).

Figures 3 and 4 show how temperature and relative humidity values change in TRY model starting from the beginning of January until the end of December.

When TRY model temperature distribution values are compared with 30-year average data (long term data) (Figure 5), TRY model shows a good agreement with the long-term data. TRY model's maximum temperature value deviation from long-term data is 151 hours per year at 5 °C. The total TRY model's temperature deviation from 30-year average data is 1384 hours. TRY for Alūksne deviation from 30-year average data was 1044 hours (Ruduks & Lešinskis, 2015).

Most typical wind speed value in TRY model is 3 m s^{-1}, it is observed for 1749 hours. TRY model's maximum wind speed value deviation from long-term data is 162 hours per year at 4 m s^{-1}. The total TRY model's wind speed deviation from 30-year average data is 826 hours. (Figure 6).

One of the most important results that can be obtained from TRY models is shown in Figure 7. This figure show how many hours per year each temperature and content of moisture combination can be observed. Most typical content of moisture and temperature combination in TRY model is 4 g kg^{-1} at

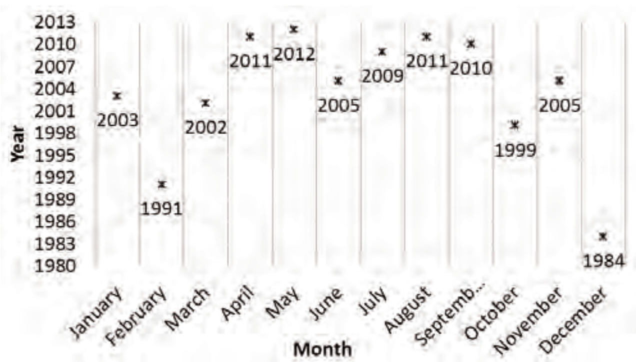

Figure 2. The month/year combinations for the composition of TRY.

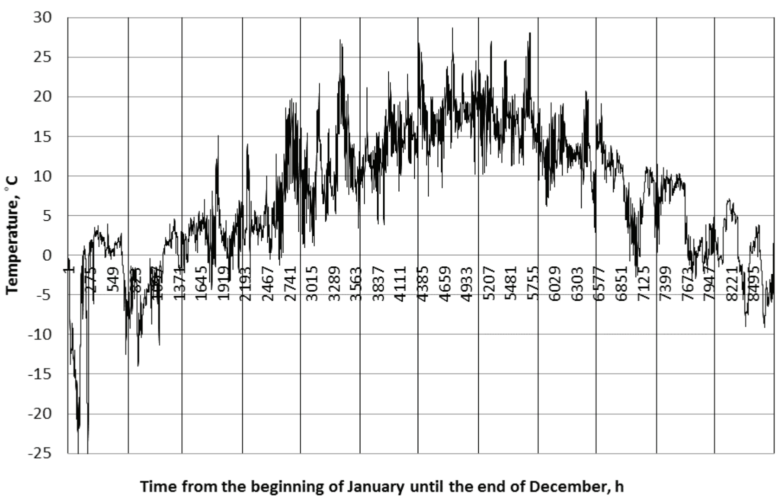

Figure 3. Temperature fluctuation in TRY.

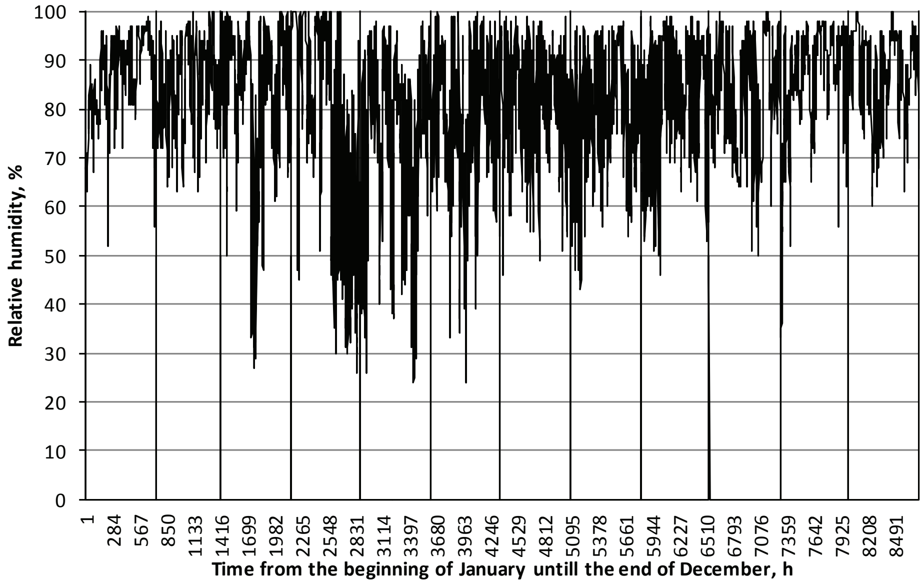

Figure 4. Relative humidity fluctuation in TRY.

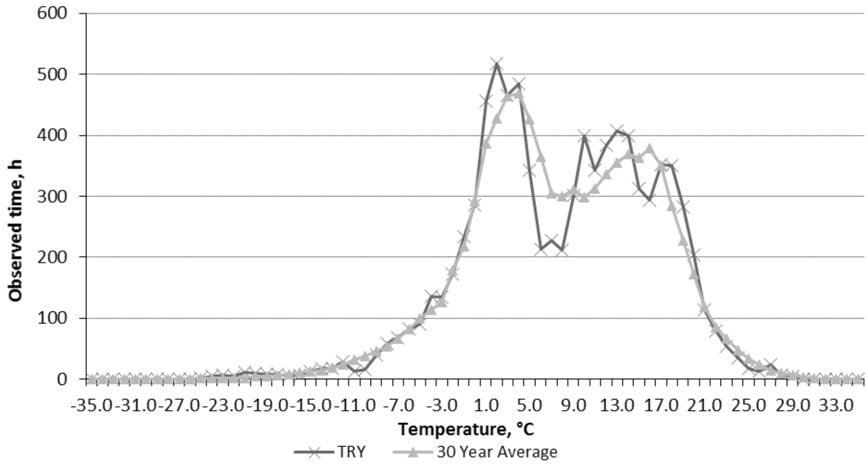

Figure 5. Hourly temperature distribution for TRY and 30-year average data.

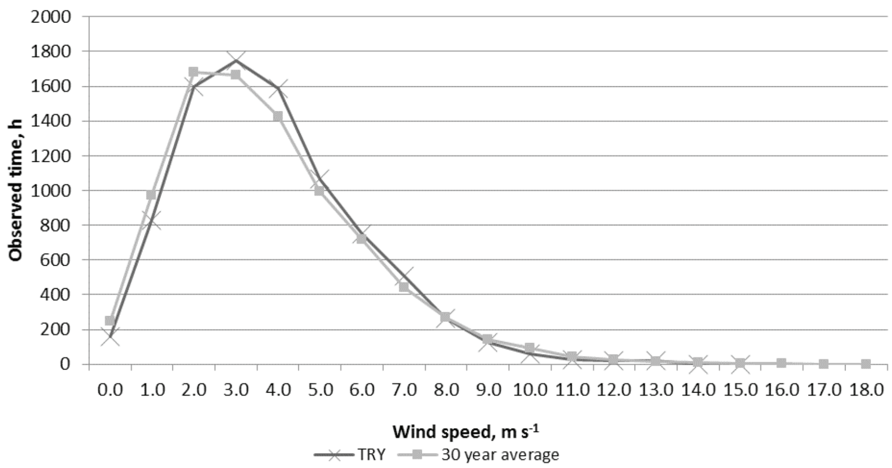

Figure 6. Wind speed distribution for TRY and 30-year average data.

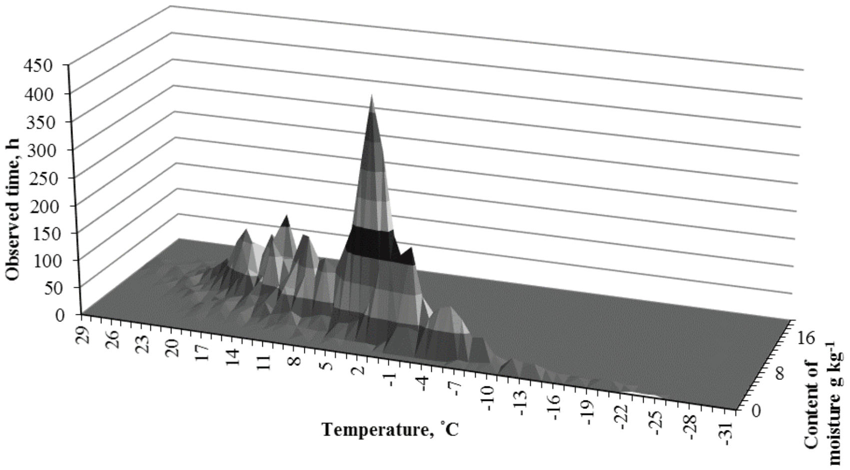

Figure 7. Combination of temperature and content of moisture for TRY.

2 °C. This combination can be observed for 432 hours (Figure 7). Most typical content of moisture value of TRY for Alūksne is also 4 g kg^{-1}, but most typical temperature is two degrees lower – 0 °C (Ruduks & Lešinskis, 2015). These results can be used for HVAC system analysis and building energy simulations. Data from Figure 7 gives an ability to calculate how long it will be necesary to use heating and cooling devices for buildings in this region, and choose optimal capacity for these devices.

Average year temperature value for TRY is 7.5 °C, but for 30-year average data it is 7.5 °C. Comparing results with LBN 003-15 values the difference is 0.8 and 1.1 °C respectively (Table 1). The difference with LBN 003-15 value can be explained by the fact that they have been obtained from 1961 – 1990, but TRY values were obtained from 1984 – 2013. The climate change can be the factor for the difference. Average relative humidity value for TRY and LBN 003-15 data is identical – 82%, but difference with 30-year average value is 1% (Table 2).

Table 1

Average monthly temperature values (°C)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul
30 year average	-1.0	-1.6	1.1	6.3	11.4	14.9	17.9
TRY	-3.3	-2.8	2.7	6.7	11.2	13.7	17.9
LBN 003-15	-3.0	-3.0	-0.2	4.6	10.3	14.3	16.4
Month	Aug	Sep	Oct	Nov	Dec	Average	
30 year average	17.6	13.4	8.8	3.9	0.6	7.8	
TRY	17.4	12.7	8.7	4.5	–0.1	7.5	
LBN 003-15	16.4	12.9	8.5	3.7	–0.3	6.7	

Table 2

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

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
30 year average	87	85	82	77	75	79	79	79	80	83	86	84	81
TRY	87	86	83	77	73	80	81	79	83	83	87	87	82
LBN 003-15	85	84	83	79	76	78	80	80	80	83	85	86	82

Table 3

Average monthly wind speed values (m s^{-1})

Month	Jan	Feb	Mar	Apr	May	Jun	Jul
30 year average	4.5	4.1	3.8	3.5	3.2	3.3	3.2
TRY	4.1	4.2	4.5	3.3	3.2	3.3	3.1
LBN 003-15	5.9	5.3	5.4	5.1	4.6	4.5	4.6
Month	Aug	Sep	Oct	Nov	Dec	Average	
30 year average	3.2	3.6	4.0	4.1	4.3	3.7	
TRY	3.3	3.8	4.2	3.9	4.5	3.8	
LBN 003-15	4.7	5.3	5.7	6.3	6.0	5.3	

Table 4

Summary of climate parameters

Parameter	TRY	LBN 003-15
Maximum temperature, °C	28.7	31.5
Minimum temperature, °C	-25.1	-26.1
Duration of heating period, days	189	193
Average temperature in heating period, °C	1.2	0.6
Number of heating degree days (HDD)	3175	3358

Average year wind speed value for TRY and 30-year average data are similar, the difference is 0.1 m s^{-1}, but difference with LBN 003-01 value is 1.5 and 1.6 m s^{-1} respectively (Table 3). The difference can be explained by the fact that LBN 003-01 values have been obtained from 1961 – 1990, but TRY values were obtained from 1984 – 2013, and latest studies show that wind speed values decrease (Green *et al*., 2012).

Comparing TRY and LBN 003-15 values (Table 4), LBN 003-15 has the longest duration of heating period, the lowest average temperature in heating period, and it also has the greatest number of degree days. All these parameters show the impact of increased average temperature value (Table 1) that can be explained with global changes. This tendency has also been observed in TRY for Alūksne (Ruduks, Lešinskis, 2015).

Conclusions

The aim of this research was to generate TRY for Liepāja, and it was generated based on the most recent 30-year (1984 – 2013) climate data. The generation of a TRY is very useful for optimal HVAC system design and building energy simulations. With hourly climate data, provided by TRY, it is possible to make building energy simulations and make calculations to determine necessary power for HVAC devices that was not possible with data from LBN 003-15.

Comparing TRY model values with LBN 003-15 ones, LBN003-15 has the longest duration of heating period, lower average temperature in heating period and has more HDD. All that can be explained with climate changes. These differences show that there is a need for TRY creation and the latest possible climate data should be used. In this paper, TRY is created for one city of Latvia, but results suggest that the research needs to be continued, and TRY models need to be generated for all 10 cities that are described in LBN 003-15.

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