Bin weather data for City of Niš

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Energy analysis - general

- Four major purposes:
  - Evaluation various architectural design concepts
  - Demonstration of code compliance
  - Estimation of operating and maintenance cost over building lifetime
  - Understanding energy use patterns in buildings

Energy analysis – models & methods

- Several models available – each with strengths & weaknesses
- Models:
  - steady-state
  - quasi-steady-state
  - dynamic
- Methods:
  - simplified
    - Single measure – Degree Day
    - Multiple measure – Bin method
  - simulation

Energy analysis – practice in Serbia

- Fixed-base Heating Degree Day method widely accepted
- Heating Degree Day data available for most of the cities
- Only for heating energy consumption
- Used for all building types and all systems
- Mainly used to estimate building retrofit measures
- Cooling energy consumption not estimated
  - Cooling Degree Days missing
- Alternative – use other simplified or simulation methods
  - Bin methods – do not require special computer skills, appropriate weather files needed

Bin Methods - general

- For non-residential buildings – heat loss coefficient, system efficiency or balance point temperature are not constant
- Bin weather data – number of hours that the outside temperature was in each of a set of equally sized intervals of outdoor dry bulb temperature
- Presumption - all the hours of the time period for which we need to determine energy requirement, when a particular temperature interval (bin) occurs, can be grouped together and the energy calculations can be done for those hours with the equipment operating under those particular conditions
- Hourly measurements for the period greater than 5 years

Bin Methods - general

- Instantaneous sensible energy requirements – hourly measurements of outdoor dry bulb temperature necessary:

$$Q_{bin,i} = N_{bin,i} \frac{K_{tot}}{\eta} \left(t_b - t_i\right)^{\pm}$$

$N_{bin,i}$ - corresponding number of hours for bin
K_{tot} [W/K] - total heat loss coefficient of the building
η [-] - efficiency of HVAC system
t_b - balance point temperature
t_i - outdoor dry bulb temperature – middle of bin

- Total energy consumption - sensible:

$$Q_{tot} = \sum_{i=1}^{i=m} Q_{bin,i}$$

m – total number of bins

- Latent energy requirements: - mean coincident wet bulb temperature (MCWB)

Meteorogical database

- Quantifying values of $N_{bin,i}$:
  - hourly measurements of outdoor dry bulb temperature needed for sufficient period of time
    - classification into intervals (bins) with constant temperature increment and selected number of daily shifts
    - for every month and every year of the time period
    - Averaging over the whole time period for each month - monthly data and for year – annual data
- MCWB:
  - hourly measurements of relative humidity
  - hourly measurements of atmospheric pressure or barometric pressure if not applicable

Mean coincident wet bulb temperature

- Necessary for latent energy requirements
- The following procedure should be applied:
- Step 1: saturation pressure, p_{ws}, (dry bulb temperature needed- hourly values)

T<273K $$\ln(p_{ws}) = \frac{C_1}{T} + C_2 + C_3 T + C_4 T^2 + C_5 T^3 + C_6 T^4 + C_7 \ln(T)$$

T>273K $$\ln(p_{ws}) = \frac{C_8}{T} + C_9 + C_{10} T + C_{11} T^2 + C_{12} T^3 + C_{13} \ln(T)$$

C_1 = -5.674 535 9 E+03
C_2 = 6.392 524 7 E+00
C_3 = -9.677 843 0 E-03
C_4 = 6.221 570 1 E-07
C_5 = 2.074 782 5 E-09
C_6 = -9.484 024 0 E-13
C_7 = 4.163 501 9 E+00

C_8 = -5.800 220 6 E+03
C_9 = 1.391 499 3 E+00
C_{10} = -4.864 023 9 E-02
C_{11} = 4.176 476 8 E-05
C_{12} = -1.445 209 3 E-08
C_{13} = 6.545 967 3 E+00

Mean coincident wet bulb temperature

- Step 2: partial water vapor pressure, p_w, (relative humidity needed – hourly values)

$$p_w = \varphi \cdot p_{ws}$$

- Step 3: humidity ratio, w, (atmospheric pressure needed – hourly values)

$$w = 0.62198 \cdot \frac{p_w}{p - p_w}$$

- Step 4: humidity ratio on saturation , w_s

$$w_s = 0.62198 \cdot \frac{p_{ws}}{p - p_{ws}}$$

Mean coincident wet bulb temperature

- **Step 5:** trial and run procedure for estimated wet bulb temperature, t^*, with calculation of humidity ratio w'

$$w' = \frac{(2501 - 2.381 \cdot t^*) \cdot w_s^* - 1.006 \cdot (t - t^*)}{2501 + 1.805 \cdot t - 4.186 \cdot t^*}$$

- **Step 6:** when values w and w' coincide, the estimated wet bulb temperature t^* represents **coincident wet bulb temperature**
- If pressure measurements are not available, barometric pressure should be used for calculations in steps 3-6

$$p = 101325 \left(1 - \frac{2.25577}{10^5} Z\right)^{5.2559}$$

Bin weather data for city of Niš

- Hourly measurements of outside air dry-bulb temperature, relative humidity and atmospheric pressure
- Period 2002 – 2017 (except 2010, 2011, 2012)
- Obtained from Meteorogical observatory Niš (21°54’E; 43°20’N, 202m)
- 2°C temperature increments from minimal to maximal recorded temperature
- Six daily 4h shifts: $01^{\underline{00}}$-$04^{\underline{00}}$, $05^{\underline{00}}$-$08^{\underline{00}}$, $09^{\underline{00}}$-$12^{\underline{00}}$, $13^{\underline{00}}$-$16^{\underline{00}}$, $17^{\underline{00}}$-$20^{\underline{00}}$, $21^{\underline{00}}$-$24^{\underline{00}}$
- Coldest month - January
- Warmest month - July

Bin data for January for Niš

Temperature range [˚C]	Time period							MCWB ˚C
	1-4	*5-8*	*9-12*	*13-16*	*17-20*	*21-24*	*Total h*	
-18/-16	1	1	0	0	0	0	2	-17.16
-16/-14	1	1	0	0	0	1	3	-15.3
-14/-12	2	2	1	0	1	2	8	-13.4
-12/-10	4	5	2	1	2	3	17	-11.57
-10/-8	6	6	5	3	3	5	28	-9.73
-8/-6	8	9	6	5	5	7	40	-7.66
-6/-4	13	13	10	7	11	13	67	-5.74
-4/-2	13	14	13	11	14	13	78	-3.96
-2/0	18	18	10	10	12	17	85	-1.91
0/2	24	24	20	15	18	22	123	-0.15
2/4	16	14	16	14	19	17	96	1.75
4/6	8	8	13	13	13	11	66	3.3
6/8	5	5	11	12	13	8	54	4.99
8/10	3	2	8	12	6	3	34	6.13
10/12	1	1	5	10	4	1	22	7.36
12/14	1	1	3	6	2	1	14	8.31
14/16	0	0	1	3	1	0	5	9.36
16/18	0	0	0	1	0	0	1	10.39
18/20	0	0	0	1	0	0	1	11.11

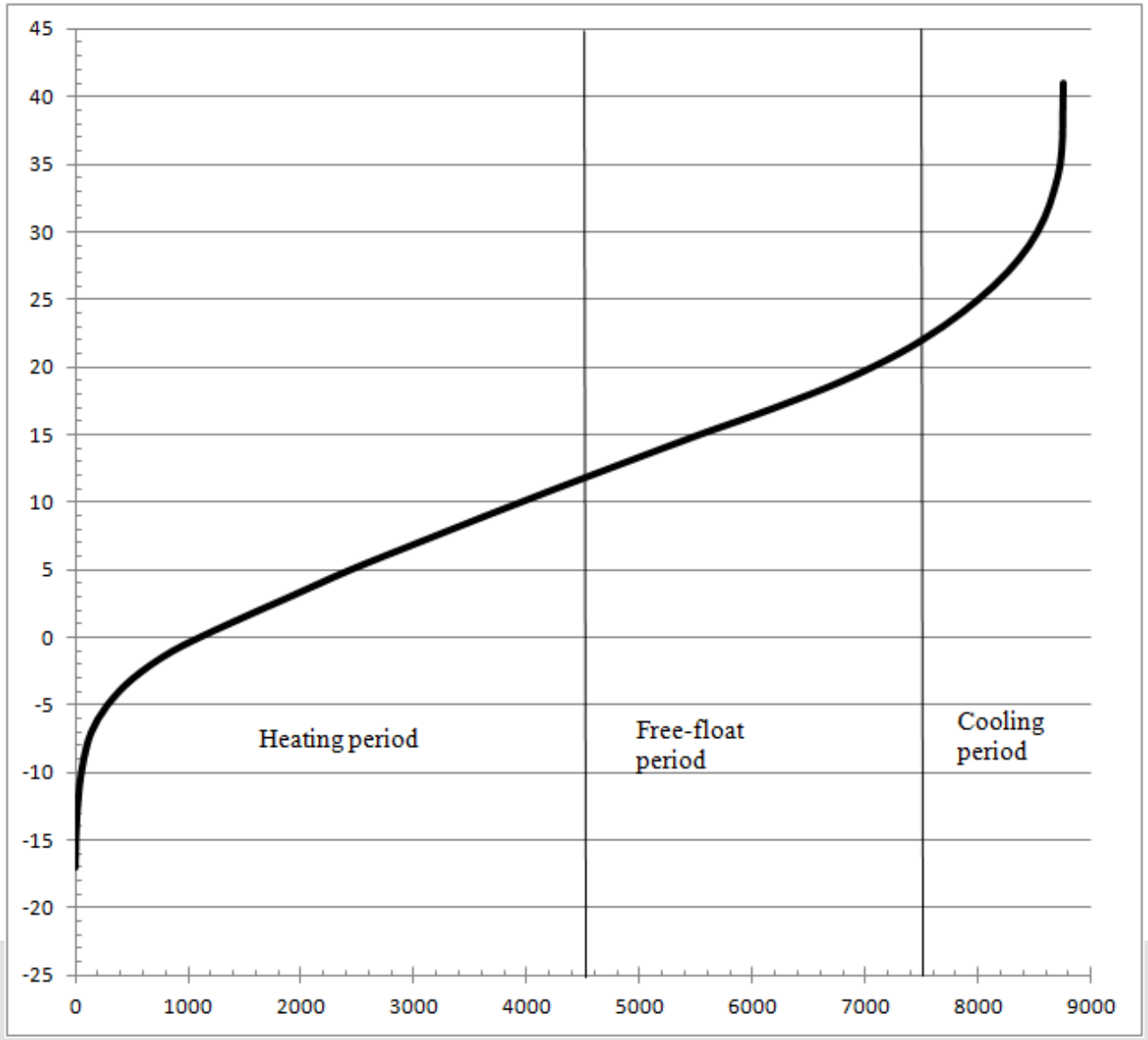
Bin data for July for Niš

Temperature range [°C]	Time period							MCWB °C
	1-4	*5-8*	*9-12*	*13-16*	*17-20*	*21-24*	*Total h*	
10/12	1	1	0	0	0	0	2	10.30
12/14	11	6	0	0	0	2	19	11.80
14/16	20	15	1	0	2	8	46	13.49
16/18	31	23	5	1	5	18	83	15.03
18/20	31	31	6	5	8	25	106	16.33
20/22	19	24	13	4	14	26	100	17.11
22/24	7	12	17	9	16	20	81	17.68
24/26	3	8	19	12	18	12	72	18.13
26/28	1	3	22	16	17	8	67	18.81
28/30	0	1	16	17	16	4	54	19.49
30/32	0	0	13	19	12	1	45	20.14
32/34	0	0	8	17	9	0	34	20.68
34/36	0	0	3	14	5	0	22	20.98
36/38	0	0	1	7	2	0	10	20.95
38/40	0	0	0	1	0	0	1	20.50
40/42	0	0	0	2	0	0	2	20.64

Annual bin data for Niš

Temperature range [°C]	Time period							MCWB °C
	1-4	*5-8*	*9-12*	*13-16*	*17-20*	*21-24*	*Total h*	
-18/-16	1	2	0	0	0	0	3	-17.23
-16/-14	2	2	0	0	0	1	5	-15.31
-14/-12	3	2	2	0	1	3	11	-13.39
-12/-10	5	5	3	1	3	4	21	-11.54
-10/-8	9	8	6	3	5	7	38	-9.70
-8/-6	15	19	8	6	8	11	67	-7.66
-6/-4	31	33	18	13	20	27	142	-5.76
-4/-2	49	54	31	21	33	42	230	-3.84
-2/0	76	77	44	37	46	68	348	-1.87
0/2	102	107	66	54	68	98	495	-0.03
2/4	112	106	76	56	79	112	541	1.76
4/6	103	99	79	59	77	120	537	3.44
6/8	121	116	83	71	87	120	598	5.21
8/10	121	112	85	74	91	120	603	6.90
10/12	134	117	88	77	91	112	619	8.69
12/14	124	116	95	89	101	108	633	10.37
14/16	140	121	93	90	98	100	642	12.05
16/18	143	127	103	83	104	111	671	13.75
18/20	96	104	103	99	103	99	604	14.92
20/22	46	70	97	98	95	86	492	15.90
22/24	17	37	99	98	85	55	391	16.74
24/26	7	19	92	87	79	30	314	17.67
26/28	3	5	79	88	65	17	257	18.51
28/30	0	2	50	84	51	7	194	19.26
30/32	0	0	33	67	32	2	134	19.97
32/34	0	0	19	47	19	0	85	20.53
34/36	0	0	7	37	13	0	57	20.95
36/38	0	0	1	15	4	0	20	21.04
38/40	0	0	0	3	1	0	4	20.65
40/42	0	0	0	3	1	0	4	21.03

Outdoor temperature frequency curve for Niš



Conclusion

- *In order to improve accuracy in estimating building energy requirements in the design phase in Serbia, using one of the bin methods, this paper should give idea how to generate bin weather data for locations in Serbia (or elsewhere) where hourly measurements of climatic parameters are available for a continuous number of years, preferably more than 5*
- *This would lead to better understanding of building energy requirements and designing "optimal" HVAC systems to suite particular building*
- *The next step is to start using dynamic simulation tools in the design phase on regular basis*

Thank you for Your attention!

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