Assessment of domestic hot water demand: various criteria checked against real life data

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Assessments in this presentation are based solely on the author's personal opinions.

Introduction

- One of the data needed for designing the heating installation in a flat or in an apartment building: yearly need for Domestic Hot Water.
- DHW demand depends on:
  - the number of people living in the dwelling
  - the supply temperature of cold water
  - the utilization temperature of hot water.
- Such information is not always available at time of designing: approximate estimates are usually needed.

Introduction

- [1] UNI/TS 11300-2, “Energy performance of buildings – Part.2: Evaluation of primary energy need and of system efficiencies for space heating, domestic hot water production, ventilation and lighting for non-residential buildings”, October 2014.

- [4] European Standard EN 15450, “Heating systems in buildings – Design of heat pump heating systems”, October 2007.

Introduction

- UNI/TS 11300-2 assumes that the bigger the apartment, the more numerous are the occupants, and the more DHW is needed.
- As a result, DHW demand (cubic meter per day, or kWh per day) is assumed to increase approximately linearly with apartment area, except when very large (>200 m2) or very small (<50 m2) areas are involved, in which cases DHW demand is constant.
- Such estimates are inevitably approximate; it is interesting to compare them with “real life” data, in order to evaluate their accuracy.

Introduction

- 45 methane-fired, central heating installations in apartment buildings have been examined. Each one of them provides both heating and DHW production .

- The total volume of the apartments is 438,191 cubic meters, which amounts to some 1,900 average size dwellings.

Introduction

- The above installations have been monitored for several years (2011-2016) as a whole.
- Heat produced (kWh) and fuel consumed by each boiler have been measured.
- Data collected will be referred to as “Actual Operation Data”, or AOD.

Verisimilitude analysis

- Load factor (denoted by “Fc”) can be defined both for each individual boiler, and for all the boilers as a whole (overall load factor).

- For each boiler, Fc is the ratio of heat (kWh) that was in fact produced during the monitoring time to maximum heat (kWh) that could have been produced.

- The latter (maximum heat) is in turn the product of boiler power (kW) times monitoring time (hours).

Verisimilitude analysis

- The overall load factor is the weight-average of individual load factors, weights being the respective maximum heats that could have been produced.
- Hypothetically, if all boilers had been constantly operated at full (rated) power, all individual Fc's, as well as overall Fc, would be 1.

Verisimilitude analysis

- In real life, however, DHW load profiles are far from constant: very high peaks for short times, and zero load for long times.

- As a result, average load is much lower than peak load (average-to-peak ratio is low).

- Since DHW boiler powers are chosen based on peak, rather than on average, load, a low load factor (Fc<<1) is to be expected overall.

- Indeed, in the present case, overall load factor is 0.178, which confirms expectations: AOD are realistic.

Verisimilitude analysis

- Boilers' overall efficiencies were also calculated, including both heating and DHW.
- Not surprisingly, a few efficiencies turned out to exceed 100%, which is consistent with the ever increasing spread of condensation boilers.
  - Lowest efficiency: 0.92.
  - Highest efficiency: 1.116.
- The latter figure was regarded as possibly inaccurate.

Verisimilitude analysis

- DHW consumption, all included:
  - 42.68 kWht/(m2 year);

- DHW consumption after excluding boilers with very high efficiencies (suspect of inaccurate data):
  - 41.79 kWht/(m2 anno);

- Uncertainty due to lack of accuracy:
  - 2% approximately. Comparable to typical measuring instruments errors.

Conclusion: result is highly robust and reliable.

Calculations

- We then checked for correlation between building useful area and yearly DHW heat production (kWht/year).

- Correlation turned out to be very strong (0.92 correlation coefficient).

- DHW consumption is proportional to useful area.

- UNI/TS 11300-2 criterion is realistic, anyway between 50 e 200 m2 (which is the case for most flats).

Calculations

- AOD yield 42.68 kWht/m2year average unitary consumption (AUC), based on following conditions:
  - *climate zone: E (second coldest) ;*
  - *draw-off temperature: 53°C:*
  - *cold water temperature: 10°C*

- Average overall consumption (AOC)=138,416 kWh/year
- ρ = 0.92
- β1=41.68 kWh/m2 year (=AUC)
- β0=3,114.75 kWh/year (<< AOC)

Calculations

- In order to perform a calculation based on UNI/TS 11300-2, the average dwelling area in Italy (76.8 square meters, [3]) was chosen as a typical useful area.

- For such surface value, UNI/TS 11300-2 yields a 16.38 kWh/m2 year DHW demand.

Results

- Although based on a realistic approach (DHW consumption proportional to useful area), UNI/TS 11300-2 underestimates DHW yearly demand for dwellings.

- After adjusting for temperature difference (60-10 °C):

estimated consumption= 66% of AOD consumption.

Results

- A more precise assessment is yielded by European Standard EN 15450 (Table E.4; family of three, with bath and shower).
- In order to compare with former case, it is necessary to assume that a family of three tipically lives in an average apartment.
- This a much more accurate evaluation, and it is "on the safe side" (overestimate).
- A 60-10°C temperature difference was assumed.

Estimated data=111.6% of AOD

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Family of three with bath and shower use

In the absence of precise information, average daily consumption can be assumed to be kWh per person (60°C)

cfr. EN 15450: 2007, par. 4.4.1

	Liters	No	Time of day	Energy consumption (kWh)
small	3	1	7	0,105
shower	40	2	7.05	1,4
small	3	3	7.30	0,105
small	3	4	7.45	0,105
bath	103	5	8.05	3,605
small	3	6	8.25	0,105
small	3	7	8.30	0,105
small	3	8	8.45	0,105
small	3	9	9.00	0,105
small	3	10	9.30	0,105
floor	3	11	10.30	0,105
small	3	12	11.30	0,105
small	3	13	11..45	0,105
dishwashing	6	14	12.45	0,315
small	3	15	14.30	0,105
small	3	16	15.30	0,105
small	3	17	16.30	0,105
small	3	18	18.00	0,105
cleaning	2	19	18.15	0,105
cleaning	2	20	18.30	0,105
small	3	21	19.00	0,105
dishwashing	14	22	20.30	0,735
bath	103	23	21.00	3,605
small	3	24	21.30	0,105

Results

- For the sake of completeness, the daily load profile in Table E.4 of European Standard EN 15450 was then modified to better reflect modern life style.
- Family of three, with bath and shower, but one of the daily baths was replaced with a shower.
- Temperature difference: 60-10°C, as usual.
- Comparison to AOD provided yet another underestimate, as was the case with UNI/TS 11300-2, but a more precise one.

Estimated data= 90% of AOD

Results

- Finally, comparison between UNI/TS 11300-2 and European Standard EN 15450.
- Very good agreement after significant modification of European Standard EN 15450: both baths replaced with as many showers.
- Temperature difference: (60-10)°C.

Assessment based on EN 15450 =

=1.05 x assessment based on UNI/TS 11300-2 .

T2: 60°C; T1:10°C ; useful surface:76.8 m2

		Energy consumption (kWh/year)	Energy consumption (kWh/m2 year)
b)	Family of three, with bath and shower (60°C)	4254,08	55,39
g)	Values derived from measured ones		49,62
n)	Same as B) except one bath replaced by one shower	3449,25	44,91
d)	Same as B) except two bath replaced by two showers	2644,43	34,43
l2)	11300-2:2014 (60-10)		32,76

Conclusions

- DHW yearly demand of an apartment can be regarded as proportional to the apartment's useful area, in the most common cases anyway.
- Based on measured data, a sound assumption for the proportionality coefficient is 43 kWht/m2 year (T2: 53°C; T1:10°C).
- Although based on the above assumption, UNI/TS 11300-2 underestimates DHW yearly demand for dwellings. It is therefore recommended that a review of proportionality coefficients be considered in future editions of UNI/TS 11300-2 .
- The closest prediction of the above figure is provided by EN 15450 (table E,4), which features good accuracy and is conservative. Besides, after a realistic modification, Table E.4 still represents a very close underestimate.
- Where no specific indication is provided, conclusions are based on a 60-10°C temperature difference between hot water and cold water.

References

- [1] S.Bergero, P.Cavalletti, M.Michelini, "Termoregolazione e contabilizzazione: convenienza economica per zona climatica di unità immobiliare italiana tipo mediante aggregazione di dati campione", in "La Termotecnica", Novembre 2016, pag. 58(in Italian).
- [2] UNI/TS 11300-2, "Energy performance of buildings – Part.2: Evaluation of primary energy need and of system eficiencies for space heating, domestic hot water production, ventilation and lighting for non-residential buildings", October 2014.
- [3] European Commission, "M/324 - Mandate to CEN and CENELEC for the elaboration and adoption of measurement standards for household appliances: water-heaters, hot water storage appliances and water heating systems", September 2002
- [4] European Standard EN 15450, "Heating systems in buildings – Design of heat pump heating systems", October 2007 Impianti di riscaldamento negli edifici – Progettazione degli impianti di riscaldamento a pompa di calore", April 2008 (in Italian).
- [5] UNI EN 15450, "Impianti di riscaldamento negli edifici – Progettazione degli impianti di riscaldamento a pompa di calore", April 2008.

Thank you for your attention

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