PROPOSAL OF NEW USE PROFILES FOR RESIDENTIAL SPACES IN FINLAND

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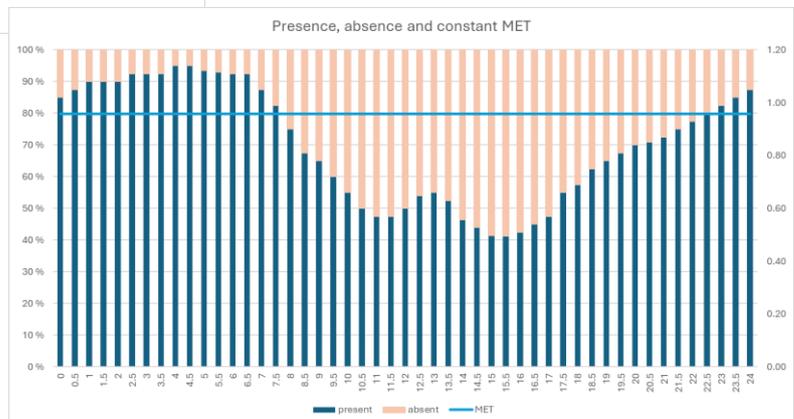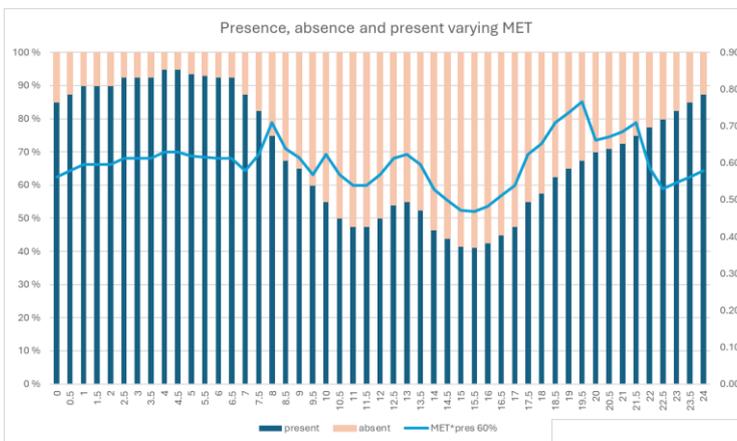
Table of Context

Preface

In Article 11 of the Decree 1010/2017 "Decree of the Ministry of the Environment on the Energy Performance of New Buildings", the standardized use of a building describes the daily and weekly occupancy of the building used in the energy calculation, the average occupancy rate of lighting, consumer equipment and occupants present during the occupancy period and the internal heat loads per net heated area. For the residential Use Classes 1 (single family house) and 2 (multi-story buildings), the loads are continuous 24/7. In Article 12, the standardized use of domestic hot water is given as the annual consumption of domestic hot water per square meter.

The Directive now being transposed places greater emphasis on the building's own production and on the flexibility of demand. Their impact cannot be assessed in building projects without a more realistic profiling of loads and use.

The work is based on a literature review on recent research articles from Finland and the results of previous studies (Sustainable Energy Project). Profiles are not done on individual household basis but applied to the entire Finnish building stock. The work also examines whether from calculation reliability point of view, new profiles should be created separately for weekdays and weekends and whether seasonal variations should also be considered in the profiles, such as variations in domestic hot water consumption in winter vs. summer and plug loads.

Cover page profiles: occupancy with presence/absence variation, with weighted and constant MET, listed values available at page 14.

1. Occupancy profile

Background

The occupancy profile the Finnish Building Code (FBC) residential buildings is static all around the year: 1 person/28m², 60% presence, 1.8 m² body surface area with a default MET = 1.2, 0.85 ± 0.25 clo, 80% dry heat and 3 W/total indoor m² power accounted as load.

For the assumed energy use, arbitrary occupancy profiles are used. The uniform profile poses obvious risks: a gap between the estimated and actual annual energy consumption, relevant for any building profile. Due to climate change and rising external temperatures some form of cooling will be necessary to be introduced in the residential design guides for new and renovation construction. The current schedule causes a proven underestimation of the peak cooling load in different office layout and presence designs (Fig. 1), such as single and open offices *(1)* and the trend might be identical to residential cooling usage as well.
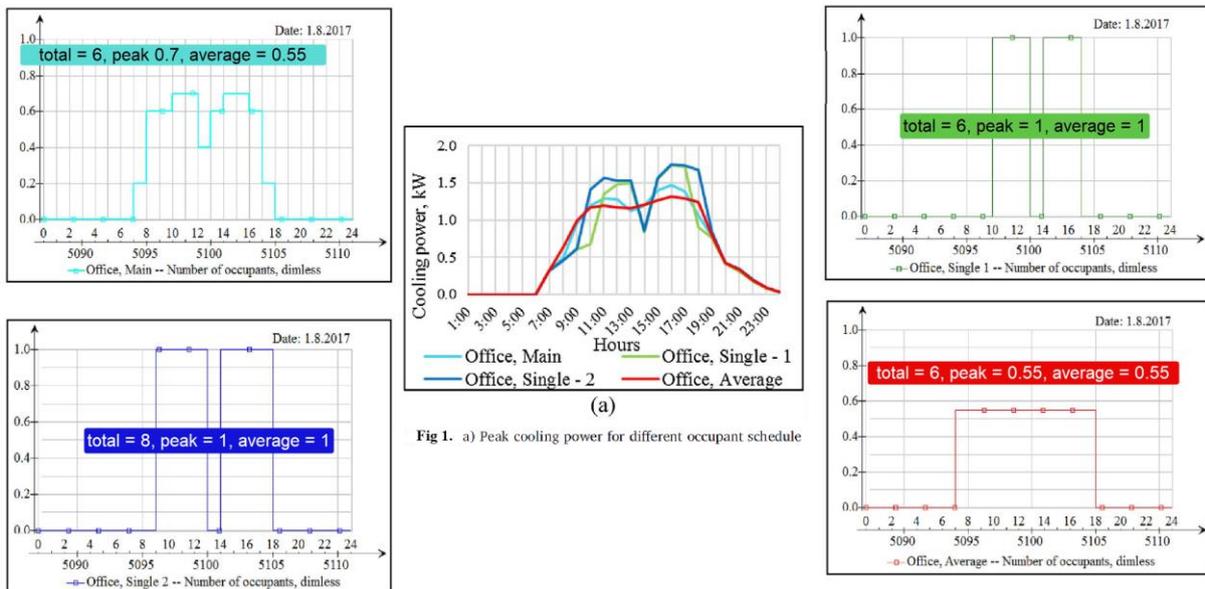

Fig 1. a) Peak cooling power for different occupant schedule

There is a clear and proven link between occupant presence and a variation of both plug loads and domestic hot water usage; the occupancy should be primary load in full agreement with the secondary loads. Surveying the number of occupants and the state of being active/inactive and generating stochastic time series upon occupancy surveys could give a very exact description of occupant behavior *(2)*, with an assumption on the space use.

Occupant presence and behavior is a crucial contributing factor to the HVAC system; therefore a more detailed, representative input schedule is strongly suggested. The schedule is valid both for weekends and weekdays.

Proposal

i. An activity-level based aggregated presence-absence schedule, based on Aerts et al. (2014) *(3)*: at home and awake, sleeping and absent. The original study considers overall building users behavior patterns (Fig.2
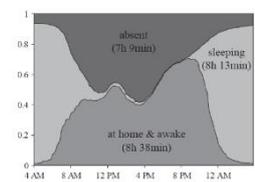
Fig 2. The average occupancy profile indicates the overall probability that individuals re at home and awake, sleeping or absent.

and Fig. 3 (*3*)). To be simplified into a present-absent schedule that will be weighted with a variable MET (~1.2, 1.0 (transitional) and 0.7) and weighted to 60%.
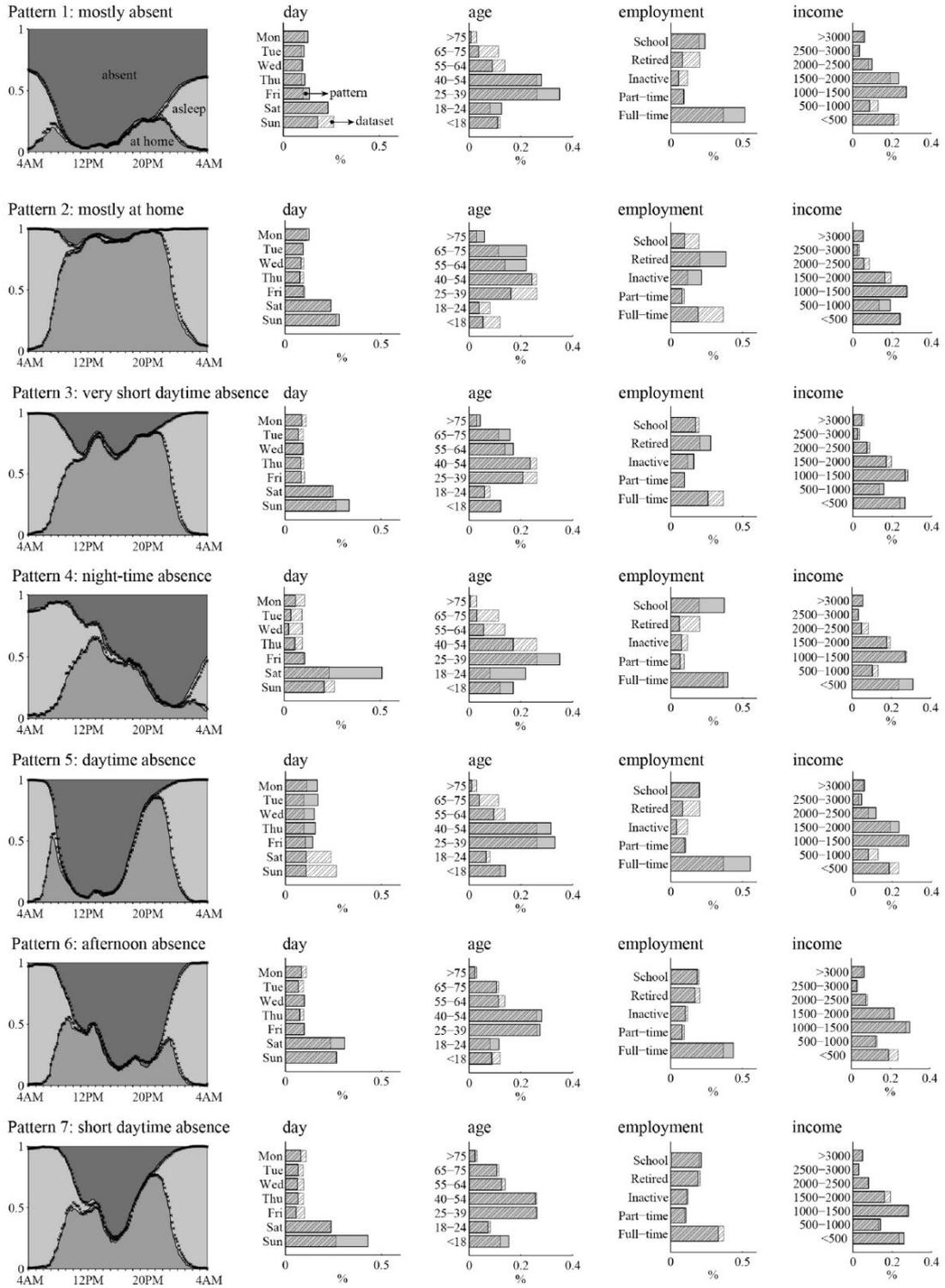
Fig 3. Overview of the results: first column = average occupancy patterns (The coloured areas correspond to the original TUS data, the crosses correspond to the average profile of the simulated data), second column = characterisation based on the day of the week, third to fifth column = characterisation based on socio-economic variables.

2. Lighting profile

Background

Lighting in the FBC is defined with a density [6W/m^2] and a schedule (10%). The measurements that serve as the base of literature typically aggregate the plug load and lighting load into one, observations on the lighting energy alone therefore are challenging. In the context of homes, the main characteristics are: due to the relatively rare usage of dimmable lights in Finnish homes the lights have only on/off modes. The awareness in the Finnish population about lighting efficiency is high (*4*), and according to Statistics Finland the consumption due to lighting has been constantly dropping, to approx. a constant 6 % of the total electricity consumption (Fig.4: 2022: 1373 GWh / total of 22 173 GWh).
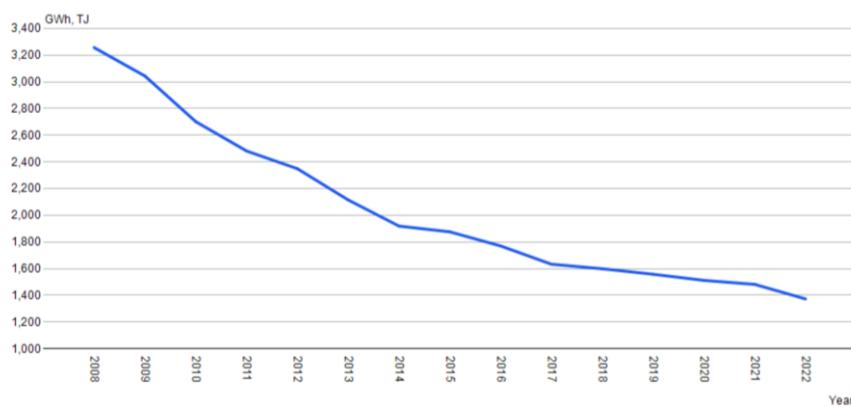
Fig 4. Energy consumption in households by Year. Electricity, Lighting, Energy consumption in households.

It is generally assumed that the residential lighting is correlating to daylight availability, but it proves to be rather difficult to establish any practical relationship *(5)*. Research on office electrical consumption shows that the assumed relationship between ambient temperature is difficult to prove but holidays have a major impact (due to absence) (*6*).

Proposal

i. Seasonal variation may be expressed in the lighting schedules, applied on the top of the occupancy presence as an assumed weight factor. No literature was found to suggest a direct correlation. The Plug load chapter includes a proven annual variation (page 6, Fig. 5 a) that is to be adapted to the light load.

3. Plug load profile

Background

Plug load has been a permanent part of the FBC due to its heat emission and direct effects on the annual energy and heat balance. Because of the varying nature of residential electricity usage (schedules, powers, modes, etc) a constant profile of 60% and power intensity level of 3 W/m² has been used. While this power intensity makes energy calculations fast and simple, it leads to underestimated electric and cooling power results. Additionally, it leaves little to no space to consider the differences between household measures, e.g. sauna, cooking and housework frequency, home office patterns, individual HVAC equipment usage, social factors etc. The uniform profile also does not differentiate between daily, weekday/weekend and seasonal changes either, even though several studies in Finland since the 1980s have proven a systematic, annual repetition of these temporal changes. Below an example on the annual variation in Finland (Paatero & Lund 2006 (*7*)):
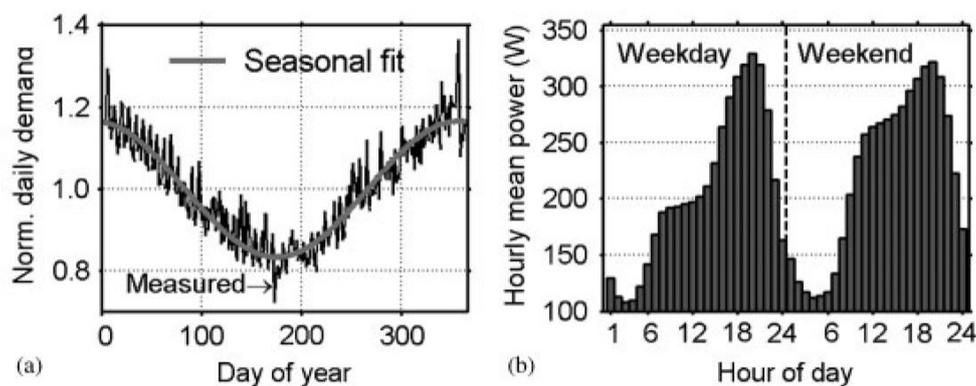
Figure 5. (a) Daily electricity consumption of measured data set 1. The mean curve is presented by the line; (b) mean hourly consumption curve of a household for weekdays and weekend days for the data set

The European Union expressed a strong need to raise the energy efficiency of a wide scope of home and professional electronic devices, by introducing the Ecodesign and Energy Label Directive 2009/125/EC and Regulation (EU) 2017/1369 [link here]. The label informs the nominal annual consumption rate (kWh/annum) but does not inform the nominal power [W] nor nominal usage schedule. Energy calculations are sparsely available.

Constructing a more tailored profile from statistical and measured data appears to be an established desired output for a longer while: using bottom-up modeling computing individual household load generation with typical load assumptions, probability factors and cycles *(7)*. The appliance and device types and powers however need an update. A continuation to this bottom-up model, a Master's Thesis (*8*) differentiates between dwelling types, stating that blocks (43% of all Finnish population's form of residence) have the lowest plug load consumption compared to single- and semi-detached family houses (rivitalo). The consumption distribution is known (Taulukko 2), the variation upon occupant number, flat area and equipment level is described (Kuva 2).

Taulukko 2. Kotitaloussähkön laiteryhmittely ja laiteryhmän kulutuksen suhteellinen osuus kerrostaloissa (Adato 2008)

Laiteryhmä	Kulutuksen suhteellinen osuus
Kylmälaitteet	22 %
Sisävalaistus	21 %
Viihdelaitteet	13 %
Liesi ja ruoanvalmistuksen pienlaitteet	11 %
Tietotekniikkalaitteet	7 %
Pyykinpesu ja -kuivaus	5 %
Sähkökiuas	4 %
Lattialämmitys	4 %
Astianpesukone	2 %
LVI-laitteet	2 %
Muut laitteet	9 %
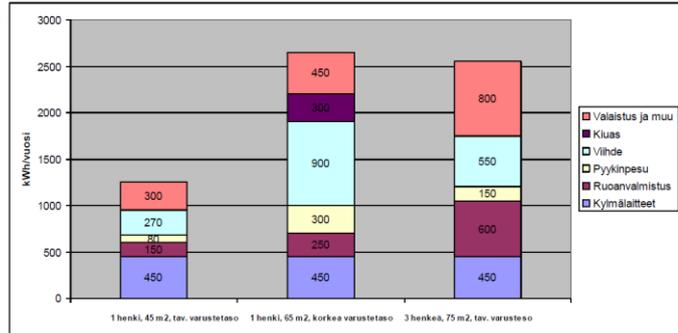
Kuva 2. Esimerkkikerrostalojen kotitaloussähkön kulutus asukasluvun, pinta-alan ja varustetason mukaan

With detailed (5-minute interval from 2008) consumption logging clear electric peaks are visible (Kuva 4). The sharp peaks by nature soften up with adding more apartment. The created simulation model used an averaged curve separating WE and WD to obtain profiles.
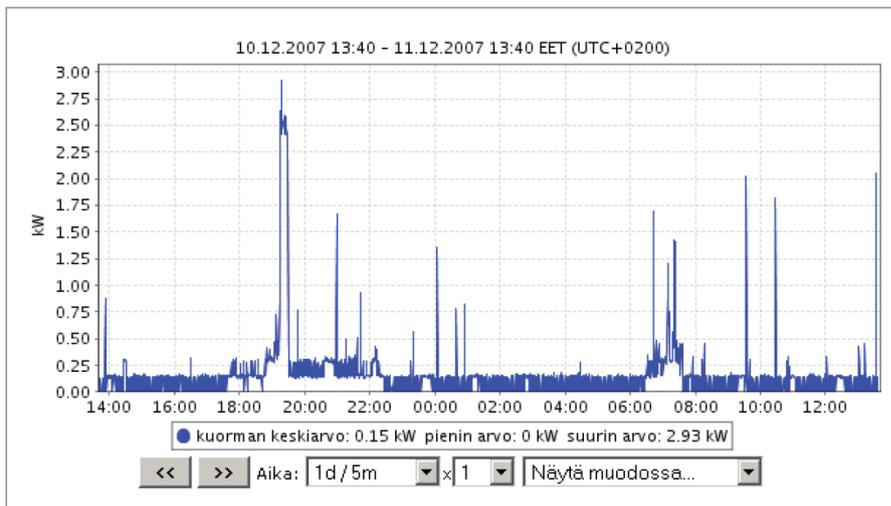
Kuva 4. Yhden asukkaan 56 m² kerrostalohuoneiston yhden vuorokauden kuormitus-

käyrä viiden minuutin tarkkuudella esitettynä (Suomen Ympäristökeskus 2008)

Proposal

i. Utilization of available statistical data on the weekday/end and seasonal variations (Fig 5) that shall reflect external temperatures and daylight hours. Major social events (such as national holidays) are not to be included.

ii. A combined annual daily profile with 5:2 balancing.

4. Domestic hot water usage

Background

Similarly to the other loads DHW is also defined as uniform energy use in the residential buildings (35 kWh/m² yearly), and 46 L/day. The hot part/full water supply ratio is suggested to be varying at ~0.3-0.4 (VTT) and proven total annual average as 0.388 *(9)(1)*. DHW includes only showers (baths), handwashing and kitchen facilities, dishwasher and washing machine use only cold tap water. Measurements from different countries and extensive literature have covered several social factors contributing to the fluctuation of DHW consumption, such as geological location, apartment size, ownership status, occupants' number, age, income, culture, events, activity and lifestyle. All foreign countries verified consumption differences due to annual seasons.

A detailed, 2-year long study on Finnish rental homes in Tampere from 2015 *(1)* found the arithmetic mean total consumption over 182 homes and 379 occupants being 43 L/day, aggregating from different occupancy presence patterns. It showed (Fig. 9) a consistently higher consumption in the winter (November-February) and lower in the summer season (May-August). The weekday (WD) - weekend (WE) difference did not prove statistically significant. A clear connection was established between the occupant number and the daily consumption (Fig. 10): the less the occupant, the higher the consumption. Monthly factors were obtained (Table 1) from the rental homes measurement data and used in an additional solar thermal simulation to see the effect on DHW production's energy efficiency.
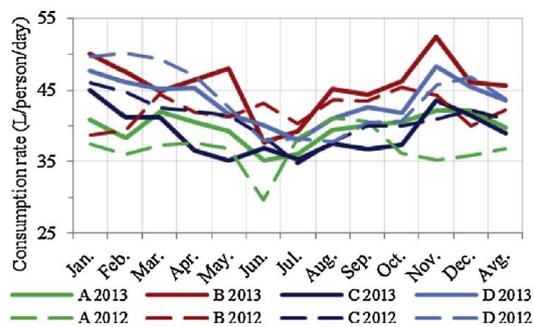
Fig. 9. Comparison of mean consumption rate of DHW for two consecutive years.
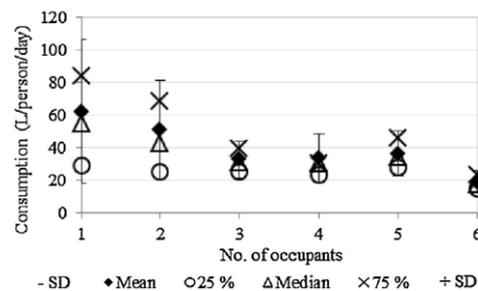
Fig. 10. Specific consumption variations depending on the apartment size. The results are based on arithmetic mean consumption values of the full population of 379 occupants.

Table 1
DHW monthly consumption factor for Finnish apartment buildings (Ahmed et al., 2015a,b).

	Annual average specific consumption, L/person/day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Arithmetic mean (Total)	43	1.105	1.040	1.033	1.005	0.977	0.895	0.880	0.964	0.969	0.980	1.111	1.041
Arithmetic mean (WD)	43	1.119	1.049	1.020	0.999	0.941	0.912	0.892	0.964	0.982	0.987	1.100	1.030
Arithmetic mean (WE)	43	1.067	1.017	1.062	1.023	1.062	0.860	0.845	0.964	0.940	0.961	1.136	1.067

The simulation model was constructed as a single-family house with 3 occupants. The produced contribution varied 50-62% depending on the thermal collector area (4 or 6 m²) in the case of a 0.6m³ hot water tank. The used monthly, hourly and WD-WE profiling proved (Table 5) that the monthly and hourly variation (Case 3) is sufficient when modeling the demand. This result underlines the importance of an accurate DHW profile: an unrealistic profile could lead to a wrong sizing in the SthC-HWT system.

Table 5
Annual energy use and production (kWh/a) with derived DHW profiles and two different sizes of solar thermal panel.

Solar collector area	Case 1 (constant water consumption)		Case 2 (hourly daily profile)		Case 3 (monthly and hourly daily profile)		Case 4 (WD and WE profile, hourly daily profile)	
	6 m²	4 m²	6 m²	4 m²	6 m²	4 m²	6 m²	4 m²
DHW system energy use (kWh/a)	2653	2653	2656	2656	2655	2655	2656	2655
Solar thermal production (kWh/a)	1782	1490	1821	1522	1776	1489	1778	1489
Solar thermal utilized (kWh/a)	1641	1389	1642	1395	1595	1355	1598	1356
Top-up heating (kWh)	1012	1264	1014	1261	1060	1300	1058	1299
The share of solar thermal in total energy use (%)	61.9	52.3	61.8	52.5	60.1	51.0	60.2	51.1
Difference relative to Case 1 (%)	–	–	0.2	0.2	4.7	2.8	4.5	2.8

Hourly variation was considered in the 2015 study as well but a more detailed study from the same authors from 2016 *(10)* was published, drawing conclusions from 86 owner-occupied apartments and 191 occupants for one year in Helsinki. The main peak water usage at 20-22 and a second peak at 7-9, with a 2-3 hour delay in the weekend mornings but identical evenings and amplitude (Fig. 11). Ahmed et al. proposed an hourly profile including seasonal variation (representative months: November, Table 6 and August, Table 7) for 1,3,10, 31 and 50+ persons including WD and WE. The grouping expresses the tendency: lower occupant density leads to significantly higher consumption in the peak hours and lower consumption in the non-peak hours and vice versa (Fig. 12 and 13).
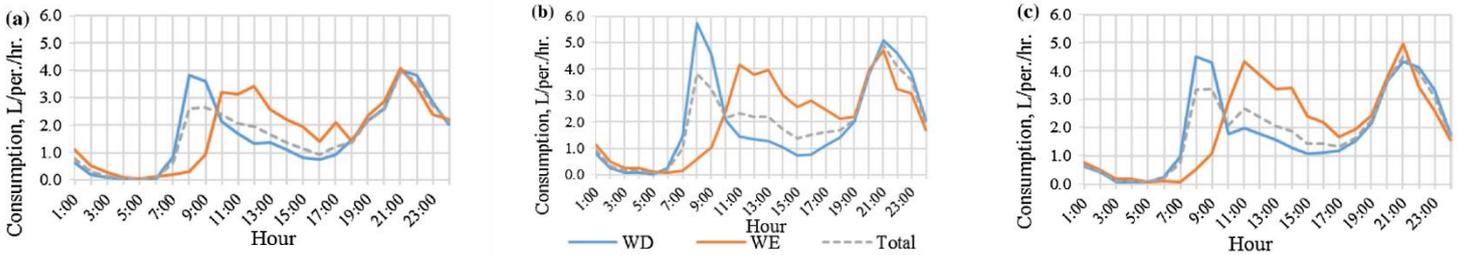
Fig. 11. Hourly average profile of DHW consumption for month of (a) August, (b) November and (c) January.
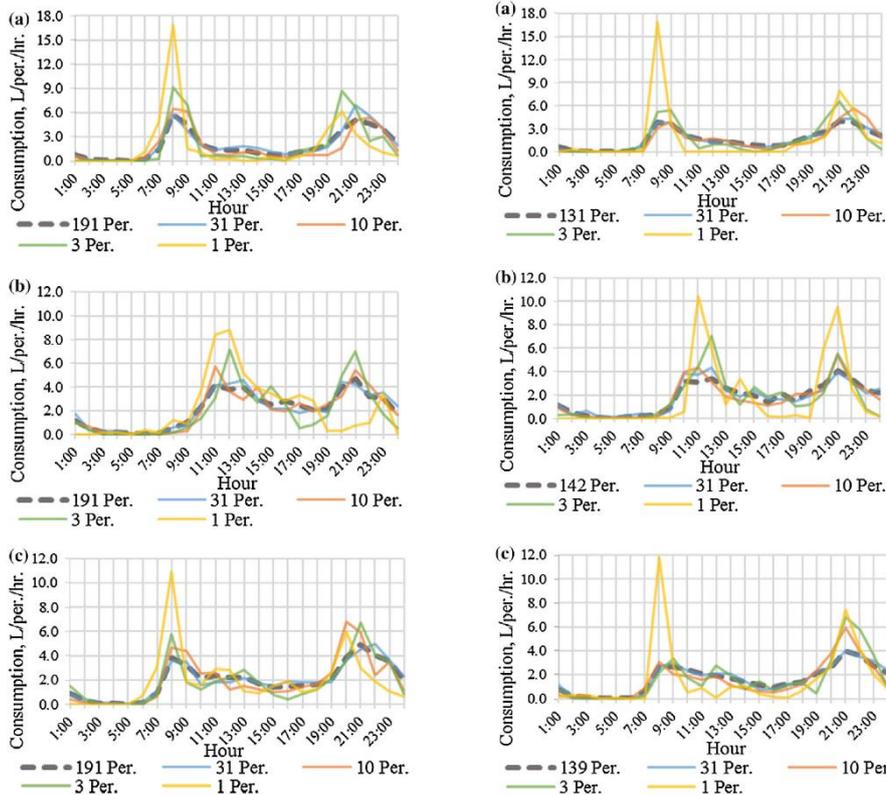
Fig 12. Proposed profiles of 5 groups for month of November (a) Weekday, (b) Veekend, (c) Total day.

Fig 13. Proposed profiles of 5 groups for month of August (a) Weekday, (b) Weekend, (c) Total day.

Table 6
Hourly consumption factors of 5 groups for month of November.

		1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
Weekday	≥50 Per.	0.43	0.14	0.05	0.05	0.01	0.14	0.76	3.00	2.38	1.07	0.75	0.71	0.67	0.54	0.38	0.39	0.57	0.74	1.06	1.99	2.67	2.41	2.01	1.08
	31 Per.	0.33	0.07	0.02	0.02	0.02	0.09	0.79	2.85	1.82	0.96	0.70	0.78	0.93	0.77	0.57	0.38	0.57	0.56	0.87	1.82	3.39	2.78	1.98	0.94
	10 Per.	0.37	0.03	0.02	0.02	0.01	0.29	1.33	3.66	3.47	1.24	0.47	0.40	0.57	0.64	0.26	0.25	0.39	0.42	0.43	0.90	2.87	3.04	2.20	0.74
	3 Per.	0.05	0.03	0.00	0.00	0.01	0.01	0.14	4.77	3.62	0.32	0.31	0.25	0.31	0.14	0.12	0.03	0.66	0.83	0.99	4.58	3.53	1.32	1.60	0.37
	1 Per.	0.04	0.00	0.00	0.00	0.00	0.61	2.53	8.91	0.79	0.58	0.11	0.15	0.04	0.04	0.26	0.04	0.33	0.63	2.09	3.25	1.77	0.96	0.57	0.31
Weekend	≥50 Per.	0.55	0.23	0.11	0.11	0.05	0.03	0.08	0.28	0.49	1.16	1.99	1.81	1.89	1.44	1.22	1.34	1.17	1.01	1.04	1.90	2.26	1.55	1.47	0.81
	31 Per.	0.83	0.18	0.13	0.13	0.04	0.03	0.05	0.30	0.36	1.15	1.95	2.02	2.17	1.41	1.03	1.04	0.86	0.98	0.91	2.09	1.97	1.56	1.67	1.14
	10 Per.	0.47	0.33	0.09	0.09	0.05	0.03	0.01	0.07	0.14	0.94	2.76	1.76	1.44	1.92	1.03	0.97	1.30	0.97	1.26	1.58	2.62	2.02	1.38	0.80
	3 Per.	0.54	0.21	0.03	0.03	0.00	0.01	0.04	0.08	0.32	0.68	1.53	3.56	2.00	1.37	2.03	1.27	0.28	0.41	0.79	2.49	3.48	1.72	0.87	0.26
	1 Per.	0.00	0.00	0.07	0.07	0.00	0.19	0.09	0.58	0.44	1.72	3.90	4.09	2.41	1.81	1.62	1.35	1.53	1.35	0.14	0.14	0.37	0.46	1.62	0.05
Total	≥50 Per.	0.47	0.17	0.07	0.07	0.03	0.10	0.50	1.95	1.65	1.09	1.20	1.12	1.13	0.88	0.71	0.76	0.82	0.85	1.06	1.97	2.51	2.09	1.82	0.98
	31 Per.	0.45	0.14	0.06	0.06	0.04	0.12	0.55	1.82	1.77	0.81	0.94	0.92	1.10	0.89	0.78	0.97	0.95	0.94	0.94	1.87	2.30	2.54	1.85	1.20
	10 Per.	0.21	0.06	0.03	0.03	0.01	0.04	0.34	2.37	2.22	1.31	1.33	0.63	0.79	0.62	0.53	0.56	0.73	0.84	1.29	3.46	3.02	1.23	1.78	0.59
	3 Per.	0.83	0.28	0.01	0.01	0.01	0.03	0.44	3.10	0.96	0.65	1.03	1.20	1.51	0.93	0.41	0.25	0.47	0.66	1.13	1.92	3.60	2.20	1.89	0.47
	1 Per.	0.02	0.00	0.00	0.00	0.00	0.38	1.58	5.57	0.92	0.83	1.50	1.46	0.57	0.47	0.77	0.98	0.53	0.64	1.35	3.06	1.53	0.96	0.55	0.32

Table 7
Hourly consumption factors of 5 groups for month of August.

		1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
Weekday	≥50 Per.	0.40	0.13	0.05	0.02	0.02	0.04	0.52	2.39	2.25	1.33	1.05	0.83	0.86	0.69	0.52	0.46	0.58	0.92	1.37	1.63	2.49	2.39	1.77	1.27
	31 Per.	0.24	0.05	0.03	0.01	0.03	0.04	0.64	2.35	2.37	1.43	0.92	0.80	0.92	0.51	0.39	0.46	0.67	0.84	1.30	1.42	2.61	2.60	1.91	1.47
	10 Per.	0.05	0.00	0.02	0.00	0.01	0.00	0.11	1.98	2.54	1.17	0.97	1.12	0.93	0.64	0.42	0.27	0.62	0.62	0.79	1.31	2.80	3.59	2.84	1.18
	3 Per.	0.05	0.00	0.00	0.00	0.00	0.20	0.36	3.30	3.42	1.50	0.30	0.63	0.60	0.23	0.04	0.13	0.49	0.89	1.09	2.73	4.14	2.53	1.11	0.24
	1 Per.	0.04	0.18	0.06	0.04	0.00	0.00	0.04	9.70	2.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.70	1.15	4.56	3.12	0.99	0.70
Weekend	≥50 Per.	0.64	0.29	0.15	0.05	0.03	0.08	0.12	0.18	0.53	1.81	1.76	1.94	1.46	1.26	1.10	0.80	1.18	0.81	1.33	1.63	2.31	1.93	1.35	1.25
	31 Per.	0.63	0.22	0.37	0.07	0.05	0.13	0.24	0.07	0.37	2.12	2.06	2.40	1.33	1.01	1.31	0.92	0.92	0.83	1.05	1.39	2.20	1.72	1.20	1.39
	10 Per.	0.53	0.15	0.13	0.05	0.03	0.03	0.06	0.04	0.68	2.55	1.85	1.09	0.94	0.77	0.65	0.79	1.23	1.22	1.39	3.21	1.79	1.47	0.96	
	3 Per.	0.18	0.19	0.04	0.01	0.00	0.00	0.00	0.19	0.67	1.62	2.56	4.08	1.59	0.67	1.57	1.08	1.32	0.59	0.67	1.26	3.20	1.96	0.45	0.11
	1 Per.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.35	5.91	3.40	0.66	1.92	0.79	0.13	0.06	0.16	0.03	3.33	5.38	1.42	0.31	0.09
Total	≥50 Per.	0.49	0.19	0.08	0.03	0.03	0.05	0.40	1.63	1.65	1.50	1.28	1.21	1.04	0.86	0.71	0.58	0.76	0.85	1.35	1.60	2.46	2.24	1.69	1.34
	31 Per.	0.70	0.12	0.03	0.03	0.03	0.04	0.22	1.63	1.81	1.43	1.21	1.26	1.25	0.89	0.47	0.51	0.76	0.81	1.30	1.60	2.45	2.10	1.91	1.41
	10 Per.	0.23	0.09	0.05	0.00	0.00	0.01	0.61	2.02	1.32	1.24	1.03	1.22	0.76	0.54	0.42	0.36	0.58	0.77	1.50	2.44	3.88	2.60	1.73	0.59
	3 Per.	0.46	0.02	0.00	0.00	0.02	0.00	0.13	1.31	2.01	1.03	0.63	1.66	1.15	0.52	0.88	0.43	0.66	0.81	0.28	1.83	4.09	3.47	2.16	0.46
	1 Per.	0.09	0.20	0.20	0.03	0.06	0.03	0.03	7.23	1.66	0.34	0.55	0.06	0.61	0.64	0.25	0.12	0.06	0.43	1.01	1.59	4.54	2.54	1.20	0.52

Proposal

DHW profile changes:

  i. Consider keeping the current 46 L/day/person for Use Case 1 (single family house) and 43 L/day/person for Use Case 2 (multistorey building). Separate schedule for Use Case 2.

  ii. Weekend-weekday variation to consider.

  iii. Annual seasonal variation (monthly factors (Table 1)) combined with hourly profile (Tables 1, 6 and 7).

   • The hourly profile for WD, WE, TD of all months could be generated from obtaining profiles with monthly consumption factors (Table 1) and hourly consumption factors (Tables 6 and 7).

Solar thermal collectors:

A reservation of a solar thermal collector (SThC) could dampen the peak demand and contribute to the annual production energy costs. SThC-HWT features and properties (sizing, heat losses) to be optimized upon location.

5. Conclusion

Research stresses that the occupant density and their presence/activity level schedule are the most crucial factors that influence the HVAC supply systems and DHW consumption. From calculation point of view, it is more beneficial to separate these loads when generating profiles for the entire population.

Several suggestions occur: different profiles for different types of simulations, such as E-value (E-luku) annual energy calculation, more refined profile for overheating and different resolutions of metabolic rate.

In the [newest EPBD update](#) Article 11 states "Päästöttömän rakennuksen on kyettävä, jos se on taloudellisesti ja teknisesti toteutettavissa, reagoimaan ulkoisiin signaaleihin ja mukauttamaan omaa energian käyttöä, tuotantoa ja varastointia." More detailed profiles, especially on shorter time intervals may inform the supply and generation system the momentary demand and the possible energy storages to prepare (pre-charge). This way integrating and utilizing renewables into the energy system could be enhanced, e.g. PV panels, solar thermal collectors, ground heat exchange but it also requires the installation of an advanced building control and automation system. Without profiling high-resolution input data it could be rather challenging to study and draw further conclusions about the subsystems behavior.

Additionally, the same Article 11 sets the requirement of new buildings to present a certain level of readiness for future energy efficiency development options. This includes a possibility of building communication to modify the energy behavior in respect of usage, production, storage, nearby produced energy's access and utilization.

Article 10 requires state member-level optimization of solar potential utilization, both technically and financially. Providing detailed profiles, especially electric consumption supports and enhances optimal photovoltaic system design, investments and their return. Profiled DHW consumption supports a coordinated solar thermal collector-hot tank sizing.

Below the summary of suggested profiles for additional discussion and decision-making:

i) Occupancy profile. All residential use remains to be profiled at 60% but the options are:
   a. varying presence/absence with permanent MET (1.2). The absence never goes 0 nor 100%.
   b. presence/absence balanced with a variable MET rate (between 1.2 and 0.7, average 0.96, ~1.0) and weighted according to the ratio of presence/absence. The profile is repetitive for every day, no seasonal nor weekly variation is included. A 30-minute interval is a considerable refinement. Time series attached in the Appendices.

ii) Lighting load: due to lack of separate data an annual correction factor (monthly) is proposed to add to the profiles. The formerly used 10% remains but annually is to be weighted. The trend is registered in the context of Plug loads. Monthly factors attached.

iii) Plug loads. Both monthly and weekend/weekday variation is identified in Finnish household research. The former 60% profile remains in use, 2 options identified, to be used with the monthly factors attached at the Lighting load. Profiles are attached:

a. separate WE/WD variation
b. a combined, 5:2 ratio balanced single series for the entire year.

iv) Domestic hot water profiles: expressing both weekly and seasonal variation, profiles and monthly factors attached.

Different profiles shall be used at different calculations:

Calculation / load profile type	Monthly energy method	Dynamic annual energy	Overheating (dynamic)	PV sizing	Solar thermal + tank sizing
Occupancy	No variation in MET nor presence	MET and presence variation	MET and presence variation	-	-
Lighting	Monthly factor	Monthly factor	Monthly factor	Production-consumption matching factor for the monthly method	-
Plug loads	Monthly factor	Monthly and WD/WE variation	Monthly and WD/WE variation		-
DHW	Monthly factor	Monthly factor	-	-	Production-consumption matching factor for the monthly method

6. References

Occupancy:
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(2) Ian Richardson, Murray Thomson, David Infield. 2019. A High-resolution Domestic Building Occupancy Model for Energy Demand Simulations. Loughborough University [link]
(3) Dorien Aerts, Joeri Minnen, Ignace Glorieux, Ine Wouters, Filip Descamps. 2014. A method for the identification and modelling of realistic domestic occupancy sequences for building energy demand simulations and peer comparison. Building and Environment, volume 75, pages 67-78.

Lighting:

(4) https://www.kesko.fi/en/media/news-and-releases/news/2022/energy-awareness-on-the-rise/
(5) Gabriele Lobaccaro, Simona Esposito, Francesco Goia, Marco Perino. 2017. Daylighting availability in a living laboratory single family house and implication on electric lighting energy demand. Energy Procedia, volume 122, pages 601-606.
(6) Andrea Ferrantelli, Helena Kuivjõgi, Jarek Kurnitski, Martin Thalfeldt. 2020. Office Building Tenants' Electricity Use Model for Building Performance Simulations. Energies, open access article by MDPI.

Plug loads:
(7) Jukka V. Paatero and Peter D. Lund. 2006. A model for generating household electricity load profiles. International Journal of Energy Research, volume 30, number 5, pages 273-290.
(8) Mikko Haulio. 2009. DI-työ, TKK. Sähkönkulutuksen analysointi ja mallintaminen kerrostaloissa.

Domestic hot water:

(9) Kaiser Ahmed, Petri Pylsy, Jarek Kurnitski. 2015. Monthly domestic hot water profiles for energy calculation in Finnish apartment buildings. Energy and Buildings, volume 97, pages 77–85.
(10) Kaiser Ahmed, Petri Pylsy, Jarek Kurnitski. 2016. Hourly consumption profiles of domestic hot water for different occupant groups in dwellings. Solar Energy, volume 137, pages 516-530.

7.Appendices

Occupancy profile

MET-balanced profile (on the left) and presence-absence profile with constant MET (0.96).

time	MET*pres 60%
0:00	0.56
0:30	0.58
1:00	0.60
1:30	0.60
2:00	0.60
2:30	0.61
3:00	0.61
3:30	0.61
4:00	0.63
4:30	0.63
5:00	0.62
5:30	0.62
6:00	0.61
6:30	0.61
7:00	0.58
7:30	0.62
8:00	0.71
8:30	0.64
9:00	0.61
9:30	0.57
10:00	0.62
10:30	0.57
11:00	0.54
11:30	0.54
12:00	0.57
12:30	0.61
13:00	0.62
13:30	0.60
14:00	0.53
14:30	0.50
15:00	0.47
15:30	0.47
16:00	0.48
16:30	0.51
17:00	0.54
17:30	0.62
18:00	0.65
18:30	0.71
19:00	0.74
19:30	0.77
20:00	0.66
20:30	0.67
21:00	0.69
21:30	0.71
22:00	0.59
22:30	0.53
23:00	0.55
23:30	0.56
0:00	0.58

time	present	absent	MET
0:00	0.85	0.15	0.96
0:30	0.875	0.125	0.96
1:00	0.9	0.1	0.96
1:30	0.9	0.1	0.96
2:00	0.9	0.1	0.96
2:30	0.925	0.075	0.96
3:00	0.925	0.075	0.96
3:30	0.925	0.075	0.96
4:00	0.95	0.05	0.96
4:30	0.95	0.05	0.96
5:00	0.935	0.065	0.96
5:30	0.93	0.07	0.96
6:00	0.925	0.075	0.96
6:30	0.925	0.075	0.96
7:00	0.875	0.125	0.96
7:30	0.825	0.175	0.96
8:00	0.75	0.25	0.96
8:30	0.675	0.325	0.96
9:00	0.65	0.35	0.96
9:30	0.6	0.4	0.96
10:00	0.55	0.45	0.96
10:30	0.5	0.5	0.96
11:00	0.475	0.525	0.96
11:30	0.475	0.525	0.96
12:00	0.5	0.5	0.96
12:30	0.54	0.46	0.96
13:00	0.55	0.45	0.96
13:30	0.525	0.475	0.96
14:00	0.465	0.535	0.96
14:30	0.44	0.56	0.96
15:00	0.415	0.585	0.96
15:30	0.4125	0.5875	0.96
16:00	0.425	0.575	0.96
16:30	0.45	0.55	0.96
17:00	0.475	0.525	0.96
17:30	0.55	0.45	0.96
18:00	0.575	0.425	0.96
18:30	0.625	0.375	0.96
19:00	0.65	0.35	0.96
19:30	0.675	0.325	0.96
20:00	0.7	0.3	0.96
20:30	0.71	0.29	0.96
21:00	0.725	0.275	0.96
21:30	0.75	0.25	0.96
22:00	0.775	0.225	0.96
22:30	0.8	0.2	0.96
23:00	0.825	0.175	0.96
23:30	0.85	0.15	0.96
0:00	0.875	0.125	0.96

Lighting load

Monthly factor to be used both at lighting and plug loads.

Monthly corr factors	
January	1.15
February	1.075
March	1.025
April	0.95
May	0.875
June	0.85
July	0.875
August	0.9
September	0.99
October	1.075
November	1.125
December	1.15

Plug load

Weekday/end profiles (on the left) and WD/WE 5:2 balanced annual profile (on the right).

Time	WD Profile	WE profile
0 -1	0.37	0.40
1-2	0.33	0.34
2-3	0.30	0.31
3-4	0.31	0.30
4-5	0.35	0.30
5-6	0.41	0.31
6-7	0.49	0.36
7-8	0.55	0.44
8-9	0.55	0.55
9-10	0.56	0.64
10-11	0.56	0.70
11-12	0.57	0.72
12-13	0.58	0.73
13-14	0.61	0.74
14-15	0.67	0.75
15-16	0.76	0.77
16-17	0.84	0.81
17-18	0.89	0.84
18-19	0.93	0.86
19-20	0.95	0.88
20-21	0.93	0.85
21-22	0.81	0.74
22-23	0.63	0.60
23-24	0.47	0.47

time	profile
0 -1	0.38
1-2	0.33
2-3	0.30
3-4	0.30
4-5	0.34
5-6	0.38
6-7	0.45
7-8	0.52
8-9	0.55
9-10	0.58
10-11	0.60
11-12	0.61
12-13	0.62
13-14	0.65
14-15	0.69
15-16	0.76
16-17	0.83
17-18	0.87
18-19	0.91
19-20	0.93
20-21	0.90
21-22	0.79
22-23	0.62
23-24	0.47

Domestic hot water

Weekday/weekend profile (on the left) and a monthly usage factor (on the right).

Time	WD profile	WE profile
0 -1	0.58	0.35
1-2	0.10	0.69
2-3	0.03	0.38
3-4	0.00	0.07
4-5	0.00	0.04
5-6	0.01	0.00
6-7	0.20	0.01
7-8	0.48	0.04
8-9	7.73	0.26
9-10	6.75	0.95
10-11	1.74	2.20
11-12	0.58	3.92
12-13	0.84	7.32
13-14	0.87	3.44
14-15	0.35	1.96
15-16	0.15	3.45
16-17	0.15	2.25
17-18	1.10	1.53
18-19	1.65	0.96
19-20	1.99	1.40
20-21	7.01	3.59
21-22	7.35	6.40
22-23	3.69	3.53
23-24	2.60	1.27

Monthly corr factor	
January	1.105
February	1.04
March	1.033
April	1.005
May	0.977
June	0.895
July	0.88
August	0.964
September	0.969
October	0.98
November	1.111
December	1.041