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Original Publication

Philip Fairey, Danny Parker, "A Review of Hot Water Draw Profiles Used in Performance Analysis of Residential Domestic Hot Water Systems", July 20, 2004.

Publication Number

FSEC-RR-56-04

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A Review of Hot Water Draw Profiles Used in Performance Analysis of Residential Domestic Hot Water Systems

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July 20, 2004

Abstract

As a result of efforts on the part of various organizations to improve the specifications for performance-based analysis of energy use in residences, the literature on residential hot water use has been reviewed, specifically as it relates to typical hot water use draw profiles. A number of daily hot water use draw profiles have been identified and reviewed.

Existing Data and Sources

Perhaps the historically most widely used daily hot water draw profile has been the so-called “ASHRAE draw profile.” Review of the literature revealed that there are at least two ASHRAE hot water draw profiles: one coming from the *HVAC Applications Handbook* (2003) and the second coming from ANSI/ASHRAE Standard 90.2 (1993). The source for the profiles contained in the Applications Handbook is research conducted by Perlman and Mills (1985) and the source of the profile specified by Standard 90.2 is not provided. The data most often abstracted from the Applications Handbook for use as a hot water draw profile are those given by Figure 10 that are labeled as “typical.” Review of the source for these data (Perlman, 1985) reveals two important considerations: first, all monitored data within the data set are from Canadian residences; and second, and more important, “typical” is defined as only those homes with two adults and two children where a cloths washer and dish washer are present. While Perlman (1985) provides two sets of data, one for “all families” and one for “typical” families, the tendency of users has been to select the “typical” hot water draw profile, believing it to be the most representative based on its nomenclature. In fact, the opposite is more likely true. Considering current U.S. Census (2000) demographics showing an average of 2.59 residents per household, Perlman’s definition of “typical” is unfortunate.

In a research project designed to update the data on residential hot water use patterns, Becker and Stogsdill (1990) gathered, analyzed and reported on nine different data sets consisting of more than 3 million data points on hot water use in residences. This project included the data used by Perlman (1985) as well as a number of additional data sets that were gathered in both Canada and the continental U.S. From the continental U.S., Becker’s database included measurements from 110 single-family residences from 11 utilities reported by Gilbert et al. (1985); measurements from 142 homes in the Hood

River Oregon area reported by Hirst, et al. (1987); and monitoring data from 74 homes in Florida and 24 homes in North Carolina reported by Merrigan (1988). Each of these data sets contained measured hot water use data of one year or greater in duration, from which Becker reports the average hourly hot water use in gallons for the continental U.S.

Bouchelle and Parker (2000) reported on hot water demand profiles for a large 204-home sample study conducted in central Florida. Parker (2002) reports the hourly demand profiles for this study by month of the year. More recently Parker (2004) has compiled and analyzed the data for the 170-home statistical sample to provide a normalized annual hourly hot water demand profile.

The Solar Rating and Certification Corporation (SRCC)¹ provides ratings for solar hot water systems under its OG-300 certification program. To rate the annual performance of certified systems, SRCC uses tested performance parameters and annual hourly computer simulations using TRNSYS (1994) and an hourly hot water draw profile. SRCC's annual performance reports cite the source for the hot water draw profile as "adapted from the 1995 ASHRAE Applications Handbook, Chapter 45, and 'A Domestic Hot Water Use Database', Becker and Stogsdill, ASHRAE Journal, September 1990." The ASHRAE Application Handbook data are sourced to Perlman and Mills (1985) and the Becker and Stogsdill article is sourced to their *ASHRAE Transactions* article (Becker, 1990), both of which have been previously cited in this review. The authors obtained the actual hot water draw profile used in these SRCC analyses from Huggins (2004).

Thus, the primary sources for hot water draw profiles are Perlman (1985) – "typical" Canadian use profile; Becker (1990) – average U.S. use profile; ASHRAE Standard 90.2 (1993) – a national consensus standard; SRCC – a not-for-profit certification corporation; and Bouchelle (2000) – hot water demand data from 170 Florida homes.

Comparison of Draw Profiles

Each of the above hot water draw profiles may sum to a different total daily hot water use or demand, depending on climate. To facilitate direct comparison of the above hot water use or demand profiles, dividing each hour's hot water use or demand by the total daily hot water use or demand normalizes them. This computation results in hourly hot water profiles that are each equal to the fractional portion of the total daily draw, reducing each data set to directly comparable hourly values. Figure 1 on the following page provides a comparison of all of these normalized hot water draw profiles.

¹ SRCC is a not-for profit corporation that provides certification and ratings for solar collectors and systems for a fee. See <http://www.solar-rating.org/>

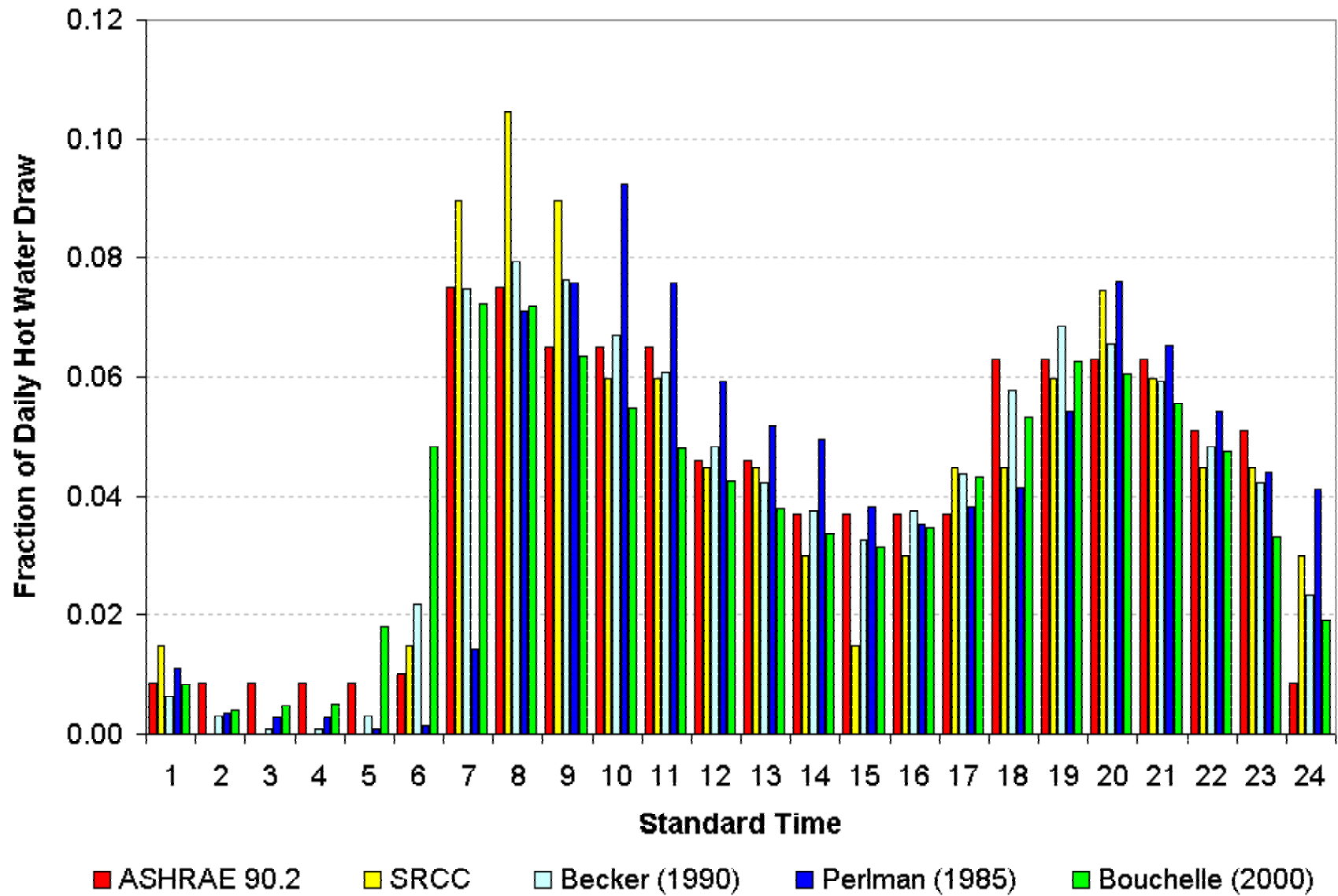


Figure 1. Histogram of identified hot water draw profiles, normalized as the fraction of total daily hot water use or demand.

Review of Figure 1 shows that the SRCC and Perlman (1985) “typical” draw profiles stand out as significantly different from the others. Removing them from the data set produces the chart given by Figure 2 below.

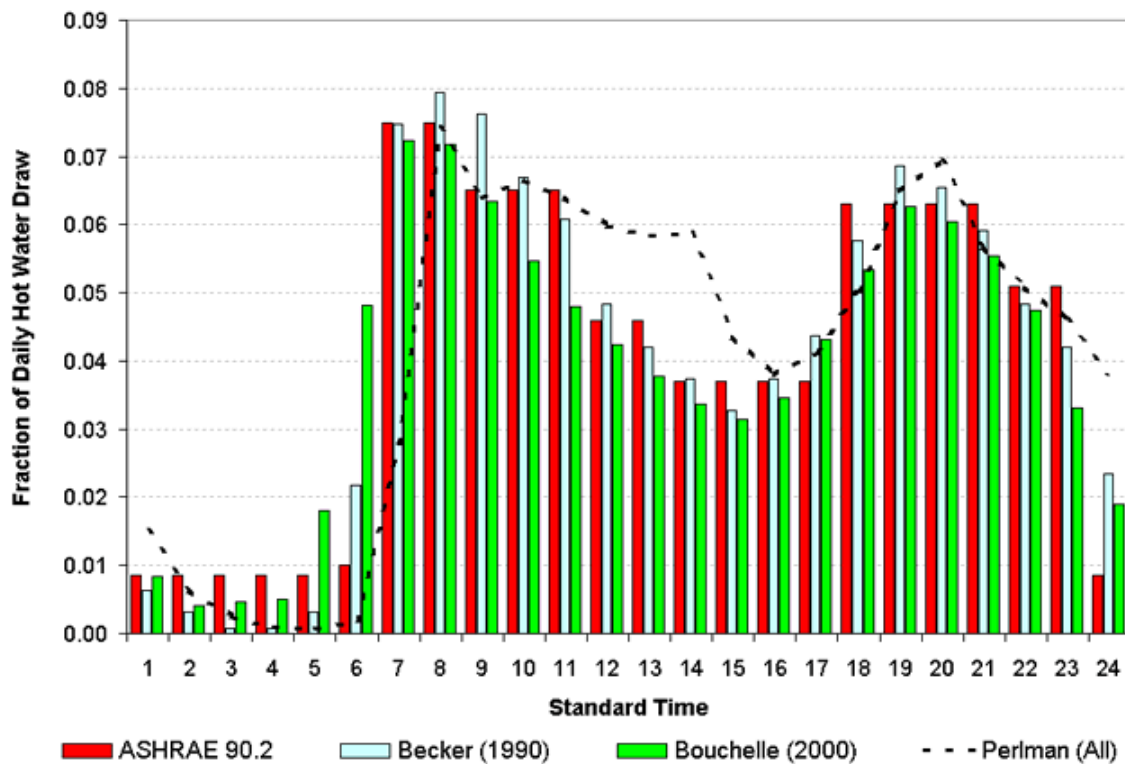


Figure 2. Histogram of identified hourly hot water draw profiles with SRCC and Perlman, 1985 profiles removed.

Figure 2 shows that there is significant similarity among the identified hot water draw profiles once the SRCC and Perlman (1985) “typical” profiles are removed. The Perlman (1985) “all families” profile is added to the Figure 2 chart to illustrate that this hot water draw profile, albeit preferable to the “typical” profile, is also inconsistent with the remaining three profiles. In fact, the comparison indicates that there may be a time lag inconsistency in the Perlman (1985) data set. It is also interesting to note that while the actual source for the ASHRAE Standard 90.2 draw profile is not given, its profile is reasonably similar to that of the largest compilation of U.S. hot water use data sets (Becker, 1990) and also to that of a large sample of monitored demand data measured in 170 Florida homes.

Of the identified data sets, Becker (1990) is the most comprehensive compilation of U.S. measured use data and ASHRAE Standard 90.2 and SRCC are the draw profiles that are specified by organizations for use in hot water system performance analysis. Thus, it is useful to compare Becker (1990) with these other two specifications for hot water draw profiles. Figure 3 provides this comparison.

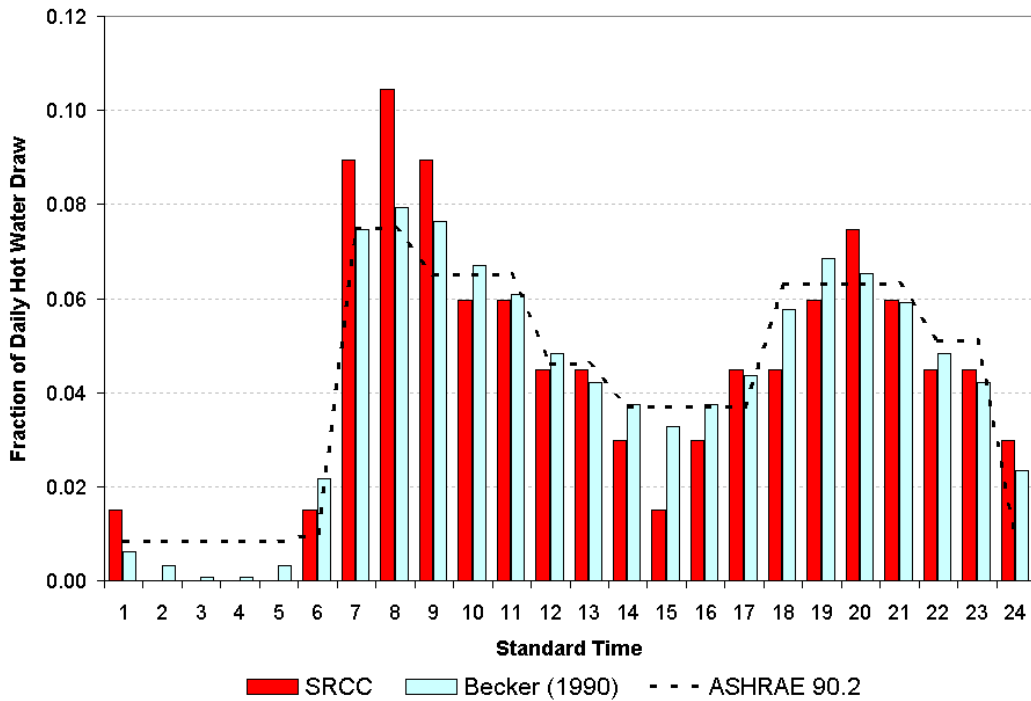


Figure 3. Comparison of SRCC, Becker (1990), and ASHRAE Standard 90.2 hot water draw profiles showing similarity between Becker (1990) and ASHRAE Standard 90.2.

And the SRCC draw profile shown in figure 3 is “adapted from” Perlman (1985) and Becker (1990) so it is also useful to make that comparison as well, as shown in Figure 4 below.

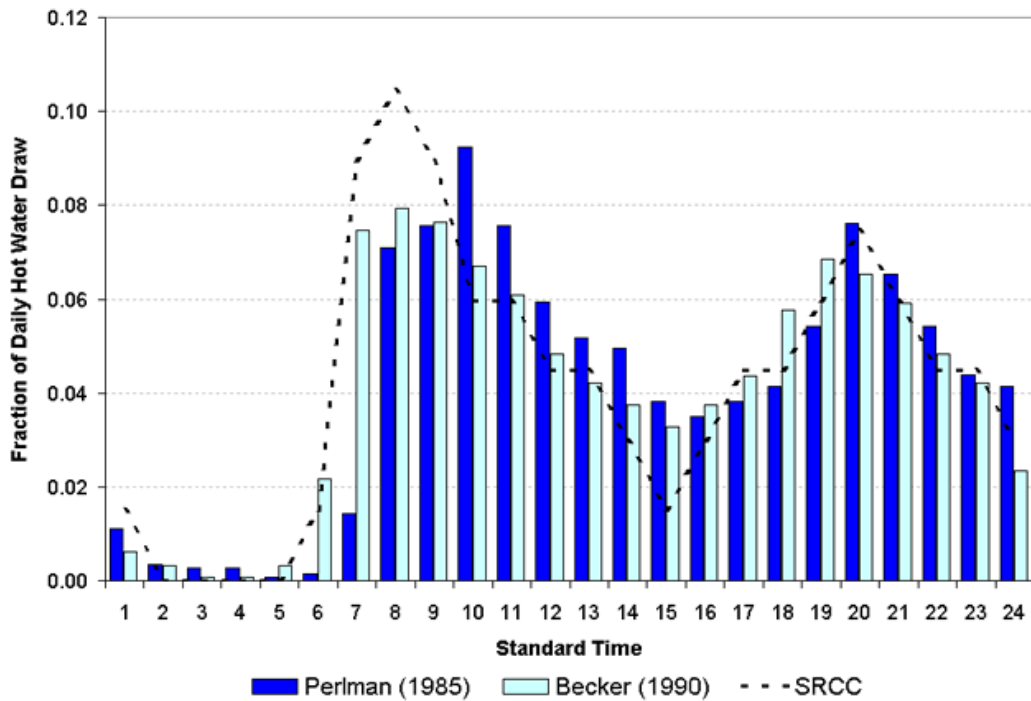


Figure 4. Comparison of Perlman (1985), Becker (1990) and SRCC hot water draw profiles.

Conclusions

Figure 1 shows that there is significant variance in reported hot water draw profiles that might be used in performance analysis of hot water systems. One of these data sets, Perlman (1985), may be seriously questioned for use in the U.S. because its data comes solely from Canadian climates and because its definition of “typical” households is not based on realistic current U.S. demographic patterns.

Figure 2 illustrates that there is general agreement between at least three reported hot water draw profiles, one of which is specified in an ANSI Standard and one of which contains the largest compilation of U.S. measured hot water use data sets to date. The third data set in the group that is in general agreement is monitored hot water demand data from a sample of 170 Florida homes (Bouchelle, 2000).

Figure 3 demonstrates that there is general agreement between the largest compilation of U.S. hot water use data (Becker, 1990) and the hot water draw profile specification of ASHRAE Standard 90.2 but poor agreement between these two profiles and the draw profile specified for use by SRCC.

Figure 4 compares the SRCC hot water draw profile with the two data sources from which it is “adapted” (Perlman, 1985 and Becker, 1990). This figure shows little relationship between the SRCC hot water draw profile and the cited sources from which it is adapted.

From this review of identified hot water draw profiles that are available for use in performance analysis, one can conclude the following:

- The most defensible of the available hot water draw profiles are Becker (1990) and ASHRAE Standard 90.2 – Becker (1990) because it is based on the largest compilation of measured U.S. data to date, and ASHRAE Standard 90.2 because it is a national consensus standard sanctioned by ANSI.
- The ASHRAE Application Handbook hot water draw profile is limited in application because it is based solely on Canadian data (Perlman, 1985) with four-person households and is not consistent with current U.S. demographic patterns.
- The SRCC hot water draw profile is inappropriate because it is inconsistent with the two data sets of its cited references and it is out of line with other national consensus standards.

Recommendations

- Either the ASHRAE Standard 90.2 or the Becker (1990) hot water draw profile should be used for performance analysis of hot water systems.
- The ASHRAE Applications Handbook should be revised to provide the Becker (1990) hot water draw profile data instead of the Perlman (1985) hot water draw profile data, making it more consistent with ASHRAE Standard 90.2.

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