Annex 1

Revision of Power Ratings of Variable-load Appliances in the Pilot Residential End-Use Energy Consumption Survey

Ir. Leong Siew Meng

Green Tech Solutions, Malaysia

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ANNEXES

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IR. LEONG SIEW MENG
Green Tech Solutions, Malaysia

A1-1: Introduction

In conducting the pilot residential end-use energy consumption survey, it was recognized that there were constraints and potential sources of inaccuracy if certain technical considerations were not taken into account in the interpretation and analyses of the survey data. Unlike commercial buildings where energy consumption breakdowns through sub-metering are available, data can be easily extracted for accurate analysis of end-use energy consumption from the records of sub-metering readings. Survey of residential energy consumption needs to rely on respondents' response with accuracy in furnishing data such as utility bills, power ratings of appliances, quantity of appliances and fittings and estimated duration of usage. The following sections discuss the constraints and potential sources of inaccuracy, which were based on a review conducted on the Malaysian survey results.

A1-2: Constraints of the Pilot Survey

It should be noted that this pilot survey has its limitations due to the limited scope and scale of the survey. The WG members from the ASEAN and China were requested to conduct the survey for 6 months from September 2011 to February 2012. Each country was asked to collect at least 10 samples from urban households and 10 samples from rural households.

The pilot survey was conducted mainly on voluntary basis through each country's representative, who in turn needs to rely on his/her own resources and goodwill of

his/her networking contacts (predominantly his colleagues) in order to access to some of the urban and rural households. The lack of coverage with respect to the extensiveness on locations of households and their respective social strata might have caused limitation on the survey results. Some of the rural households may not be distinctly rural and vice versa. Some of the rural households could be semi-urban households, for example. The small sampling size is likely to be influenced by the inherent inconsistency due to the demographic conditions and limited survey data. Nevertheless, the pilot survey study would serve to provide an exercise and illustration on the methodology and format for conducting and analyzing residential end-use energy consumption survey.

A1-3: Analysis of Pilot Survey Results

Power Rating of Household Appliances

Energy consumption for the usage of various household appliances can be calculated from the power ratings of appliances and the duration of usage provided in the survey data filled in by survey respondents from the following formula:

$$\text{Energy Consumption (kWh)} = \text{Power Rating (kW)} \times \text{Usage Duration (h)}$$

This calculation method is correct for constant load usage such as lighting, for example, 14 watt CFL (compact fluorescent light) for a daily usage duration of 5 hours would consume an estimated 2.1 kWh per month but a 1-hp (0.746 kW) split-unit air conditioner for a daily usage of 5 hours would not consume 112 kWh per month (i.e. 0.746 kW x 5 x 30). This is because the energy consumption profile of an air conditioner is not a constant-load process. This observation was verified through an experiment conducted in Malaysia, where power data-logging exercises on a 1-hp split-unit air conditioner and a refrigerator were conducted. This exercise was conducted in an office in Subang Jaya in Selangor, Malaysia but it was representative of typical household appliance. Electrical load profiles of the air conditioner and refrigerator were plotted and are shown below.

Figure A1-1: Power data-logging of a 1-hp split unit air-conditioner to establish electrical load profile & determine diversity factor (DF)

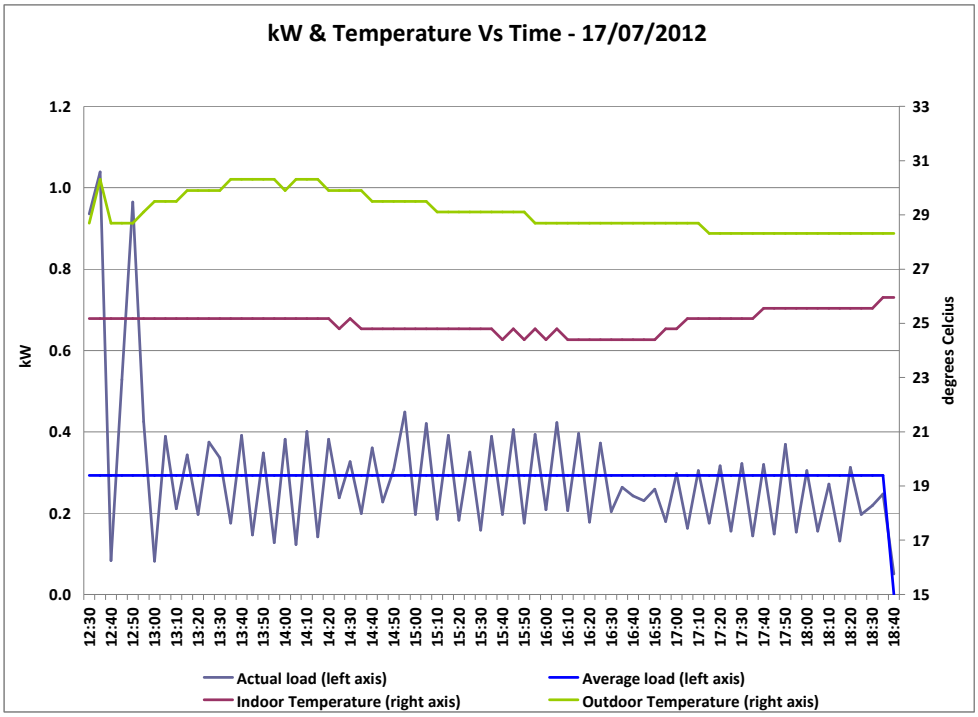

Figure A1-1 shows that the outdoor temperature during this experiment was about 29^0 to 30^0C and the indoor temperature was about 25^0C with air conditioner switched on. Except for the start-up load registered at a peak of about 1 kW, the steady-load range was about 0.2 kW to 0.4 kW, which can be translated to a constant load of about 0.3 kW. Therefore, the energy consumption of this particular air-conditioning exercise could be estimated to be 1.2 kWh (based on 0.3kW x 4h) instead of 2.984 kWh if the estimation was based on the air conditioner's power rating of 1-hp (i.e. 0.746 kW x 4h).

Figure A1-2: Power data-logging of a 150 W refrigerator to establish electrical load profile & determine diversity factor (DF)

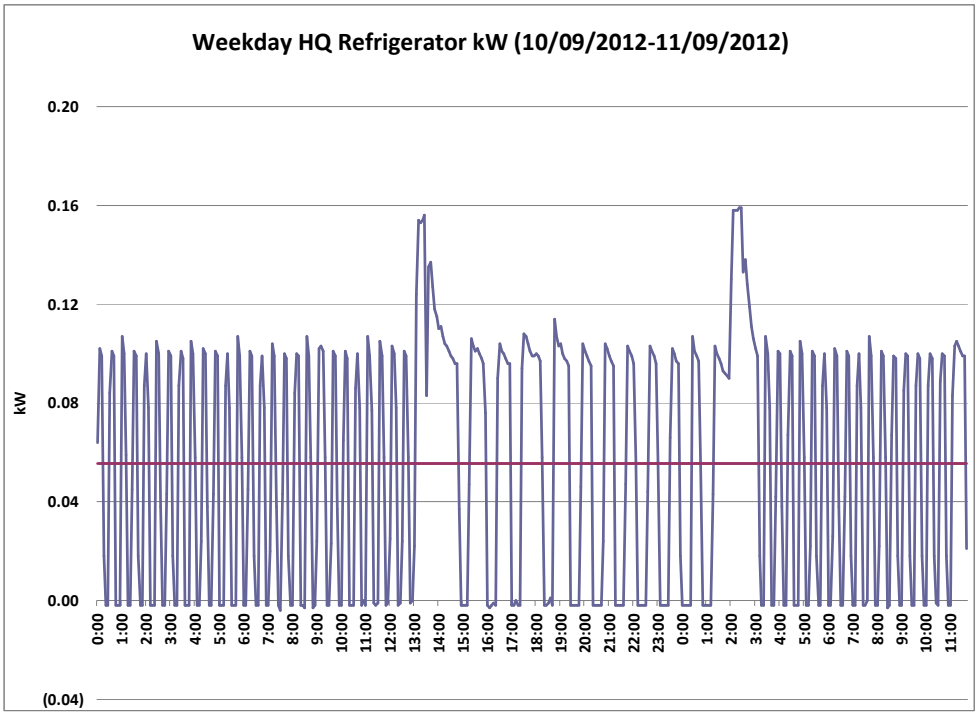

Figure A2-2 shows that the electrical load profile of a refrigerator which has a power rating of 150 W. The average electrical load worked out to be about 0.058 kW and the daily energy consumption of this particular refrigerator could be estimated to be 1.392 kWh instead of 3.6 kWh if the estimation was based on the refrigerator's power rating of 150 W (i.e. 0.15 kW x 24h).

Diversity Factors

It can be seen from these two experiments that appliances such as air conditioners and refrigerators have variable electrical loads due to the functioning of such appliances, which undergo power "on-off" or modulating phenomenon. Therefore, the estimation of energy consumption of variable load appliances will need to apply a diversity factor, which is an approximate value to take into account of the fluctuating loads. Based on the experiments mentioned in the above, the diversity factor for the air conditioner worked out to be 0.4 (i.e. 1.2kWh / 2.984kWh). However, it was recognized that the experiment was conducted in an office room within an air-conditioned office environment. The heat gained and cooling energy leakages would

be much less than a residential environment. It was recommended that the diversity factor for split-unit air conditioners be based on industry-practice value of 0.6.

Similarly, the diversity factor of refrigerators worked out to be 0.386 (i.e. 1.392kWh / 3.6kWh). Again, due to the fact that the experiment was conducted in an office environment where the ambient temperature was generally lower than that of a residential environment, it was thought that the diversity factor for refrigerators used in residential environment should be higher due to the higher ambient temperature and generally higher load contents for household refrigerators. It was noted that the diversity factor derived from a Japan refrigerator pilot survey was 0.4. This value was further deliberated in the WG meetings. To take into account of the climate in Southeast Asia that can affect the performance, the diversity factor for refrigerators in the analysis of survey data was taken as 0.45.

Table A1-1: Diversity Factors for typical household appliances

Appliances	**Power Rating** (Watt)	**Diversity Factor**
Air-conditioners		0.6
Fans	Ceiling fans: 73 Stand fans: 58	0.7
Refrigerators		0.45
Water heaters	3,600	0.8
Lighting	Fluorescent lamps T8 (120cm): 36 + 6 = 42 T8 (60 cm): 18 + 6 = 24 T5 (120cm): 28 + 2 = 30 T5 (60 cm): 14 + 2 = 16	40%
Washing machine		Nil
Rice cooker		Nil

It was mentioned above that lighting has a constant-load consumption profile but due to the questionnaire in the survey form which asked for quantity of light fittings in a household and the fact that not all light fittings are switched on all the time, a usage factor of 40 percent would be applied for the estimation of lighting energy consumption.

A1-4: Other Observations

Other observations made in the review of the survey data obtained in Malaysia were highlighted and discussed in the WG meetings as follows:

1. Some of the energy consumption units (kWh) filled in did not tally with the utility billing amount if the tariffs were taken into consideration.
2. Not all the survey forms returned were provided with 6 months' data as some were 3, 4, and 5 months.
3. Some households do not have electric range/stoves, microwave ovens, food processors, blenders, etc. For these appliances, the energy consumptions were recommended to be classified under "other appliances" category.