European and Canadian non-HVAC Electric and DHW Load Profiles for Use in Simulating the Performance of Residential Cogeneration Systems

A Report of Subtask A of
FC+COGEN-SIM
The Simulation of Building-Integrated
Fuel Cell and Other Cogeneration Systems

Annex 42 of the
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Preface

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster co-operation among the twenty-four IEA participating countries and to increase energy security through energy conservation, development of alternative energy sources and energy research, development and demonstration (RD&D).

Energy Conservation in Buildings and Community Systems

The IEA sponsors research and development in a number of areas related to energy. The mission of one of those areas, the ECBCS - Energy Conservation for Building and Community Systems Programme, is to facilitate and accelerate the introduction of energy conservation, and environmentally sustainable technologies into healthy buildings and community systems, through innovation and research in decision-making, building assemblies and systems, and commercialisation. The objectives of collaborative work within the ECBCS R&D program are directly derived from the on-going energy and environmental challenges facing IEA countries in the area of construction, energy market and research. ECBCS addresses major challenges and takes advantage of opportunities in the following areas:

- exploitation of innovation and information technology;
- impact of energy measures on indoor health and usability;
- integration of building energy measures and tools to changes in lifestyles, work environment alternatives, and business environment.

The Executive Committee

Overall control of the program is maintained by an Executive Committee, which not only monitors existing projects but also identifies new areas where collaborative effort may be beneficial. To date the following projects have been initiated by the executive committee on Energy Conservation in Buildings and Community Systems (completed projects are identified by (*)):

Annex 1: Load Energy Determination of Buildings (*)
Annex 2: Ekistics and Advanced Community Energy Systems (*)
Annex 3: Energy Conservation in Residential Buildings (*)
Annex 4: Glasgow Commercial Building Monitoring (*)
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities (*)
Annex 7: Local Government Energy Planning (*)
Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9: Minimum Ventilation Rates (*)
Annex 10: Building HVAC System Simulation (*)
Annex 11: Energy Auditing (*)
Annex 12: Windows and Fenestration (*)
Annex 13: Energy Management in Hospitals (*)
Annex 14: Condensation and Energy (*)
Annex 15: Energy Efficiency in Schools (*)

Annex 16: BEMS 1- User Interfaces and System Integration (*)
Annex 17: BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18: Demand Controlled Ventilation Systems (*)
Annex 19: Low Slope Roof Systems (*)
Annex 20: Air Flow Patterns within Buildings (*)
Annex 21: Thermal Modelling (*)
Annex 22: Energy Efficient Communities (*)
Annex 23: Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24: Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25: Real time HEVAC Simulation (*)
Annex 26: Energy Efficient Ventilation of Large Enclosures (*)
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28: Low Energy Cooling Systems (*)
Annex 29: Daylight in Buildings (*)
Annex 30: Bringing Simulation to Application (*)
Annex 31: Energy-Related Environmental Impact of Buildings (*)
Annex 32: Integral Building Envelope Performance Assessment (*)
Annex 33: Advanced Local Energy Planning (*)
Annex 34: Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36: Retrofitting of Educational Buildings (*)
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38: Solar Sustainable Housing
Annex 39: High Performance Insulation Systems
Annex 40: Building Commissioning to Improve Energy Performance
Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG)
Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM)
Annex 43: Testing and Validation of Building Energy Simulation Tools
Annex 44: Integrating Environmentally Responsive Elements in Buildings
Annex 45: Energy Efficient Electric Lighting for Buildings
Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)
Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings
Annex 48: Heat Pumping and Reversible Air Conditioning
Annex 49: Low Exergy Systems for High Performance Buildings and Communities
Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings

Working Group - Energy Efficiency in Educational Buildings (*)
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)

(*) - Completed

Annex 42

The objectives of Annex 42 are to develop simulation models that advance the design, operation, and analysis of residential cogeneration systems, and to apply these models to assess the technical, environmental, and economic performance of the technologies. This is being accomplished by developing and incorporating models of cogeneration devices and associated plant components within existing whole-building simulation programs. Emphasis is placed upon fuel cell cogeneration systems and the Annex considers technologies suitable for use in new and existing single and low-rise-multi-family residential dwellings. The models are being developed at a time resolution that is appropriate for whole-building simulation.

To accomplish these objectives Annex 42 is conducting research and development in the framework of the following three Subtasks:

- Subtask A : Cogeneration system characterization and characterization of occupant-driven electrical and domestic hot water usage patterns.
- Subtask B : Development, implementation, and validation of cogeneration system models.
- Subtask C : Technical, environmental, and economic assessment of selected cogeneration applications, recommendations for cogeneration application.

Annex 42 is an international joint effort conducted by 26 organizations in 10 countries:

Belgium	▪ University of Liège / Department of Electrical Engineering and Computer Science ▪ COGEN Europe ▪ Catholic University of Leuven
Canada	▪ Natural Resources Canada / CANMET Energy Technology Centre ▪ University of Victoria / Department of Mechanical Engineering ▪ National Research Council / Institute for Research in Construction ▪ Hydro-Québec / Energy Technology Laboratory (LTE)
Finland	▪ Technical Research Centre of Finland (VTT) / Building and Transport
Germany	▪ Research Institute for Energy Economy (FfE)
Italy	▪ National Agency for New Technology, Energy and the Environment (ENEA) ▪ University of Sannio ▪ Second University of Napoli
Netherlands	▪ Energy Research Centre Netherlands (ECN) / Renewable Energy in the Built Environment
Norway	▪ Norwegian Building Research Institute (NBRI) ▪ Telemark University College
United Kingdom	▪ University of Strathclyde / Energy Systems Research Unit (ESRU) ▪ Cardiff University / Welsh School of Architecture
United States of America	▪ Penn State University / Energy Institute ▪ Texas A&M University / Department of Architecture ▪ National Institute of Standards and Technology ▪ National Renewable Energy Laboratory ▪ National Fuel Cell Research Center of the University of California-Irvine
Switzerland	▪ Swiss Federal Laboratories for Materials Testing and Research (EMPA) /

Building Technologies Laboratory

- Swiss Federal Institute of Technology (EPFL)/ Laboratory for Industrial Energy Systems
- Hexis AG (Hexis)
- Siemens Switzerland AG (Siemens)

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Ian Knight
Subtask A Leader and Report Editor

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1 Overview

This report discusses the production of realistic standard electrical and domestic hot water consumption profiles suitable for use in the assessment and comparison of the economic, carbon and energy performance of residential cogeneration systems within this Annex.

The profiles specifically required were representative residential electrical consumption profiles (excluding Heating, Ventilation and Air-Conditioning (HVAC) loads) and Domestic Hot Water (DHW) consumption profiles. The profiles obtained needed to be suitable for assessing annual loads and would ideally be applicable in a number of countries.

A further ambition was to provide energy profiles suitable for assessing the detailed operation of cogeneration systems, i.e. the profiles should be recorded in the order of second intervals.

The main purpose of the profiles is to be a standard dataset for this Annex which can then be used to allow comparisons between the energy performances of various residential cogeneration systems as modelled in the remainder of the Annex. Ideally the profiles should be as representative as possible of reality.

2 Methodology

The methodology initially adopted for this work was to:

- Review existing studies and data collections, and ascertain which consumption profiles or profile generators were available to the Annex.
- Obtain real data from these existing studies where feasible.
- Depending on the data availability, then analyse this against building and occupant characteristics.
- Produce standard datasets at as frequent a time interval as the data will allow, with supporting documentation for use within the Annex.

3 Review of existing data collections and profile generators

From a review of existing literature, as well as our own monitoring work, we know that domestic non-HVAC electrical energy consumption is primarily dictated by the following factors:

- Floor area of the dwelling
- Number of occupants
- Geographical location
- Occupancy patterns
- Seasonal and daily factors
- Ownership level of appliances
- Fuel type for DHW, heating and cooking etc.
- Social status of occupants

As the profiles are required for assessing the design of cogeneration systems for domestic properties, **the effect of the number of occupants and the occupancy patterns is ignored**, except for the effects on weekday and weekends generally. The rationale for this is that we cannot predict the number or working patterns of the likely occupants of any domestic property, therefore the cogeneration system must be designed to meet the likely range of consumptions for any particular dwelling.

It was intended to retain social status as a determinant, as the use of cogeneration systems can often be directed at certain social classes. In the UK this determinant makes little difference to the profiles, but we were not sure whether this would be the case in other countries. However, the small sizes of the datasets available outside the UK meant that in the end **it was not possible to retain social status** as an indicator. **Ownership level of appliances is assumed to be linked to social status** and is therefore also not considered directly.

Floor area and **geographica**l effects are self-explanatory, as are **seasonal** and **diurnal** effects. Due to the limited amount of data available, the **geographical effects are considered only to differentiate between Europe and Canada**.

The final profiles produced therefore provide information on total consumption and consumption per unit floor area, by time of day and time of year.

3.1 Datasets

The work revealed that there were very few monitored data sets for domestic energy consumption available to the Annex from around the world.

Of those data sets that were available the most extensive were the electrical energy consumption profiles collected by the Florida Solar Energy Centre (FSEC); the New Zealand Household Energy End-use Project (HEEP); the Canadian Residential Energy End-use Data and Analysis Centre (CREEDAC) study and part of the UK Department of Trade and Industry DTI Photovoltaic Study.

The datasets for the FSEC and HEEP studies were too extensive to be supplied directly to the Annex, and it was intended that the Annex would revisit them to obtain data when a final dataset format had been decided. However, a change in personal circumstances for a key member of the Welsh School of Architecture team meant that it transpired that it was not possible to revisit these two studies in time for the Annex work.

The final monitored datasets used in the Annex came from 8 countries, and were as shown in Table 1.

The work also looked for existing validated domestic electrical energy consumption models. It found two potential UK models but the authors would not make these available to the Annex. The Canadian members of the Annex have produced an electrical consumption profile generator which could potentially be used across the World. However, this model will require country specific inputs to be useful outside of Canada.

For Domestic Hot Water (DHW) the consumption profiles available were very limited in number but there was a model produced by IEA Solar Heating and Cooling Programme (SHC) Task 26 available against which these profiles could be compared.

Table 1 - Domestic Hot Water (DHW) and non-HVAC Electricity Consumption Data Sets provided and used in this Subtask

	DHW		Non-HVAC	Electricity
Country	No. of Profiles (used in the analysis)	Monitoring interval [min]	No. of Profiles (used in the analysis)	Monitoring interval [min]
Canada	12 (10)	5 and 60	85 (57)	5, 15* and 60
USA	4 (2)	1,5 and 60	9 (1)	1,5 and 60
Switzerland	1 (1)	60	NA	NA
Finland	6 (6)	60	6 (6)	60
Belgium	2 (0)	15	2 (0)	15
UK	5	60	69 (69)	5
Germany	1	60	1	15
Portugal	NA	NA	1	10
EU	3 (1)	60	NA	NA

3.2 Obtaining the Standard non-HVAC Electrical Consumption Profiles to be used in the Annex 42 work

Due to the generally small number of separate domestic profiles in the data obtained from the various countries a revised approach from that originally envisaged had to be taken to obtain the required standard profiles from the data available.

This revised approach yielded two sets of profiles: a European one and a Canadian one.

The European profile uses the UK social housing profiles obtained from the DTI study as its basis, and considers this data with that obtained from the other limited European data sets.

The second electrical profile was produced from the Canadian dataset, which addresses the Canadian situation only.

The derivation of both these profiles is discussed in more detail in sections 4 to 8.

3.3 Obtaining the Standard Domestic Hot Water (DHW) Consumption Profiles to be used in the Annex 42 work

There were only a few Domestic Hot Water (DHW) consumption profiles available to the Annex. The use of these profiles to provide confidence in an existing DHW model from IEA SHC Task 26 is discussed in Section 12.

* Only the 15 minute data was used in the profiles produced for this Annex

4 Methodology for Derivation of the European Domestic Electrical Energy Consumption Profiles

The lack of any previous comparative study for International or European Domestic Electrical Energy Consumption Profiles meant that this work would be the first to try and establish such profiles. The relatively small number of energy profiles available to the Annex means however that the profile derived from this work can only be suggested as a possible profile for Europe, as there is too small a sample to provide any statistical significance to the work. However, where the Annex sample date can be compared to previously published **national** domestic electrical profiles, i.e. the UK, the profile shape is very similar, and it is only the magnitude that varies slightly. This therefore provides additional confidence that the data represents the domestic population.

The methodology for producing the 'European Standard' profiles is therefore to use the largest monitored dataset from the UK as the European profile, and then to show how individual countries case study dwellings domestic electrical consumption data compare to this profile. No adjustment is made to the UK profile, the comparisons shown are simply for information and to allow the end user of the information to come to their own judgement on the potential applicability or otherwise of the work in the countries concerned.

The Electrical Energy Consumption Profiles produced for use in the Annex for assessment of the performance of Cogeneration Systems in Residential Buildings in Europe should therefore be viewed in this light. They are probably best described as the first draft of a European Profile.

Sections 5 to 7 therefore deal in order with the basis of the UK Electrical Domestic Profile dataset (and hence the proposed European Electrical Domestic Profile dataset); the comparison of this proposed dataset with other European Electrical Domestic Profiles; and finally a concise review of the exact contents of the data files provided with this Annex for use as the European Domestic Electrical Consumption Profiles.

5 Social Housing Electrical Energy Consumption Profiles in the United Kingdom

Social housing forms a significant part of the overall UK housing stock, and is of interest from an energy efficiency viewpoint as a number of social housing providers are closely examining many ways of reducing the energy bills for their tenants – including cogeneration systems.

The term `social housing` refers to housing provided mainly by local authorities and registered landlords. The energy performance of houses within this sector are usually at least on a par with the UK private sector and in many cases much better, to reduce the burden of the fuel bills on this sector. The prices for dwellings rented within the social housing are below the prices for private rented houses. There are usually waiting lists where people apply for these type of housing. The access criteria, set by the government, is not necessarily low income but it will usually contribute to the decision[1]. Members of the social housing sector are, for example, elderly or lone parent families (nearly 50% of lone mothers in the UK live in social housing[2]). The behaviour patterns of people living in the social housing sector usually differ slightly from the average pattern; one indicator of this discrepancy is the rate of employment. National Statistics[2] show that among people from the social housing sector, 33%

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[1] J. Ditch, A. Lewis, S. Wilcox, Social housing, tenure and housing allowance: an international review, Department Work and Pensions, United Kingdom, 2001

work, where the average of employment in the non-social housing sector (renting from private and owner-occupied) is 60%.

This section of the report presents measured electrical energy consumption profiles for this sector in the UK, obtained over a period of 2 years. The measurements were all obtained at 5 minute intervals. Annual energy consumptions, daily and overall profiles were derived for the dwellings from the data. To create a link between the energy consumption profiles and socioeconomic factors a user survey was undertaken among the people living in the monitored dwellings. The survey included questions regarding the following aspects: the number of tenants living in the household, tenant's age, ownership of electrical appliances and the general times of use of appliances and occupancy in the household.

The level of detail and confidence in the information available for this dataset has resulted in the decision to use this dataset as the basis for the European Energy Profiles.

5.1 Introduction

The housing stock of the United Kingdom consists of 25 Million households with an annual electricity energy consumption of 115TWh[2,3]. Around 20 per cent of these dwellings can be considered as part of social housing and, using the UK average of 2.4 occupants per dwelling, it can be estimated that this sector of UK society is represented by 12 million people[4]. These figures stress the large influence on overall UK domestic electrical energy consumption of this section of society.

There have been two reported end use monitoring campaigns in the UK where the electric energy consumption of individual dwellings was obtained. The Load Research Group of the Electricity Association undertook the monitoring of 1200 homes and carried out a user survey where the household type, socioeconomic characteristics and the ownership level of appliances were recorded[5]. Based on these data sets a load model for domestic electric energy consumption and load profiles has been developed by Stokes[6]. Another monitoring campaign was undertaken by Newborough[7] where the energy demand data of 30 homes has been obtained. A user survey among a sample of over 1000 adults has been conducted mainly in the south-east of England regarding the socio-economic aspects of energy use[8]. The results of this investigation, such as ownership level, differences in consumption in different classes of society, and total energy consumption of certain appliances are usually used when modelling of domestic energy is carried out for the UK (for example Yao and Steemers[9]).

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[2] National Statistics Online, http://www.statistics.gov.uk – Accessed February 2006

[3] Department of Trade and Industry, http://www.dti.gov.uk – Accessed February 2006

[4] Domestic Energy Fact File 2003, http://projects.bre.co.uk/factfile - Accessed February 2006

[5] Electric Association, Load Research Group, http://www.electricity.org.uk – Accessed February 2006

[6] M. Stokes, A fine-grained load model to support low voltage network performance analysis, PhD Thesis, De Montfort University, Leicester, 2005

[7] M. Newborough, P. Augood, Demand-side management opportunities for the UK domestic sector, IEE proceedings generation transmission distribution,1999, 283-293.

[8] I. Mansouri, M. Newborough, D. Probert, Energy Consumption in UK Households: Impact of Domestic Electrical Appliances, Applied Energy, 1996.

[9] R. Yao, K.A. Steemers, A method of formulating energy load profiles for domestic buildings in the UK, Energy and Buildings, 2004

5.2 Data collection

This section deals exclusively with the electrical energy consumption of houses within the social sector.

The data for this work is based on 4 monitoring projects with a total number of 90 homes. Monitoring took place between 2002 and 2005 in Newcastle (25 flats/England), Llanelli (18 town-houses and flats/Wales), Nottingham (22 semi-detached houses/England) and Derry (25 semi-detached houses/Northern Ireland). The monitoring duration of each project was 24 months and measurements were taken at 5 minute intervals. The data has been collected by EETS Ltd.[10] as part of the Domestic Field Trial Project[3] where the performance of PV systems in the domestic sector as well as the electric energy imported and exported from the dwellings was monitored.

Although initially 90 dwellings were monitored, the number of useable records has been reduced by abnormally low or non-occupation of the dwellings to 69 sets.

The floor area of the households varies between $52m^2$ and $124m^2$ with an average of $75m^2$ and the average number of occupants per dwelling is 2.4 (ranging between 1 and 9 people), which is the same as the UK average noted earlier. The dwellings use fossil fuel for space heating and DHW. The energy type for cookers and showers varies within the data sets. There are 19 households with electric cookers/showers, 20 households with gas cookers and electric showers and 30 households with fossil fuel powered cookers/showers.

5.3 Overall load profiles and total annual consumption

To understand the range of electricity demand, the daily Winter (as represented by January) and Summer (as represented by July) profiles for weekday and weekend days, averaged over all the dwellings monitored and normalised for floor area, are presented in Figure 1 through to Figure 4 using deviation bars. The range encompassed by the bars is plus and minus one standard deviation from the mean value at that point.

The base load of the demand in the four figures occurs overnight and is mainly from appliances in stand-by mode and appliances driven by a thermostat e.g. refrigerator. This base load ranges between 0 – 6 W/m^2. The figures show that there is not a significant difference in terms of base load between summer/winter and weekend/weekday.

The main difference between the weekend and weekday profile is the period between 09:00am and 04:00pm, where the weekend profile shows a higher demand due to higher occupancy.

[10] Energy Equipment Testing Service Ltd., http://www.eets.co.uk – Accessed February 2006

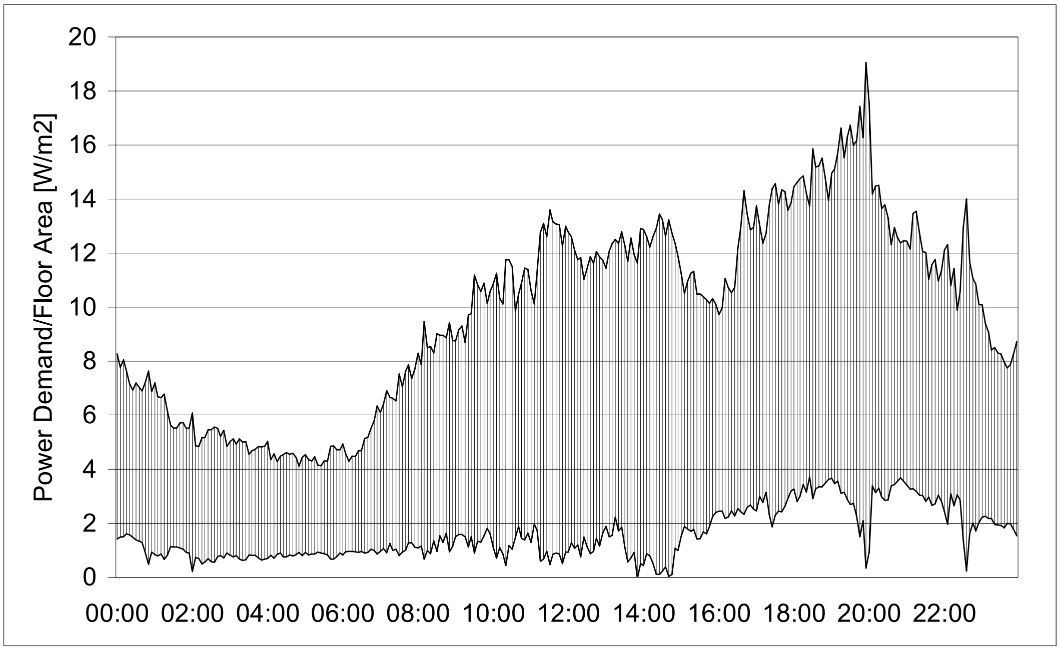

Figure 1 - Normalised overall Winter Weekend profile

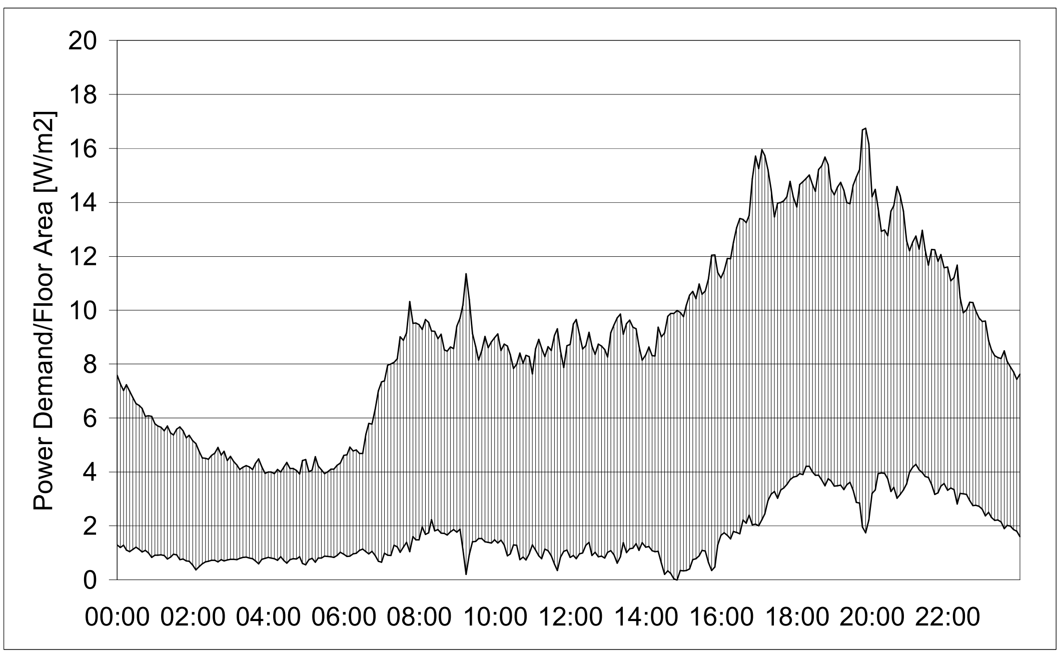

Figure 2 - Normalised overall Winter Weekday profile

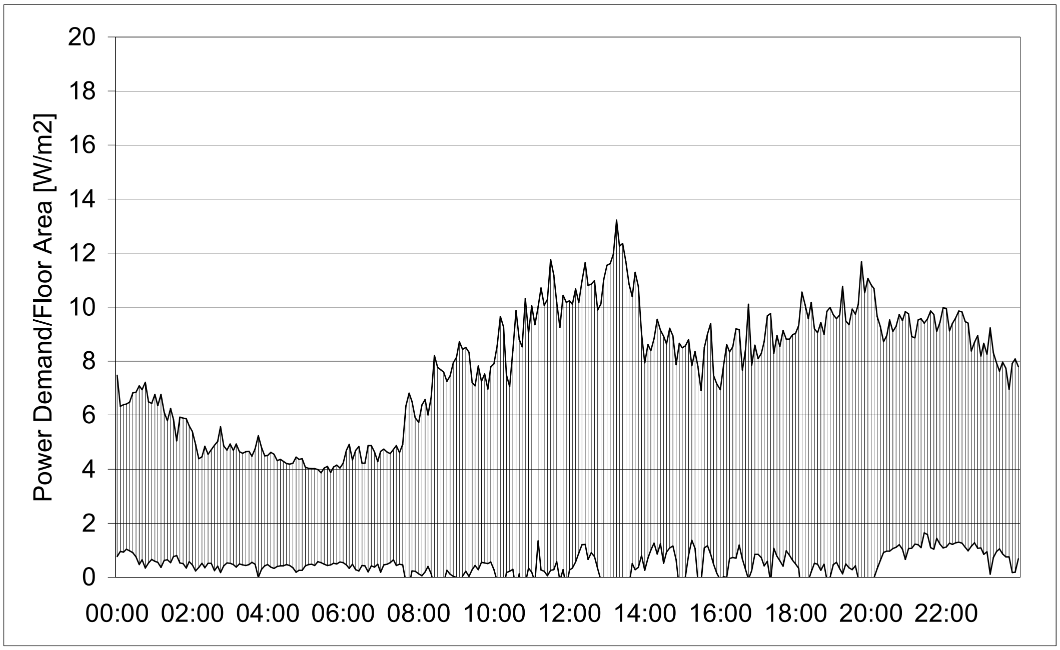

Figure 3 - Normalised overall Summer Weekend profile

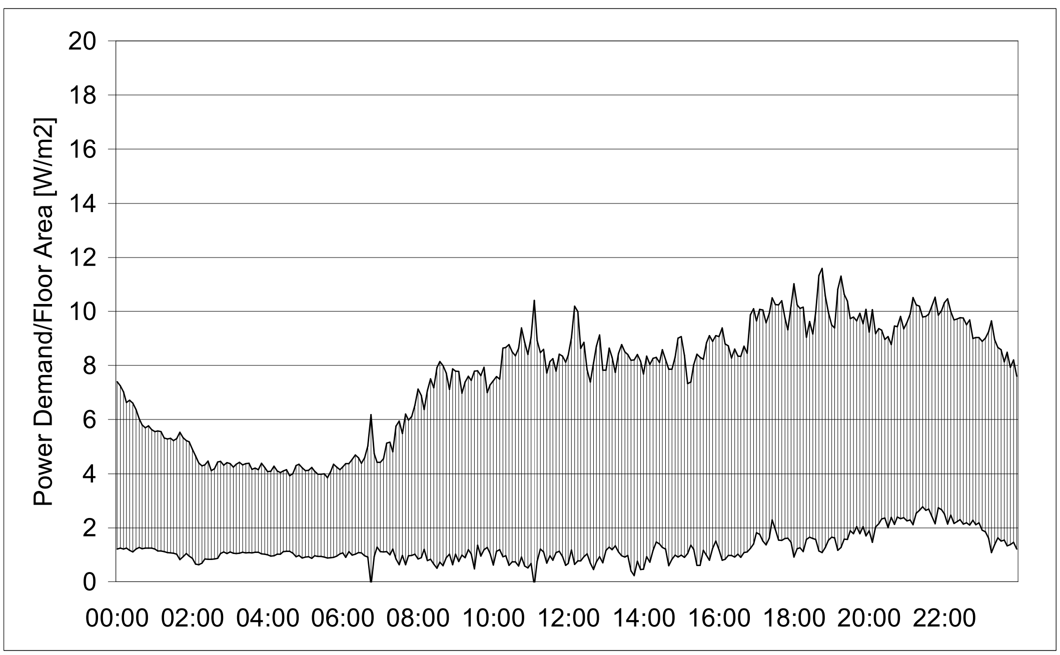

Figure 4 - Normalised overall Summer Weekday profile

Figure 5 compares the hourly profiles of the average power demand over all dwellings for the winter and summer season.

The base load period starts at 03:00 and finishes at 06:00 with an average demand of 200W. The Winter Weekday profile shows a considerable morning peak caused by a larger lighting and possibly a space and DHW heating-related demand, e.g. distribution pumps. The Summer Weekend profile has a peak around 13:00 when food is usually prepared for lunch. The two winter power profiles peak at 750W and both represent a daily electrical energy consumption of ~10kWh. The energy consumption of the summer profiles amounts to ~7.8kWh per day with an evening peak around 450W.

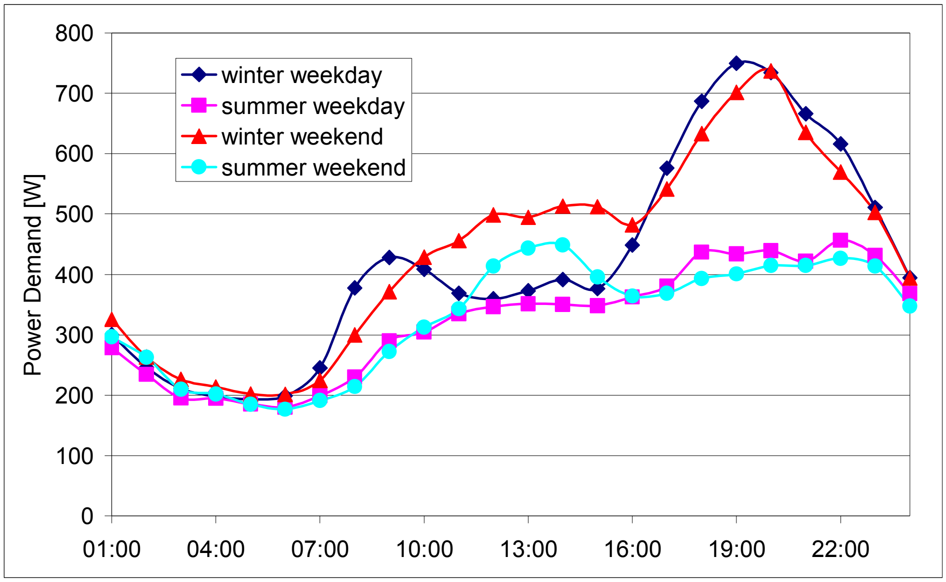

Figure 5 - Comparison of overall Winter and Summer profiles

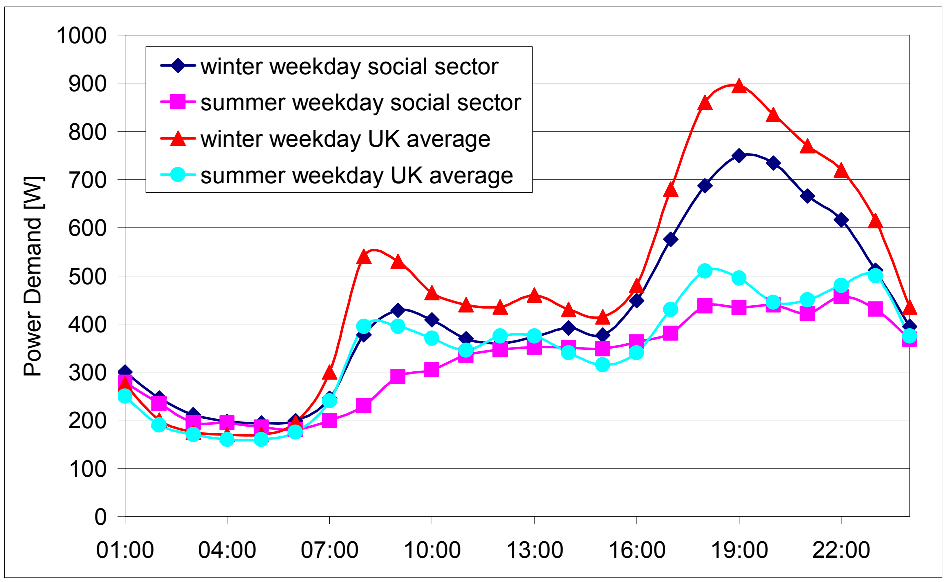

Figure 6 - Comparison of UK average and social sector daily electric energy consumption profiles

Figure 6 presents a comparison of the weekday profiles obtained for the social sector and the profiles recorded by the Electricity Association, here considered to represent the UK average. The figure shows that the period from midnight until 6am is very similar; including the base load. Evident is the missing morning peak in the summer weekday profile of the social housing data and the smoother shape of these records. Unfortunately nothing is known about the ownership level of appliances or the proportion of electrical space heating within the Electricity Association records but it is clear that the typical social sector profile shows a lower energy demand. The energy consumption of a UK average winter day is around 11.5 kWh, the figure for the social sector amounts to 10 kWh.

Comparison of the annual electrical energy consumption per unit floor area supports this finding. The UK average amounts to ~55 kWh/m2/year (derived from the total domestic consumption, number of households and the average Floor area) whereas the social sector use ~43 kWh/m2/year [2,3,4].

The annual total electric energy consumption of the monitored social sector dwellings varies between ~800kWh and ~7800kWh with an average of ~3100kWh.

5.4 Analysis of Single Load Profiles

As well as the overall profiles and the total consumption already presented, the base and peak load demands, along with the load factor, are further data that are useful in order to optimise the integration of microgeneration systems.

Figure 7 shows the distribution of the monthly average **base load** demands for all the houses. This base load demand was considered to occur between midnight and 07:00am for all the dwellings. The data is derived from the monthly averaged electrical load profile of each dwelling and it shows that the base load is generally between 50W and 200W independent of the time of year or week. The bins are labelled at the highest figure in each bin, e.g. the bin labelled 50W covers all values in the range 0 to 50W.

Figure 8 shows the Winter (January) weekday **peak load** distribution for the same set of data, averaged over 5 minutes. The majority of the dwellings have a recorded maximum electrical power demand between 500W and 2000W. The monthly load factor (the ratio between average demand and the peak demand) for January ranges between 0.15 and 0.52 (average 0.34). This figure provides an indication of the variation in load on the system, with a smaller figure indicating greater variation over the period. This figure shows that even where electricity is used for showering, the demand does not exceed 4kW on average in any 5 minute period.

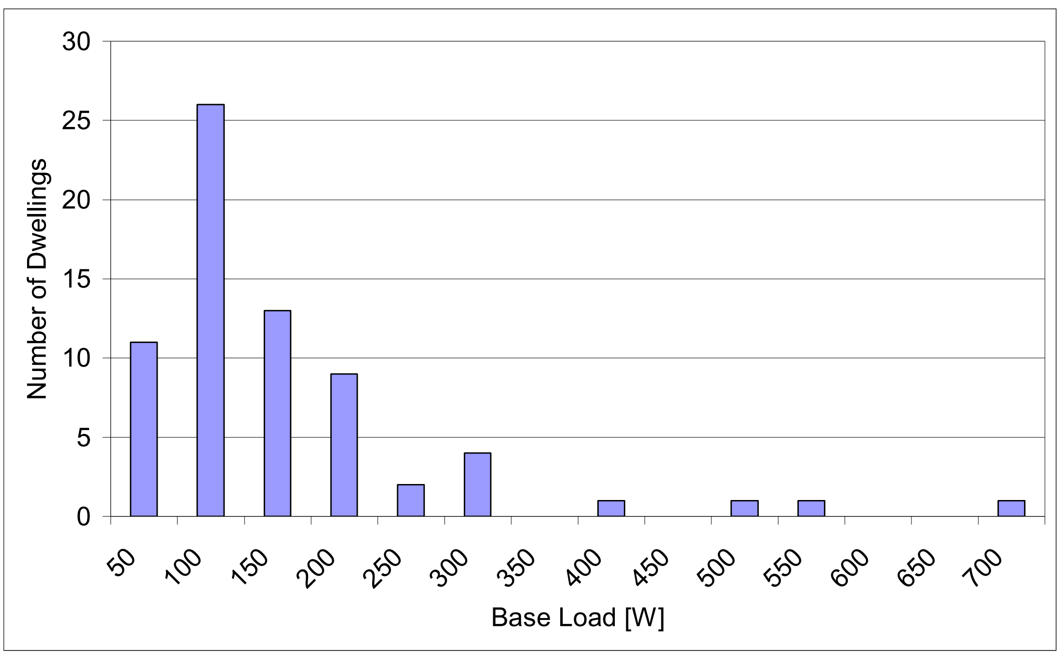

Figure 7 - Distribution of monthly Base Load – Winter Weekday data

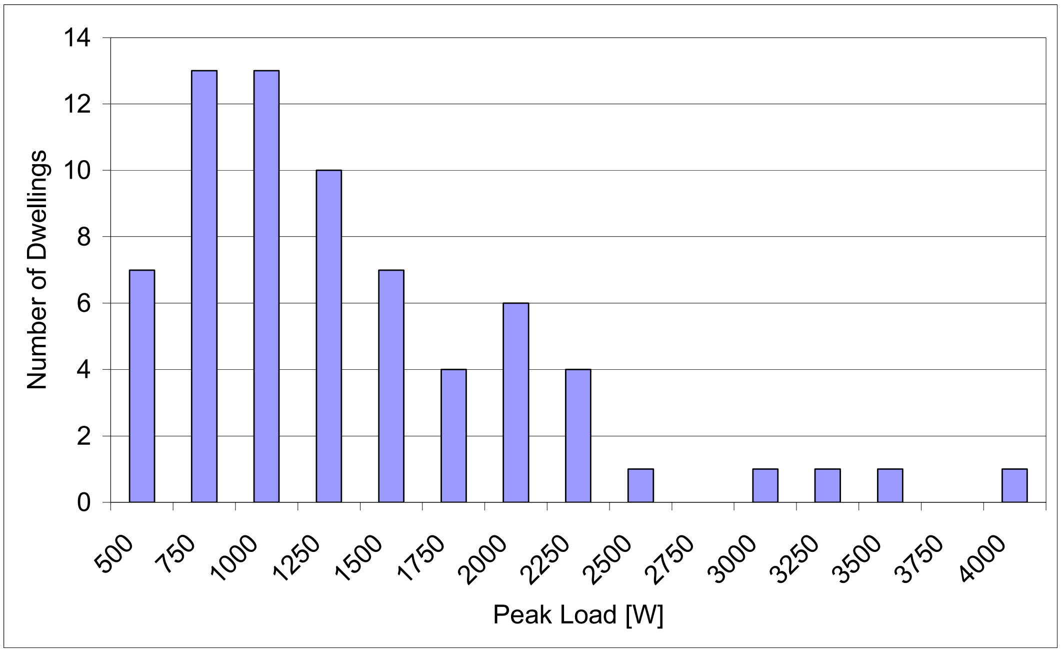

Figure 8 - Distribution of monthly Peak Load – Winter Weekday data

5.5 User survey

The user survey was undertaken among the occupants of the monitored dwellings, and 46 out of the 69 households have been interviewed face to face. The occupation and composition of the households, and their comparison with the UK average, is shown in Table 2 and Table 3.

The results of the survey indicate that the majority of the interviewed people do not have a fixed pattern of activities during the day. As already noted, this sector has a relatively low percentage of employed people compared to the UK average. This means that, for example, the high power demand activity of clothes washing can be done in the course of the day rather than after work. This uncertain activity pattern is reflected in the size of the standard deviation during the daytime shown in Figure 1 through to Figure 4. The overall effect is that the predicted power demand levels can vary by up to 50% from the mean value over the course of a day.

Table 2 - Occupation of surveyed households and the UK National Average[11]

Number of persons in the household	1	2	3	4	5	6 or more
Proportion (National Statistics, 2002)	29%	35%	16%	14%	5%	2%
Proportion (present study)	33%	26%	15%	15%	7%	4%

[11] UK Office for National Statistics Online. Social_Trends_35_Ch02 edition 2005. http://www.statistics.gov.uk/StatBase/Product.asp?vlnk=5748. Accessed 18th January 2007.

Table 3 - Composition of surveyed households

Family composition	Number of households
1 adult	15
1 adult + 1 child	5
1 adult + 2 children	4
1 adult + 3 or more children	4
2 adults	7
2 adults + 1 child	3
2 adults + 2 children	5
2 adults + 3 or more children	3

The ownership level of appliances obtained from the survey is compared with the results from Mansouri [8] in Table 4. The biggest discrepancy between the UK average and the social housing is the level of dishwashers. The possession of this appliance is likely to be even higher than shown here as the Mansouri data is from 1997.The people living in social housing spend more time watching TV (~10h/day) than the UK average (~5h/day) which is also reflected in the number of TV sets per household.

Table 4 - Comparison of appliance ownership levels

Appliances	Average ownership level Social Sector	Average ownership level UK Average
Refrigeration	1.35	1.77
TV	2.15 (all)	1.60 (Colour)
DVD player/video	1.64 (Video and DVD)	0.76 (Video only)
Computer	0.33	-
Hi-fi	0.74	-
Electric kettle	0.91	0.90
Toaster	0.67	-
Microwave	0.87	0.74
Washing machine	0.96	0.93
tumble dryer	0.54	0.53
dishwasher	0.09	0.43
vacuum cleaner	0.96	1.00
iron	0.80	1.00

The possession of vacuum cleaners is less than one because the interviewed dwellings had partly wooden floors.

The results from the survey give a possible explanation for the overall lower consumption in the social sector. The ownership level of high demand appliances is, according to this user survey, lower than the average, taking into consideration that refrigeration and the dishwasher are the main consumers in the household. On the other hand, the possession of low demand appliances, such as TV and DVD player/video, is higher in the social sector than the average.

5.6 Conclusions

This section of the report focuses on the domestic electrical energy consumption of the social housing sector in the United Kingdom. The data from a user survey and a monitoring campaign has been analysed and presented in this work. The monitored dwellings have been characterised regarding floor area, number of occupants and ownership level of appliances. Although the sample size of the investigation is relatively small, it still gives some useful information on the energy usage behaviour. The findings were compared with the available records for the UK average and the analysis indicates that there is a general lower consumption in the social sector. The difference can possibly be explained by the absence of high energy consumers such as dishwashers and a lower ownership level of refrigeration.

A reasonable agreement was obtained from the comparison of the Electricity Association profiles[5] and the social sector profiles, and therefore – as we do not have any further details of the EA dataset – these Social Housing Profiles are presented as being the standard profiles for the UK domestic sector excluding HVAC loads.

It should be noted that there is a small component of HVAC and DHW related electrical energy use in some of the data used in the UK profiles, principally for heating pumps and some DHW heating for showers. However, the duration of these loads are not deemed to be sufficiently large to be significant in terms of overall energy use. They are potentially significant in terms of peak electrical power demand, but none of the data available to the monitoring indicated demands greater than 4 kW over a 5 minute period, a peak load that would be within the expectations for a house without electrically heated DHW. The demands presented are believed to be suitable therefore for sizing domestic cogeneration systems.

Whilst there appear to be two models for predicting domestic electrical energy consumption profiles in the UK[6,9], neither of the two organisations were willing to make these models available to the Annex so they are not included here.

The format and data contained in the final electrical load profiles dataset for the UK will be discussed in section 7. The Domestic Hot Water (DHW) profiles will be dealt with as a separate dataset in section 12.

6 European Electrical Energy Consumption Profiles

This section discusses the relationships observed between the detailed UK consumption profiles and the generally less extensively detailed energy consumption profiles obtained from other European states.

The individual European datasets are not included on the data CD with this report.

Given the general lack of information available with each profile supplied, the work treats each profile as a Case Study rather than a representative sample for the country from which it was obtained.

The methodology used to assess this data was to compare it with the general UK profiles previously established and discuss whether these Case Studies from each country showed similar magnitudes and profiles to the UK dataset.

The overall findings from these comparisons were that the general UK profile appeared to be replicated in a number of the Case Studies in terms of increasing winter energy use compared to the summer, and also in terms of the timing of the peaks and troughs throughout the day.

Whilst these observations are not sufficient on their own to provide confidence that the UK profiles are therefore applicable throughout Europe as well, it was decided that in the absence of any data indicating that they were not suitable for Europe, that they would serve this end for the purposes of the Annex 42 work.

6.1 Individual European Country Domestic Electrical Load Profiles

In total we had domestic electrical load profiles or information supplied from 7 European Countries: UK, Finland, Italy, the Netherlands, Germany, Portugal and Belgium.

For each country we have provided an overview of their average profile and the data this was obtained from, where known.

6.1.1 Finland

The Finnish daily electrical consumption profile data was provided by the Technical Research Centre of Finland, VTT and has been obtained from 6 houses monitored at hourly intervals in 1999. Three of the houses were low energy exemplar houses and three were standard houses. All were connected to the local District Heating System. The number of occupants in the housing varied between 1 and 6 people, with an average of 3.7 occupants in the 'standard' housing and 2.7 in the low energy housing. The floor areas are not known.

Figure 9 shows that the Finnish Electrical consumption profiles exhibit similar characteristics to the UK profiles, in terms of general magnitude of consumption and the overall shape, though in this case the daily profile distribution refers to the whole year's data rather than the various parts of the year as shown in the UK profiles. The average annual consumption of the houses supplied was around 3200 kWh in a range from 1500 to 6000 kWh. As there are only 6 houses in the sample, three of which are by definition not representative of the domestic Finnish population, then the best that can be said is that there is nothing in these profiles to suggest that the UK domestic profiles are not a reasonable estimate of the Finnish situation.

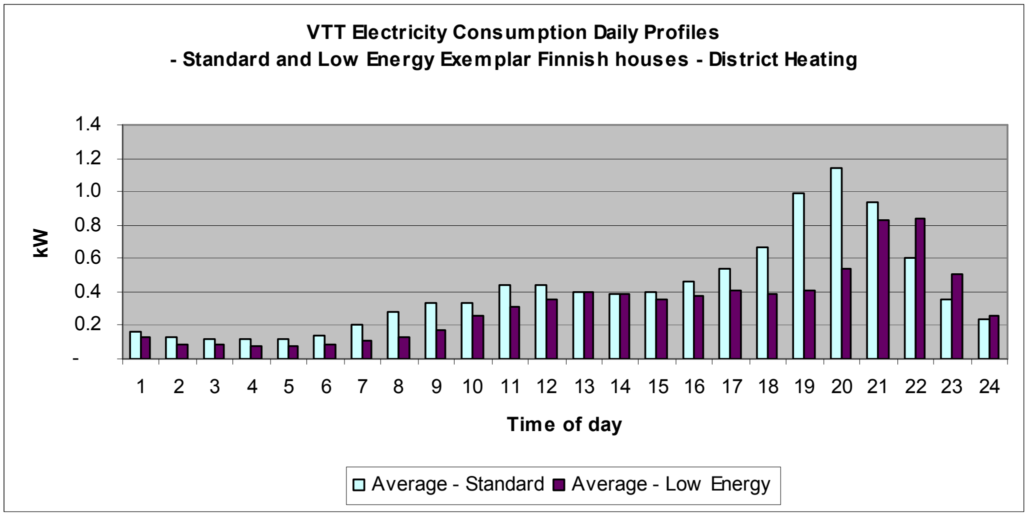

Figure 9 – Average Daily Electrical Consumption Profiles for Low Energy and Standard Finnish Housing

6.1.2 Italy

The Italian load profiles were provided by Università del Sannio, Benevento and Seconda Università degli Studi di Napoli at the April 2006 Penn State University meeting, and have been derived from a dataset comparable to the UK dataset.

The Italian domestic electrical non-HVAC dataset has been obtained from a report of the Politecnico of Milano derived from on site measurements of the electric consumptions in the Italian residential sector for the SAVE EURECO and MICENE projects. This report considers data for:

- 110 flats located in 5 Italian regions analyzed for 3 years.
- The monitored electrical energy consumptions and electric power demand of the total household appliances and lighting systems.
- Electric energy consumptions and electric power demand of each flat and of the whole building.

The measurement interval was 10 minutes, and this is apparently the only database of domestic electrical energy consumption available in Italy. The data provided to the Annex did not include total annual consumption profiles or figures. Data from 1996 in another study[12] suggests an annual figure of around 2,700 kWh then, so it would be expected that this would have risen significantly since then, and a range of 3000 – 3500 kWh per annum in line with the other European countries would seem reasonable to expect.

The occupancy characteristics of the monitored Italian sites are shown in Figure 10 and Figure 11. It can be seen that 77% of the sample consists of households of 3 or 4 people, and that the average household floor area is around 106 m^2.

[12] Fawcett T, Lane K and Broadman B – Carbon Futures for European households. Environmental Change Institute, Oxford University – March 2000. Country pictures supporting material – Italy. .http://www.eci.ox.ac.uk/research/energy/downloads/lowercarbonfuturereport.pdf.. Accessed 7th January 2007

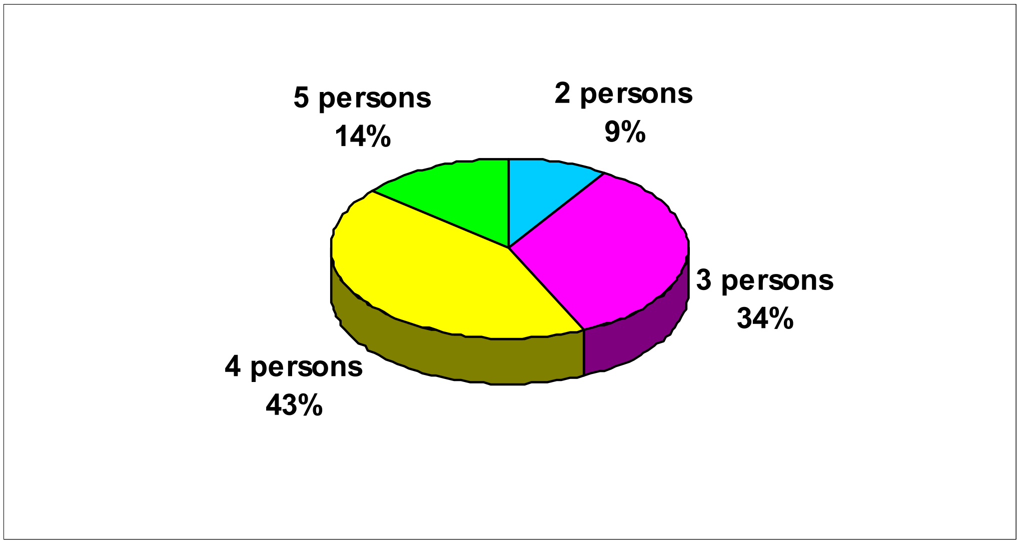

Figure 10 – Household occupancy for the monitored Italian dwellings

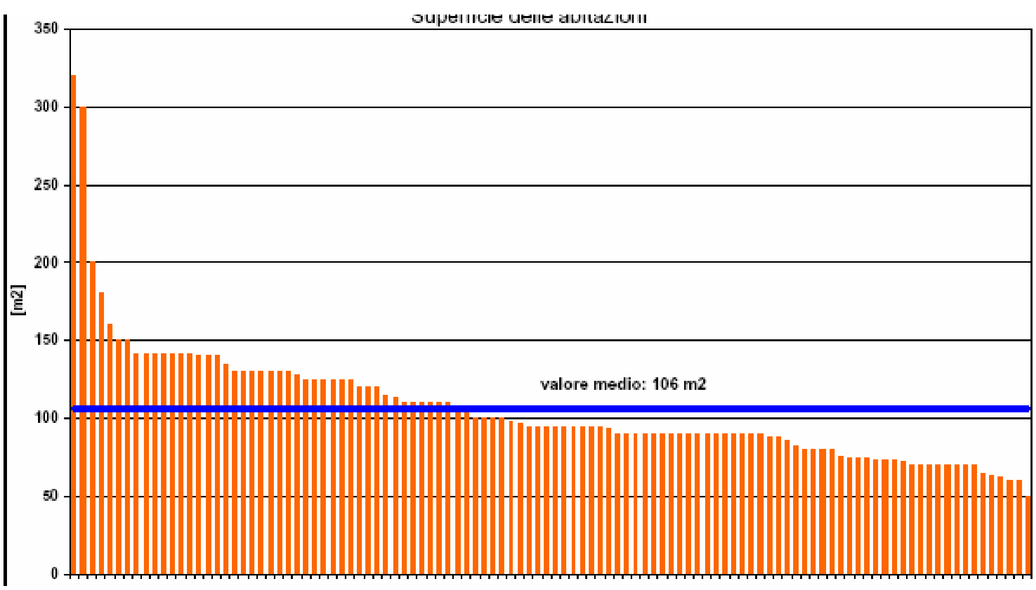

Figure 11 – Floor areas of Italian Housing Sample.

Due to the presence of electrically driven air-conditioning in many Italian Households the derived dimensionless PEAK electrical consumption graphs for a 7-day period shown in Figure 12 are only for Cool, Cold and Warm periods of the year, as the Hot periods of the year are distorted by the A/C HVAC demand. This data showed that the average PEAK load does not drop below 50% of the MAXIMUM PEAK load throughout the week in all 3 seasons.

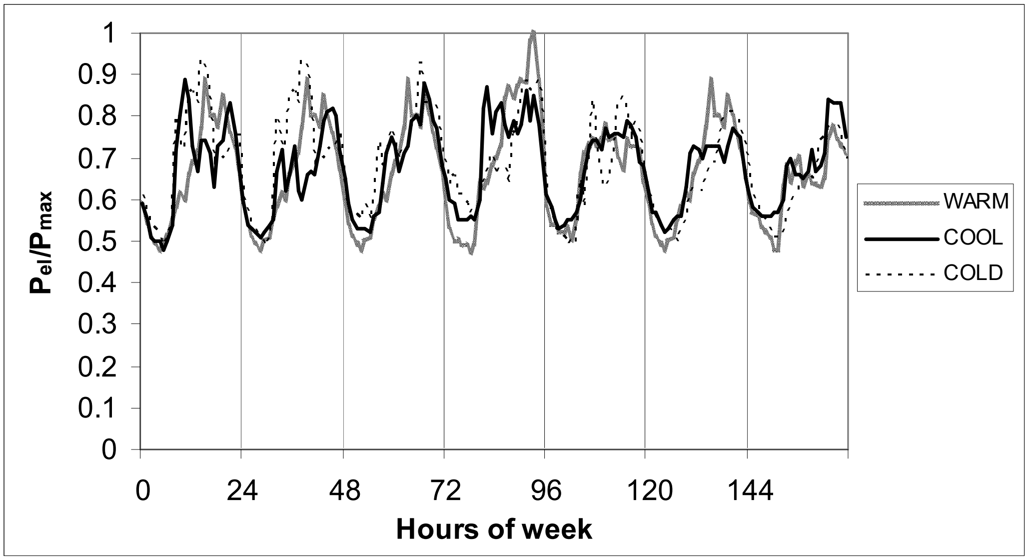

Figure 12 – Dimensionless average electrical consumption profile for Italian Domestic Housing by day of week.

Figure 13 presents the average daily profile in the cold season where it can be seen that the average baseload figure is less than 50W. Figure 13 also shows the normal morning and evening peaks seen in other country profiles - though it would be expected that there would be more of a lunchtime load due to cooking activities.

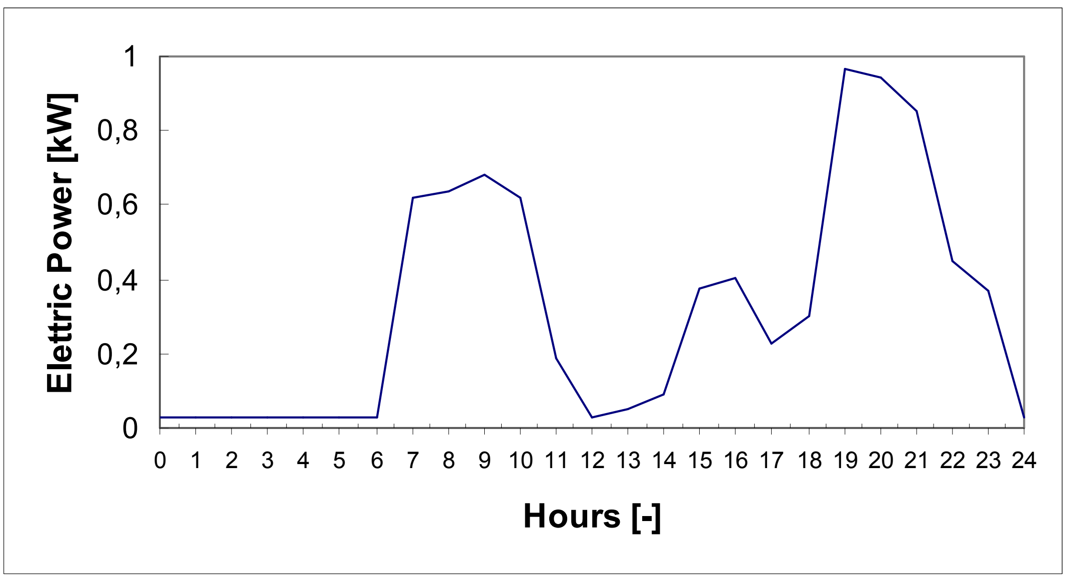

Figure 13 – Italian Cold Season Daily Electrical Consumption Profile

Figure 13 also shows that the magnitude of the Italian consumption profiles is very similar to those of the UK.

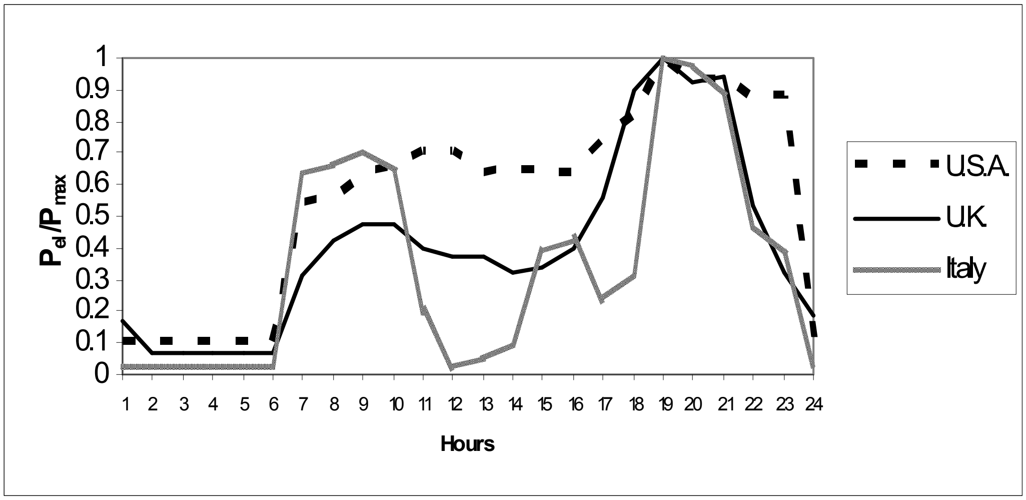

Figure 14 – Comparison of Dimensionless non-HVAC daily domestic electrical consumption profiles for the UK, USA and Italy

With the caveat about the midday dip in the Italian profile in mind, Figure 14 appears to suggest that the use of the UK profile as the European profile would result in a reasonable match to the Italian domestic profiles. The Italians also refer to a US dataset in this figure which we do not have access to, but has been included here for information.

6.1.3 The Netherlands

We did not have any daily electrical consumption profiles provided to the Annex, but the following report[13] provided by the Energy Research Centre of the Netherlands, ECN gives an overview of the annual consumption in Dutch Households.

The study is an annual survey of about 3000 Dutch households. The most recent detailed report available describes the situation in 2000, though the most recent annual average consumption dates from 2003 (no details available). Table 5 shows the consumption trends over the years from 1995 to 2003.

The average total annual electricity consumption in the 3000 Dutch households in 2000 was 3230 kWh. Based on the population size, the 95% interval limits are 3165 and 3300 kWh.

The most recent average reported consumption of 3,400 kWh per annum per household in 2003 is similar to the monitored UK average social housing consumption of around 3100 kWh per household, and very similar to the German 2002 figure of 3,340 kWh per household. This similarity is as close as we can get to suggesting that the UK profiles are representative of the Dutch situation, though it suggests that the German and Dutch profiles might also be similar.

Table 5 – Average domestic annual electricity consumption for the Netherlands

Year	1995	1996	1997	1998	1999	2000	2002	2003
Household electricity consumption [kWh/year]	3190	3255	3155	3200	3220	3230	3375	3402

[13] Source: "Basisonderzoek Elektriciteitsverbruik Kleinverbruikers 2000"

The study from 2000 offers some details on consumption as a function of household size, income, social status etc. See figures below.

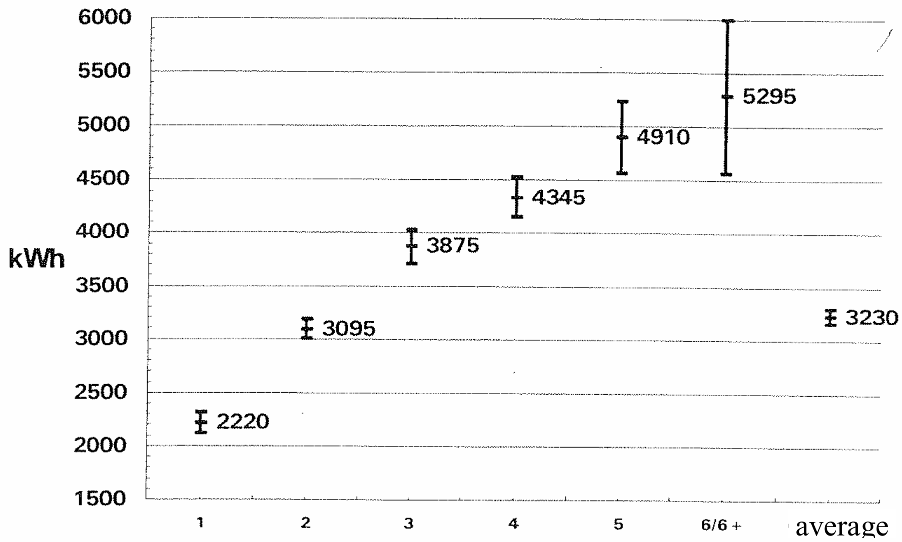

Figure 15 - annual household electricity consumption in The Netherlands in 2000 as a function of the number of people in the household.

The study distinguishes between several social classes: A, B1, B2, C and D (from high to low).

Two parameters define the social class: education and profession. The classes A to D cover the complete range found in society.

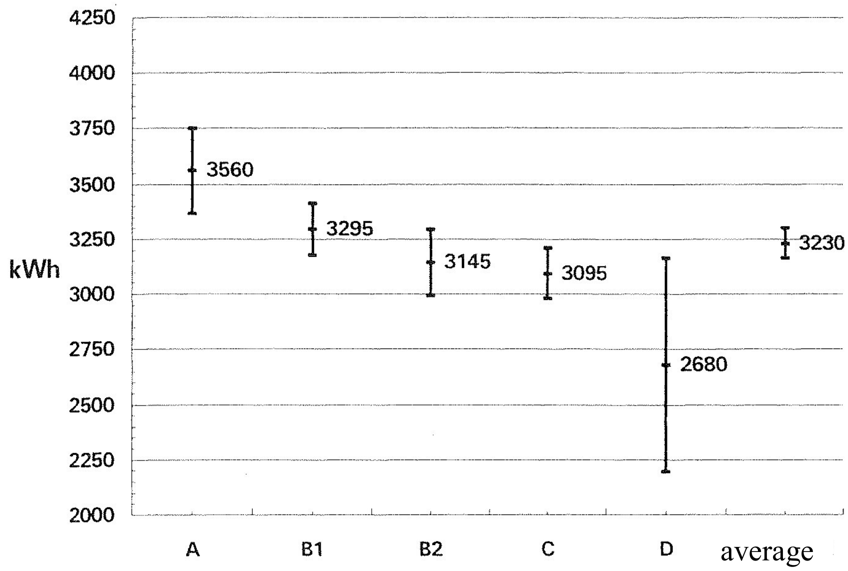

Figure 16 - annual household electricity consumption in The Netherlands in 2000 as a function of social class (high to low, A to D).

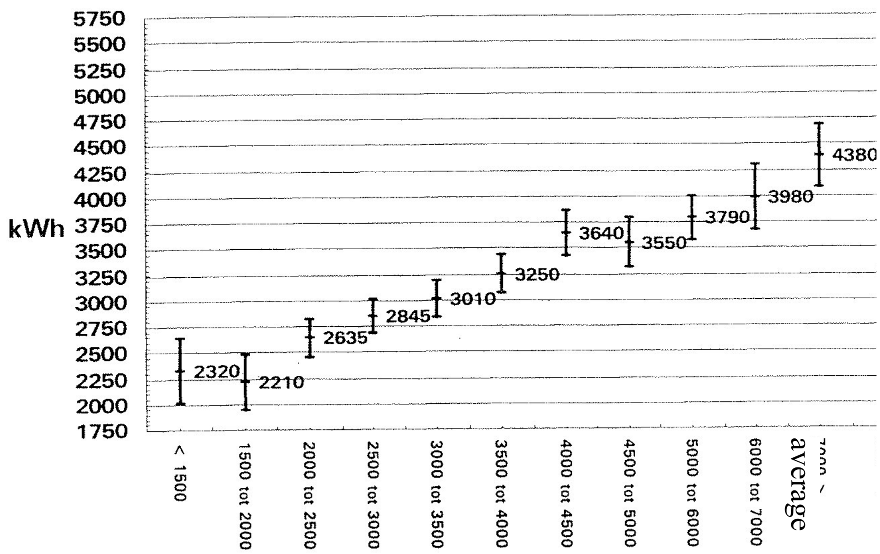

Figure 17 - annual household electricity consumption in The Netherlands in 2000 as a function of net household income per month (in NFl, divide by 2.20371 for euro)

This figure was taken from a Dutch report and could not be altered. The average figure is believed to be 3,230 kWh as in the previous two figures. The 4,380 kWh is believed to refer to consumption for households earning more than 7000 NFl/month.

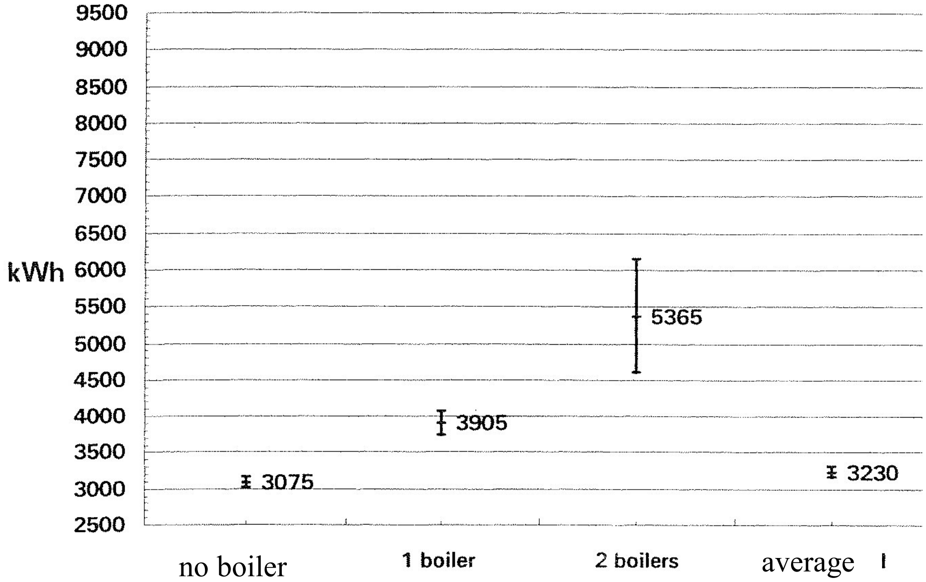

Figure 18 - annual household electricity consumption in The Netherlands in 2000 as a function of the number of electrical boilers for DHW

The presence of an electrical boiler (for DHW) has a strong influence on the electricity consumption.

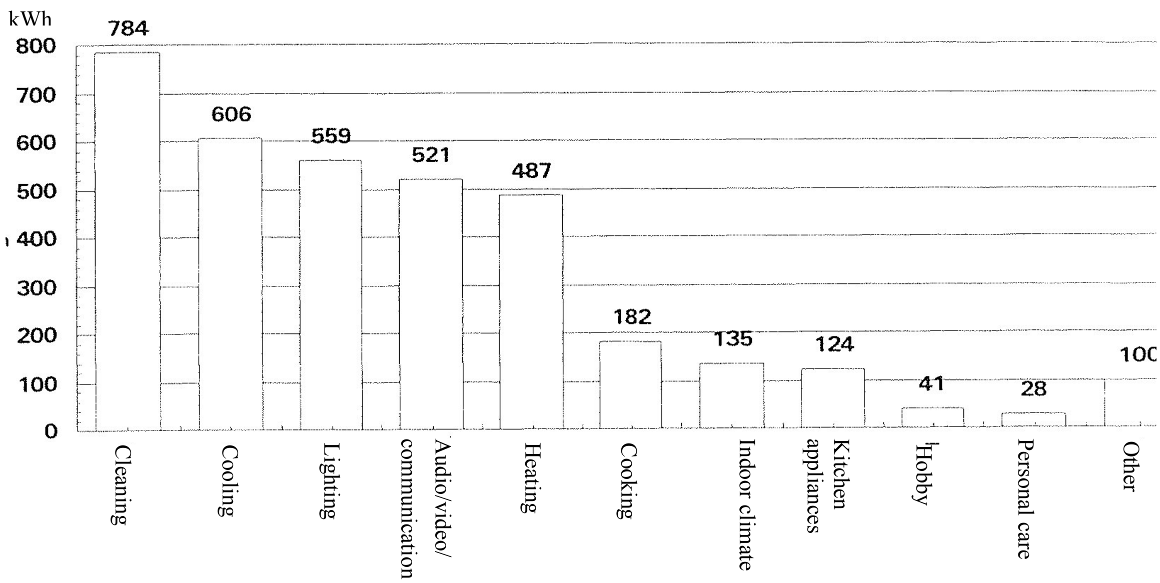

Figure 19 - annual household electricity consumption in kWh in The Netherlands in 2000 as a function of the application

The application categories in Figure 19 contain the following items:

Cleaning: washing, drying, dishwasher, vacuum cleaner, ironing, etc.

Cooling: refrigerator, freezer, etc.

Heating: electrical boiler, central heating (fans, pumps etc), electrical heating, etc.

Cooking: micro wave, furnace, oven etc.

Indoor climate: ventilation, air-conditioning, etc.

Other: doorbell, battery charger, sun shading, alarm, etc.

The sum of the electricity consumption per application (3567 kWh) is a little higher than the average total electricity consumption. The study does not explain the difference.

The study does not provide the average electricity consumption as a function of the type /size of the house. The average usable floor area in residences is about 110 m^2 in The Netherlands and the range is 59 to 172 m^2.

6.1.4 Germany

The average electricity consumption is calculated by the quotient of the electricity consumption of households (140.1 TWh)[14] and the total number of households in Germany (39.1 million)[15]. The result is an average electricity consumption of 3581 kWh per household per annum in 2004. With 82.5 million inhabitants the average electricity consumption per person amounts to 1698 kWh per annum. Consequently the average household size is around 2.1 persons per household.

An undated report from the Fraunhofer Institute[16] reports an average German Domestic Electricity consumption of 3,340 kWh per household per annum in 2002 based on 20,235 households. It also reports 1,840 kWh per person per annum, suggesting an average household size of 1.8 people in that year, which is less than the 2.4 people per household noted in the UK housing profiles.

The German profiles used for comparison in this report were supplied by the Research Institute for the Energy Economy (FfE), Munich, and are the representative residential load profiles used for Germany[17].

Representative load profiles normalised to the maximum consumption are given for three seasons of the year - winter, shoulder and summer - and three different periods of each week – Weekday, Saturday and Sunday.

Figure 20 through to Figure 22 show these profiles. It can be seen that the difference between the morning and evening peaks is far less pronounced than with the UK profiles, as are the differences between the Winter and Summer profiles.

Assuming that these profiles are still representative, then the use of the UK domestic profiles to represent the German situation is therefore not as secure as with some of the other countries compared, despite the overall average annual consumption of 3,340 kWh/household reported in 2002 being very similar to the 3,100 kWh/household monitored in the UK social housing sector in that year.

[14] Source: Verband der Elektrizitätswirtschaft - VDEW - e.V.: Final energy consumption in Germany 2004, www.ag-energiebilanzen.de

[15] Source: Statistical year book 2005 for the federal republic of Germany, Statistisches Bundesamt, 2005

[16] Gruber, E and Schlomann B – The current and future electricity demand of appliances in German Households. http://mail.mtprog.com/CD_Layout/Day_3_23.06.06/0900-1045/ID210_Gruber_final.pdf. Accessed January 3rd, 2007.

[17] Source: C. Fünfgeld, BTU Cottbus - Chair of Energy Economy, October 1999

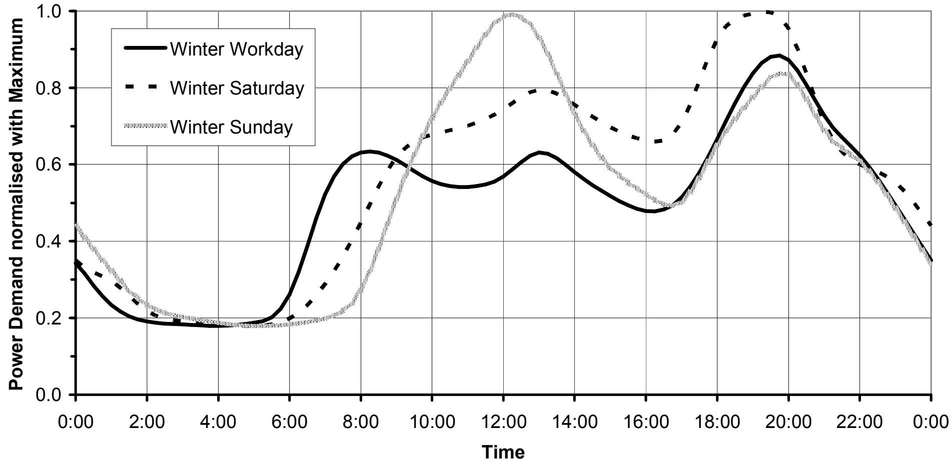

Figure 20 – Winter representative domestic electrical consumption profile for Germany

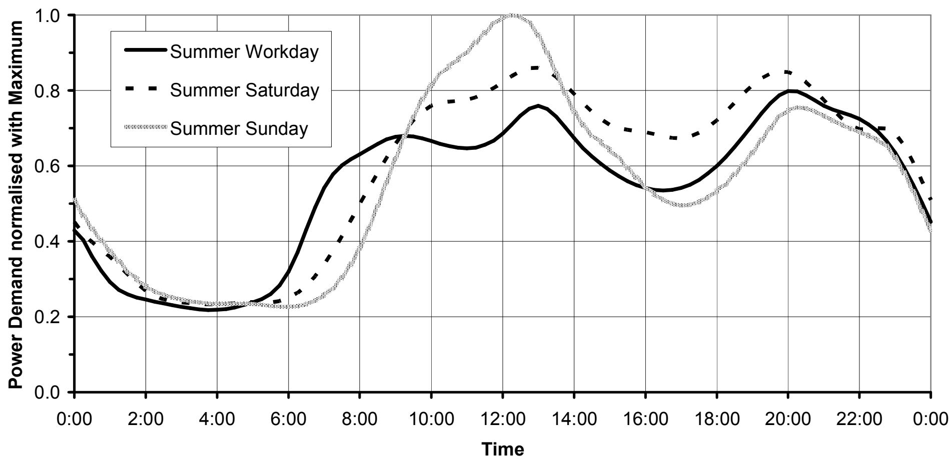

Figure 21 – Summer representative domestic electrical consumption profile for Germany

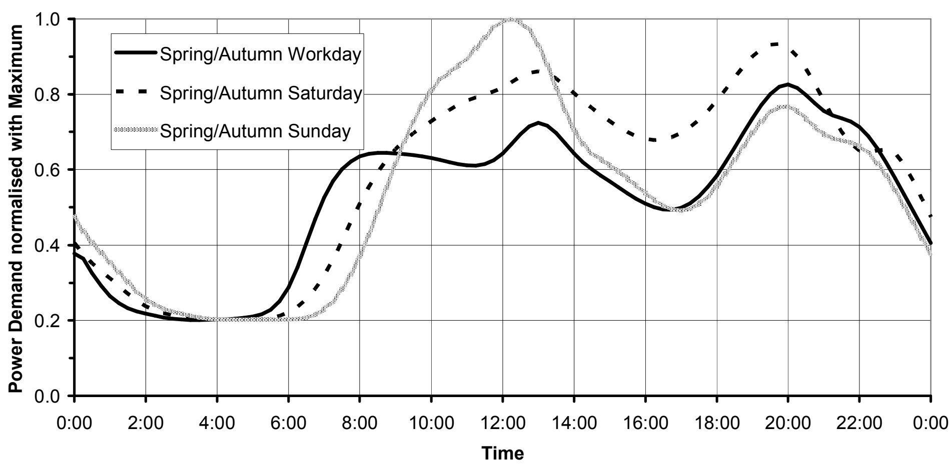

Figure 22 – Spring/Autumn representative domestic electrical consumption profile for Germany

6.1.5 Portugal

ADENE in Portugal provided the following domestic energy consumption data. There are uncertainties over the size of property being monitored and whether the electrical consumption included or excluded HVAC and DHW use. However it can be seen that essentially the daily energy consumption profiles are very similar to those seen in the rest of Europe. The data were recorded during the European Save project in 2000 and 2001 and the monitoring campaign included 28 households. The average monitoring duration per household was 38 days. In total 1064 days of data were available for this investigation.

Table 6 – Portuguese Household Monitoring Schedule

household																		
994001	■	■	■															
994002	■	■	■															
994003	■	■	■															
994006	■	■	■															
994010		■	■	■														
994014			■	■														
994018			■	■														
994019					■	■	■											
994020					■	■	■											
994023							■	■										
994025									■	■								
994028							■	■										
994033									■	■								
994035									■	■								
994041										■	■							
994044										■	■	■						
994045										■	■	■						
994046										■	■	■						
994047										■	■							
994051												■						
994060													■					
994062													■	■				
994063													■	■				
994066													■	■				
994070													■	■				
994074														■				
994079															■	■		
994096																	■	■
houses	4	5	7	3	2	2	4	2	3	8	5	4	5	5	1	1	1	1
	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01
		spring			summer			autumn			winter							

The data have been recorded with an interval of 10 minutes. Table 6 shows which months were used for the analysis.

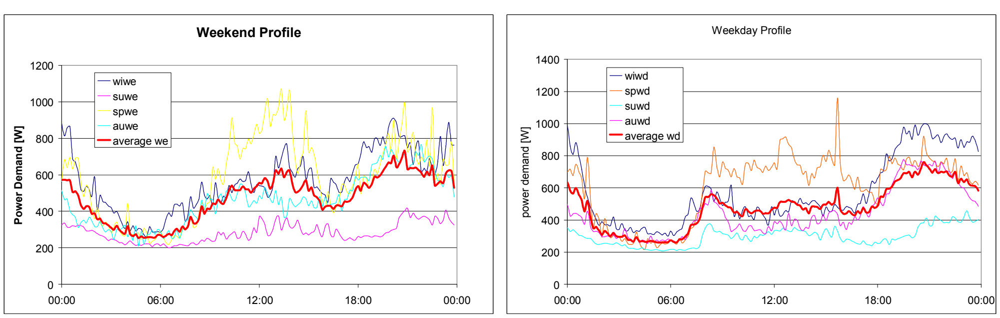

Figure 23 - Portuguese Weekend and Weekday electricity profiles for Winter (wi), Summer (su), Spring (sp) and Autumn (au)

The profiles for each season of the years have been averaged over three month because of the low data density. Figure 23 shows that the spring profiles have the highest demand during the daytime. This is explainable by the fact that different households are used to generate the different seasonal profiles. Therefore the results of this investigation can only be an indicator about the average domestic electric energy consumption in Portuguese households. Nevertheless it can be used to compare with the electrical energy profiles from other countries.

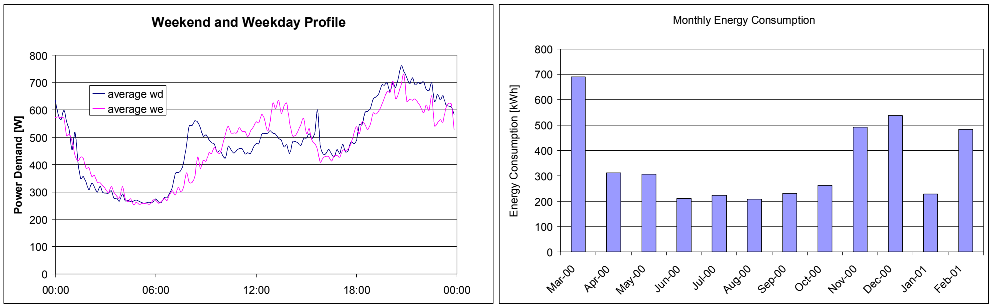

Figure 24 - Average Portuguese daily and annual consumption profiles

The comparison of yearly averaged weekend and weekday profiles shows similarities in the morning and at night. The biggest difference can be found during the daytimes.

The total annual energy consumption of the analysed houses amounts to 4183kWh, which is above the general European country average figures. Overall, the consumption curves for Portugal are not as robust as desired, but they still provide confidence that the overall shape of the proposed consumption figures is correct, even if the average monitored consumptions are higher in Portugal in this sample than in other countries. However to balance this, Figure 24 does suggest that the February and March consumptions are anomalous, and that removing the 'additional' 700kWh for these two months would bring Portugal down to the European average consumption as well.

6.1.6 Belgium

The final data available to us came from a monitoring study of two houses by the University of Liege. However, despite repeated attempts, we were never satisfactorily able to explain why the electrical energy consumption of the Belgium houses was so large at between 11000 and 22000 kWh per annum. This is totally at odds with a 1997 study[18] which showed an average Belgium annual domestic electricity consumption of 2534 kWh per household excluding heating and DHW energy use. In line with the Italian consumption figures discussed earlier this suggests a figure of around 3000 kWh per annum today, which is again in keeping with the data from the other European countries.

It was assumed therefore that there was some space and/or DHW consumption included in the data profiles provided that we were not able to separate out satisfactorily. This data has therefore been ignored.

6.2 Overall summary of European Domestic Electrical Energy Consumption Data supplied

The overall data sets supplied for use in the Annex by the various European countries varied in their content and detail.

[18] Fawcett T, Lane K and Broadman B – Carbon Futures for European households. Environmental Change Institute, Oxford University – March 2000. Country pictures supporting material – Belgium .http://www.eci.ox.ac.uk/research/energy/downloads/lowercarbonfuturereport.pdf.. Accessed 7th January 2007

In the author's opinion the general conclusion is that the datasets where the monitored data could be more explicitly referred to all tended to exhibit similar daily profiles during the weekdays and similar overall magnitudes of consumption.

The larger differences in the datasets tended to appear where it was more difficult or impossible to refer back to the original source data.

Where we were able to assess the annual consumptions of the profiles supplied against various whole country data sources we generally obtained good agreement that the average European dwelling in each country tended to consume between 3000 and 3500 kWh of electricity per annum, excluding space and DHW heating energy use.

It is the authors opinion therefore that, in the absence of further substantial datasets, the Standard and Specific European Electrical Consumption Profiles presented here, which are the UK domestic profiles monitored by EETS Ltd and the Welsh School of Architecture, are likely to be a good first estimate of domestic electrical energy consumption profiles for many European countries. They are therefore a reasonable basis for assessing the potential performance of Cogeneration systems when meeting this load.

7 The European Domestic Electrical Energy Consumption Profile Data provided by IEA Annex 42.

This section describes what is in the Annex 42 European Domestic Electrical Energy Consumption Profile datasets provided with this Annex. The data used for this work is fully described in Section 5.2

Table 7 – European Domestic Electrical Energy Consumption Data Filenames

File Name	Period	Daily Consumption [kWh]	Month
wiwd.xls	Winter weekday	9.465	January
wiwe.xls	Winter weekend	9.804	January
sswd.xls	Shoulder season weekday	8.176	April and October
sswe.xls	Shoulder season weekend	8.483	April and October
suwd.xls	Summer weekday	7.754	July
suwe.xls	Summer weekend	7.912	July

The six standard DAILY profiles provided and shown in Table 7 represent a monthly average of the 69 households at various times of the year, i.e. for each 5 minute timestep in the month indicated the average load at that time of day over all weekdays or weekend days across all 69 households is provided.

The **time resolution of each profile is 5 minutes** and the unit is Watts (W).

To obtain a full year's profile the user can aggregate the profiles together in blocks of 3 months, using the weekend and weekday profiles as appropriate, as follows:

Winter: December, January and February

Shoulder Season: March, April, May and September, October, November

Summer: June, July, August

An example of this aggregation to produce an annual profile has been provided as **standard annual average electric energy consumption FINAL.xls** based on the Year 2003.

All of these files are contained within the zip file "**European Electrical Standard Profiles – Annex 42 September 2006.zip**"

There is a second set of profiles provided as well, which represent the **ACTUAL** recorded domestic electrical energy consumption profiles of 3 different properties over a year.

These three dwellings are those considered to be most representative of low, medium and high electric energy consumption amongst the sample of buildings monitored (see Figure 25 through to Figure 27) as their consumptions for the year chosen are those which provide the most complete high, average and low consumptions identified in the overall dataset.

The profiles presented are the average power consumption over a 5 minute time interval in two flats in Newcastle (England) and one town house in Llanelli (Wales). These profiles are presented as being the best current option to represent 'standard' European domestic profiles based on the data available to the Annex.

The data presented are complete annual files every 5 minutes. As with most monitoring projects there is some missing data. Missing data points are replaced by data points assumed to have the same characteristic (e.g. a missing Monday has been replaced by another existing

Monday). This replaced data is marked in the file by a yellow cell. The files have a time and a day tag (day tag: 1=Monday, 2=Tuesday…..).

The monitoring fractions for the dwellings (the amount of data collected as a percentage of the maximum possible in that period) are shown in Figure 28 and Figure 29. The annual monitoring fraction for the files "low electric energy consumption" and "medium electric energy consumption" amount to 90.3% and for the file "high electric energy consumption" to 97.0%.

The unit of the energy consumption data is Watts (W) and the data starts on the first of each month on each sheet. Table 6 provides more detail on each of the properties. The data for all the properties is contained in the file "**European Electrical Specific Profiles – Annex 42 September 2006.zip**". These three specific profiles do not include any electrically heated DHW.

Table 8 – Dwelling characteristics

File Name	Annual Consumption [kWh]	Location	Year	Size of dwelling [m²]	Occupancy type
Actual low electric energy consumption FINAL.xls	1155	Newcastle	2005	65	Single male
actual medium electric energy consumption FINAL.xls	3028	Newcastle	2005	65	Mother and two children
actual high electric energy consumption FINAL.xls	8387	Llanelli	2003	108	Mother and 5 children

Flats (Newcastle – England)

Town houses (Llanelli - Wales)

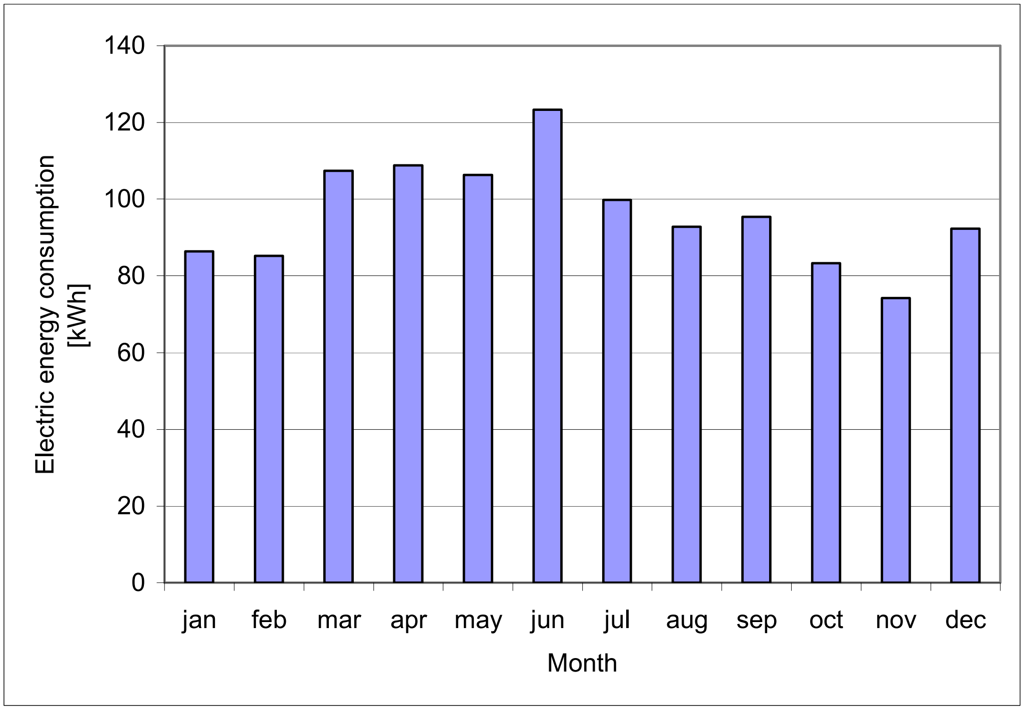

Figure 25 - Monthly electric energy consumption file "low electric energy consumption"

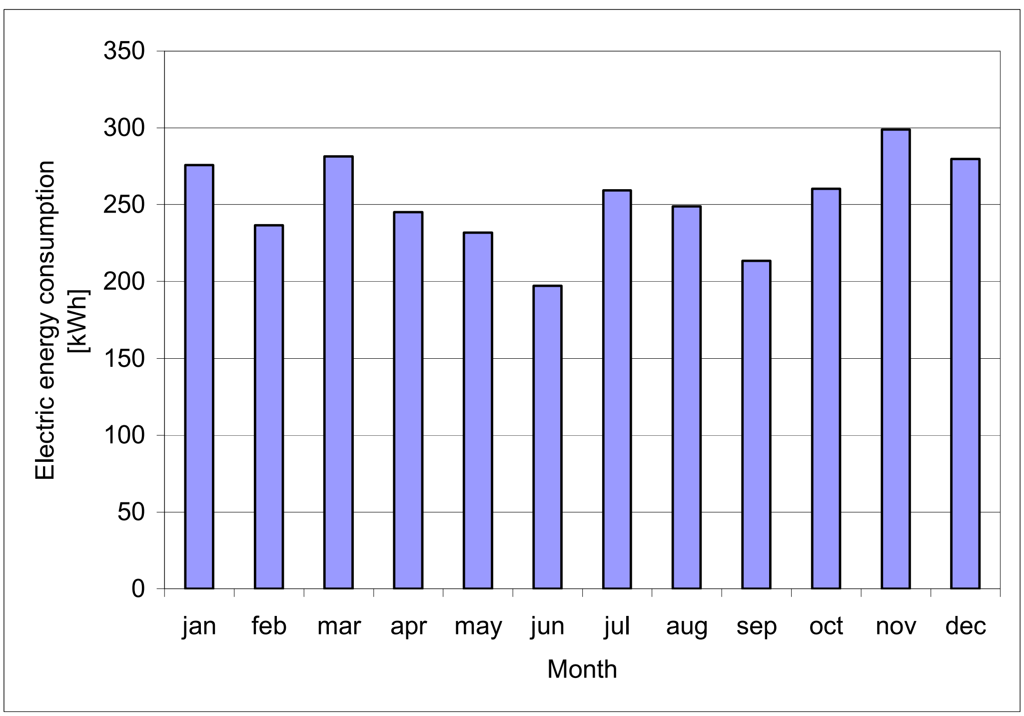

Figure 26 - Monthly electric energy consumption file "medium electric energy consumption"

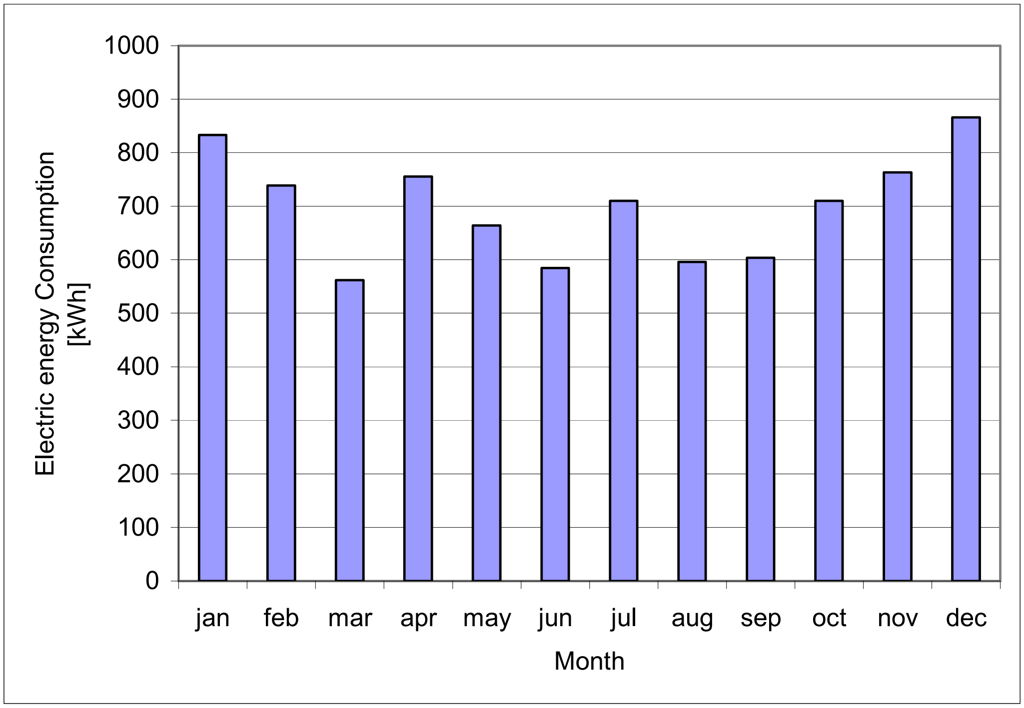

Figure 27 - Monthly electric energy consumption file "high electric energy consumption"

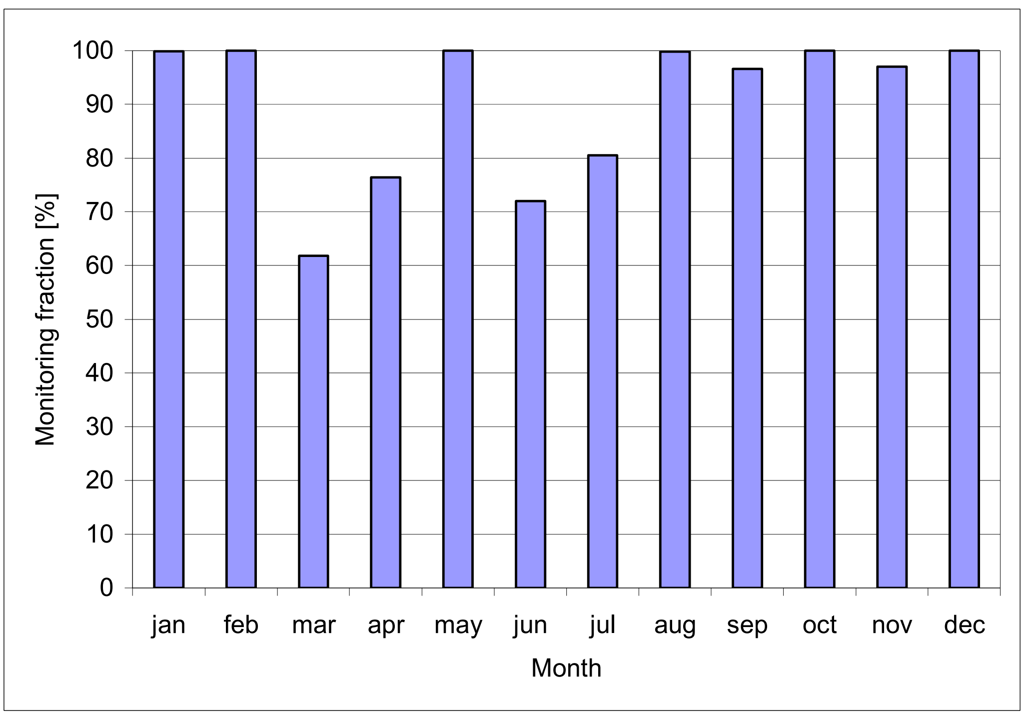

Figure 28 - Monthly monitoring fraction file "low electric energy consumption" and "medium electric energy consumption"

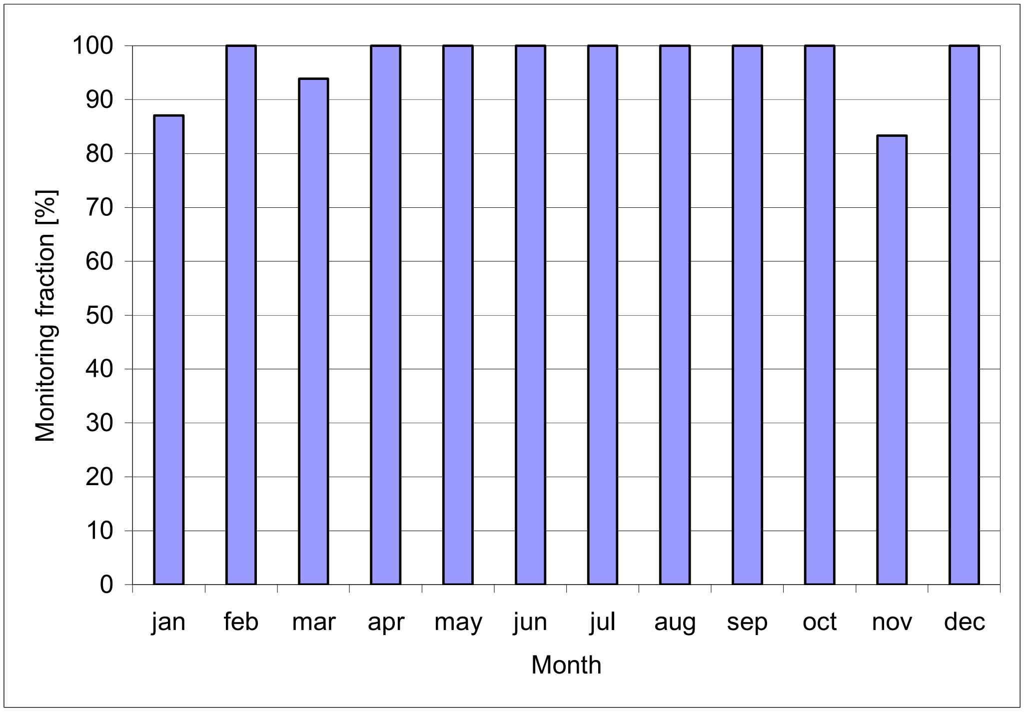

Figure 29 - Monthly monitoring fraction file “high electric energy consumption”

8 Electricity demand profiles for Canada

8.1 Introduction

Two types of electricity demand profiles were produced for assessing the potential performance of Cogeneration systems when meeting the electrical energy demand profiles in single detached houses in Canada:

- Generated profiles using the profile generator from the National Research Council of Canada (NRC), and
- Measured profiles using data from Hydro Québec.

Both types of profiles are based upon the same starting points, which are described below.

8.2 Total Annual Electricity Consumption – Use Targets for the Generator

The electricity demand profiles will generally be used as model inputs for performance assessment studies in which the heating and/or cooling systems of the house (including their electrical load) will be modelled separately in the building simulation models. Therefore, the approach described herein is for electricity demand profiles that exclude the HVAC component. As such, the result is labelled 'non-HVAC profiles', i.e. the profiles will contain the electric draws of appliances and lighting only.

Target values for the total annual consumption as well as for major appliances and lighting in Canada were obtained from the Comprehensive Energy Use Database of the Office of Energy Efficiency of Natural Resources Canada[19]. This database contains information on the electricity use of the average Canadian household based upon data from surveys and other sources (manufacturers, electricity distribution companies, Statistics Canada, etc). The database gives the type and average number of appliances per household, and the average electricity use for appliances and lighting (for average stock as well as for new ones). Table 9 presents the electricity use for appliances and lighting for the average Canadian household, based upon data for 2003 for the average stock of appliances.

[19] http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/comprehensive_tables/index.cfm?fuseaction=Selector.showTree

Table 9- Electricity use for appliances and lighting for the average Canadian household (average stock of appliances)

	Nr of appl	kWh/y	kWh/appl
Refrigerator	1.24	992	801
Freezer	0.56	346	614
Dishwasher*	0.55	39	72
Clothes washer*	0.81	62	76
Clothes dryer	0.79	780	988
Range	0.92	711	769
Other appliances	8.98	1896	
Lighting (/m^2)	121 m^2	1742	14.4
Total		**6567**	

* excludes hot water requirements

The average detached house, however, is not the same as the average house. The average detached house is larger than the average house (141 m^2 vs. 121 m^2) and will have more people living in it than the average house. The electricity consumption data for appliances and lighting have therefore been adjusted to reflect these differences by adjusting the number of appliances per household and by the introduction of a 'use factor' for the appliances. The use factor presents the use of the appliance compared to the use in the average household. For instance, the clothes washer and clothes dryer will be used more often in the average single detached house, because more people will be living in it compared to the average Canadian house. The value of the use factor had to be estimated (based upon the differences in occupancy between the average house and the average detached house), because no specific data was available. The electricity use for appliances and lighting for the average detached house is given in Table 10.

Table 10 - Electricity use for appliances and lighting for the average detached house

	appl/household	kWh/appl	Use factor	kWh/y
Refrigerator	1	801	1.0	801
Freezer	1	614	1.0	614
Dishwasher	1	72	1.3	94
Clothes washer	1	76	1.3	99
Clothes dryer	1	988	1.3	1284
Range	1	769	1.0	769
Other appliances	8.98	1896	1.3	2465
Lighting (/m^2)	141 m^2	14.4*	1.0	2030
Total				**8156**

* in kWh/m^2

8.3 Low, medium and high electricity demand profiles

Low, medium, and high electricity demand profiles for Canadian detached houses were developed using the above described method. The number of appliances per household and the use factors per appliance were chosen with the following typical families/households in mind:

1. Low electricity demand: An energy minded family in an average detached house.
2. Medium electricity demand. A regular family in an average detached house.
3. High electricity demand. A large family with no interest in energy conservation, living in a large detached house.

Table 11, Table 12, and Table 13 display the details on the number of appliances per household, the use factor for each appliance, and the annual electricity consumption target per appliance for the low, medium, and high electricity demand profile, respectively. The resulting target values for the annual power consumption are:

1. Low electricity demand profile: 4813 kWh/y
2. Medium electricity demand profile: 8156 kWh/y
3. High electricity demand profile: 13011 kWh/y

Table 11 - Electricity use for appliances and lighting for the low electricity demand profile

	appl/household	kWh/appl	Use factor	kWh/y
Refrigerator	1	801	1.0	801
Freezer	0	614	0.0	0
Dishwasher	1	72	0.8	58
Clothes washer	1	76	0.8	61
Clothes dryer	1	988	0.6	593
Range	1	769	1.0	769
Other appliances	8.98	1896	0.8	1517
Lighting (/m^2)	141 m^2	14.4*	0.5	1015
Total				**4813**

* in kWh/m^2

Table 12 - Electricity use for appliances and lighting for the medium electricity demand profile

	appl/household	kWh/appl	Use factor	kWh/y
Refrigerator	1	801	1.0	801
Freezer	1	614	1.0	614
Dishwasher	1	72	1.3	94
Clothes washer	1	76	1.3	99
Clothes dryer	1	988	1.3	1284
Range	1	769	1.0	769
Other appliances	8.98	1896	1.3	2465
Lighting (/m^2)	141 m^2	14.4*	1.0	2030
Total				**8156**

* in kWh/m^2

Table 13 - Electricity use for appliances and lighting for the high electricity demand profile

	appl/household	kWh/appl	Use factor	kWh/y
Refrigerator	2	801	1.0	1601
Freezer	1	614	1.3	798
Dishwasher	1	72	1.7	122
Clothes washer	1	76	2.0	152
Clothes dryer	1	988	2.0	1976
Range	1	769	1.4	1077
Other appliances	8.98	1896	1.7	3223
Lighting ($/m^2$)	210 m^2	14.4*	1.34	4061
Total				**13011**

* in kWh/m^2

8.4 Generated profiles using the NRC profile generator

The Random Profile Generator is a Microsoft Excel based program that was conceived and created by the National Research Council Institute for Research in Construction with assistance from Natural Resources Canada for IEA Annex 42. This section outlines the assumptions and methodology used to create these profiles, and also describes the profile generator output.

8.4.1 Purpose

The Canadian Random Profile Generator was born from the desire to simulate electrical loads due to occupant actions in a much finer time resolution (5-minute intervals) than is generally available from known sets of monitored data (typically at 1-hour intervals). Having data at 5-minute intervals for a whole year would assist the CHP modellers in trying out their simulations with realistic load variations associated with 5-minute load profiles. The purpose of the NRC profile generator is therefore to simulate the random actions of a household on a 5-minute basis, in order to create electrical load profiles that match the low, medium and high consumption targets.

8.4.2 Strategy

A total of 8 different loads were simulated individually and then combined to create an annual profile for each of the following: the dishwasher, range, clothes washer, clothes dryer, lights, small appliances, refrigerator and freezer. The appliance sets and target annual consumptions are presented in Table 11, Table 12 and Table 13. A separate set of assumptions and inputs were used to guide the generation of load profiles for each of the eight appliances and loads. These are described below.

8.4.2.1 Dishwasher, Clothes Washer, Range and Clothes Dryer

For the dishwasher, clothes washer, range and clothes dryer, the electrical draw was calculated using the annual consumption target for the medium electricity demand profile (kWh/year), cycle duration, and the cycles per year for the average house – as described in

Equation 1. The average cycles per year were derived from standard appliance test methods of the Canadian Standards Association[20,21,22]. Cycle duration was chosen based on measured data from the Canadian Centre for Housing Technology (CCHT). For appliances with variation in cycle time (range , dishwasher, and clothes dryer), the average cycle duration was used in Equation 1.

$$\text{Appliance Electrical Draw} = \frac{\text{Annual Consumption}}{\text{Cycle Duration} * \text{Cycles per Year}} \qquad \text{Equation 1}$$

The calculated electrical draw was compared to data from the Canadian Renewable Energy Network[23] to assure realistic values. To match the target annual consumptions for the low and high electricity demand profiles, the number of cycles per year was varied. Details of appliance loads and cycles are presented in Table 14.

The duration of major appliance events was chosen at random from within a set range, which is provided in Table 14.

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[20] Energy Consumption Test Methods for Household Dishwashers. (1992). CSA Standard CAN/CSA-C373-92.

[21] Energy Performance, Water Consumption and Capacity of Automatic Household Clothes Washers. (1998). CSA Standard CAN/CSA-C360-98.

[22] Test Method for Measuring Energy Consumption and Drum Volume of Electrically Heated Household Tumble-Type Clothes Dryers. (1992). CSA Standard CAN/CSA-C361-92.

[23] Micro-Hydropower Systems – A Buyer's Guide. Natural Resources Canada. (2004). Appendix C. [Available online at: http://www.canren.gc.ca/app/filerepository/buyersguidehydroeng.pdf, 15-Aug-06.]

Table 14 - NRC Random Profile Generator Appliance set

Appliance	Power (W)	Cycle Duration (min)	Cycles per year	Target Annual Consumption (kWh/year)
Dishwasher	467	30 to 45	200 (low) 322 (average) 418 (high)	58 (low) 94 (average) 122 (high)
Clothes Washer	505	30 (two 15-minute cycles)	242 (low) 392 (average) 601 (high)	61 (low) 99 (average) 152 (high)
Clothes Dryer	4115	30 to 60	192 (low) 416 (average) 640 (high)	593 (low) 1284 (average) 1976 (high)
Range	1600	15 to 70	678 (low) 678 (average) 950 (high)	769 (low) 769 (average) 1077 (high)
Refrigerator	265 (peak)	----	----	801 (low) 801 (average) 1602 (high: 2 refrigerators)
Freezer	202 (peak) 263 (peak)	----	----	0 (low) 614 (average) 798 (high)

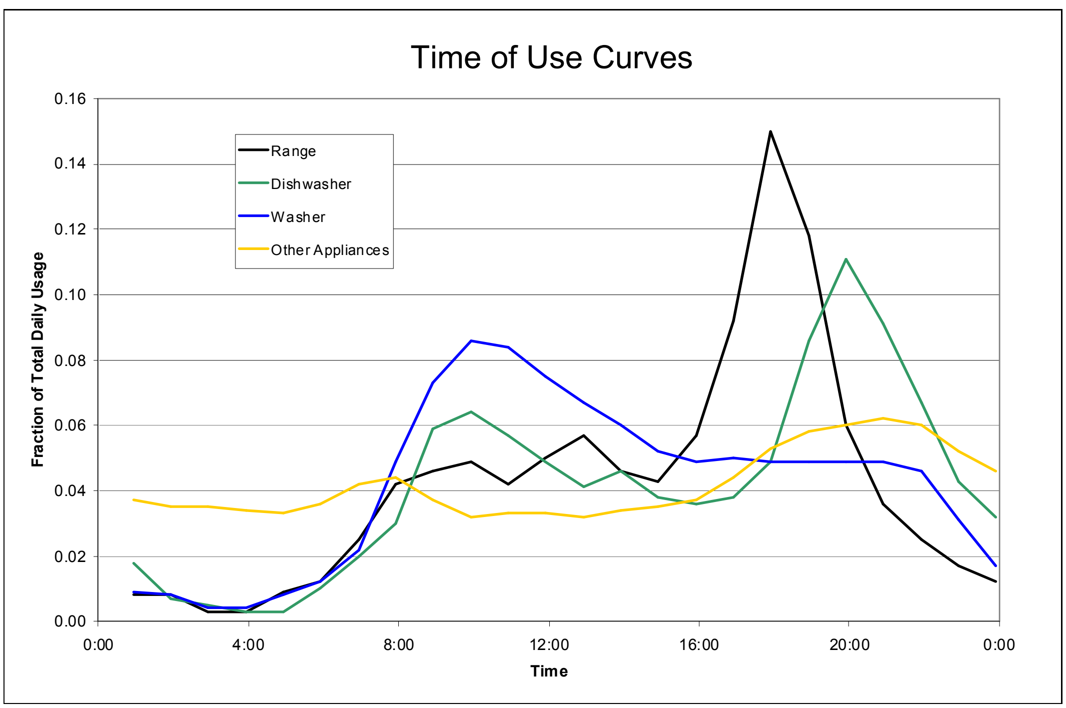

Figure 30 - Time of use curves that guide appliance events

Major appliance events are guided by "time of use" curves, first published by Pratt[24] in 1989 and subsequently in the Building America Research Benchmark Definition[25]. These curves are presented in Figure 30.

Based on these curves,

Probability: 1 in c/f (P = 1/(c/f)) **Equation 2**

Where

- P is the probability,
- f is the fraction of total daily usage – from the time of use curves in Figure 30
- c is the chance factor – chosen to attain the desired annual consumption target

gives the probability of an event triggering in any 5-minute period, provided the event is not already occurring. The chance factor in this equation is determined through trial and error to generate the desired cycles per year and meet the target annual consumption for that appliance. The smaller the chosen chance factor, the greater the likelihood an event will occur, and the higher the resulting annual consumption. No time of use curve was used to control the clothes dryer operation. Instead, clothes dryer events were coupled to clothes washer operation. Clothes dryer cycles were allowed to trigger between 30 and 120 minutes following the end of the washer cycle.

The end result of this control by the time of use curves is demonstrated by Figure 31 and Figure 32. Figure 31 presents a sample of a daily consumption profile for the clothes washer. In this profile, a single event is triggered at 9:00 (as washer event consists of a wash and a rinse cycle). When the average of one thousand similarly generated days is taken, the shape of the time of use curve becomes apparent, see Figure 32. The chance factor was varied for the high and low energy cases, to produce a higher and lower number of events respectively and to meet the annual consumption targets.

[24] Pratt, R., C. Conner, E. Richman, K. Ritland, W. Snadusky, and M. Taylor. (1989). Description of Electric Energy Use in Single-Family Residences in the Pacific Northwest – End-Use Load and Consumer Assessment Program (ELCAP). DOE/BP-13795-21, Richland, WA: Pacific Northwest National Laboratory.

[25] Hendron, R. (2006). Building America Research Benchmark Definition, Version 3.1, Updated December 29, 2004. 37 pp; NREL/TP-550-37529. [Available online at: http://www.nrel.gov/docs/fy05osti/37529.pdf, 14-Aug-06]

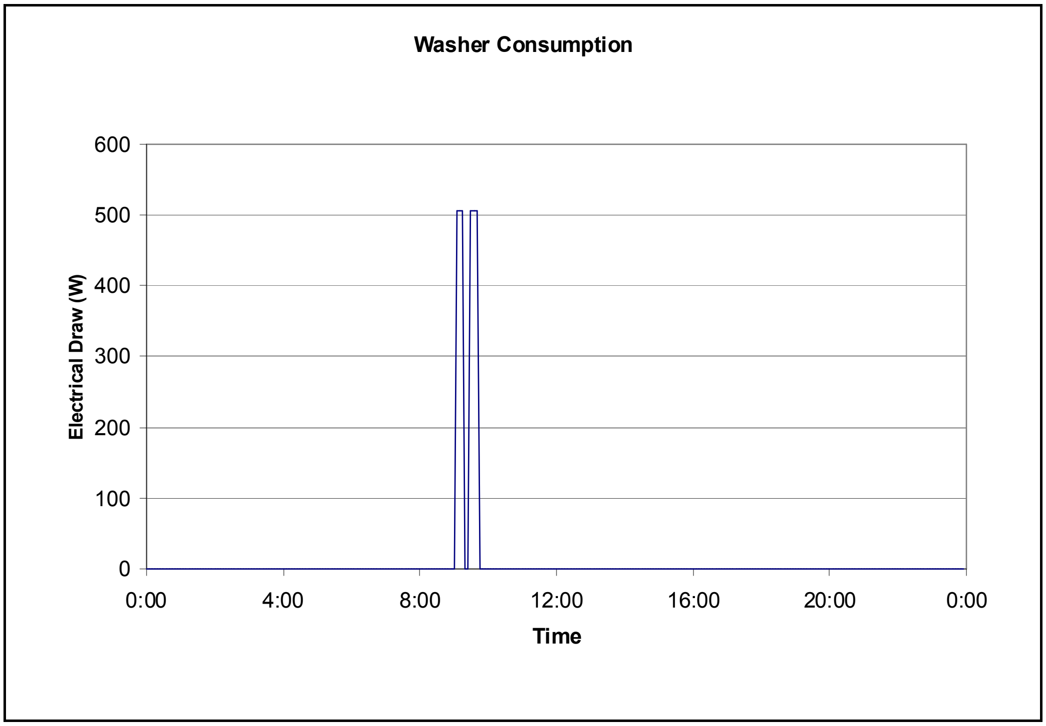

Figure 31 - Sample Daily Clothes Washer Consumption Profile

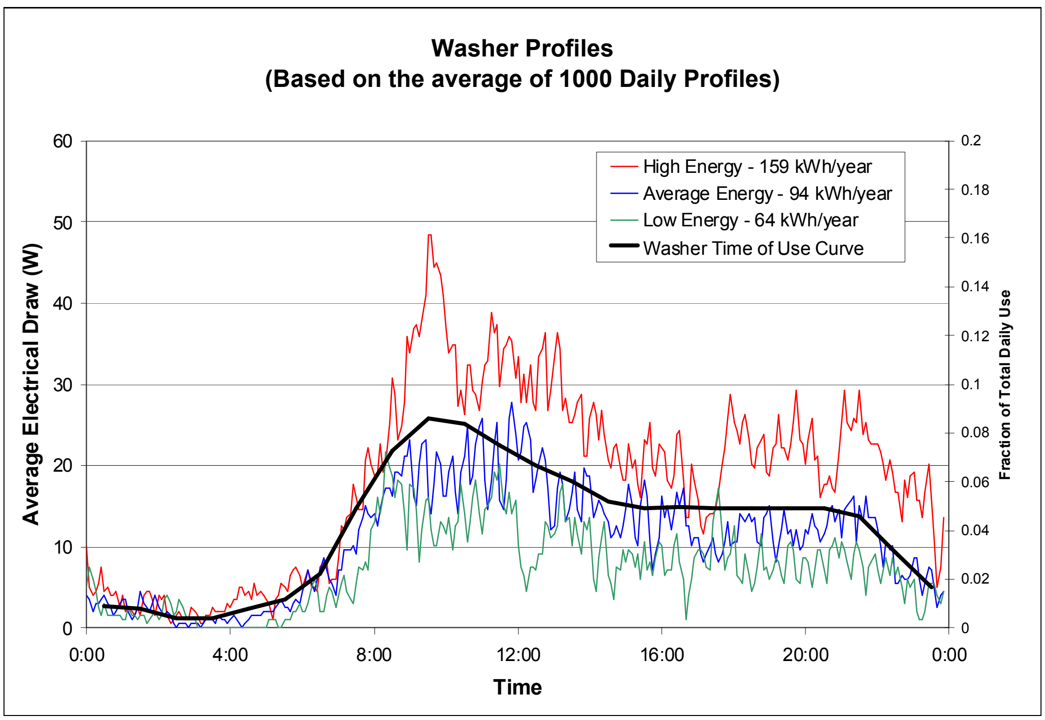

Figure 32 - Average Daily Clothes Washer Consumption - based on 1000 randomly generated daily profiles

8.4.2.2 Refrigerator and Freezer

The shape of the refrigerator and freezer profile was based on measured refrigerator data from the CCHT. The shape of the CCHT profile was scaled to match a desired peak load. The same 70-minute cycling sequence was repeated throughout the day, randomly offset forward or back to ensure a different starting point each day. A single 105 minute defrost cycle was also added randomly during the day, matching the cycle sequence. The defrost cycle was again scaled to reach the desired peak loads. A sample daily refrigerator consumption profile is shown in Figure 33.

It was assumed that both the low and average target houses were equipped with identical refrigerators, while the high energy house contained two of the same model (see Table 14). The low energy house was assumed not to have a freezer. The average energy house had an average freezer, whereas the high energy house had a larger freezer.

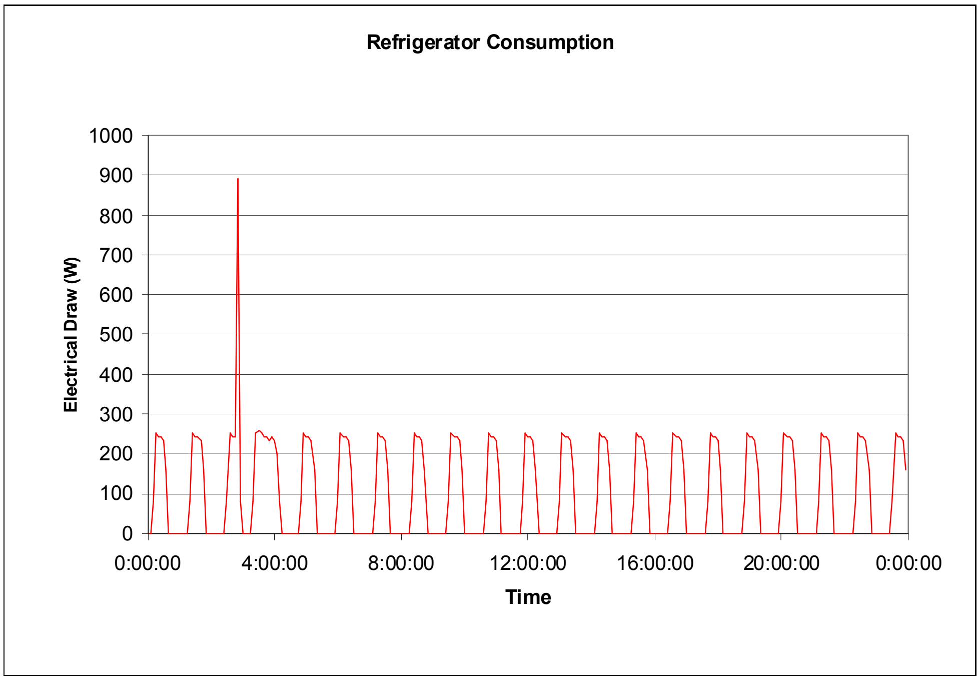

Figure 33 - Sample Daily Refrigerator Consumption Profile

8.4.2.3 Lights and Small Appliances

The control methods for lighting and small appliances differ slightly from the control of the major appliances. A time of use curve and chance factor were still used. However, lighting events were allowed to overlap, and whenever a light was randomly activated, the load was chosen at random from a set list of loads. Each lighting or small appliance event was assigned a duration between 5 and 120 minutes.

The list of lighting loads is presented in Table 15. These loads were assumed based on reasonable lighting loads. It was also assumed that the low energy house would be using more efficient light bulbs, while the high energy house would have more lights – based on its larger floor area. In addition, the lighting profiles were adjusted by season. Three different curves were used to control the lighting, one for winter, one for summer, and one for the shoulder season. These curves are shown in Figure 34. December through February were considered winter, and June through August were considered summer, with the remaining six months considered as the shoulder season. The effect of control by these different seasonal curves is demonstrated in Figure 35. Each series in the graph is the average of 1000 randomly generated daily profiles, each controlled by a separate seasonal curve.

The list of small appliance loads is presented in Table 16. This data was derived from the typical household appliance loads in Appendix C of NRCan's publication – Micro-Hydropower System, A Buyer's Guide[23]. The time of use curve that controlled small appliance events is given in Figure 30

All appliances were given a chance of occurrence based on the hours of operation per month. For instance, an iron event – with only 12 hours of operation per month, was four times more likely to occur than a mixer event – with only 3 hours per month of operation. Additionally, a constant baseload of 65 Watts was applied for standby loads from appliances such as microwaves, telephones, clocks and VCRs.

Table 15 – Lighting loads

Name	Average House Load (W)	High Energy House Load (W)	Low Energy House Load (W)
Lights 1	60	120	30
Lights 2	100	200	50
Lights 3	120	240	60
Lights 4	410	820	205
Lights 5	200	400	100
Target Annual Consumption (kWh/year)	**2030**	**4061**	**1015**

Table 16 – Other Appliance loads[23]

	Appliance	Power Rating (W)	Hours per month
Kitchen	Blender	350	3
	Coffee Maker	900	12
	Deep Fryer	1500	8
	Exhaust fan	250	30
	Electric kettle	1500	15
	Hot plate (one burner)	1250	14
	Microwave oven	1500	10
	Mixer	175	6
	Toaster	1200	4
Laundry	Iron	1000	12
Comfort and Health	Electric blanket	180	180
	Fan	120	6
	Hair dryer	1000	5
Entertainment	Computer (desktop)	250	240
	Computer (laptop)	30	240
	Laptop charger	100	240
	Radio	5	120
	Stereo	120	120
	Television	100	125
	VCR	40	100
Outdoors	Lawn mower	1000	10
Tools	Drill	250	4
	Circular saw	1000	6
	Table saw	1000	4
	Lathe	460	2
Other	Sewing Machine	100	10
	Vacuum cleaner	800	10

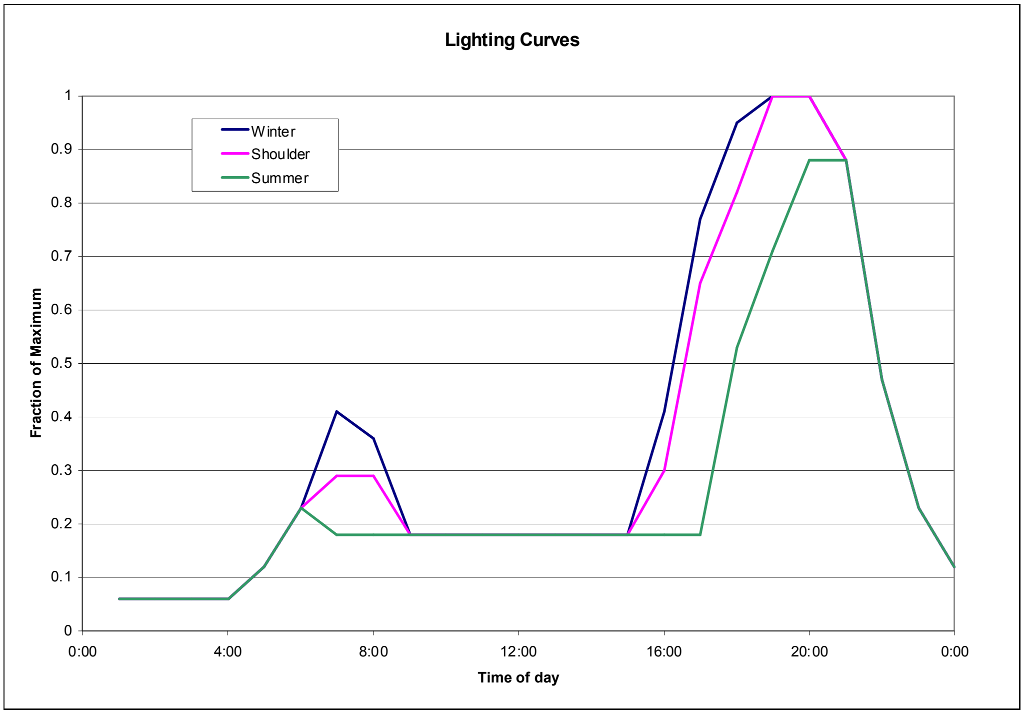

Figure 34 - Lighting Use Curves for Winter, Summer and Shoulder seasons

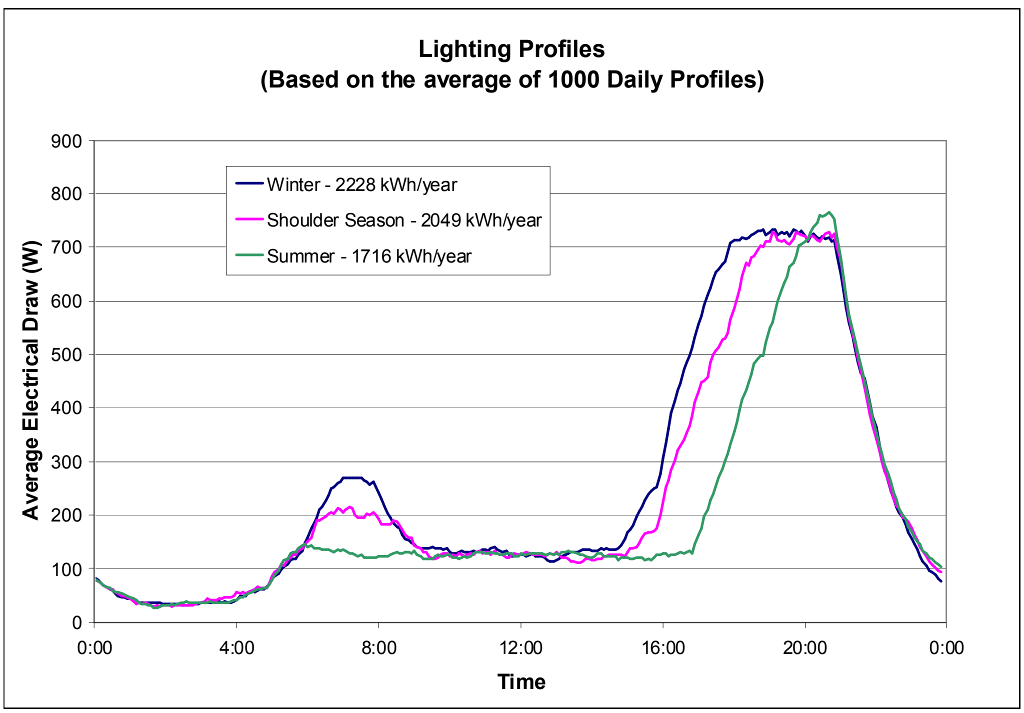

Figure 35 - Average Lighting Profiles by season, based on the average of 1000 randomly generated daily profiles for the average energy house

8.4.3 Sample Daily Profiles

The eight loads and their associated profiles combine to create a random daily electrical load profile for the house. Although there is no change in the controlling assumptions of the profile generator for weekend and weekday operation, the stochastic variations produced through the generation process create a wide range of daily profiles. When used in simulation, these profiles will expose cogeneration devices to a variety of test conditions.

Figure 36, Figure 37, and Figure 38 show the broad spectrum of daily profiles that are generated randomly. The figures present low, high, and average daily profiles for a constant set of inputs to the generator. In these figures, individual loads are presented stacked one upon another, accumulating to the total 5-minute electrical draw shown on the y-axis.

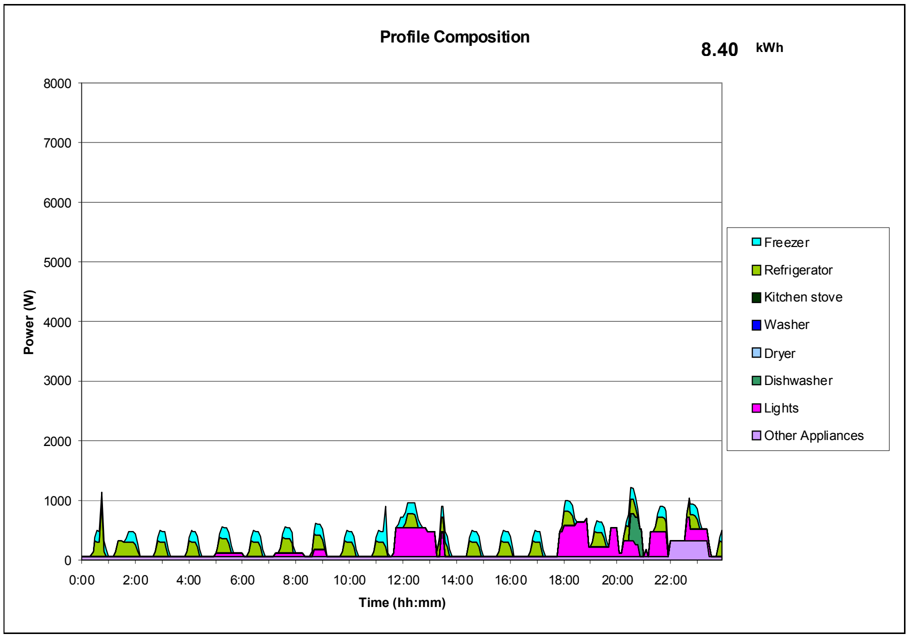

Figure 36 - Sample Daily Profile, Low Consumption

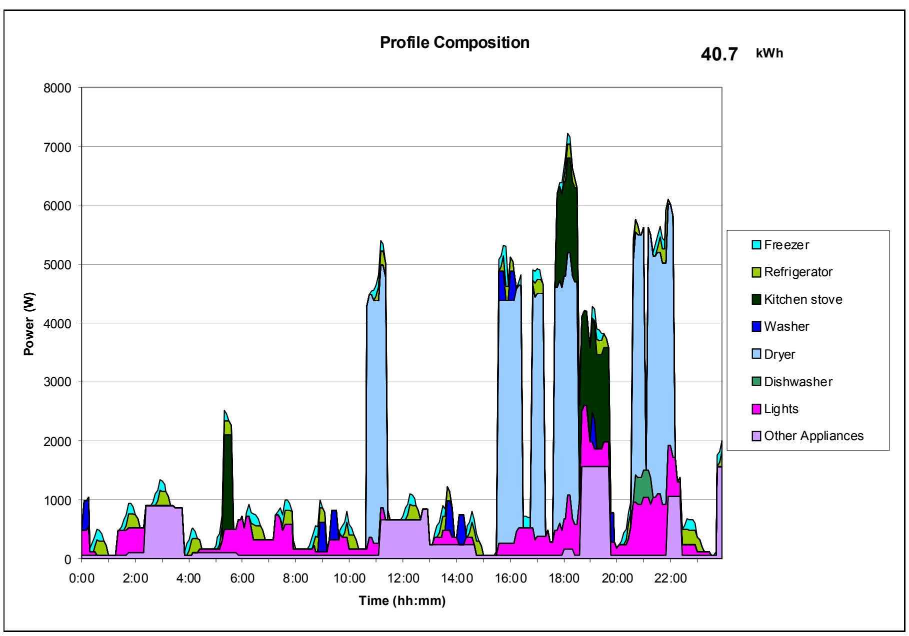

Figure 37 - Sample Daily Profile - High Consumption

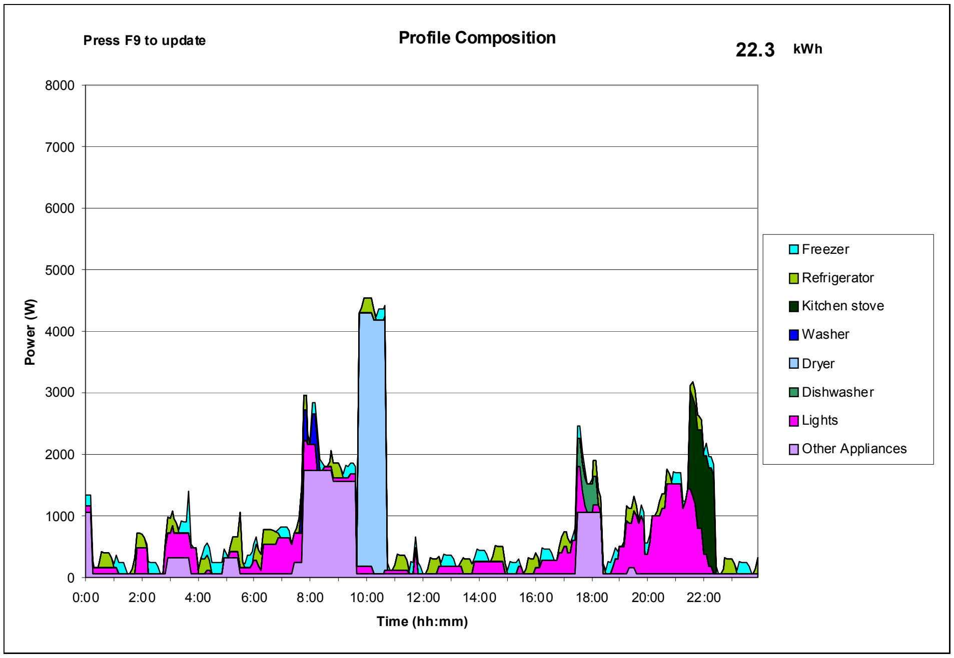

Figure 38 - Sample Daily Profile - Average Consumption

The 5-minute profile that is created by the generator contains many peaks and valleys. The data can be averaged hourly to generate a smoother profile – similar to the curves we see in hourly data obtained from utilities. Figure 39 presents the 5-minute and hourly profiles for the data presented in Figure 38.

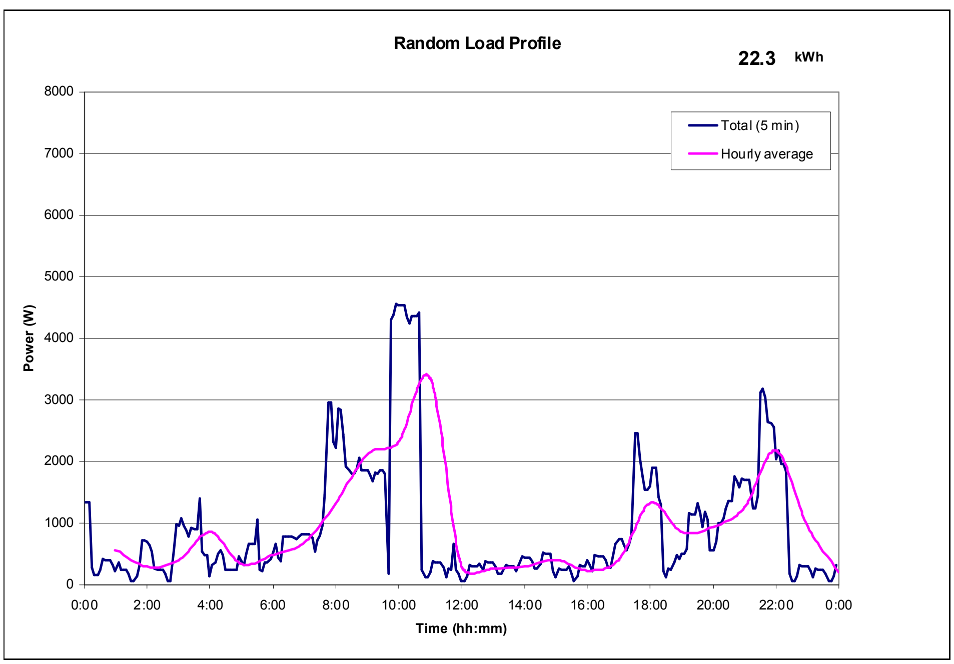

Figure 39 - Hourly Average Profile

8.4.4 Generated Yearly Profiles

The random profile generator produces a full year of 5-minute data (365 days) based on the individual loads and specifications. A sample of a resulting average yearly profile is shown in Figure 40.

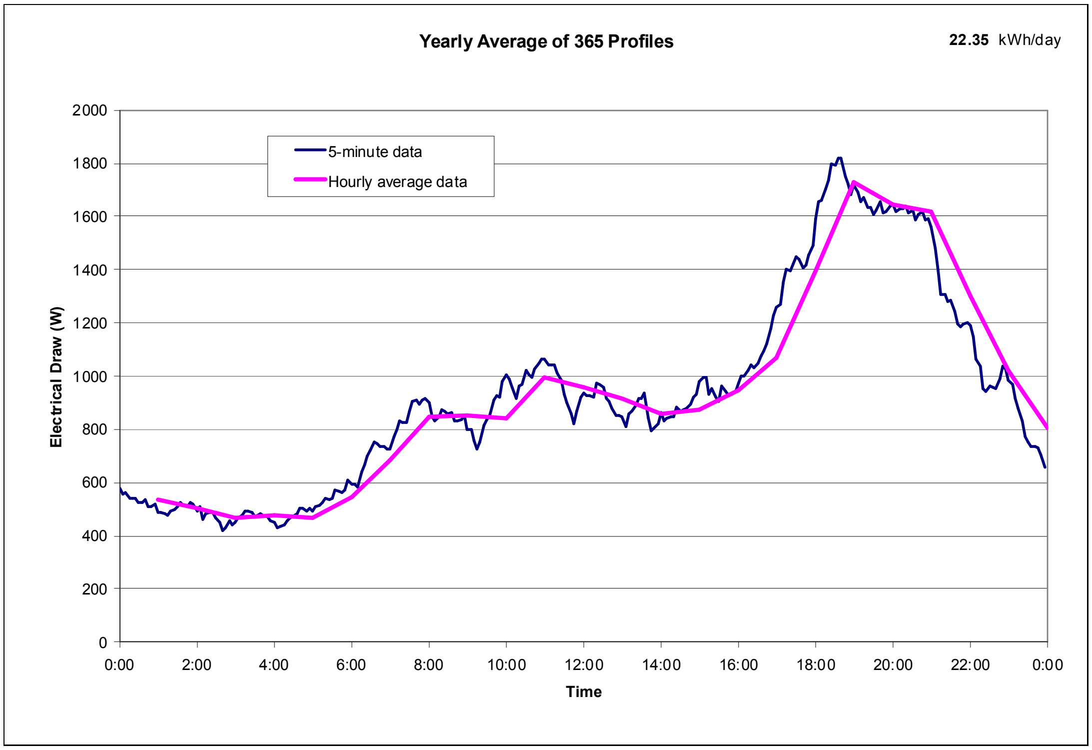

Figure 40 - Yearly Average of 365 Daily Profiles

To investigate the variation in the output of the generator, yearly profile generation was repeated 3 times for each condition: low energy, average, and high energy. The resulting annual profiles are compared in Table 17. Figure 41 presents the yearly profiles in graphic form. The variation between the 3 years of data is only small and is the result of the random generation process and the degrees of freedom available during the profile generation. In general, the peak draw, the maximum daily consumption, and the minimum daily consumption all increase correspondingly to the increase in annual consumption from the low, to average to high energy detached home profiles.

Table 17 - Comparison of Annual Profiles

	Low Energy Detached House			Average Energy Detached House			High Energy Detached House		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Target Annual Consumption (kWh/year)	4813	4813	4813	8156	8156	8156	13011	13011	13011
Annual Consumption (kWh/year)	**4762**	**4672**	**4837**	**8159**	**8218**	**8112**	**12956**	**13140**	**13044**
Average Daily Consumption (kWh/day)	**13.1**	**12.8**	**13.3**	**22.4**	**22.5**	**22.2**	**35.5**	**36.0**	**35.7**
Maximum / Minimum Daily Consumption (kWh/day)	28.0 / 6.4	24.8 / 6.9	26.2 / 6.9	43.2 / 10.7	39.2 / 10.4	42.3 / 11.7	53.1 / 21.2	58.4 / 19.9	55.4 / 20.6
Average Draw (W)	544	533	552	931	938	926	1479	1500	1489
Maximum yearly 5-minute peak (W)	**8099**	**7432**	**6973**	**8808**	**8313**	**8760**	**10480**	**10927**	**10047**

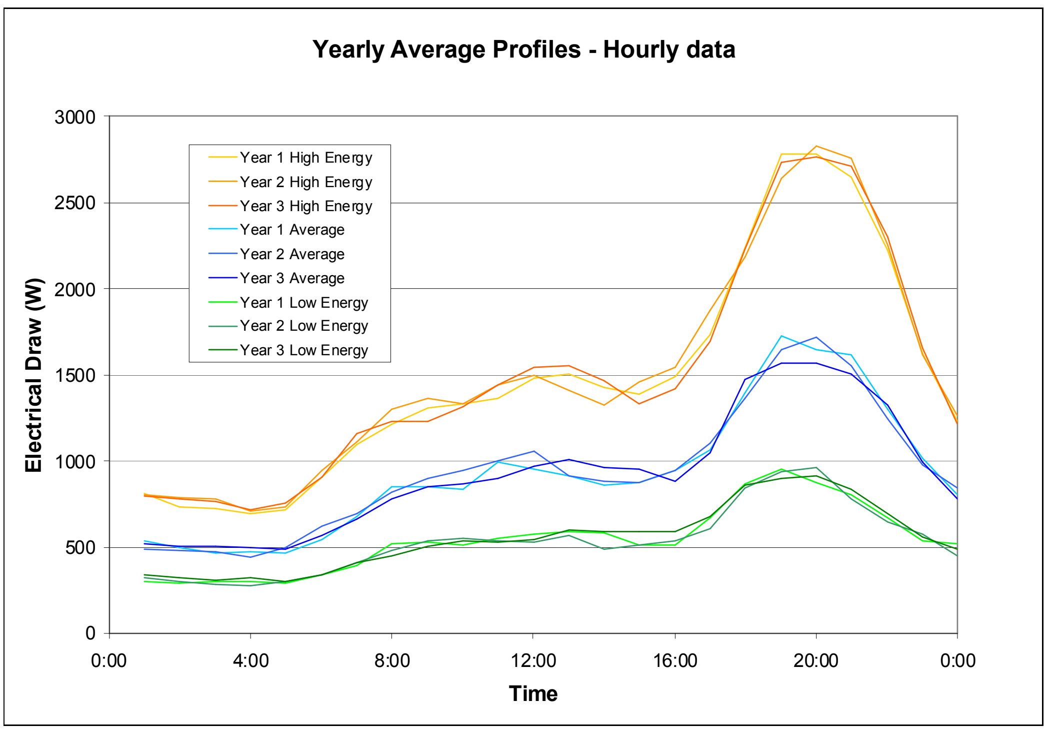

Figure 41 - Yearly Average Profiles for Low, Average and High Energy Houses

8.4.5 Generated Profile Files

The nine generated profiles are available in individual files. The characteristics of the generated profiles are shown in the following order (name file, annual non-HVAC electric load). All the data in these files is **at 5 minute intervals**:

Low electricity demand profiles	(target: 4813 kWh/y)
can_gen_low_y1.fcl	4762 kWh/y
can_gen_low_y2.fcl	4672 kWh/y
can_gen_low_y3.fcl	4837 kWh/y

Medium electricity demand profiles	(target: 8156 kWh/y)
can_gen_med_y1.fcl	8159 kWh/y
can_gen_med_y2.fcl	8218 kWh/y
can_gen_med_y3.fcl	8112 kWh/y

High electricity demand profiles	(target: 13011 kWh/y)
can_gen_high_y1.fcl	12956 kWh/y
can_gen_high_y2.fcl	13140 kWh/y
can_gen_high_y3.fcl	13044 kWh/y

The generated profiles are provided on the CD that comes with this report. The file Can-Elec-Load-Profiles.zip contains the files in .fcl format (for direct use in ESP-r). A readme file explaining the specific format of the files is included. The profiles are also provided in an EXCEL file, which can be extracted from the files Canadian Electrical Profiles_Excel Format_low.zip, Canadian Electrical Profiles_Excel Format_avg.zip and Canadian Electrical Profiles_Excel Format_high.zip

The generated profiles have been generated with the same inputs for all days of the year. So the profiles do not have any differentiation between weekdays and weekend days.

8.5 Measured profiles from Hydro-Québec

Hydro-Québec measured the electricity demand at a 15-minute time step in 57 single detached houses during the period Jan 1, 1994 to Sep 30, 1996[26]. Total electricity demand, electricity for heating, and power consumption for domestic hot water were measured, allowing the determination of non-HVAC profiles by subtracting the electricity consumption for heating and domestic hot water from the total power consumption. The total monitoring period of over 2.5 years provided sufficient data to make 2 yearly profiles for some houses or to build up a profile out of data from different years in case part of the data could not be used.

From the available data, 3 yearly profiles could be created that matched the range of annual non-HVAC electricity consumption of the low electricity demand detached house (4813 kWh/y). For the average or medium electricity demand detached house (8156 kWh/y) 4 profiles could be found. Although several profiles were available in the range of the high electricity demand detached house (13011 kWh/y), none of these profiles was suited for use in the Annex due to the quality of the data available.

The characteristics of the measured profiles are shown in the following order (name file, annual non-HVAC electric load, data period). All the data in these files is **at 15 minute intervals**:

Low electricity demand profiles	(target: 4813 kWh/y)	
can_meas_low_21_y1.fcl	4660 kWh/y	(Jan 01 – Dec 31, 1994)
can_meas_low_21_y2.fcl	4750 kWh/y	(Jan 01 – Dec 31, 1995)
can_meas_low_40_y1.fcl	5223 kWh/y	(Jan 01 - Jul 31, 1995 + Aug 01 – Dec 31, 1994)

Medium electricity demand profiles	(target: 8156 kWh/y)	
can_meas_med_30_y1.fcl	8265 kWh/y	(Jan 01 – Feb 28, 1996 + Mar 01 – Dec 31, 1994)
can_meas_med_30_y2.fcl	8426 kWh/y	(Jan 01 – Dec 31, 1995)
can_meas_med_45_y1.fcl	7425 kWh/y	(Jan 01 – Feb 28, 1996 + Mar 01 – Dec 31, 1994)
can_meas_med_45_y2.fcl	7713 kWh/y	(Jan 01 – Dec 31, 1995)

High electricity demand profiles (target: 13011 kWh/y)

No suitable profiles were available.

The measured profiles are provided on the CD that comes with this report. The file Can-Elec-Load-Profiles.zip also contains the files for the measured profiles in .fcl format (for direct use in ESP-r). A readme file explaining the specific format of the files is included. The profiles are also provided in an EXCEL file, which can be extracted from the file Canadian_Measured_Elec_Load_Profiles.zip.

[26] Millette, Jocelyn, Hydro-Québec, Personal Communications. (2006).

All the measured profiles start at January 1st and end at December 31st. As the profiles are measured, they do display weekday / weekend day variation. However, some profiles have been made by using data from measurement periods from different years. For these profiles a discontinuity in the weekday/weekend day pattern is observed between the two parts of the profile.

9 Effect of different recording time intervals on the data profiles

During the Annex work, and in particular the UK monitoring programme, some power consumption data was obtained at 1 minute as well as 5 minute intervals. Figure 42 shows these two sets of data plotted over an example day.

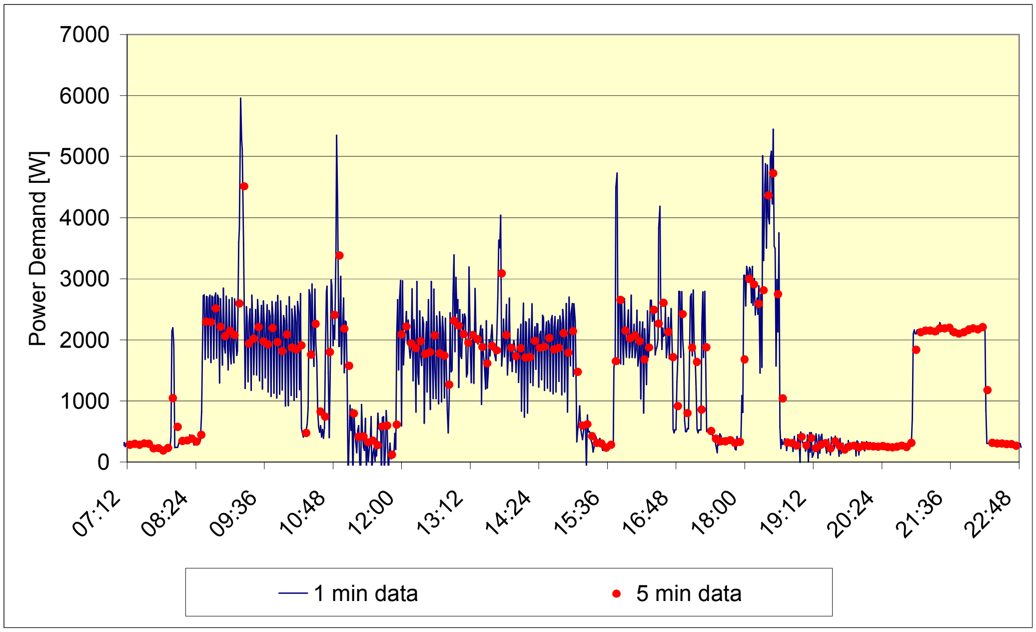

Figure 42 – Comparison of data values recorded at 1-minute and 5 minute intervals

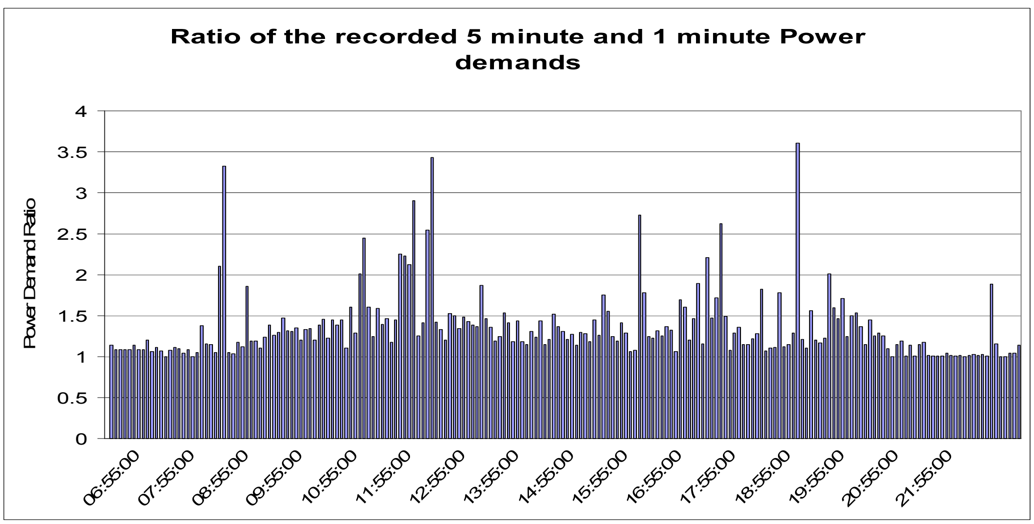

Figure 43 – Ratio in peak demands between 1-minute and 5-minute recording intervals.

Figure 43 shows the ratio in the peak demands found between these two sets of data in any one 5 minute interval, i.e. it is the peak 1 minute demand divided by the 5 minute demand in that 5 minute interval. This ratio is plotted at 5 minute intervals.

It can be seen that the peak 1 minute loads are up to 3.5 times the 5 minute average. This finding is supported by the NZ HEEP study[27] as well, which shows 1 minute values of up to 2

[27] BRANZ. Energy Use in New Zealand Households - Report on the Year Three Analysis for the Household Energy End-Use Project (HEEP). Energy Efficiency and Conservation Authority. 1999. ISBN 0-477-01894-7

times the 5 minute average, and the US Hathaway House data[28] which shows 1 minute peaks up to 4.5 times the 5 minute average.

10 Short-term high frequency electrical consumption data

Part of the wish-list for the Annex was to obtain some energy consumption data recorded in the order of seconds, to enable the more accurate modelling of the effects of transients and control issues on the performance of the cogeneration systems assessed.

There was only one set of data obtained in the order of seconds and that was provided by the National Fuel Cell Research Center (NFCRC), University of California, Irvine. This data was recorded at 3 second intervals on the incoming feed to the house, and covers a period from the 4th to the 14th February 2005.

The data comes from a six person single family residence in Irvine Ca. The predominant electric loads consist of stove and oven, microwave, two refrigerators, coffee maker, televison, lighting, and other small power loads. There was no air conditioning load. Data was recorded on a 3 second interval using Dent Elite Pro data loggers. Voltage and current measurements were applied to both legs of a split single phase grid feed to the home and the data represents the sum of the two legs (i.e., total power). The data may capture a Superbowl party!

The description of the data is too vague to allow any very detailed analyses, but will allow the effect of real transient switching behaviour on the performance of cogeneration systems and their subsystems to be modelled.

The data is provided on the accompanying disk as "**IEA 3 Second Daily Demand 2_4_05 to 2_14_05.zip**".

11 Overall comparison of Canadian and European Datasets

It is important to underline the different approaches taken for the European and Canadian profiles. The former are derived from data measured mainly in flats and townhouses while the latter have been obtained from modelling based mainly on data from detached housing. The derivation methods should be borne in mind when deciding on the applicability of the profiles to a particular end use. In particular, end users should ensure they are familiar with the assumptions made in the derivation of the profiles, and hence their potential limitations.

With the above in mind, the main observations to be drawn from the European and Canadian Datasets are:

- The general shapes of the daily profiles are very similar, with a morning peak and reduction in the middle of the day, followed by a larger evening peak
- The overall annual consumption of the low energy Canadian house described in the Canadian data set is about 1.5 times that of the average European house in the European data set, and the average Canadian house consumes over 2.5 times the annual use of the average European house. These observations should be read in the context of the different housing stocks from which the data are drawn. The European data are primarily from smaller area apartments and townhouses whereas the Canadian data are mainly drawn from detached housing, which it is assumed would have a larger floor area.

[28] Personal correspondence.

Other observations can also be made, but these serve to illustrate why two different profiles were required to assess the sizing of cogeneration systems in the two different markets.

12 Domestic Hot Water (DHW) Consumption Profiles

As well as representative Domestic non-HVAC Electrical Consumption Profiles, the Annex requires representative Domestic Hot Water (DHW) profiles to enable the overall economic, carbon and energy performance of residential cogeneration systems to be assessed through modelling.

The Annex however was unable to source many DHW profiles, and did not have a sufficient number to start proposing its own representative consumption profiles. However, in this task there was already a DHW model available from IEA SHC Task 26 that might be considered for use, and which provided the ability to model the DHW loads at intervals as frequently as 1 minute.

The approach taken in this section of the report was therefore as follows:

- To assess and compare the monitored DHW profiles available to the Annex in terms of annual consumption, profile and magnitude by country.
- To assess and compare these profiles with available DHW models in order to provide confidence in the model(s) to be used.
- To obtain other DHW data available to increase confidence in the models used.

12.1 DHW consumptions and profiles by country

Table 1 is reproduced below showing the numbers of DHW profile datasets provided to the Annex by country.

Table 1 - Domestic Hot Water (DHW) and non-HVAC Electricity Consumption Data Sets provided and used in this Subtask

	DHW		Non-HVAC	Electricity
Country	No. of Profiles (used in the analysis)	Monitoring interval [min]	No. of Profiles (used in the analysis)	Monitoring interval [min]
Canada	12 (10)	5 and 60	85 (57)	5, 15* and 60
USA	4 (2)	1,5 and 60	9 (1)	1,5 and 60
Switzerland	1 (1)	60	NA	NA
Finland	6 (6)	60	6 (6)	60
Belgium	2 (0)	15	2 (0)	15
UK	5	60	69 (69)	5
Germany	1	60	1	15
Portugal	NA	NA	1	10
EU	3 (1)	60	NA	NA

* Only the 15 minute data was used in the profiles produced for this Annex

Table 18 shows the daily DHW consumptions for a few countries in terms of the consumption per dwelling per day and consumption per person per day. It can be seen that DHW consumption ranges between 100 and 300 l/day per household, and between 20 to 94 l/day per person.

This table also contains information from a draft report by VHK[29] which reviews the EU standards for DHW water heaters by country.

It appears that again there is a split between the Canadian and European data, with the Canadians consuming approximately twice as much DHW per day as the Europeans. If we just use published data for comparison then the USA also consumes as much water per day as the Canadians.

Table 18 – Daily DHW consumptions per household and occupant by country

Country	Daily DHW Consumption per Household [l/day]	Daily DHW Consumption per Occupant [l/Occupant.day]	Source
Canada	236 (303)	(94)	NREL Report
USA	250 (202) 243 (at a 42.8°C rise)	(40)	NREL Report USA water heater standard
Switzerland	NA	(55 at a 50°C rise) (range from 24 to 74)	RAVEL (CH) (20 Buildings)
Finland	(135)	(43)	VVT (6 Houses)
UK	117 (102) 116 (at a 45°C rise for a 100 m^2 dwelling)	39 (20)	Yao, 2004 UK water heater standard
Germany	NA	(64)	FFE
France	1.74 per m^2 (at a 30°C rise)	NA	France water heater standard
Spain	NA	30 (at 60°C)	Spain water heater standard
Portugal	100 (at a 45°C rise) (apartments)	40	Portugal water heater standard

The figures in brackets are derived from the data provided to the Annex as shown in Table 1, other figures are derived from the published literature in this area.

The table indicates that for an average 45°C rise in DHW temperature, European countries would generally consume around 100 to 120 litres/day for a dwelling with a 100 m^2 floor area. Reported Canadian and USA consumption is around twice this at about 200 to 250 litres/day, but the dwelling areas are not known.

[29] Kemna R, van Elburg M, Li W, van Holsteijn R – Preparatory Study on Eco-design of Water Heaters. Task 1 Report (DRAFT). Definition, Test Standards, Current Legislation and Measures. VHK, Delft, December 2006

The following profiles represent the data provided to Annex 42 by various countries. The data generally has very little information with it other than that already shown in Table 1, i.e we have little or no information on occupancy numbers, how the data was obtained, date of data collection, etc. This data has also come in various forms so **please note the units on the Y-axis for each graph before attempting comparisons**.

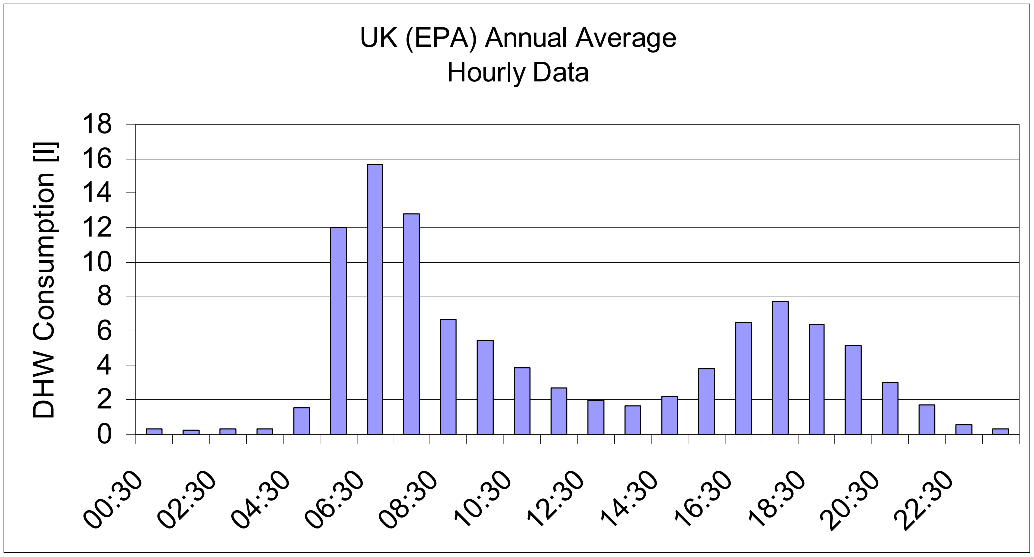

Figure 44 – Average Daily DHW Consumption for the UK in litres per hour.

This profile was obtained from the Welsh School of Architecture's Energy Performance Assessment measurements in the 1990's, and perhaps does not accurately reflect the current magnitude of usage within the UK. It reveals that on average the major DHW demand in the UK occurs in 2 peaks during the day – an early morning peak presumably coinciding with the morning shower or bath, and a smaller evening peak coinciding with the evening meal and possibly children's bath time it appears.

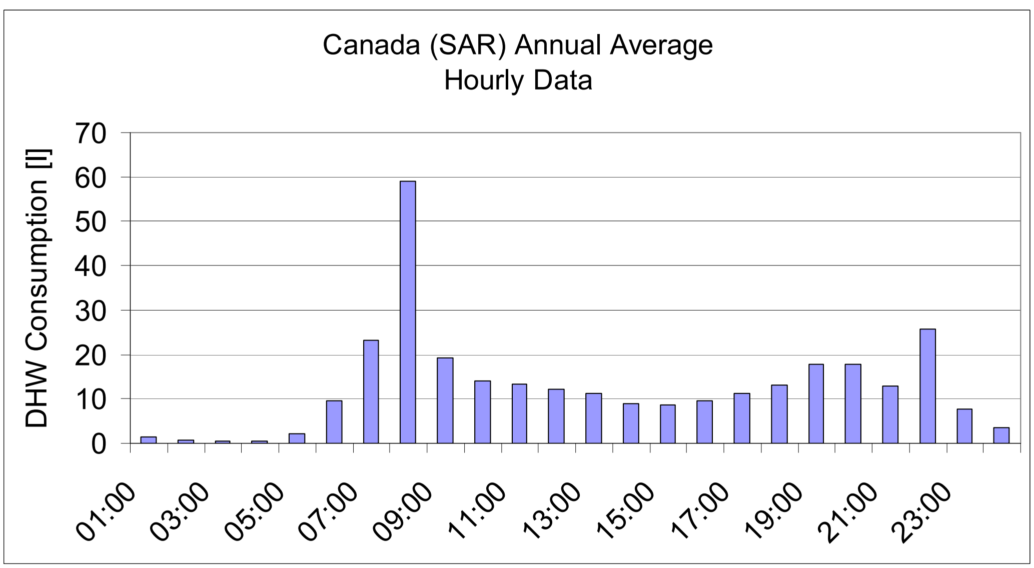

Figure 45 - Average Daily DHW Consumption for Canada in litres per hour.

This profile from SAR Engineering Ltd, Canada reveals a very similar shape to the UK except that there is a very pronounced morning draw-off possibly caused by either greater numbers of showers in the morning, or more use of the bath rather than the shower perhaps. In Canada clothes washers and dish washers are generally fed with hot water, in contrast to the situation in a lot of European countries. The morning high peak may also include the water draw of one of these appliances.

There also appear to be two evening peaks, the timing of which also suggest an earlier bathing slot possibly for children, and also a second peak indicating adult showering or bathing.

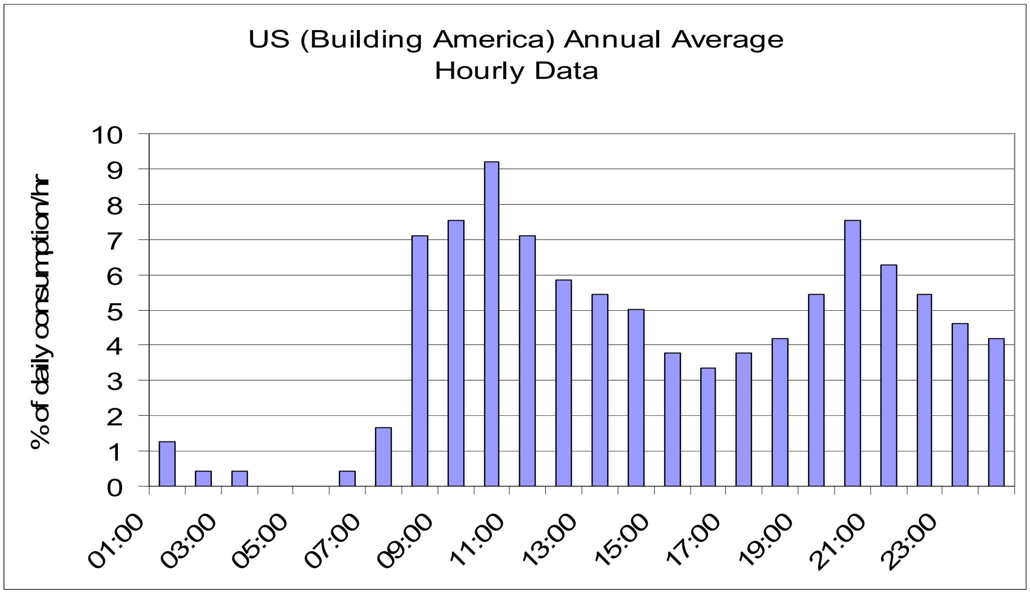

Figure 46 - Average Daily DHW Profile for the US Building America programme. Profile is in terms of % of daily consumption per hour.

This profile has been taken from the Building America programme and shows only when the greatest hourly daily demand is likely to occur - not the magnitude of this demand. The demand profile is very similar to the previous two profiles, except in the timing of the peaks with the morning peak unusually occurring at 11:00.

From the average daily demand for the USA shown in Table 18 we could use this profile to estimate the actual consumption occurring at any particular hour e.g. the just over 9% of the daily demand peak occurring at 11:00 would be equivalent to around 23 litres per hour.

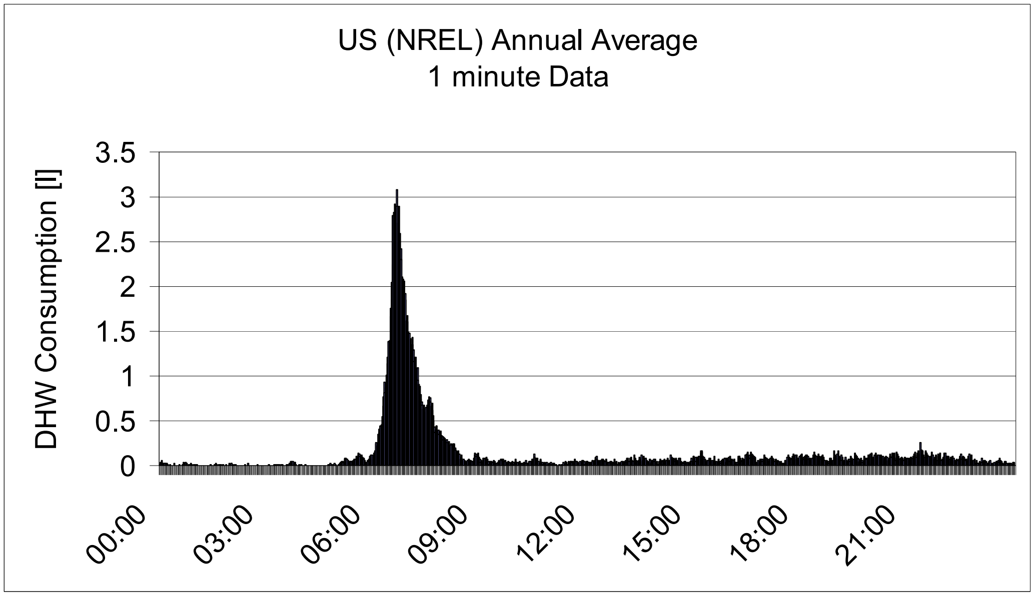

Figure 47 - Average Daily DHW Consumption for a US house in litres per minute.

This particular profile, taken from NREL's Hathaway House, is very interesting as it provides a snapshot of the average 1-minute DHW flow profiles from a particular house in the US. The magnitude of this flow peaks at an average of around 3 litres per minute or 180 litres per hour. It also shows no evening peak, implying that all the major DHW consumption occurs in the morning in this household.

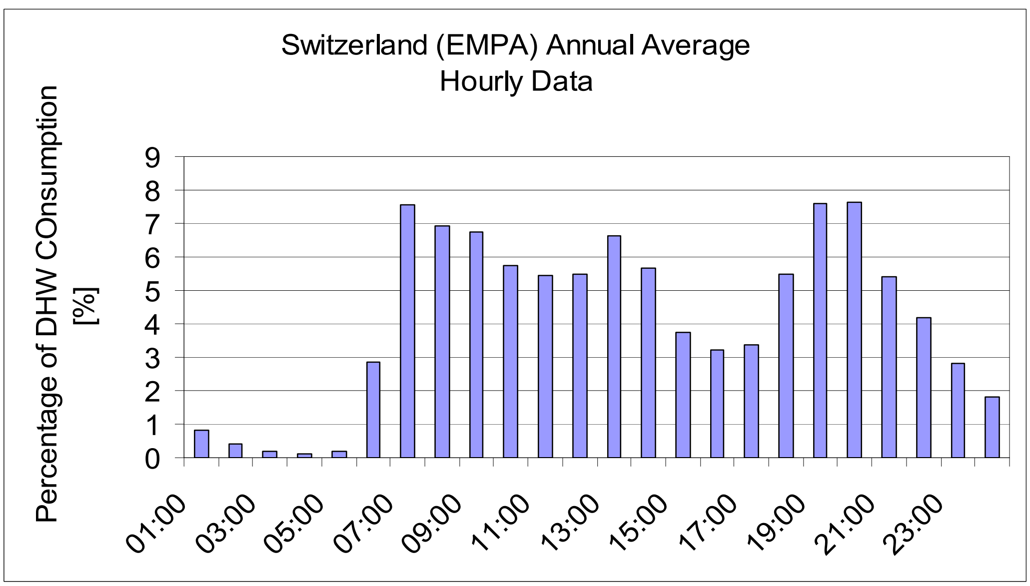

Figure 48 - Average Daily DHW Profile for Switzerland. Profile is in terms of % of daily consumption per hour.

The profile in Figure 48 was provided by EMPA from the RAVEL report[30] and again only shows when in the average day the demand occurs, not the magnitude of the demand. Table

[30] RAVEL Report: M. Blatter et al., "Materialien zu RAVEL - Warmwasserbedarfszahlen und Verbrauchscharakteristik", 1993, Bern

18 could be used to estimate a demand, but in this case the figure is provided in terms of DHW l/day per person so we would also need to how many people were in the house as well. At an average demand of 55 l/person per day then a 4 person household would expect to consume around 16.5 litres per hour on average at 07:00.

The shape however also shows a morning and evening peak, but this time also a midday peak, presumably associated with food preparation and cleaning.

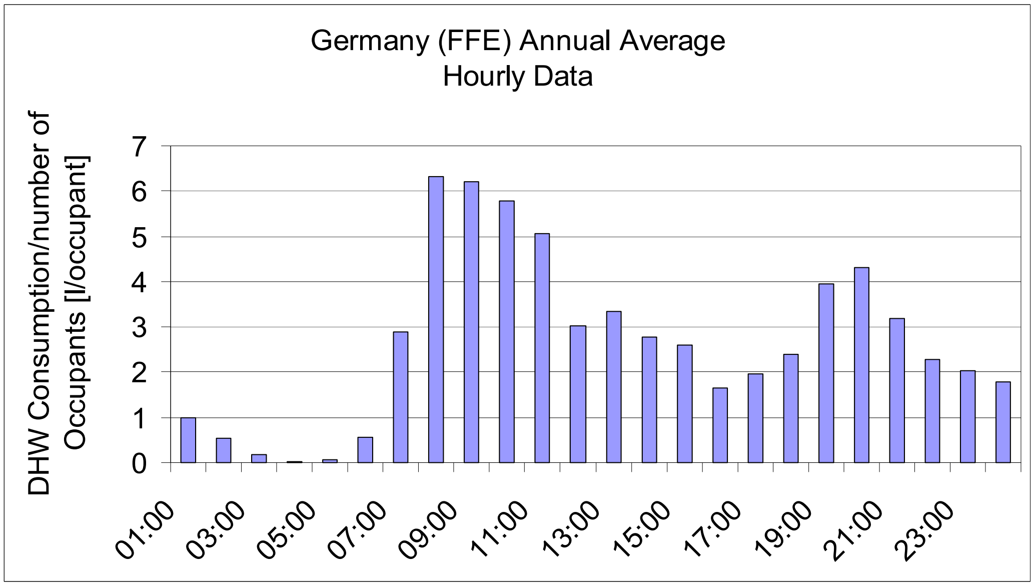

Figure 49 - Average Daily DHW Profile for Germany. Profile is in terms of litres per occupant per hour.

This profile was supplied by the Research Institute for the Energy Economy (FfE), Munich. It shows that peak demand occurs in the morning – though slightly later than in most countries, with a lower evening peak. A four person household would on average have a peak demand of around 25 litres per hour at 08:00.

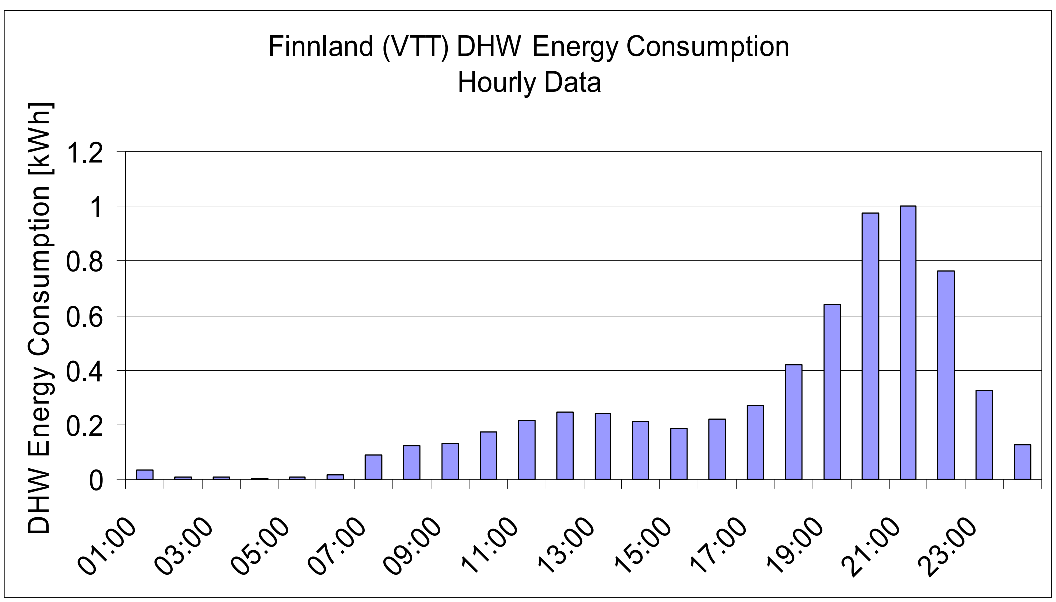

Figure 50 – DHW Energy consumption in Finland.

This profile is different from all the previous profiles in that it shows the energy consumed by the DHW system at different times of the day. We know nothing more of this data, we are not even sure whether the DHW is provided via the District Heating System or individually in each household. The actual DHW consumption may therefore differ from this profile, though it would be unlikely that this is the case, as it would require a very large, well-insulated thermal store to provide this sort of profile.

It is more likely therefore that cultural behaviour in Finland means that most showering or bathing occurs in the evening. This profile is therefore the most markedly different from all the previous profiles.

12.1.1 Comparison of the DHW profiles provided to Annex 42

Figure 51 plots all the previous figures on a single graph by converting them all to a % of daily DHW consumption by hour. It also shows the average profile drawn from all the data given. This average profile clearly shows the morning and evening peaks seen in most of the data.

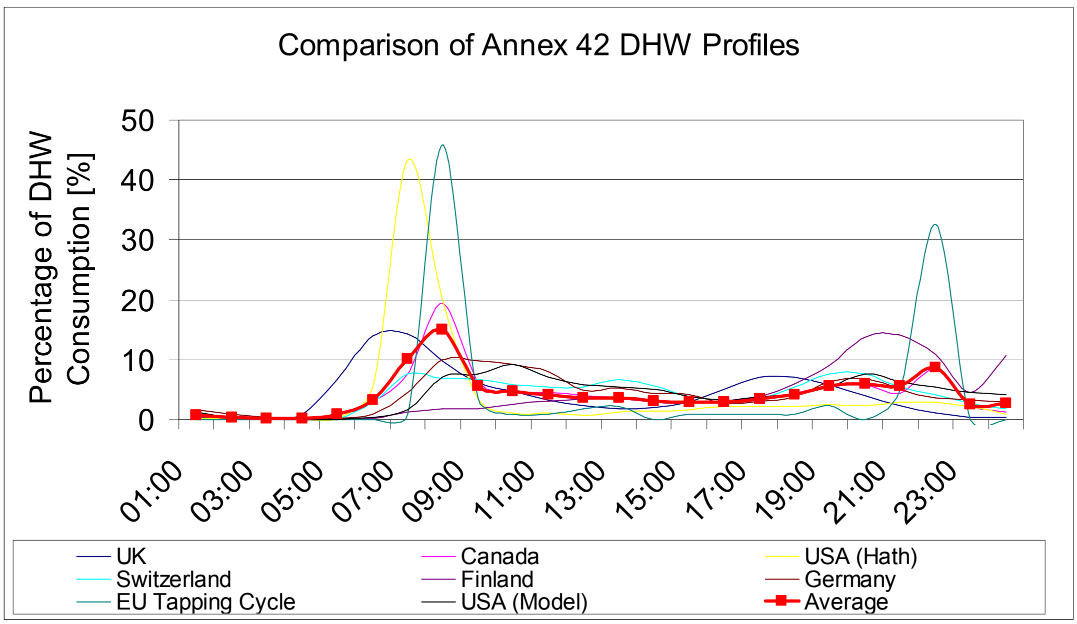

Figure 51 – Comparison of DHW Profiles supplied to Annex 42 – loads given as a percentage of daily consumption per hour.

12.2 The IEA Solar Heating and Cooling Programme Task 26 DHW model

This model is fully described in the IEA SHC Task 26 webpage[31] so will not be described in detail here. The main features of this model are:

- It uses a probability based approach with limited monitored DHW consumption data to inform its shape and magnitude
- An ability to model residential DHW demand at 1, 6 and 60 minute intervals
- 1 year of data can be derived from the model
- Daily DHW consumption in 100 litre steps can be generated by superimposition

[31] http://www.iea-shc.org/task26/

- Resolution is 0.2l/min
- Based on DHW monitoring in Germany and Switzerland
- Includes DHW consumption for washing machines and dishwashers
- Consideration of day of the week, season and holidays

We have used this programme to produce a set of standard DHW profiles at 1, 5 and 15 minute timesteps and 100, 200 and 300 litres/day consumption for the Annex. The derivation of these profiles was undertaken firstly by deriving annual 1-minute data for the 3 daily DHW consumptions (100, 200 and 300 litres/day) at 45°C using the SHC Task 26 model. The 1-minute data was then aggregated into the 5 and 15 minute data profiles to ensure that the quantities consumed were consistent over these different time intervals, as we did not wish to introduce a further uncertainty into the comparison of the results from the cogeneration system modelling to be undertaken by the Annex 42 team.

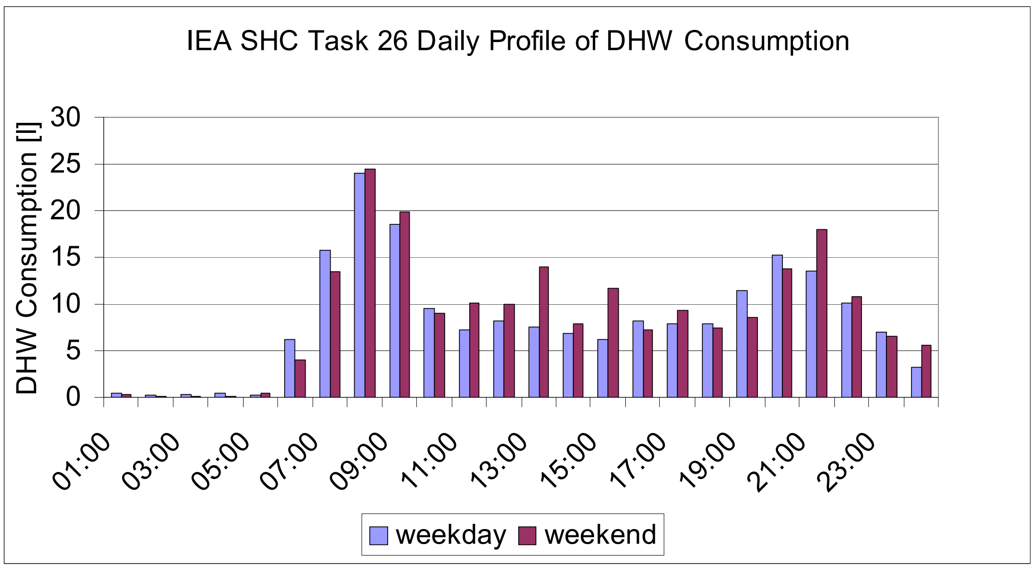

Figure 52 – Average Daily hourly consumption profile for a 200 l/day household as predicted by the SHC Task 26 model

Figure 52 shows the AVERAGE weekday and weekend DHW hourly consumption profiles predicted by the model for a household consuming 200l/day of water at 45°C. The morning and evening peaks seen in the Task 26 data can also be seen in the output from this model. The model produces a different profile for each day of the year based on its probability principles.

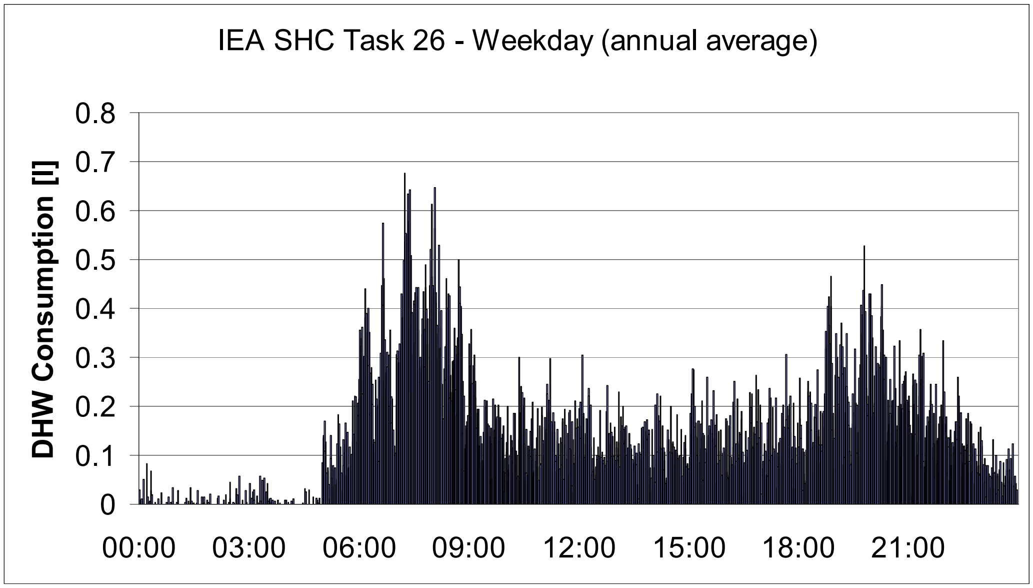

Figure 53 - Average Daily weekday consumption profile for a 200 l/day household at 1 minute intervals as predicted by the SHC Task 26 model

Figure 53 shows the same data as in Figure 52 but using the 1 minute model profiles instead of 5 minute. Figure 54 shows the same data but for the weekend instead of the weekday. The purpose of showing these graphs is to show the difference in detail between the two timesteps that the model is capable of generating.

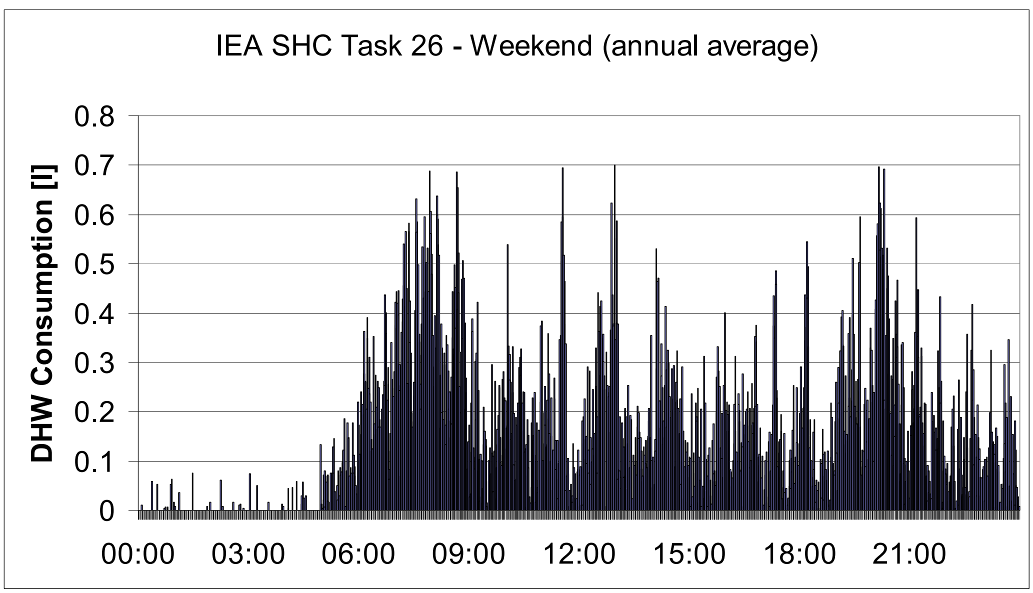

Figure 54 - Average Daily weekend consumption profile for a 200 l/day household at 1 minute intervals as predicted by the SHC Task 26 model

The most striking thing about the 1-minute modelled data is how realistic it appears, and its apparent similarities with the real data obtained for Annex 42 serves to underline the potential usefulness of the model to Annex 42.

12.2.1 Comparison of the Annex 42 DHW profiles with the SHC Task 26 DHW model

The final step in obtaining confidence in the applicability of the Task 26 model to the Annex 42 work is to compare the SHC Task 26 predicted DHW consumption data with the limited Annex 42 profiles obtained from the various countries.

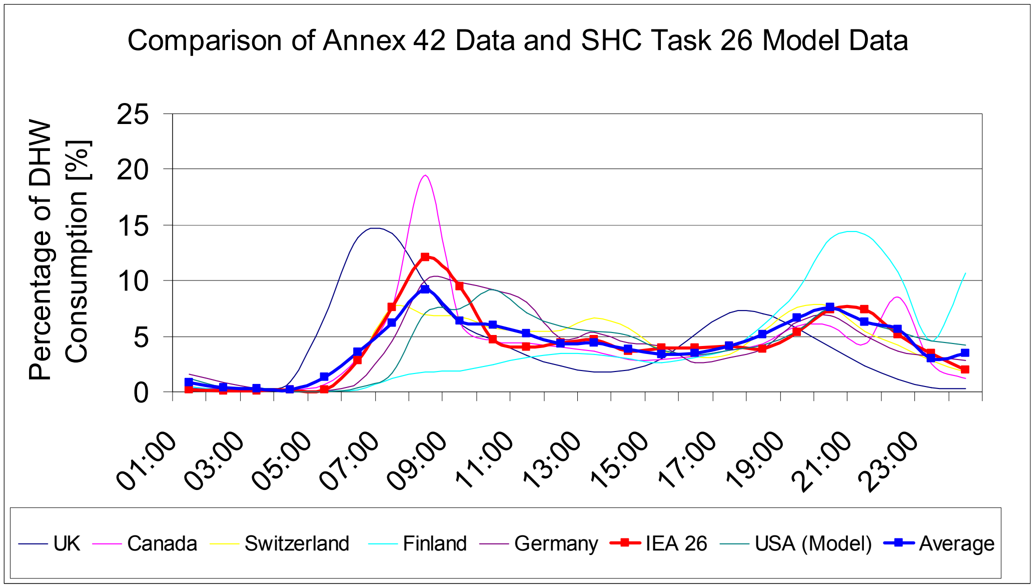

Figure 55 - Comparison of the Annex 42 DHW profiles with the SHC Task 26 DHW model profiles.

Figure 55 shows that the Task 26 predicted average daily DHW consumption profile and the Annex 42 average monitored daily DHW consumption profile are very close in their hourly profiles.

In the absence of any further profile data for this section of the work this match will be taken as providing sufficient confidence in the Task 26 model to enable it to be used to generate 5 minute profiles for use in the Annex 42 work.

12.2.2 The magnitude of the DHW consumption profiles to be used in the Annex 42 work

The last issue to discuss is how to decide what magnitude of DHW consumption should be used in the Annex 42 modelling work. It is the authors suggestion that in single family houses that an average figure of 100 – 120 litres/day at a 45°C temperature rise from the cold feed inlet be used for European countries (as noted in the EU tapping cycles description document as being an average figure for European houses, and backed up by the data in this Annex and the VHK draft report), and 200 litres/day at the same temperature rise be used for North American single family houses.

As the SHC Task 26 model only produces figures for a 45°C DELIVERED water temperature, then on average each 100 litres from the model would correspond to about 70 litres of DHW drawn from a storage tank at 55 – 60°C.

The suggestion is therefore that the Annex 42 work uses the 200 litres/day modelled annual profiles for the European DHW profiles (corresponding to around 140 litres of water from the DHW storage tank) and the 300 litres/day modelled profile data for the Canadian DHW profiles (corresponding to around 210 litres of water from the DHW storage tank).

12.3 DHW consumption profiles for use in the Annex 42 work

The DHW consumption profiles for use in the modelling undertaken in Annex 42 have been produced at 1 minute, 5 minute and 15 minute intervals.

The volume of DHW provided in the profiles assumes a supply temperature of 45°C and a cold feed water temperature of 10°C. If DHW water is stored and supplied at a different temperature in a particular situation to be modelled then the user should alter the volume of DHW provided in the profiles by using the following correction:

$$actual\_volume = \frac{35}{(stored\_water\_temperature - cold\_feed\_temperature)} x profile\_volume$$

This correction will need to be done on at least a monthly basis across the year.

The end user should also be aware that the probability nature of the Task 26 model means that the 1 minute, 6 minute and 60 minute profiles obtained from the model may not necessarily agree with each other when summed over short periods, but the overall annual consumptions should be roughly the same.

The files included with this work however DO agree with each other. In order to ensure standard profiles are used throughout the Annex 42 comparisons, the 5 minute and 15 minute profiles have been produced by simply aggregating the 1-minute profiles over the longer time intervals.

Other issues to be aware of in the supplied data are:

- It appears that the data starts on Monday 1st January - but this is not certain, as the SHC Task 26 model description does not specify the start day or date.
- The 300 l/day consumption has been obtained from superimposition of the 100 and 200 l/day profiles, which themselves were generated from probability functions.
- The SHC Task 26 model assumes a 10°C cold water feed temperature and a delivery temperature of 45°C, the temperature lift by the system from the DHW cold inlet feed temperature is therefore 35K.
- The profiles provided therefore assume a 35K rise in temperature. In reality most hot water draws are at 55- 60°C, not 45°C. Therefore LESS DHW will be supplied if the end user is assuming provision of DHW at 60°C. The correction of the volume of water profiles provided is shown above.

Table 19 – DHW consumption profile data files provided for Annex 42 work.

File Name	Daily Consumption [l]	Resolution [min]	NB
01DHW001.txt	100	1	Original File provided by Task 26
01DHW002.txt	200	1	Provided by Task 26
01DHW003.txt	300	1	Derived by using ***SUPERPON.EXE*** (superimposition of file 01DHW001.txt and file 01Dhw002.txt)
05DHW001.txt	100	5	Calculated by aggregation of profiles in 01DHW001.txt over 5 minutes
05DHW002.txt	200	5	Calculated by aggregation of profiles in 01Dhw002.txt over 5 minutes
05DHW003.txt	300	5	Calculated by aggregation of profiles in 01DHW003.txt over 5 minutes
06DHW001.txt	100	6	Provided by Task 26
06DHW002.txt	200	6	Provided by Task 26
06DHW003.txt	300	6	Derived by using ***SUPERPON.EXE*** (superimposition of file 06Dhw001.txt and file 06Dhw002.txt)
15DHW001.txt	100	15	Calculated by aggregation of profiles in 01DHW001.txt over 15 minutes
15DHW002.txt	200	15	Calculated by aggregation of profiles in 01Dhw002.txt over 15 minutes
15DHW003.txt	300	15	Calculated by aggregation of profiles in 01DHW003.txt over 15 minutes
60DHW001.txt	100	60	Provided by Task 26
60DHW002.txt	200	60	Provided by Task 26
60DHW003.txt	300	60	Derived by using ***SUPERPON.EXE*** (superimposition of file 60DHW001.txt and file 60DHW002.txt)

Table 19 shows the data files provided in the zip file "**DHW WSA Annex 42.zip**".

The Annex 42 1, 5 and 15 minute annual data files as noted in Table 19 are also provided in Excel format in the file "**Annex 42 DHW profiles - 1, 5 and 15 minute data by month FINAL.xls**".

13 Overall summary

This report has shown how standard non-HVAC domestic electrical consumption profiles and standard domestic hot water (DHW) consumption profiles have been produced for use in assessing the economic, carbon and energy performance of cogeneration systems in residential properties.

The report an the accompanying CD contain detailed daily electrical consumption datasets for Europe at 5 minute interval and for Canada generated profiles at 5 minute intervals and measured profiles at 15 minute intervals; and modelled daily DHW consumption at 1, 5, 6, 15 and 60 minute intervals.

14 Annex A – Electrical Energy and DHW consumption files contained on the accompanying CD

The files contained on the accompanying CD are shown in the following Tables.

14.1 European Electrical Energy Consumption Profiles

Table 20 - European Average Electrical Consumption Profiles

File Name	Period	Daily Consumption [kWh]	Month
wiwd.xls	Winter weekday	9.465	January
wiwe.xls	Winter weekend	9.804	January
sswd.xls	Shoulder season weekday	8.176	April and October
sswe.xls	Shoulder season weekend	8.483	April and October
suwd.xls	Summer weekday	7.754	July
suwe.xls	Summer weekend	7.912	July

The six standard profiles provided and shown in Table 20 represent a monthly average of the 69 households at various times of the year, i.e. for each 5 minute timestep in the month indicated the average load across all 69 households is provided until the average 24 hour profile has been obtained for both the weekday and weekend situation. The **time resolution is 5 minutes** and the unit is Watts (W).

A full year's profile of this data has been provided on the CD as **standard annual average electric energy consumption FINAL.xls** based on the Year 2003.

All of these files are contained within the zip file "**European Electrical Standard Profiles – Annex 42 September 2006.zip**"

Table 21 - European Specific Electrical Consumption Profiles

File Name	Annual Consumption [kWh]	Location	Year	Size of dwelling [m²]	Occupancy type
Actual low electric energy consumption FINAL.xls	1155	Newcastle	2005	65	Single male
actual medium electric energy consumption FINAL.xls	3028	Newcastle	2005	65	Mother and two children
actual high electric energy consumption FINAL.xls	8387	Llanelli	2003	108	Mother and 5 children

Table 21 shows the second set of European profiles provided. These represent the **ACTUAL** recorded domestic electrical energy consumption profiles of 3 different properties over a year.

These three dwellings are those considered to be most representative of low, medium and high electric energy consumption amongst the sample of buildings monitored (see Figure 25 through to Figure 27). The profiles presented are the average power consumption over a 5 minute time interval in two flats in Newcastle (England) and one town house in Llanelli (Wales). These profiles are presented as being the best current option to represent 'standard' European domestic profiles based on the data available to the Annex.

The data presented are complete annual files. As with most monitoring projects there is some missing data. Missing data points are replaced by data points assumed to have the same characteristic (e.g. a missing Monday has been replaced by another existing Monday). This replaced data is marked in the file by a yellow cell. The files have a time and a day tag (day tag: 1=Monday, 2=Tuesday…..).

The unit of the energy consumption data is Watts (W) and the data starts on the first of each month on each sheet. Table 21 provides more detail on each of the properties. The data for all the properties is contained in the file "**European Electrical Specific Profiles – Annex 42 September 2006.zip**". These three specific profiles do not include any electrically heated DHW.

14.2 Canadian Electrical Energy Consumption Profiles

14.2.1 Average Consumption Profiles

The nine profiles generated from the Canadian model are available on the CD in individual files. The characteristics of the generated profiles are shown in the following order (name file, annual non-HVAC electric load). All the data in these files is **at 5 minute intervals** and the layout is specifically for use in the ESP-r programme:

Low electricity demand profiles	(target: 4813 kWh/y)
can_gen_low_y1.fcl	4762 kWh/y
can_gen_low_y2.fcl	4672 kWh/y
can_gen_low_y3.fcl	4837 kWh/y
Medium electricity demand profiles	(target: 8156 kWh/y)
can_gen_med_y1.fcl	8159 kWh/y
can_gen_med_y2.fcl	8218 kWh/y
can_gen_med_y3.fcl	8112 kWh/y
High electricity demand profiles	(target: 13011 kWh/y)
can_gen_high_y1.fcl	12956 kWh/y
can_gen_high_y2.fcl	13140 kWh/y
can_gen_high_y3.fcl	13044 kWh/y

The file Can-Elec-Load-Profiles.zip contains the files in .fcl format (for direct use in ESP-r). A readme file explaining the specific format of the files is included. **The profiles are also provided in the more general EXCEL file format**, which can be extracted from the files

Canadian Electrical Profiles_Excel Format_low.zip, Canadian Electrical Profiles_Excel Format_avg.zip and Canadian Electrical Profiles_Excel Format_high.zip

The generated profiles have been generated with the same inputs for all days of the year, so the profiles do not have any differentiation between weekdays and weekend days.

14.2.2 Measured Specific Consumption Profiles

From the Hydro Quebec data, 3 annual profiles could be created that matched the range of annual non-HVAC electricity consumption of the low electricity demand detached house (4813 kWh/y). For the average or medium electricity demand detached house (8156 kWh/y) 4 annual profiles could be found. There were no suitable non-HVAC profiles available in the range of the high electricity demand detached house (13011 kWh/y).

The characteristics of the measured profiles are shown in the following order (name file, annual non-HVAC electric load, data period). All the data in these files is **at 15 minute intervals** and the layout is again specifically for use in the ESP-r programme:

Low electricity demand profiles	(target: 4813 kWh/y)	
can_meas_low_21_y1.fcl	4660 kWh/y	(Jan 01 – Dec 31, 1994)
can_meas_low_21_y2.fcl	4750 kWh/y	(Jan 01 – Dec 31, 1995)
can_meas_low_40_y1.fcl	5223 kWh/y	(Jan 01 - Jul 31, 1995 + Aug 01 – Dec 31, 1994)

Medium electricity demand profiles	(target: 8156 kWh/y)	
can_meas_med_30_y1.fcl	8265 kWh/y	(Jan 01 – Feb 28, 1996 + Mar 01 – Dec 31, 1994)
can_meas_med_30_y2.fcl	8426 kWh/y	(Jan 01 – Dec 31, 1995)
can_meas_med_45_y1.fcl	7425 kWh/y	(Jan 01 – Feb 28, 1996 + Mar 01 – Dec 31, 1994)
can_meas_med_45_y2.fcl	7713 kWh/y	(Jan 01 – Dec 31, 1995)

High electricity demand profiles (target: 13011 kWh/y)

No suitable profiles were available.

The file Can-Elec-Load-Profiles.zip contains the files for the measured profiles in .fcl format (for direct use in ESP-r). A readme file explaining the specific format of the files is included. **The profiles are also provided in the EXCEL file format**, which can be extracted from the file Canadian_Measured_Elec_Load_Profiles.zip.

14.3 Short-term high frequency electrical consumption data

There was only one set of data obtained in the order of seconds and that was provided by the National Fuel Cell Research Center (NFCRC), University of California, Irvine. This data was recorded at 3 second intervals on the incoming feed to the house, and covers a period from the 4th to the 14th February 2005.

The data comes from a six person single family residence in Irvine Ca. The predominant electric loads consist of stove and oven, microwave, two refrigerators, coffee maker, televison, lighting, and other small power loads. There was no air conditioning load. Data was recorded on a 3 second interval using Dent Elite Pro data loggers. Voltage and current measurements were applied to both legs of a split single phase grid feed to the home and the data represents the sum of the two legs (i.e., total power). The data may capture a Superbowl party!

The description of the data is too vague to allow any very detailed analyses, but will allow the effect of real transient switching behaviour on the performance of cogeneration systems and their subsystems to be modelled.

The data is provided on the accompanying disk as "**IEA 3 Second Daily Demand 2_4_05 to 2_14_05.zip**".

14.4 DHW Consumption Profiles

The DHW consumption profiles for use in the modelling undertaken in Annex 42 have been produced at 1 minute, 5 minute and 15 minute intervals.

The volume of DHW provided in the profiles assumes a supply temperature of 45°C and a cold feed water temperature of 10°C. If DHW water is stored and supplied at a different temperature in a particular situation to be modelled then the user should alter the volume of DHW provided in the profiles by using the following correction:

$$actual\_volume = \frac{35}{(stored\_water\_temperature - cold\_feed\_temperature)} xprofile\_volume$$

The end user should also be aware that the probability nature of the SHC Task 26 model means that the 1 minute, 6 minute and 60 minute profiles obtained from the model may not necessarily agree with each other when summed over short periods, but the overall annual consumptions should be roughly the same.

The files included with this work however DO agree with each other. In order to ensure standard profiles are used throughout the Annex 42 comparisons, the 5 minute and 15 minute profiles have been produced by simply aggregating the 1-minute profiles over the longer time intervals.

Other issues to be aware of in the supplied data are:

- It appears that the data starts on Monday 1st January - but this is not certain, as the SHC Task 26 model description does not specify the start day or date.
- The 300 l/day consumption has been obtained from superimposition of the 100 and 200 l/day profiles, which themselves were generated from probability functions.
- The SHC Task 26 model assumes a 10°C cold water feed temperature and a delivery temperature of 45°C, the temperature lift by the system from the DHW cold inlet feed temperature is therefore 35K.
- The profiles provided therefore assume a 35K rise in temperature. In reality most hot water draws are at 55- 60°C, not 45°C. Therefore LESS DHW will be supplied if the end user is assuming provision of DHW at 60°C. The correction of the volume of water profiles provided is shown above.

Table 22 – DHW consumption profile data files provided for Annex 42 work.

File Name	Daily Consumption [l]	Resolution [min]	NB
01DHW001.txt	100	1	Original File provided by Task 26
01DHW002.txt	200	1	Provided by Task 26
01DHW003.txt	300	1	Derived by using ***SUPERPON.EXE*** (superimposition of file 01DHW001.txt and file 01Dhw002.txt)
05DHW001.txt	100	5	Calculated by aggregation of profiles in 01DHW001.txt over 5 minutes
05DHW002.txt	200	5	Calculated by aggregation of profiles in 01Dhw002.txt over 5 minutes
05DHW003.txt	300	5	Calculated by aggregation of profiles in 01DHW003.txt over 5 minutes
06DHW001.txt	100	6	Provided by Task 26
06DHW002.txt	200	6	Provided by Task 26
06DHW003.txt	300	6	Derived by using ***SUPERPON.EXE*** (superimposition of file 06Dhw001.txt and file 06Dhw002.txt)
15DHW001.txt	100	15	Calculated by aggregation of profiles in 01DHW001.txt over 15 minutes
15DHW002.txt	200	15	Calculated by aggregation of profiles in 01Dhw002.txt over 15 minutes
15DHW003.txt	300	15	Calculated by aggregation of profiles in 01DHW003.txt over 15 minutes
60DHW001.txt	100	60	Provided by Task 26
60DHW002.txt	200	60	Provided by Task 26
60DHW003.txt	300	60	Derived by using ***SUPERPON.EXE*** (superimposition of file 60DHW001.txt and file 60DHW002.txt)

Table 22 shows the data files provided in the zip file "**DHW WSA Annex 42.zip**".

The Annex 42 1, 5 and 15 minute annual data files as noted in Table 22 are also provided in Excel format in the file "**Annex 42 DHW profiles - 1, 5 and 15 minute data by month FINAL.xls**".