The secrets of load profiles

Georg Benke, Franz Huemer

e7, Walcherstraße 11, 1020 Wien, 0676-789 2157,
georg.benke@e-sieben.at; www.e-sieben.at

Abstract: For years the electricity grid operators records the load profile every 15 minutes of customers, whose electricity consumption is over higher than 100,000 kWh/a or a power consumption higher than 50 kW (costumers with special contracts). These time series illustrate very well how the object´s demand structure looks like. By applying a standardized analysis tool based on MS Excel the load profile is evaluated economically and energy saving potential > 10% is reached. Usually it is not necessary to inspect the property directly. About 300 analyses have helped to create an extensive knowledge of electricity demand structures mainly in services buildings.

Keywords: Load profile, energy analysis, benchmarks, standardization, analytical tool, electricity

1 Starting Position

Whereas several significant achievements have been made in energy saving and efficiency of space heating during the last years, less improvement exist for electricity demand. Since the year 2000, in Austria the electricity demand has grown by 22.3%. Commercial buildings, especially hospitals are affected by this increase much stronger: During the last four to five years many hospitals have experienced an annual increase of three to four percent. In most cases neither the structure of usage nor the reasons for the increase are known.

How to analyses quickly a service building with an annual electricity consumption of less than 500.000 kWh/a to provide an economic evaluation of its demand structure and thus its potential for saving energy without investing a lot of effort, is a question that arises rapidly. Qualitative and valuable conclusions can be drawn from energy monitoring systems. Depending on the duration of measurement, excellent data can be provided. To offer these kinds of data not only (reasonable) investments are required but also time is needed - from the moment of authorization for the investment until the data is available.

Table 1: Tabular representation of a time series (Example secondary school in Salzburg)

TIme	Power
Date & time	[kW]
06.11.2012 05:15	3.2
06.11.2012 05:30	4.8
06.11.2012 05:45	4
06.11.2012 06:00	4.8
06.11.2012 06:15	5.6
06.11.2012 06:30	11.2
06.11.2012 06:45	14.4
06.11.2012 07:00	11.2
06.11.2012 07:15	12.8
06.11.2012 07:30	10.4
06.11.2012 07:45	15.2
06.11.2012 08:00	13.6
06.11.2012 08:15	11.2
06.11.2012 08:30	12

To conduct a qualitative analysis quickly, data of the overall consumption (data from the main electric meter of the utility) is sufficient if the user consumes less than 500 MWh. For years grid operators have recorded the electricity demand of costumers with energy consumptions higher than 100.000 kWh/a or the maximum power levels of over 50 kW. The average power consumption is determined every 15 minutes and recorded (data structure see table 1). On the day prior to the implementation of smart meters, most costumers and even energy consultants are not aware of the fact that records of the time data series on energy consumption already exist and that individual measuring is not always necessary.

For short termed applications consumption curves depicting the object´s overall demand in form of cardioids are available. Figure 1 shows the consumption curve of school during a period of 17 days.

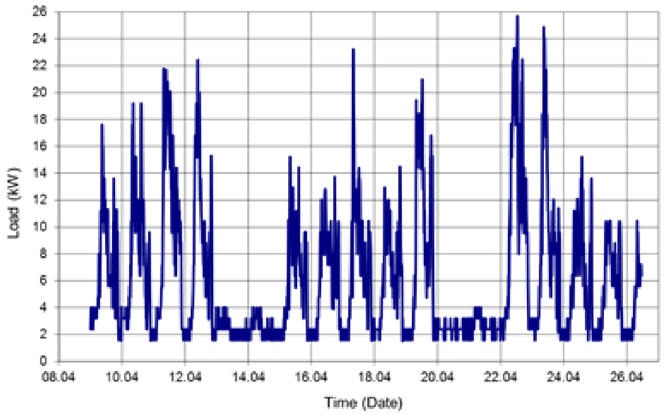

Figure 1: Graphic representation of a load profile (17 days in secondary school in Salzburg, Austria)

If requested electricity grid operators in Austria and also in many other EU Member States have to supply their clients with this data - at least once a year without charging a fee. Some electric utilities provide on line services where these data series are available given for small fees (ca.€ 7/month) daily. Mostly the dates are covering the time until the previous day. Normally the data is made available in Excel files.

35,000 individual records with time information are provided when ordered for the last twelve months. These records show how an object “behaves”. As a first step, this data can be combined with the outside temperature (average daytime temperature). In this way, comprehensive data for analysing are available. Recommendations for increasing energy efficiency can be derived through analysing. Experience from conducting 300 analyses has shown that these time series do not only result in excellent analyses for objects with a consumption lower than 500 MWh, but are also applicable for objects with higher consumption levels. The evaluation of a hospital with a consumption of over 11 GWh could demonstrate the management that there is the need for further monitoring the energy consumption.

2 Load Profile Analysis

e7 has developed a tool based on MS Excel for analysing load profiles in a standardized way. Thanks to the information provided in form of around 35 different figures and additional benchmarks, the consumption curve can be interpreted within short time. Which information provided by the graphic representations and individual records is used for interpretation, depends within the expertise of the observer. Of course the standardisation of data is very helpful, since it enables the expert to interpret all curves in an uniform way.

Even though the object´s inspection is not necessary, the conversation with the object´s operator of topics related to the analysis is crucial. Firstly, he or she knows the usage structure of the object better. Secondly, it shows whether the client´s expectations differ from the object operators´.

Thanks to the visual representation it will be easier to explain the situation to the object operator. Experiences made so far, have shown that this transparency evokes a high disposition to implement energy efficiency measures.

3 Evaluation

Excel is the most suitable tool for evaluating, since it is easy to handle and positive experiences have been made. The modification of additional enquiries is easier than using a separate web based tool.

The tool´s entire assets become visible after using it several times, since abnormalities are detected easier. By analysing and comparing several evaluations (standardisation) it easier to see if individual load profiles met the expectations and if some require more detailed monitoring.

A project to provide a web based solution has already been initiated.

3.1 Benchmarks

Following benchmarks are currently applied:

1. Specific consumption per reference parameter (m^2, beds, co-workers, ...). Four different reference parameters may freely be chosen, e.g. kWh/ m^2 a.
2. Specific base load: Specifies the power consumption (e.g. W/m^2) during night or on weekends. Food discount retailers no matter of which chain usually always show almost the same parameters (21 Watt/m^2). Offices usually have a specific base load of 6 Watt/m^2.
3. Base load consumption: Specifies how much of the annual electricity consumption is caused by the base load. This should not to be underestimated. In many discount shops this consumption has a share of approximately 52%, hospitals up to 78%.
4. Consumption of 4000 hours: Here the assumption is made that a commercial building (e.g. office) operated 4,000 hours a year. The percentage indicates the consumption which exceeds annual electricity consumption outside these 4,000 hours. Experiences have shown that offices surpass this by 30%. This means that 30% of an office´s electricity consumption occurs when nobody uses the building.
5. Peak load percentage: How high is the share of the peak load caused by the 25 hours with the highest power. This value indicates if there is a possibility the reduce the peak load and give information about the structure of the peak power is.

3.2 Figures

Around 35 different graphic representations help conducting a well-grounded analysis of the consumption within one to two days. Among other things following visualizations are used:

1. Arranged load profile: The power values are displayed in a 15 minute tact and in descending order by its size. This figure illustrates very well, how much energy the object is consuming outside the times where it is mainly used (Figure 2). To some extent conclusions regarding the use of the building can be drawn by interpreting the curves´ forms.

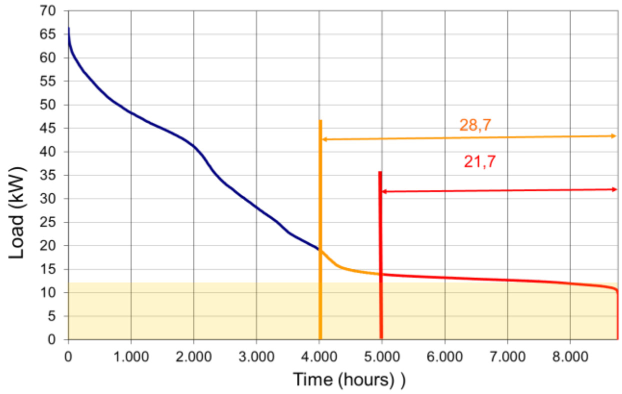

Figure 2: An administration building´s permanent base load. The area on the right side of the orange line displays the consumption (28.7%) made outside the operation hours (4.000 h) of the building.

Comparison between two seasonal load profiles depicting certain week days (

2. Figure 3 3).
   a. If the average of the same weekdays is applied three weeks in a row, the individual events are diluted and seasonal events are displayed in a clearer way. Thus, seasonal impacts such as heating, cooling and illumination, become more visible. For instance this approach helps displaying elevated consumption levels during night time caused by cooling or heating devices.

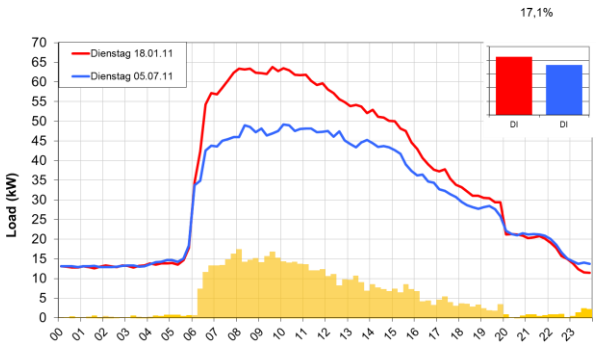

Figure 3: Comparison of two load profiles of an administration building during the day: Tuesday in January (January 18th) and July (July 5th). The consumption differs by 17.1% probably due to the illumination. The curves don´t depict any deviation during the night (circular pump????) but during the day it differs by almost 15 kW (illumination). The building starts operating at 05:45 AM. The maximum demand for electricity occurs from 08:00 AM to 12:00 AM.

3. Load profiles during holidays (no images). This figures shows how a building „behaves“, when e.g. an office building is not used during holidays and there is no

demand for energy. Experiences have shown that, despite this, building services are kept running. With this insight, operation hours of individual subsections might be determined.

4. Visualization of the weekly consumption´s average consumption and its procentual deviation (Figure 4). This graphic representation depicts seasonal dependencies in form of tangible magnitudes.

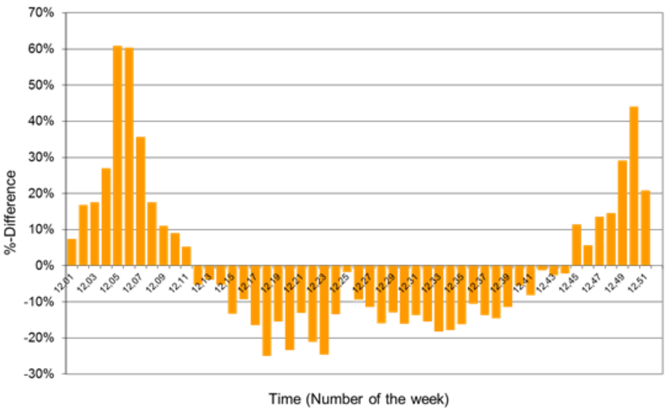

Figure 4: Percentage deviation from a car dealer´s consumption during certain weeks and her or his average consumption. This chart illustrates an additional demand, especially in winter (additional electrical heating device??)

5. Consumption during night time (f.e 10:00 PM to 04:00 AM)

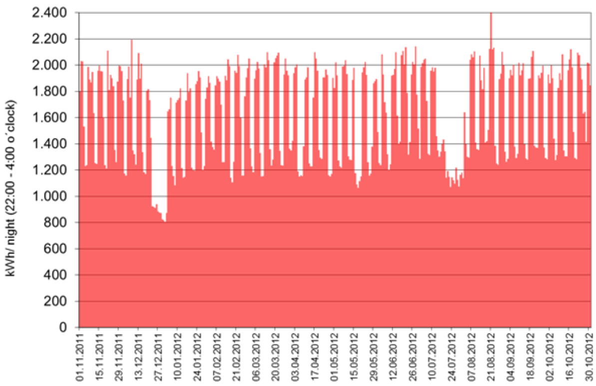

Figure 5: Electricity consumption of a production plant during nigh time (10:00 PM to 04:00 AM). It is clearly evident that the plant was not operating during Christmas and in summer, even though there is a consumption of over 800 kWh during the night. A slight increase of power is noted during the period of observation. The fact that the electricity consumption at night time during the weekends is lower, is not typical: As soon as the plant was informed that it consumes approx. 150 kW even on days where it is closed, comprehensive measures were taken. The main reason was the clean room, since it was operating fully even on holidays. By setting numerous small measures (particularly regarding the ventilation system´s regulation) 11.2% electricity is saved. The extent of additionally saved heat is unknown.

6. Comparison of individual days of a calendar week (without images). This illustrate whether individual weekdays possess a similar load profile and if every day has an individual demand structure.

7. Daily consumption and its connection to the average temperature during daytime. This figure depicts the daily consumption and its connection to the daily average

temperature. In particular cases it may be necessary to ignore holidays and weekends among other things in the visualization.

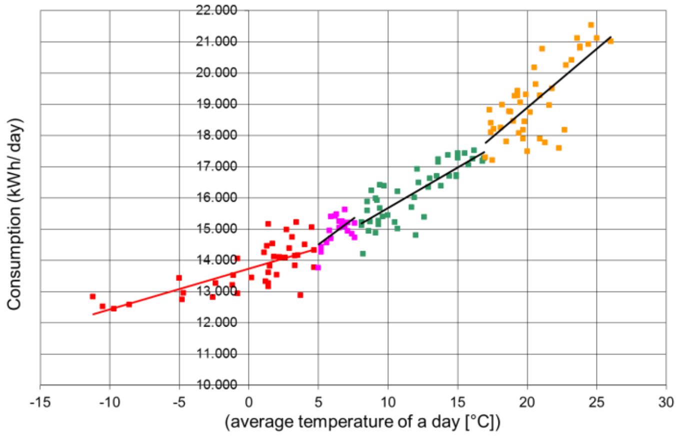

Figure 6: A wholesaler´s (comestibles) daily consumption and its connection to the average temperature during day time (°C). The graphic demonstrates that the electricity consumption depends on the outdoor temperature. It is assumed that the object was cooled by an air source heat pump.

8. Power consumption of certain weekdays at specific times (no images): This figure reveals if the power consumption (at e.g. 02:00 AM) of a specific period changes and if there is a specific date when power consumption has obviously grown.
9. The interconnection of the consumption of single weekdays (no images)
   a. This visualization illustrates if an object shows an elevated consumption during certain week days. This way, a nursing home´s washing day home as well as other things were detected. Even in offices such differences are detected, these deviations do not include Fridays where people usually leave work earlier.
10. Comparison of permanent base load curve depicting a short period (e.g. three weeks).

4 Previous Experiences with the Tool

Up to now, approx. 300 load profiles were analysed. The same approach was applied for every single analysis, extending the evaluation options multiple times due to the new insights the experiences brought new awareness with them. For example in the mean time the number of working days in an office building, in a school can be determined in a simple way.
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Following kinds of properties were already analysed:

Kinder gardens	Ice hockey stadia
Primary schools	Ski lifts
Secondary schools	Comestibles - retail
Vocational schools	Comestibles - wholesale
Government agencies and offices	Hardware stores
Nursing homes	Clothing markets
Hospitals	Hotels
Soccer stadia	

Different kinds of trades in manufacturing	Butchery, gravel mill, car dealer, lumber mill Gas stations

Counselling experience

The tools´ advantage is rather the improved graphic processing of the demand situation than the determination of the savings potential. The graphic visualization helps the user of the object to determine if the actual load profile meets her or his expectations. Usually an exact description of the situation is sufficient to stimulate measures. For instance pointing out the time of changes in the demand structure may be sufficient to initiate further proceedings.

4.1 Duration of analyse

Approx. 1.5 days are required for conducting a standardized analysis and producing a report encompassing 20 to 25 pages.

4.2 Savings Potential

Our experience has shown that a standardized analysis of the load profile causes a potential for saving energy of 10% without expecting the property directly. Do get a better understanding of the situation within the single building, sometimes we use web conferences to discuss the situation with the use.

Our experience has shown that the analysis is only an intermediate step towards final results. For instance, a consultant detected an energy saving potential of 8%, but the analytical report offered even more information for the property owner. This helped the object operator to implement measures saving 18% of the energy consumed.

To which extent these experiences of energy saving potentials are applicable to private households (smart meters) cannot be established.

4.3 Target Group

The analysis of load profiles is especially suitable for objects consuming less than 500 MWh. A comestible discount store consumes 250,000 kWh - an example to grasp the proportionality of these dimensions. Thus, a market segment difficult to counsel in questions of energy efficiency due to economic reasons is now much easier, especially for small consumers.

Even though the analysis was designed for small consumers, it is also applied to bigger consumers, e.g. 20 hospitals were analysed on their request (consumption up to 11 GWh). This mainly helped to create a sensibility for measures affecting the base load, but also successful energy saving measures have been proven several times.

4.4 Base Load

Generally the base load is very high. Here great potential for energy saving exists. In table 2 following ways of using an object and their corresponding basic consumption caused by the base load are presented:

Table 2 Common share of annual electricity consumption caused by the base load.

Use of the object	Percentage of the base load within the overall consumption	Comments
Hospitals	62-78%	Elevated value (78%) even though it is not an acute hospital!
Comestibles discount shop	52%	Same benchmark observed in different store chains
Governance agencies	48-70%	Elevated values due to cooling of IT-systems
Primary schools	25%	including holidays
Nursing homes	52-57%	
Hotels	62%	
Clothing markets	7%	Peak value (ignoring the cooling- and ventilation systems, since it comes from a central facility)

4.5 Composition of the demand structure

In some cases the demand structure and its part may be assigned to individual users by using the load profile. This requires even more experience. Currently, a research project is investigating top down (load profile) and bottom up approaches for the same 25 objects to improve the analysis method.

- Illumination: In the case of a comestible discount store not only the illumination´s power of connection was determined (23 W/m^2), but also the annual consumption. Whereas energy consultants receive 25% according to calculations of the actual load profile, there are still values up to 35% saved
- Cooling: Hospital with cooling requirements caused by outdoor temperatures form 7% of the entire annual consumption.
- Reasons for elevated base loads in the business sector are u.a. cash machines and anti-burglary protection devices.
- An underestimated problem might be electric water heating. This is partly due to the elevated requirements enforced by the drinking water ordinance (legionella).

5 Thermal analysis

In the meantime, several thermal load profiles were analysed, too. This was more demanding, since it was difficult to use the experience from the electricity load curves analyse. Therefore an individual analysis method was required differing strongly from the method used for electricity analysis.

We didn´t only manage to illustrate whether the control for the heater is set correctly, but also the percentage of warm water used for the heating and warm water. In the case of a hospital we demonstrated that 45% of the specific heat consumption (138 kWh/m^{2}a) is used for warm water and/or circulation of warm water