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6. MANAGEMENT OF POOL RESOURCES AND ENERGY CONSUMPTION IN BUILDIGNS

6.1. Pool Resources

The integration of energy resources in buildings must be analysed from two points of view or perspectives. Firstly, the quantification of needs and the dynamics of these needs must be known, making it possible to establish orders of magnitude, as well as types of technologies for the extraction, storage, and use of energy resources.

Secondly, the availability and viability of each energy resource must be analysed in terms of economic, logistical, or strategic parameters.

6.1.1. New Technologies and Real Integration

There is currently a great diversity of energy generation and accumulation systems aimed at the construction, comfort, and habitability of buildings. New applications and systems that take advantage of different available resources (sun, wind, biomass, hydrogen, geothermal energy, heat transfer, changes of state, etc.) are frequently appearing. A detailed study of their characteristics is the first step towards a correct choice of resources and their appropriate application to the needs of each building. In addition to the technical point of view, the economic viability and availability of resources is not a minor problem and must be carefully considered to avoid problems of unavailability or cost over the useful life of the installations (Fischer, 2016). This availability must include the different energy storage systems that will reduce the energy dependence of each building with the dynamics of markets and availability of resources.

6.1.2. Improved Energy Availability

The transport structures of the different energy resources (oil, gas, electricity, coal) have always been dependent on exoenergy factors that are more related to political structures, strategies, and market interests than to energy viability or optimization. The increase in the use of different renewable resources on a small scale has made it possible to go beyond the limits of the large resource distributors, establishing alternative energy supply procedures with less dependence on exoenergy factors. The cost of these installations, their suitability in each case, obsolescence, technological maturity, and state aid programmes for their implementation are parameters that ultimately determine the success or failure of different energy generation and use systems. It is essential at this point to remember that there is no standard solution in the field of buildings, as criteria of load, location, receivers, availability, time flexibility, building typology, state of conservation, etc. must be considered.

6.2. Load Curves

The first step in any energy analysis to define resources and strategies is to obtain load curves. This concept integrates all the energy demand data of a building, considering both the inputs dedicated to direct consumption and those dedicated to storage for later use. Electricity, Natural Gas, Coal, Water, Steam, Communications, as well as intermediate process elements (Hydrogen, refrigerant gas, thermal solids, etc.) (Ahmad, 2014). To these demand curves must be added the generation curves, both from direct usable energy generation systems and from systems that increase the stored energy resource.

6.2.1. Load Curve Model as Function of Location, Size or Other Requirements

The shape of the load curve depends mainly on whether it is a residential, commercial, industrial load, the day of the week, the season (winter, summer) and climatic factors (mainly temperature).

Analysing the different types of curves for different conditions provides crucial information on the overall load curve of any building over a recurring period of study. This recurrent period usually has a resolution of 8760 values, corresponding to each hour of the study year (Liao, 2015).

Figure 6.1 shows the evolution of the load curve of a mixed-use building (residential and commercial) over a typical day for different weather periods.

To analyse the load curves over a long period, two types of curves are used: the hourly annual demand curve and the ordered annual demand curve (Fig. 6.2). The first is the representation of numerical values at each hour of the year for each of the generators and receivers of the installation or building under analysis. The ordered annual curve is constructed from the sum, for each level of demanded power, of the number of hours in which this power has been equalled or exceeded throughout the year. The area under the annual ordered curve corresponds to the energy demanded.

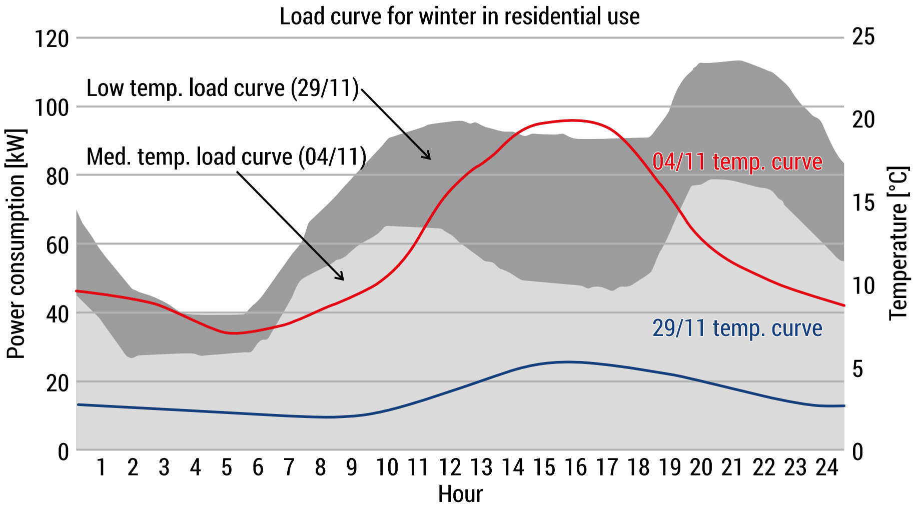


FIG. 6.1. Winter type day load curve (Source: own elaboration)

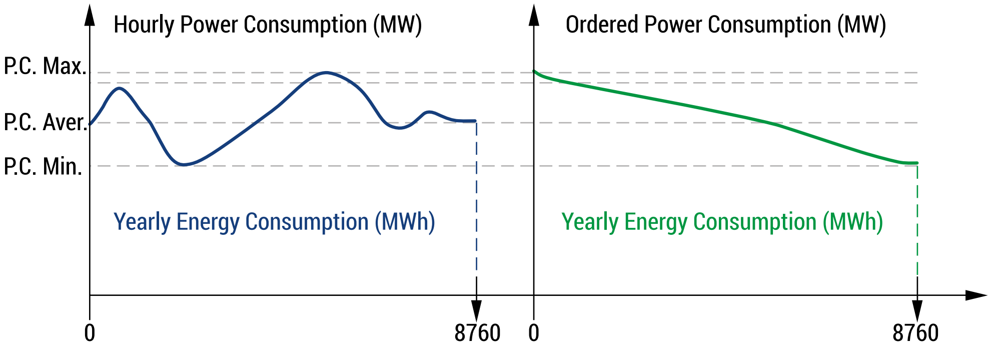


FIG. 6.2. Hourly and orderly load curve (Source: own elaboration)

The following parameters define the characteristics related to energy demand and generation during the period considered.

Yearly energy consumption: energy demanded by the load in the period of one-year Y_{ec} [MWh] is equivalent to the area under the hourly load curve or orderly load curve.

Average Yearly Consumption Power: PC_{aver} [MWh]

$$PC_{aver} = \frac{Y_{ec}}{8760} \tag{6.1}$$

Maximum consumed power: PC_{max} [MWh] is the peak demand that is reached in the period of the year under analysis.

Minimum consumed power: PC_{min} [MWh] is the value of the lowest demand reached in the year under analysis.

Load Factor: *LF*, It is the ratio between the energy demanded, Y_{ec}, and the energy that the load would demand in the considered period *T*, if it were connected to a maximum regime PC_{max}:

$$LF = \frac{Y_{ec}}{PC_{mzx}T} = \frac{PC_{aver}}{PC_{max}} \tag{6.2}$$

6.2.2. Flexible Patterns and Immovable Patterns

In the electricity sector, there are different types of activities, from which the consumption problem can be approached in different ways.

Initially, the main pattern prediction alternatives can be classified into two categories: top-down and bottom-up. This classification arises from the hierarchical position of the information used in relation to the residential sector. Top-down methods use macroeconomic parameters (Gross Domestic Product, Unemployment rate, Population statistics in analysis and projections of their evolution, Growth rates of the availability of electrical receivers, Climatic conditions, Construction, and demolition rates of buildings) to disaggregate the aggregate demand of a building and produce simplified curves of equipment consumption. The evolution of the demands can then be determined by projections. It does not allow the technological evolution of loads connected to the electricity grid to be assessed.

On the other hand, bottom-up methods are based on building-specific information (Area of the rooms, technical properties of equipment and receivers, Individual consumption of some electrical devices. Load usage schedules, Climate characteristics, Internal temperatures, User behaviour) as well as the corresponding usage characteristics of the receivers or loads and extrapolate the information to more general (aggregated) scenarios. These bottom-up methods generate a high level of detail, allow finding specific areas for improvement, consider the effect of customer behaviour and accurately quantify the evolution of demand, allowing to simulate the impact of the discontinuation of some technologies. Bottom-up statistical methods use historical billing information from energy distribution companies together with socio-economic information on buildings to define equipment end-use curves. These methods employ regression techniques and neural networks that correlate electricity consumption with building characteristics. In addition, several regressions can be performed and variables that do not have a significant impact on the final characterization can be progressively eliminated, so that simplified models are obtained.

Within these statistical methods, Conditional Demand Analysis (CDA) is based on the presence of electrical loads or devices in buildings. In this way, a mathematical regression is used to start from the aggregate curve and correlate it with the use of all the indicated receivers. These methods correlate the presence of various electrical devices and their characteristics with other characteristics, such as building areas, demographic factors, number of people, price of electricity, among others.

The classification of top-down and bottom-up methods is shown in Figure 6.3.

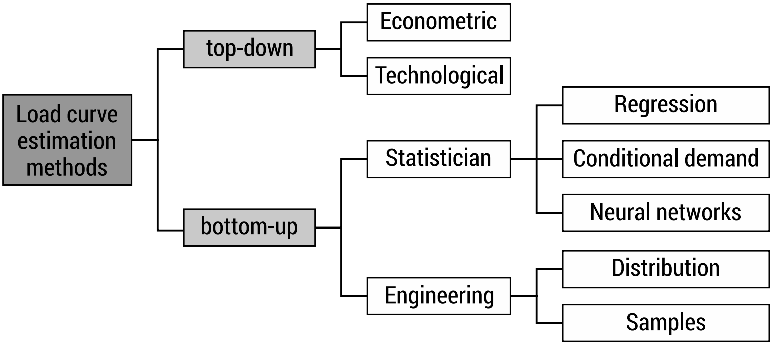


FIG. 6.3. Classification of top-down and bottom-up methods (Source: Altrabalsi, 2014)

Bottom-up engineering methods perform the characterization of end-use curves without using historical consumption information. They rely on the classifications and characteristics of end-use consumptions for modelling. This methodology calculates each end-use energy consumption as a function of the ownership of electrical devices, their use, their classification, and their efficiency. The inputs to this group of methods correspond to data sampled from buildings. The data can be extrapolated if the sampling is representative. For these methods, Smart Metering has made great progress towards effective recognition of electricity consumption patterns and correct forecasting of electricity consumption. It is also of great importance to complement the consumption data obtained from smart meters with external data such as weather conditions or temperature (Kim, 2011). Up to 80% of electricity consumption in buildings can be explained by analysing these variables together.

To correlate the aggregated curve with each end-use, the curve must be disaggregated. The disaggregation of a curve corresponds to separating it into the electricity consumption of each of the electrical devices used in the building under analysis, as shown in Figure 6.4.

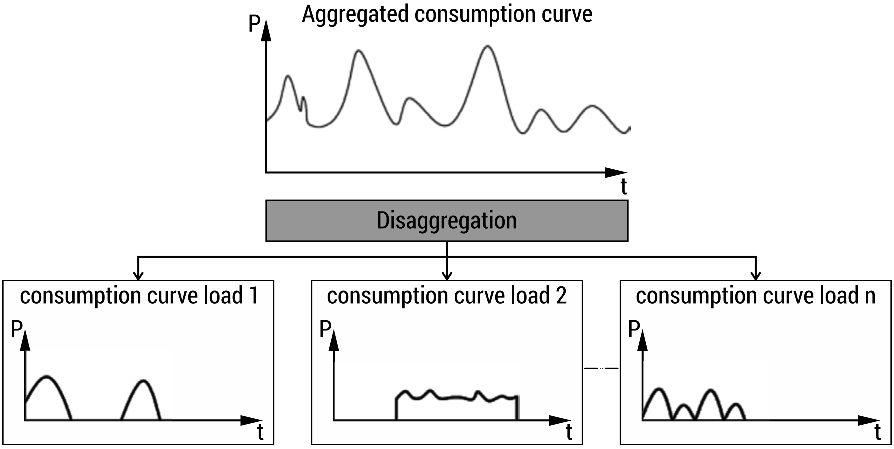


FIG. 6.4. Disaggregation of electricity consumption curves (Source: own elaboration)

The result of the pattern analysis should show a curve as in Figure 6.5 for each variable building scenario (seasonal, weekly, hourly).

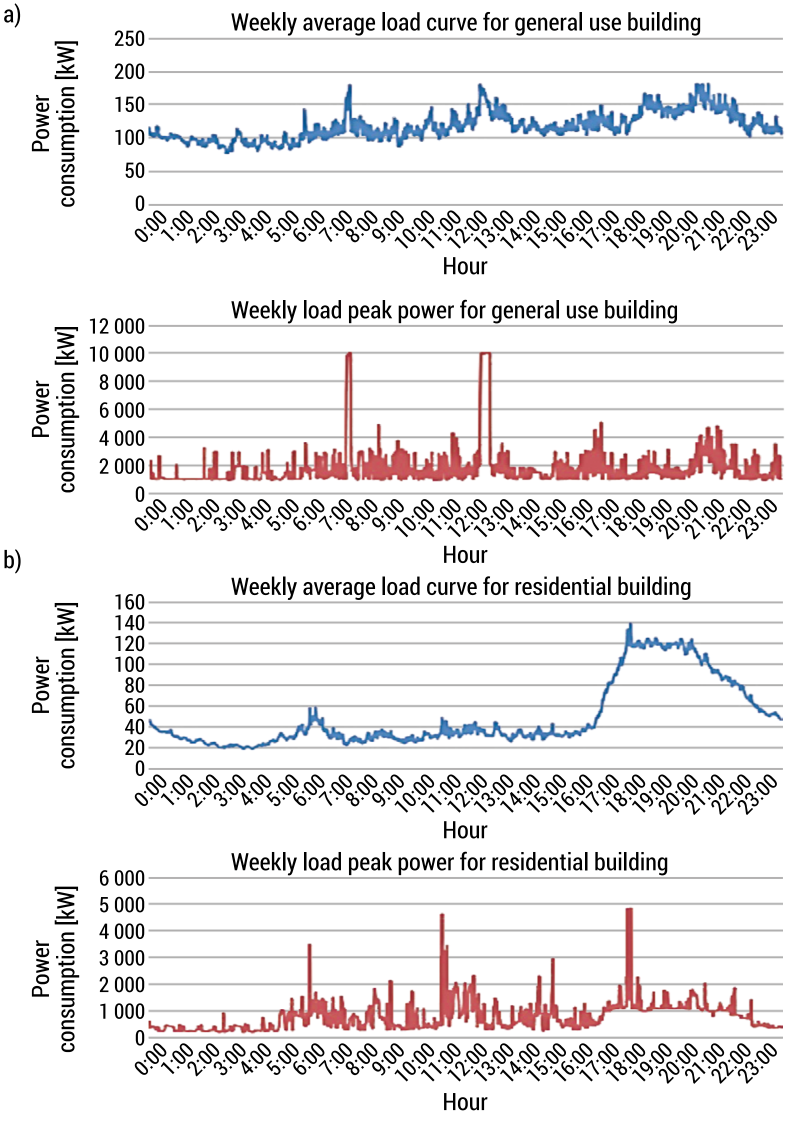


FIG. 6.5. Load Curve and Peak Power for General use buildigs (a) and residential buldings (b) (Source: own elaboration)

This curve, consisting of disaggregated loads shown as a whole, allows easy identification of variable consumption patterns (dependent on the use of the building according to its occupants) and fixed consumption patterns, independent of the flow of users, and responsible for the residual consumption of the building on a continuous basis (Fig. 6.6).

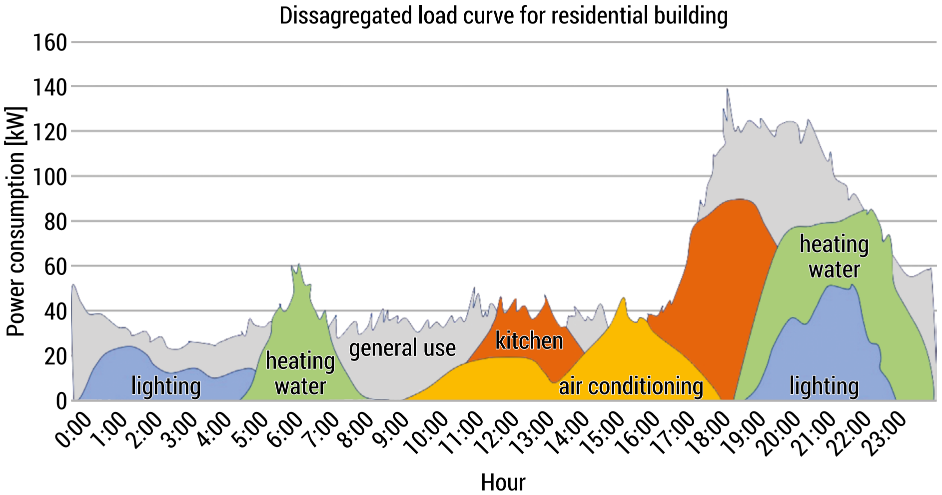


FIG. 6.6. Disaggregated Load Curve for residential buildings (Source: own elaboration)

6.3. Management of Energy Consumption

The load pattern curves analysed in the previous section provide exhaustive information on the periods and destination of the energy consumption of each building throughout the different scenarios that it usually faces. A first analysis of these consumption patterns makes it possible to identify periods of residual consumption (the reduction of which will considerably affect energy savings and efficiency as they are present during most of the time the building is in use). This analysis also makes it possible to identify the periods of maximum consumption to distribute their loads to other periods and stabilise these maximums by means of deferred consumption.

6.3.1. Management of Energy Consumption Using Storing and Self-Consumption With Integration of Renewable Energy

Self-consumption is the consumption by one or several consumers of electrical energy from production facilities close to the consumption facilities and associated with them.

Storing solar electric energy obtained from photovoltaic solar panels (or other renewable and clean energy systems) is the greatest contribution that has been developed to encourage and make solar self-consumption in homes a reality (Nasir, 2019).

This means that any building can be energy self-sufficient without the need for a third party. It also saves a great deal of energy and money. In addition, it is a positive contribution to the environment, as it does not use traditional energy sources (Merino, 2020).

The most used battery storage technology for stationary applications is lithium iron phosphate (LiFeP). The efficiency of a battery is between 80% and 90%. They are found in medium to high consumption solar installations. They can be used in household appliances with higher power, such as ovens and washing machines. Stationary batteries have a useful life of approximately 20 years, have longer charge and discharge cycles, but obviously have a higher economic cost.

Currently, the prices of the energy consumed depend on the contracted tariff and vary from one hour to another. In low energy price scenarios (less than €60/MWh and the difference between the cheapest and most expensive tariffs, corresponding to day and night respectively, close to €40/MWh), the difference between the cheapest and most expensive hours is not large enough to compensate for the cost of purchasing batteries, the current cost of which for stationary systems is around €50-60/MWh.

To assess the economic sense of installing batteries for the purpose proposed and estimate the payback period, it is necessary to analyse these three concepts:

1. The difference in price paid for each MWh consumed, between the most expensive and the cheapest time of the day.
2. The energy consumed.
3. The cost of the batteries.

This price difference between the most expensive and the cheapest time of the day is determined by the contracted tariff.

The next aspect to assess is the energy consumed. We consider the extreme hypothesis that we can buy all the energy we consume at the cheapest time, accumulate it, and consume it from batteries at the most expensive time. This consideration will give us the maximum savings that can be achieved through deferred consumption, which sets the maximums for investment costs.

The third element of the equation – the cost of the batteries – at current domestic battery prices and typical building consumption volumes, the payback may be longer than the lifetime of the battery itself (9-10 years). Furthermore, it should be borne in mind that it is not only the batteries that need to be invested in, but also the installation, the space they occupy and the safety measures.

If the battery is combined with a solar photovoltaic system (Fig. 6.7), the number of years in which the investment is amortised can be reduced to 4 or 5 years. If the PV system is not considered, the payback period is easily extended to nine years as the profit income is significantly lower.

Storage therefore contributes to improving the efficiency of the electricity system. With the entry of storage, we will be able to flatten demand curves, avoiding the peaks that occur at certain times of the day (Fig. 6.8). This will lead to a more efficient use of system resources. In the same way, storage will allow us at certain times of the day to avoid the spillage that would occur in scenarios of high penetration of solar photovoltaic or wind technology, so that the contribution of solar or wind production could be shifted to other times of the day.

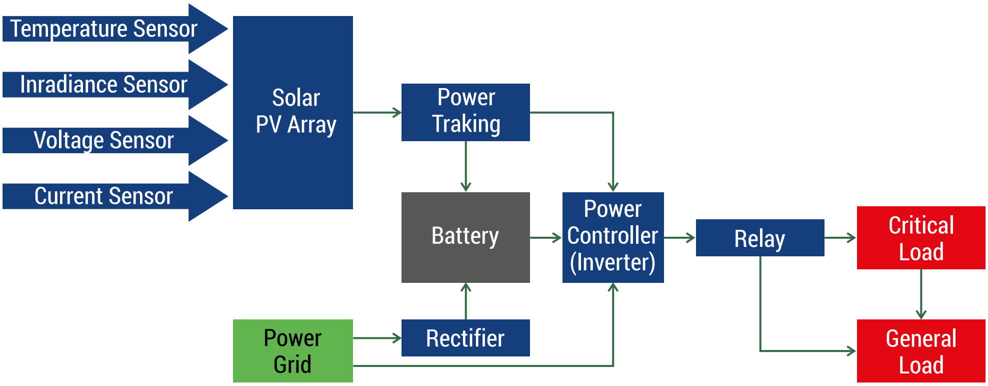
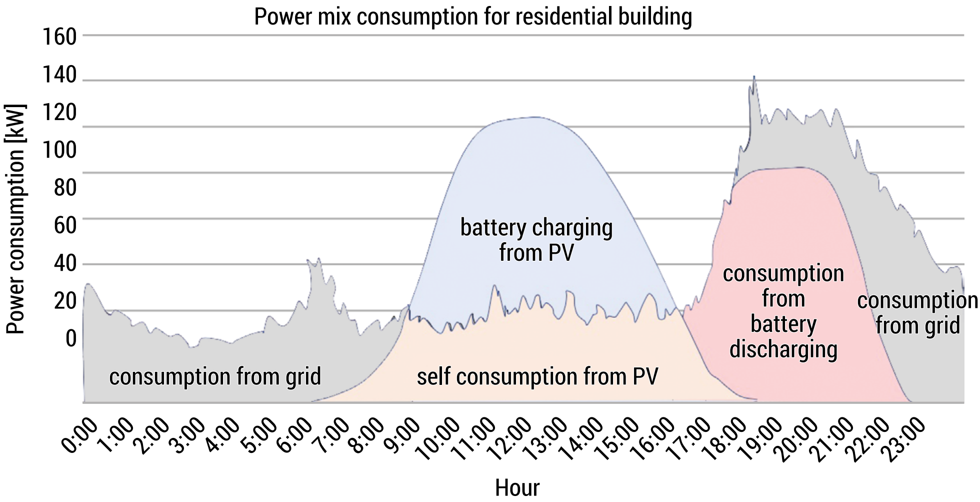


FIG. 6.7. Self-Consumption with storage general scheme (Source: own elaboration)



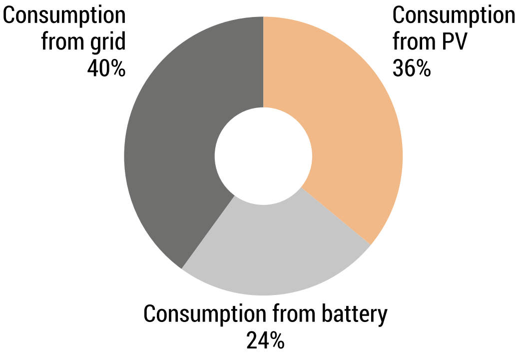


FIG. 6.8. Mix Power consumption (Source: own elaboration)

Only in users with a high peak contracted power and low consumption in terms of energy could the energy storage solution with batteries without self-consumption be of interest.

In conclusion, self-consumption systems using renewable resources without storage require lower initial investments but require longer payback periods.

The inclusion of storage systems increases the initial investment in exchange for reducing the payback period by increasing the efficiency of the self-consumption system, adapting the energy availability to the load curves of the building.

6.4. Optimization of the Energy Consumption

6.4.1. Optimization of the Energy Consumption as Function of the Prize Acquisition

The analysis of consumption patterns, introduction of alternative generation sources and improvement of consumption parameters can be complemented by improving energy procurement by adapting its dynamics to the lowest energy cost periods according to the results of the different markets.

Firstly, load curves should be analysed to identify power peaks and try to reduce the number and frequency of these peaks, reducing the fixed energy cost parameters related to this power availability, which in specific periods may exceed the limits of each contract.

This power reduction involves improving the efficiency of the energy consuming systems (loads) not only in their operation in permanent regime, but also in the previous transient regimes, which appear in the start-up processes or change of load regime. This improvement can be achieved by means of intelligent load regulation and current and power controllers that allow reaching a full load regime through paths of lower power demand in the transient phases.

Consumption habits are a complementary option, whose advantages are the low economic cost and the improvement in self-consumption and energy storage processes, but which, in exchange, are difficult to implement and, above all, to maintain over time. Therefore, efficiency cannot be based on this type of measures as the main point of the energy strategy.

6.4.2. European Regulation, Modalities, Contracts, and Markets

The market structures in each country within the European Union are classified into systems based on fixed or regulated prices, indexed systems or systems based on wholesale markets, two-way market systems and futures market systems. Each country offers, depending on its energy structure, different energy prices and distribution of final energy prices, depending on the final price on the wholesale market, the costs of the transmission networks and the corresponding taxes, as shown in Figure 6.9.

Depending on the power required, the volume of energy consumed and the voltage of the installation, each building may require a different type of energy contract.

Thus, a building with variable consumption and unstable or unpredictable patterns must adapt its consumption to fixed or regulated electricity tariffs, which allow, in any case, to avoid electricity price rises in periods of higher consumption. This damping of price peaks is penalised by a higher average price than would be obtained with other types of more dynamic contracts.

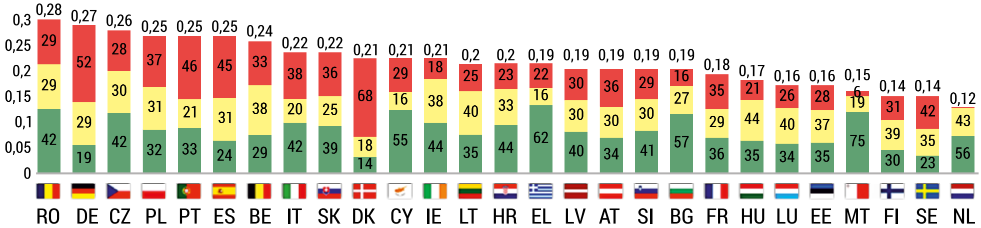


FIG. 6.9. European electricity market prices (Source: WEB-1)

For systems where the volume of energy consumed is considerable, and consumption patterns are known, wholesale electricity markets as well as futures markets offer various options to purchase electricity on an INDEXED basis either at auction results of energy sales in wholesale markets or energy packages in futures markets, which require a commitment to consumption at a pre-agreed date and time. Results are shown in Figure 6.10.

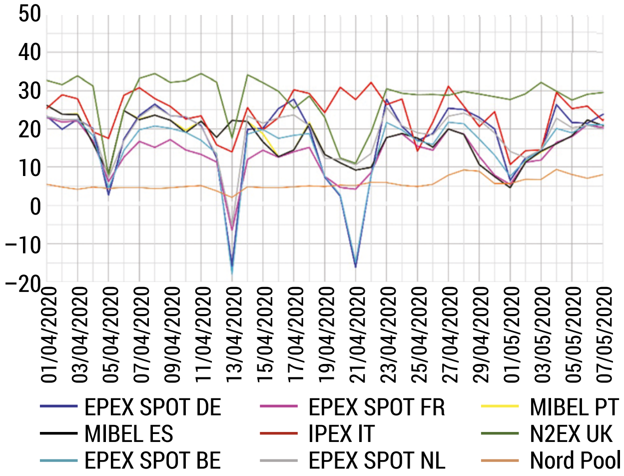


FIG. 6.10. European electricity wholesale market prices (Source: WEB-2)

These variable tariff systems offer considerable savings on bills, although they do not cushion price rises in the electricity market due to contingencies, volatility, or unforeseen causes.

References

[1] Ahmad, A.S., Hassan, M.Y., Abdullah, M.P., Rahman, H.A., Hussin, F., Abdullah, H., Saidur, R. (2014) A review on applications of ANN and SVM for building electrical energy consumption forecasting, *Renewable and Sustainable Energy Reviews*, 33, 102.

[2] Altrabalsi, H. Stankovic, V. Liao, J., Stankovic, L. (2014) Low-complexity energy disaggregation using appliance load modelling. AIMS Energy., 4, 1, 884.

[3] Fischer, D., Wolf, T., Scherer, J., Wille-Haussmann B. (2016) A stochastic bottom-up model for space heating and domestic hot water load profiles for German households. Energy Build. 124, 120.

[4] Kim, H., Marwah, M., Arlitt, M., Lyon, G., Han, J. (2011) Unsupervised Disaggregation of Low Frequency Power Measurements. Proc. SIAM Conf. Data Min., 747.

[5] Liao, J., Elafoudi, G., Stankovic, L., Stankovic, V. (2015) Non-intrusive appliance load monitoring using low-resolution smart meter data. *2014 IEEE International Conference on Smart Grid Communications*, (SmartGridComm 2014), 535.

[6] Merino, L. (2020) Cómo Avanza el almacenamiento. *Energías Renovables*, 190. Available from: https:// https://www.energias-renovables.com/ficheroenergias/productos/pdf/Revista661.pdf [Accessed 30th April 2022].

[7] Nasir, M., Khan, H.A., Khan, I., Hassan N.U., Zaffar N. A., Mehmood, A., Sauter, T., Muyeen, S.M. (2019) Grid Load Reduction through Optimized PV Power Utilization in Intermittent Grids Using a Low-Cost Hardware Platform *Energies*, 12, 1764.

[8] WEB-1: Eurostat (2022) *Energy – Overview* Available from: https://ec.europa.eu/eurostat/web/energy [Accessed 30th April 2022].

[9] WEB-2: Red Eléctrica de España (2022) REData API. Available from: https://www.ree.es/es/apidatos [Accessed 30th April 2022].