# Electricity Tariffs and Solutions for Optimal Energy Management

Subjects: Energy & Fuels | Others

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Today, electricity tariffs play an essential role in the electricity retail market as they are the key factor for the decision-making of end-users. Additionally, tariffs are necessary for increasing competition in the electricity market. They have a great impact on load energy management. Moreover, tariffs are not taken as a fixed approach to expense calculations only but are influenced by many other factors, such as electricity generation, transmission, distribution costs, and governmental taxation. Thus, electricity pricing differs significantly between countries or between regions within a country. Improper tariff calculation methodologies in some areas have led to high-power losses, unnecessary investments, increased operational expenses, and environmental pollution due to the non-use of available sustainable energy resources.

cost-effectiveness | electricity tariffs | electricity retail pricing | energy management systems | optimal energy utilization | pricing systems | renewable energy resources | tariff designs

## 1. Introduction

Electricity tariffs are the process of charging consumers for using electricity. Electricity tariffs now play a vital role in the electricity retail market, as they are considered the main aspect influencing consumers' decisions. Additionally, they are crucial for boosting competition in the electricity market. Electricity pricing varies between countries or between regions within a country.

In order to design electricity tariffs, there are various factors which influence electricity pricing [1][2][3], such as the cost of producing electrical energy at the power plant, the cost of capital investment in transmission and distribution networks, the cost of operation and maintenance of delivering electrical energy, and a reasonable profit on the capital investment. "Reasonable" may be explained considering the electricity market competition principle, this profit is added to the price of generating and supplying electrical power and ensures the continuity and reliability service of the company supplying electricity to purchasers. The profit should be modest and limited to about 8% every year. **Figure 1** illustrates these main components' percentages. Additionally, the wide usage of sustainable energy resources, such as wind, solar, and hydropower, has recently affected electricity pricing in the residential, commercial, and industrial sectors [4][5][6][7][8][9][10][11][12][13][14][15][16][17].

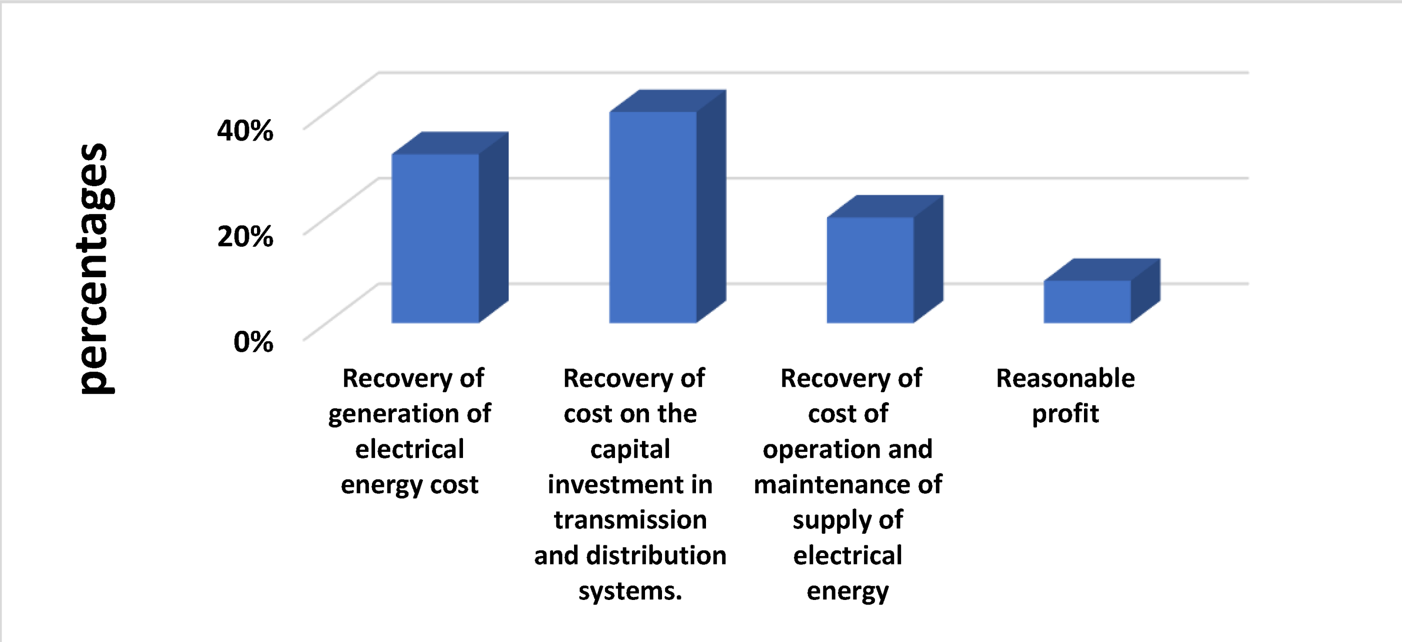


**Figure 1.** The main constituents' percentages included in the electricity tariffs.

Moreover, other factors should be regarded when designing the electricity tariffs, as illustrated in **Figure 2**.

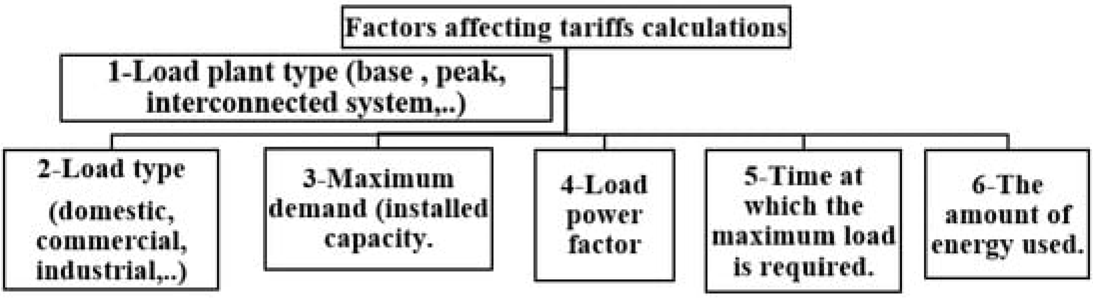


**Figure 2.** Factors affecting electrical tariff calculations.

A base-load plant is a type of plant which continually produces electric power all year round. Such plants run 100% of the time, except during maintenance times, in a similar manner to nuclear and coal-fired plants. Additionally, a peak-load plant supplies a load only during the hours of peak demand for electricity. These plants help over short-term demand peaks, such as gas turbines, hydro plants, and solar and wind power plants. Finally, the interconnected grid system is a network topology for interconnecting different power-generating stations to enable peak load exchange and ensure economical operation [18][19][20].

Moreover, some primary desirable aspects should be considered when designing electricity tariffs, which are listed as follows [21][22][23][24]:

Fairness: fixed charges at a lower rate should be imposed on large consumers, rather than smaller ones, and thus lead to a reduction of the total electrical energy generation cost. Additionally, variable load big consumers should be charged at a higher rate than consumers with no deviations from the preset non-variable load conditions.

Simplicity: the tariffs ought to be clear and easily interpretable by end-users. Consumers may object to complex tariffs as they generally have a negative perception of suppliers' companies; thus, simplicity of tariff calculations will avoid the distrust of the supply companies.

Attractiveness: it is necessary to encourage consumers to utilize electricity, and thus efforts to utilize tariffs in a way that makes it simple for customers to pay are required.

## Electricity Tariffs and Energy Management

Energy management is the procedure of monitoring and optimizing energy usage in buildings. The goal of energy management is sustaining optimal energy purchasing and utilization within the various utilities as well as minimizing energy prices without reducing productivity. Additionally, lowering expenses by effectively reducing consumption and increasing market competencies.

This section discusses the relationship between electricity tariffs and demand-side energy management. Electricity pricing has a great impact on the redistribution of energy on the demand side.

Many methodologies have been introduced in the last few years for detecting the present loads and improving EMS strategies. As in [25], the evaluation of the existing load requirements and production plan to comprehend the present requirements and their production techniques is discussed.

A supporting system method that regulates electrical energy usage is suggested in [26]. This system improves the EMS of non-residential buildings and compares all the installations' energy performances.

The relationship between load EMS and electricity tariffs is discussed in many references. As an example, a number of EMS methodologies are discussed in [27] and compared in terms of pricing benefits for PV and electric vehicle systems supplying electrical energy to a residential building. Calculating the cost of power delivered and consumed yields a total profit and considers the optimal method as the most “profitable”.

In a previous study [28], a new method known as a multifunction strategy was proposed by adjusting the PV system's charging and discharging ratios with a TOU tariff, which resulted in a new EMS methodology for controlling pricing manipulation and peak shifting.

The impact of four energy pricing tariffs on energy planning is discussed in [29].

Additionally, for the financial cost reduction, a multilevel collaborating optimal configuration approach of a multi-energy microgrid group was constructed.

A predictive optimized nano-grid energy purchasing model that minimizes energy trading costs and offers the best energy-sharing strategy for neighbors linked to a nano-grid network is discussed in [30].

In [31], referring to the ISO 50001 standard, EMS is carried out as energy planning and its first step is the optimal tariff management analysis.

## 2. Main Types of Electricity Tariffs

In the last decade, many tariff types have been introduced. Tariffs differ according to the method of their calculation and the factors included in them. Tariffs can be divided into two main categories, energy-based and power-based [32][33][34][35][36]. The main tariff types are mentioned in **Table 1** [37][38][39][40][41][42][43][44]. Equations (1)–(11) show the calculation methods of electricity tariffs.

**Table 1.** Main tariff types.

| No. | Tariff Name | Time of Energy Consumption Dependency | Energy/Power Dependency | Smart Meters | Equation | |
|---|---|---|---|---|---|---|
| 1 | Simple or uniform tariff | independent | (Energy-based) | Not needed | TC = C | (1) |
| 2 | FR | independent | (Power-based) | Not needed | TC = A ∗ x | (2) |
| 3 | Straight-line meter rate tariff | independent | (Energy-based) | Not needed | TC = B ∗ y | (3) |
| 4 | Increasing/Block meter rate tariff | independent | (Energy-based) | Not needed | C1, 0 < t1 < t2<br>C2, t2 < t < t3 | (4) |
| 5 | Two-part tariff | independent | (Energy- and power-based) | Not needed | TC = A ∗ x + B ∗ y, | (5) |
| 6 | Seasonal rate tariff | independent | (Energy-based) | Not needed | TC = B ∗ y max. (yearly) | (6) |
| 7 | Peak-load tariff | independent | (Energy-based) | Not needed | TC = B ∗ y max. (Same as Equation (6) but calculated on daily basis) | |
| 8 | Three-part electricity tariff | independent | (Energy- and power-based) | Not needed | TC = A ∗ x + B ∗ y + C | (7) |
| 9 | Power factor tariff | independent | Power-based | Not needed | -------- | |

| No. | Tariff Name | Time of Energy Consumption Dependency | Energy/Power Dependency | Smart Meters | Equation | |
|---|---|---|---|---|---|---|
| 10 | Tiered (or step) Tariff | independent | (Energy-based) | Not needed | TC = Bn ∗ y | (8) |
| 11 | Tiered/TOU | dependent | (Power-based) | needed | TC = An ∗ x | (9) |
| 12 | Demand rates | independent | Power-based | Not needed | TC = A ∗ x max | (10) |
| 13 | Weekend/holiday rates | independent | (Energy-based) | Not needed | TC = Bn ∗ y. (Same as Equation (8) but calculated on weekends and holidays) | |
| 14 | FIT | independent | (Energy-based) | Not needed | -------- | |
| 15 | Net metering | independent | (Energy-based) | Not needed | --------- | |
| 16 | Critical peak pricing | dependent | (Energy-based) | Needed | TC = An ∗ x. (Same as Equation (9) but time intervals are longer) | |
| 17 | Real-time pricing /Dynamic pricing | dependent | (Energy-based) | Needed | ---------- | |
| 18 | Two-part real-time pricing (Block- and-Index Pricing | dependent | (Energy-based) | Needed | TC = An ∗ x + extra charges (Same as Equation (9) but extra charges are added.) | |
| 19 | Sell back | dependent | (Energy-based) | Needed | ----------- | |
| 20 | Stand by rates | dependent | (Energy-based) | [45][46][47][48] Needed | --------- | |
| 21 | Ramsey pricing | independent | (Energy-based) | Not needed | TCα1/y, | (11) |
| 22 | Tempo tariff | dependent | (Energy-based) | Needed | ---------- | |

plest and must pay o decrease their electricity consumption.

2—Flat demand rate tariff: The bill for power usage is determined by the maximum load demand and is unrelated to energy consumption. This method is simple but separate meters are needed for different loads.

3—Straight-line meter rate tariff: The bill generation of this type is based on load energy consumption.

4—Increasing/block meter rate tariff: Energy usage is classified into three main categories. where the first one is taken at the highest rate, the following unit will be at a somewhat lower rate, and the last unit will be at a very low rate. This method motivates the consumer to consume more electric energy, which leads to the generation cost decreasing; however, it lacks the consumer demand measures.

5—Two-part tariff: The first part is fixed and depends on the maximum demand, while the second part is the running charge and includes the energy consumption by the load.

6—Seasonal rate tariff: The highest price in kWh utilized by the consumer annually is measured.

7—Peak-load tariff: The highest price in kWh utilized by the consumer daily is measured.

8—Three-part electricity tariff: The consumer’s total bill during each billing period depends upon fixed charges, semi-fixed charges, and running charges.

9—Power factor tariff: The consumer load power factor is taken into consideration in this method. Consumers with low power factor are penalized.

10—Tiered (or step) tariff: Rate changes according to the amount of energy used, which encourages conservation and use.

11—Time of use (TOU): This method implies different rates depending on the time of day. This method encourages consumers to decrease their consumption at peak times, thus decreasing peak load costs.

12—Demand rates: Depends on the electricity peak demand utilized by the consumer.

13—Weekend/holiday rates: In this method, rates on weekends and holidays are different from that during normal times.

14—Feed-in tariffs (FIT): This is a governmental strategy that was created to accelerate investments in sustainable energy by offering long-term contracts to sustainable energy producers.

15—Net metering: This is a billing criterion supporting sustainable power production development, especially solar power. This mechanism credits owners of the solar energy system for the electricity added to the network.

16—Critical peak pricing: This pricing method is close to the TOU tariff, with two major differences, namely the time intervals, which are longer than those in TOU, and the specified periods, which are also less, and the rates during these periods are higher than in TOU.

17—Real-time pricing/dynamic pricing: Each instance has a pricing modification. These costs frequently correlate to retail market costs.

18—Two-part real-time pricing (Block and Index Pricing): Consumers purchase their standard baseline according to their TOU; they may also pay extra charges at a higher price according to their deviation from this baseline.

19—Sell back: Used mainly in distributed generations and refers to the charges that a consumer with onsite generation ability should receive to reinject power to the main grid.

20—Standby-rates: The appropriate pricing of DEG consumers for periods when there is no generation due to maintenance considerations.

21—Ramsey pricing: Consumers with higher demands obtain pricing reductions.

22—Tempo tariff: Designated for the PV installation consumption; when the PV is not self-generating its energy and the consumer need to connect to the grid and this self-consumption tariff comes at a cheaper price.

For the various aforementioned tariffs, dynamic and block meter rate electricity tariffs may be utilized for optimizing electricity consumption [49]. As for tariffs designs related to sustainable energy resources, such as FIT, stand-by rates and sell back are more complicated in the design due to the high initial cost of generation. As an example, the capital cost of a photovoltaic power plant may reach 4500 USD/KW [50][51][52][53][54][55]. Although the other types of tariffs, such as the uniform tariff designs, are simple, they do not encourage consumers to optimize their energy usage, and other methods do not verify the fairness concept as the customer is charged with fixed rates regardless of their energy consumption. A good way to improve tariff designs in some countries is to be aware of the worldwide used designs and compare them in order to recognize their impact on the energy utilization and electricity market.

Therefore, the following section introduces an overview of the different electricity tariff designs used in some countries.

## 3. Electricity Tariffs Applied in Some Countries

In this section, some types of electricity tariff methodologies utilized in various countries, such as Australia, China, Turkey, the U.S., the U.K., and Russia, are reviewed, showing their different impacts on the usage of electrical energy consumption.

In Australia, residential tariffs are applied to encourage the installation of the photovoltaic systems by residential consumers. Additionally, financial assistance is offered by utility companies to the end-users to install a PV system instead of placing the financial burden on the users. The tariffs used are the (FIT), which means that a preset daily rate is established, and a variable cost, depending on the amount of energy consumption, is then added. Early in the 1990s, the electricity industry in Australia utilized the characteristics of a monopoly. However, currently, more than 19% of residents own their own PV systems [56][57][58]. This transition from a monopolistic to a competitive strategy resulted in a reduction in residential demand and improvements in PV system efficiency, which in turn led to optimization in energy usage and the decrease in the usage of conventional sources [59][60].

FIT market mechanisms are also utilized in Turkey and provide a constant FIT price for the same renewable electricity energy source. The fixed FIT applied in Turkey is simple and does not need a detailed electricity generation project analysis [61][62]. Additionally, the Turkish government encourages sustainable electrical power generation investments. Turkey's tariff system guarantees constant rates per kWh of power generated from sustainable resources [63][64].

In Norway, the grid rent cost model implemented in 2018 consists of two parts; the first is the same for all end-users and equals the fixed cost annually, while the other part represents a cost model depending on the energy usage of individual customers, as mentioned in [65]. Conventionally governed monopoly markets utilize multilevel governing systems to determine electricity tariffs, and hourly RTP is used predominantly in countries such as Bulgaria, Slovakia, Spain, Estonia, Latvia, and Slovenia. CPP is utilized in France, where 1.2% of residents chose tempo tariffs [65][66][67]. Moreover, the EU states that island microgrid kWh production prices are 4.5–5 times more expensive than the price for the French mainland [29].

In China, on-grid electricity tariffs were used for attracting investment in power generation. Additionally, tiered electricity pricing (TEP) was re-introduced in China as a new electricity tariff methodology for the residential electricity sector. Since China has great potential for sustainable energy resources, FIT is being used [68][69][70].

Electricity rates in the United States are similar to those found in Europe, and increasing block metering and flat rate tariffs are also used individual locations, such as Austin and Texas [71][72][73][74].

In the U.K., FIT began in 2010 in order to provide fixed pricing for generation from sustainable resources from PV plants under 5 MW. Later, a generation tariff (FIT) coupled with a feed-in premium or a quota system with tradable certificates was applied according to the PV generation capacity [75][76].

The Russian electricity market is divided into wholesale and retail parts, both regulated and competitive. The market determines both energy and capacity prices [77][78].

The worldwide electricity rate pricings are illustrated in **Figure 3**.

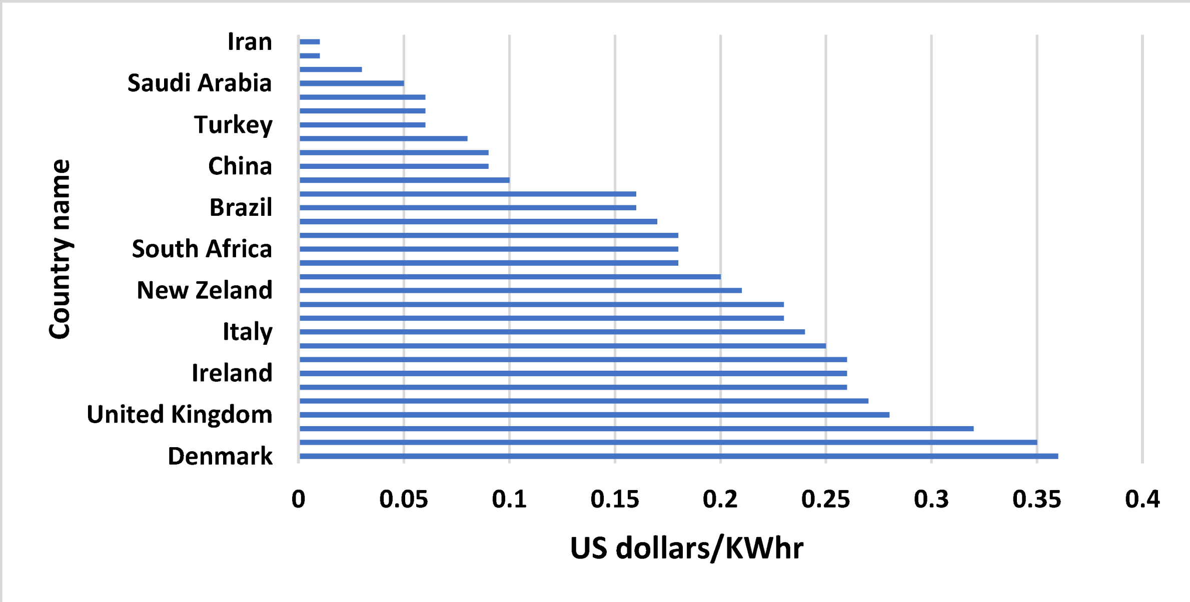


**Figure 3.** Electricity tariff pricing in different countries in 2021.

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