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# A Review of Electricity Tariffs and Enabling Solutions for Optimal Energy Management

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**Abstract:** 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. Due to the importance of electricity tariffs, the authors of this paper have been inspired to review all electricity tariff designs used worldwide. In this paper, 103 references from the last ten years are reviewed, showing a detailed comparison between different tariff designs and demonstrating their main advantages and drawbacks. Additionally, this paper reviews the utilized electricity tariffs in different countries, focusing on one of the most important countries in the Middle East and North Africa regions (Egypt). Finally, some recommended solutions based upon the carried-out research are discussed and applied to the case study for electricity tariff improvement in this region. This review paper can help researchers become aware of all the electricity tariff designs used in various countries, which can lead to their design improvements by using suitable software technologies. Additionally, it will increase end-users' awareness in terms of deciding on the best electricity retail markets as well as optimizing their energy usage.

**Keywords:** cost-effectiveness; electricity tariffs; electricity retail pricing; energy management systems; optimal energy utilization; pricing systems; renewable energy resources; tariff designs



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## 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 [1–3], 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 [4–17].

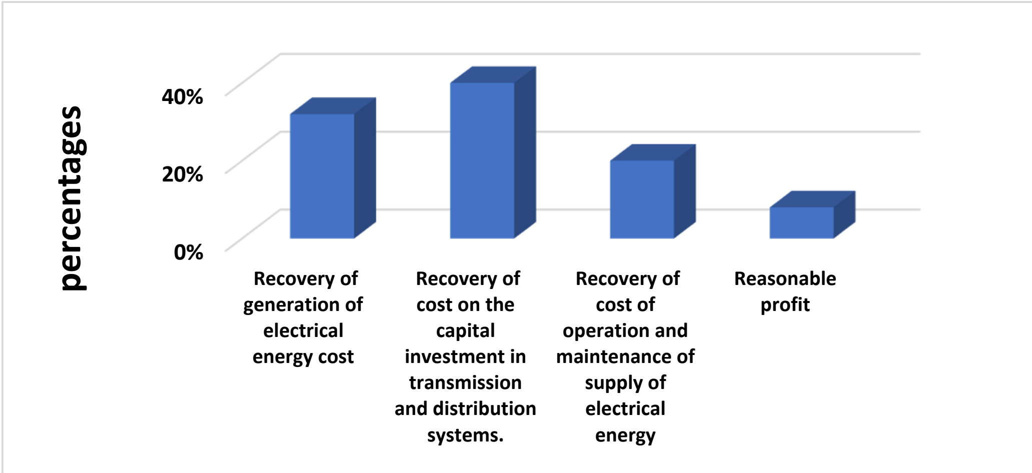



**Figure 1.** The main constituents' percentages included in the electricity tariffs.

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

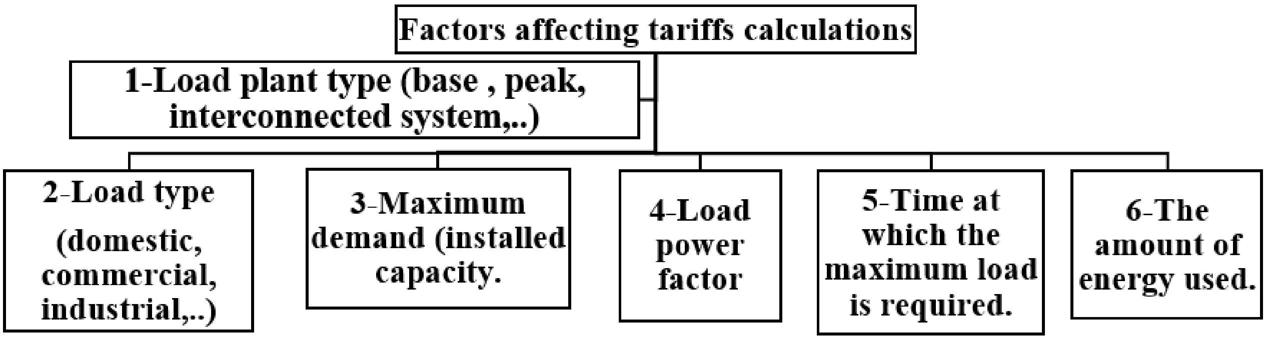



**Figure 2.** Factors affecting electrical tariff calculations.

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 [18–20].

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

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.

The target of this review paper is to provide a map for the electricity tariffs researcher where they can find the policy recommendations, elaborating methodological choices and an accurate methodology for electricity tariffs designs techniques, as well as to enable policymakers to understand the challenges associated with applying certain electricity tariff designs and how to overcome these challenges to optimize energy usage.

This literature review is intended to provide insights into worldwide governmental mechanisms in tariff designs and their impact on energy usage. Additionally, it highlights the enabling solutions used or planned for optimal energy utilization. The review started with a systematic search on the Clarivate Analytics Web of Science. The papers and abstracts were reviewed and filtered. Articles chosen were related to optimal energy usage, sustainable energy sources, worldwide governmental tariff designs, and energy management systems.

This paper is divided onto five sections. In Section 2 a detailed comparison is carried out between different electricity tariff types introduced in the last few years, indicating their advantages and drawbacks. The examples of worldwide governmental mechanisms used in electricity tariffs are explained in Section 3. Moreover, in Section 4, a detailed study of the electricity market and the applied electricity tariffs in Egypt is highlighted. Section 5 is a review of the recommended solutions for tariff design improvements for optimal energy management worldwide and how to apply them to the case study. Finally, conclusions are discussed in Section 6.

## 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 [32–36]. The main tariff types are mentioned in Table 1 [37–44]. 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 | —— | |
| 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) | Needed | —— | |
| 21 | Ramsey pricing | independent | (Energy-based) | Not needed | TCα1/y, | (11) |
| 22 | Tempo tariff | dependent | (Energy-based) | Needed | —— | |

Electricity tariff description [45–48]:

1—Simple or uniform tariff: A fixed rate per unit of energy consumption. It is considered to be the simplest and easiest understood tariff type. However, the main disadvantage of this method is that the consumer must pay equally for the fixed charges irrespective of load variation, which does not encourage consumers to 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 [50–55]. 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 [56–58]. 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 [65–67]. 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 [68–70].

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 [71–74].

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.

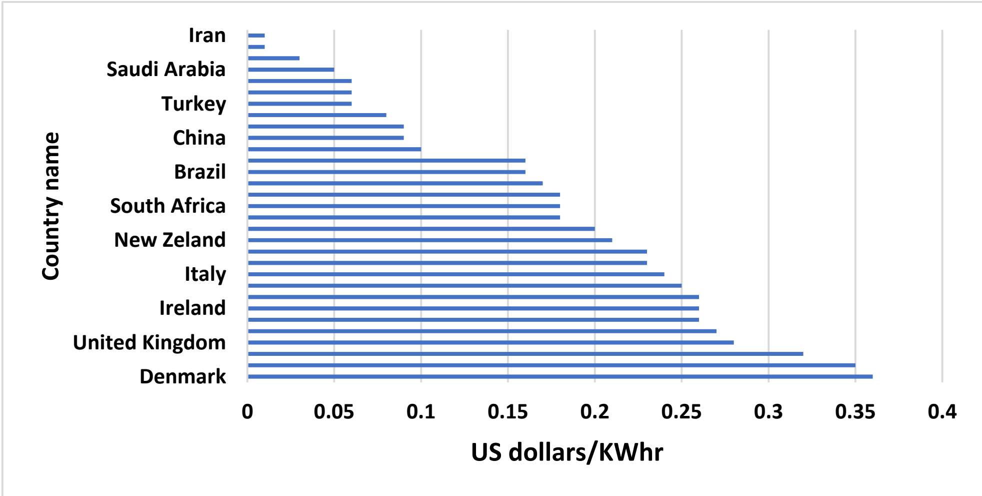



**Figure 3.** Electricity tariff pricing in different countries in 2021.

## 4. Case Study in the MENA Region (Egypt)

In this section, a case study in the MENA region is discussed, and Egypt is used as an example, as it is the most important country in this region. Additionally, in this section, the authors highlight good electricity market requirements, the Egyptian electricity sector, and challenges occurring in this country. Moreover, we will discuss the tariff methodologies applied and the governance mechanisms in the last 10 years.

### *4.1. Challenges Facing the Good Electricity Market in the MENA Region*

There are six principles identified according to MEDREG (Association of Mediterranean Energy Regulators) that MENA region countries should comply with, which are [79]:

1. National and regional governmental independence so that regulators' decisions cannot be affected.
2. Expertise, where responsibilities and authorities define a minimal set of skills that define a regulator's specific duties.
3. Accountability refers to how a regulator takes responsibility and can demonstrate the outcomes of its regulatory changes.
4. Transparency, which facilitates understanding the regulator's work for the consumers.
5. Enforcement, which guarantees that market participants follow the rules.
6. Internal organization, the ability to make clear decisions.

As a result of the non-fulfilment of the previous principles in the (MENA) region area, many countries with ideal conditions for sustainable energy resources are not attracting enough foreign direct investment (FDI), which is the main requirement to enhance the energy development in such countries [80].

### *4.2. Egypt's Electricity Sector Overview*

In this section, a detailed study of the electricity sector in Egypt is reviewed. Figure 4 illustrates an overview of the electric sector history in Egypt [81].

As is obvious from the previous figure, the sole market player was the main strategy until 2001. Later, the sole market was changed to a regulated market in 2016. Figure 5 shows the institutional structure of the electricity sector in Egypt today.

- The current situation regarding the energy sector in Egypt:

According to the Egyptian electricity holding company in Egypt, there are great challenges facing Egypt in providing sufficient energy supplies, particularly natural gas and petroleum, as the dependency percentage on these resources exceeds 95% of all of Egypt's energy requirements. All research suggests that Egypt will have a shortage regarding meeting its needs from these sources, despite having reserves, due to increasing use and the high cost of extraction. It is predicted that Egypt will be a permanent trader of oil and gas within a few decades. Due to this situation, the Egyptian economy faces an additional struggle as it is subjected to the international electricity market's unpredictable and uncontrollable variations in energy pricing. Additionally, Egypt's foreign exchange depletion of resources will affect the balance of trade and decrease the national economy's competitiveness. According to Egypt's energy policy, the country plans to increase sustainable sources of electricity to 42 percent by 2035. Thus, it is important to consider the diversity of energy resources in order to increase local usage, which is characterized by stable pricing and sustainability. Figure 6 shows the primary energy consumption in Egypt today according to the Egyptian electricity holding company annual report for 2020/2021.

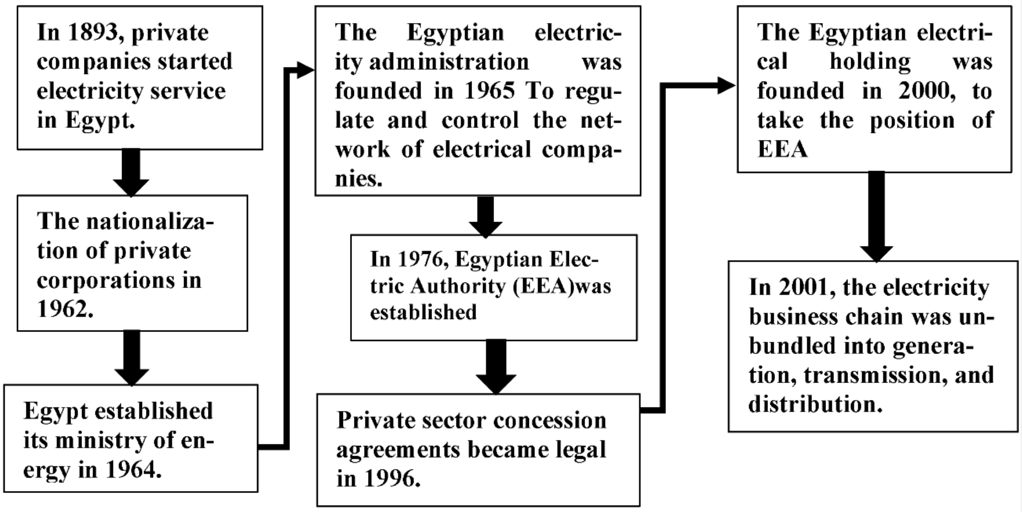



**Figure 4.** The electric sector history in Egypt overview.

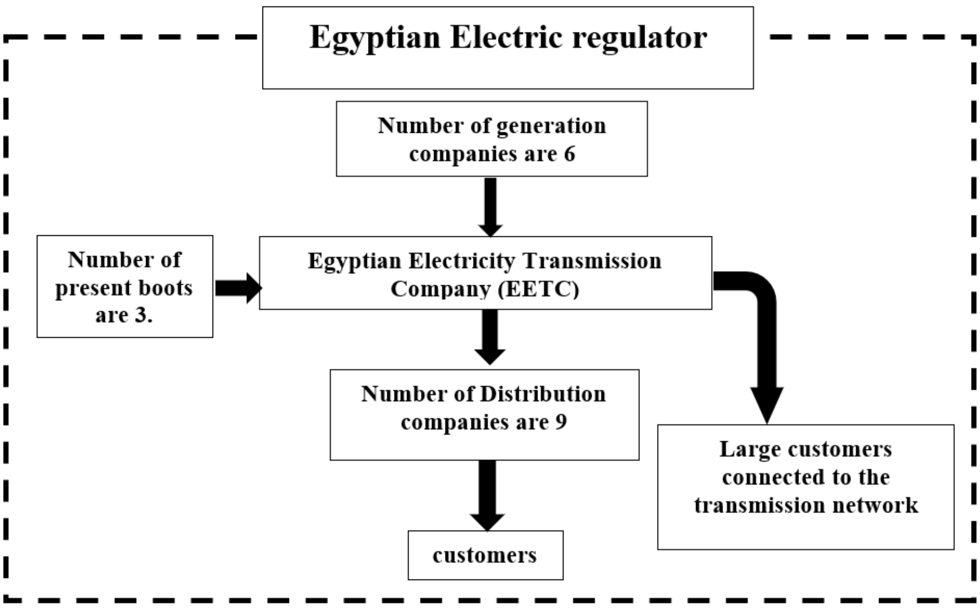



**Figure 5.** The organizational structure of the electrical sector in Egypt today.

Today, renewable energy power plants can be constructed, managed, and owned by the private sector. Additionally, they can export the electricity produced via power purchase contracts to the Egyptian Electricity Transmission Corporation or authorized distribution firms, on the condition that the length of power purchase agreements will not exceed 25 or 20 years for solar and wind power plant energy projects, respectively [82].

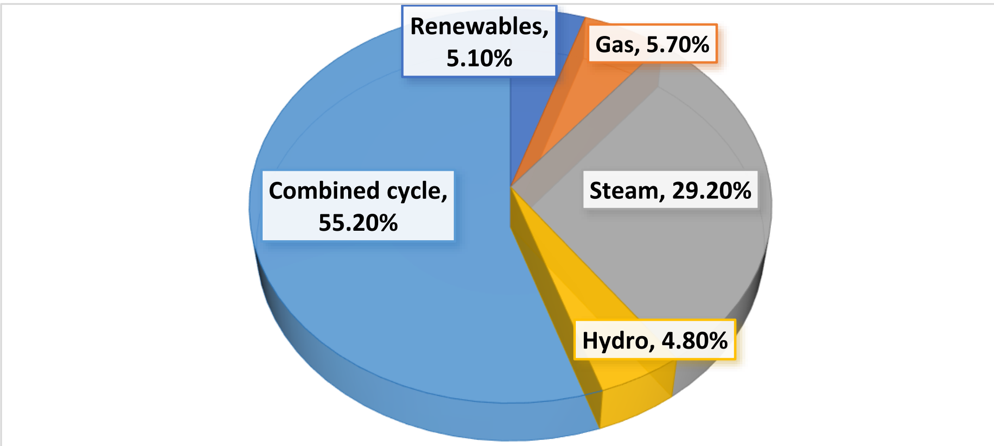
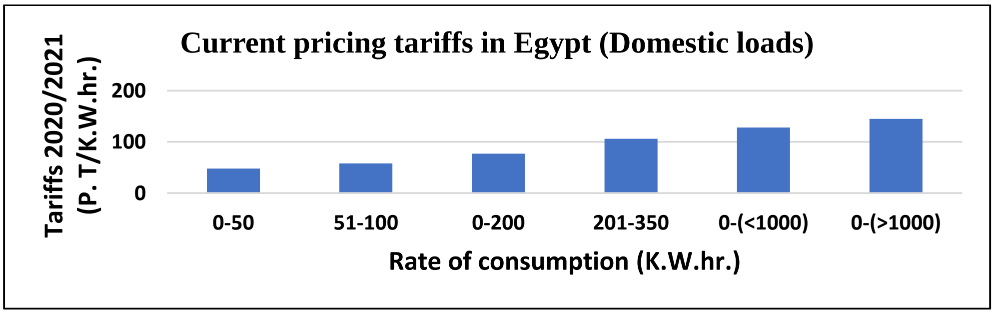


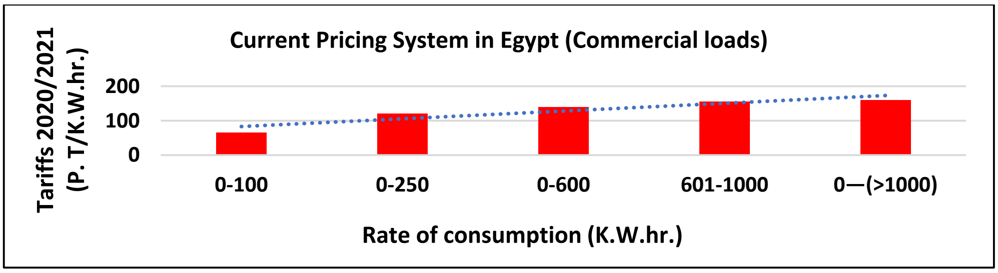

**Figure 6.** Primary energy consumption in Egypt.

- Egypt's Current Pricing System:

In previous years, the government exerted great efforts to adjust energy pricing, not to control demand or reduce consumption but to reconsider its support [83,84]. As a result, the energy allocation function price appears to be regularly ignored, and mispricing persists. The announced electricity tariffs in Egypt for domestic, and commercial usage are illustrated in Figure 7a,b.




(**a**)




(**b**)

**Figure 7.** The 2021/2022 electricity tariffs for various loads. (**a**) The 2021/2022 electricity tariffs versus the consumption rate for domestic loads. (**b**) The 2021/2022 electricity tariffs versus the consumption rate for commercial loads.

As for the current pricing methodology for renewable energy resources in Egypt, FIT is applied. This mechanism is utilized to encourage electricity production from sustainable energy sources. The electricity companies buy sustainable energy from their producers at a pre-announced price. This method achieves an attractive investment return through long-term agreements for power purchases. As for the agreements for wind and solar energy, the agreements are for 41 and 49 years, respectively. This varies according to the technology used and station capacity and location. Based on this system, the transmission company and distribution companies are obligated to buy the electric energy produced by both solar and wind energy at fixed prices [85]. Thus, electricity produced from sustainable sources will be supported by the government, but the cost will be charged to customers [83]. Feed-in tariff values for solar energy resources in Egypt are illustrated in Figure 8.

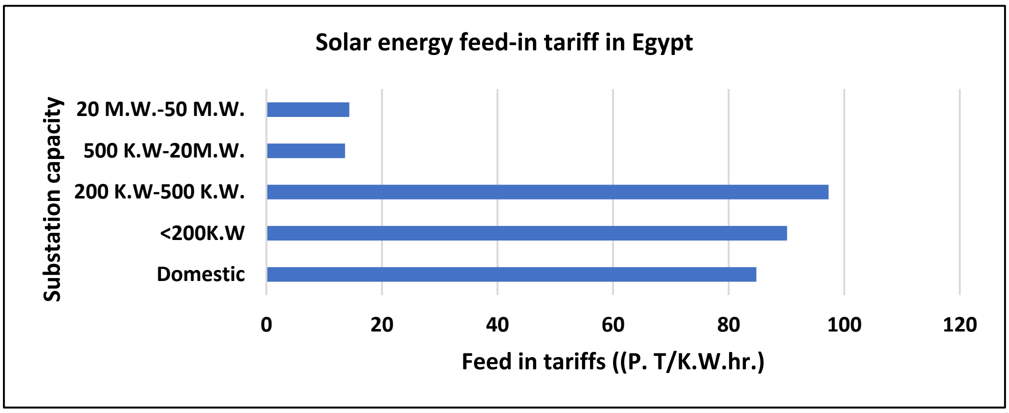



**Figure 8.** Feed-in tariff values for solar energy resources in Egypt.

The drawbacks of the current set tariffs in Egypt:

The cost of electricity is significantly less than the actual economic price of both supply and generation. These low prices increase the energy waste and the instability in demand, resulting in increasing the power generation capacity [84,85].

According to the "Electric rate" electricity pricing in 2022, Egypt is among the least expensive prices among the different countries. The price of electricity is 0.042 U.S. dollars per kWh for domestic loads and 0.058 U.S. dollars for commercial ones. If this pricing is compared to that in other countries, we can recognize that the average electricity price in the world is 0.139 U.S. dollars per kWh for domestic loads and 0.134 U.S. dollars for commercial loads for that period. This also emphasizes that the electricity tariff mispricing problem persists despite the tariffs having been raised in the last few years.

Egypt's electricity sector has faced many problems since 2009, such as inefficient monopolies, high power losses, increasing operating costs, unnecessary investments, and monopolies that do not face penalties for mistakes. However, this sector has started to improve its criteria to become attractive to investors [86].

## 5. Recommended Solutions for Improving Electricity Tariff Design

In this section, a brief review of some of the methodologies found in the literature that may improve and facilitate tariff design in the electricity sector are discussed.

### *5.1. General Recommendations*

i. Software technologies:

There are many available agent-based tools for power systems and electricity market simulation. Some examples of such tools are the Simulator for Electric Power Industry Agents (SEPIA), Reinforcement Learning techniques, the Electricity Market Complex Adaptive Systems (EMCAS), and Agent-based Modeling of Electricity Systems (AMES). Additionally, the Multiagent Intelligent Simulator (MAIS) is used for U.S. wholesale prices simulation [84–87].

Bunn and Oliveira have modelled a new pool and balancing markets operation on a single-day basis. Similar simulations have also been carried out in Belgium and Germany [85–95].

The Hybrid Optimization of Multiple Energy Resources (HOMER) Grid software was also used to simulate a hybrid sustainable model and analyze the data and economic feasibility of a hybrid power system [96,97].

The System Advisor Model (SAM) was also utilized in the modelling of the performance and financial design of the renewable energy industry to facilitate decision-making [98,99].

ii. Media:

Since the media has a great impact on individuals' views, awareness, and beliefs, through it, customers should be made aware of the tariff methodologies applied in their countries. Additionally, media platforms are needed for sharing ideas and solving problems, as carried out in many countries [100,101].

iii. Smart meters utilization:

Electricity smart meters are a very important requirement for improving energy usage as they increase the customers' electricity consumption behaviour awareness. Additionally, they enable the electricity suppliers to monitor the system and charge the customers according to their actual consumption. Advanced Metering Infrastructure (AMI) is the main requirement to activate wide-spread smart meter usage. There have been many efforts exerted in the development of smart meters, such as using artificial intelligence and data clustering for the full supervision of the customers' energy consumption [102,103].

In [104], the importance of smart meters is clarified regarding the possibility of the early detection of electricity consumption abnormalities. Additionally, cost calculation and assess the viability of centralized energy procurement and inspection.

iv. Electricity tariffs research developments:

Research should be carried out to cope with actual electricity market needs. Additionally, it can provide new techniques to optimize energy usage. Today there are many approaches to satisfy such needs; for example, in [105], the author built a machine learning model to predict the hourly retail market and to study the electricity tariff rate. A suggested peak load pricing system is introduced, which could decrease power capacity growth by 2000–3000 MW, in addition to savings in the transmission network capacity [57]. The analysis of various electricity tariffs' effects on the profit of the PV residential systems has been undertaken. The impact of energy regulatory policies and implemented rates on the electric utility was studied using the HOMER program. To develop tariff designs and PV-supporting policies, energy retailers and decision-makers can use the results concluded in this paper as a benchmark.

In [61], instead of using the constant rates in Turkey, electrical utility companies have adopted dynamic pricing plans to encourage their customers to reduce their demand during peak times. FIT is calculated for electricity generation projects utilizing sustainable energy sources and its value rises in proportion to the source's demand. Additionally, two multi-criteria decision-making approaches are used in determining a rating of alternative sustainable electrical energy resources.

A method for evaluating tariffs based on mathematical programming is introduced in [106]. It enables tariff portfolio comparison, intermittent renewable power interactions, distributed energy resources, and tariff structures, which can be accounted for using this strategy. A simple approach for finding globally optimal solutions for the linked nonlinear optimization problem is discussed.

A cost-oriented method for examining the economic incentives of various energy and power dynamic pricing tariffs for companies and electric-grid users, including residential users, is introduced [65].

A comparison held between two bi-level programming models to design TOU tariffs in the electricity retail market is discussed in [107]. The objective of the first includes the retailer's profit maximization and the second is the consumer's cost minimization.

In [108], new mechanisms for electricity tariff retail are discussed in order to buy reasonable sustainable energy generation from producers and transfer costs to them. Additionally, a comparison between measuring generation and consumption independently and infrastructure for advanced metering, which enables more precise energy transaction accounting, is highlighted. The effects in a high-D-RES distribution grid are studied using high-resolution energy data. Multiple tariffs and metering scenarios are considered.

A (DT) concept is applied to low-voltage end-users instead of a traditional fixed price of energy [109]. The paper presented a system for 24 h load prediction in a dynamic tariff setting. In [110], a genetic algorithm, is proposed to search for TOU tariffs using a randomized objective function. Additionally, various search methods and objective functions, along with trade-offs in GA and simulation parameter settings, are examined. In [103], the researchers introduced three different patterns for various building types in Norway, intending to determine the model that provides the best incentive control for the demand side in buildings. The algorithm is used to calculate different tariffs total pricing of the buildings' heat load shift and the savings per kWh of relocated load. The results reveal that different tariffs provide appropriate incentives for structural enhancement and load shifting for various scenarios. All three tariffs proposed a raised grid rent for users who continue to use power in the same way they do currently.

After reviewing the electricity tariffs used in various countries and highlighting the main enabling solutions for optimal energy usage, the next section is a detailed case study of one of the MENA region countries, illustrating the main applied electricity tariff methodologies, the challenges facing optimal energy usage, and some suggested solutions to overcome these barriers.

### *5.2. Suggested Solutions for Overcoming Problems in Egypt*

The suggested solutions are based upon the previous review of the techniques used worldwide, such as:

- Increasing the end-user's awareness of the tariff's methodologies applied in Egypt through the media, including printed, outdoor, online, and TV ads. Additionally, consumers should be aware of their social responsibilities.
- Increasing public campaigns that encourage consumers to regulate their consumption and change their attitudes and knowledge regarding optimal energy usage. These campaigns should categorize their targets according to age, language, and the living standard of the end-users.
- Starting these behavioural changes and awareness in the new generations by teaching new curricula in basic education.
- Persistence and constant reminders are very important for long-term success.
- Tariffs applied should take into consideration the living standard of consumers.
- Applying various software tools to facilitate tariff calculations and enable the end-users to optimize their consumption.
- Smart meter development and improving the AMI of smart grids.
- Introducing mobile applications with lower prices designed by specialized companies to enable the end-users to calculate their bills according to the best-fit tariff.
- The break-up of governmental utilities to profitable companies, introducing ISO (Independent System Operator), and allowing market participation opportunities.
- TOU and dynamic tariffs should be applied, as they have many advantages, such as fostering competition for sustainable energy prices [83].

## 6. Conclusions

Electricity tariffs now play a significant role in the electricity retail market, as they are the main elements influencing consumers' decisions. Additionally, prices are crucial for boosting competition in the electricity sector.

Due to tariffs' importance and impact on the electricity market and their relationship with the loads' energy management, this paper presents a detailed review of the various types of electricity tariffs, indicating their advantages and disadvantages. Additionally, the worldwide electricity tariff mechanisms applied are discussed, focusing on one of the most important countries in the MENA region (Egypt).

In this paper, recommended solutions for improving tariff designs, methods for increasing the end-users' awareness for optimizing their energy usage, and enabling technologies for designers to facilitate tariff calculation and design have been reviewed. Finally, applying those recommendations to overcome the drawbacks of the electricity market in Egypt.

Among the recommendations to be implemented in Egypt is applying dynamic tariff methodologies, such as the TOU, which encourage the end-users to optimize their consumption. Sustainable energy usage expansion should be regarded. Additionally, increasing consumers' awareness of the tariff calculation methodologies applied in Egypt through the media and how to reduce their electricity consumption should be undertaken. Moreover, applying new software techniques to facilitate tariff calculation and simulation should be prioritized. Smart meter development and the preparation of their infrastructure is also recommended to enable cost-calculation accuracy, providing energy usage transparency and real-time household consumption and expenses tracking control. Additionally, the break-up of the governmental utilities into profitable companies, introducing ISO (Independent System Operator) and allowing market participation opportunities should be encouraged.

Finally, this paper will help researchers to be aware of all the electricity tariff designs used throughout the last decade and still utilized in some countries today, which in turn will enable them to improve their designs. Additionally, customers will be able to choose the best electricity retail markets and optimize their energy use.

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## Abbreviation

| | |
|---|---|
| A | charges per kW of the demand |
| $A_n$ | variable cost per kW of the demand (n = 1, 2, . . . .) |
| B | charges per kWh of energy consumed |
| $B_n$ | variable cost per kWh of energy consumed |
| $C_n$ | constant |
| EMS | energy management systems |
| EU | European Union |
| FIT | feed-in tariffs |
| FR | flat demand rate tariff |
| MENA | Middle East and North Africa |
| TC | total charge for a specific period |
| TOU | tiered within USE/time of use |
| X | the demand during a certain period (kW) |
| $x_{max}$ | maximum demand (kW) |
| Y | energy consumed during a certain period (KWh) |
| $y_{max}$ | maximum energy consumed (KWh) |

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