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Political Economy of Iran's Electricity Industry: Long-Run Marginal Cost Approach

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ABSTRACT

Set forward-looking electricity tariffs is very important to the political economy. Therefore, determining the basis for electricity prices will provide a diagnostic criterion for politicians and legislators to avoid mandated pricing. The present article investigates the long-run marginal cost forecasting of Iran's electricity based on the predicted demand of vision 2041. Two scenarios of continuing the current trend and the high growth with frugality determine and distinguish the future power plant generations for each base year in a desired vision. In other words, total power generations and the share of each power plant type were scheduled, and consequently, long-run marginal costs are estimated based on the average incremental cost approach and levelized cost of electricity concept. The effects of fuel price and discount rate variations are investigated in this study. The LRMC variation trend based on the domestic fuel price is opposite to corresponding global fuel price.

1. Introduction

Electricity pricing is one of any country's most critical and strategic issues. It depends on many factors, such as existing infrastructures, access to natural and financial resources, environmental policies, energy demand and world crises. One of the most important complications of the electricity industry is mandated pricing. Mandated pricing has put pressure on producers and for this reason, there is no incentive to invest in the power plant sector. As long

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as these conditions continue and the electricity purchase price of power plants is not adjusted, the growth of the power plant industry is not expected. Mandated pricing disrupts production, reduces supply and increases imports. Another problem for electricity producers is that power plant development has received exchange facilities in previous years, and with the increase in the exchange rate, the repayment of them has imposed a heavy cost on the power plants. Power plants sell their electricity in Rials and have foreign exchange costs. In addition, the same income from the sale of electricity at an unreasonable price is collected with a long delay. If policymakers do free the electricity economy, a lot of resources will enter the construction of power plants and the semi-finished units will be completed and the amount of productivity will increase. In other words, if the policymakers stop the mandated pricing and buy electricity from the power plants at a more reasonable price, investments will be directed toward power generation. In the case of reforming the economic structures of electricity, major industries, subscribers and consumers will move towards developing technology, increasing efficiency and reducing losses, and this will become the basis for the country's economic progress. The essential step for electricity pricing is estimating the minimum cost spent on power generation, transmission and distribution. In other words, the final price of electricity should be adjusted based on the minimum calculated cost and other important factors, such as the competitive market rate and government economic incentives for different consumer groups. Furthermore, a necessary condition for economic efficiency is that the price of an offered service equals marginal cost (Nunn et al., 2015).

A variety of approaches have been studied for electricity price forecasting. One of the viewpoints on classifying this concept is the time horizon. Therefore, many articles can be organized according to the short-term, medium-term and long-term forecast duration. Short- and medium-term electricity price forecasting corresponds to a few minutes up to a few days ahead and a few days to a few months ahead, respectively. While long-term price forecasting deals with future months, quarters or even years and requires different approach (Weron, 2014). Long-run marginal cost (LRMC) is one of the methods used to set the electricity price that includes the cost of an incremental change in demand. The LRMC method estimates the cost of power generation for the future horizon without using past data and only considering the forecast of requirements and the increase in power plants' generation capacity. Three LRMC approaches can be described based on the future demand state: the perturbation approach, the average incremental cost approach and the stand-alone cost approach (Nunn et al., 2015). The perturbation approach deals with a fixed and permanent increment of demand growth (Nunn et al., 2015). The stand-alone approach (or Greenfields) estimates LRMC assuming no pre-existing network serves prevailing electricity demand (Nunn et al., 2015). The average incremental cost (AIC) approach is used when future demand shows the incremental trend (Nunn et al., 2015). According to the report of the energy and environment research institute of Niiroo research center (January 2020), the perspective of electric energy demand and necessary power plant development of Iran was determined for the horizon of 2041. Important issues such as restrictions, forward-looking energy demand, policies related to greenhouse gas emissions, and necessary investments were considered in this report (The energy and environment research institute, 2020). It should be noted that in the analysis of the report, two scenarios were investigated:

The scenario of continuing the current trend with frugality (S1) and the high growth scenario with frugality (S2). They were defined by an average annual GDP growth rate of 4.2 and 8 percent, respectively. S1 and S2 were considered as two different scenarios with different predicted generation demands according to economic growth policies. Therefore, the various capacities of power plants in the five-year intervals have been considered. Also, in both scenarios, efficiency improvement in energy generation technologies has been considered. Furthermore, the demographic data needed to predict energy demand was the same in both scenarios. Based on the energy and environment research institute report, the population of Iran will be 99.5 million at the end of the planned period, with an urban population of about 67 million. Currently, Iran's electricity generation capacity is more than 90000 MW and based on predicted values, electricity demand will gradually increase to 481.7 and 995.16 Terawatt-hour for the scenario of continuing the current trend with frugality (S1) and the high growth scenario with frugality (S2), respectively (The energy and environment research institute, 2020). Growth of renewable power plant capacity and reduction of electricity supply through fossil fuels have been planned for the next twenty-year period.

Table 2 indicates the planned power generation ratios of different technologies for the scenario of continuing the current trend with frugality (S1) and the high growth scenario with frugality (S2) in 5-year periods up to the year 2041. Based on the predicted perspective of each power plant generation in the target year, combined-cycle power plants have almost kept their generation shares because of their essential role in supplying the demand peaks. Unlike gas-type power plants, steam power plants will gradually be removed from the generation portfolio. Considering the report of the energy and environment research institute and its mentioned policies to use clean energy and reduce the use of fossil fuels, the increasing ratio of the solar power plant is apparent. This increment is such that the share of electricity generation by solar power plants should be increased to more than 20% at the end of the horizon.

The authors of the present article use the AIC approach to estimate LRMC concerning the predicted increasing trend of electricity demand in Iran based on the energy and environment research institute report (The energy and environment research institute, 2020). In other words, the results of the present article can be used as one of the most important tools for comprehensive planning for the correct and efficient use of electricity and the correct direction of investments to meet electricity demand. It is very important to have a valid scientific estimation basis for determining the energy tariff and corresponding policies from the country's development perspective. Also, the results of this article show the changes in energy prices compared to the current values and help policymakers to support different consumer groups with proper provident planning.

This article for the first time forecasts LRMC based on the latest energy development information of Iran and up to the year 2041. LRMC approximated concerning the international standard costs of different types of power plants and two different global and subsidized domestic fuel costs.

2. Literature review

According to the purpose of this paper, the previous studies directly conducted the long-run marginal cost (LRMC) will be reviewed. Of course, it should be noted that the literature related to LRMC is limited compared to the other methods, especially the short-run approach (Ziel and Steinert, 2018). Anderson and Bohman (1985) stated that the LRMC method should be used for growth in production and demand. Also, they expressed that LRMC is equivalent to dividing the total cost by the number of kilowatt-hours produced in the entire economic life of the power plant. The authors noted that long-run marginal cost pricing is the same as the average cost pricing in practice. (Valle, 1988), who was a senior consultant at national economic research associates in New York, considered the LRMC method a complicated but possible approach that depends on factors such as future capital cost, fuel sources, demand, interest rates and inflation. The author considered the stability of prices until the early 1970s as proof of the reliability of pricing calculations based on the long-run marginal cost method. Soldatos (1991) described a simple computational algorithm for estimating the final cost of electricity delivered to rural areas in Greece. In the article, the total cost was calculated by summation of adjusted running cost, adjusted annual generating capacity cost, adjusted transmission capacity cost and adjusted annual distribution capacity cost. Bakirtzis et al., (2001) investigated two geographically differentiated transmission usage tariffs based on the long-run marginal cost. In other words, the investment cost-related pricing and the DC load flow pricing were compared for transmission usage tariffs in the Greek power system. Davalloo (2002) presented the long-run cost of Iran's electricity through the optimal development program WASP for future ten years in the production sector. LRMC was estimated based on input parameters such as capital, fuel, fixed and variable O&M, and transmission and distribution costs. (The Marsden-Jacob consulting group, 2004) explained the LRMC concepts due to the increase of demand, such as demand and supply efficiency, fairness and objectivity, pricing stability, transparency, practicality and variability of time-dependent parameters in time horizon. Wang (2007) in his doctoral thesis, presented a set of new long-run pricing methods for broadcast and distribution networks and evaluation processes. In this thesis, the developed LRMC-DC method was used and compared to the corresponding LRMC-AC approach. The methodologies were demonstrated on distribution test network in the South Wales. Li (2007) proposed a novel method for LRMC pricing in network charges by utilizing of the unused capacity of an existing network. The proposed approach provides forward-looking charges that shows both the extent of the network needed to service and the degree to which that network is utilized (Li, 2007). Heng and Li (2007) reviewed the literature on the long-run cost pricing approaches, emphasizing both the National Grid's DC load flow ICRP and Bath LRIC models. Pierru (2007) investigated the relationship between long-term marginal cost and short-term marginal cost of a given product by an optimal capacity adjustment function. Aggarwal et al., (2008) presented the wavelet transform based neural network model to forecast price profile in an electricity market. Also, results were compared with IESO, MLR, NN, ARIMA, DR and TF models. Aggarwal et al., (2009) reviewed its previous papers based on three main methodologies: stochastic time series, causal models and artificial intelligence based models. Also, this survey article studied some important parameters such as forecasting time horizon, input and output variables and architecture of each model. Gu and Li, (2011) presented a novel long-run marginal cost pricing methodology to reflect the impacts on the long-run costs imposed by a nodal injection through sensitivity analysis. They compared the LRIC and LRMC approaches and subsequently concluded that the proposed LRMC saves significant computational time to similar results with that of LRIC for most operating conditions. Tooth (2014) from the Australian economic consulting group explained the strengths and weaknesses of using the long-run marginal cost method. Also, issues and implications of pricing at LRMC, such as price variability, uncertainty and variation in supply and demand, equity and consumer acceptance of usage prices, were discussed. Weron (2014) reviewed survey articles based on their forecasting horizons and modeling approaches. Weron (2014) studied the complexity of available solutions such as multi-agent, fundamental, reduced-form, statistical, computational intelligence models and their combinations to investigate the strengths, the weaknesses, the opportunities and threats of each model. Ekwue (2014) reviewed recent applications of the LRMC technique based on practical networks of the United Kingdom, Greece and Oman. Ekwue (2014) concluded that the average incremental cost (AIC) technique is easier to implement and explain than the marginal incremental costs (MIC) because of its price stability. Biskas et al., (2015) calculated the LRMC for high-voltage consumers by the perturbation approach. Biskas et al., (2015) used the product development planning model to calculate the optimal production capacity development plan that can cover the future increased demand. The estimation was done using data from five high-voltage consumers in Greece for a planning period of 20 years. Furthermore, marginal capacity cost and marginal operating cost were studied in various cases. Nunn et al., (2015) presented three main methods and their corresponding formulas for calculating the long-run marginal cost: the perturbation approach, the average incremental cost approach and Greenfields. The authors recommended the average incremental cost approach to one of Australia's state-owned electricity infrastructure companies to estimate the LRMC of each of its services. Ziel and Steinert (2018) introduced a new approach to simulate electricity prices and provide probabilistic forecasts up to three years. They found that using the supply and demand based model in the long-run leads to realistic patterns and promising results. Also, they reviewed and categorized some previous articles them with respect to markets, inputs, models and accuracy measurements. Reichelstein and Sahoo (2018) developed a model framework and an empirical inference procedure to estimate the long-run marginal cost in solar photovoltaic industries where production costs decline over time. Sedaghati (2021) used the modified long-run marginal cost to create the economic signal for future investment. UK's practical distribution network was used to simulate and illustrate the theoretical and practical principles of the proposed solution. Results showed that the price of the proposed solution involves not only the future development costs of the network but also the distance between production and consumption and shows the factors that affect network tariffs.

Based on the next part of this article (Theory section) and the concept of LCOE, some recent corresponding literature are reviewed, either. Rusman Sinaga et al., (2019) presented a modeling and analysis of the LCOE related to solar Photovoltaic power plants of the Republic of Indonesia, especially in Kupang Regency. The results of PV modeling showed the maximum level of 0.24 US$/kWh by 2030. Lee and Ahn (2020) used the stochastic approach to estimate the LCOE for solar photovoltaic in South Korea. Their results indicated that the LCOE ranged from KRW115 (10 cents)/kWh to KRW197.4 (18 cents)/kWh. Also, Lee and Ahn (2020) presented a sensitivity analysis to show that capital expenditure has the most significant effect on the LCOE estimation. (Veronese et al., 2021) defined a general methodology to estimate integration costs PV by LCOE for the future Italian energy system. They estimated Italian PV LCOE in 2030 ranged from 12.55 to 15.93 €/MWh. Bastiani et al., (2023) evaluated the LCOE and investigated the important parameters such as performance, stability, manufacturing costs and temperature effects.

3. Model

Not only is LRMC forecasting a complicated method, but also it depends on time-varying parameters. Therefore, corresponding articles analyzing this concept is limited. In other words, researchers are less interested in this topic due to the possibility of changing essential variables used in LRMC estimation. LRMC is defined as the cost of supplying an additional unit (Tooth, 2014). The perturbation, the average incremental cost and the stand-alone cost approaches are three methods to estimate the electricity long-run marginal cost. Considering the existence of the network in Iran and the energy and environment research institute report (The energy and environment research institute, 2020), both perturbation and stand-alone cost approaches can’t be used. In other words, the predicted increasing trend of electricity demand in Iran makes us calculate and forecast the LRMC by the average incremental cost (AIC) approach (Tooth, 2014).

The AIC method estimates the LRMC of network services as the average change in projected operating and capital expenditure attributable to future increases in demand (Nunn et al., 2015). LRMC can be calculated via the AIC approach by the following relation (Nunn et al., 2015):

$$LRMC = \frac{PV(\text{expenditure } related\ to\ new\ network\ capacity)}{PV(\text{additional demand serviced})} \tag{1}$$

According to the above relationship, the present value of both additional electricity generation and its costs should be estimated in the base year. Based on the energy and environment research institute report (The energy and environment research institute, 2020), various power generation technologies have been scheduled with different characteristics. Since the calculation of electricity generation cost in each power plant type is dependent on fundamental parameters such as capital cost, fixed and variable O&M cost, capacity factor, construction period and life of power plant, and also, these characteristics are different between various generation technologies, therefore there should be a similar method to estimate LRMC at base year. LCOE (levelized cost of electricity) is conceptually similar to LRMC and defined as the net present value of the power plant's generation total cost divided by the net present value of power generation over the plant's lifetime (Goswami et al., 2022). Equation (2) shows the corresponding relation to calculate the LCOE (Goswami et al., 2022):

$$LCOE = \left(\begin{array}{c} \sum_{t=1}^{t_1} \frac{KC_t + IDC}{(1+r)^t} + \sum_{(t_1+1)}^{(t_1+PL)} \frac{ICC}{(1+r)^t} + \sum_{(t_1+1)}^{(t_1+PL)} \frac{OM_f}{(1+r)^t} + \sum_{(t_1+1)}^{(t_1+PL)} \frac{OM_v}{(1+r)^t} + \\ \sum_{(t_1+1)}^{(t_1+PL)} \frac{FC_t}{(1+r)^t} + \sum_{(t_1+1)}^{(t_1+PL)} \frac{RE_t}{(1+r)^t} + \sum_{(t_1+1)}^{(t_1+Loan\ sched.)} \frac{DC_t}{(1+r)^t} - \sum_{(t_1+1)}^{(t_1+TB\ sched.)} \frac{TB_t}{(1+r)^t} + \frac{DCOM}{(1+r)^{(t_1+PL+1)}} \end{array} \right) / \sum_{(t_1+1)}^{(t_1+PL)} \frac{TPG}{(1+r)^t} \quad (2)$$

Table 1 illustrates the parameters used in Equation (2). The levelized cost of electricity is the minimum price at which the energy produced in a project must be sold. LCOE is calculated during the power plant's lifetime and is expressed in currency per kilowatt-hour or megawatt-hour.

Table 1. Description of the parameters of the Equation (2)

Variable	Description
KC	Capital cost of construction
IDC	Interest payment during construction period
ICC	Incremental capital cost starting from (t_1+1) to the end of plant life
OM_f	Fixed O&M cost starting from (t_1+1) to the end of plant life
OM_v	Variable O&M cost starting from (t_1+1) to the end of plant life
FC	Fuel cost starting from (t_1+1) to the end of plant life
RE	Return on equity starting from (t_1+1) to the end of plant life
DC	Cost of debt starting from (t_1+1) to the end of loan schedule
TB	Tax benefit of deprecation of power plant starting from (t_1+1) to the end of its schedule
DCOM	Decommissioning cost of the power plant at ending of plant life

Variable	Description
TPG	Total electricity produced over the life span of the plant from (t_1+1) to the end of plant life
APG	Annual power generation
r	Discount rate
t_1	years of the construction period
PL	Power plant life
t	time

Source: Goswami et al., (2022)

The energy and environment research institute only reports Iran's necessary demand for the vision and doesn't describe the details of desired developments (The energy and environment research institute, 2020). In other words, specifications, such as the number of power plants, their technology level and the possible investment method, have not been detailed. Therefore, the authors of the present article use the total capacity needed and the scheduled power plant types to estimate the LRMC. According to limitations and a lack of real-life data on planned power plants, Equation (2) is simplified and used as follows:

$$LCOE = \left(\sum_{t=1}^{t_1} \frac{KC_t}{(1+r)^t} + \sum_{(t_1+1)}^{(t_1+PL)} \frac{OM_f}{(1+r)^t} + \sum_{(t_1+1)}^{(t_1+PL)} \frac{OM_v}{(1+r)^t} + \sum_{(t_1+1)}^{(t_1+PL)} \frac{FC_t}{(1+r)^t}\right) / \sum_{(t_1+1)}^{(t_1+PL)} \frac{APG}{(1+r)^t} \tag{3}$$

Where, KC_t, OM_f, OM_v and FC_t at the numerator of the fraction are capital cost of construction, fixed and variable operation and maintenance costs and fuel cost, respectively. Also, *APG* at the denominator is annual power generation of the plant or total electricity produced over the life span of the plant.

Therefore, LCOE is estimated based on capital cost, operation and maintenance cost and fuel cost. Finally, power generation's LRMC is forecasted by the ratio of each power plant's electricity generation in each scenario from the following relationship:

$$LRMC = \sum_{i=1}^{n} (LCOE_i \times PGR_i) \tag{4}$$

Where PGR_i and n are power plants' generation share and number according to the desired set in the base year for each scenario. The values of PGR_i are mentioned in Table 2. In other words, by multiplying the ratio of the predicted annual production of each power plant technology to the total production capacity in its corresponding levelized cost of electricity, and adding the resulting values related to different power plants, power generation's LRMC will be forecasted. Table 2 represents the quantities of variables of Equation (3) based on the energy and environment research institute report (The energy and environment research institute, 2020). Fixed O&M costs include labor, materials, contracted services for maintenance, and general and administrative costs. Also, variable O&M costs include ammonia, water, and chemical consumption. According to the energy and environment research institute report (The energy and environment research institute, 2020), the use of fuel oil and diesel fuel should be stopped from 2020 onwards. As a result, natural gas is assumed as the only fuel consumed by the power plants in this research. Considering the abundance of natural gas resources in Iran, its domestic price has been set very cheap and with government subsidies. Therefore, the natural gas price is considered 0.00235 cents per kilowatt-hour for the domestic price (Ziel and Steinert, 2018), and 14.6 cents per kilowatt-hour for the global price (Reichelstein and Sahoo, 2018). To convert the subsidized fuel price, each US Dollar is considered 400,000 Rials. Furthermore, the discount rate is set at 5% in LRMC calculations.

Table 2. The quantities of variables of Equation (3)

Power plant type	**Construction period (year)**	**Power plant life (year)**	**Capacity factor (%)**	**Capital cost ($/kW)**	**Fixed O&M cost ($/kW-year)**	**Variable O&M cost ($/MWh)**
Steam	4	30	80	3676	40.58	4.50
Gas	2	20	70	713	7.00	4.50
Combined-Cycle	3	40	75	958	12.20	1.87
Wind	2	20	30	1265	26.34	0.00
Solar	1	25	22	1313	15.25	0.00
Nuclear	9	60	98	6041	121.64	2.37
Geothermal	6	35	85	2521	128.54	1.16
Biomass	2	25	80	4339	174.00	1.90
Hydroelectric	3.5	30	16	1350	13.50	0.00
Coal	4	40	80	2690	129.70	2.00

The energy and environment research institute, (2020)

Based on the energy and environment research institute report (The energy and environment research institute (2020), the total transmission and distribution costs for new capacity of the base year 2026 have been calculated at 1.16 and 0.96 cents per kilowatt-hour for two scenarios S1 and S2, respectively. It should be mentioned that there aren't any exact data on transmission and distribution costs for other base years of the vision 2041. Therefore, LRMC will be estimated and reported for all base years 2026, 2031, 2036 and 2041 based on generation cost and for the base year 2026 based on the summation of generation, transmission and distribution costs.

4. Analysis of the results

According to the report of the energy and environment research institute (The energy and environment research institute, 2020), the perspective of electric demand and necessary power plant development of Iran was established for 5-year periods up to the year 2041 in the scenario of continuing the current trend with frugality (S1) and the high growth scenario with frugality (S2). Based on this report (The energy and environment research institute, 2020), the AIC approach will estimate LRMC concerning the predicted increasing trend of electricity demand in Iran. Using Table 2, natural gas price and discount rate value explained in the previous part, corresponding LCOE of different power plant technologies are determined concerning domestic and global fuel prices.

Table 3 indicates calculated values of levelized cost of electricity for scheduled power plant types via the substitution in Equation (3). Results show that LCOE for technologies such as steam, gas, combined-cycle and coal types depends on fuel price. In other words, there is a direct relation between LCOE and fuel price for the mentioned technologies. Based on global fuel price, the estimated values for LCOE for this group is much higher than others.

Table 3. Levelized cost of electricity for scheduled power plant types ($/kWh)

Power plant type	Based on domestic fuel price	Based on global fuel price
Steam	0.040572	0.186540
Gas	0.014348	0.160316
Combined-Cycle	0.011473	0.157441
Wind	0.045933	0.045933
Solar	0.053951	0.053951
Nuclear	0.052970	0.052970
Geothermal	0.035915	0.035915
Biomass	0.065671	0.065671
Hydroelectric	0.065837	0.065837
Coal	0.042870	0.188838

In the next step, LRMC is predicted in each scenario using Equation (4) and the values in Table 4.

Table 4. The planned power generation ratios of different technologies of Iran for scenarios S1 and S2 in 5-year periods up to the year 2041 (percentage)

Power plant type	**Scenario S1**				**Scenario S2**			
	2026	2031	2036	2041	2026	2031	2036	2041
Steam	13.46	9.57	6.95	4.12	11.29	6.84	4.22	1.91
Gas	22.22	21.10	13.77	13.84	21.03	18.85	13.97	21.33
Combined-Cycle	38.49	39.23	41.45	42.70	39.75	41.49	43.17	37.20
Wind	3.47	3.07	2.55	0.55	2.91	2.20	1.55	0.26
Solar	6.82	11.33	17.76	21.25	10.32	16.24	22.00	24.60
Nuclear	1.01	1.81	2.39	2.09	0.85	1.30	3.40	3.91
Geothermal	0.00	0.00	0.00	0.00	0.00	0.00	0.005	0.02
Biomass	0.02	0.00	0.00	0.00	0.03	0.02	0.005	0.63
Hydroelectric	14.51	13.89	15.13	15.45	13.82	13.06	11.68	8.84
Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30

The energy and environment research institute, (2020)

Table 5 shows predicted electricity demand values for these two scenarios and in 5-year periods up to the year 2041.

Table 5. Predicted annual electricity demand values of Iran for scenarios S1 and S2 in 5-year periods up to the year 2041 (TWh)

Year	**Scenario S1**	**Scenario S2**
2026	322.9	390.05
2031	363.25	515.21
2036	413.41	702.34
2041	481.7	995.16

The energy and environment research institute, (2020)

Tables 6 presents the power generation's LRMC in each base year for 5-year periods up to the year 2041 and in the scenario of continuing the current trend with frugality (S1) and the high growth scenario with frugality (S2). Comparing the LRMC results based on the generation and domestic fuel price shows an incremental trend in the time period of vision. While the LRMC results based on the generation and global fuel price indicate a decreasing trend. To investigate the difference in these trends, it is necessary to pay attention to the changes in the contribution of each type of power plant technology in the adopted layout of the report of the energy and environment research institute (The energy and environment research institute, 2020).

Table 6. LRMC of power generation (cent/kWh)

Year	Based on domestic fuel price		Based on global fuel price	
	Scenario S1	Scenario S2	Scenario S1	Scenario S2
2026	2.97	2.97	13.01	12.81
2031	3.00	3.02	12.62	12.27
2036	3.20	3.11	11.98	11.83
2041	3.21	3.21	11.75	10.99

Considering the cheap domestic fuel price, the levelized costs of electricity for fossil fuel technologies are equal to or less than renewable energy technologies. Also, the growth of renewable power plants' share is considered a policy on the horizon of 2041. Therefore, based on domestic fuel price, by increasing the share of energy generation by renewable power plants, LRMC will increase too.

For example, the levelized cost of electricity for a steam power plant in the state of calculation based on the domestic fuel price is calculated as 4.05 cents per kilowatt-hour, while the corresponding value based on the global fuel price is equal to 18.65 cents per kilowatt-hour. In comparison, the levelized cost of electricity for the solar power plant for both domestic and international fuel prices is the same and calculated as 5.39 cents per kilowatt-hour. In other words, considering the cheap domestic fuel price, the trend of long-run marginal cost changes of electricity production in the twenty-year horizon is increasing, while considering the global fuel price, this trend is inverse and decreasing.

Based on the energy and environment research institute report (The energy and environment research institute, 2020), the total transmission and distribution costs for the base year 2026 have been presented at 1.16 and 0.96 cents per kilowatt-hour for two scenarios S1 and S2, respectively. Therefore, LRMC is reported in Table 7 for the base year 2026 as the summation of generation, transmission and distribution costs. The values estimated in Tables 6 and 7 are policy criterions for electricity pricing.

Results of table 7 estimates the minimum of LRMC for the base year 2026 as 3.93 and 13.77 c/kWh respect to domestic and global natural gas price, respectively. Based on Iran's electricity tariffs (Iran’s Ministry of Energy), the average price was approximately 900-1000 Rials per kWh (0.25 cc/kWh). Therefore, the electricity tariffs can be increased from 0.25 to 3.93 c/kWh. In other words, without changing the domestic fuel price, the electricity price will show at least 15.70 incremental trend in less than four years. Meanwhile, if the global fuel price is included, the electricity tariff for each kilowatt-hour in 2022 will increase from 0.25 cents to a minimum amount of 13.77 cents in 2026, which presents 54.08 incremental trend.

Table 7. LRMC based on the total generation, transmission and distribution (cent/kWh)

Year	**Based on domestic fuel price**		**Based on global fuel price**	
	Scenario S1	**Scenario S2**	**Scenario S1**	**Scenario S2**
2026	4.13	3.93	14.17	13.77

LRMC sensitivity analysis to discount rate variation is presented in Fig 1. Global fuel price and scenario S1 are used for this analysis. The figure represents the corresponding LRMC for the discount rate range of 1, 5, 10 and 15%. Based on the results, increasing the discount rate tends to increase the LRMC of electricity generation. The obtained results agree with and are similar to the literature (NEA, 2020).

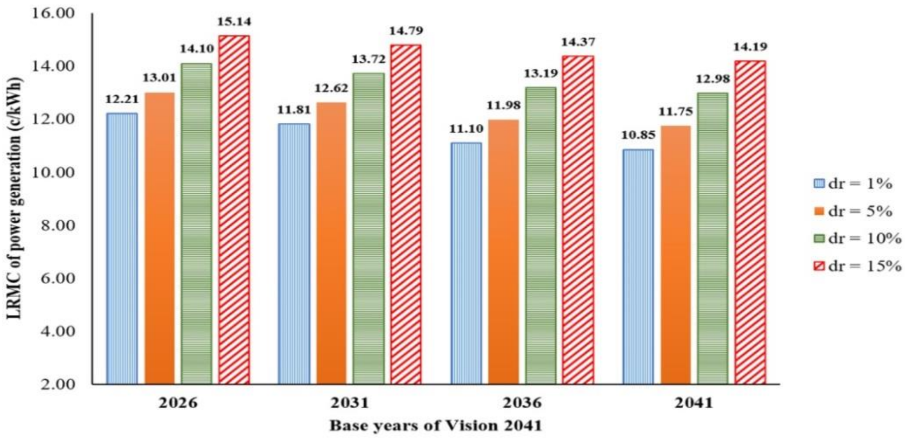

Fig 1. LRMC sensitivity analysis to the discount rate values 1, 5, 10 and 15% based on global fuel price and the scenario of continuing the current trend with frugality.

5. Discussion

In Iran's economy, energy carriers, especially electricity, are subject to subsidies, and the government provides electricity to the people at a price far lower than its cost price, and therefore always incurs heavy costs to provide hidden subsidies. Based on Fig 2 which shows household electricity prices of different countries, Iran is the second country with the cheapest electricity price. Subsidy by preventing the optimal resources allocation makes reducing economic growth and budget deficit. According to the law on the targeting of subsidies, the government is obliged to liberalize the prices of all types of energy carriers, including electricity, in a phased manner, and this liberalization always acts as a shock and this shock will have many effects on the electricity demand. Therefore, the change in the price of electricity and its increase is one of the issues that influence the change in the financial flow of the electricity industry. The low price of electricity in the household budget has caused consumers to consume electricity unnecessarily, and as a result, electricity consumption in Iran is higher than the world average. The fact that the price of electricity is not realistic causes many problems including the budget deficit of the electricity industry operators and the impossibility of a stable supply of electricity and subsequent blackouts. Considering the great importance of electricity in people's lives, the correct pricing helps the development of the economic development.

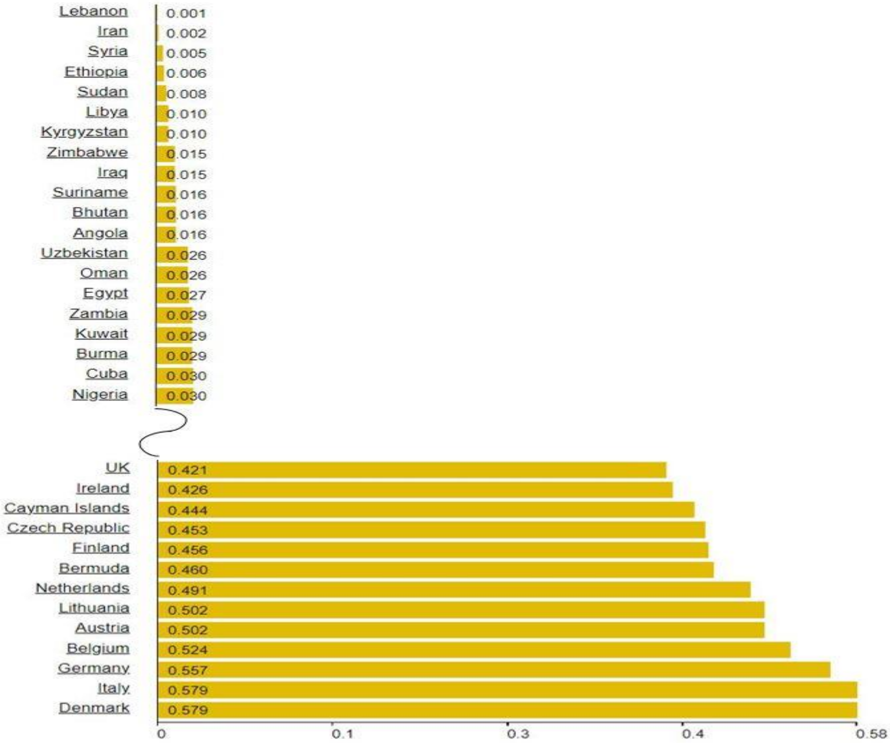

Fig 2. Household electricity prices of different countries based on US$ per kilowatt-hour, (GlobalPetrolPrices.com, September 2022).

Based on 2023 Iran's electricity tariffs in table 8, the average electricity price is approximately 1060 Rials per kWh. This article's results predict a minimum increase of 15 and 54 times in the electricity price concerning subsidized domestic and international fuel-based prices up to vision 2041. Increasing the availability and transparency of energy subsidy data is necessary to overcome some of the challenges related to price corrections. The government should sustainably support domestic and international investors. Also, the pre-announcement of strategies and the time frame for the gradual modification and support of the infrastructure should be compatible with each other. Furthermore, the government's commitment to compensate the vulnerable groups should be valid and obvious. Groups that will be most affected by subsidy amends should receive subsidies in some way. The subsidy should be significant enough to mitigate the adverse effects that may occur, especially in the initial post-amend period. In this regard, it is important to use successful models with regional similarities. In other words, financial aid is usually cash payments and incentive discounts such as low-interest loans that are paid or provided by the government to producers, and these policies should be used to support new technologies. Also, vulnerable consumer groups should be protected from the sudden rise in electricity prices in the form of support programs under the supervision and management of optimal consumption methods.

Table 8. Electricity tariff for Iran's household customers for 2023 (Rial/kWh)

Consumption type	Minimum	Maximum
Conventional consumption of normal areas	686	1721
High consumption of non-hot months in normal areas	913	15488
Hot months in the tropics	305	12390

(https://tariff.moe.gov.ir/)

International sanctions and domestic economic instability are the most important constraints to achieving the vision 2041 of Iran's electricity sector. In other words, these constrains prevent the attraction of domestic and international investors. By removing the mentioned obstacles and preparing the necessary foundation, the results of this study can be used as prospective indicators of electricity prices through the economic development path.

6. Conclusions

Electricity pricing based on generation, transmission and distribution costs is an important issue for the development of political economy programs in countries. As a result, determining the minimum basis for electricity prices will provide a diagnostic criterion for politicians and legislators. The authors of the present article estimate the long-run marginal cost of Iran's electricity based on the predicted demand of vision 2041. According to the energy and environment research institute report (The energy and environment research institute, 2020), two scenarios of continuing the current trend and the high growth with frugality were defined by an average annual GDP growth rate of 4.2 and 8 percent, respectively. Also, total power generation and the share of each power plant type was scheduled for base years in vision. The AIC approach and LCOE concept are used to forecast the LRMC for all base years 2026, 2031, 2036 and 2041 based on generation cost and for the base year 2026 based on the summation of generation, transmission and distribution costs. The effects of fuel price and discount rate variations are investigated in this study.

Results show a direct relation between LRMC and the fuel price. Based on domestic subsidized fuel prices, by increasing the share of energy generation by renewable power plants, LRMC will increase too. Concerning domestic and global fuel prices, the electricity price will show at least 15 and 54 incremental trends in less than four years, respectively. To avoid mandated pricing and modify the economic structures of the electricity industry, the pre-announcement of electricity price increments, corresponding strategies and the time frame for the gradual modification should be forecasted based on presented results. Also, the government should support investors, manufacturers and consumers with stable plans. Investigating the successful similar economies can help to overcome obstacles. After overcoming international sanctions and domestic economic instability, this article's results can be used as prospective indicators of electricity prices through the economic development path.

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