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Economic Evaluation of Urban Lighting LEDification in Iran

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Abstract

Due to the low cost of energy in Iran, as one of the world's largest oil and gas producers, any private sector investment to optimize energy consumption will lack economic reason. However, high energy consumption within Iran reduces the quantity of gas exports to other countries and the prospect of exporting electricity to Iraq. In other words, the opportunity cost of surplus gas and electricity utilized within Iran is equivalent to its global price. Therefore, government-implemented efforts to reduce energy use are economically justifiable. Among these plans is the LEDification of city roadways, which will significantly reduce electricity consumption. This paper describes in detail the economic evaluation of this plan's implementation of a 4-year plan and a 10-year financial horizon. The results indicate the presence of an economic advantage. Additionally, the paper includes information regarding the recovery of metal scraps from obsolete light fixtures and the decrease of carbon emissions.

Keywords: energy, lighting, LED, urban roads, LEDification
Jel codes: R59, Q48, H41

1. Introduction

Iran possesses one of the world's greatest natural gas deposits. The electricity industry in this country has become nearly indigenous, and CNG is the energy source for electricity production. Despite the involvement of private sector firms in electricity production, the government maintains a monopoly on electricity distribution and sale. In addition, the government has exclusive ownership of the countries' gas resources. Despite Iran's large CNG gas reserves, which cannot be exported due to international sanctions, the Iranian government delivers one of the cheapest types of electricity in the world to Iranian households and companies, regardless of the cost of CNG and subsidies provided to electricity providers. The average price per kilowatt-hour of energy for homes in Iran is about 0.01€, whereas the price of electricity in Italy is about 0.31€. The price of electricity in Iran is far less than its production cost. Although an amount of natural gas is required to produce each kilowatt of electricity, the government pays power producers 0.018 € per kilowatt to convert gas into electricity. It means not only that the government provides natural gas to power plants for free, but also gives them subsidies. At the time of writing this paper, Iran had the cheapest energy prices in the world. The price per liter of gasoline is less than 0.05€ per liter. It means that in Iran, approximately 600 kilometers can be driven for 2.5€.

Energy subsidies are one of the largest government expenses in Iran, and as a result, periodic energy price adjustment policies are enforced in Iran. Iran, for instance, implemented one of these policies regarding the price of energy in 2019. However, as a result of the United States' exit from the JCPOA, the exchange rate in Iran surged dramatically. That is after four years, the exchange rate has climbed approximately tenfold, while the price of energy, such as electricity has remained unchanged.

As previously stated, the price of electricity is so low relative to the investment cost that practically no plan can be cost-effective for reducing electricity consumption costs. However, in a country with enormous natural gas resources and low-cost energy production, this event is not out of the question. Nonetheless, international sanctions have reduced infrastructure investments in the building of energy capacity from 2018 to 2022, and Iran's energy supply (combination of gas and electricity) during peak periods falls short of Iran's requirements. In the past, August was the only month during which the supply fell short of the demand. Currently, however, the demand for power during summer evenings exceeds the supply due to a lack of supply, climate change, the warming of various regions, and the availability of cooling equipment. Winter nights are another season when energy use is at its greatest. Due to rising CNG use, there is not enough CNG to inject into power plants, petrochemical industries, etc. Therefore, the policymaker must first lower the quantity of gas pumped into industry, then reduce the amount of gas injected into power plants, causing blackouts, and finally ration the distribution of CNG for home consumption.

There are four primary factors to consider when selecting a street LEDification plan. First, the LEDification falls under the jurisdiction of the public sector. Due to the low price of electricity, there is little economic motivation for the private sector to participate in LEDification, as the advantages of lowering electricity consumption can never recoup the cost of purchasing new light fixtures. This problem worsens as the interest rate exceeds 10%. The second reason why LEDification has an immediate effect on lowering the energy crisis is that energy usage decreases immediately after installing new light fixtures. Other solutions to the energy crisis, such as the construction of a power plant, need a significant amount of time to implement and cannot be considered quick answers. Thirdly, LEDification is one of the investments whose value added is developed domestically to the greatest extent. This form of investment will result in minimal foreign currency withdrawals compared to other options. The fourth reason is that experience from 2019, 2020, and 2021 indicates that turning off city light fixtures is one of the quickest ways to reduce energy consumption on winter evenings with surplus gas demand and summer evenings with excess electricity demand. This study demonstrates that when the illumination on metropolitan highways is switched off, traffic accidents increase, security decreases, and economic growth decreases. Therefore, lighting in a city is neither a luxury nor an unneeded service, and there is no need to disconnect it if its energy consumption is lowered.

Typically, municipalities are responsible for street LEDification. In locations where municipalities have significant financial resources, extensive initiatives have been implemented for the LEDification of urban roads, as this move has a clear advantage for urban furniture. This list includes Tehran, Isfahan, Razavi Khorasan, Fars, and Mazandaran.

2. Literature Review

Multiple studies have investigated various facets of the topic of replacing high-energy-consuming gas light fixtures with LED lighting. In economic studies, among other things, the legitimacy of various plans and the environmental benefits of such an activity have been studied. In some studies, LEDification has been examined for specific applications, such as Filmotuva et al. (2017)'s investigation of LEDification for residential projects. In this study, the return on investment is estimated to be between four and ten years depending on the type of use and the price of electricity in Europe. In Hussin et al. (2020)'s study, the plan of using LED lighting in educational facilities was studied. The findings of this study indicated a 50% reduction in energy consumption. In the study conducted by Lakshmi & Sudha (2018), hospital and medical center illumination has also been evaluated.

However, among the studies that have particularly analyzed the investment of LED in the usage of roads or urban passages, we can note Campisi et al. (2018)'s evaluation of the replacement of Rome's old light fixtures with LED lighting. They indicated that in addition to the multiple benefits of LEDification in Rome, the high cost of investing in LED technology was a hindrance that challenged the project's economic feasibility, according to their findings. In their study, while listing the management benefits and controllability of smart lighting, they also emphasized the volatility of electricity rates. In the coming years, it is probable that electricity prices could rise, and in light of this uncertainty, they demonstrated that LED lighting in Rome will be cost-effective.

In the study by Islam et al. (2019), the environmental benefits of LED lighting and the role of this type of lighting in the sustainable development of Kazakhstan were outlined, along with the specifics of this sort of investment in three categories of workplace usage, residential use, and roadways. In this study, the present value of replacing lights in these three applications was computed, and their respective efficiency rates were compared. The efficiency rates for office-commercial use, residential use, and road use were 8.4%, 15.4%, and 21.8%, respectively. In other words, they demonstrated that street LEDification has more economic benefits than other sectors.

Since 2016, the Brazilian government has established LED lighting laws to replace light bulbs. Massare (2019), in analyzing this policy, demonstrated that reducing energy consumption was merely one of the benefits of LEDification. She indicated that the presence of heavy metals such as mercury in gas lamps was deemed a hazard to the environment. On the other hand, LED lighting substantially improves nighttime visibility. Regarding the cost of electricity in Brazil, Massare demonstrated that the price of electricity consumed with gas lamps would be $389, whereas this cost would be lowered to $65 with LED lighting.

In a new study, Thungtong et al. (2021) showed that LED lighting has the potential to integrate Internet of Things (IOT) technology, in addition to reducing energy usage. These lighting's transformers (smart drivers) will be able to be regulated online, enabling the intelligent control of the light output and energy consumption of these light fixtures. For instance, it is not necessary for the light fixtures to emit the same degree of brightness at all times, and they can be turned off during hours when there is no traffic. This study also lists a variety of additional benefits for regulating traffic and minimizing traffic accidents.

Even in countries where electricity is inexpensive, LEDification is on the agenda of policymakers due to the numerous benefits of LED lighting. According to the study by Galindo et al. (2022), the Ecuadorian government intends to replace more than 530 thousand old light fixtures with LED lighting by 2025. Currently, they consume around 5.3% of Ecuador's energy, which will be reduced to less than half with LEDification.

3. Data and Assumptions of the Plan

In Iran, there are around 9 million old urban light fixtures with sodium vapor, mercury vapor, and fluorescent light sources. Iran's Power Generation, Distribution, and Transmission Company (Tavanir) is the entity responsible for street lighting maintenance that was consulted to acquire the data used in this study. The variety of light fixtures utilized in this province is extensive, but for simplicity of studying, they can be categorized into four primary categories. The first group consists of 400-watt light fixtures illuminated by mercury vapor and sodium vapor. These light fixtures are utilized at high elevations and to illuminate vast roads and boulevards. The second group consists of 250-watt light fixtures used with mercury vapor or sodium vapor lighting. They are mounted at a medium height and are typically used to illuminate ring roads and medium-width city streets. The third group consists of light fixtures that are positioned at a modest height yet are utilized in locations where a great deal of light is required. Because of the existence of overhead cables, it is not practical to install a lengthy light fixture base in urban areas such as markets, busy roads, or streets, so this category of light fixtures is employed with lamps ranging from 110 to 175 watts. Unfortunately, there are no exact figures regarding the amount of low-power light fixtures installed in alleyways, which make up the fourth and largest group of light fixtures. Typically, these types of light fixtures consist of lamps suspended from metal shades or small compartments. This form of care shortens their lifespan and increases their maintenance costs.
The lifespan of the lamps used varies depending on the lamp's brand and quality, however based on an average usage of 11 hours per day for 365 days, the lamps of the above light fixtures must be replaced at least once every five years, which is a highly optimistic assumption. The research conducted by Principi & Fioretti (2014) has established parameters for determining the lifespan of light fixtures and also for equalizing their light intensity.

Table 1. Information on replaceable urban light fixtures in Iran

Group	Average power of the old lamp	Number	Amount of reduction in power consumption	Price of the replaced LED lamp (Million Tomans)
1	400	750,000	180	4,000,000
2	250	2,000,000	130	3,000,000
3	125	1,250,000	70	2,000,000
4	80	5,000,000	40	850,000

Source: Tavanir

Numerous aspects must be studied in order to assign the sort of LED lighting that can replace the aforementioned light fixtures. The required specifications include the height of the light fixture base, the luminous flux of the LED light fixture, the required angle of radiation, the required lumens on the road surface, the hue of the light, and the temperature of the warmest night of the year, etc. Given that the goal of this research is the economic appraisal of a project, technical elements that do not have a significant financial impact have been disregarded. By employing the worldwide lighting plan software DIALux, which comprises the products of an Iranian factory (Mazinoor), it is possible to select the type of replaceable product. The price of the selected light fixture can then be determined by referring to the pricing lists for the products of these two firms. It should be mentioned that Tavanir must approve the product brand for the installation of new lights on urban roadways. The most qualified brands is

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Mazinoor approved by Tavanir for all variations. Therefore, the price list of this company for the four essential lighting groups has been computed and is regarded an investment cost. In addition, the quantity of reduced electricity consumption is computed based on the technical parameters of the selected products.
Accordingly, 15,000 billion Tomans have been set aside to replace the complete number of selected light fixtures. This cash is required to build 9,000,000 light fixtures. According to the information received, 10% of the price of the light fixtures can be attributed to the cost of installation. After installing all of these light fixtures, 2,745 billion watt-hours of electricity will be saved. With an average 20% reduction in the transmission system and 5% internal power plant consumption, the total savings after all light fixtures are installed in one year and based on 11 hours of electricity consumption is 3,500 billion watt-hours per year. According to the efficiency of Iran's gas power plants, each cubic meter of gas is utilized to generate three kilowatts of electricity, resulting in a savings of around 1,153 million cubic meters of gas.[1] Taking into consideration the price of 15 cents per cubic meter of gas and the exchange rate of 32 thousand Tomans per dollar, the annual savings from the gas site for street LEDification in Iran is 5,535 billion Tomans.

Table 2. Results of project evaluation assumptions

The total amount of investment (billion Tomans)	The annual sum of gas savings after the project is done (billion Tomans)
15,780	5,535
Savings in lamp replacement (billion Tomans)	Revenue from the selling of old lamp's aluminum scrap (billion Tomans)
540	900

Source: Research findings

This investment can also be effectively evaluated using two additional datums. The usage of bulbs, the existence of vast chambers, and the necessity for reflectors necessitate the use of a great deal of aluminum in the construction of the older street light fixtures. According to the acquired information regarding the technical parameters of the four groups of obsolete light fixtures, more than 15,000 tons of aluminum scrap can be extracted. Yet, there is also the possibility of copper waste in magnetic transformers, as well as steel and used bulbs, but due to the diversity of these things and the questionable information, they have been excluded from the calculation. Considering the price of 60 thousand Tomans per kilogram of aluminum scrap, the sale of scrap aluminum will generate 900 billion Tomans in revenue. According to the price lists of lamp manufacturers, the cost of replacing a lamp every five years for four groups of old light fixtures will be around 14 billion Tomans. This cash is also intended as savings inside the plan. It is important to note that the lifespan of Tavanir-approved LED light fixtures exceeds 50,000 hours. In other words, LED street lighting will not require any maintenance or repair for 13 years.
Taking into account the limited possibilities for installing lighting fixtures, the most significant of which is the number of available lifts, we are allowed to install 50,000 light fixtures per week from a combination of four groups; therefore, 171 weeks are required to complete this action. Considering 48 working weeks, the replacement timeframe is four years.

4. Plan Evaluation

If we denote the price of LED light fixtures as P, the number of required light fixtures as Q, the quantity of electricity saved as Y, the efficiency rate of the power plant as ϑ, and the efficiency rate of the distribution network as ω, the amount of gas saved will be denoted by X, whose value is equal to Equation 1:

$$X = Y \cdot \vartheta \cdot \omega \qquad (1)$$

The cost of installing and changing the light fixture is S, which is proportional to its price, s. The revenue from aluminum recycling is M, and its ratio to the light fixture's price is given by m. The period needed to change the

[1]The efficiency of power plants and the quantity of gas consumed are supplied as fundamental data in Niroo Research Institute's project evaluations.

light fixtures is signified by F, whose measurement scale is monthly and is denoted by f. The justification plan's time horizon is denoted by T, and the monthly progression of time within the period is denoted by t. If t is greater than f, the project will evidently cost nothing. The total cost of the undertaking is C. In this manner, the plan's effectiveness will obtain by Equation 2:

$$R_t = \sum_{t=1}^{T} X_t \theta_t - \sum_{f=1}^{F} \frac{1}{F}(C) \qquad (2)$$

In the equation above, θ equals the selling rate of the CNG coupon, whose price can be determined on the market for energy and environmental optimization. Equation 3 is formed by decomposing Equation 2 into its components:

$$R_t = \sum_{t=1}^{T} Y_t \frac{\omega}{\vartheta} \theta_t - \sum_{f=1}^{F} \frac{1}{F}((1 + s - m(PQ)) \qquad (3)$$

Considering it takes 48 months to install and replace the light fixtures, the required cost is spread evenly over four years. The monthly investment amount has been reduced by the revenue from waste disposal. With the installation of light fixtures, however, the plan accounts for a receipt equal to one-twelfth of the annual electricity savings revenue. This amount will reach approximately 461 billion Tomans in month 48, including a gas price of 15 cents[2] and a dollar price of 32 thousand Tomans, which is less than the Nima dollar pricing. The plan also includes, as a lump sum in the month 48, the amount of money arising from the savings realized by replacing the light bulb. As shown in Chart 1, the monthly income of the plan exceeds the monthly investment cost in the 32nd month. The accumulation of 32 months of the prior investment cost is likewise repaid after 22 months, and by the 55th month, all of the project's expenditures have been entirely recovered, and a net profit resulting from reduced gas usage is realized.

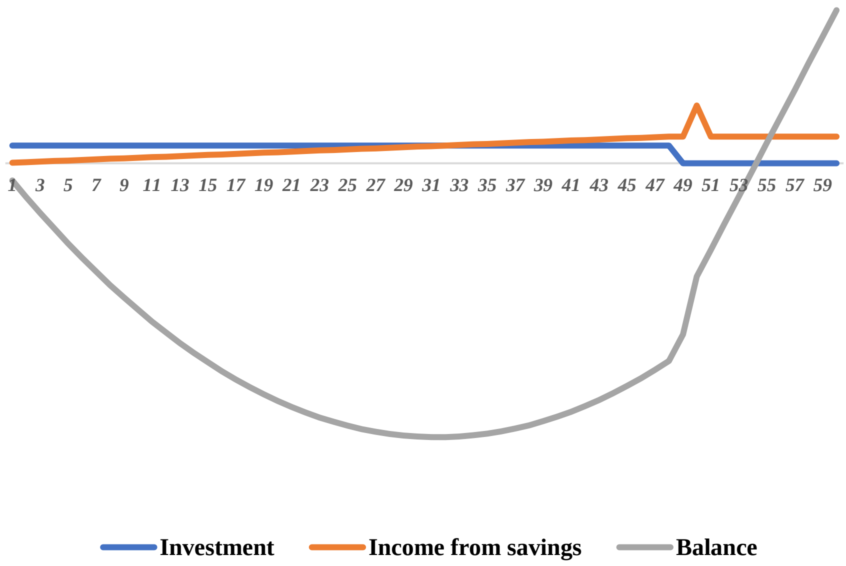

Figure 1. Cash flow of the plan
Source: Research findings

The plan will require a peak liquidity of 4,711 billion Tomans. This is another strength of the plan, as a credit line of only 4,711 billion Tomans is required for an investment of around 15,780 billion Tomans.

[2].It is significantly lower than the worldwide gas price and is the price that can be received for gas sales to petrochemical enterprises.

Table 3. Indices of economic evaluation of the plan with a discount rate of 14%

Period	NPV (billion Tomans)	IRR	Return on investment period in years
6-year	2,400	27%	
8-year	6,810	42%	5
10-year	10,193	44%	

Source: Research findings

Based on the cash flow arrangement outlined above and the discount rate of 18%, the project's net return in eight years is 6000 billion Tomans with a return rate of 40%. With a yield rate of 44%, the NPV will exceed 10,193 billion Tomans in ten years. With a 27% rate of return and a positive present value, this plan is economically advantageous even over a six-year period. In addition to economic savings, this plan offers other benefits. One of these instances is the decrease in environmental pollution resulting from reduced gas consumption. The second advantage is enhancing urban furniture and fostering economic growth. According to the research, LED lighting has increased foot traffic, and businesses have benefited from this issue owing to the establishment of high clarity and the formation of bright spaces. The third benefit is safety and fewer traffic accidents. Due to the current energy crisis in Iran, the first step the government takes to address the energy shortage is to turn off the electricity in the city streets. Evidence from the winter of 2020 and the summer of 2021 suggests that the turning off the urban roadways lighting has contributed to an increase in urban accidents and theft, which can be remedied with the use of energy-efficient light bulbs.

Another benefit of the LEDification plan is the creation of jobs in domestic factories. According to data collected from the Mazinoor factory, the production of the four types of street light fixtures described in the previous section generates an average of two labor-hours of employment. Taking into account the range of 48 months and 170 hours of productive labor per worker per month, this plan will create approximately 2,200 direct jobs in light fixtures factories. Clearly, the rise in production in these facilities will raise the need for suppliers of raw materials, thereby creating indirect employment. In addition, approximately 1,500 billion Tomans will be invested to install light fixtures throughout the province. This amount is sufficient to engage 1,000 service personnel, drivers, and electricians, as well as rent the equipment and lifts necessary to install 50,000 light fixtures per week for four years. Therefore, more than 3,000 individuals will be directly employed by this initiative. The economic evaluation of the project does not incorporate any of the five benefits listed above; instead, the evaluation is based simply on the quantity of gas saved. In the selection of rates, on the other hand, utterly pessimistic conditions were compared to the actual conditions. In other words, the benefit and effectiveness of the plan to replace the light fixtures will likely exceed the calculations of this study by a significant margin.

5. Conclusion

In brief, this research's preliminary findings indicate that there are more 9,000,000 aging urban light fixtures. These types of light fixtures typically utilize energy-intensive gas lamps. By replacing outdated light fixtures with LED lighting –whose replacement criteria and how to select the lights to be replaced are given in the text- annual CNG consumption will be reduced by 3.5 billion cubic meters. Consequently, environmental pollution will be decreased. More than 3,000 direct jobs will be generated, city furniture will be greatly improved, and the possibility of road blackouts, which hurt business growth, will be eliminated. This research is innovative and introduces new topics to Persian audience: first, the ability of LED lighting to improve Iran's energy consumption, which can be considered not only for roads, but also for industry and government. Secondly, attention is paid to the technical aspects of the LEDification project, which was compiled based on the field observations of this research, and thirdly, the use of the coupon from the energy optimization market approved in 2022 to finance the project is introduced, and this approach can be used by economic activists. This investment demands more than 1,500 billion Tomans, yet the savings from reduced electricity consumption are so negligible as to never justify this strategy. Using the solution provided by the market for energy consumption and environmental optimization, however, conserved CNG can be sold to significant customers, such as petrochemical companies, at a price close to its global rate. In other words, the contractor who will implement LEDification can sell the CNG saved to the region's

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primary users on the stock market. Utilizing such technology will economically justify the approach. The payback period will be about six years. In ten years, the rate of return will approach 43%. Regional limits and the ability to install 50,000 light fixtures per week determine the technique of project implementation. In the current state of Iran's energy crisis, increasing the supply of electricity and gas is a time- and resource-intensive endeavor that requires significant investment. However, these plans can immediately reduce consumption with a lot less investment.

Finally, it may be important to note that many laws and facilities in various domains, such as optimizing energy consumption, are passed annually in Iran, but only a specific and limited group is informed of these facilities, and few businesses are able to defend their plan, in addition to completing the requirements to use these facilities. Internet searches are sometimes used by economic activists and specialists to find evidence to support their economic plans. Universities and economic journals can make substantial advancements in this direction. Identifying, offering, and employing solutions for these types of facilities in scientific journals can lay the groundwork for cooperation and proximity between economic activists and universities as a reliable resource while pushing development projects.

References

Campisi, D, Gitto, S., Morea, D. (2017), Economic feasibility of energy efficiency improvements in street lighting systems in Rome, *Journal of Cleaner Production*, 175,190-198.

Filimonovaa, A., Barbasovaa, T. Shnaydera, D. (2017). Outdoor lighting system upgrading based on Smart Grid concept, *Energy Procedia*, 111, 678-688.

Galindo, S., Borge-Diez, D., Icaza, D. (2022), Energy sector in Ecuador for public lighting: Current status, *Energy Policy*, 160, 112648.

Hussin, M., Abdul Shukor, S., Md Sin, N., Yusof, Y., Muhammad Nor, Z., Abdul Rahman, N. (2020). Integration of LED-based lighting in academic buildings for energy efficiency considerations, *Bulletin of Electrical Engineering and Informatics*, 10(1), 93-100.

Islam, G., Darbayeva, E., Rymbayev, Z., Dikhanbayeva, D., Rojas-Solórzano, L. (2019), Switching-off conventional lighting system and turning-on LED lamps in Kazakhstan: A techno-economic assessment, *Sustainable Cities and Society*, 51, 101790.

Khorasanizadeh, H., Parkkinen, J., Parthiban, R., & David Moore, J. (2015). Energy and economic benefits of LED adoption in Malaysia, *Renewable and Sustainable Energy Reviews*, 49, 629–637.

Lakshmi, A., & Sudha, M. (2018). A Novel Approach to Using Energy-Efficient LED-Based Visible Light Communication in Hospitals, *Intelligent and Efficient Electrical Systems.*

Massara, V. M. (2019). *The replacement of tradiotional lamps by LED in Brazil: A case of environmental and economic sustainability (short review). Brazil: Department of Adjunct Researcher*, Polytechnic School, University of São Paulo.

Principi, P., & Fioretti, R. (2014). A comparative life cycle assessment of luminaires for general lighting for the office – Compact fluorescent (CFL) vs Light Emitting Diode (LED) – A case study, *Journal of Cleaner Production*, 83, 96–107.

Thungtong, A., Chaichan, C., Suwannarat. K. (2021), A web-based control system for traditional street lighting that uses high-pressure sodium lamps, *Heliyon*, 7, e08329.