

Review Article

Reduction of Coal Consumption by Using Municipal Combustible Waste as a Fuel in Cement Kiln with Special Focus on Hetauda Cement Industry in Nepal

Shyam Krishna Karki*, Khet Raj Dahal

Lumbini International Academy of Science and Technology, Lalitpur, Nepal

Email address:

cjanshyam1@gmail.com (S. K. Karki)

*Corresponding author

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Abstract: The paper aims to enlighten the financial benefits by reducing the coal consumption from use of municipal combustible waste as a fuel in cement kiln of Hetauda Cement Industry of Nepal. Hetauda Sub Metropolitan and Hetauda Cement Industries Ltd were selected for the present study and the study was conducted during the period from March to December 2019. Published literature such as reports, manuals, paper, database and thesis were collected from different sources and went on thoroughly. Conclusions were drawn on the basis of the studied materials. Depletion in nonrenewable source of fuel energy, mining costs and its mining difficulties and also environmental consideration, the greater efforts are given in inventions of alternative fuels. Most of the cement industries of developed country are following the use of alternative fuels. In this context, possibility of applying such fueling technologies in cement industries of developing country like Nepal are to be studied by considering economic, social and environmental aspects. This paper summarizes and reviews studies related to the use of alternative fuel in cement industries of different country with different benefits. In addition, this paper serves as a valuable reference for in-depth studies of use of combustible municipal waste of Hetauda Sub Metropolitan in Hetauda Cement Industry.

Keywords: Combustible Waste, Alternative Fuel, Energy, Coal, Cement

1. Introduction

After the hydropower and tourism, Nepal has a great potential in cement production sector due to the availability of huge amount of limestone mines in the country. It is found that about 7000 sq km area of Nepal is covered by mines of limestone [1]. Limestone, gypsum, iron ore and coal are the raw material required to produce cement. Limestone which is main ingredient of cement (60%-66%) is quarried from mines within Nepal itself but other ingredients like coking coal, gypsum and iron are used to import from other country mostly from India. In cement production process, powder of limestone is burnt in kiln above 1450°C to produce clinker. Huge amount of heat energy about 3000-6500 MJ is required to produce one ton of clinker by maintaining the cement kiln

temperature above 1450°C [2]. In Nepal, most of the cement industries are using coal to produce this heat energy in cement kiln. Production capacity of cement in 2014 is estimated to be 2.46 million MT which is expected reach 25.41 million MT by 2030 [3].

Cement industries are energy intensive, and they contribute significantly to national employment and gross domestic production. In Nepal, 77 cement industries are registered and only 15 have their own clinker producing facilities that means they have kiln and consumes coal as burning fuel [4]. Till now, 26 cement industries have been in operation with the capacity of 20 thousand tons of cement per day, and five new cement industries are under construction. Due to significant achievement in the development and operation of the cement industries, the import of cement has decreased by producing 4.5 million tons of cement (above 90% of demand) in the

country [5].

Main sources of energy used in the cement industries in Nepal are electricity and coal. Coal is mainly used in the kilns for calcination in limestone-based units and in some cases also used for electricity generation in plants having co-generation system. Approximate share of electrical energy used in Nepal's cement industry is 9%; thermal energy amounts to 91%. According to a baseline study in cement sector of Nepal energy cost of product value in limestone-based cement industries is with 48%. In clinker-based industries energy cost amounts to at least 5% of product value. Energy saving potential on the product cost is estimated to be Limestone based industry is above 19% [6].

The histories of Nepalese cement industries started with the installation of Himal Cement Industry of 160 TPD in 1975. After some time, next unit of 200 TPD was added with the financial support of China. Similarly, two big plants; Hetauda Cement Industries Limited of 750 TPD and Udayapur Cement Industries Limited of 800 TPD were established. In 2002 the Himal Cement Industry was stopped due to the environmental issues [4].

Hetauda Cement Industries Ltd. (HCIL) is one of the oldest cement industries established under the government of Nepal. The plant has cement production capacity of 750 TPD located at Hetauda Sub metropolitan-9. It has four mines named as Bhaise, Okhare, Majhuwa and Jogimara. Currently it is producing around 1,00,000 MT of cement annually and consumes about 22,000 MT of coal costing 42 crore rupees (USD 3.6 million) [7]. Coal mines in Nepal are not significantly developed and it will be of time and cost taken work. This is creating situations of exiting national currency for import of coal and environmental pollution. Development of various methods and techniques to short out this problem is use of alternative burning fuel rather than coal and it would be better that they are of waste, pollutants hazardous to environment [8].

2. Overview of Cement Industries in Nepal

The use of cement in Nepal as binding material came into effect from the beginning of early 1950s. Early users of cement were dependent on imports from India to meet their needs. The history of cement in Nepal dates back to 1970 when Himal cement factory established. The cement was mostly imported from India china, South Korea (space), North Korea, Burma, Indonesia, Thailand, Hong Kong and many other countries before the establishment of Himal cement factory in the Kathmandu valley in 1972. The restoration of democracy in 1990 gave the first initial thrust to the cement industry in Nepal and the industry started growing at a fast rate in terms of production, manufacturing units, and installed capacity [9].

The overall industry (production of cement) has been growing at around 10% annually. There is currently a shortfall in domestic production to meet the increasing demand for

cement, creating ample opportunities to exploit existing cement grade limestone and establish more cement and allied industries in Nepal. The profitability of the cement sector can be gauged by the possible entry of four foreign cement manufacturers, which have obtained approval from the Investment Board Nepal (IBN) for foreign investment with cumulative expected investments of approximately USD 1.5 billion as at December 2016 [10].

2.1. Status of Energy Consumption in Cement Industries of Nepal

It is considered that, the optimum energy consumption in cement manufacturing process is 105 kWh/Ton of cement and 750 Kcal/kg (3.138 MJ/kg) of clinker in limestone-based industries standardized by Energy Efficiency Centre, Nepal. Similarly, in clinker based industries the standard energy consumption is 35 kWh/T of cement. But, it was estimated that, the average specific energy consumption in limestone based industries are 148.56 kWh of electricity and 5.411 MJ/kg of thermal energy. Similarly in clinker based industries, the energy consumption is 48.69 kWh/T of cement [4]. From these we can estimate that the total coal consumptions in cement industries of Nepal are 2.7 million ton/annum costing NRs. 48 billion (USD 410 million) per annum.

2.2. Solid Waste Management Practices in Nepal

If we look towards the urbanization of Nepal, it is found that it is growing rapidly and haphazardly producing huge amount of waste and creating challenge in waste management work. Municipalities of Nepal are the major source of waste production.

The earlier practice of solid waste management by the city dwellers in the Kathmandu valley is not clearly documented. with (w should be smaller) a small population, low amount of industrial (space) activity inside the Kathmandu valley and with abandoned land available, the waste generated was dumped on the river banks on the outskirts of the urban core or collected, decomposed and used as organic manure in the agricultural field. The collection and disposal of these wastes was assigned to kuchikars, which in Nepalese means cleaners [11]. Nepal has big cities like Kathmandu, Lalitpur, Bhaktapur, Biratnagar, Birgunj, Hetauda, Bharatpur, Butwal etc. Hetauda is the capital city of Bagmati province having around 1,50,000 number of population. Nepal's largest industrial estate is located in Hetauda with area is spread up to 2829 ropanies and almost more than 80 number of industries are in operation condition. Waste management of this city is done by Hetauda sub metropolitan itself by disposing them in landfill site located in Bhutandevi Community Forest occupying 27,085 sq. m of land. About 12 tons per day of waste is disposed of at a distance of 1.5 km from the main city. Such practice is under operation since 2058 [12].

2.2.1. Waste Generation and Composition of HSM

The average HH waste generation rate in this municipality is 0.20 kg/person/day. This rate is same as the national

generation rate and it is lower than the waste generation rate of the capital Kathmandu, which is 0.39 kg/person/day. The daily waste generation of Hetauda municipality is 30.57 tons. The composition of waste at source was found to be: paper 12 percent, plastic 27 percent, rubber & leather 1%, organic waste 51 percent, glass 1%, metal 5 percent textile <1% and 3% others [12].

2.2.2. Waste Management Methods and Techniques of Hetauda Sub Metropolitan

Solid waste management in Hetauda is done by Hetauda Sub Metropolitan in correspondence with two organizations named Green and Clean City services Pvt. Ltd. and Clean the Nepal. It is doing by collection & segregation, primary transportation and transfer station, resource recovery methods (recycling, composting, special waste management) [12].

2.3. Classification of Fuels for Cement Kilns

a) Coal and petroleum coke

Coal is a complex polymer made up of carbon, hydrogen, oxygen, nitrogen and sulphur. It is a compact, aged form of biomass containing volatile matter, moisture and mineral matter. The chemical properties of coal depend upon the relative proportions of the chemical constituents present at deposition, the nature and extent of changes over time, and the presence of inorganic matter. Coal rank indicates the relative proportions of volatile matter (VM) and fixed carbon (FC) present in the coal [13]. Coal rank increases with decreasing VM. Typically, a medium rank coal consists of 40% VM and 60% FC, while a high-rank coal has about 10% VM. Petroleum coke is a high carbon content (90–95%), low hydrogen content, black solid residue obtained from the thermal decomposition and carbonization of petroleum-derived feedstock. It is a product of additional processing of the crude residue collected after refining crude oil. Coal and petroleum coke are the conventional solid fuels used in cement kiln burners for pulverized fuel combustion [13].

b) Alternative Fuels

Alternative fuels and alternative sources of energy usually fall under eight broad headings: biofuels; natural gas; waste-derived fuels; wind energy; hydroelectric power; solar energy; hydrogen; and nuclear energy. Alternative fuels discussed in this chapter are predominantly agricultural biomass, non-agricultural biomass (e.g. animal waste and by-products), chemical and hazardous waste, and petroleum-based fuels [14].

Biofuels are from organic origin (plants or animals based) including organic waste, residues from agriculture and energy crops, meat and bone-meal, methane from animal excrement or as a result of bacterial action, ethanol and biodiesel from plant materials, as well as the organic part of waste [14].

Candidate materials for the hazardous waste fuel/waste derived fuels are too many to list. They include almost every residue from industrial or commercial painting operations from spent solvents to paint solids including all of the wash solvents and pot cleaners, metal cleaning fluids, machining lubricants, coolants, cutting fluids, electronic industry solvents

(chlorinated/fluorocarbon solvents), oils, resins and many more. The list of candidate materials for use as alternative waste fuels continues to expand. Regulatory pressures, economic considerations, shrinking traditional solid waste disposal capabilities, and a host of similar factors are reflected in the constant change of the candidate waste fuel universe [15].

2.4. Use of MSW in the Cement Industry

Waste to fuel as “the use of waste materials in manufacturing processes for the purpose of energy and/or resource recovery and resultant reduction in the use of conventional fuels and/or raw materials through substitution [16]. This is also a concept in industrial ecology, related to the potential role of industry in reducing environmental burdens throughout a product’s life-cycle. The Basel Convention further defines co-processing as an operation “which may lead to resource recovery, recycling, reclamation, direct reuse or alternative uses”.

Waste as fuel has been practiced for more than 20 years, especially in developed countries/regions such as Europe, Japan, the United States, and Canada [17].

The European Integrated Pollution Prevention and Control Bureau has identified the following characteristics of cement production that allow for the co-processing of waste materials [18]:

- a) Maximum temperatures of approximately 2,000°C (main firing system, flame temperature) in rotary kilns
- b) Gas retention times of about 8 seconds at temperatures greater than 1,200°C in rotary kilns
- c) Material temperatures of about 1,450°C in the sintering zone of the rotary kiln
- d) Oxidizing gas atmosphere in the rotary kiln
- e) Gas retention time in the secondary firing system of more than 2 seconds at temperatures greater than 850°C; in the proclamer, correspondingly longer retention times and higher temperatures
- f) Solids temperatures of 850°C in the secondary firing system and/or the calciner
- g) Uniform burnout conditions for load fluctuations because of high temperatures and sufficiently long retention times
- h) Destruction of organic pollutants because of high temperatures and sufficiently long retention times
- i) Sorption of gaseous components like hydrogen fluoride (HF), hydrogen chloride (HCl), and sulfur dioxide (SO₂) on alkaline reactants
- j) High retention capacity for particle-bound heavy metals
- k) Short exhaust-gas retention times in the temperature range known to lead to de-novo synthesis of dioxins and furans
- l) Complete utilization of burnt waste ashes as clinker components
- m) No product-specific wastes because materials are completely incorporated into the clinker matrix (some European cement plants dispose of bypass dust)
- n) Chemical-mineralogical incorporation of nonvolatile heavy metals into the clinker matrix

Not all waste materials are suitable for co-processing in the cement industry. When wastes are selected for co-processing, several factors must be considered, including the chemical composition of both the wastes and the final product (cement) and the environmental impact of co-processing. Examples of wastes that are not suitable for co-processing in the cement industry are waste from nuclear industry, infectious medical waste, entire batteries, and untreated mixed municipal waste. GTZ/Holcim, 2006 gives a full list of waste materials suitable for co-processing [19].

2.5. MSW and Its Conversion into Energy

MSW constitutes a complex and very variable fuel due to their heterogeneous composition. The availability of the MSW makes it one of the most alternative fuels in cement manufacturing. Refuse-derived fuel (RDF) is the homogenous part of MSW and preferred as alternative fuel due to their high calorific value and low moisture content [20]. Over time, as the world population grows, the excess amount of MSW becomes an environmental concern, and cement industry seizes that opportunity to replace coal by the alternative fuel MSW.

Cement kilns are potentially the best option over incineration of MSW in thermal power plant and co-combustion in a biomass combustor. Generally MSW contains various components including plastic, paper rubber, wood, and textile [20].

The following process flow diagram, Figure 1 presents the activities that would need to be undertaken in the production of pellets from municipal wastes.

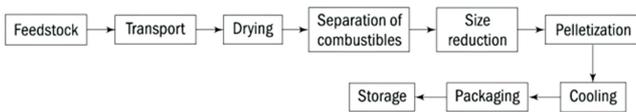


Figure 1. Production of pellet from municipal waste

Then MSW can be dried and pelletized to form dens RDF. MSW typically has a calorific value of 8–11 MJ/kg, while the calorific value of RDF ranges from 15 to 20 MJ/kg [20]. Belt conveyor is used to feed MSW or RDF directly to the burning zone. From environmental point of view, SO_x and NO_x emissions decrease when MSW is utilized in cement kiln [20].

2.6. Advantages of Alternative Fuels

One major environmental advantage of substituting alternative fuels in the cement industry is the reduction of waste disposal sites. As the consumption of goods increases to satisfy our consumer-driven life-styles, the manufacturing wastes also build up considerably [21]. As industries produce wastes such as oils, plastics, tires, etc., the environmental impact of landfilling or incinerating these wastes becomes a serious problem [22]. Landfills require large areas of land that may become unsightly and ecologically detrimental. The waste incinerators too are hazardous to the environment. Incinerators burn garbage, but do not use the heat generated; however a cement plant does the same thing while using the

heat generated to manufacture portland cement. Therefore a cement facility serves in both ways [23].

2.7. Disadvantages of Alternative Fuels

In order to make educated decisions concerning the use of alternative fuels in cement production, the disadvantages must be addressed and, if possible, overcome. Fundamentally, the co-firing of alternative fuels must be carried out under conditions guaranteeing total efficiency of combustion. Otherwise, problems associated with the quality of the product and/or environmental protection may occur [20]. Additionally, in order for alternative fuels to be implemented, many logistical problems such as fuel preparation and conditioning, storing, dosing, feeding, and burning must be overcome [24].

2.8. Effect of Municipal Combustible Waste on Clinker and Product Quality

The combustible solid alternative fuels contain ash in such amount that they can affect the mineralogical composition of clinker and so the cement quality. High levels of alkalis such as (K₂O and Na₂O) in cement can, in the presence of moisture, give rise to reactions with certain types of aggregates to produce a gel which expands, leading to cracking in concretes and mortars [25]. In order to maintain the kiln exhaust gas temperature and hence keep the clinker quality unchanged when replacing around 45% of the primary coal energy, production capacity may have to be reduced by 1.2% to 14.7% [25]. The waste materials used were solid hazardous waste (SHW), RDF, waste wood and liquid hazardous waste (LHW).

2.9. Financial Analyses of Using Municipal Waste as Alternative Fuel

The CMW is considered here as a stand-alone capital project: an initial investment that earns a net benefit over time through an annual net income or savings that occurs due to the project, which effectively “pays off” the initial cost of the project. The following three common methods for analyzing capital projects are used in this paper: net present value (NPV), payoff period and internal rate of return (IRR). Overviews and equations associated with these terms are presented here under [26].

a) Net Present Value (NPV)

NPV is a measure of the total current value of the cash inflows and outflows throughout the life of a project; a positive NPV signifies a profit over the life of the project, while a negative NPV shows a loss. It can be calculated using Equation

$$NPV = \sum_{t=0}^n \frac{NCF_t}{(1+i)^t} - NCF_0 \tag{1}$$

Where:

n=life of the project

i=required rate of return

NCF_t=the net cash flow at time t.

NCF₀ = Initial Investment.

NPV helps investors to understand not only if the proposed

investment will result in a profit, but also whether it is attractive compared to other options. These unspecified “options” are represented by the discount rate, which is the estimated return that the investor’s capital could achieve elsewhere. Many firms have a certain discount rate that all investments must exceed.

b) Payback Period

Payback period is the time it takes for an investment to be repaid. It does not take the time value of money into account as NPV does. Payback period can be calculated as follows:

$$\text{Payback Period} = \frac{\text{initial investment}}{\text{average annual net cash flow}} \quad (2)$$

However, given that cash flows are rarely consistent from year to year, it is easiest to find the payback period by calculating a cumulative net cash flow for each year, and then finding the year in which that cumulative cash flow exceeds the initial investment. Due to this caveat, the measure’s lack of accounting for the time value of money and its inability to quantify project value after the payback period, many organizations prefer other financial benchmarks. However, payback period is the financial measure that is often easiest to communicate to those not familiar with finance or other technical aspects of projects.

c) Internal Rate of Return (IRR)

Internal rate of return (IRR) is defined as the discount rate at which the NPV of a project is zero. It is a measure of the profitability of a project over its life, with higher IRRs being more desirable. To calculate IRR, the NPV equation is set equal to zero with as an unknown, as shown in Equation 2.16-3. In order to find the IRR then, the unknown is solved for.

$$\text{NPV} = 0 = \sum_{t=0}^n \frac{\text{NCF}_t}{(1+i)^t} - \text{NCF}_0 \quad (3)$$

Where:

n=life of the project

i=required rate of return

NCF_t =the net cash flow at time t.

NCF_0 = Initial Investment.

Since cash flows are often not uniform, it is necessary to use numerical or graphical methods to find IRR. In Microsoft Excel, the formula IRR (values,[guess]) can be used.

For each of the three economic analyses, annual cash flows (after year zero) are found by

$$\text{NCF}_t = (\text{Annual Benefit} - \text{Annual Cost}) \times (1 + j)^t \quad (4)$$

Where:

NCF_t =Net cash flow at year t

j=assumed rate of inflation

t=year of the cash flow

In its simplest form, then, the economic analysis of a capital project can be completed with three pieces of information: the initial investment, the annual costs and the annual benefits. In reality, annual costs and benefits will shift significantly depending on many factors, such as worker competency and

the scale-up of operations over time, but here it is assumed that these figures only rise with inflation (as shown in Equation 4). The remainder of this chapter is dedicated to justifying the figures used to calculate the initial investment, annual costs and annual benefits [26].

d) Sensitivity Analysis

A sensitivity analysis determines how different values of an independent variable affect a particular dependent variable under a given set of assumptions. In other words, sensitivity analyses study how various sources of uncertainty in a mathematical model contribute to the model’s overall uncertainty. This technique is used within specific boundaries that depend on one or more input variables [26].

3. Waste Generation in Hetauda Sub Metropolitan (HSM)

Since the waste generation is proportional to number of person located in particular wards, it was found to be highest waste generation of 2994Kg is in ward number 4 which is at the core location of city and lowest of 872.2 Kg in ward no 7 (Figure 2) [27].

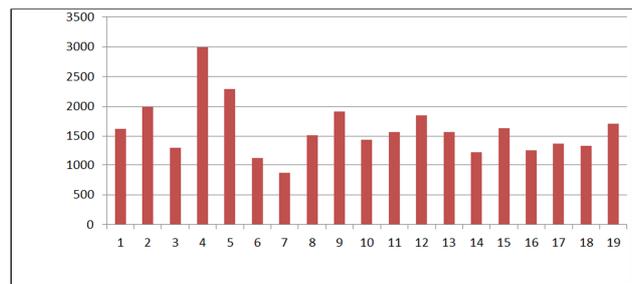


Figure 2. Ward wise waste generation of HSM [27].

But the existing collection practice and requirement shows the highest amount of 2994 Kg from ward no 4 and lowest i.e. no waste from ward no. 18 at the landfill site (Figure 3) [27].

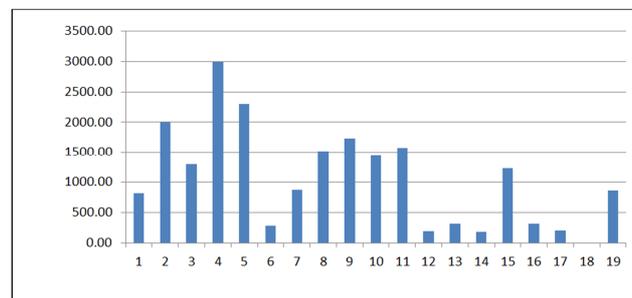


Figure 3. Waste at the landfill side of HSM [27] (GCC/HSM, 2019).

If we see at nature of generated waste it was found that food waste (organic) were dominant in the household of Hetauda Municipality which was around 51%. Paper and plastic products were generated around 12% and 27% respectively. Remaining 10% constituted of leather, glass and some metals and textiles [27].

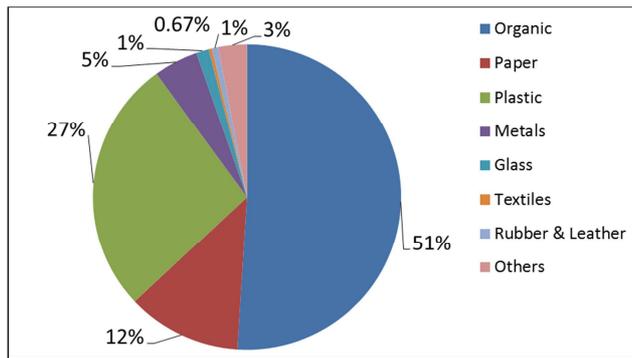


Figure 4. Waste generation of HSM [27].

4. Assumptions to be Considered While Doing Financial Evaluation.

- a) Land required for the proposed project is assumed to be free or grant from government [28].
- b) Plant Life: Construction period of the project shall not exceed 2 year (which is estimated to be 18-22months) starting from machine suppliers/EPC contractors selection and contract agreement to final test and commissioning. For the calculation of the financial analysis 10 years plant operational life is considered which means the costs and benefits are calculated for 11 consecutive years [28].
- c) Depreciation: the following depreciation rates are applied to the assets of the waste processing plant [28].
 1. Buildings and associated Civil works: 5% and in straight line method.
 2. Plant and Machinery: 20% and using declining balance method.
 3. Vehicles and handling machinery: 20% and declining balance method.
 4. Office furniture and equipment: 20% and using declining balance method.
 5. Pre-production Expenditure: 10% and in straight line method.
- d) Working Capital: As this project is a project aiming to substitute some 8.75% of the existing coal by combustible waste fuel, no new working capital is required; it only requires shifting some of the working capital from the coal procurement [28].
- e) Discounting: The total investment and equity capital of the project are discounted at 15 percent over the life of the project [28].
- f) Source of Finance: The initial total investment cost is envisaged to be covered 30% by equity and 70% by bank loan. The type of loan is further assumed to be a constant principal bank loan, with a loan repayment period of 5 years after starting operation. Two year for construction of the plant is considered as grace period; the annual interest rate including the various fees is taken to be 12% [28].

5. Conclusions

Cement industry is energy intensive since cement kilns

need high temperature to make the limestone powder to form clinker. Mostly coal is used as burning fuel in cement kiln which is non renewable sources of fuel. Now days, the world is seeking a suitable renewable sources of fuel energy for cement industry. The research shows that municipal wastes can be used as alternative fuel in cement industries due to its chemical composition. Combustible waste having calorific value of required degree can be used in cement industry. Therefore, the combustible waste which has greater calorific value of Hetauda Sub Metropolitan can be used in Hetauda Cement Industry by doing some waste to energy conversion process and modification in waste feed mechanism of industry results in reduced in coal consumptions and achievement of great economic, social and environmental benefits.

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