

**Costs and benchmarks for formulating
investment projects in the power sector
- 2011 –
Generation**

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CFE A world class company

Programming Sub direction
Assessment Coordination

INTRODUCTION

In this thirty-first edition of the study "Costs and Benchmarks or Parameters of Reference for the Design of Investment Projects in the Electricity Sector " - (COPAR Generation), *Comisión Federal de Electricidad (CFE)* (Federal Electricity Commission) has updated major technical and economic parameters involved in the calculation of levelized cost of net kWh generated, expressed in currency of 2011, for various processes involved in the production of electrical energy.

The purpose of these editions is to build a reliable information base that can be used as a reference by the electro - technical and economic models that CFE uses in power system planning as well as in the economic and financial evaluation of technology in general and generation projects in particular.

Because each project has its own characteristics, it is not possible establish a single cost to apply indiscriminately to each technology, and therefore, we call the results of this study Costs and Benchmarks for the Formulation of Investment Projects in the Power Sector.

The development of COPAR Generation is performed annually based on an analysis of the results of costs and technical characteristics, up until the year in question, based primarily on:

- i). Purchases of equipment by CFE
- ii) Fixed price contracts awarded by CFE for the construction of power generators
- iii) Specialized information on studies conducted abroad for new technologies
- iv) Specialized information from equipment manufacturers
- v) Economic and fuel prices scenarios.

The study was conducted in the Assessment Coordination Department with information from various areas of the Construction and the Generation Assistant

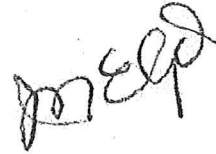
Departments Generation as well as from its own Assistant Department of Programming.

Mexico DF, May 2011

For clarifications and comments, please contact:

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A handwritten signature in black ink, appearing to read 'I. Jimenez', is located to the right of the contact information.

1. SUMMARY

1.1 TOTAL GENERATION COSTS

The total cost of generation is composed of the sum of investment costs, fuel, and operation and maintenance.

The costs used in this document are expressed at average costs of 2011.

The fuel surcharge is a levelized cost, which depends on the scenario of evolution of energy prices in question, the internal reference or benchmark price and the discount rate used. The internal reference price is representative of the value of the energy in Mexico, while the discount rate used in this edition is 12%.

Table 1.1 and Chart 1.1, show the costs per net MWh generated under the heading of investment concept, fuel, and operation and maintenance of such facilities or type of technology.

The basic parameters that will most affect the cost of net MWh generated are presented in Table 1.2 and provide a baseline to generically characterize different means of generation however; they do not necessarily accurately represent the values corresponding to a specific project.

I, MARÍA ELENA GARZA QUEST, Expert Translator and Interpreter, named by the Superior Court of Justice of the Federal District of Mexico as Assistant in the Administration of Justice, as appears on the lists published in the Official Judicial Gazette of the 16th of February of 2007, Tome CLXXXIV, No. 33, hereby certify that the above translation into the English language on 4 pages is, to the best of my knowledge and belief, the true and complete translation of its original in the Spanish language on 4 pages.

Mexico City, D.F., the 8th day of January of 2013.


MARÍA ELENA GARZA QUEST.

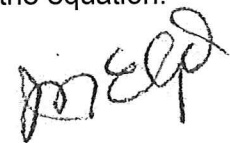
C.2 METHODOLOGY FOR THE CALCULATION OF THE LEVELIZED COST

This concept summarizes the available economic information regarding a project. Its value expresses the average cost of the good or service produced and is particularly useful for comparing two or more elective projects which can obtain the same product.

This paper the concept applies of MWh levelized cost of energy generated by each of the technologies discussed for comparative purposes. The cost of an MWh generated is composed of three parts: investment cost, fuel and operation and maintenance. This section describes the technique for obtaining levelized cost for investment concept; however, the same technique can be used for levelized costs for other items. For example, in the case of geo-thermo-electricity replacement costs of the wells involve disbursements throughout the economic life of the plant, whereby they are incorporated into the cost per MWh in the form of level charge. In the case of nuclear power plants, fuel presents similar characteristics, in terms of its use and method of payment, and it is therefore incorporated as levelized cost.

Determining the levelized cost per MWh of investment concept involves technical and economic aspects that define a technology, such as: investment costs, investment program, the plant factor mean, the power per unit and total economic life and the discount rate.

The levelized cost per MWh of investment concept is defined as the value that when multiplied by the present value of the generation plant, taking into consideration its useful life, equals the present value of costs incurred in the construction of the plant in question¹. From this definition we obtain the equation:



¹ When using this definition, an entire power station, a unit or an MWh may be considered.

$$\overline{CI} = \frac{\sum_{t=-N}^{-1} I_t (1+i)^{-t}}{\sum_{t=0}^{n-1} GNA_t (1+i)^{-t}} \quad \dots(1)$$

where:

CI Levalized cost of the MVH by way of investment-

I_t Investment during the year (in pesos)

GNA_t Net generation in the year t (in MWh)

N Construction period (in years)

n Economic life (in years)

I Discount rate (as a fraction of the unit).

If the annual net generation (GNA) is uniform² year in and year out, the relation defined in equation 1 can be expressed as follow:

$$CI = \left[\frac{i(1+i)^{n-1}}{(1+i)^n - 1} \right] \left[\frac{1}{GNA * C} \right] \left[\sum I_t (1+i)^{-t} \right] \quad \dots(2)$$

where:

C Power station capacity expressed in MW

GNA Net Annual Generation in MWh/MW)

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$$GNA = (1 - up) * fp * 8,760$$

² If it is not uniform, a GNA equivalent net generation can be estimated that is (uniform), as follows:

$$GNA = \frac{i(1+i)^{n-1}}{(1+i)^n - 1} \sum_{t=0}^{n-1} GNA_t (1+i)^{-t}$$

where:

up its own uses (as a fraction of the unit)

fp Plant factor (as a fraction of the unit)

8,760 Number of hours in one year

The factor $\frac{i(1+i)^n}{(1+i)^n - 1}$ is known as *capital recovery factor* and is denoted

the symbol $frc(i, n)$.

Therefore, the first term of the equation (2) can

be written as follows:

$$\frac{frc(i, n)}{(1+i)}$$

On the other hand, the expression may take the following form

$$\overline{CI} = \left[\frac{I}{C} \right] \left[\frac{1}{GNA} \right] \left[\frac{frc(i, n)}{(1+i)} \right] \left[\sum_{t=-N}^{-1} W_t (1+i)^{-t} \right] \quad \dots(3)$$

where:

$$I = \sum_{t=-N}^{-1} I_t$$

and:

$$W_t = \frac{I_t}{I}$$

$$\frac{I}{C} = CU \text{ is the unit cost of investment per KW}$$

The numbers W_t are known as profile factors or investment chronogram and are expressed as fraction of the unit.

The summation $\sum_{t=-N}^{-1} W_t (1+i)^{-t}$ is called present value factor and is denoted $fvp(i, \bar{w})$.

Expression (3) can then be written as follows:

$$\bar{CI} = CU \left[\frac{1}{GNA} \right] \left[\frac{frc(i, n)}{(1+i)} \right] \left[fvp(i + \bar{w}) \right] \quad \dots (4)$$

Expression (4) involves the product of the unit cost of investment (CU) for an expression known as the levelized cost factor.

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