Int. J. Production Economics 119 (2009) 207–216

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Cost analyses and predictions for a fuel ethanol plant in a rural and landlocked African country: Lang factor approach

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ARTICLE INFO

Article history:
Received 9 January 2008
Accepted 25 February 2009
Available online 9 March 2009

Keywords:
Fuel ethanol
Fixed capital investment
Lang factor
Ball park estimate
Battery limit

ABSTRACT

Research on improving ethanol production as an alternative to petroleum based fuel has been accelerating for both ecological and economical reasons. A simplified procedure for rapid ball-park cost estimate that can be used as a research tool by energy policy makers for targeting area of cost reduction in a project, for comparing alternative design and for reviewing achieved costs on completed projects is described. In this study, an operating, commercial scale fuel-ethanol plant annexed to a sugar industry and based on molasses in a poorly accessible rural and landlocked African country was used to determine the cost structure. Analysis of the breakdown of the fixed capital investment (FCI) cost, based on the principle of factorial method of capital cost estimation and using Lang factor (f_L) analysis was used to create an econometric model for calculating FCI cost. The model suggests a Lang factor of 2.40 and 2.81 for outside and inside battery limits plant, respectively.

1. Introduction

The use of ethanol as an alternative motor fuel has been steadily increasing around the world for several reasons. These reasons can be attributed mainly to an international convergence of ecological, political, economic and social factors (Von Sivers and Zacchi, 1995; Berndes et al., 2001; Zhang et al., 2003; Farrell et al., 2006; Amigun et al., 2008; Cardona and Sanchez, 2007; Sorbara, 2007). Domestic production and use of ethanol for fuel can decrease dependence on foreign oil, reduce trade deficit, reduce air pollution and carbon dioxide emissions and create jobs in rural communities relatively cost effectively compared to other agro-industrial alternatives (Goldemberg, 2007; Cardona and Sanchez, 2007). Specifically, the expanded use of fuel-ethanol would have significant health benefits in replacing lead as an octane enhancer in most African countries where leaded fuel is still widely used (Johnson and Matsika, 2006). Africa represents the largest leaded fuel user in the world. Of a total of 44 countries in Sub-Saharan Africa, 17 countries use leaded fuel only, 13 dual systems and 14 unleaded (UNEP, 2005).

Ethanol programmes that produce a blend of ethanol and gasoline (gasohol) for use in existing fleets of motor vehicles have been pursued in a number of African countries (most of these plants are concentrated at the southern tip of the continent), including Malawi, Zimbabwe, Kenya and South Africa. Others countries with molasses distillation plants include Mauritius, Swaziland, Zambia, Mozambique, Tanzania, Angola, Uganda, Egypt and Ethiopia. Many of these countries are landlocked, which means that it is not feasible to sell molasses as a byproduct on world market, while oil imports are also very expensive.

Rapid cost estimating systems are necessary to enable product designers and product development teams to

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doi:10.1016/j.ijpe.2009.02.006

make sound decisions early in the conceptual design phase and not, as is often the case, provide fodder for later value-analysis teams. Techniques for capital cost estimation have been developed over the years (Guthrie, 1969; Wilson, 1971; Ulrich, 1984; Kharbanda and Stallworthy, 1988; Turton et al., 1989; Peters and Timmerhaus, 1991; Sinnott, 1996; Brennan, 1998; Garret, 1998; Brennan and Golonka, 2002; Jebson, 2002). Estimating the cost of a process plant can vary from a rapid ball-park estimate to a carefully prepared, detailed calculation, depending on how much information is available, level of accuracy required, how much time and effort is available to do the estimate (Montaner et al., 1995). The total fixed capital cost of a process plant may be estimated as the sum of the fully installed costs for each item of equipment, based on estimate of purchased equipment cost and the additional cost of any associated plant by using appropriate factors (factor methods) (Brennan and Golonka, 2002; Maroulі and Maroulis, 2005). These factors, known as 'Lang factors—f_L', are characteristic of the industry sector considered, particularly the type of products manufactured, the average cost of equipment items used, plant capacity and location (Lang, 1948).

Most of the existing Lang factors are from American and European sources, and are fairly old. In most African countries typically characterised by low labour rates for semi and unskilled personnel and very few locally established engineering equipment suppliers and or specialist support services, the purchased equipment is mostly imported, leading to increased cost due to additional freight, legal, administrative, custom and import duties and insurance fees. The use of Lang factors, which are based on high labour cost, on project with no additional cost of equipment importation, may well result in a preliminary capital cost which is unrealistic, and the project may probably not proceed. The greater the uncertainties of capital cost, the more cautious investors are likely to be. Hence, the more accurate these factors are, the greater the likelihood of the more marginal projects proceeding to the benefit of all concerned.

The study of economic parameters involved in the functioning of an ethanol plant has rarely been carried out from an engineering point of view, and there are no publications in this regard for ethanol plants in Africa. This paper aims to present an analysis of the breakdown of the fixed capital investment (FCI) cost of one African distillery, operating in a landlocked country, in a poorly accessible rural area in an equation format. This simplified procedure will enable easier and more rapid use of the data in numerical and economic models, and in the preliminary design and optimisation of fuel ethanol plants in Africa.

2. FCI analysis: the Lang factor (f_L) approach

Capital costs have been identified by Tiffany and Eidman (2003) as one of the secondary success factors in ethanol production. The installed cost of an entire process plant as mentioned earlier, is often estimated in preliminary project work as a multiplier or a factor of the total purchased cost of all equipment items. This approach is attractive to process engineers, since equipment specification is a major function of process engineering and represents an important interface between process design and more detailed plant design.

FCI for process plant can be divided into outside battery limit or off sites (OBL) or inside battery limits (IBL) (Brennan, 1998). "Battery limits" comprises one or more geographic boundaries, imaginary or real, enclosing a plant or unit being engineered and/or erected, established for the purpose of providing a means of specifically identifying certain portions of the plant, related groups of equipment, or associated facilities. It generally refers to

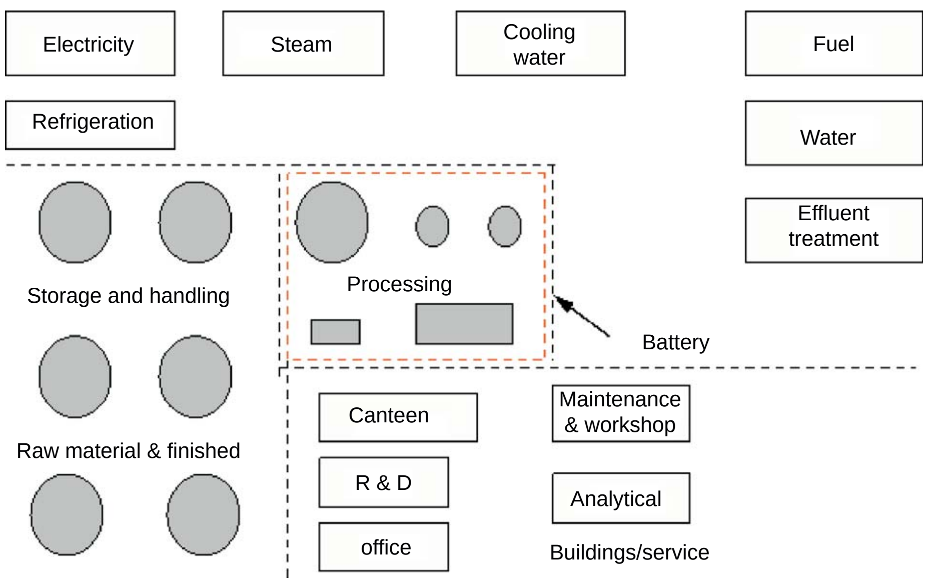

Fig. 1. Inside and outside battery limits investment (Brennan, 1998).