

## THE ROLE OF THE INDUSTRIAL ENGINEER IN AN ENERGY SYSTEM DEVELOPMENT

### *El Papel del Ingeniero Industrial en el Desarrollo de un Sistema Energético*

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**Resumen.** En la actualidad se investigan múltiples formas de proveer energía a partir de recursos renovables y de una eficiente explotación de recursos convencionales. Se piensa que esta tarea concierne únicamente a ciertas ramas especializadas como la química, la mecánica, la electricidad o la hidráulica. Sin embargo, la Ingeniería Industrial representa un conjunto de destrezas que permiten agregar valor a investigaciones relacionadas a este tema. Un sistema energético comprende varios aspectos interconectados entre los cuales están: La materia prima o recurso primario a explotar, el proceso de conversión de energía, el producto deseado y la demanda a satisfacer. Todos estos aspectos son variables que deberán ser estudiadas en conjunto. Un ingeniero industrial posee capacidades únicas como planificador y administrador que le permiten optimizar y gestionar adecuadamente los recursos utilizados en un proyecto de este tipo. En este estudio se presenta algunas de las aplicaciones del perfil del ingeniero industrial en el desarrollo de un sistema energético.

**Palabras Claves:** Conversión, Energía, Industrial, Recurso, Renovable, Administración.

**Abstract.** Multiple renewable and more efficient nonrenewable energy systems are studied these days. It is thought that this task only concerns to some specialized fields like chemistry, mechanics, electricity or hydraulics. However, The Industrial Engineering provide a group of skills to add value to any energy related study. An energy system means many interconnected aspects such as: the primary energy source, the conversion process, the desired product and the demand. All of them are variables that must be studied as one system. An Industrial Engineer has unique planning and managing abilities to optimize and manage the resources used in energy projects. This study shows some applications of the Industrial Engineer profile in the developing of a new energy system.

**Keywords:** Conversion, Energy, Industrial, Resource, Renewable, Management.

## 1. Introduction

The current energy supply is oil dependent for most countries, particularly for industrialized economies like the United States, China or India [1]; for other countries, oil became the most important income generator [2]. This situation urges to develop new energy systems capable to overtake the oil industry in cost and efficiency. Nonetheless, this task entails challenges in terms of source availability, process design and logistics. For that reason, an energy system must be planned by a multidisciplinary team in different stages such as: Conversion technologies, supply and demand management, financial and cost analysis.

A modern Industrial Engineer, from an industry point of view, must be educated in emerging topics like: Project management, optimization methods, financial engineering and lean enterprise [3]. It means that not only the nowadays engineer, but the new Industrial Engineer can apply its knowledge to deal with most of the relevant aspects of an energy system development. According to [4] the Industrial Engineer can make a research career analyzing the interaction between energy, environment and industry, increasing the efficiency of the processes and reducing emissions. The later statement implies that these engineers must have knowledge in terms of energy systems functioning, therefore, that knowledge could be used during the development of a new energy system. Figure 1 shows some of the most desired abilities of new engineers in the industrial sector.

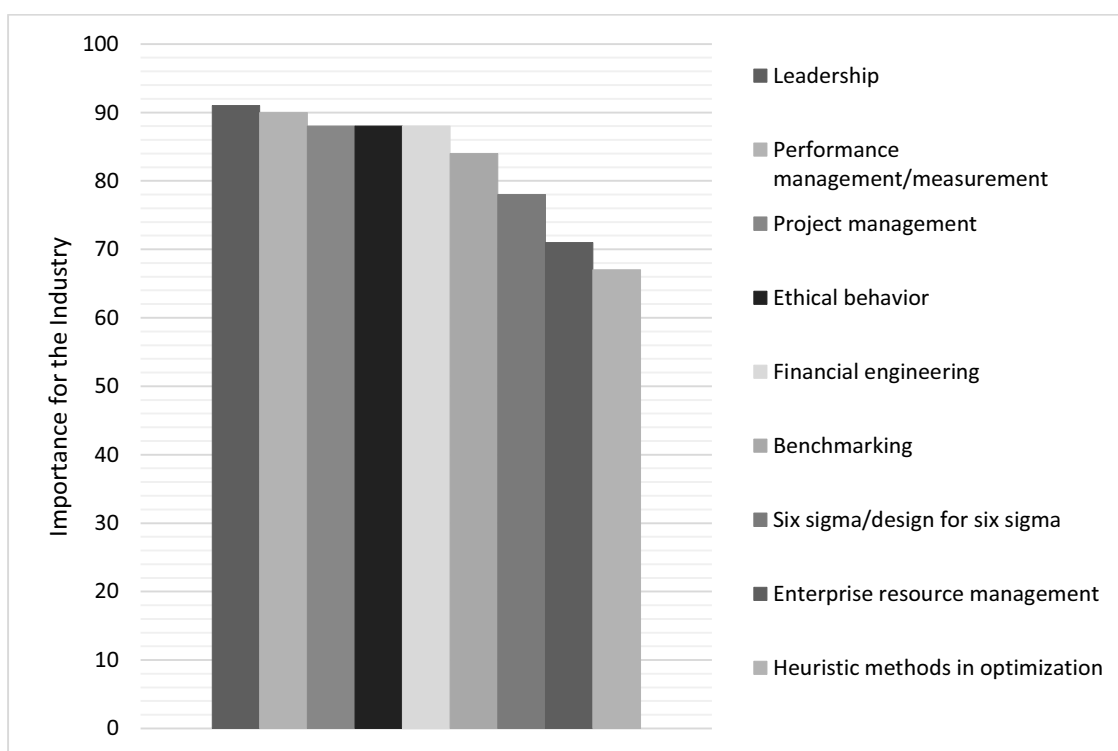


Figure 1: Importance in a 0 to 100 scale of emerging topics in the Industrial Engineer formation from an Industry point of view [3].

The Industrial Engineering curriculum offers a broad training spectrum which can be applied in the development of an energy system. According to [5] an Engineer can manage a project from various aspects including: integration, scope, cost and risk. An Industrial Engineer is capable to deal with all of these due to its multidisciplinary formation on technical subjects, administrative subjects and even humanities. On one hand, their technical formation in thermodynamics, mechanics and electromagnetism permit the analysis of such aspects during the development of an energy system. On the other hand, the administrative

subjects and humanities allow these professionals to deal with non-technical issues of the project [6] [7] [8]. An energy system comprises the interaction between primary energy sources, energy conversion technologies, energy distribution technologies and energy demand. The successful system design integrates efficiently these four aspects. Figure 2 shows the basic scheme of an energy system, where the interaction between them must be, in terms of energy, as efficient as possible.

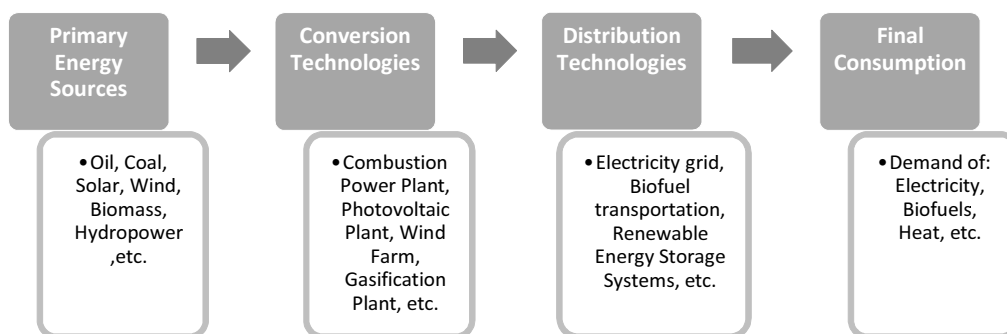
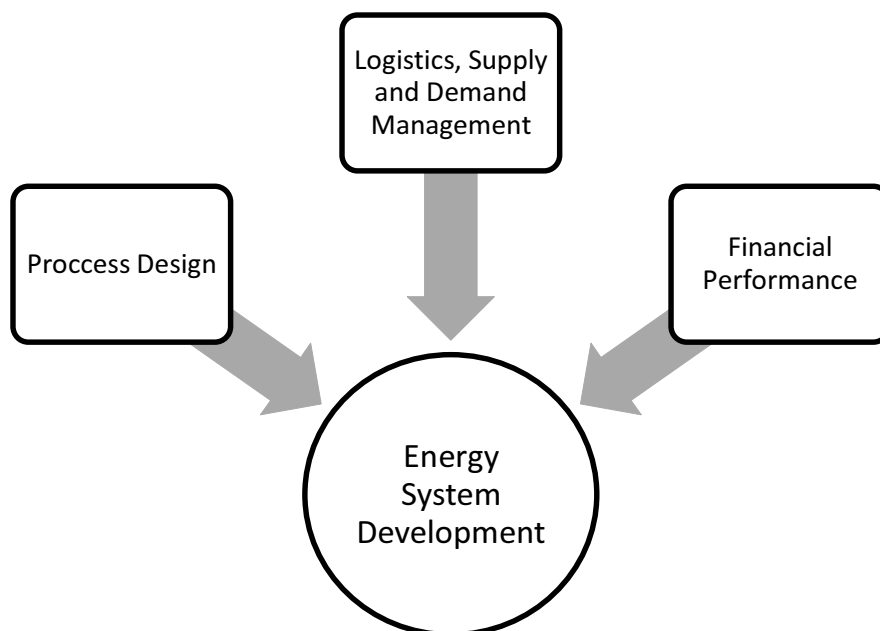


Figure 2: Basic Energy System [9]

Although, some energy conversion processes, materials selections and power distribution designs are specialized tasks, the Industrial Engineer is capable to analyze the interaction between them and suggest improvements based on the global performance of the project. According to Conergy, Industrial Engineers are “the ones who are responsible for coordinating and managing the project. They determine what is needed to complete the installation and ensure that the system works efficiently” [10]. Nowadays, there are some engineering programs focused on energy systems which include on their courses industrial engineering concepts [11]. However, since the energy sector is a big industry, Industrial Engineers can adapt their knowledge to solve energy problems. According to [12]: “Industrial Engineers are involved in all aspects of the energy sector including oil drilling and refining, gas pipeline transportation and storage, power/heat generation and transmission, and gas/electricity markets”. In countries like Ecuador where the economy relies on oil and the energy supply comprises a combination of renewable and nonrenewable systems, especially for electricity [13], there is an increasing importance to potentiate current energy systems and to develop more efficient ones in order to tackle the dependency on oil products. This task represents an opportunity for Industrial Engineers to undertake related research due to their multiple competencies. Therefore, an energy system development comprises different subjects and specializations which interact according to the main goal of the project, being the Industrial Engineer the one who is responsible of maintaining all the aspects aligned. This study describes three stages during the developing of an energy system (figure 3) where Industrial Engineering plays a leading role.



*Figure 3: Aspects of analysis of an energy system.*

## 2. Process Design

Planning, designing and managing an energy system is a difficult task. On one hand, it must cover a variable energy demand and be able to adjust to unexpected changes. On the other hand, it must comply with current environmental and social policies. The design of a conversion process is usually a specialized assignment, chemical engineers, mechanical engineers, generally work on chemical reactions, equipment design and material selection that convert energy in the most efficient way. Nonetheless, a renewable energy conversion process is usually designed or studied from previous information of the potential from a determined source like wind, solar or biomass. However, the Industrial Engineer can perform further studies in terms of feasibility of the process in different scales, for example: The residues generation from the agricultural activity in Ecuador shows great potential for certain crops like banana, rice and cacao [14], at this point some research can be performed on those crops, nevertheless, it is important to consider also other aspects like heat capacity and the periodicity of these crops, where, the Industrial Engineer is able apply economic, technical and social knowledge in order to determine the integration between the resource availability and the best configuration of equipment that offers the maximum performance at the minimum cost. Some researchers focus their studies on finding the configuration of systems and processes that use energy in the most efficient way, using thermal based energy integration models [15], Other studies focus on developing algorithms that determine the optimum configuration of equipment of a specific energy system at the minimum cost [16]. In other words, it is important to optimize the technical and the economic aspects of the energy project. The Industrial Engineer holds skills to perform both, applying subjects like numerical methods and linear programming in order to obtain optimized solutions. An example of the application of linear programming is the optimization of solar thermal systems using mixed integer linear programming (MILP) where, areas of collector and volume of tanks must be mutually optimized in order to meet the demand and take the most out of the available daily radiation at the minimum cost [17].

### 3. Logistics, Supply and Demand Management

During the developing of an energy system, not only the conversion process is important, but the supply and distribution aspects have to be thoroughly studied and integrated to the process design. An Industrial Engineer is capable to study the logistics of the system as a whole, from the raw materials logistics to the energy distribution, storage and demand management. The transportation of raw materials for a biomass powered plant is an example of a complex logistics problem due to the limited time that the biomass can withstand before degrading or absorbing more moisture [18]. However, the Industrial Engineer must use numerical methods to optimize transportation time comprising the minimum cost. Additionally, the energy supply must be managed in order to satisfy a variant demand. The dispatchability refers to the ability of an energy facility to be turned on and off and be turned up and down [19]. Therefore, when planning an energy system, the dispatchability of energy sources must be considered. Generally, the renewable sources with high availability and low dispatchability make the base load generation, like hydropower. And, the highly dispatchable sources, like non renewables, work during peaks and unexpected demand changes. Nonetheless, most renewable sources are very intermittent, which implies that exhaustive analysis must be performed in order to utilize these dispatchable and non dispatchable resources in the most efficient way, according to [20], optimization methodologies can achieve reduction in energy losses with an optimum mix of these resources. After the conversion process, the energy produced must be transmitted and distributed, generally in form of electricity; additional infrastructure gets involved for this purpose. Transmission and distribution lines usually form intricate networks that connect generation side and demand side; these networks present complex problems in terms of capacity and costs. Figure 4 shows a network configuration of transmission/distribution lines where GA, GC and GE are generators (supply) and LB and LD are loads (demand), here, generators, transmission and loads have different capacities, still, the network must satisfy demand needs. Generally, these networks have to be managed in order to respond almost immediately to any change in each of the sides. According to [21] transmission must not only be analyzed from a technical view, but, from an additional economics view where it responds to immediate changes in demand reducing transmission costs and, therefore, generating more benefits to the market. Professionals like electric engineers and economists can perform these kind of studies, however, the formation in supply chain management, operations research and economics give the Industrial Engineer the potential to work on these studies with success [22].

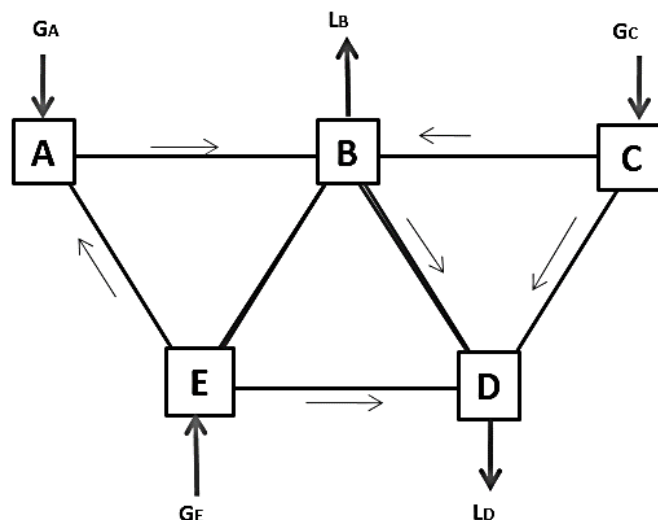


Figure 4: Example of transmission/distribution network with loads and generators.

The capacity of certain productive processes must be sized according to a demand forecast, nevertheless, when an energy generation process has to be sized, it is necessary to consider, besides demand, the availability and variability of primary energy sources. This is the case of renewable energies which present high intermittency. For example, solar energy can present fluctuations of about 75% in seconds [23]. The Industrial Engineering looks for the best configuration that optimizes cost and performance. Therefore, in order to use efficiently the solar resource available, for example, a photovoltaic plant can be sized according to the variant radiation covering an average demand and, with an energy storage system, supply the peak demand [16]. Figure 5 shows an example of photovoltaic energy produced versus the electricity demand during one day. In this case, the maximum energy generation occurs during the low demand times; however, this can be solved adding an energy storage system in order to dispatch energy during high demand times.

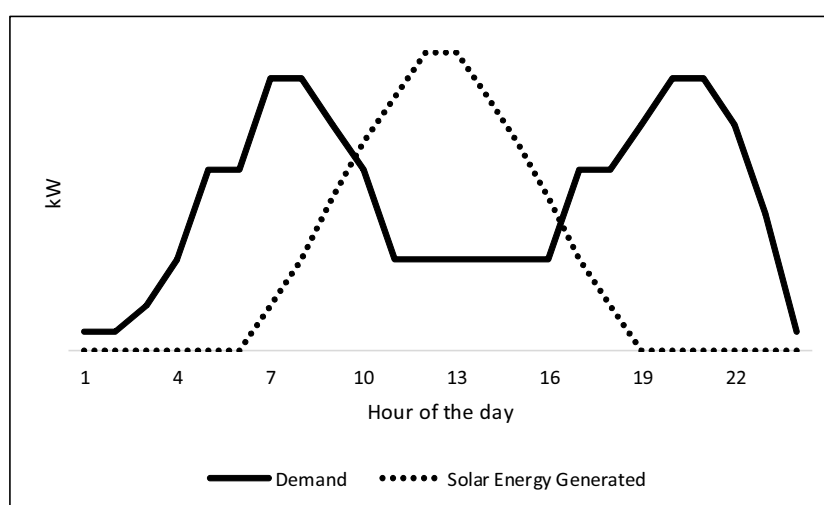


Figure 5. Example of solar energy generation and energy demand during 24 hours.

Figure 6 displays another sizing problem, here, the plant is designed to process an average amount of biomass, and, the excess of biomass generated during certain months can be stored to be utilized during low months. However, storage of biomass must be studied in order to maintain its characteristics during storage time.

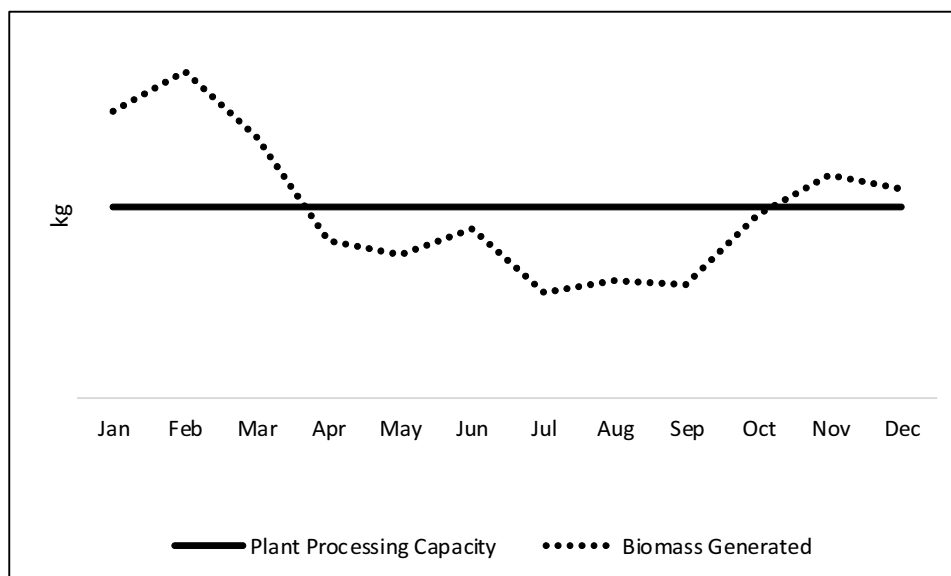


Figure 6. Example of biomass generation and processing plant capacity.

#### 4. Financial Performance Analysis

According to figure 1, financial engineering is one of the most desired skills for Industrial Engineers, it suggests that these professionals can participate in an investment decision. Energy projects are not different to any other, generally, an investment decision on these projects is made based on various rules: The Net Present Value (NPV) rule, the Internal Rate of Return (IRR) rule or the Payback Period (PBP) rule [24]. NPV and IRR rules are often used to find the net benefits of the project, these rules are chosen depending on the investor's point of view. According to [25], NPV rule serves properly as a decision tool from a society point of view since it indicates the net value of the investment. On the other hand, the IRR rule is a good decision making tool if the financial arrangements are considered, say, the amount of equity and debt of the investment. The Industrial Engineering curriculum includes economics and financial subjects providing the knowledge to perform techno economic analysis focused to: 1) make the best investment decisions on new projects and 2) implement improvements in the process to increase the financial and technical performance of the ongoing project [8].

#### 5. Discussion and Conclusions

Industrial Engineering comprises multiple subjects and fields, where, each engineer can choose a different path like energy systems studies. Therefore, this study has presented some aspects during the developing of an energy systems where Industrial Engineers play a prominent role. It has been demonstrated that these engineers can perform technical as well as financial and economic analysis in order to increase the benefits from the new system and improve existent energy infrastructure. Nonetheless, developing an energy system requires a multidisciplinary team which also works in very specific activities like energy conversion process designs, supplier selection, material selection, etc. The Industrial Engineer however, has been prepared as a team leader and has been equipped with important research tools with sufficient knowledge to coordinate and investigate all the activities of an energy project focusing them on obtaining the highest benefits and performance.

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