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Monitoring and evaluation of energy use in oil treatment facilities

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Abstract
The paper presents the steps required to undertake an energy audit in oil treatment facilities and presents key energy performance indicators that can be applied to benchmarking and monitoring of this type of system. The proposed indicators are classified into the five following categories: production, consumption, efficiency, cost and reliability indicators. The paper also presents some general initiatives, short, medium or long term, that are classified according to their maturity and their economic benefits in order to increase energy efficiency.

Keywords: Production facilities, Key performance indicators, Energy performance.

Monitoreo y evaluación del uso de la energía en estaciones de tratamiento de crudo

Resumen
El artículo presenta los pasos a seguir para realizar una auditoría energética en estaciones de tratamiento de crudo y los indicadores claves de desempeño energético que pueden ser aplicados para el monitoreo y el desarrollo de estudios comparativos de éste tipo de sistemas. Los indicadores propuestos se agrupan en 5 categorías que son indicadores de producción, consumo, eficiencia, costo y confiabilidad. También se presentan algunas iniciativas generales orientadas a incrementar la eficiencia energética de las estaciones las cuales se clasifican de acuerdo a su plazo de amortización y a sus beneficios económicos en iniciativas de corto, mediano o largo plazo.

Palabras clave: Facilidades de producción, indicadores energéticos, gestión energética.

1. Introduction

Production Facilities include processes, equipment and required materials to collect, separate, handle, characterize and measure oil, gas and water from producing wells. Considering that energy use has a very important role in the process cost, the following general strategies should be taking in account to optimize energy consumption, starting from the design phase [1]:

- Evaluation and quantification of the thermodynamic constraints of treatment processes and the selection of the processes with minimal energy requirements.
- -Selection of the process units with operation conditions similar to the ones used in the reservoir, which allow the reduction of heat exchange processes.
- Avoid hot fluids transportation to minimize energy losses.
- Evaluation of the use of direct contact heat exchangers instead of indirect heat contact exchangers.
- Maximization of fuel efficiency through heat recovery by steam generation (if cogeneration is required).
- Maximization of heat integration between processes to minimize external heating or cooling.
- Selection of equipment such as heaters and pumps that are highly efficient.

When oil treatment facilities are in operation, energy optimization is performed by applying a methodology to systematically monitor the processed energy performance and identify technological alternatives for optimization. The general applied methodology steps for the evaluation of energy management are shown in Fig. 1.

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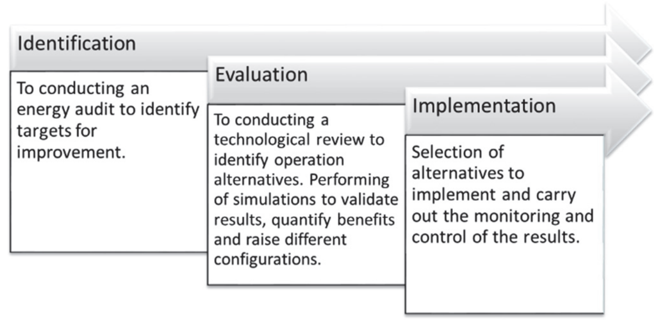

Figure 1. Methodology to evaluate energy management.
Source: Authors´ presentation.

The energy audit is one of the most important steps in the methodology. The main objective of an audit is to study the current status of processes, cost analysis, and identification of areas, equipment or facilities that could be improved and the enumeration of possible measures that could be applied. In addition, the audit seeks to adapt the current energy consumption of the plant to nominal energy consumption, ensuring proper maintenance of the facilities, reducing nominal consumption with new technologies that increases the efficiency of energy usage and reduces demand of the processes, optimizing the operation of energy services. The results of the audits have shown increases in the efficiency of electricity consumption by 12% and savings in fuel consumption between 8 and 15 % per unit of product [2].

The the stateof-the-art presents the general steps to -conduct energy audits in industrial process. Despite this,, neither the requirements of each step, in order to apply them in oil treatment facilities, nor key performance indicators to be used for analysis of energy use and to monitor the results of the proposed initiatives in the plan obtained from the energy audit are presented. For this reason, this article will focus on the steps that must be followed in order to ensure a proper energy audit, the requirements of each step, and the key performance indicators that may be applicable to oil treatment facilities.

2. Energy audit: Types and methodologies

The type of audit to be performed depends on several factors: on the industry and its principal function, on the depth of analysis to be performed, on the potential and the magnitude in cost reductions desired. There are two types of audits: preliminary and detailed [3].

2.1. Preliminary audit

This is the most economical type of audit and it allows preliminary energy savings to be identified. By means of a visual inspection, basic information is collected to identify opportunities for energy savings in operational and maintenance areas and it draws attention to whether any further analysis is required. To summarize, this type of audit is performed to [4]:

- Set the global energy consumption of the processes.
- Build the energy consumption baseline.

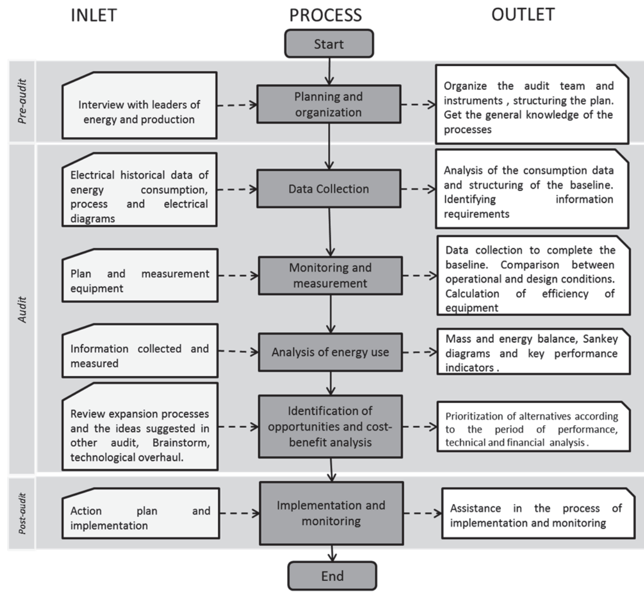

Figure 2. Stages of a detailed audit.
Source: Authors´ presentation.

Table 1.
General information of oil treatment facilities. Source: Authors´ presentation.

General information	Units
Design capacity	BOE
Current processing capacity	BOE
Streams input	
Inlet fluid (oil + water)	BOE
Water cut	%BSW
API gravity	°API
Diluent (if applicable)	%v
Streams output	
Crude	BOE
Water cut of the crude	% BSW
API gravity of the crude	ºAPI
Gas (if applicable)	MMSCFD
Condensates	BOE
Specific gravity of gas (if applicable)	-

Source: Authors´ presentation

- Identify energy losses that can be corrected through operative and maintenance actions.
- Estimate the savings
- Categorize areas depending on investments and savings.

2.2. Detailed audit

The detailed audit involves all the components of the preliminary audit, including tests and measurements to evaluate the energy use and its losses, as well as evaluating the economy for the proposed changes. It also incorporates the assessment of how much energy should be used in each process and operative function by using computer modeling simulations [5]. The detailed audit is divided into 3 stages which are: pre-audit, audit and post-audit. Fig. 2 presents the processes that are to be followed in each stage. Each process will be later explained for oil treatment facilities [6].

3. Information required for energy analysis of oil treatment facilities

Tables 1 and 2 present the required information to perform an energy audit in oil treatment facilities.

Table 2.
Information required for the energy analysis of oil treatment facilities.

Information	Source	Description
Basic information	Operation Manual	Process description and operating procedures.
	Block Flow Diagrams (BFD) and Process Flow Diagrams (PFD)	Conceptual approach to the processes´ functions.
	Control and instrumentation diagrams (P&ID)	Graphic approach of measurement, monitoring and control systems.
	Industrial services diagrams (Water, steam)	Graphic approach of industrial services
	Line diagrams	Graphic approach to electrical installations.
	General list of equipment and data sheets of major equipment	Design data of equipment (diameter, height), Current operational status and optimum operating conditions. Design and operation capabilities. Maximum levels of fluids, pressure, temperature, other.
Statistical Data	Production	Total fluid (oil, water and gas)
	Properties and composition of the fluids	Fluid compositions, BSW, Calorific (gases and condensable) and properties of the diluent (if applicable).
	Chemical treatment	Chemical product (volume, concentration, injection, chemical cost per barrel of fluid).
	Historical consumption and cost (electricity and fuels)	Consumption and cost of electricity, gas, diesel and other fuels.
	Historical properties and composition of fuel	Characteristics and composition of the fuel gas: average molecular weight, specific gravity and net LHV.
	Power quality measurements of the main equipment	Current, voltage, power factor and frequency.
	Gas flare Tea	Gas flow, evaporated diluent (if applicable) and other fuels burned.
Reliability	Operation and performance indicators of equipment	Measurement of performance indicators
	Historical databases of failures	Equipment , date, type and cause of the failure and downtime
	Factory test equipment	Operating curves
	Periods of equipment operation	Lifetime of the process and equipment
General Data of equipment	Management systems and programs	Programs and initiatives for management and consumption of Energy. Maintenance and reliability management, and operation and production management.
	Separators and tanks	Input and output flows of oil, water and gas (separated). Inlet and outlet temperatures. Flow of diluent (if applicable). Operation level fluid and retention times.
	Heaters and Coolers	Inflow and outflow, inlet and outlet temperatures, fuel flow, composition and characteristics of the fuel, stack temperature, % excess oxygen.
	Pumps	Rotational speed, power and nominal efficiency, net positive suction, suction and discharge pressures, pump capacity, rated capacity, hydraulic power; voltage, current and power factor.
	Vapor Recovery Unit (VRU)	Process equipment, temperatures (input/output), pressures (input/output).
Environmental Requirements	Environmental management plan and other requirements	Regulations and environmental requirements. Delivery quality criteria for products output.
	Climatic and geographical conditions	Elevation above sea level, minimum day and night atmospheric pressure, relative humidity, average temperatures (wet bulb and dry bulb).
	Emissions	Exhaust gas analysis (temperature, flow and composition), composition (CO, CO_2, NO_x, SO_x, H_2O, etc.) and operational conditions at the time of gas analysis.

Source: Presentation of the authors.

4. Analysis of energy use

Energy use diagrams are presented in Fig. 3. These apply to a treatment facility without crude heating processes.

The analysis should include energy consumption per process, calculation of current and optimal yields of processes, the list of equipment with higher energy consumption and the key performance indicators´ approaches (KPIs).

In this stage, KPIs play an important role because they are control tools that allow the planned goals to be monitored. The indicators should provide enough and relevant information to not bias the analysis, and in addition they should allow for decision-making and effective processes control. In order to do this, an indicator must at least comply with features that are internationally recognized by the acronym SMART (Specific, Measurable, Actionable, Relevance, Timely). The suggested steps to formulate or adjust the indicators are:

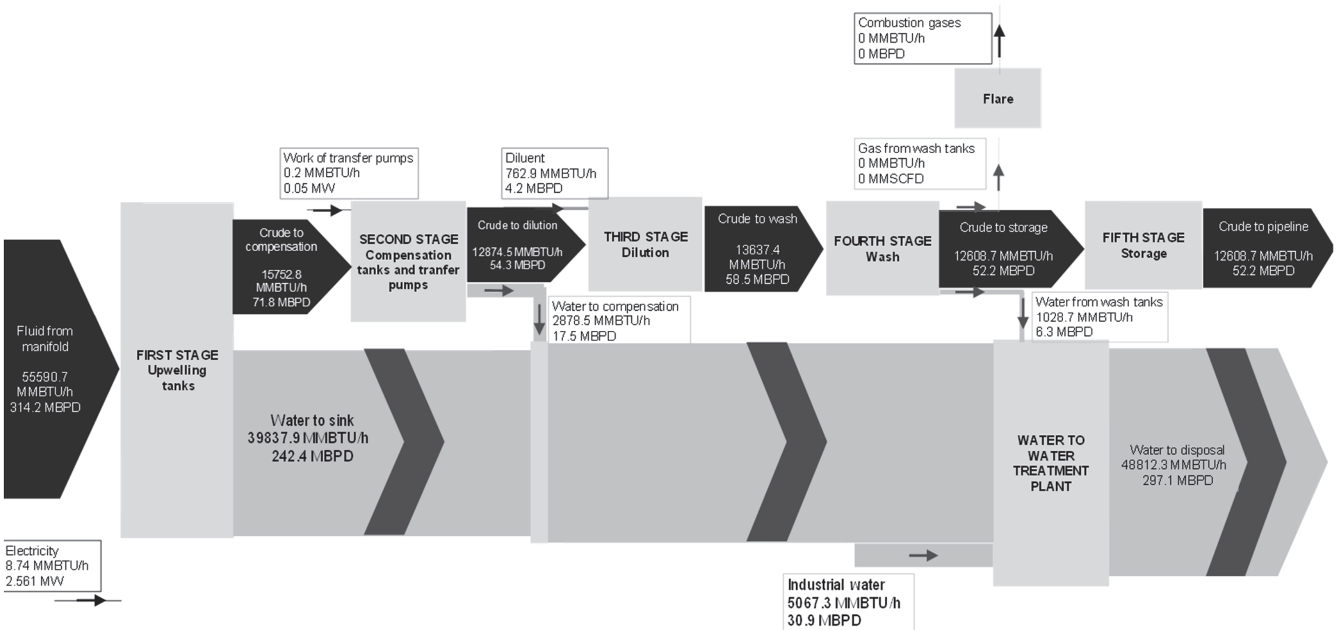

Figure 3. Sankey diagram for an oil treatment facilitie.
Source: Authors´ presentation.

- Set the variables required for measurement.
- Identification of the benchmarks.
- Set the target to be measured.
- Identification over what information is required from the target.
- Identification of people for whom this information is useful.

There are two kinds of indicators: management and results. Management indicators measure how the process is performing in terms of resource optimization. This kind of indicator is used to detect what is happening and is used to take appropriate actions to improve the situation. Results indicators are associated with management goals as well as the efficiency and effectiveness of their achievement. This kind of indicator is used to measure situations when they have already occurred and to take appropriate measures to prevent reoccurrences. The proposed KPIs for oil treatment facilities are presented in Table 3.

The analysis of energy consumption can be performed based on both internal and external benchmarking performance studies. Internal studies include the analysis of historical data and trends, while external audits are undertaken based on data or indicators obtained from systems or similar processes. Comparative factors to be taken into account for external analysis are the maximum capacity of the station, the technologies used in the processes and the quality specifications for both raw and treated products. Benchmarking studies allow:

- Quantification of fixed and variable energy consumption according to production levels.
- Comparison of the usability factor with other facilities.
- Identification of gaps and best practices.
- Establishment of the basis for monitoring and goal setting.
- Quantification of the target variability margin for consumption and energy cost.

5. Identifying opportunities for optimization

The last step in the energy auditing process is to recommend an action plan to optimize the use of energy, the cost of operation and to reduce emissions. The plan should include the period of implementation for each initiative and the investments´ payback period [7].

Initiatives for energy management can be classified as short, medium or long term, depending on their maturity and their economic benefits. Short-term projects are those that must be performed quickly to resolve a compliance issue regarding air quality, or that have a very short payback period (a high rate of return).

The projects that are to be carried out for environmental reasons are sometimes to be implemented in the future, but are still classified as short-term because the work should begin as soon as possible [8]. Initiatives with high rates of return should be classified according to their ease of implementation. If little or no capital is required, projects should be performed immediately. If projects require time and capital but have a high rate of return, they should be started as soon as possible.

The medium-term initiatives have periods of economic return that is usually between one to three years. Because they require capital investment, they should be retested to make sure they are economically feasible [8].

The long-term initiatives are characterized by simple economic returns over three years. If capital investment is large or the return is small, initiatives are classified as having a low priority. However, it is important not to dismiss such initiatives because they may have changes in energy costs, in technologies and environmental regulations: situations that make their implementation imperative.

Table 3.
KPIs for an oil treatment facility.

Category	Indicator	Description	Unit
Cost	Energy cost per product	Total cost of energy consumed by product yield	$/BOE
	Energy cost per treated fluid volume	Total cost of energy consumed per fluid volume (water + oil treated)	$/Bbl
	Relative energy cost	Ratio of energy cost and total cost of treatment	%
Consumption	Total energy consumed	Fuel consumption (burned, vented) and electricity	BTU, HP, J
	Energy intensity	Energy consumption per gross production	BTU/Bbl
Efficiency	Thermodynamic efficiency of equipment	Ratio of useful energy and the supplied energy to the equipment	%
Production	Usability Factor	Ratio of treatment capacity by the maximum capacity of the facility	%
Reliability	Failure index	Failure rate of the equipment or system	#failure/equipment/year
	Mean time between failures	Expected time between two failures for a repairable system	days
	Mean time to repair or replace	Average time needed to restore an asset to its full operational capabilities after a failure	days
	Carbon intensity	Emissions (venting, combustion)	t $CO2_{eq}$/BOE

Source: Authors´ presentation

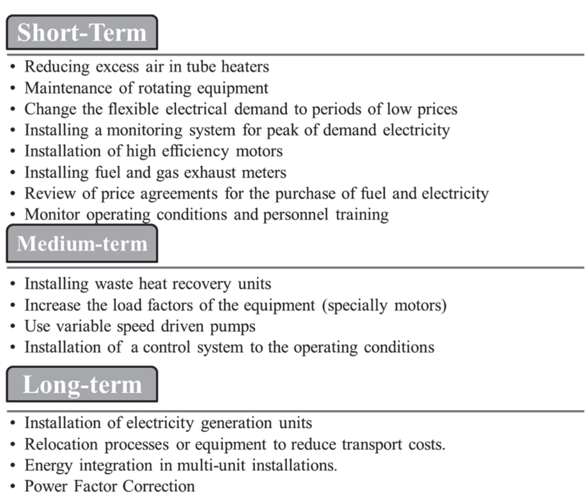

Figure 4. Alternatives to optimize oil treatment facilities.
Source: Authors´ presentation.

The reduction in energy costs associated with short-term initiatives is between 10 and 20%, while initiatives with a repayment period of two years or less offer additional reductions: between 20 and 30% [9].

Some initiatives to optimize treatment facilities are presented in Fig. 4. The size of the installation will determine whether an initiative is short, medium or long term [10-13].

6. Conclusions

An energy audit quantifies the consumption and energy costs of industrial processes, in order to identify gaps and establish a plan of initiatives to reduce losses, maximize efficiency, optimize energy supply and costs associated with processes. Energy auditing affects three key factors: profitability, through the optimization of energy consumption; productivity through optimization of equipment and processes; and performance, to use energy rationally.

Structuring an optimization plan is one of the most important steps in an energy audit. The initiatives proposed in this article are focused on improving models to contract the purchase of electricity and fuel, improve power quality, reduce energy loss from processes and equipment, include and track maintenance plans and improve operating conditions´ control systems. Additionally, they can help to minimize emissions associated with the processes.

The sustainability of the audit´s results of will be ensured through monitoring and control of key performance indicators, accompanied by an energy management program. Additionally, these indicators will allow comparative studies with other treatment facilities that have similar characteristics (production capacity, used technologies in processes, crude and products quality).

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