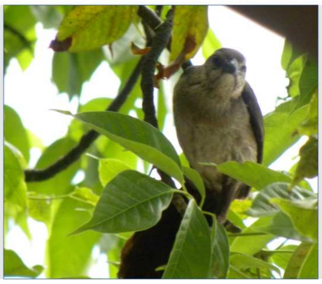
ARPEL Guideline
Energy Indicators in the oil & Gas Industry

Best practices



REGIONAL ASSOCIATION OF OIL, GAS AND BIOFUELS SECTOR COMPANIES IN LATIN AMERICA AND THE CARIBBEAN

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Energy Indicators in the Oil & Gas Industry

February 2013

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This document was devised within the context of the Energy Efficiency Project, of the ARPEL Climate Change and Energy Efficiency Committee, as an updated version of the ARPEL Environmental Guideline n° 27 "*Estimating Energy Indices for Upstream and Downstream Oil and Gas Facilities***".** The ARPEL Climate Change and Energy Efficiency Committee, was in charge of the content and review of this new updated edition.

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ENERGY INDICATORS IN THE OIL & GAS INDUSTRY

Table of Contents

1) Introduction and objective of the guideline

Energy is a resource that should be adequately managed so as to guarantee the sustainability of men's activities in the world and minimize its environmental impacts. The use of energy in the value chain of oil and gas may involve an emission of substantial amounts of greenhouse gases, depending on the type of fuel used, which can be reduced by optimizing processes or introducing new production technologies in the oil and gas chain.

Sustainable energy management needs indicators that allow to know the development of productive processes, in order to know how much is consumed and how. A good indicator should allow identifying the real consumption trends and the saving potential, as well to plan objectives and carry out actions to optimize the use of energy. The last energy management standards taken (EN-16001 and ISO-50001) reveal it: energy management indicators are a key point of its methodology which aim is to increase energy efficiency and reduce the environmental impact of the greenhouse gas emissions linked with the fuels used to generate energy.

Aware of the importance of this subject, in 1999 ARPEL published the first version of this guideline on energy indexes1. This first document gathers factors that should be taken into account when energy indexes are set and estimated, for the different sectors of the oil and gas industry.

At this moment in which the main energy management standards are being updated (ISO50001 / EN16001), it was considered appropriate to review the guideline to describe the calculation methodologies of indicators, together with elaboration and follow up criteria in a more specific way. In this way, this new edition of the guideline emerges, in which contents have been reviewed, adapted and updated. The purpose is to describe clearly and concisely the calculation methods and formulas to establish energy indicators for the oil and gas industry sector. Likewise, indicators developed by organizations outside ARPEL, also known in the sector, are enumerated (as the case of Solomon, CAPP, etc.). One of the points to be highlighted is the intention of clarifying basic concepts. Also, it will be shown how indicators systems that allow to compare the performance of different facilities based on its efficiency can be built, although they have different characteristics and complexity (by comparing the standard consumption of a facility with the same characteristics or considering a similar fuel mix).

The objective is to write a summary of an indicators system that reflects the performance of each business in an oil company and that can be consolidated in one company indicator. In this line, a calculation method will be proposed for a consolidated energy saving indicator (ESI), and another one for a consolidated energy intensity indicator (GEI). These indicators could be used to the saving objectives, integrating them into an energy management system and even to disseminate the energy performance of companies through their Corporate Social Responsibility reports. For this purpose, this version of the guideline is intended to be, above all, very practical and applicable.

[1] *"Estimation of energy indices for oil and gas upstream and downstream facilities" ARPEL Environmental Guideline n° 27*

2) Energy Consumption and Energy Efficiency Indicators

a) *General Considerations and Basic Concepts*

Energy management indicators can be classified into two main categories:

- The first type of indicators includes those that reflect the total energy consumption. They measure the total amount of energy consumed to generate a given volume of products or activity. They are related to the production volume (the more production or activity, the greater consumption). They are measured in Joules, kWh, calories, tFOE, BOE, Btu, etc. They show "how much energy is consumed".

- The second type of indicators measures specific consumption or energy intensity. They show the necessary energy to obtain a production unit (specific consumption), or they compare the real energy consumed by a productive process and the theoretical consumption that was expected to have had to carry out the same activity if a reference consumption standard[2] was followed (theoretical or standard consumption). Unlike the previous category, these indicators are independent of the activity or production volume. Their value is characteristic of the condition of the facility. They are measured in GJ / (production unit). They show "how energy is consumed".

As a general consideration, the energy intensity informs on energy efficiency, as the terms "intensity" and "efficiency" are inversely proportional. An increase in the energy intensity of a process represents a decrease in its efficiency (and inversely).

On the other hand, it should be highlighted that there is a connection between the first and the second type of indicators: the activity term. In the case of specific consumption, it is easy to define the activity term, as it is usually equivalent to the production value. Then, the values of energy consumed per ton of product can be indicated. However, there are processes which correlation between energy consumption and activity is usually more complex, in which it is not that simple to establish that correlation.

Even though some of these types of indicators are used more frequently than others, a good management system should be able to complement the use of several types of indicators that allow to report simultaneously on consumption, savings, efficiency, improvement potential, etc.

b) *Definitions and calculation principles*

In order to make clear what is referred to by each indicator, the definition of some basic concepts is included below, ordered by level of complexity. These types of indicators can be defined for any type of facility, despite their size or configuration:

[2] *The reference standard may refer either to the average consumption of a facility with the same characteristics, to the optimal consumption, to the minimum consumption, or to the design consumption, etc.*

i. Real energy consumption of a facility

This is the simplest concept of all. It refers to the amount of energy consumed by the facility. It directly depends on the production level of the facility. The greater the use of the facilities to produce more, the greater energy consumption. The least use, the least energy consumption. Values are obtained from meters, control instruments´ measurings, energy balances, etc.

The real energy consumption is usually quantified in GJoules, although there are many other equivalent units (kWh, calories, tFOE, BOE, m^3OE, Btu, among others).

ii. Activity parameters

It refers to the group of parameters characteristic of a productive sector that connect the goods or services produced with the real energy consumed by the equipment used in the operation. The greater the value of the activity parameter; the greater the energy consumption (and viceversa). In general, each sector of the economy has defined a certain number of specific activity parameters. For example, DOE suggests the following:

- Transport sector: kilometers per passenger and kilometers per freight ton
- Industrial sector: value of production (that is, tons produced)
- Residential sector: number of homes
- Commercial buildings sector: square meters of the area
- Electricity sector: kilowatt-hour of electricity produced

This guideline proposes -throughout the following chapters- a certain number of specific parameters for each sector of the oil and gas industry.

iii. Specific consumption

For each group, plant or facility characterized by a single activity parameter, the energy SPECIFIC CONSUMPTION can be calculated: it is the quotient between the real energy consumption of the facility and each activity unit. It is measured in (energy units) / (production unit). For example: [GJ / BOE], [GJ / ton], [GJ / FOE ton], or [kWh / liter]

The specific consumption is characteristic of the production technology (it does not depend on the production volumes): the specific does not vary depending on how much is produced by the facility. It would only do so in the case that facilities would increase or reduce their efficiency due to modifications in operation or maintenance conditions, as well as if the process technologies are changed by other ones which are more or less efficient.

iv. Theoretical consumption and baseline for a group of facilities

Knowing the specific consumption of the facilities that are part of a business, it is very easy to calculate its REAL energy consumption with the following formula:

$$\text{REAL Energy Consumption}_{\text{Year N}} = \sum(\text{Specific Consumption}_{\text{Year N}} \times \text{Activity}_{\text{Year N}})_{\text{facility}}$$

Likewise, its energy consumption can be estimated for a year (N) according to the specific consumption of the previous year:

$$\text{THEORETICAL Energy Consumption}_{\text{Year N}} = \sum(\text{Specific Consumption}_{\text{Year N-1}} \times \text{Activity}_{\text{Year N}})_{\text{facility}}$$

This value shows which would have been the theoretical consumption if the same specific consumption of the previous year was kept (that is: same energy efficiency).

According to the same principle, a reference (or standard) theoretical energy consumption can also be estimated, assuming that specific consumption correspond to a reference value (in general for one year, called year/baseline). The theoretical consumption is calculated with the following formula:

$$\text{THEORETICAL Energy Consumption}_{\text{year X / reference}} = \sum(\text{Specific Consumption}_{\text{Reference}} \times \text{Activity}_{\text{Year X}})_{\text{facility}}$$

In this way, the energy consumption of facilities can be estimated if the same consumption standard of the period of reference was kept. It shows which would be the consumption in a *"Business as usual"* scenario, that is: assuming that facilities keep the technical characteristics of the year of reference (without changes in their specific consumption or in its efficiency), but with the activity values budgeted for the Year X. In the cases in which the calculation of specific consumption is complex, its numerical value can be calculated with statistical methods.

v. Energy intensity indicator

The energy intensity indicator of a business unit or a facility compares their real energy consumption with the theoretical consumption (or standard consumption). This means in practice the following equation:

$$EI = \frac{\text{Real Energy Consumption}_{\text{year X}}}{\text{THEORETICAL Energy Consumption}_{\text{year X}}}$$

So, for a group of facilities, the energy intensity can be calculated:

$$EI = \frac{\sum(\text{Specific Consumption Year X} \times \text{Activity Year X})_{\text{facility}}}{\sum(\text{Specific Consumption Base Year} \times \text{Activity Year X})_{\text{facility}}}$$

This indicator allows seeing in percentage terms how much has the real energy consumption of facilities improved or worsened compared with the theoretical consumption, on an equal basis regarding activities. This way, a comparison is made between the consumption of the real facility and the consumption of a reference theoretical facility with the same characteristics and activity. The periodical monitoring of the indicator informs on the efficiency of a facility with regard to the standard and allows deducing the status of its maintenance or of its operation.

In order to determine the EI index of a business unit, it would be enough to know for each production facility operated the Specific Consumption (SC) values for a reference year and of the Production values projected (historical data or estimations in future), for the base year as well as for the year that is being studied.

The definition of the energy intensity indicator is similar to the one of the Consumer Price Index, CPI. For this reason, the type of analysis and information that can be obtained from the energy intensity indicator and from the CPI is similar or equivalent. That is why, throughout several periods, savings are accumulated not just by a simple addition, but by means of the compound interest formula.

The energy intensity indicator leads to the definition and monitoring of energy saving. If the real energy consumption of operations is equal to the consumption standard of the year of reference, the EI value is 1 (100% concordance). Any deviation from the value of reference is explained by an increase or saving of energy consumption with regard to the baseline (reference consumption standard). The EI value is equal to EI = (1-savings%).

This indicator could be used for setting annual saving objectives.

3) Systems of indicators by activity

In this section there is a detailed description of the indicators available for the following areas of activity of the oil and gas industry:

A. Oil and Gas Exploration and Production
B. Oil Refining
C. Petrochemical Production
D. LPG Bottling Plants
E. Service Stations´ Networks
F. Generic Indicator for other types of facilities (asphalts, lubricants, etc.)

When possible, it will be briefly described how to define and obtain the parameters defined in the previous section for each area:

i. Real energy consumption
ii. Activity parameters
iii. Theoretical energy consumption
iv. Energy intensity indicator

It will be noticed that, in some cases, there can be several possibilities to define the activity parameter that can better characterize a specific area (like in production or refining, for example). Likewise, there are cases in which there can be many ways to establish the models that define the theoretical energy consumption. This means in practice the existence of several types of energy intensity indicators for the same sector.

a) Indicators for exploration and production activities

1. Energy saving indicators system (ESI)

i. Real Consumption

The real consumption can be calculated from the energy balance of fields. It will include the energy consumption of fuels and the energy wasted by venting, fugitive and by combustion of gas in torches and incinerators.

Real energy consumption $_{Asset\ i\ year\ x}$ (GJ) = (Energy consumption by fuels[3]) $_{Asset\ i\ year\ x}$ + (Energy consumption by losses in venting or fugitive[4]) $_{Asset\ i\ year\ x}$ + (Energy consumption in torches and incinerators[5]) $_{Asset\ i\ year\ x}$

The real total energy consumption of the oil and gas production area is calculated as the addition of the consumption of each asset (of each field):

Real energy consumption UN $_{year\ x}$ = Σ Real energy consumption $_{Asset\ i\ year\ x}$

ii. Activity parameters

It will be considered as activity parameters: the volume of the fluids processed in each field, that is, the tons of Hydrocarbon Produced (HC); the cubic meters of fluid processed (hydrocarbons and water) (m^3 processed); and the tons of oil equivalent (toe).

Numeric calculation of sold or accumulated HC

Sold or accumulated HC toe used in the calculation of the indicators of gas venting, combustion of torches and the energy intensity indicator will be calculated as the addition of crude and gas toe:

Sold-accumulated HC[6] $_{Active\ i\ year\ x}$ = crude toe $_{Active\ i\ year\ x}$ + gas toe $_{Active\ i\ year\ x}$

*crude toe $_{Active\ i\ year\ x}$ = kt Crude $_{Active\ i\ year\ x}$ * ICV Crude $_{Active}$ (GJ/t) * 1000 / (41.868)*

*gas toe $_{Active\ i\ year\ x}$ = kt Gas $_{Active\ i\ year\ x}$ * ICV Gas $_{Active}$ (GJ/t) * 1000 / (41.868)*

(1 toe = 41.868 GJ [7])

If the crude and gas ICV value is not available, toe will be calculated with the following ICV values: 52.5 GJ/t for gas and 43 GJ/t for crude.

Numeric calculation of processed m^3

The processed m^3 used in the calculation of specific consumption will include, besides the crude and gas produced the injected and produced water and injected gas.

m^3processed $_{Asset\ i\ year\ x}$ = m^3oe crude $_{Asset\ i\ year\ x}$ + m^3oe gas $_{Asset\ i\ year\ x}$ + m^3injected water $_{Asset\ i\ year\ x}$ + m^3 produced water $_{Asset\ i\ year\ x}$ + m^3oe injected gas $_{Asset\ i\ year\ x}$

[3] *Fuels energy consumption $_{Asset\ i\ year\ x}$: according to the environmental parameters report.*
[4] *Energy consumption in ventings and fugitive $_{Asset\ i\ year}$ = 52,5 * (TOTAL Gas Vented+ Fugitive Emissions); TOTAL Gas Vented, Fugitive Emissions: tons according to the environmental parameters report*
[5] *Energy consumption in torches and incinerators $_{Asset\ i\ year\ x}$*
*= 52,5 * (Combustion in Torches + Combustion in Incinerators); Combustion in Torches and Incinerators) : tons according to the environmental parameters report*
52,5 according to "Methods for Estimating Atmospheric Emissions from E&P Operations. E&P Forum 1994"
[6] *Sold or accumulated HC are the addition of sales plus inventory variations.*
[7] *Organization for Economic Co-operation and Development, International Energy Agency, Energy Balances of OECD Countries 1992-1993 (Paris: OECD, 1995).*

with: $m^3oe\ crude_{\ Asset\ i\ year\ x} = toe\ crude_{\ Asset\ i\ year\ x} /\ crude\ density$

$m^3oe\ gas_{\ Asset\ i\ year\ x} = toe\ gas_{\ Asset\ i\ year\ x} /\ crude\ density$

$m^3\ produced\ water_{\ Asset\ i\ year\ x} = kt\ produced\ water_{\ Asset\ i\ year\ x} \cdot 1000 /\ water\ density$

$m^3\ injected\ water_{\ Asset\ i\ year\ x} = kt\ injected\ water_{\ Asset\ i\ year\ x} \cdot 1000 /\ water\ density$

$m^3oe\ injected\ gas_{\ Asset\ i\ year\ x} = kt\ injected\ gas_{\ Asset\ i\ year\ x} \cdot ICV\ gas\ injection_{\ Asset}\ (GJ/t) * 1000 / (41{,}868) / crude\ density$

Reference average: crude relative density 0.8636

Water density = 1 t/m^3

Data on produced crude, produced gas, injected water and produced water should be clearly defined based on reliable sources. Assets in which there is injected gas should be identified and information provided (for operations such as "gas lift", etc.).

iii. Theoretical consumption

For the calculation of theoretical consumption, the following analytical indicators should be previously determined for each field or asset:

$Specific\ consumption\ indicator_{\ Asset\ i\ year\ x}$

$= Fuel\ energy\ consumption_{\ Asset\ i\ year\ x} / m^3\ processed_{\ Asset\ i\ year\ x}$

$Gas\ venting\ indicator_{\ Asset\ i\ year\ x}$

$= Energy\ consumption\ in\ venting\ and\ fugitive_{\ Active\ i\ year\ x} / HC\ sold\ or\ accumulated\ (toe)_{\ Asset\ i\ year\ x}$

$Flaring\ combustion\ indicator_{\ Asset\ i\ year\ x}$

$= Energy\ consumption\ in\ flares\ and\ incinerators_{\ Asset\ i\ year\ x} / HC\ sold\ or\ accumulated\ (toe)_{\ Asset\ i\ year\ x}$

Based on this data, the theoretical energy consumption of each asset is calculated from the analytical indicators of the previous year with the activity data (HC toe or processed m^3) of the present year:

$$Theoretical\ energy\ consumption_{\ Asset\ i\ year\ x} = Specific\ consumption\ indicator_{\ Asset\ i\ year\ x-1} \cdot processed\ m^3_{\ Asset\ i\ year\ x} + (gas\ venting\ indicator + flaring\ combustion\ indicator)_{\ Asset\ i\ year\ x-1} \cdot toe\ HC\ sold\ or\ accumulated_{\ Asset\ i\ year\ x}$$

The theoretical total energy consumption of the business unit is calculated as the addition of the consumption of each asset:

$$Theoretical\ energy\ consumption\ UN_{\ year\ x} = \Sigma\ Theoretical\ energy\ consumption_{\ Asset\ i\ year\ x}$$

iv. Energy indicator

It is an energy intensity indicator. As we have just seen, the theoretical consumption that can be used as reference is based on the specific indicators of the previous year. For this reason, it informs on the variation of energy consumption (saving or increase) from one year to the next with the same operation conditions.

$$\text{Energy saving indicator}_{\text{Asset i year x}} = \frac{\text{REAL energy consumption UN}_{\text{year x}}}{\text{Theoretical energy consumption UN}_{\text{year x}}}$$

2. *CAPP´s Energy Intensity Indicators System*

The Canadian Association of Petroleum Producers (CAPP) – has developed energy intensity indicators for the industry. The detailed methodology can be consulted in a document available on CAPP´s website, through the following link: http://www.capp.ca/raw.asp?NOSTAT=YES&dt=PDF&dn=55904.

CAPP´s system does not deploy all the indicators previously indicated, or establish a way for calculating theoretical consumptions. It just calculates the energy intensity of operations and indicates the industry's average values as reference. Its main calculation basis is summarized below.

i. Real consumption

For each field, the real energy consumption is calculated as the addition of the fuels consumption (diesel, fuel gas, crude, etc.), of electricity consumption (making a balance between electricity imports and exports), of fugitive emissions + venting and of gas combustion in torches. The calculation is carried out from the mass consumptions of each type of hydrocarbon (by mass balance, flowmeters or meters) and is expressed in energy values (in GJ) based on their Intrinsic Calorific Values.

$$\textit{Real energy consumption}_{\textit{year x}} = \Sigma\ \textit{Energy consumption}_{\textit{Asset i year x}}$$

ii. Activity parameters

It is considered as activity parameter the m^3 oil equivalent produced (m^3OE – of gas as well as of crude).

iii. Reference consumptions

CAPP´s guideline does not establish any theoretical consumption model. However, in order to establish a reference that can be the basis for evaluating data, a table (table 1 below) is shown with the average energy intensity values of the oil and gas industry in Canada (1995), according to the type of field (gas, light crude, heavy crude, bituminous sands, etc.).

Table 1: Average values for the oil and gas upstream industry (PEI) in Canada (1995 values)

Process / Product Type	Industry Average PEI GJ/m^3OE
Sweet natural gas	1.4
Sour gas / natural gas	2.2
Sulphur recovery / natural gas	3.7
Light oil	2.12
Conventional heavy oil / crude	1.2
CSS Thermal heavy oil / bitumen	8.5
SAGD Thermal heavy oil / bitumen	6.6
Straddle plant / NGLs	3.4

iv. CAPP´s Energy Intensity Indicator

This energy intensity indicator also shows the specific energy consumption of the field. Unlike other indicators systems, it does NOT make a comparison with a theoretical consumption.

CAPP´s energy intensity is defined with the following formula:

$$\text{CAPP Indicator}_{\text{year x}} = \frac{\text{REAL Energy Consumption}_{\text{year x}}}{(\text{Crude Production})_{\text{year x}} + (\text{Gas Production})_{\text{year x}}}$$

It is expressed in GJ/m3OE.

In order to determine if the indicator value is high or low, CAPP´s guideline suggests to compare it with the average values of the Canadian Oil and Gas production industry (according to data from 1995), depending on the type of field evaluated.

This indicator (energy consumption by m3 of equivalent Oil produced) gives an idea of the energy performance of facilities, but it does not indicate how its consumption should be comparing it with the one of reference of an equivalent facility with the same production conditions (same production levels, field maturity, existence of secondary recovery technology, etc.). For this reason, although it roughly shows the performance of a facility, this indicator has not been considered a reference for the industry.

b) Indicators system for oil refining activities

Given the characteristic complexity of oil refining facilities, there are several indicators systems for quantifying energy performance of the facilities in a refinery. Some of them are discussed in the next sections practically: consumption and losses indicators, energy saving indicator. Additionally, generic information on Solomon and Nelson indicators is included, which content and details can not be dealt with for copyright reasons. They are mentioned as they eventually became reference points when it comes to comparing facilities among companies (they are the only "benchmarks" that compile data of different companies in the sector confidentially)

i. Consumption and losses indicators – energy saving indicator

a. Energy Consumption

- Energy Consumption
  The energy consumption in a refinery is very diverse. It comes from several types of fuels (vectors) which include, among others: fuel oil, fuel gas, natural gas, propane, etc. The energy value of each vector is established by using the Intrinsic Calorific Value (ICV) of each product/vector. The energy consumption should be expressed in homogeneous units (For example: GJ):

Energy Consumption FuelGas = (Mass Consumption FuelGas) x ICV FuelGas = (Fuel Gas)

Also, there are other types of consumption (energy vectors) that transport energy generated from these fuels (for example: electricity, water and vapor for exchangers, etc.) and that is sometimes imported from outside the refinery. In all these cases, energy flows and consumption can be calculated with more or less direct methods using meters, gauges, flowmeters, etc. or calculating heat exchanges, enthalpy latent heat, etc. It should be noticed that the refinery flows that enter as raw material and come out as product, can also be used for the energy consumption.

Taking the previous considerations into account, the total energy consumption of the refining processes can be established, adding the consumption of each existing vector:

Energy Consumption = (FuelGas) + (FuelOil) + (Electricity) + (Vapor) + etc…

Values will be expressed in homogeneous energy units (GJ)

- Losses
  Apart from the energy used in the refining processes, LOSSES (or “wastes”) of energy products in facilities due to leaks, fugitive emissions, gas combustion in torches, etc… should be also taken into account. Losses are determined by mass balance, with the following formula:

t Losses = Processed raw material – Hydrocarbons consumption – Products

- Consumption and Losses (C+L)
  From this perspective, the total Consumption and Losses (C+L) value is:

Total Consumption C+L = (t Consumption) + (t Losses)

Consumption will be expressed in homogeneous energy units (GJ)

b. Activity Parameters

Activity parameter is the amount of Processed Raw Material (RRMM, Hydrocarbons). It can be expressed in mass units:

t RRMM expressed in mass units (metric tons)

However, the plain application of this parameter implies the addition of tons of hydrocarbons from different nature (Fuel oil, Naphtas, Gasolines and other hydrocarbons). That is, they are not homogeneous quantities. For this reason, a corrected parameter is defined, transforming the tons of each fuel to tons of fuel oil equivalent of 9590 kcal/kg.

t RRMM in units of energy (t FOE) (t Fuel Oil Equivalent)

c. Consumption and Losses Index

The consumption and losses index is a specific consumption indicator of a refinery. It is defined as:

C+L Index= (t consumption + t losses)/ t RRMM

This index can be used as a basis for calculating the real consumption of a facility (using the consumption and processed raw material data of a same year), as well as for calculating theoretical consumption (based on the C+L index of the previous year and the processed materials of the present year).

d. Real Energy Consumption

For the calculation of the real and theoretical consumption, follow up data on the Consumption and Losses of refineries will be used. The real energy consumption of the refinery is calculated from the C+L Index (tFOE/tRRMM) and the processed raw material data (tRRMM) from the group of refineries included in the indicator.

$$\text{Real energy consumption}_{\text{Refinery } i \text{ year } x}\ (tFOE) = I\ C{+}L_{\text{Refinery } I \text{ year } x} * tRRMM_{\text{year } x}$$

For turning tFOE into energy units of the IS (GJ) a ICV FOE value should be predetermined (the value is nearly 9600 Kcal/kg).

The total consumption of a group of refineries will be calculated as the addition of the consumption of each Refinery:

$$\text{Real energy consumption UN}_{\text{RE year } x}\ (GJ) = \Sigma\ \text{Real energy consumption}_{\text{Refinery } i \text{ year } x}$$

e. Theoretical Energy Consumption

For the calculation of the theoretical consumption, follow up data on the Consumption and Losses of refineries of the previous year and the processed raw material data (tRRMM) (assumed or real value) from the group of refineries included in the indicator.

$$\textit{Theoretical Energy Consumption}_{\textit{Refinery i year x}}\ (tFOE) = I\ C{+}L_{\textit{Refinery i year x-1}} * tRRMM_{\textit{year x}}$$

For turning tFOE into energy units of the IS (GJ) a ICV FOE value should be predetermined (the value is nearly 9600 Kcal/kg).

In the Consumption and Losses follow up, the consumption of bought electricity and the use of fuels should be adequately considered. The calculation of theoretical consumption, based on which the objectives follow up will be made, will include all the fuels consumption in all the process and services units, as well as the losses detected when mass balances are carried out. When fuels consumption is calculated, the electricity generated (self-consumption and sale) or the electricity bought will be taken into account.

f. Energy Indicator

It is an energy intensity indicator. As we have just seen, the theoretical consumption that can be used as reference is based on the specific indicators of the previous year. For this reason, it informs on the variation of energy consumption (saving or increase) from one year to the next with the same operation conditions.

$$\text{Energy Saving Indicator}_{\text{Asset i year x}} = \frac{\text{REAL Energy Consumption UN}_{\text{year x}}}{\text{Theoretical Energy Consumption UN}_{\text{year x}}}$$

As it was shown in chapter 2, this indicator can be linked to the saving concept based on a business continuity scenario ("Business as usual") under the same activity conditions.

The theoretical energy consumption is calculated for the whole group from the savings budgeted annually provided by the unit, and the savings on budget from the group indicated in the consumption and losses follow up report:

$$\textit{Theoretical energy consumption UN}_{\textit{RE year x}}\ (GJ) = \textit{Real consumption UN}_{\textit{RE year x}}\ (GJ) / (1\text{-}Savings)$$

Savings = Budgeted Savings + Savings on budget

ii. Nelson Complexity Indicator

Wilbur L. Nelson complexity index was described in a series of articles published by the Oil & Gas Journal in 1960-61. Through this method, a refinery is subdivided into its individual process units and a complexity factor is assigned to each of them. Nelson compared the different process units based on its installation costs (the initial purpose was to compare the cost of refineries). In this way, the cost of a crude atmospheric distillation unit was selected as a basis and was assigned a factor of 1. The relative costs of other units determined the factors of those units.

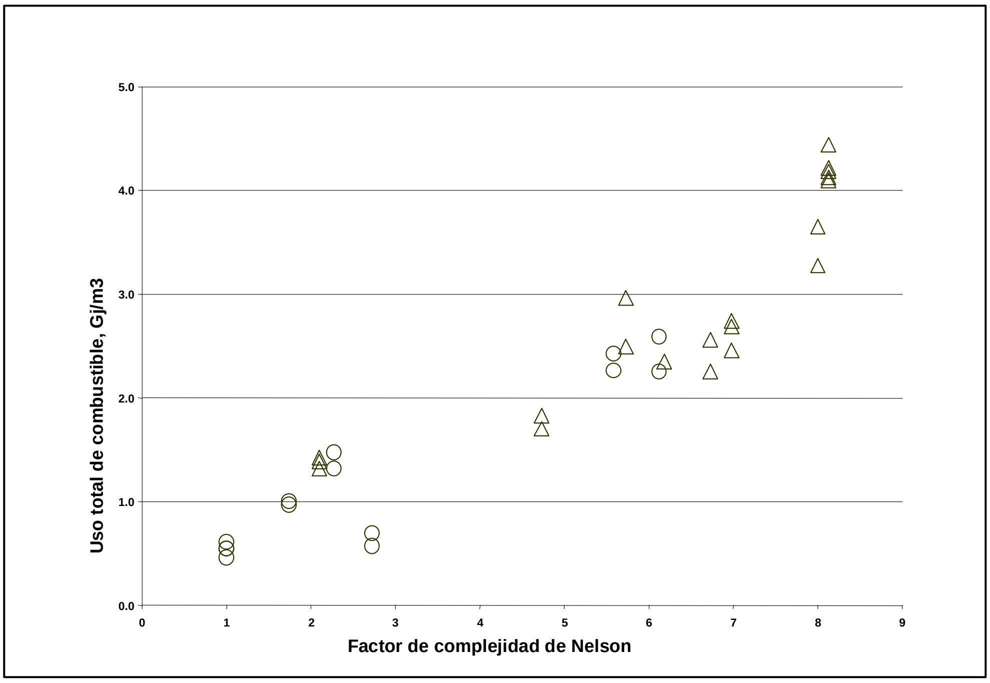
In general, the complexity of a refinery is determined through the proportional average of the complexity index of each unit, including the distillation unit. A refinery with a complexity index of 10 is considered to be ten times more “complex” than a refinery that has only the crude atmospheric distillation for the same amount of processed product. Over the years, the method has become more sophisticated. At present, the method differentiates between variations of the same basic technology and takes into account the use of multiple process trains. From the creation of the method, Nelson reviewed its factors, in view of the technological changes or the other companies in the field (like Solomon Associates) created their own factors under similar premises.

iii. Relation between complexity and energy consumption

One of the results of the use of complexity factors is the fact that many aspects of the operation of a refinery are related to complexity. And in particular, it is possible to correlate energy consumption with its complexity. This was very well proved in comparative studies of refineries. The link between the energy and the size/the complexity, can be used by plants to evaluate the relative success of their energy management programs. Figure 1 is an example of the relation between the fuel use and the complexity of the refinery. Data is taken from two groups of multiple refineries, using fuel consumption results from two years ago, or more. This type of chart allows carrying out comparative studies of the energy consumption among facilities with equivalent complexity. By the use of significantly large numbers of refineries, it has been possible to classify the energy consumption in any complexity/specific load rate, in a spectrum that varies from excellent to bad.

The most significant advantage of comparative studies is that they show the energy consumption of a refinery for the same complexity/load rate, and induce companies to try to improve their relative position in the database. This improvement is achieved through the implementation of adequate energy management programs and the introduction of more efficient technologies. Therefore, the repeated participation in comparative studies allows a facility to determine not only the efficiency of its energy management program, but also its progress rate, compared to its competitors.

Figure 1: USE OF FUEL IN REFINERIES AS A COMPLEXITY FUNCTION



? refineries group #1 O refineries group #2

iv. Solomon Energy Intensity Indicator (EII)

There is an internationally recognized study called Solomon Study, in which all the aspects required to operate a refinery are analyzed: costs (maintenance, personnel, energy…), operation, management efficiency indexes… The Solomon study implies confidential information on the operation of most of the refineries in the world. With this data, it establishes standards for each refining scheme. Comparing the results of a refinery with that standard, an idea of the performance of the refinery and its opportunities for improvement is obtained.

The Solomon Study index to measure Energy Efficiency is called Energy Intensity Index (EII). It represents the percentage of the total energy consumption of the refinery against Solomon's standard consumption for a refinery with the same process units, correcting by operation type, quality of products, performance, etc.

$$\text{EII} = \frac{\text{Units Real Consumption}}{\text{Solomon Standard Consumption}} * 100$$

Solomon Associates developed the calculation methodology based on confidentiality agreements and with copyrights on the calculation procedure. For this reason, it is difficult to describe in this document the calculation methodology of the EII indicator. However, it can be said that Solomon's EII indicator takes into consideration the configuration of a standard refinery and complexity factors aligned with those developed by Nelson.

Like the Energy Saving Indicator (ESI), the EII of a refinery is calculated by multiplying the load rate of each process unit by its energy consumption standard factor. The net result is an estimate of the amount of energy that "should" be consumed by the refinery, that is, the "standard" consumption. The real consumption is divided by the “standard” consumption, and then the result is multiplied by 100. In other words, if there is a “standard” energy consumption level, there is going to be an EII of 100. It should be explained that an EII of 100 does not mean an excellent energy management, but a standard performance. Therefore, a grade of over 100 shows that the efforts of the energy management program should be intensified.

This approximation implies a methodology that is not described in this guideline (and can not be described). Nevertheless, it is conceptually compatible with the terms indicated in the first chapters of ARPEL guideline.

c) Indicators System for Petrochemical Activities - Energy Saving Indicator (ESI)

i. Activity Parameters

In the case of chemical plants, the activity data is its production (in tons).

In the case of olefins crackers, the activity data is the value in production tons of “High Value Chemicals” – HVC (ethylene, propylene, etc).

The starting data for the calculation of real and theoretical consumption is the Specific Consumption of chemical plants (S.C.) – that is, its real energy consumption divided by the respective activity parameter (Production or HVC).

ii. Real Consumption

- **Calculation of the real energy consumption in a petrochemical complex (chemical plants)**

  From the specific consumption and production by plant indicated the real consumption of each complex is calculated as:

  $\textit{Real energy consumption}_{\textit{Complex i year x}} (GJ) = \Sigma\, CE_{\textit{Plant i year x}} * Prod_{\textit{Plant i year x}}$

  The total consumption will be the addition of all the complex consumption:

  $\textit{Real energy consumption } UN_{\textit{QE (without crackers) year x}} = \Sigma\, \textit{Real energy consumption}_{\textit{Complex i year x}}$

- **Calculation of the real energy consumption in crackers**

  The real consumption is half-yearly calculated from the specific consumption as:

  $\textit{Real energy consumption}_{\textit{cracker year x}} (GJ) = CE_{\textit{cracker year x}} * HVC_{\textit{cracker year x}}$

- **The total consumption of plants and crackers is calculated with the following formula:**

Real energy consumption $UN_{QE\ year\ x}$ *(GJ) = Real energy consumption* $UN_{QE\ (without\ crackers)\ year\ x}$ *+ Real energy consumption* $_{cracker\ year\ x}$

iii. Theoretical Consumption

- **Theoretical energy consumption in a petrochemical complex (chemical plants)**

  It is calculated from the specific consumption of the previous year:

  Theoretical energy consumption $_{Complex\ i\ year\ x}$ *(GJ) =* $\Sigma\ CE_{Plant\ i\ year\ x-1} * Prod_{Plant\ i\ year\ x}$

  The total consumption will be the addition of all the complex consumption:

  Theoretical energy consumption $UN_{QE\ (without\ crackers)\ year\ x}$ *= Σ Theoretical energy consumption* $_{Complex\ i\ year\ x}$

- **Theoretical energy consumption in crackers**

  It is calculated from the specific consumption of the previous year:

  Theoretical energy consumption $_{cracker\ year\ x}$ *(GJ) =* $CE_{cracker\ year\ x-1} * HVC_{cracker\ year\ x}$

- **The total consumption of plants and crackers is calculated with the following formula:**

  Theoretical energy consumption $UN_{QE\ year\ x}$ *(GJ) = Theoretical energy consumption* $UN_{QE\ (without\ crackers)\ year\ x}$ *+ Theoretical energy consumption* $_{cracker\ year\ x}$

iv. Energy Indicator

It is an energy intensity indicator. As we have just seen, the theoretical consumption that can be used as reference is based on the specific indicators of the previous year. For this reason, it informs on the variation of energy consumption (saving or increase) from one year to the next with the same operation conditions.

$$\text{Energy Saving Indicator}_{\text{Asset i year x}} = \frac{\text{REAL Energy Consumption UN}_{\text{year x}}}{\text{Theoretical Energy Consumption UN}_{\text{year x}}}$$

d) *Indicators System for LPG bottling activities - Energy Saving Indicator (ESI)*

i. Real Consumption

The real energy consumption of the global LPG bottling activity will be calculated as the addition of the real energy consumption of each facility:

Real Energy Consumption $_{GLP\ Global\ year\ x\ (GJ)}$ *= Σ Real Consumption* $_{Facility\ i\ year\ x\ (GJ)}$

ii. Activity Parameters

It is the number of LPG tons sold (processed) by each LPG bottling facility.

iii. Specific Consumption (SC)

The specific *energy consumption of each LPG facility is defined as the existing relation between the real energy used and the production (GJ/produced ton)*

Specific Consumption $_{Facil.\ i\ year\ x}$ = *Real Consumption* $_{Facil.\ i\ year\ x}$ / *Production* $_{Facil.\ year\ x}$

iv. Theoretical Consumption

The theoretical consumption for each facility will be obtained from the Specific Consumption (GJ/t) of the previous year and from the production of the current year.

Theoretical energy consumption UN $_{Facil.\ year\ x}$ *(GJ) = CE* $_{Facil.\ year\ x-1}$ *x Production* $_{Facil. Year\ x}$

Production = Sold (or processed) tons by each facility

The theoretical energy consumption of the group of LPG facilities will be calculated as the addition of theoretical energy consumption of facilities:

Theoretical Energy Consumption $_{GLP\ Global\ year\ x}$ *(GJ) = Σ Theoretical Energy Consumption* $_{Facility\ i\ year\ x}$ *(GJ)*

v. Energy Saving Indicator

It is an energy intensity indicator. As we have just seen, the theoretical consumption that can be used as reference is based on the specific indicators of the previous year. For this reason, it informs on the variation of energy consumption (saving or increase) from one year to the next with the same operation conditions.

$$\text{Energy Saving Indicator}_{\text{Asset i year x}} = \frac{\text{REAL Energy Consumption UN}_{\text{year x}}}{\text{Theoretical Energy Consumption UN}_{\text{year x}}}$$

e) Indicators System for the activity of selling fuels in service stations

i. Real Consumption

It is the addition of the energy consumption of each service station (in general, it is the value of the station's electrical supply meter).

ii. Activity Parameters

A service station has many types of areas of activity: the shop – the fuels sale area – carwash.

For the calculation of indicators, the following activity data is taken into account: the volume of fuels sold (l), shop area (m^2), number of tunnel car wash and boxes car wash of the service stations´ network.

iii. Reference Specific Consumption

Based on the total real consumption data and on the activity data of a reference year, the average specific consumption of a large number of service stations can be calculated for each activity area. This average Specific Consumption will be used as reference Specific Consumption. The numerical value of the Specific Consumption of each area (S.C.area) can be carried out through a multiple linear regression analysis.

iv. Theoretical Consumption

From the activity data and the reference specific consumption of each area, the standard consumption for the year will be calculated:

Standard Consumption UN $_{ME\ year\ x}$ *(GJ) = (SCpetrol pumps *Fuel Liters + SC shops ** m^2 *shop + SC tunnel *Wash Tunnel + SC Boxes *Wash boxes)*0.0036*

In which SC is the specific consumption of the different areas of activity of the service station (shop, petrol pumps, tunnel car wash and pressure washer guns/boxes).

The numerical values of this specific consumption can be determined by a statistical method by analyzing the energy consumption data and shop area, liters of fuels sold, number of washes in tunnels and boxes parameters in a large number of service stations.

v. Energy Intensity Indicator

Aligned with the definitions initially specified, the indicator compares the real consumption of the group of service stations with the theoretical consumption, reporting on the variation of the energy consumption (saving or increase) compared with the reference year with the same operation conditions.

$$\text{Energy Saving Indicator}_{\text{Asset i year x}} = \frac{\text{REAL Energy Consumption UN}_{\text{year x}}}{\text{Theoretical Energy Consumption UN}_{\text{year x}}}$$

4) Development of Consolidated Indicators

In general, oil and gas companies manage a group of Business Units that includes several of the activities described in the previous sections (oil and gas exploration and production – oil refining - petrochemical – LPG bottling - fuels sale in service stations, etc.)

Once the energy indicators are developed for each activity sector, it is of interest to develop a global indicator of the company that consolidates the information of each activity area. Two consolidation indicators are described below:

- Consolidated Energy Saving Indicator (ESI): This indicator takes as reference the standard consumption of the previous year. In this way, this indicator reports on the energy savings obtained from one year to the other for a complex group of activities (E&P, Refining, Chemical and others).

- Consolidated Energy Intensity Indicator (EII): This indicator takes as reference the standard consumption of a reference year (here we will arbitrarily indicate 2005). In this way, this indicator reports on the energy savings obtained for a complex group of activities (E&P, Refining, Chemical and others) in connection with that reference year.

a) Consolidated Energy Saving Indicator (ESI)

The indicator will be calculated directly consolidating in energy units the real and theoretical energy consumption values expressed by each Business Unit, values on which Units base their objectives follow up. The ESI will be obtained with the accumulation of performance annual variations. For the calculation of the indicator a base year should be set, consistent with the greenhouse gas reduction objective, if considered appropriate. For the reference year, the value of the ESI Group $_{\text{year 2005}}$ is 100.

ESI Group $_{\textit{year x}}$ *= ESI Group* $_{\textit{year x-1}}$ *· (Group real energy consumption* $_{\textit{year x}}$ */ Group theoretical energy consumption* $_{\textit{year x}}$*)*

Group real energy consumption $_{\textit{year x}}$ *= Σ Real energy consumption UN*$_{i \textit{ year x}}$

Group theoretical energy consumption $_{\textit{year x}}$*= Σ Theoretical energy consumption UN*$_{i \textit{ year x}}$

The theoretical consumption is the total energy consumption which a unit would have had in a certain year, under the operation conditions of that year, in the case that the energy intensity of the previous year was the same.

The Group's ESI in a certain year will be less or more than 100, depending on whether in the period between that year and the reference year, real consumption lower than theoretical ones predominated, or, on the contrary, if real consumption higher than theoretical ones predominated.

i. Characteristics of the Energy Saving Indicator (ESI)

The Energy Saving Indicator (ESI):

- Gives an idea of how we are doing compared with the base scenario. That is, it gives an idea of performance or saving.
- Allows freeing the effect of buying / selling of assets, as the baseline is corrected.
- Will be used to set objectives and follow up their achievement; that is why the data with which units carry out their objectives´ follow up will be used.

b) Calculation of the Group Energy Intensity Indicator (GEI)

The calculation of the GEI is carried out from several unit indicators: ex. Solomon EII, specific consumptions, etc. Given the different nature of Units/Operation Centers indicators of Repsol YPF, it is necessary to transform them into dimensionless indicators, common unit for comparing indicators. For the calculation of the indicator, 2005 will be taken as the base year, consistently with the greenhouse gases reduction objective.

IIE UNi (dimensionless) year x = IIE year x / IIE reference year •100

For all the units and for the year of reference 2005, the EII UNi (dimensionless) is 100.

From these dimensionless EII of units and by weighting according to their contribution to the total energy consumption, the Group Energy Intensity Indicator (GEI) will be calculated.

GEI (dimensionless) year x= Σ α UNi year x • EII UNi (dimensionless) year x α UN i year x = Real energy consumption UNi year x / Group Real energy consumption year x Group real energy consumption year x

i. Characteristics of the Group Energy Intensity Indicator (GEI)

The Group Energy Intensity Indicator (GEI):

- Gives a direct idea of the energy intensity of operations.
- Allows to visualize the effect of buying/selling of assets, as the baseline will not be reviewed for its calculation (that is, values of previous years are not corrected to make the assets consolidation scope match).

5) Examples of the use of Indicators

a) Benchmark

Indicators can be used to make a ranking of facilities and compare them among themselves. Nevertheless, this can only be carried out with those indicators that report on their energy performance regardless of its configuration or production level or activity (measuring the intensity or the energy efficiency). Several indicators have suitable characteristics for this exercise. It is the case of energy intensity indicators, as long as they compare the real consumption of a facility against the consumption of a facility with the same characteristics, if the same reference consumption standard was kept.

In some cases, energy intensity indicators take into account complexity factors that allow meeting the same conditions (example: Solomon's EII for Refining).

Benchmark as a Potential detection tool

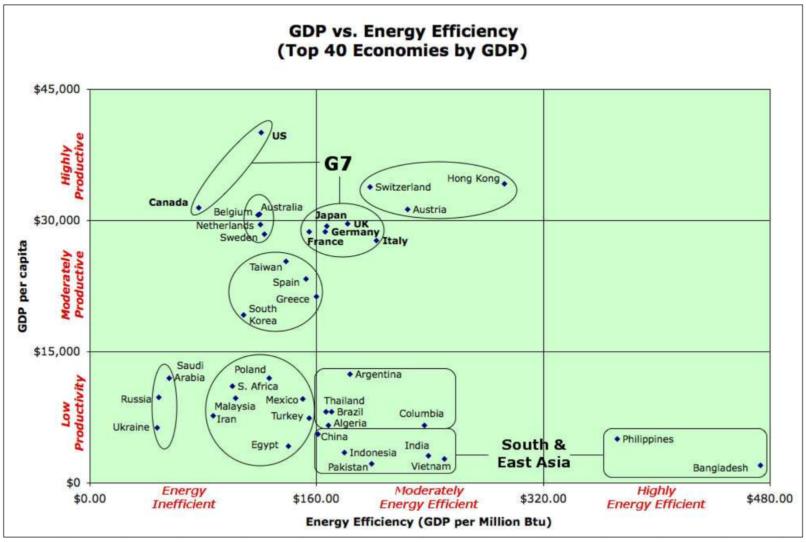
A benchmark allows identifying facilities with better and worse energy performance, indicating those that could be taken into account as efficiency reference points, and those in which there is improvement potential and on which concrete actions should be focused.

b) *Energy Efficiency Maps*

The previous indexes also set out, allow elaborating energy efficiency maps, crossing an efficiency indicator value (the specific consumption or also the energy intensity) against the total production of the unit. This is how energy efficiency maps are established which allow identifying the processes with the greatest improvement potential of efficiency in relative terms (intensity), but also in absolute terms: the main actions have to be aimed at facilities with low efficiency and among these, as a priority, to those with the greatest production.

To discuss a general case, we present the following example in which an energy efficiency indicator of several countries is classified (calculated in GDP/Btu) against the activity unit considered (the GDP of the country in question). This type of exercise can be carried out in any type of asset of the oil sector´s value chain.

Figure 2: GDP per capita vs. 'Economic Energy Efficiency' for the top 40 national economies



Source: Peter Corless 30 Sep. 2005.

Regional Association of Oil, Gas and Biofuels Sector Companies in Latin America and the Caribbean

ARPEL is a non-profit association gathering companies and institutions of the oil, gas and biofuels sector in Latin America and the Caribbean. It was founded in 1965 with the primary purpose of promoting industry integration and growth as well as seeking ways to maximize its contribution to sustainable energy development in the region. Its membership represents over 90% of the upstream and downstream activities in the region and includes national and international oil companies, companies providing technology, goods and services to the industry value chain, and oil, natural gas and biofuels sector institutions.

Since 1976 ARPEL holds Special Consultative Status with United Nations Economic and Social Council (ECOSOC). In 2006, the association declared its adherence to UN Global Compact principles.

Mission

To foster and facilitate industry development and integration, continuous operational improvement and effective management of environmental and social issues, by:

- developing, sharing and disseminating best practices;
- carrying out studies that translate in information of value;
- broadening knowledge and helping build required competencies;
- networking and engaging members and stakeholders in constructive dialogue.

Vision

A growing, competitive and integrated oil, gas and biofuels industry that achieves operational and management excellence, and effectively contributes to the sustainable energy development in Latin America and the Caribbean.

Value proposition

ARPEL is a well established industry association in Latin America and the Caribbean, offering members a unique means for networking, sharing knowledge, joining efforts and building synergies in favor of the industry’s competitive and sustainable development. As a recognized regional body of representation, the association also seeks to advocate in favor of the common interests of its membership and to enhance the industry’s public image and reputation.

A significant part of ARPEL´s value is reflected in its condition of cost-effective vehicle for the development of regional publications on best practices, emerging issues and sectoral studies, of value-added service center, and of means of access to non-reimbursable financial resources for projects related to the social and environmental management improvement of its member companies.

Socio-environmental sustainability
Operational excellence
Sectoral development