Energy Statistics Manual 2017

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Latin American Energy Organization

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Latin American Energy Organization (OLADE)

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FOREWORD

The Latin American Energy Organization-OLADE has made available this publication to its Member Countries and the public of the energy sector, with the main objective to become a reference guide for the administration of the energy statistics.

Through this document, OLADE seeks to promote in each Member Country the strengthening and sustainability of a structured system, fundamental for the organized, standardized, effective and efficient administration of energy statistics, which meet the characteristics of; consistency, completeness and timeliness.

These Parameters, which in combination with economic, social and other information, allow us to analyze how the trends and inertia of the past can affect the future development of the energy sector.

This manual contains the basic concepts necessary for the management, compilation, administration and validation of the energy sector's statistics. To obtain the preparation of energy balances in terms of final energy, the calculation of the inventory of greenhouse gases and the generation of a range of energy, economic, economic-energy and environmental impact indicators.

In addition to the information related to the balance sheet, this document also includes complementary topics that help in the analysis of the energy sector such as reserves and potentials, energy prices, energy infrastructure and socio-economic variables.

Another aspect to consider regarding the energy statistics, is the importance of maintaining a systematic organization, according to international standards. To back up this information, the document has made reference to the International Recommendations for Energy Statistics (IRES) of the United Nations Statistical Commission UNSD.

We would like to thank to the governmental authorities of our Member Countries, especially the information system advisors, and the team of consultants and officials who make up the Permanent Secretariat of OLADE, who have contributed to the preparation of this consultation document.

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Executive Secretary
OLADE

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CHAPTER I

Energy Statistics

1. Energy Statistics

1.1. INTRODUCTION

Energy statistics play an important role in energy balances because they are developed from the data countries report to international organizations. Given their relevance, it is essential to organize the information systematically according to international standards to ensure that the data submitted are comparable.

Thus, since the 2011 version of the Energy Statistics Manual, OLADE has made an effort to align its structure with that of energy information transparency initiatives such as the JODI (Joint Organisations Data Initiative).

Major international organizations have made a significant effort to create a standard for mutual understanding among countries, as in the case of the International Recommendations for Energy Statistics (IRES), the International Energy Agency (IEA), and the International Renewable Energy Agency (IRENA). And of course OLADE, aware of the important role it plays in collecting energy statistics for Latin America and the Caribbean, has made significant efforts through its SIEE and SIER energy information systems, and each of the SIEE advisors who review and approve the methodologies proposed in this document.

This update of the Energy Statistics Manual includes decisions made at the 16th Work Meeting of SIEE Advisors in Port of Spain, Trinidad & Tobago, on October 23, 2015, regarding the new structure of the Energy Balance Matrix presented by OLADE.

1.2. IDENTIFYING SOURCES OF STATISTICAL DATA

Typical sources of statistical data are surveys of the population under study. These are carried out by either consulting the entire population, which will be called a census, or a representative sample, which will be called a survey, discussed later in this manual. Censuses are intensive exercises that require a lot of time and resources because they consult the entire population. However, depending on the population of interest and the resources of individual countries, a census can be a good option for obtaining energy data.

Sample surveys are used to gather information from part of the population that is called a sample, from which conclusions will be drawn about the entire population; in most cases, they are less expensive than a census. The surveys that are most commonly used depending on the sample are: 1) Business surveys, 2) Household surveys and 3) Mixed surveys of homes and businesses. It should be noted that a significant part of the effort in statistics should involve finding a suitable design for sources of energy statistics, where surveys play a very important role, as they are the main sources of data.

In the case of OLADE, the main sources of information are official institutions related to the energy industry, through an organized structure of contacts by which communication is established between an OLADE specialist and a focal point or SIEE Advisor in each member country.

The information required for analyzing and processing statistics comes from different sources. Operational information on energy should be collected from both public and private organizations; the entities have these records for their internal management processes and they are subsequently used for energy statistics.

State institutions collect information to monitor, record and supervise activities related to the production and consumption of energy to reduce compilation times and update data more often, among other reasons.
Private entities such as industries and energy producers collect statistical information for internal production control processes, of vital importance to their activities, and for measuring efficiency indices.

It is important when analyzing energy statistics to identify and review the country’s various sources of operational data, as they collect information for different purposes, often unrelated to the energy sector.

Important records that countries collect, which are valuable as sources of operational data on energy, include customs records (import/ export of energy sources), records on the types of fuel taxes, registration of regulated gas and electricity market operators and population censuses. It should be noted that countries do not necessarily collect this information for the purpose of energy statistics, so the information must be classified.

Data collected by private sector organizations can also help understand the industrial and commercial sectors as well as several important aspects of their productive activities. This information may be confidential, so the necessary efforts should be made to lift confidentiality restrictions. Information from some consulting firms that perform energy project studies or market research may have a cost, so it is necessary to evaluate the cost-benefit of that source of information.

1.3. INSTITUTIONALIZING ENERGY DATA

We should mention that where this publication refers to an Information Management System, it means an organized structure with roles, responsibilities, methods, procedures, methodologies and timelines to handle and publish information on the energy sector. This should not be confused with the Energy Information System, which makes it possible automate that system.

The legal framework is one of the most important points to be resolved when the energy information system is institutionalized, as it must be considered for all matters relating to statistics; it specifies the responsibilities and laws that govern entities that collect and provide data, or produce or use statistics.

A second important point to address is the creation of appropriate institutional arrangements between agencies with important data for energy statistics, so that they can implement appropriate processes of data collection and analysis. It is useful to create a standard for these processes among all the institutions involved, as well as a centralized information system for energy statistics. It is recommended that these standards be consistent with international methodologies so that they can be compared and if appropriate data held by international energy agencies can be utilized.

1.3.1. Identifying Information Providers

Like other international agencies, OLADE distinguishes three main groups of information providers: energy industries, energy self-producers, and energy consumers.

Energy industries are entities whose main activity is energy production; they can be involved in processing a particular fuel or specialize in part of the energy supply chain. This group includes electricity generators, gas processing plants and refineries.

For energy producers it is important to have detailed records of their processes not only for managing the business but also to meet the reporting requirements of regulatory agencies. Data from this source can easily be obtained without much delay and is of high quality.

When the person who processes statistical data has no direct contact with energy producers, it is common for some institutions such as producer associations, industrial chambers, regional offices and civil society organizations to act as intermediaries between the data processor and the original sources to facilitate the data collection process.

The Self-producers: these are energy producers that generate power for their own consumption; this group includes companies carrying out industrial activities as well as residential producers. Companies sometimes supply power to other consumers but not as part of their core business. For example, companies that produce cogeneration electricity for their own use from the heat generated by other industrial processes. From an energy statistics point of view it is not unusual for data from these companies to have the same quality as information from those whose main activity is energy production; in these cases, special surveys are needed to collect the data.

Although in many cases, the self-producers represent only a small percentage of national energy production, international recommendations suggest that they be included in the national energy statistics, in particular because of the trend towards an increase in total energy production and because their energy consumption is important for measuring CO_2 emissions and calculating energy efficiency indicators. In countries where other energy producers play a significant role in the national aggregate of energy supply and consumption, procedures that are more appropriate should exist to help obtain better data. In some countries, self-production (or cogeneration) requires a government permit, which helps monitor these companies to obtain data that are more meaningful.

Energy Consumers: Sectors with energy supply needs such as industrial, transportation and residential belong to this group. The processes for obtaining information from these groups require greater effort by statistics organizations because they have to consider factors such as dispersion, diversity, mobility and others, so consumer surveys are the main means of data collection; however, the design should include specific collection methodologies and strategies using consumer subgroups, given their particularities.

In most cases, producers provide information on the energy consumption of their users. However, if the information is incomplete it is necessary to design consumer surveys. In other cases such as firewood consumption, residential areas need to be surveyed in order to obtain that information.

1.3.2. Formalizing the Energy Information Committee

In order consolidate a sustainable information management system to handle energy statistics, OLADE recommends an organizational structure called an “Energy Information Committee”.

According to OLADE, the energy information committee is a group of specialists in the energy sector that provide and receive current energy information with the effective participation of representatives of the main institutions in the sector.

There are three types of members: first, the technical team responsible for management and technical support; second, sub-sector coordinators who are a group of specialists from the Ministry or Department of Energy; and third, representatives of public and private energy sector entities.

The members of the Energy Information Committee have two main functions. First, they advise the System Administrator in order to establish the characteristics, availability and requirements of the information, in particular for each of the sub-sectors they represent and in general for the entire energy sector. Second, they provide access to information and facilitate collaboration by the organizations they represent, and propose suitable alternatives regarding the operation, functionality, management and dissemination of the information system.

The information administrator has the following functions:

- Coordinating with the agency serving as the platform administrator (OLADE) and the Energy Information Committee regarding the content, scope and breakdown of information that is provided to the information system
- Coordinating data collection, processing and entry into the system
- Identifying issues to be considered by the Committee
- Convening and coordinating Committee meetings
- Maintaining the information system in constant production, and ensuring the quality, timeliness and accuracy of the information
- Connecting the Energy Information Committee with the agency that manages the information (OLADE in our case)
- Informing the rest of the Committee about the status and operation of the information system
- Promoting the dissemination of the energy information system between the authorities of the sector and the energy community.

OLADE supplies its Member Countries with the IT platform of the Regional Energy Information System (OLADE-SIER). If an IT system is available, a computer specialist should be designated to advise the Energy Information Committee on information technologies related to the tool, to be entrusted with the following activities:

- Installing and upgrading Energy Information System components
- Managing the system as a software tool
- Providing technical computer support to Committee members and users of the system
- Promoting a technical computer link with the administrative body

Sub-sector Coordinators are responsible for coordinating the provision of information that is recorded in the Energy Information System with sector entities; supporting data entry, review and quality control with their expertise; and developing or participating in the development of analyses and assessments in their area of expertise and in the sector in general. They will support the System Administrator in the following activities:

- Providing technical support in a particular energy sub-sector
- Facilitating interaction between the System Administrator and sub-sector Advisers
- Maintaining the consistency, accuracy and timeliness of the information
- Managing the collection and updating of sub-sector information
- Defining the requirements for the Ministry, Department or Entity that implements the Computer System
- Defining the parameters (configuration) for information related to their sub-sector

Sub-sector Advisors advise the System Administrator on the characteristics of the information, and the content, scope and functional specifications of the system, facilitate the provision of information by each of their institutions and promote the use of the system by their institutions. They are responsible for the following activities:

- Ensuring an adequate procedure for the flow and management of the statistics required by the System
- Defining the System configuration according to the structure of the energy sector
- Implementing, managing and maintaining the Information System
- Managing access to the Information System by external users and the general public
- Advising the Statistical Committee on the definition and implementation of a data structure suitable for their country
- Defining the parameters (configuration) of the information related to its sub-sector
- Facilitating access to information and collaboration among the entities represented by its members
- Setting criteria for the consistency, accuracy and timeliness of information
- Managing the provision and consolidation of sub-sector information

The following describes some of the benefits of having an Information Management System:

- The Information System will integrate all the information from the energy chain, establish uniform criteria for its standardization and guarantee the reliability of the results and analyses that involve it.
- The System will have historical series for the most important energy sector variables to establish trends, and identify the causes of changes in the composition of the energy mix and prospects for the future performance of the sector.
- The implementation of the Computer System will optimize the timing and frequency with which energy data from each country has been provided and published up to now.
- Indicators obtained with the Information System will combine economic and energy information, permitting sector analysis and providing better elements for planning.
- In addition to the benefits mentioned above, implementing an IT system such as OLADE-SIER will provide a single platform with numerical data, documentation, texts, and information on laws that affect the energy industry.
- As a computer tool, OLADE-SIER uses cutting-edge technology that makes updating, managing and querying simple, practical and user-friendly so that anyone can use it with no need for special platforms or expertise. Future expansions and improvements will also be possible with minimal technological effort and resources.
- The system increases the possibility of a better understanding of energy sector behavior, both by authorities and society in general, and provides the best elements for its development and planning.

To *establish the Energy Information Committee*, the System Administrator will convene a meeting with representatives of the entities and institutions linked or related to the energy sector who are from the areas of statistics and information processing and/or analysis to present the features, activities, scope, and benefits of the system, and request their participation as Information System Advisors.

It is recommended that the Committee be formalized by means of a resolution or regulation issued by the Ministry or Department to give it institutional backing to be able to seek the cooperation of other entities. It should agree on a procedure that will allow the representatives of each entity to be officially appointed so that they will have institutional support.

1.4. Sources of statistical data: statistical surveys

As was explained in this chapter, censuses and surveys are the most important sources of energy data, but since a census requires a large investment of time and money, a survey is mainly used as a typical source of statistics. Statistical surveys are carried out in the population of interest and the results for the entire population are inferred from them.

Typical surveys can be classified according to the international standard of IRES: 1) industrial surveys (for energy supply, applied to companies that produce energy), 2) Household surveys (groups of people with similar economic and social characteristics); these surveys investigate the characteristics of energy demand and, 3) Mixed surveys that are a combination of the two.

The design of statistical surveys is very important and is expected to take into account important aspects such as the particular information needs for which the survey will be conducted as well as the objectives of that information; the sample (size and group(s) of interest) to be surveyed can then be defined. It is important to note that the end product of the survey design will be questionnaires and supporting documentation for training interviewers to resolve any issues that may arise with the interviewees.

Based on OLADE's experience collecting data from different energy sources, it is recommended that coordination and permanent dialogue be established among the institutions that implement surveys such as the different ministries of the country. This will ensure that they do not overlap and generate unnecessary expenditures on the design of the survey or impose an additional burden on the interviewers who carry out the surveys.

Energy surveys generally provide better information on fuel consumption than other sources such as official records. In particular, when surveys of biomass consumption are designed to target specific rural groups, they will be the best option for collecting energy information. However, often these data need to be estimated when time and financial resources are not available.

When specific surveys of the biomass sector are designed, the Renewable Energy Agency (IRENA) recommends that the number of inhabitants using firewood for cooking purposes be studied, how many have access to other fuels and how many use firewood for heating purposes. For this type of survey, it is recommended that questions be simple and direct with answers that are 'yes' or 'no,' so that a clear understanding is possible between the interviewer and the interviewee to optimizing the time used to conduct the survey. In rural areas, this can be very significant due to the long distances involved.

Finally, it is important to note that in some cases it will be a difficult task to sample all the subgroups of interest, therefore estimates based on survey results must be used and results must be inferred based on the geographic and socioeconomic characteristics of similar subgroups.

1.5. STATISTICAL DATA COLLECTION

It is important for each country to have programs and methodologies for collecting data on energy statistics, which must comply with information quality criteria, standardized calculation methods and national and international data sources to ensure that the information is detailed, complete, timely and reliable.

OLADE's energy planning manual recommends that countries carry out the following actions in order to ensure a proper collection process:

- *Identify organizations that are specifically responsible for the data and statistical analysis.*
- *Review and verify the scope, quality and reliability of basic data. This evaluation may include availability of data, frequency of reporting or collection of data, time periods, quality, reliability and relevance. Statistics should be consistent in form and definition. Units of measurement should be standardized.*
- *Determine the existence and type of energy indicators that are already in use. In this case, it would be necessary to determine whether these indicators are in line with what is proposed in this chapter.*
- *Identify sources of information and mechanisms and protocols for accessing data.*
- *Evaluate the institutional structure responsible for generating information and verifying the appropriate systemic or organizational coordination.*

As mentioned earlier in this chapter, data collection for energy statistics can involve a significant expenditure of resources, and due to the situation of some countries this renders the task at least partially unviable; in these cases the best solution may be to recur to more general estimates that do not involve large amounts of resources. The regulatory framework and methodologies of the countries should carry out an organized evaluation of the scope and coverage of the data collection process and determine the cases in which the best choice will be to estimate the data.

According to the international recommendations of the IRES (2011), built into the OLADE's Energy Planning Manual (2014), data collection should take into account the conceptual design, the institutions from which information is obtained, the geographical coverage, the reference period, and the frequency of data collection.

According to IRES, the conceptual design defines the general objective of data collection. The scope should take into account the structures of the different production chains and their current situation, the type of statistical data to be collected, such as, for example, flows and stocks of energy sources and units of measure. Moreover, international standards should be applied during the process of designing the database.

Institutions and organizations from which data is obtained should be known by the working group that will carry out data collection in order to ensure efficient work. It is recommended that they be classified into groups such as energy companies, self-producers and energy consumers.

The geographical coverage identifies the physical area where statistical data are collected, which is generally at the national level; however depending on the priorities of the countries, it can also be done at the regional level, and in that case the energy data collected will have a better level of detail.

The reference period refers to the time period covered by the data that is collected. During the reference period, data can be collected on an hourly, daily, monthly or other basis.

The reference period of the data must be carefully planned and recorded since the data collected may exhibit cyclical or seasonal behavior. The latter can make a big difference in the analysis, and can be a source of error if the time of year when the information is collected is not appropriate.

Frequency of data collection

Most international energy statistics agencies collect data annually due to the need for more detailed information covering the whole chain, production, transportation and consumption. Other agencies, such as JODI, collect data on a monthly basis. In general, the data collection frequency (monthly, quarterly, semiannually or annually) will depend on the priority of the data; for example, it is important to have monthly petroleum production and marketing data. Although its scope is narrower than the one carried out annually due to the higher data collection frequency, in general the associated costs are greater.

In some cases, data collection with a frequency of less than one year is used for special reasons such as filling gaps in the data collected annually, in order to establish a baseline for the information.

In OLADE an annual data collection is performed in order to elaborate the energy balance, reserves' annual information, potential, energy prices, energy infrastructure, and national and environmental impact variables. There is also a proposal to collect monthly data on supply and demand of oil in order to harmonize structures with JODI, also collect monthly information on electricity , biofuels, final consumer prices and foreign trade.

1.6. DATA ANALYSIS

The data obtained in the previous step (collection) is processed in this stage to obtain new information. Processing involves the organized use of statistical models that follow a set of rules to take the data and transform it into statistical outputs. According to the experience of OLADE and based on international standards such as IRES (2011), data analysis involves the following steps:

1. Data validation and editing,
2. Assignment of missing data and
3. Estimation of the characteristics of the population.

The first stage organizes and processes the data to provide a first look at the information and determine whether errors were made in the collection stage, including insufficient coverage, questions that remained unanswered, answers outside the expected range or contradictory answers. The next stage processes data that contains insufficient or conflicting answers by replacing values in order to treat the data with statistical techniques. Finally, in the third stage, if data with reliable features are not observed, it will be necessary to estimate the missing data according to historical values.

The problems encountered in statistical information are often related to deficiencies in questionnaire design, generally due to a lack of knowledge of the characteristics of the population, interviewer mistakes made due to inadequate training, errors in the forms of institutions that provide energy information and errors from inadequate processing due to a lack of staff training in statistical tools.
The above data processing steps are described below.

1.6.1. Data Validation and Editing

This is a necessary process that guarantees the quality of data collected from several statistical sources, primarily surveys. A systematic analysis of the information is carried out to identify and/or modify questionable data; this involves the use of systematic statistical procedures.

Validation procedures and criteria must be defined by the relevant statistical authority based on the type of information being processed. It is important to note that these systematic procedures are to prevent the improper modification of original data.

Some problems with data can be prevented in the questionnaire design stage (in the case of surveys) by linking several questions so that if no response is obtained for one question, there are several options for replacing it. Another possible solution for obtaining proper responses is to give information providers more time to obtain the data.

Since the data validation and editing stage requires highly trained personnel and statistical tools that are very expensive, it is important to assess appropriately the most important areas where efforts should be focused in order to avoid correcting unnecessary information, both for its insignificant impact on the final results and the fact that it might be repeated.

1.6.2. Data Assignment

According to IRES, the next step in data analysis is assignment, which refers to the process of replacing incorrect answers or missing data with consistent values in order to obtain a consistent set of data.

There is a wide range of assignment methods involving simple to complex statistical methods that include optimization stages to improve data processing times. In general, the choice of a data assignment method should take into account the characteristics of the missing data and the relevance of such data in the overall analysis.

Some of the characteristics of data assignment suggested by international agencies are:

1. The amount of assigned data should always be minimized to preserve the original data as much as possible,
2. Assigned data must undergo an editing process to confirm its validity, and
3. Data that has been assigned and the procedure used for assignment must always be shown.

1.6.3. Procedures for Estimating Data

After the data has been validated and edited, and assignments have corrected erroneous responses and unanswered questions, special procedures are applied to sample values to estimate the required characteristics of the population (known as 'extrapolation' procedures). This consists of raising the value of the sample by a factor based on the sampling fraction in order to obtain the levels of data for the framework population of the sample. In some cases, more sophisticated statistical methods can be used for this purpose. The use of estimations is a complex process and it is recommended that this task always be performed by specialists.

According to IRES, the treatment of outliers is an important estimation, particularly in energy statistics. These values are data that are correct but unusual in that they do not represent the sampled population and therefore can distort estimations. If the sampling weight is large and the unadjusted outlier is included in the sample, the final estimation will be unduly large and representative, as it is driven by an outlier. The easiest way to deal with an outlier is to reduce its weight in the sample so that it represents only itself. Alternatively, statistical techniques can be used to calculate a greater weight that is appropriate for the outlier unit. Details about the treatment of these values should be provided in the metadata.

1.7. DATA QUALITY CONTROL

Ensuring data quality is a crucial matter for statistical offices. Energy data available to users are the end product of a complex process with many stages, including the collection of data from multiple sources, data processing, adaptation to the needs of end users and, finally, dissemination of the data. The quality of the final data depends on ensuring excellence in each of the stages of data collection, processing and analysis.

According to the good practices recommended in OLADE's Energy Planning Manual (2014), data quality can be divided into static and dynamic quality dimensions.

The dimensions of data quality have to do with static as well as dynamic quality elements. The static dimension involves elements that tend to change relatively slowly. Static elements of data quality are associated with features such as relevance, credibility, accuracy, timeliness, coherence and accessibility.

Each of these dimensions is presented according to the IRES (2011) recommendations.

1. *The relevance* of energy statistics reflects the degree to which the data are available for the needs of end users. Thus, the relevance of the information requires that user groups and their data needs be identified. The responsible agencies should balance the different needs of current and potential users through a program that meets their most important needs in terms of energy data content, coverage and timeliness, given the constraints on resources. Strategies for measuring relevance include users' tracing requests and the capacity of energy statistics programs, user satisfaction surveys and analysis of the results; direct consultation with key users about their interests, needs and priorities, and their views with respect to gaps and deficiencies in the statistics of the energy program. Statistics programs should be adjusted periodically because user needs change dynamically.
2. *The credibility* or integrity of energy statistics develops over time and is the trust that users place in the data, based on the reputation of the bodies responsible for producing them. A key aspect is confidence in the objectivity of the data, which means treating it according to internationally accepted standards.
3. *The accuracy* of energy statistics refers to the degree to which the data are correctly estimated or describe the quantities or characteristics for which they were designed. There is no single overall measure of accuracy, so errors are characterized in terms of the inaccuracy of statistical estimations and are traditionally broken down into bias (systematic error) and variance (random error).

   However, it also includes a description of any process carried out by the agencies responsible to reduce measurement errors. For energy estimates based on survey data from sampling, the accuracy can be measured by the following indicators: rates of coverage, sampling errors, errors due to unanswered questions, processing errors, and measurement and model errors.
4. *The timeliness of the information* refers to the time between the end of the reference period of the information, and its availability to users. Of particular importance is the period during which the information is still useful for its main objectives. This varies according to the rate of change of the phenomenon being measured, the frequency of measurement and the immediacy of the user response to the latest data.
5. *The coherence* of energy data is the degree to which the data are logically connected and mutually consistent, that is, the degree to which they can be successfully assembled with other statistical information within a broad framework of analysis. The use of concepts, definitions, classifications and target populations promotes coherence, as does the use of a common methodology across surveys. It should be noted that this does not necessarily mean numerical consistency.
6. *The accessibility* of information refers to the ability of the information to be disseminated and adopted in work environments. This includes the means of accessing the information (the ease of obtaining it), the availability of the data and the support received by users.

CHAPTER II

General Definitions

2. General Definitions

Below are some important definitions from an energy production perspective. They are part of the daily work of the staff drafting the energy balance of each country and are essential to developing a general framework of understanding among the different parties engaged in developing energy statistics.

The definitions given below were compiled from international standards and formulated in accordance with the needs of the region, using simple language to provide an understanding of energy sector concepts and facilitate consultation among the entire community engaged in developing energy statistics.

This chapter introduces concepts, definitions and classifications that will be presented in greater detail in the following chapters.

2.1. DEFINITION OF ENERGY

Energy is the ability of a natural or artificial element to produce changes in its environment, and can be used and/or transformed as motion, light, heat, electricity, radiation, etc.

Energy has different definitions, depending on the field of study, such as classical mechanics, quantum mechanics, or relativity theory. In physics, it is the ability of a system to perform work. For the purposes of this document, energy is the ability of a natural or artificial element to produce changes in its environment.

2.2. FORMS OF ENERGY

Energy manifestations may or may not be perceptible to the senses, but can be used or transformed by various means in the form of motion, light, heat, electricity, radiation, etc. Energy can be divided into two categories: potential and kinetic. The former is stored in some form, such as the potential energy of water, while the latter is associated with the energy of motion.

2.3. ENERGY SOURCES

Conceptually, energy sources are all natural or artificial products from which energy can be obtained in any of its forms and manifestations. However, the field of energy statistics only considers those that can produce heat and/or electricity.

2.4. ENERGY MEASUREMENT

From a statistical perspective, energy is quantified according to the sources from which it is obtained, with the following distinctions:

a) Fuel sources, such as solids, liquids and gases, can be measured as physical units of mass or volume, or as units of energy, according to its ability to produce heat by combustion.
b) Non-fuel sources, such as solar, geothermal, hydropower, and wind power, are only measured as units.

2.5. ENERGY CONTENT AND CALORIC VALUE

For the purposes of energy statistics, this is the energy content of a source and its ability to produce electricity and/or heat. Caloric value or power is the amount of heat per unit of mass that a source material can produce through combustion.

There are two measurements of caloric value: a) higher caloric value, and b) lower caloric value.

a) Higher or Gross Caloric Value
This is the amount of heat generated through the combustion of a product, including the latent heat of steam, which is formed by combining its hydrogen content with oxygen from the air.

b) Lower or Net Caloric Value
This is the amount of heat generated by the combustion of a product, not counting the latent heat in the steam that is formed. Note that the lower caloric value is taken to quantify the caloric content of a fuel source, since the combustion heat contained in steam, which is released when the water condenses, is lost when the steam dissipates into the atmosphere.

2.6. DEFINING THE ENERGY CHAIN

The energy chain is a series of steps, activities and events through which an energy source passes from origin to use, such as production, transportation, processing, storage, etc.

2.7. DEFINING A COUNTRY'S ENERGY MIX

This is a study of the energy industry to quantify the supply, demand and transformation of each energy source within a country, as well as its inventory of energy resources, taking into account their historical evolution and future projection. Understanding and analyzing the energy mix are key aspects of planning and ensuring energy supplies.

2.8. DEFINITION OF ENERGY BALANCE

An energy balance quantifies the energy flows at each stage of the energy chain and the balance of supply and demand by which energy is produced, traded abroad, transformed, and consumed. The field of analysis is a country or region over a specified period (usually a year).

2.9. DEFINITION OF ENERGY STATISTICS

Energy statistics are series of figures over time, which quantify both energy flows through the energy chain and other sectoral variables such as reserves and potential, production capacity, processing capacity, transportation capacity, storage capacity, prices, etc. These statistics may also include economic and social variables of great importance to the analysis of a country's energy performance.

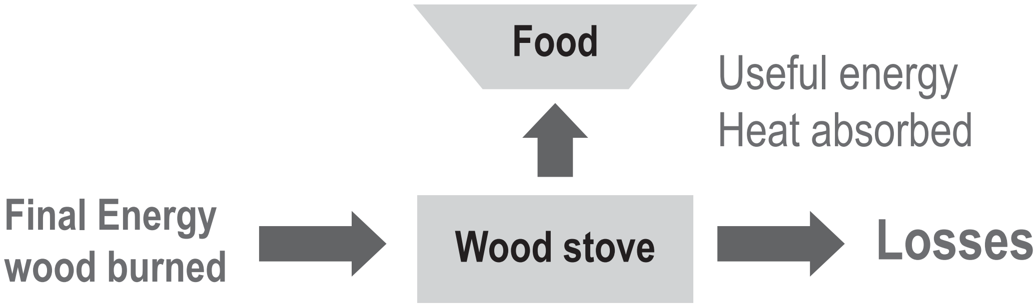
2.10. DEFINITION OF FINAL ENERGY

Final energy is the amount of a given energy source consumed by each of a country's economic and social sectors, regardless of the efficiencies of the equipment or household appliances used.

2.11. DEFINITION OF USABLE ENERGY

Usable energy is the amount of energy actually used to fulfill the productive purpose of a piece of equipment or household appliance.

Figure 1. Final Energy and Usable Energy



Source: OLADE

2.12. END USES

End uses are useful applications of energy to meet the specific needs of a productive or social activity, which include the following:

- Lighting
- Heating
- Refrigeration
- Air conditioning
- Cooking
- Process heat
- Movement
- Electromagnetic waves

CHAPTER III

Definitions of Energy Sources

3. Definitions of Energy Sources

Definitions of the main energy sources in the energy balance are presented below. They were reviewed in the light of international energy statistics manuals and adjusted according to the realities of the region.

3.1. PRIMARY ENERGY SOURCES

Primary energy is defined as energy sources in their natural state; i.e., they have not undergone any physical or chemical transformation through human intervention. They can be obtained from nature, either directly as in the case of hydro, solar and wood energy and other plant fuels, or after an extraction process such as petroleum, coal, geothermal energy, etc. Primary energy sources are subdivided into two groups: a) non-renewable energy sources such as fossil fuels and nuclear energy, and b) renewable energy sources such as hydropower, wind energy, solar energy, biomass, etc.

NON-RENEWABLE PRIMARY ENERGY SOURCES

Fossil resources that are exhaustible over time and have a very long period of formation are considered to be non-renewable primary sources.

3.1.1. Primary Hydrocarbons

3.1.1.1. Primary petroleum

This group includes all hydrocarbons that are the main feedstocks for refineries and fractionation plants, from which the secondary petroleum products are obtained. In specific cases, they are also used for final consumption in certain industrial activities. This energy source group has been subdivided into three categories: a) crude oil, b) natural gas liquids (NGL) and c) other hydrocarbons.

Petroleum Classification Criteria
Crude oil can be classified according to the following criteria:

1. By its sulfur content:
   - Sweet crude oil
   - Sour crude oil

2. By its density:
   - Light crude oil (30-40 °)
   - Medium crude oil (22-29.9 °)
   - Heavy crude oil (10-21.9 °)
   - Very heavy crude oil (less than 10°)

3. By its chemical composition
   - Paraffin
   - Naphthene
   - Aromatics

Crude oil
A complex mixture of hydrocarbons of different molecular weights with a fraction, generally small, of compounds containing sulfur and nitrogen. The composition of crude oil is variable and can be divided into three classes according to its distillation residues: paraffin, asphalt or a mixture of both.

In its natural state, it is in the liquid phase and remains in this stage under standard temperature and pressure conditions, although the field it may be associated with gaseous hydrocarbons. This category includes associated gas liquids that condense in production facilities when they reach the surface (petroleum condensates) or other liquid hydrocarbons that are mixed with the commercial flow of crude oil. Crude oil is the main feedstock for refineries that produce petroleum products and derivatives.

Other hydrocarbons
This item includes other refinery feedstocks that are not natural crude oil, including synthetic crude oil and Orimulsion.

3.1.1.2. Natural gas liquids

They are liquefiable low molecular weight hydrocarbons, recovered from associated or free natural gas in separation or processing plants, or they condense during the handling, transportation and compression of natural gas. They include propane, butane, ethanol and pentanes and are feedstocks for refineries and fractionation plants.

3.1.1.3. Natural gas

A gaseous mixture of hydrocarbons. It includes both the free natural gas and associated gas and it also occurs in coalmines or geopressure areas. Both free gas and net produced associated gas are considered to be from the same source for the energy balance since nature and use are similar.

It is defined as a mixture of gaseous hydrocarbons, mainly methane, but it generally also includes ethane, propane and other hydrocarbons in smaller percentages and some non-combustible gases such as nitrogen and carbon dioxide. When distributed, natural gas may also contain quantities of biogas and manufactured gases from gas plants and gas ovens.

Natural gas is usually obtained from oil fields, associated with oil flows, and from free gas fields. Natural gas also includes coalmine gas, coal seam gas and shale gas. The latter is natural gas trapped in shale rock formations, and is becoming increasingly important as a source of natural gas in certain countries.

For transport, natural gas can be subjected to a liquefaction process in which its temperature is lowered for ease of storage. Liquefied natural gas occupies about 1/600 of its volume under normal conditions, and temperatures are lowered to levels of -160 ° C.

➢ **Associated natural gas**

A hydrocarbon gas mixture that is associated with crude oil. It generally contains lighter fractions of liquid hydrocarbons (condensables), so it is often called 'wet gas.'

➢ **Non-associated natural gas**

A hydrocarbon gas mixture consisting mainly of methane obtained from gas fields. Since it generally does not contain condensables, it is often called 'dry gas' or 'free gas.'

➢ **Unconventional Hydrocarbons**

The technologies used to produce oil and gas from unconventional hydrocarbons vary according to the formations from which they are extracted:

- Oil sands: Loose sand or partially consolidated sandstone; the hydrocarbons in these deposits are a type of dense and extremely viscous petroleum (also known as asphalt) or very heavy crude oil, mixed with other non-energy components such as clay and water. Due to their high viscosity, they cannot be produced or treated using conventional methods.
- Shale Gas: It is light crude oil in crude oil accumulation formations with low permeability such as shale and tight sandstone. Modern drilling and recovery techniques such as hydraulic fracturing are required in order to produce it, frequently using the same technology as horizontal wells.
- Oil Shale: It is organic fine-grained sedimentary rock containing significant amounts of kerogen from which synthetic liquid hydrocarbons (oil shale), fuel oil and shale gas can be produced. Hydraulic fracturing is the technique used to extract oil from these formations using horizontal access. The rock obtained is then heated (cooked) in order to extract the petroleum.

3.1.2. Mineral Sources

3.1.2.1. Coal

A solid black or dark brown mineral fuel that contains essentially carbon and small amounts of hydrogen and oxygen, nitrogen, sulfur and other elements. It is produced by the degradation of plant debris over long periods through the action of heat, pressure and other natural physical-chemical phenomena. Since varying degrees of change occur in the process, coal is not a uniform mineral and is classified by ranks according to its degree of degradation, ranging from lignite to anthracite, including sub-bituminous and bituminous coal; their volatile content, fixed carbon and caloric value vary considerably. In terms of end use, coal can be divided into two classes: a) coking or metallurgical coal and b) thermal or steam coal.

- **Coking or Metallurgical Coal**

The properties of this coal permit pyrolysis or destructive distillation for the production of coke, which is used in the manufacture of steel in blast furnaces.

The annexes contain the classification of coal according to its caloric value.

- **Steam or Thermal Coal**

This coal is used as fuel to produce steam for generating electricity and for industrial processes. It is characterized by a relatively high caloric value.

3.1.2.2. Fissionable Fuels and Nuclear Energy

Fissionable fuel is uranium ore after purification and/or enrichment. Primary nuclear energy is not the uranium ore itself, but the heat content of the steam that enters the turbine from the reactor. This heat content can be estimated from the electricity produced by the nuclear power plant and the average efficiency of the turbine-generator set.

RENEWABLE ENERGY SOURCES

Non-fossil resources having relatively short or continuous periods of formation are considered to be renewable energies; with a system of rational exploitation, the availability does not diminish over time. Currently the most important energy source is solid biomass, mainly firewood, which is used mainly for cooking in developing countries.

Renewable energy sources are considered: Hydropower, geothermal, wind, solar and biomass (wood, cane products and other biomass)

In energy balances, bioenergy is treated similarly to fossil fuels despite the great differences between them. For biofuels significant losses occur in the combustion process, and can be as high as 95% when biomass is used for cooking food; moreover, it is impossible to determine the useful energy.

Many of the uses of biomass involve the final consumption sector; what is captured through surveys (for example) is the amount of biomass consumed domestically, not the amount of useful energy produced. Measurement of the useful energy is thus not practical at this level. Instead, an estimate should be made based on the physical units input to energy production by estimating the caloric value and assuming the efficiency of the conversion process.

When renewable energy is transformed into electricity it is easier to include it in energy balances because final energy consumption in GWh can be measured; these energy sources appear after transformation and often power generating companies know the efficiency of their processes, so it is relatively easy to estimate the primary energy produced.

Renewables and waste can be classified into two categories: direct Energy and Biomass

3.1.3. Direct Energy

These are forms of energy that are counted as sources only when exploited to generate electricity or as end uses, such as hydro, geothermal, wind and solar. That is, they are not energy *commodities* that can be traded or marketed.

- **Hydro Energy**

It is the energy contained in a water flow.
When water is allowed to flow through a turbine connected to an electrical generator, waterpower is converted into electricity.
Water can be taken from a reservoir, generally in large generation plants, or from a river, where the power generation plant will be called a run-of-the-river plant.

- **Geothermal Energy**

Energy that is stored beneath the surface of the earth as heat, which can be transmitted to the surface by a fluid that is in contact with the hot rock. That fluid consists of liquid water, steam or a mixture of both. The energy is used for generating electricity –the first category of renewable energy- and in some cases also as process heat (cogeneration)

- **Wind Energy**

Energy produced by the wind, which can be used with a turbine-generator set.

- **Solar Energy**

Energy produced by the sun is used primarily for electricity generation through photovoltaic and solar thermal power plants. It can also be used directly in end consumption sectors for water heating (using solar collectors) and for drying grain.

3.1.4. Biomass

Plant and animal organic matter used for energy purposes. Biomass can be used directly as fuel or processed into liquid and gaseous products.The most widely used sources include wood, agricultural crops, municipal organic waste and manure.

- **Firewood**

Energy that is obtained directly from forest resources. It includes tree trunks and branches but excludes logging waste, which is designated 'plant waste' used for energy purposes. The energy harnessed from firewood is known as wood energy

- **Cane Products**

Sugarcane products that are used for energy purposes. These include bagasse, cane juice and molasses. The latter two are the main feedstocks for ethanol production.

- **Other Biomass**

Organic Waste

Organic materials obtained from biological and industrial processes that produced by various sectors such as agriculture, livestock, timber, etc.

Depending on the sector where it originates, waste can be classified as a) animal waste, b) vegetable waste, c) industrial or recovered waste, d) urban waste.

a) Animal waste
Waste from agricultural activities and urban waste. It may be used directly as fuel in dry form or converted to biogas through a fermentation or decomposition process.

b) Plant waste
Energy resources obtained from agribusiness and forestry waste. They include all agricultural waste (except bagasse), including rice husks, coffee husks, palm hearts, etc., and sawmill waste (not included under wood or bagasse, etc.) used for energy purposes.
Wood waste: Waste that is typically produced in sawmills, lumberyards and fiberboard factories.

c) Industrial or recovered waste
Substances with energy content that are produced in industrial plants as a byproduct of the production process, such as black liquor from paper, chemical industry waste (excluding petrochemicals that should be considered byproducts because they come from natural gas or petroleum derivatives), etc.

d) Urban waste or municipal waste
City waste (garbage or liquid waste), which due to their organic components can release methane as a fuel gas, liquid fuels or heat.

Vegetable Oils
The main raw material for producing biodiesel. These oils come from all types of oil crops such as oil palm, coconut, canola, peanuts, sunflower, castor beans, soybeans; the crop with the highest yield is African palm.

Traditional Uses of Biomass
This refers to the use of firewood, charcoal, or crop and animal waste in residential cooking and heating processes. The conversion efficiency of these processes is very low (less than 20%).

Other Sources of Renewable Energy
This group includes other sources not specified in the above categories and can involve the development of new technologies such as wave energy, fuel cells, etc.

3.1.5. Other Primary Sources

All primary energy sources that could not be located within the above categories, it is considered here.

3.2. SECONDARY ENERGY SOURCES

Energy sources obtained by processing primary sources or other secondary sources are called secondary energy sources. The sources and forms of secondary energy included in the energy balance are classified according to the primary source from which they were obtained and are as follows:

3.2.1. Electricity

Energy transmitted by moving electrons. It includes electric power generated from any primary or secondary, renewable or nonrenewable resource in different types of power plants.

3.2.2. Petroleum Products and Natural Gas

This group includes products from crude oil refining and natural gas liquids, and those obtained from natural gas fractionation plants.

➢ **Liquefied Petroleum Gas (LPG)**

A mixture of light hydrocarbons obtained as a product of refining processes, crude oil stabilization and the fractionation of natural gas liquids. There are three types: a) a mixture of C3 hydrocarbons (propane, propene, propylene), b) a mixture of C4 hydrocarbons (butane, butene, butylene), and c) a mixture of C3 and C4 in any proportions. LPG typically liquefies under pressure for transportation and storage.

➢ **Gasoline**

A mixture of light liquid hydrocarbons obtained from petroleum distillation and/or natural gas processing, with a boiling range generally between 30-200 °C. This group includes:

Aviation Fuel
It is a mixture of reformed, highly volatile, stable, high-octane naphthas with a low freezing point that are used in propeller aircraft with piston engines.

Automobile gasoline
A complex mixture of relatively volatile hydrocarbons, with or without additives (such as tetraethyl lead), used as fuel for land vehicle engines with spark ignition (Otto Cycle)

Naphtha
A light oil fraction obtained by direct distillation between 30 and 210 °C. It is used as a feedstock for manufacturing gasoline and in the petrochemical industry. It is also used as a solvent in the chemical industry (manufacture of paints and varnishes).

- **Kerosene and Jet Fuel**

A liquid fuel composed of a petroleum fraction distilled between 150 and 300 °C. They could be classified as follows:

Jet Fuel

It is kerosene with a special degree of refining and a freezing point below that of common kerosene. It is used as fuel for jet and turboprop engines.

Kerosene

It is a fuel used for cooking, lighting, motors, refrigeration and as a solvent for asphalt and household insecticides.

- **Diesel and Gas Oil**

Liquid fuels obtained from atmospheric distillation of petroleum between 200 and 380 °C; they are heavier than kerosene and are used in diesel internal combustion engines (cars, trucks, power generation, marine and railway engines) and heating in industrial and commercial applications. This group includes other heavier gas oils that are distilled between 380 and 450 °C and used as petrochemical feedstocks.

- **Fuel Oil**

A residual fuel from petroleum refining that includes all heavy products (including those obtained by blending). It is generally used in boilers, power plants and marine engines.

- **Refinery Gas (not liquefied gas)**

Non-condensable gas obtained during crude oil refining that is composed mainly of hydrogen, methane and ethane. It is used as an energy source in the refining process itself.

- **Petroleum Coke**

A non-meltable porous solid fuel, usually black, with high carbon contents (90% - 95%), which is obtained as residue in petroleum refining. It is used as a heating fuel and a feedstock for coke ovens in the steel industry, and for producing electrodes and chemicals.

- **Other Petroleum and Gas Products**

This includes all refinery and gas treatment plant products that are not specified above, which are used as fuels.

3.2.3. Coal Products

This group includes coke from coke ovens and gases from coke ovens and blast furnaces.

- **Coking Coal**

Non-meltable solid material with a high carbon content that is obtained from the destructive distillation of coal in coke ovens

- **Industrial Gases**

Coke Oven Gas

The gas obtained as a byproduct during the intense heating of coal or coke with a mixture of air and steam in coke ovens. It is composed of carbon monoxide, nitrogen and small amounts of hydrogen and carbon dioxide.

Blast Furnace Gas

It is obtained as a byproduct of steelmaking in blast furnaces and is generally used as fuel for plant heating.

- **Other products from mineral sources**

It is a product of a mineral source that does not fit in the above definitions within this category.

3.2.4. Biomass Products

This group includes all the secondary sources produced during the processing of biomass.

- **Charcoal**

Fuel obtained from the destructive distillation of wood in the absence of oxygen in charcoal clamps.

This product absorbs moisture rapidly, so it usually contains 10 to 15% water, 0.5 to 1.0% hydrogen and 2 to 3% ash, and has a lower caloric value of around 6500 kcal/kg. These features may vary depending on the quality of the wood used.
In some cases, it can replace coke in iron and steel processes for use in industry. It is also used for cooking in the residential sector.

Liquid Biofuels

These are partial, or in some cases complete, substitutes fuels for fossil fuels such as gasoline and diesel; they are obtained by processing of biomass and include bioethanol, biodiesel, biogasoline and bio jet fuel.

- **Ethanol**

Ethanol is a colorless liquid that can be produced by fermenting plant materials that have a high sugar content, such as sugar cane juice or molasses; plant materials with a high starch content such as cassava, corn, etc.; and materials with a high cellulose content such as wood and plant waste. It can be used in internal combustion engines as hydrated or anhydrous alcohol, alone or mixed with gasoline.

Obtaining ethanol from starch is more complex because it must first be hydrolyzed to convert it into sugar.
From cellulose is even more complicated because the plant material must first be pretreated so that the cellulose can be attacked by the hydrolyzing enzymes. The yield of ethanol is higher for substances with high sugar contents; the yield is medium for substances containing starch and low for cellulose.

Ethanol to be blended with gasoline fossil takes the name of biogasoline and according to their percentage ownership in the mix is assigned designations as E5, E10, E20, etc.

- **Biodiesel**

A liquid fuel obtained from the transesterification of vegetable oils with a light alcohol, primarily methanol. Glycerin is obtained as a byproduct.

Its properties are similar to those of petroleum diesel and it can be used in internal combustion diesel engines after minor adjustments. It can be used alone or mixed with diesel.

The main advantage of this fuel is that it comes from renewable primary sources and thus contributes to reducing CO_2 emissions.
T
he biggest disadvantage is that for large volume production, vast expanses of oil crops are required, which is a limiting factor in small countries.

Mixtures of Biodiesel and conventional diesel are named according to the percentage share of biodiesel as B5, B10, B20, etc.

- **Biogas**

A gas, primarily methane, which is obtained during the anaerobic fermentation of biomass and from landfill waste. It is used as fuel for internal combustion engines coupled to electrical generators. It can be classified into three groups:

- ***Landfill gas:*** Biogas obtained from organic matter in landfills
- ***Gas from sludge:*** Gas from anaerobic fermentation in sewage treatment plants
- **Other biogas*:*** Other biogases obtained from unspecified anaerobic fermentation

3.2.5. Other Secondary Energy sources

This includes all secondary products that are not specified in the categories above.

3.2.6. Non-Energy Petroleum Products

Products that are not used for energy purposes even though they have a high energy content, such as asphalts, solvents, oils, greases and other lubricants.

CHAPTER IV

Energy Balances

4. Energy Balances

There are two ways to present energy balances. The first is a balance of products, with each item expressed in terms of physical units to reflect the balance of supply and use of these energy sources. The second deals with energy units, which requires knowing the caloric properties of each fuel to make the appropriate conversion. This second kind of balance is called an energy balance, which gives us the conversion efficiencies of each fuel.

Some of the key energy indicators for both consumption and efficiency are developed using the data obtained from energy balances.

4.1. DEFINITION OF ENERGY BALANCES

An energy balance is a set of ratios that quantify energy streams through a series of events from production or origin to end use. This is usually done for a single country over a specific time period (usually one year), and can take two forms: a) as a physical balance, or b) as a caloric balance.

- **Physical Balance**

Also called a product balance, shows energy flows using physical measurement units for each source, which can be volumes (of liquid and gas), mass (for solids) or, in some cases, energy. Often, each source uses a different unit of measure, which makes it difficult to compare or aggregate energy sources.

- **Calorific Balances**

For calorific balances to allow comparisons and aggregations between streams from different sources, all measurements would have to be in common units. This is why physical streams are converted to caloric streams. The conversion factors are lower caloric values for fuel sources and unit equivalences for sources measured directly as caloric or energy units.

A balance is a tool used to enable comprehensive energy planning, but should be analyzed alongside other elements in the economic system. An energy balance provides an overview of the physical ratios in an energy system over a given time period and the way energy is produced, exported or imported, transformed and consumed by the different economic sectors. This makes it possible to calculate efficiency ratios and assess the energy status of a country, region or continent.

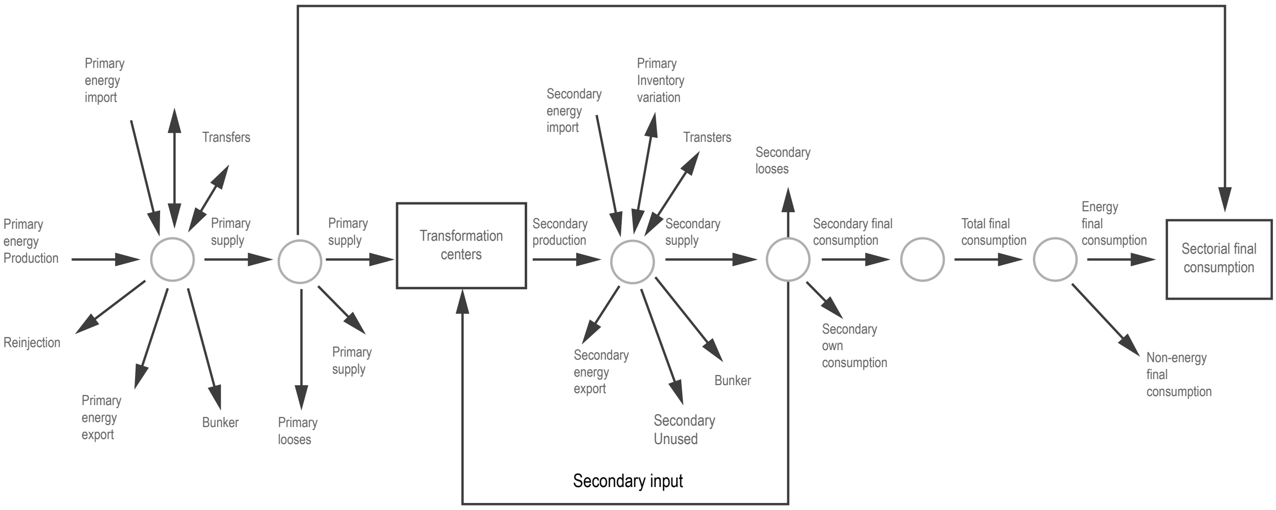
Thus, when analyzing the past (including the recent past) it is logical to begin with supplies of different energy sources and then to determine how each has been used, gained or even lost. This logical sequence produces what can be called a top-down energy balance, which takes the following general form:

- SUPPLY
- TRANSFORMATION
- FINAL CONSUMPTION

However, it is by their relation to other socio-economic variables that energy balances can become planning tools. Accordingly, having an energy balance is an essential precondition for energy planning. In the energy industry, a balance plays a role that is analogous to that of the input-output matrices of the paper industry. Moreover, when assessing the future it is sometimes advisable to project consumption by relating it to the GDP, its structure and distribution, to total consumer equipment and to likely technological developments for energy use, and then to estimate supplies based on projected consumption. This sequence leads to what is known as a bottom-up energy balance, as follows:

- CONSUMPTION
- TRANSFORMATION
- SUPPLY

Figure 2. Energy Balance Diagram



Energy balances in terms of final energy[1] (EBFE) have the limitation of not assessing energy reserves and not reaching the stage of usable energy[2] (EBUE). Efforts to take energy calculations from the stage of reserves to that of usable energy will facilitate analysis and policymaking, especially in the field of energy substitution.

Moreover, for developing countries, given the importance of the rural sector and 'non-commercial'[3] energy sources, it is essential to include this consumption in the balance to understand the energy structure of the rural sector, its problems and its implications for the national economy.

4.2. BASIC GOALS OF THE ENERGY BALANCE

Below are the basic goals for developing energy balances:

- To assess the dynamics of the energy system in accordance with each country's economy, by identifying the key economic and energy relations among different sectors of the national economy
- To serve as a tool for energy planning
- To understand the structure of the national energy sector in detail
- To determine competitive and non-competitive uses for each energy source, in order to boost substitution processes whenever possible
- To lay the appropriate groundwork to improve and systematize energy information
- To use for energy projections and prospects in the short, medium and long term

4.3. OVERALL ENERGY BALANCE STRUCTURE

To express the ratios revealed in an energy balance, it is essential to create a structure that is general enough to show this industry's physical variables properly. OLADE's energy balance in terms of final energy (EBFE) is shown in matrix form with columns for energy sources (primary and secondary) and rows for activities, namely the origins and destinations or uses of energy (Table 3). Energy balance activities are divided into three groups according to their contribution to the relations of equilibrium: a) supply-side activities, b) transformation activities and c) consumption activities.

1 Final Energy (FE) is primary or secondary energy used directly by the different socio-economic sectors. It is energy that enters the consumer sector and differs from net energy (with no transformation, transmission, transportation, distribution, and storage losses) for consumption by the energy sector. It includes both energy and non-energy consumption.

2 Usable Energy (UE) is what is actually used in final energy processes, as not all energy entering a consumer system is used, depending on the efficiency of each consumer appliance. It is the net energy after subtracting losses due to use (at the user level), to the equipment used, or to the appliance using it. It applies to both self-use and end use, whether pertaining to energy or non-energy consumption.

3 [See " Treatment of Non- Commercial Energy"]

4.3.1. Supply-Side Activities

These are activities or events used to calculate the domestic energy supplies, i.e., available energy amounts within a country, either for direct final consumption or for transformation into other energy sources. This group includes the following activities:

- Primary production
- Reinjection or recirculation
- Imports
- Exports
- Inventory variations
- Unused energy
- Transfers
- Bunker

4.3.1.1. Primary Production

This includes all primary energy that is extracted, exploited, harvested, or developed domestically, which is of importance to the country.

Hydrocarbons Primary Production

➢ **Crude Oil Production**

This is the individual production of all oil fields in a country after the separation process, which produces natural gas liquids and water in addition to crude oil. It is related to commercial oil production.

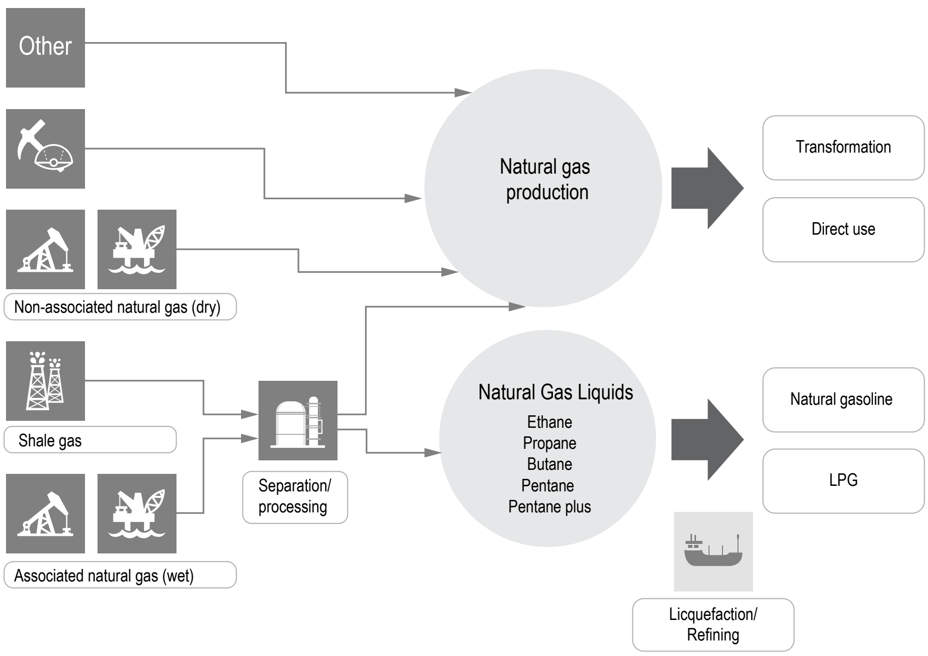
➢ **Natural Gas Production**

Natural gas production refers to the production of commercial dry gas, including offshore production in national waters. It is measured after purifying and extracting natural gas liquids and sulfur. Total natural gas production should include both associated gas and that from gas fields (non-associated gas), as well that obtained from shale gas and coal mines.

➢ **Primary Production Natural Gas Liquids**

This is the volume of liquids obtained by producing associated gas after separating it from oil extracted at the wellhead. Note that liquids obtained from gas treatment plants in the form of LPG and gasoline are considered secondary products in the energy balance. Some of the most important products obtained are condensates, natural gasoline and LPG.

Figure 3. Production of natural gas and natural gas liquids



Source: Prepared by author based on APEC

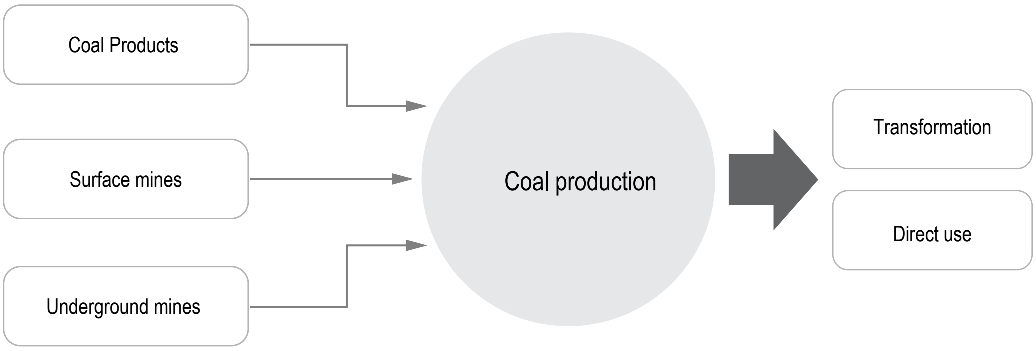
Mineral Source Production

- **Coal production**

This is the total production of the country's coalmines. Coal has very different heating value before and after purification. To avoid inconsistencies, you should always consider pure coal, that is, without impurities. This coal is known as anthracite, hard coal, lignite and peat, which are the main varieties and have precise caloric values between 4000 and 8000 kcal/kg.

Coal production can come from three sources: underground mines, surface mines and recovery. It is measured after eliminating inert matter, i.e., after the impurities have been removed. Include the amounts used for the production process and delivered to other energy producers.

Figure 4. Coal production



Source: Prepared by author based on IEA (2011)

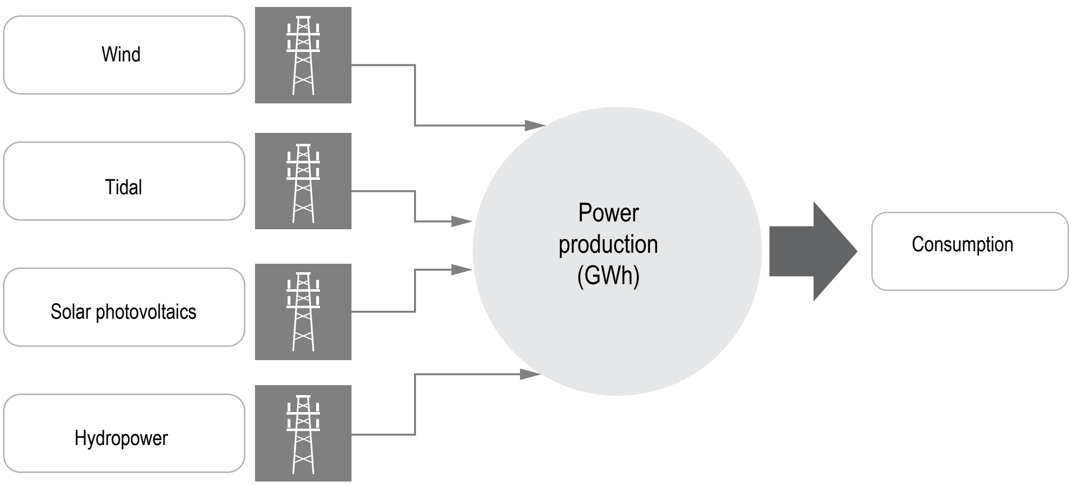
- **Nuclear Energy Production**

It is the energy obtained from uranium ore after the process of purification and/or enrichment. The production of nuclear energy is considered the heat obtained from the burned of fissionable fuels in a reactor (Annex IV)

- **Direct energy production**

Renewable energy sources associated with electricity include wind and tidal energy, solar photovoltaics and hydropower, among others. All these require a process of transformation into usable energy (kWh) and cannot be stored, but rather are used directly by final consumers once transformed.

Figure 5. Renewable Sources Associated with Electricity Production



Source: Prepared by author based on IEA (2011)

➢ **Hydropower Production**

OLADE's new energy balance method considers hydropower production as equal to the amount of electricity generated by hydroelectric plants, expressed in any of the caloric units (kboe, ktoe, GWh, TJ, etc.).

➢ **Geothermal Production**

As in the case of hydropower, here too, power generation is equal to the inputs for transformation and the production of geothermal energy, i.e., using an efficiency of 100%.

➢ **Wind Energy production**

This refers to wind energy, once it has passed through a turbine and power generator and become electricity (kWh). (Annex VIII)

As in all energy transformation systems, turbine-generator sets have an efficiency value lower than the unit, so the electricity generated is less than the wind energy captured. However for energy balance purposes, it is considered the production of wind energy equal to the power generated by wind turbines.

➢ **Solar Energy production**

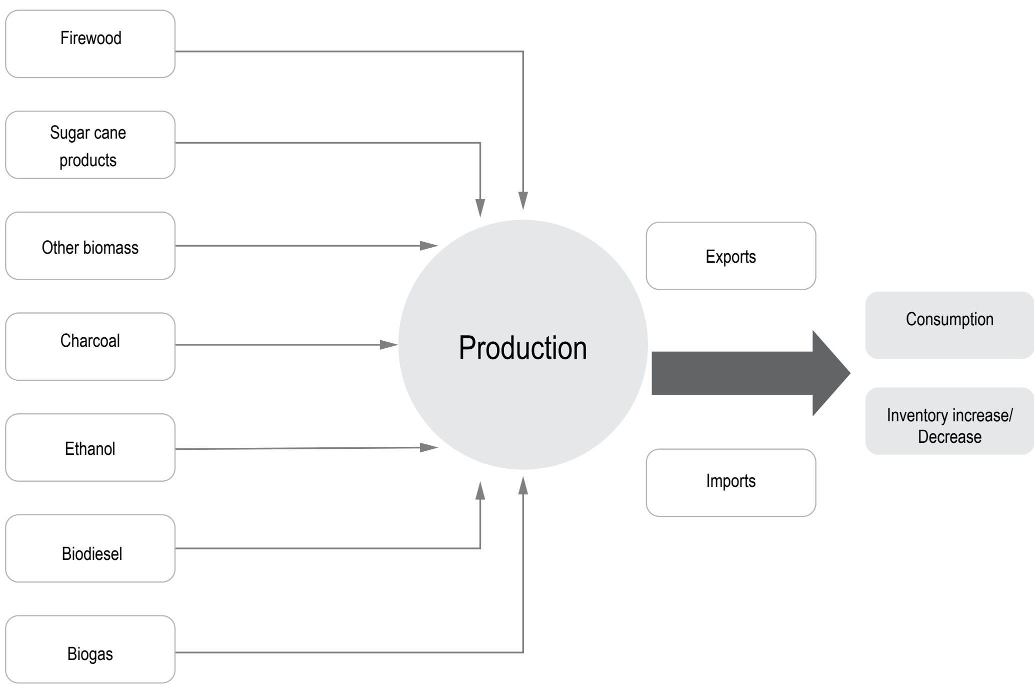
Solar energy production is the energy from solar radiation, harnessed for electricity production through photovoltaic and solar thermal plants, plus the amount used as heat in solar collectors for water heating and materials driers.

In the case of power generation, the solar energy used is assumed to be equal to the electricity generated. In the case of solar collectors, the amount of solar energy harnessed is calculated as the heat required to raise the water temperature, and in the case of drying, it is the heat needed to lower the percentage of humidity.

➢ **Biomass production**

Primary sources in the biomass category, such as firewood, sugarcane products, organic waste, etc., are usually not commercial sources with defined market supplies and demands. Therefore, production is counted as the amounts of such sources used for energy purposes in transformation centers and for end consumption, plus any exports and inventory variations, minus imports.

Figure 6. Renewable energy production with inventory variations



Source: Prepared by author based on IEA (2011)

- **Firewood Production**

Normally, firewood production is not recorded, so the usual procedure used is:

PRODUCTION = FINAL CONSUMPTION

If imports or exports are recorded, it is calculated as follows:

PRODUCTION = FINAL CONSUMPTION – IMPORTS + EXPORTS

Sometimes some portion of production, however small, is recorded. If it is very small compared to final consumption, it is better to ignore it and conduct research to clarify the matter of non-commercial consumption, which supposedly represents most of final firewood consumption. Therefore, production is calculated by estimating the consumption of this source for energy purposes.

This explanation also applies to different types of waste, which are considered 'non-commercial sources.'

- **Production of Sugarcane Products**

This includes the production of bagasse, cane juice and molasses, which are used to produce energy.

Bagasse Production

Only the bagasse used for energy purposes should be accounted for, assuming that production equals consumption. Bagasse is used primarily as fuel for self-generation in sugar mills and as a heat source for industrial sugar manufacturing processes.

Production of Sugarcane Juice and Molasses

These are products derived from sugarcane, which are raw materials for distilleries producing ethanol for energy use.

- **Other Biomass Production**

Waste Production

This the amount of animal, vegetable, industrial, and urban waste used for energy purposes. As in the case of firewood, it is considered a non-commercial source, because there is usually no fully identified chain of production, transportation, processing, marketing, and consumption. Given the lack of information at different stages of the energy chain for these sources, production can be assumed to equal consumption for energy purposes as inputs to biodigesters, power generation, raw material for biofuel production, etc.

Vegetable Oil Production

This is the amount of oil extracted from different oleaginous plants, allocated to biodiesel production.

Production of other Renewable Primary Sources

This is the amount of energy obtained from the renewable sources included under this heading.

4.3.1.2. Reinjection or recirculation

This category applies primarily to the natural gas chain, and refers to gas volumes typically associated with oil returned to wells to maintain well pressures.

Imports and Exports

This definition is valid for any energy source that can be imported and/or exported. The most common energy sources exchanged among countries are petroleum, natural gas, coal, electricity, liquefied gas, gasohol, jet kerosene/fuel, diesel oil, fuel oil, charcoal, non-energy sources, and other secondary products.

4.3.1.3. Imports

Exports are primary and secondary energy sources that originate outside the borders and enter the country to form part of the total energy supply.

4.3.1.4. Exports

Exports are primary and secondary energy sources that cross the boundaries of a country and are not allocated to meet the domestic demand. Excluded from this concept are the amounts of fuel sold to international aircraft and ships.

4.3.1.5. Inventory Variations

Inventory variations are the differences between initial and final stocks during the balance period at the storage facilities for different products. Inventory variations are usually recorded for all storable sources and products such as solids, liquids and gases. This does not apply to electricity or such intangible renewable sources as wind, solar, and geothermal energy. Inventory variations are recorded with their appropriate signs: a negative sign means a growth in stocks and therefore a drop in domestic supplies, while a positive sign indicates a decrease in stocks and an increase in domestic supplies for the period under study. Inventory variations should be calculated at all stages of the energy chain where storage capacity exists, including the facilities of distributors and large consumers that have this capability.

4.3.1.6. Unused Energy

Unused energy is the amount of an energy source that is recorded in production, but that cannot be used because it is technically and/or economically unavailable.

- **Unused Natural Gas:**

It is common to flare some of the gas associated with petroleum production, either due to a lack of infrastructure for consumption or transportation to users, or when the infrastructure exists but oil extraction produces more gas than the market can absorb.

In either case, unused natural gas represents the waste of an energy source that is highly appreciated by consumer sectors. The same concept can be applied to other primary and secondary energy sources whose production is recorded, but then is discarded due to lack of demand or consumption infrastructure, e.g., flared refinery gas.

4.3.1.7. Transfers

Transfers are additions to or subtractions from the domestic supply of a product for the following reasons:

a) Product Name Change: A single product may have different names at different stages of the energy chain. For example, biogas comes from biodigesters but may be consumed under the name of natural gas because its composition is very similar. Another practical use of this activity is to transfer surplus gas from gas treatment plants to the primary natural gas stream, or liquids extracted in those plants to the flow of natural gas liquids. To carry out these transfers, the column ‘other petroleum energy sources’ can be used as a temporary step for these products.

b) Shares in Mixtures with other Products: The streams of a given product may be truncated or dropped when they become part of mixtures with other products. For example, part of residual fuel oil from a refinery can be mixed with crude oil, or all biofuels produced can become part of the commercial flow of gasoline or diesel.

Transfers must be recorded with their respective signs—positive or negative—to indicate whether the streams of the transferred product are increasing or decreasing, respectively. Whenever a transfer with a given sign is recorded in one of the energy balance columns, there must be another transfer with the opposite sign for the same amount in another column of the balance. The algebraic sum of all transfers between products must always be zero.

4.3.1.8. Bunker

Under this heading, record the amount of fuel sold to drive the engines of aircraft and embarkations travelling across international borders. This consumption is recorded separately, primarily because the IPCC methodology to inventory greenhouse gas emissions deducts this consumption from domestic supply, since it occurs outside of national borders.

4.3.2. Transformation Activities

Transformation activities are processes in which both primary and secondary energy sources are modified in facilities called transformation centers, which make physical or chemical changes to those sources and whose outputs have properties that enable their use as energy sources.

Also included are machines that convert one form of energy into another, such as power plants that convert different types of energy into electricity. The following energy streams can be distinguished in a transformation center:

- **Transformation Inputs**

These are amounts of energy sources that enter transformation centers for physical and/or chemical processing, including fuels and other sources used for power generation.

- **Transformation Outputs**

These are the final products of transformation, available for delivery to both final consumers and other transformation centers.

- **Self-Consumption**

This is the amount of a product used in the transformation center itself, for end uses such as process heat and lighting. Fuels used for electricity generation are excluded.

- **Recycling**

These are products from a transformation center that reenter the process as inputs. Recycling is not included in energy balances, since these amounts cancel each other out as both inputs and outputs. An example is the amount of diesel oil produced by a refinery, which reenters the same refinery as an input to be mixed with the crude oil stream. The transformation activities or centers included in the energy balance are:

-
- Self-producers
- Coal plants
- Coke plants
- Blast furnaces
- Distilleries
- Biodiesel plants
- Other transformation centers

4.3.2.1. Refineries

Refineries are facilities where crude oil is turned into oil products. Basically, refineries separate crude oil into its various components (Figure 3). This manual treats each refinery as a whole, as if it were a single processing unit. Although this does not fully describe the refining process or analyze the internal flexibility of each refinery, it is sufficient to establish the input-output ratio for an energy balance. Various types of refineries have different processes that do not always have the same outputs or process the same kinds of oil. The Annex shows a diagram of the refining process.

- **Inputs to Refineries**

Crude oil is the main refinery input, but it can also be natural gas liquids, synthetic crude oil and natural gas. These inputs are fed directly into the primary distillation unit of refineries, from whence intermediate streams are processed in conversion units, the main ones being as follow:

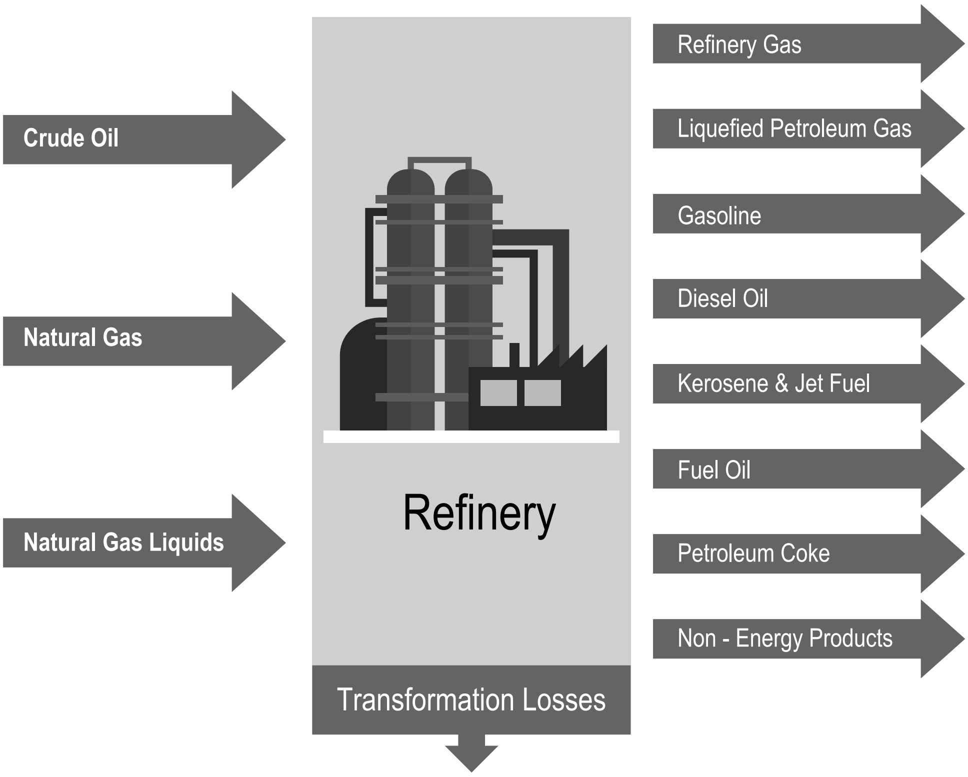
1) Reformation: increases gasoline octane values
2) Cracking: increases gasoline performance and octane values
3) Hydrocracking: enhances diesel performance and cetane rating
4) Vacuum: a very low distillation pressure used to separate primarily reduced crude oil into two fractions
5) Viscosity reduction: improves the viscosity of fuel oil
6) Coking: increases the amount of gasoline beyond what cracking achieves, but since the resulting octane value is very low, it requires reformation
7) Flexi-coking: further increases the yield of gasoline and LPG
8) Isomerizing/polymerizing: increases the octane value of gasoline beyond reformation and cracking, especially for aviation

The main products obtained from a refinery are the following:

Refinery gas and LPG, gasoline, kerosene, jet fuel, natural gasoline, diesel oil, fuel oil, petroleum coke, non energy products

Figure 7.

The Refinery Process



Source: Prepared by author

4.3.2.2. Natural Gas Treatment Plants

These are plants where associated and non-associated natural gas is processed through the physical separation of gas components to recover liquid hydrocarbon compounds such as gasoline and naphtha; pure hydrocarbons such as butane, propane, ethane or mixtures thereof; and non-energy sources such as coal (Figure 8).

The input to gas centers is the amount of natural gas that enters treatment plants to separate the condensates, and the outflows are:

a) Liquefied gas: a mixture of propane and butane known commercially as LPG
b) Natural gas: a mixture of liquid hydrocarbons from pentane, whose octane rating is relatively high (around 70), usually with a low sulfur content
c) Dry gas: a mixture of methane and ethane is pumped into pipelines for use as natural gas in networks

Since gas treatment plants use a physical separation process, their efficiency is close to 100% when input and output streams are stated in caloric units.

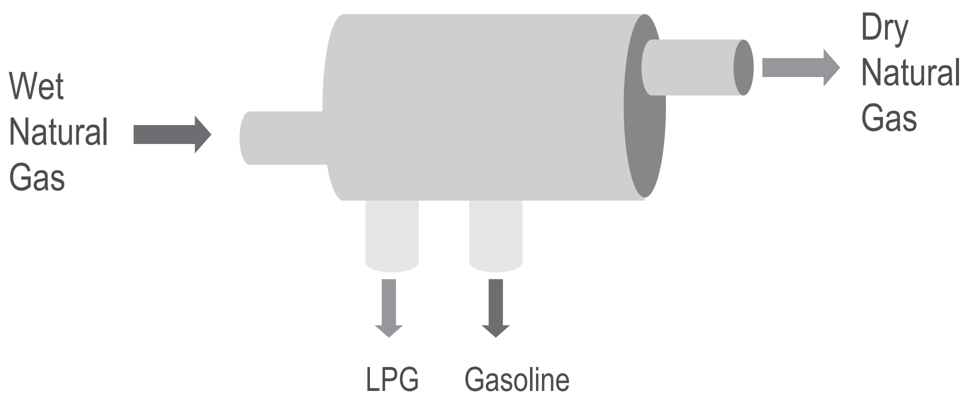
- **Inputs to Natural Gas Treatment Plants**

There are two alternative for recording inputs to gas treatment plants:

1) Allocate only the equivalent amount of natural gas that has become condensate as input. This is generally known as transformed gas, which is the total extracted condensate expressed in caloric units.
This procedure means that dry gas passes through the plant as if it were not transformed; i.e., natural gas is divided into two streams—dry and wet–-but only the latter is taken as a feed to the transformer to produce condensate. The dry component goes straight to final consumption, electricity generation, etc.

2) Allocate the total volume of natural gas entering the gas treatment center, but in this case, the volume of dry gas (after extracting the liquids) should be reported as an output. Record this volume temporarily in the column 'Other energy oil products' and then move this volume through transfers to the column of 'Non-associated natural gas,' thereby recovering its availability in the domestic supply.

Figure 8. Natural gas drying process



- **Production of Secondary Petroleum Products**

In general, secondary oil products are recorded as the amount of final outputs in marketable condition, obtained from both refineries and natural gas treatment and processing plants. These products can be liquids such as gasoline, naphtha, kerosene/jet fuel, diesel and fuel oil, gases such refinery gas and LPG (under atmospheric conditions), and solids such as petroleum coke. The production of other outputs from refineries and facilities, when not mentioned specifically in any columns of the energy balance, should be reported according to their end use. If these products are used as fuel for power generation or heating, they enter the balance as 'other petroleum energy sources.' If their end use is as raw materials for industry (solvents, additives, greases, lubricants, etc.) and other non-energy uses, they enter the balance as 'non-energy petroleum products.'

4.3.2.3. Power Plants (utilities and self-producers)

These facilities have equipment that converts different forms of energy into electricity, including both direct energy from nature, such as hydropower, geothermal, wind, and solar energy, and heat obtained from the combustion of other sources. Depending on the technology and type of source used to produce electricity, power plants are classified as:

- Hydroelectric
- Conventional thermoelectric
- Geothermal
- Wind
- Photovoltaic
- Nuclear

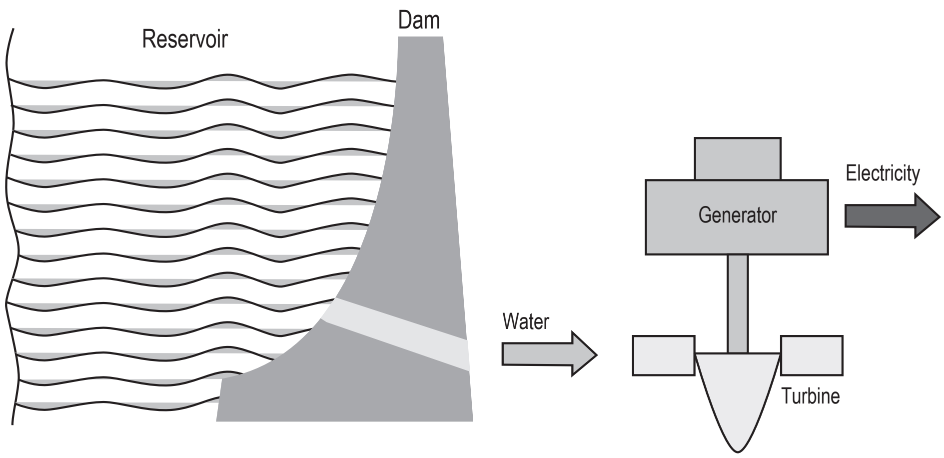
Conventional thermoelectric plants can in turn be subdivided into:

- Steam turbo
- Gas turbo (open cycle)
- Combined cycle
- Internal combustion engines

➢ **Hydroelectric Plants**

Hydroelectric plants harness the energy of water flows to drive turbines coupled to generators (Figure 9). They can be of two types: a) reservoir based, and b) run-of-the-river. The former have artificial water reservoirs that increase the head of the fall and regulate the turbinate flows over time, while the latter lack reservoirs but use the natural decline of a river. For hydroelectric plants, the input is the energy of the flow entering the turbines and the output is the electricity generated.

Figure 9. Hydroelectric plants



Source: Prepared by author

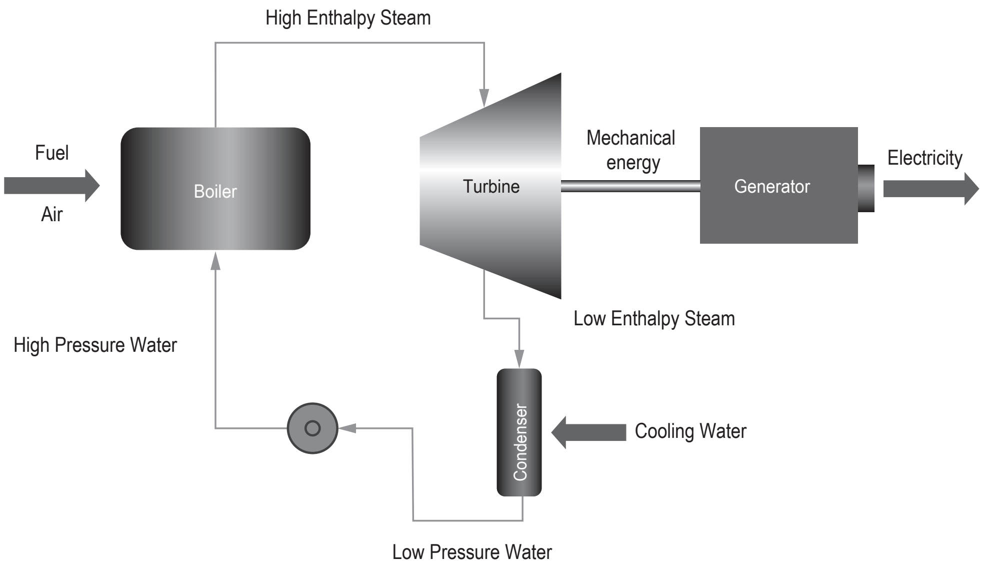
➢ **Conventional Thermoelectric Plants**

These plants convert heat from combustion into electricity and are classified into the following types:

➢ **Steam Turbo**

The heat from combustion is absorbed by the water in a boiler that generates high-pressure steam, which drives a turbine coupled to a generator (Figure 10). The input to a steam turbo plant is the volume of fuel used to heat water in the boiler, and the output is the electricity generated. The fuels used for this technology are often diesel oil, fuel oil and coal, but any fuel having an acceptable caloric value can be used. Also included as fuels are biomass products such as wood, bagasse, charcoal, and certain agro-industrial waste.

Figure 10. Steam turbo plants

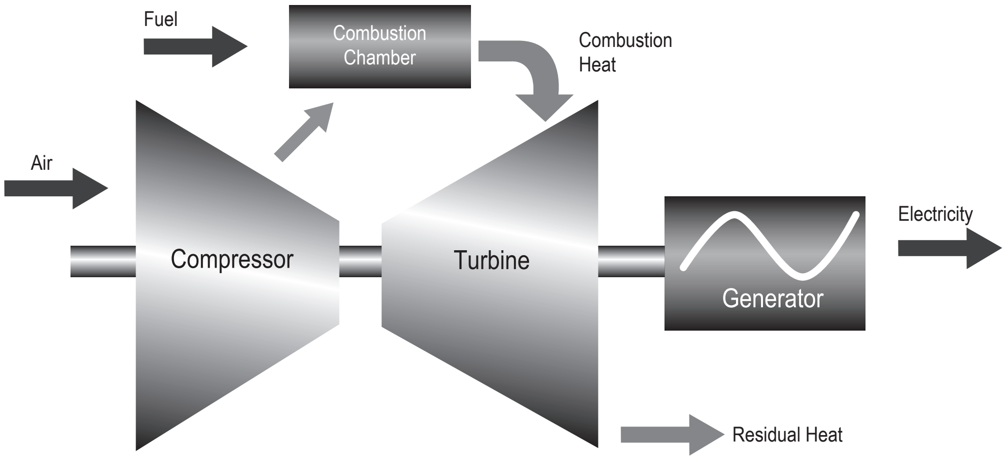


Source: Prepared by author

- **Gas turbo**

With this technology, flue gas from the source expands and directly moves the turbine-generator unit coupled to a compressor that blows air to enrich the mixture (Figure 11). The input is the fuel burned, and the output is electricity. The fuels most often used for this technology are diesel oil, natural gas and other gases.

Figure 11. Gas turbo plants



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- **Combined Cycle**

This is a combination of gas turbo and steam turbo, in which surplus heat in the flue gases from the gas turbine is used to heat boiler water that feeds into a steam turbine. This combination achieves a higher overall efficiency than steam turbo and gas turbo separately.

- **Internal Combustion Engines**

These are engines that have cylinders and pistons with an Otto cycle and a diesel cycle, coupled to a generator. The most used are diesel cycle engines (ignition by compression), which consume primarily diesel and fuel oil. Otto cycle engines are used mostly as domestic generators and consume gasoline, ethanol, LPG, and other gases.

- **Plants with cogeneration**

These are thermoelectric plants, usually steam turbo and gas turbo, in which surplus heat from steam and flue gas, respectively, is used as process heat.

It is often said that the outputs of such plants are electricity and heat. However, the OLADE energy balances do not consider heat an energy stream. Rather, harnessing that heat directly for activities other than electricity generation is deemed a final consumption of fuel. Therefore, cogeneration plants require calculating the fraction of the total fuels used for electricity generation and the fraction used for residual heat, which should be recorded the final consumption for those fuels. Annex VI shows the approach for calculating the fuel fractions consumed for electricity generation and process heat.

- **Geothermal Plants**

These plants directly harness steam flowing from geothermal wells to drive steam turbines coupled to electric generators.

The input to geothermal power plants is the enthalpy of the steam arising from the well and entering the plant. Although geothermal plants are usually located at the wellhead, on its way to the turbines, geothermal steam suffers major heat losses, which means low efficiencies in the total conversion.

In the absence of parameters for calculating the enthalpy of geothermal steam, the energy balance uses the concept of direct energy, i.e., the primary production of geothermal energy estimated on the basis of the electricity generated, at an efficiency of 100%. Thus,

$$EG = EE$$

GE = Primary geothermal energy
EE = Electricity generated

- **Wind Power Plants**

These facilities convert kinetic wind energy into electricity (see Annex). Due to the relatively low power developed by each generating unit, it takes a large number of wind turbines connected in parallel to achieve significant power values for a country. These complexes are also called wind farms. Although the input to this type of plant is wind power (which like any energy transformation process has losses through mechanical and electrical devices), the energy balance considers that the wind energy entering the plant has the same value as the electricity generated. Thus:

$$EO = EE$$

Where:
EO = Wind energy
EE = Electricity generated

- **Photovoltaic and Solar Thermal Plants**
  These two types of power plants turn solar energy into electricity with the following specifications:
- **Photovoltaic power plants**: have panels of photoelectric cells that receive solar radiation to generate an electrical current.
- **Solar thermal power plants**: the sun's rays are concentrated by mirrors on a focal point where steam is produced at temperatures and pressures high enough to drive a turbine-generator combo. These are not very common in the countries of OLADE.

For either of the above cases, the balance assumes that the primary solar energy used for generation is equal to the electricity generated by the plant. Thus:

$$SOL = EE$$

Where:
SOL = Solar energy
EE = Electricity generated

Power Production in Public Utility Plants
This is the total amount of electricity produced by public utility plants in a country, i.e., the total electricity delivered to utilities by all plants, without discounting self-consumption.

The possible types of plant are:

a) Hydroelectric,
b) Geothermal,
c) Nuclear or Fission,
d) Steam Turbines,
e) Gas turbines (open cycle and combined cycle),
f) Diesel engines,
h) Wind power plants, and
g) Photovoltaic plants.

None of these should be omitted, whether connected to or isolated from the grid. It may be difficult to collect data on the latter, and surveys may be necessary to estimate production.

- **Electricity Production by Self-Producers**

Self-producers are private or public entities, such as:

- Industry (including the energy sector)
- Farming establishments,
- Commercial establishments, and
- Private homes

While not belonging to the electricity sector, they have facilities to self-produce the electricity they require, either due to the deficiency or absence of public utilities, or as an emergency service. The types of such plants are:

- Small hydroelectric
- Steam turbines
- Gas turbines
- Internal combustion engines

In some cases, self-producers sell surplus electricity to the public utility grid, and the total electricity produced by these plants should be considered. In most countries, these data are not available, and the best way to obtain them is:

1) Try to identify self-producers that are also macro-consumers, which represent approximately 90% of all self-production.
2) As a second stage, it will necessary to conduct a comprehensive survey to capture the numerous small self-producers.

4.3.2.4. Coke Ovens and Blast Furnaces

These are used in the steel industry, where coal is turned to coke and coke oven gas in the coking plant. The coke then goes to the blast furnace, where pig iron and blast furnace gas are obtained. Coke ovens that burn coal produce coke, coke oven gas and non-energy sources (benzenes, tars, etc.). Some of the coke is consumed in the production of blast furnace gas and the rest is used for ore reduction in the blast furnace.

Coal transformation in coke ovens and blast furnaces

This is the amount of coal that enters the coke ovens. These plants are of two types:

Those that produce metallurgical coke for industry, which some countries do in primitive facilities where the produced gas is not used. Those that produce coke for the steel industry in coke ovens that are usually an integral part of steelworks. The coke oven gas produced is used largely as a fuel in the same facilities of this industry.

The coal amount to be reported here is the sum of all inputs to both types of coke ovens. While there is essentially only one type of coal, the statistical problems found in these two types of plants are very different. It is usually necessary to conduct surveys or research to determine which coking plant flows serve the metal industry, because they are often rudimentary facilities of an unknown number and capacity.

In contrast, coke ovens are large, well-organized plants that record consumption and production data. Coking plants are fed with coal and produce a) coke oven gas, b) coke and c) tar, while blast furnaces are fed with coke and produce blast furnace gas.

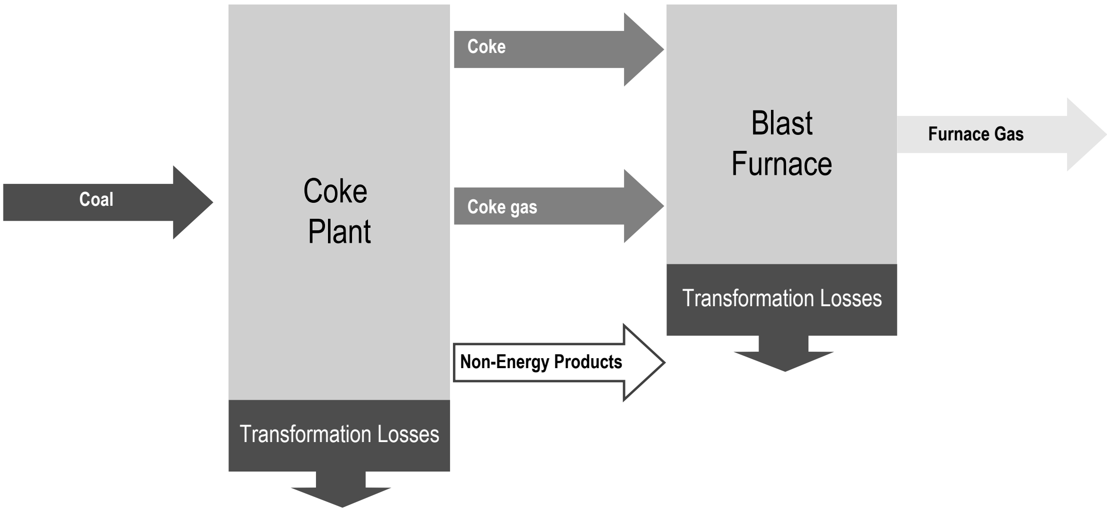
Notes:

- For gases, add up the output of coke oven gas and blast furnace gas.
- Non-energy outputs from coke ovens are primarily tar and a few chemicals of commercial value.
- Substantial portions of the coke produced by coke ovens feed the blast furnace and should be deducted from the output, as it is recycled internally within the transformation plant.

4.3.2.5. Coal Ovens

These are essentially ovens where partial combustion of wood takes place to produce charcoal and volatile/non-volatile products that are usually not exploited. It is noteworthy that wood in the form of charcoal has a higher caloric value.

Figure 12. Coal transformation process



Source: Prepared by author

Transforming wood into coal

The following calculation should be applied only if the country does not quantify the amount of wood used for coal production. Thus:

Transformation = Charcoal production/Average efficiency

Efficiency is expressed as a dimensionless number when both firewood and charcoal are expressed in caloric values; otherwise it should be reported in tons of wood per ton of charcoal. Average efficiency is obtained for a country through measurement procedures in different sizes of furnaces. The required sample size is not large, depending on the varieties of wood involved and the oven technologies employed. These are usually very primitive: wood is stacked and covered with branches, ignited and let burn for several days to obtain charcoal. The efficiency of such a primitive oven is around 20-35%, depending on the size, wood quality and atmospheric conditions. A gross reference that can be made when everything is unknown is 1/4 = 25% calories of charcoal per calorie of firewood.

Producing charcoal in charcoal ovens

In this case, use the total charcoal production, which is usually calculated thus:

Production = Final consumption – Imports + Exports

4.3.2.6. Ethanol Distilleries

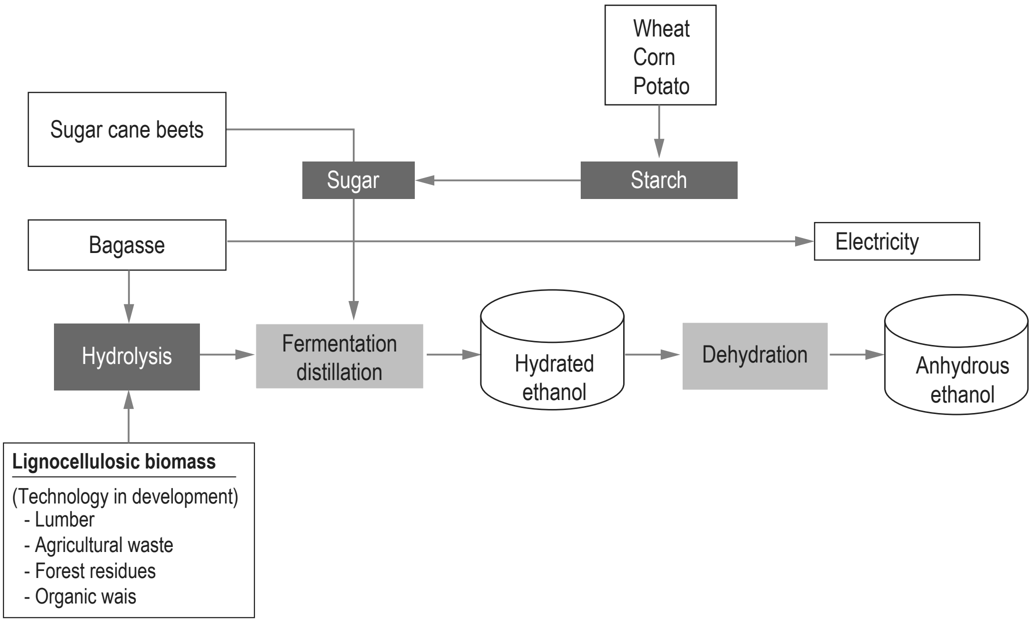
These are plants that process primarily sugar cane juice to produce ethanol. They include alcohol distilleries that process other raw materials such as beets, cassava and other crops rich in starch or cellulose.

For ethanol production, a sugary solution called wort is used, which receives chemical and thermal treatments of varying intensities, after which ferments or yeasts are added to turn the sugar into alcohol.

After this process, the ethanol is removed from the fermented mash by distillation. Prior to this step, the organic or mineral particles of the liquid phase are removed from the fermented mash in a settling tank or by using various additives to speed precipitation.

In addition to alcohol, distillation produces vinasse – a highly organic liquid that totals 12-13 times the ethanol, which is highly polluting when discharged into natural water bodies. Figure 13 shows the process of ethanol production.

Figure 13. Distilleries



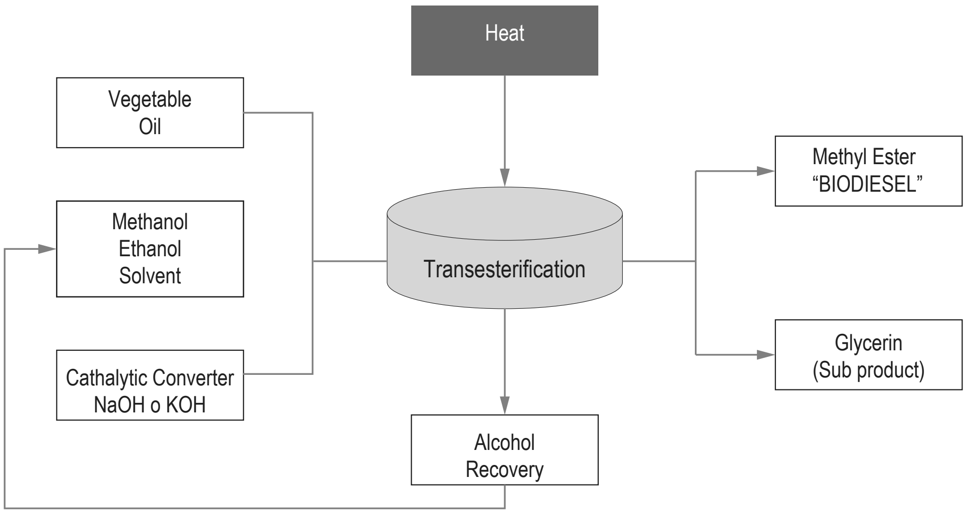
Source: Prepared by author

4.3.2.7. Biodiesel Plants

These plants produce biodiesel through the transesterification of vegetable oil, animal fats and recycled oil, which consists of replacing the glycerol with a simple alcohol such as methanol or ethanol to produce methyl or ethyl esters from fatty acids.

The Figure 14 illustrates the process of biodiesel production.

Figure 14. Biodiesel plants



Source: Prepared by author

4.3.2.8. Other Transformation Centers

This category includes any other facility not discussed above, such as anaerobic digesters (biodigesters), landfills, etc. that receive farm and forestry wastes, agro-industrial and urban wastes, and wastes from power plants, or any other processing plant that is included in the country's energy balance but is not among those mentioned above.

- **Biodigesters**

These are airtight tanks in which waste inputs are fermented without air to produce gases, primarily methane (biogas) and a residual liquid that is used as fertilizer and animal feed (biol). A typical input to biodigesters is cow dung, which is fermented to produce biogas.

- **Sanitary Landfills**

These are solid waste dumps where anaerobic reactions occur over time, which produces gases, especially methane. This group can include transformation technologies that use other renewable primary sources.

4.3.3. Final Energy Consumption

This is all energy delivered to consumption sectors as usable energy in the form of electricity and heat. It excludes sources used as inputs or raw materials for other energy sources, as this pertains to the 'transformation' activity.

The end-use sectors are classified according to the traditional division of economic sectors and the ISIC (International Standard Industrial Classification), version 3. It also includes the residential sector, which is not an economic activity.

Energy consumption can be determined using two procedures:

Top-down

Analyzes and quantifies the amount of energy used and the useful energy consumed by fuel purchases, minus non-energy uses and inventory variations.

Bottom-Up

Locates each energy source by identifying the amount of energy consumed by each process or equipment in the consumption logs.

Bearing in mind the concept of energy balance –the source and destination of energy– as the primary measure of observation.

Some characteristics must be treated with care to determine energy consumption.

Procedures Implemented	• Surveys	• Measurement
Measurement approach	• By entity	• By use
Data reliability	• Establishments	• Employees
External factors	• Sub-sector interactions	• Technology performance

Agriculture, Forestry and Fishing (ISIC Division 01-02)

This includes all primary economic activities:

4.3.3.1. Farming Sector (ISIC Division 01)

This includes rural activities of the agricultural and livestock sectors, such as plowing, sowing, harvesting, grain drying, livestock breeding, slaughtering, sheep shearing, etc. It does not include agro-industrial businesses, which should be considered within the industrial sector.

When it is difficult to separate agriculture from agro-industry, the ISIC method assumes that an establishment is classified according to the bulk of its activities. The best recommendation is to adopt the rule followed by the office in charge of drawing up national accounts. The energy sources most used in this sector are:

- Firewood, bagasse and other plant waste to produce heat, e.g., for distillation activities
- Final consumption of electricity for irrigation, water pumping, and mechanical force to farm processes.

Note: It is very common for consumed electricity to be self-produced from hydropower or diesel oil, so remember to include these amounts in the transformation sector.

- Diesel consumption for diesel pumps and grain drying. A survey may be needed to estimate consumption.
- Solar energy, used primarily for drying grain. One way to assess it is by the moisture removed.

Calculating Energy Consumption in the Farm Sector:

$$C(s,u,f) = Em * \%U(s,u,t) * Sc(f,t)$$

Where:

C(s,u,f) = fuel consumption f in process u in the sub-sector
f = Energy source
u = Process of irrigation, spraying, tractors, cooking
s = Crop sub-sector
t = Technology
Em = Economic measure (planted area, production areas, heads of livestock)
U (s,u,t): Percentage of Em applied in process u or technology t
Sc (f,t): Specific consumption f per unit Em through process u with technology t

Each country may have an unlisted activity, and each particular case should be examined carefully.

4.3.3.2. Fishing Sector (ISIC Division 01)

This refers solely to the energy consumption of fishing activities, and does not include industrial fishing, which should be reported under the industrial sector. The energy sources used mostly by this sector are diesel and fuel oil for fishing boats, which can be a significant consumer in countries with highly developed fishing industries.

4.3.3.3. Forestry Sector (ISIC Division 02)

This refers to activities relating to forest cultivation and does not include industrial logging businesses, which should be included within the industrial sector. The energy sources most used by this sector are:

- Diesel used for tractors and farm machinery
- Final consumption of electricity for irrigation, water pumping and mechanical force for farm processes

Note: It is very common for consumed electricity to be self-produced from hydropower or diesel oil, so remember to include these amounts in the transformation sector.

- Diesel consumption for diesel pumps and wood drying, which may require a survey to assess consumption.

4.3.3.4. Mining and Quarrying Sector (ISIC Divisions 10-14)

The final consumption of this sector consists of any energy source used for exploitation processes in the mining and quarrying business. This excludes exploitation of oil, natural gas and coal, because they pertain to the energy industry. The energy sources most used are:

- Coal used for smelting

- Diesel used in boilers, smelting and driving internal combustion engines
- Electricity to produce mechanical power for mining, and lighting

Calculating energy consumption in the mining sector:
Determine the total energy consumption per device, stratum or sub-sector

$$C\ (m,p,f) = P\ (m) \times PP\ (mp) \times Scf$$

m = Mineral
p = Process
f = Power source
C = Consumption of Energy
P = Production
PP = Percentage of Mineral m processed in the p process
Sc = Specific consumption

Note: It is very common for consumed electricity to be self-produced from hydropower or diesel oil, so remember to include these amounts in the transformation sector.

4.3.3.5. Manufacturing Sector (ISIC Divisions 15-37)

The final consumption of this sector includes all energy sources used in the process of transforming raw materials into finished products. It excludes industries whose end products are energy sources, as this is reported under the energy sector. Given its diverse production, the industrial sector uses virtually all types of energy sources, both primary (natural gas, coal, wood, bagasse, and plant waste) and secondary (electricity, oil and natural gas, charcoal, blast furnace gas, and coke).

Sometimes it is difficult to determine the industrial consumption of various sources. For example, it is common for certain industries, such as beverages, to distribute their products using their own vehicle fleet, which requires fuel. However, this consumption pertains to the transportation sector, not to the industrial sector. Furthermore, there is often confusion as to the distinction between industry and agriculture. The recommended approach to solving such borderline cases is to classify plowing, cultivating and harvesting as farming activities, while processing harvested materials are industrial activities.

Energy applications in the industrial sector include heat sources (furnaces, boilers and burners), driving forces (driving mills, pumps, conveyors, lighting, operating special vehicles) and electricity self-generation. Only consumption for the two first applications should be considered, because the amounts allocated to self-production and are already included in the transformation module. To obtain the consumption of each energy source, start with the purchase records for each one. Some cases, however, will require calculations and even surveys to determine which sector the consumption belongs to. Such is the case of using diesel or fuel oil for joint production of both process heat to self-generated electricity (co-generation). This topic is discussed in greater detail in Annex VI.

It may be difficult to calculate the firewood consumption of small-scale industries, as there is usually no logged data. In this case, one can resort to a survey or estimate as mentioned in Annexes.

Described below are several factors to take into consideration when calculating consumption in the industrial sector:

- Final power consumption in the industry must include both purchased and self-produced electricity.
- Natural gas and LPG consumption for cooking in restaurants and bakeries in industrial establishments: it is not advisable to separate these from industrial consumption to be reported under the commercial and services sector, as these activities are included under industries and not classified as restaurants in the ISIC.
- Consumption of sources used for purposes other than energy, as in the case of cleaning activities or as raw materials to produce non-energy goods, which should be subtracted from the total consumption of this source and recorded as non-energy consumption. For example, small amounts of kerosene are often used as a cleaning agent, and charcoal is used to produce carbon dioxide.
- Blast furnace coke consumption in an integrated steel plant is not deemed final consumption, but rather transformation for coke ovens on the supply side of the balance.

4.3.3.6. Construction Industry (ISIC Division 45)

The construction industry comprises, among others, the following activities:

a) New buildings and renovation of old buildings;
b) New industrial establishments;
c) Civil works such as bridges, dams, tunnels, etc.; and
d) New roads and maintenance of the existing road system.

Diesel oil is the main fuel used in the construction industry, primarily for the machinery that prepares concrete for buildings and public works, and as fuel for heavy road machinery. Where the appropriate information cannot be obtained from dealer sales, a survey will be necessary.

4.3.3.7. Transportation Sector (ISIC Division 60-62)

This refers to vehicle transportation of passengers and cargo. Final consumption in the transportation sector is the total fuel required to move such vehicles. The modes of transportation are by: a) road, b) rail c) air, d) river, and e) sea.

These vehicles take on fuel and consume it within the country's borders. This excludes ships and aircraft that are fueled for international travel, since this consumption is recorded under the 'Bunker' activity.

Consumption in the transportation sector should exclude the use of special vehicles such as cranes, tractors, road equipment, cement mixers, tank trucks, and others, which should be recorded under the sectors to which these special vehicles belong. For example, the fuel used for a forklift in a factory should be recorded as industrial sector consumption.
Similarly, electricity consumed in the buildings and facilities of transport companies should not be included under the transportation sector, but rather under the commercial sector. The fuels that are most used by this sector are:

- Automotive gasoline, used by motor vehicles and riverboats
- Aviation fuel used in aircraft
- Ethanol used in motor vehicles, either pure or mixed with gasoline
- Biodiesel consumed by automobiles, either pure or mixed with diesel oil
- Compressed vehicular natural gas
- Liquid petroleum gas
- Diesel oil used by railroads, riverboats, sea-going vessels, road vehicles (trucks and some light vehicles), with data from distributors, ports, and rail and shipping companies
- Coal used as fuel for railroads and ships, with data from the records of railway and shipping companies
- Jet fuel consumed by aircraft, with consumption data from fuel supply companies at airports
- Fuel oil consumed by large steamships for shipping, with consumption data from ports or shipping companies
- Electricity consumed by electric trains (elevated or underground), trams, and electric trolley buses.

In certain cases, trains may be equipped with onboard power plants, fueled by coal, diesel or others. Although it could be deemed a self-producer, we recommended reporting fuel consumption for the transportation sector.

A common method for determining the consumption of automotive gasoline is to assume that all gasoline supplied by service stations goes to automotive transportation. However, this procedure is not recommended, because consumption from these stations may also be for the residential sector (cooking) in rural and marginal urban areas and the farming sector.

Distributing diesel by sectors is one of the most difficult tasks with building energy balances, as it is consumed by virtually all sectors. Sales at service stations are usually higher than consumption for road transportation, because they also supply fuel for tractors and construction machinery, and small industries may also make their purchases at service stations. In any case, knowing the sales of service stations is a first step. To determine the diesel consumption of a type of vehicles, use the following formula:

$$Cf = Ni * E(c) * E(L)$$

Where:

Cf = Final consumption
Ni = Total vehicles in category i
c = Specific consumption
L = Annual mileage
E = the mathematical expectation of these amounts

If this formula is applied to all categories of vehicles that presumably fill their tanks at service stations, assign the appropriate values to c and L until the total calculated consumption matches sales.

The specific consumption of the resource (c) is determined by the technical characteristics of the engine, age, type of roads, altitude, etc.

4.3.3.8. Commercial and Service Sector (ISIC Division 41, 50-55, 63-93)

This includes all marketing of goods and services, both wholesale and retail, private and public, but excludes distribution services for energy sources such as electricity, natural gas, LPG, and other fuels, because they pertain to the energy sector.

It also covers national defense and police, financial institutions, hotels and restaurants, storage, airports and seaports, education, health, culture, entertainment, etc.

Care should be taken to exclude the use of vehicles belonging to commercial or service establishments, as this pertains to the transportation sector. The most used energy sources in this sector, aside from electricity, are coal, diesel oil, fuel oil, LPG, firewood, charcoal, and solar energy. They are used almost exclusively in boilers to produce steam and hot water (in hotels, hospitals, clinics, clubs, and social facilities) and for cooking (in restaurants, bakeries, hotels, clinics, and hospitals)

It is best to obtain appropriate information on commercial fuel consumption through sales distributors. Sometimes it is necessary to reclassify customer records, a procedure that can be combined with some form of survey or research.

Firewood and charcoal consumption in this sector is virtually unknown, and a comprehensive survey is necessary to obtain acceptable estimates.

With regard to solar energy consumption, it is only for heating water. The amount to be entered here is calculated using the following formula:

$$Cf = c * Q * (Tf – To)$$

Where:

Cf = final consumption
c = Specific heat of water (1 kcal/kg $_{o}$C)
Q = Annual amount of hot water produced
Tf = Final temperature (averaged)
To = Initial temperature (averaged)

Electricity is the energy source most commonly used by industry in numerous applications such as cooking, lighting, cooling, water heating, mechanical applications, electronic machinery, etc.

Electricity consumption can usually be estimated from sales by power utilities to this sector.

4.3.3.9. Residential Sector

This includes urban and rural households throughout the country, whose energy consumption is intended for end uses such as lighting, cooking, water heating, refrigeration, air conditioning, heating, electromotive force, and electromagnetic waves.

In general, the energy sources this sector uses the most are firewood for cooking and heating, and electricity for various uses. Consumer information on this sector, in the case of commercial sources, is available from supply companies.

Firewood, animal waste and charcoal can have a highly significant consumption in this sector in most developing countries. This is a non-commercial use and therefore is not recorded, so will require direct surveys to obtain data.

The oil products most commonly used by the residential sector are LPG, natural gas and kerosene. The suppliers of these products tend to keep records of their sales by type of consumer.

A household survey is a data collection process able to provide highly reliable results, especially in combination with distributor sales.

Note: In some countries, coal may follow non-commercial patterns, as people gather it with pick and shovel in open mines scattered throughout the country. This is dealt with the same as firewood. Solar energy is another source used by this sector, usually for water heating. To assess this, use the following expression:

$$H = c * Q * (Tf - To)$$

Where:

H = energy delivered by the sun
Q = amount of water heated per year
Tf = final temperature (averaged)
To = initial temperature (averaged)
c = specific heat of water (1 kcal/kg oC)

4.3.3.10. Non-Energy Final Consumption

This is more an activity than a sector, defined by the consumption of energy sources as raw materials to manufacture non-energy goods, which can occur in any socio-economic sector.

Below are some examples of the consumption of primary and secondary sources in the non-energy sector. It is up to users to identify cases that fit the situation of their countries, whether or not they are mentioned in this paragraph:

- Natural gas for steam cracking, turboexpanding or fertilizers
- Bagasse for chipboard or paper
- Animal waste as fertilizers, and plant waste as livestock feed
- Gasoline (naphtha) for cleaning or for reformation or steam cracking in the petrochemical industry
- Kerosene for cleaning
- Charcoal for carbon dioxide

One update of the energy balance methodology consists of breaking down non-energy consumption into various socioeconomic sub-sectors where this level of detail is available (Form SIEE-F03H.2)

4.3.3.11. Self-Consumption

Self-consumption is the amount of primary and secondary energy used by the energy sector itself in its operations, and consists exclusively of electricity and fuels.

It is important to distinguish 'self-consumption' from 'transformation' and 'recycling.' The latter two are raw materials transformed into new energy sources, while self-consumption is transformed into useful final energy as heat, mechanical force, lighting, etc.

For example, fuel oil burned to heat an oil furnace in a refinery is 'self-consumption,' while fuel oil that is mixed with the petroleum stream and input to the refinery is 'recycling,' and fuel oil burned to produce electricity is 'transformation.'
Note that the use of sources consumed as final energy in an energy facility is self-consumption, regardless of whether they are produced by the same facility, e.g., public electricity consumed in a refinery. To facilitate the recording of self-consumption, this activity has been divided into three sub-activities:

1) Self-consumption in the electricity sector
2) Self-consumption in the hydrocarbons industry
3) Self-consumption in other sectors

1) Self-Consumption in the Electricity Sector
This is the final energy consumed for the various activities of the electricity sector, such as generation (public), transportation and power distribution. Electricity self-consumption includes lighting for power sector facilities and offices, consumption for measuring equipment and control panels, communications equipment, power tools, etc. Self-consumption of fuels is usually to drive special equipment such as cranes for posts, forklifts, etc.

2) Self-consumption in the hydrocarbons industry
This includes electricity and fuels used by the petroleum industry itself at any of its stages, such as:

- Developing petroleum and associated gas in oil reservoirs
- Developing free gas in gas fields
- Refineries, where crude oil is processed and transformed into derivatives
- Transportation of petroleum, gas and derivatives through oil, gas and product pipelines
- Distribution and marketing of fuels
- Lighting for offices and other establishments in the petroleum industry
- Cranes, forklifts and other specialized machinery in the sector

Note: Petroleum companies usually report gasoline and diesel used to fuel land vehicles, aircraft or sea-going vessels as self-consumption. Strictly speaking, this should not be considered self-consumption, but rather final consumption in the transportation sector.

3) Self-Consumption in other Sectors
This is the amount of electricity and fuel used as final energy in the coal sector and others in the energy industry, such as:

- Machinery for coal extraction
- Lighting for coal mines
- Final energy consumption in coke ovens and blast furnaces
- Final energy consumed by ethanol distilleries and biodiesel plants

4.3.3.12. Losses

This the amount of energy lost for different reasons as it passes through the energy chain from its point of origin to final consumption, such as extraction, storage, processing, transportation, and distribution. For the energy balance, however, losses are considered neither for extraction, as they usually have already been deducted from the value of production, nor for transformation, because this is part of overall plant efficiency, so losses are only recorded for storage, transportation and distribution. Losses should not be confused with unused energy, because the latter could be fully exploited under suitable conditions, while the former are inevitable or accidental events. Losses can only refer to electricity and tangible energy sources.

- **Losses in Storage**

These apply to liquid, solid and gaseous sources, and occur due to accidental spills or leaks in reservoirs, evaporation of fluids and wind erosion on storage piles of solid sources such as coal. It is very important to distinguish storage losses from inventory variations.

- **Losses in Transportation**

This includes spills or leaks in pipelines, liquid evaporation in tanker trucks and, in the case of electricity, power loses in transmission lines caused by electric resistance. Transportation losses are calculated by measuring differences at the entrance and exit of the transportation system.

- **Losses in Distribution**

In the case of liquids and gases, these losses include spills, leaks, evaporation, and other similar events in distribution systems. In the case of electricity, they are due primarily to the resistance of power cables but may also have other causes, so electricity distribution losses are divided into two types: a) technical losses and b) non-technical losses.

a) Technical losses in power distribution: These losses occur in the primary or secondary grids of distribution systems (resistance losses in cables) and transformers (core losses: hysteresis and eddy currents). Such losses are unavoidable, since no process has 100% efficiency, but can be mitigated.

b) Non-technical losses in power distribution: These are losses that occurring due either to defects in measurement and billing or to electricity theft (pirated connections). Such losses are preventable, and reducing them increases utility revenues. Distribution losses are usually calculated as the difference between the power dispatched to the distribution system and the electricity billed to final consumers.

4.4. ENERGY BALANCE ACCOUNTS

This refers to the partial and total accounts in the columns and rows of the energy balance matrix. The format for presenting the energy balance, with its respective total and subtotal calculations, varies depending on the level of data detail and analysis required by each country.

4.4.1. Energy Balance Accounts in the OLADE Format

In the energy balance matrix currently used by OLADE, the rows are the energy chain activities and the columns are the different primary and secondary energy sources.

4.4.1.1. Accounts with Activities (rows)

- **Primary and Secondary Production**

In the OLADE format, production of both primary and secondary sources appears in the same row of the balance, the difference being that while primary production is one data item, and secondary production is a total that is calculated by adding up the outputs from all transformation centers (positive amounts).

- **Total Supply**

This is the amount of each source that is available for domestic use, whether as inputs for processing, as self-consumption by the energy sector, or as final consumption. Part of this item also covers losses that occur at different stages of the energy chain. Total domestic supply is calculated using the following formula:

$$OT = PP - RI + IM - EX + VI - NA - BK + TR$$

Where:

OT = Total domestic supply
PP = Production (both primary and secondary sources)
RI= Reinjection or recirculation NG
IM = Imports
EX = Exports
VI = Changes in inventory
NA= Unused
BK = Bunker
TR = Transfers

Note that VI and TR values can be either positive or negative in the energy balance.

Table 1. Signs of supply data in the OLADE format

Activity	Sign displayed in the balance
Primary production (PP)	Positive
NG reinjection or recirculation (RI)	Positive
Imports (IM)	Positive
Exports (EX)	Positive
Inventory variations (VI)	Positive or negative
Unused (NA)	Negative
Transfers (TR)	Positive or negative
Bunker (BK)	Negative
Total domestic supply	**PP-RI+IM-EX+VI-NA -BK+TR**

Source: Prepared by author

- **Total Transformation**

This is the sum of all inputs to transformation, and the sign convention for display in the balance is as follows:

Table 2. Activities

Activity	Sign displayed in the balance
Input to transformation	Negative
Transformation output	Positive
Total transformation	**Sum of all negative values**

Source: SIEN-OLADE

- **Final Energy Consumption**

This refers to the total amount of both primary and secondary sources used by the final consumption sectors mentioned above in this chapter.

- **Total Final Consumption**

This is the sum of the final energy consumption plus the final non-energy consumption. Consumption data are always displayed in the balance with positive signs.

- **Apparent Consumption**

This account does not appear explicitly in the balance, but represents the amount of an energy source that is apparently required to meet the internal needs of the country or region under study. It is calculated by adding up final consumption, self-consumption and losses, and then subtracting the total input to transformation.

$$CA = CF + CP + PE - TT$$

Where:

CA = Apparent consumption
CF = Total final consumption
CP = Self-consumption by the energy sector
PE = Losses
TT = Total transformation (always negative)

- **Statistical Adjustment**

An ideal energy balance should show the following equilibrium ratio:

Total supply = Apparent consumption

However, in practice, there are many reasons the two accounts do not add up exactly, such as accrued measurement errors, unit conversion approximations, incomplete data, etc. The difference between total supply and apparent consumption is known as 'statistical adjustment,' which may be positive or negative depending on which of the accounts has the highest figure. Therefore, the following expression can be used:

Total supply = Apparent consumption + Statistical adjustment

The statistical adjustment is also one of the parameters used to measure the accuracy and quality of energy balance data. Although it is hard to generalize because each source poses different difficulties for data collection, one criterion is that the absolute value of the statistical adjustment should not exceed 5% of the total supply figure.

4.4.1.2. Accounts with Energy Sources (columns)

First, we should emphasize that in order to accumulate calculations of different energy sources in an energy balance, all balance data must have a common caloric unit.

In the case of the OLADE format, account rows are usually the algebraic sum of each group of energy sources in the balance, expressed in a common caloric unit, with certain exceptions depending on the kinds of activities, as explained below.

- **Supply Activities**

In the supply activity area, the total primary, secondary and total energy sources are the algebraic sum of the figures in each row for all activities of this type. The exception is production, in which total energy production includes only total primary energy sources and not secondary energy sources.

The total domestic energy supply (TOT), located at the junction of the 'Total' column and 'Total supply' row, is calculated by applying the following formula for this item in that column:

TOT = TPP –TRI+ TIM – TEX + TVI – TNA – TBK + TTR

Where:

TOT= Total domestic energy supply
TPP = Total production
TRI= Total reinjection or recirculation { Applicable only to NG }
TIM = Total imports
TEX = Total exports
TVI = Total inventory variation
TNA = Total unused

TBK = Total bunker
TTR = Total transfers

- **Transformation Activities**

Total primary energy in this type of activity is obtained simply by adding up all the sources in this group, while total secondary energy includes only the sum of the positive figures for secondary sources, i.e., the outputs from transformation.

The cells in the conjunction between the 'Total' column and the rows for transformation activities are calculated algebraically by adding up all outputs from and inputs to transformation with their respective signs. These figures should always be less than or equal to zero, since a positive amount would imply a greater transformation efficiency than the unit.

- **Losses, Self-Consumption and Final Consumption Activities**

In these rows, the totals or accumulated sources are the algebraic sums of the figures for each group of energy sources.

So far the structure of energy balance is established according to the OLADE's methodology.

- **Electricity Generation by Source**

Given the need to detail electricity generation by source, and following a decision adopted at the XVI Work Meeting of the SIEE Advisors in October 2015, two rows were added at the end of the energy balance to record such information, with the following considerations:

- The data in these rows will in no way affect the energy balance.
- Each cell in relation to the column for each energy source is to contain the electricity generated with that source.
- The first row is for "Power Plants" and the second is for "Self-Producers".
- It is advisable to check that the Total of these rows is equal to the total of the "Electricity" column in the energy balance.

Table 3 shows the structure of the energy balance matrix used by OLADE in its information systems, with the respective formulas to calculate accounts by rows and by columns.

Table 3. Structure of the energy balance matrix

	Primary sources	Total primary sources	Secondary sources	Total secondary sources	Total
Primary production (PP)	(+)	Sum of primary sources	Sum of positive values in processing activities	Sum of secondary sources	Total primary sources
NG reinjection or recirculation (RI)	(+)	Sum of primary sources		Sum of secondary sources	Primary sources + secondary sources
Imports (IM)	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
Exports (EX)	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
Inventory variations (VI)	(+/-)	Sum of primary sources	(+/-)	Sum of secondary sources	Primary sources + secondary sources
Unused (NA)	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
Transfers (TR)	(+/-)	Sum of primary sources	(+/-)	Sum of secondary sources	Primary sources + secondary sources
Bunker (BK)	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
Total domestic supply (OT)	PP-RI+IM+-EX+VI-NA-BK+TR				
Transformation activities	(-)	Sum of primary sources	(+/-)	Sum positive figures for secondary sources (outputs)	Outputs–inputs
	(-)	Sum of primary sources	(+/-)		Outputs–inputs
	(-)	Sum of primary sources	(+/-)		Outputs–inputs
	(-)	Sum of primary sources	(+/-)		Outputs–inputs
	(-)	Sum of primary sources	(+/-)		Outputs–inputs
Total Transformation (TT)	Sum of negative values for transformation activities			Sum of secondary sources	Outputs–inputs
Final consumption sectors	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
Energy Consumption (EC)	Sum of end-use sectors				
Non-Energy Consumption (NE)	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
Final consumption (FC)	Energy Consumption + Non-Energy Consumption				
Self-consumption (CP)	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
Losses (PE)	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
Adjustment (AJ)	OT+TT–CP–PE (TT has a negative sign)				
Electricity generation: Power plants	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources
Electricity generation: Self-producers	(+)	Sum of primary sources	(+)	Sum of secondary sources	Primary sources + secondary sources

➢ Columns

Primary Energy: Below is the distribution of primary energy sources by columns is they appear in OLADE's energy balance.

Primary energy sources												
Primary Hydrocarbons			Mineral Sources		Direct Energy				Biomass			Other Primary Sources
1	2	3	4	5	6	7	8	9	10	11	12	13
Crude oil	Natural Gas Liquids	Natural gas	Coal	Nuclear	Hydropower	Geothermal	Wind	Solar	Firewood	Sugarcane products	Other biomass	
kbbl	kbbl	Mm^3	kt	t	GWh	GWh	GWh	GWh	kt	kt	kboe	kboe

Secondary Energy: Secondary energy sources are grouped in columns after the primary energy sources.

Secondary Energy Sources											
	Oil and Natural Gas Products								Products from Mineral Sources		
14	15	16	17	18	19	20	21	22	23	24	25
Electricity	LPG	Gasoline	Kerosene and Jet Fuel	Diesel oil	Fuel oil	Refinery gas	Petcoke	Oil and natural gas products	Coal coke	Industrial gases	Products from mineral sources
GWh	kbbl	kbbl	kbbl	kbbl	kbbl	kboe	kt	kboe	kt	kboe	kboe

Secondary Energy Sources					
Biomass Products					
26	27	28	29	30	31
Charcoal	Ethanol	Biodiesel	Biogas	Other secondary sources	Non-energy
kt	kbbl	kbbl	kboe	kboe	kboe

➢ Rows

The energy balance activities are broken down by rows, as shown below.

ITEM	Activity	ITEM	Activity	ITEM	Activity
1	Primary production	13	Self producers	25	Farming, forestry & fishing
2	Reinjection or Recirculation	14	Coking plants	26	Mining
3	Import	15	Blast furnaces	27	Construction and other
4	Export	16	Coal ovens	28	ENERGY CONSUMPTION
5	Stock Change	17	Ethanol distilleries	29	Non-energy
6	Unused	18	Biodiesel plants	30	FINAL CONSUMPTION
7	Transfers	19	Other transformations	31	Own consumption
8	Bunker	20	TOTAL TRANSFORMATION	32	Losses
9	TOTAL SUPPLY	21	Transportation	33	ADJUSTMENT
10	Refineries	22	Industry	34	Electricity generation: Power Plants [GWh]
11	Gas plants	23	Residential	35	Electricity generation: Self producers [GWh]
12	Power plants	24	Commercial, services & public		

CHAPTER V

Reserves and Potential

5. Reserves and Potential

5.1. RESERVES

These are the total amounts of fossil and mineral deposits available on a certain date in the country that can be exploited in the short, medium or long term. Geological and engineering knowledge allows economically extractable reserves to be estimated with a certain probability, and three categories are defined:

- **Proven reserves:**

Economically recoverable reserves in existing wells or deposits using the infrastructure and technology available in the country at the time of the evaluation. Included are improved production methods with a high degree of certainty for deposits that have demonstrated favorable production performance. They are measured using exploratory studies.

- **Probable reserves:**

These amounts have a high probability of being recovered from deposits already discovered after production technology is further developed. There are no exploratory studies to measure them; however, they are estimated according to other nearby fields.

- **Possible Reserves:**

These are amounts that it is estimated could be extracted from deposits identified in known formations, with low probability, which do not yet have exploratory studies.

1P reserves are proven reserves, 2P reserves are the sum of proven and probable reserves, and 3P reserves are the sum of all three types (Proven + Probable + Possible).

5.1.1. Hydrocarbons Reserves

- **Petroleum reserves**

The amount of crude oil found underground in all domestic deposits as of a certain date (for SIEE, on December 31 of each year). The amount of proven, probable and possible reserves must be reported.

- **Natural gas reserves**

These reserves are the amount of natural gas found underground in all the deposits on a certain date, either as unassociated gas or as gas associated with petroleum. Associated gas reserves are estimated as a percentage of petroleum reserves. The amount of proven, probable and possible reserves must be reported.

- **Reserves of natural gas liquids**

Natural gasoline, liquefied petroleum gas and sometimes intermediate cuts with the characteristics of kerosene constitute the condensable part of wet natural gas reserves, which are generally associated with petroleum. To determine the proven reserves of natural gas liquids, it is sufficient to know the proven reserves of associated natural gas and estimate them using percentages.

- **Reserves of other hydrocarbons**

Reserves of very heavy petroleum (bitumen) and sands containing bitumen are included under this heading, and are used to make synthetic oils and Orimulsion.

5.1.2. Coal Reserves

Coal is characterized by its type or quality, which depends on the geological age of the deposit. The older the coal the lower the content of volatile matter and the higher its caloric value. Depending on its quality, coal is classified as high-rank or low-rank coal; high rank coal is older than low rank coal and has a higher caloric value (between 7,000 and 8,800 kcal/kg, and includes anthracite and bituminous coal. Low-rank coals (between 3,000 and 6,500 kcal/kg) include sub-bituminous coal and lignite.

Coal reserves are the amount in the fields as of a given date that can be extracted using available technical procedures. Depending on the degree of uncertainty in the assessment, reserves can be proven, probable and possible.

Depending on the end use of the coal, reserves can be recorded as thermal coal or metallurgical coal.

Metallurgical coal is a special type of bituminous material that possesses coking properties; the sulfur and phosphorous content is usually low. All other bituminous material and other grades of coal are classified as thermal coal.

5.1.3. Uranium or Fissionable Fuel Reserves

This name includes natural uranium ores where the radioactive isotope is U235; it is generally expressed by the formula uranium oxide.

Fissionable fuel reserves are the quantity existing in the deposits as of a given date that can be extracted using available technical processes. Depending on the degree of uncertainty in the assessment, reserves can be proven, probable or possible.

5.2. Energy Potential

Potential is a measure of the ability of a country to take advantage of renewable resources for energy purposes. To calculate the potential, it is necessary to distinguish between two types of renewable sources:

a) Intangible sources cannot be quantified in units of mass or volume and therefore their potential is measured according to the end-use energy producing capacity, generally electricity. Hydropower, geothermal, wind and solar energy, and other renewable energy such as wave power are included in this category.
b) Tangible sources can be quantified in units of mass or volume, so their potential is measured directly according to the quantity of the resource that is available or recoverable in nature. Biomass for energy use is included in this item.

5.2.1. Hydroelectric potential

The hydroelectric potential (P) is the sum of the installable power capacity in hydroelectric watersheds plus the total installed power capacity in existing hydroelectric plants.

$$P = \eta . \rho . Q . g . h . 10^{-6}$$

Where:

P = Hydroelectric potential (MW)
η = The approximate efficiency of the power plant
Q = Flow in m^3/s
ρ = Water density equal to 1000 kg
g = Gravity acceleration, constant equal to 9.8 m/s^2
h = Height in meters, equal to the difference in vertical height between two specific points of the watershed.

5.2.2. Geothermal Potential

The power (W) is the sum of the installable power in all possible geothermal reservoirs and the installed power of geothermal plants that are in operation. Under the current state of technology, there is no uniform criterion as to whether geothermal energy is a 100% renewable resource, and it seems that the method of operation could lead either to its exhaustion or its preservation, at least over long periods.

The energy can be evaluated as the sum of all the energy the installable and installed power can produce during periods that can be different for each site, based on a maximum lifespan of 50 years.

Since geothermal energy is used almost exclusively for generating electricity, the energy obtainable from a geothermal resource is calculated as the electricity that can be produced by the enthalpy of the steam available at the sites.

5.2.3. Wind Potential

The power (W) is the sum of the installable power in a given area and the installed power of wind farms that are in operation.

Wind power is a function of the cube of the velocity, so it is important to make reliable measurements of the velocity over a considerable time. Wind power can be calculated using the following expression:

$$W = \frac{1}{2}\rho A v^3$$

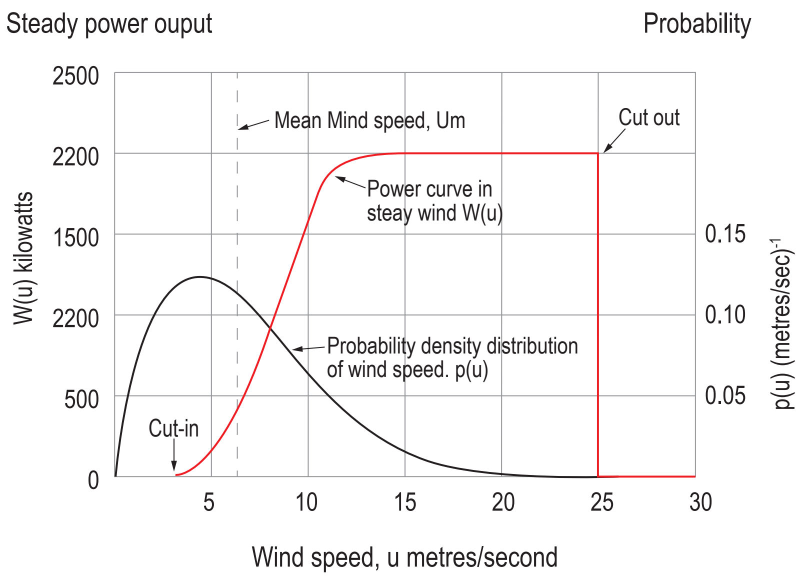
Where:

ρ = air density in kg/m^3
A = cross section to the direction of the wind swept by the rotor, in m^2
v = wind velocity in m/s.

The wind velocity is adjusted according to the Weibull probability density function. Based on this curve, the energy that can be produced by a wind turbine can be calculated, typically over a period of one year.

The Weibull distribution is defined by two parameters: a scale factor c (m/s) that can approximate the average velocity and a form factor k that indicates how narrow or biased the curve is.

Figure 15. Mathematical expectation of wind potential



Steady wind power curve and wind speed probability density

Wind potential can be calculated as the mathematical expectation of the average power developed as a function of wind speeds.

$$Pm = \int_{u=0}^{u=+\infty} p(u)W(u)du$$

Where:

Pm = the mathematical expectation of wind power
u = wind speed
P(u) = a function of the probable speed distribution
W(u) = a function of wind power with regard to speed

5.2.4. Solar Potential

This refers to the power that can be produced by capturing solar radiation on photovoltaic and thermal solar devices in a given study area.

To calculate the solar potential, the solar radiation should be determined, which corresponds to the average of the daily global radiation values (direct radiation plus diffuse radiation). This value can be determined by means of a device called a pyranometer.

If the radiation values are taken every few minutes during the day, the daily level of incident solar energy kWh/m^2/day can be determined by integration.

5.2.5. Bioenergy Potential

This is the potential of firewood, bagasse, and agribusiness, livestock and urban waste.

- **Firewood Potential**

It is equal to the sum of the quantities of firewood in tons that can be obtained each year by collecting and cutting.

- **Firewood collection potential**

This is the annual weight increase in a sustainable area permitted by firewood collection (thinning, pruning, clearing, etc.) without reducing the annual timber potential.

Sustainable area (AS): The forest area available for cutting is equal to the total forest area minus the protected forest minus areas deforested for farming or any other reason.

- **Firewood cutting potential:**

The amount of wood that can be obtained from tree trunks in the cutting area and is the annual potential timber production minus the annual industrial roundwood production (roundwood minus firewood and charcoal).

The annual cutting area (ACA): defines the cutting area each year and is equal to the sustainable area divided by the rotation cycle.

Rotation Cycle (CR): is the time it takes for a forest to regenerate between cuts. The annual timber potential (PM) is equal to the gross standing volume divided by the density t/m^3); if this is not available, use 0.625 for conifers, 0.750 hardwoods and 0.725 for mixed forest; shrub or degraded forest can have much lower densities.

Gross Standing Volume (VOB): is equal to the annual cutting area per m^3 of timber per m^2 of area.

- **Bagasse Potential**

The annual bagasse potential is evaluated in terms of the sugar produced and a bagasse/sugar coefficient. Bagasse is perhaps the only resource whose potential is equal to the annual production because the sugar used in calculating it is the actual annual production.

- **Agricultural, agro-industrial, livestock and urban waste potential**

The waste potential is calculated by multiplying the weight of the original source by a coefficient. Some reference coefficients are:

Table 4. Reference Coefficients

Reference Coefficients		
Product	**p.u.**	**boe/ton**
Agricultural		
Rice	0.40	2.10
Cotton	0.50	2.10
Sugar Cane	0.15	2.10
Agro-industrial		
Rice	0.32	2.31
Cotton	0.27	2.67
Coffee	0.60	2.52
Timber	1.00	1.92
Distillery	12.00	0.04
Urban		
Garbage	0.07	1.15
Gray water	14.60	0.00

Source: SIEE-OLADE

CHAPTER VI

Prices for Energy Sources

6. Prices for Energy Sources

Information on energy prices is an essential part of a country's energy statistics, being a variable that can directly influence the supply and demand of a source. However, the large number of parameters and conditions determining this variable, such as taxes, geographic region, type of consumer, form of distribution, transportation costs, etc., make it very complex to compile in detail, which necessitates a simplified classification like the one presented below.

6.1. REFERENCE PRICES FOR ENERGY SOURCES

The reference price is a single figure deemed the most representative of a given product within the country. It comprises the monthly value of the energy source, in domestic or foreign currency, per physical commercial unit.

All the chosen parameters, such as location, caloric value, octanes, consumption bracket, product type, and other considerations that provide this single value, should be recorded to ensure consistency in the data series.

Reference prices usually apply to commercial energy sources such as crude oil and its derivatives, natural gas, coal, and electricity, for which there is a controlled marketing infrastructure.

Reference prices can be domestic or foreign.

6.1.1. Domestic Price

This is the price of energy to the final consumer, and is usually the most frequently cited price during the month, in local currency. If this price varies by city or point of sale within the country, select the one with the highest consumption. Two types of domestic prices have been established:

a) Price before taxes: the price of energy before the application of additional items such as taxes, profits, subsidies, etc. specific consumption taxes are particularly excluded.

b) Price after taxes: the price of energy including all federal, state, municipal, consumption, and other taxes applied to energy in the country, and any additional marketing surcharges. In other words, this is the price actually paid by consumers in the market.

Domestic reference prices can be differentiated by final consumption sectors, as in the following examples:

a) Residential natural gas: the price of natural gas for the residential sector. If natural gas prices are stratified by consumption ranges (or other criteria), report the values in the highest consumption bracket.

b) Industrial natural gas: the price of natural gas in the industrial sector. Ideally, enter the monthly average gas price paid by an industrial user in a particular country, but when this is not possible, use a reference value.

Take into account the particular situation of each country, because in the event of sub-sectors with strong subsidies, taking the average as the reference price could cause major distortions in gas prices. In this case, consider whether it is best to eliminate the price for subsidized industries.

Natural gas prices paid by power plants should not be included as part of the price for the industrial sector.

a) Liquefied petroleum gas (LPG): the price paid by users in the largest consumer sector. In most countries, this is assumed to be the residential sector. If prices vary by location or consumption bracket, select the location and bracket with the highest share of consumption. If there are different grades of liquefied gas (pure propane, pure butane, various mixtures of propane and butane), take the one having the highest consumption.

b) Gasoline: the consumer price paid at service stations. If this price varies from season to season or from town to town, take the location with the highest consumption.

Report the price of the two types of motor vehicle gasoline that are sold the most in the country, classified as follows.

- Regular gasoline: gasoline with the lowest octane levels of the two types chosen.
- Premium gasoline: the highest-octane gasoline of the two types chosen.

c) Diesel oil: the price paid by users in the transportation sector for this energy source. This is the diesel sales price at service stations, not bulk purchases for industries, farms, or large passenger or cargo transportation companies, even if this consumption is larger than sales at service stations. If the price varies by location, select the one with the highest share of consumption.

d) Kerosene: the consumer price paid for the residential sector at service stations. If prices vary by location, select the one with the highest share of consumption.

e) Jet fuel: the price of fuel for jet planes. Jet fuel is generally provided under different specifications involving different denominations (JP1, JP4, etc.), so choose the one consumed the most.
Likewise, if prices depend on the airport, select the busiest airport. A very common situation is that different prices are paid for domestic flights and international flights by aircraft flying under the national flag. In this case, give preference to the prices for international flights.

f) Fuel oil: fuel oil prices paid by users in the industrial sector. Fuel oil is usually sold in bulk and may not have a single price for all industrial users, as it may be partially or entirely set through negotiations between sellers and buyers. If so, select the industrial consumer that is most representative of the country.
If the price of fuel oil industry is set by the government and is not uniform throughout the country or for all industrial sub-sectors, select an average value based on its representativeness.

g) Coal for steelworks: This is the price paid by steelworks to produce coke. The use of metallurgical coal is concentrated in a few users, but if a country has large integrated steel works with blast furnaces, the reference price will be the average of these facilities (or the most representative one), excluding the smaller units that do small-scale coking. However, if a country has only a small-scale metallurgic industry, the price taken is the average for this industry.

h) Coal for thermal use: This is the price paid by users in the industrial sector. Only if there is no industrial consumption, use the price for another sector in the following order of priority:

- Industrial
- Public Utility Power Plants
- Railways
- Ships
- Residential

i) Electricity: This is the price per kWh paid by a reference user in the residential, commercial or industrial sector. If prices vary by location or consumption bracket, select the location and bracket by its share of consumption. Preferably, record the value resulting from the relationship between the monetary value and amount of energy (kWh) billed to each economic sector. This gives a price that takes into account the different consumption tariffs and ranges. There may be macro industrial consumers with electrolysis processes that receive promotional rates that are well below the average, but exclude them even if they are the largest consumers, as they will distort the comparison with other countries.

6.1.2. International Prices

International prices are the import and export prices at which the different energy sources are sold.

a) Import price: the monthly average CIF price for imports, or else the most representative shipment price for the month.

b) Export price: the monthly average FOB price for exports, or else the most representative shipment price for the month.

For example, listed below are criteria for determining international reference prices on imports and exports for a few energy sources:

a) Exported or imported natural gas: the dollar price at the border per 1000 m^3 of natural gas having a given caloric value. This is the price received by the exporting country or paid by the importing country. If a country exports or imports natural gas at different prices, use the most representative one, i.e., the price for the largest quantity that is exported or imported.

b) Exported or imported petroleum products: This explanation is valid for liquefied petroleum gas, gasoline, kerosene, jet fuel, gas/diesel oil, and fuel oil. The price of each product should be the dollar value per barrel, FOB if exported or CIF if imported.

c) Exported or imported petroleum: the dollar price per barrel of crude oil, FOB if exported or CIF if imported. If a country exports or imports crude oils of different qualities, choose the most representative one in terms of volume.

d) Exported or imported coal and coke: this explanation is valid for steelworks coal, thermal coal and coke.

The price should be the dollar value per ton of product, FOB if exported or CIF if imported. If a country exports or imports products of different qualities, choose the most representative ones in terms of volume.

6.2. AVERAGE PRICES FOR ENERGY SOURCES

The average price in a region or country for a given energy source at a given time is the weighted average of all consumer prices paid for that source in that same region and within that same time period. This results from the relationship between the total billed amount in dollars and the volume sold.

Since the price spread around the average can be very large, it is advisable to set some degree or range of variability. In this case, the range is the price interval that covers 60% of all consumers of that source. This means that if P is the average price, its upper range (P2) is the highest price before reaching the 80% range of all possible cases, and the lower range (P1) is the highest price before reaching the 20% range of all possible cases.

When marketing an energy source depends entirely on local conditions (a free market), the price component may have a huge spread. In these cases, the only way to obtain an estimate is to apply sampling rules or, where this is not possible, choose the price where consumption is greatest. When it is not possible to collect all the data needed to calculate an average price, OLADE estimates it using a simple arithmetic average of all monthly prices for that energy source during one year.

The selected energy sources are crude oil and its derivatives, natural gas, coal, electricity, and nuclear fuels.

Note: the average prices are reported in dollars per marketing unit, including taxes and business margins.

6.2.1. Average Prices by Energy Source

6.2.1.1. Crude Oil

The weighted value of crude oil for the year is recorded for each of the following sectors:

Import and export: Report the weighted average of all prices in the year, using CIF for imports and FOB for exports.

Transformation: Before choosing the value, consider that there are three cases.
In the case of producer countries, report the weighted average prices paid by national petroleum refineries.

For importing countries, report the weighted average CIF prices of imported crude oil in the year, i.e., the same average price for imports.

For countries that import and export, report the average weighted average price as a producer country and as an importer country.

6.2.1.2. Natural Gas

Record the weighted value of natural gas for each of the following sectors:

Import and export: Some countries import or export natural gas, usually through cross-border gas pipelines. Purchase contracts are often governed by well-defined rates, or rates are calculated using adjustment formulas.

Industry: the weighted average of the natural gas used by industries. If the country sets different rates by consumption bracket, take the weighted average of them all. The best way to do this is to divide total billing by consumption. If some industries have special prices, such as petrochemical plants, then exclude them from the average.

Transportation: the total average price paid by carriers loading at all points of sale.

Transformation: the weighted average price of all natural gas delivered via gas pipelines to the power utility sector.

Residential: the weighted average price of all natural gas delivered via gas pipelines to homes.

Commercial, services and public: the weighted average price of all natural gas delivered via gas pipelines to establishments of this sector.

Note: in the residential, commercial, services and public sectors, if the country sets prices by consumption brackets, take the weighted average of all brackets. The best way to do this is to divide total billing by consumption. If there are different rates for cities, or if a sub-sector such as hospitals receives special prices, add up all billings and divide by total consumption.

6.2.1.3. Steelworks Coal and Thermal Coal

Record the weighted value taking the most representative caloric value of the coal, be it for steelworks or thermal, for each of the following sectors:

Import and export: Report the weighted average of all coal prices for the year, at CIF if imported or FOB if exported.

Industry: Coking coal is reported at the weighted average prices of coal used in the steel industry, while thermal coal is reported at the weighted average prices for other industries.

Transformation: Use the weighted average prices of coal delivered to the steel industry and to the power utility industry.

Note: To estimate total prices, it is advisable to use a fixed sample of consumer companies that are regularly consulted.

6.2.1.4. Coking Coal

Report the weighted value of coking coal for the following sectors:

Import and export: Report the weighted average coke prices in a year, at CIF for imports and FOB for exports.

Industry: Report the weighted average value of coking coal used in the industry.

6.2.1.5. Nuclear

The weighted value of nuclear fuel is recorded for each of the following sectors:

Import and export: Report the weighted average price of nuclear fuel in a year, using CIF for imports and FOB for exports.

Transformation: the weighted average of nuclear fuel, usually natural or enriched uranium, consumed by electric utility companies.

6.2.1.6. Firewood

Record the weighted value of marketed firewood, excluding directly appropriated firewood. It is advisable to obtain this price from a fixed sample to be surveyed periodically for each of the following sectors:

Industry: Record the weighted price paid annually by small, decentralized rural industries (brickyards, limekilns, salt mines, etc.).

Residential: Try to estimate the average total price paid by households by consulting the supply centers that are most representative of the towns and villages where firewood is consumed.

Commercial, services and public: The most typical case to capture here is that of urban and rural restaurants, leaving other consumers out.

Transformation: Use the price of firewood consumed by charcoal producers. The most common is direct appropriation of firewood for charcoal production, in which case, do not record this value.

6.2.1.7. Electricity

Record the weighted value of electricity. If the country sets prices according to consumption brackets, geographic areas, times of the day, social strata, types of facilities, etc., take the weighted average of all these variables by dividing the total revenues by the total consumption for each of the following the sectors:

Import and export: More and more countries import and export electricity through their interconnected systems. Often, purchase contracts are governed by well-defined rates, or rates are calculated using adjustment formulas.

Industry: Use the weighted average price of electricity sold to industrial plants, excluding industries with special prices, such as electrochemical plants. Also, exclude small isolated systems whose sales to the industrial sector are minimal and little known. Include only the price of energy and not of power.

Residential: Use the weighted average price of electricity sold to households (residential sector). Exclude from this average the prices of small isolated systems whose sales to the residential sector are minimal compared to the rest, as they usually have special rates.
Commercial, services and public: Use the weighted average of all prices for electricity sold to the establishments of this sector. Also, exclude small isolated systems whose sales to the commercial sector are minimal compared to the rest.

Note: use the weighted price of all electric companies in the country, or otherwise choose the most representative one in each sector.

6.2.1.8. Biofuels

Biofuel marketing is still very marginal in Latin American and Caribbean countries. You will mainly record the domestic production of each country and its end uses, primarily in transport and mixed with other components such as gasoline, diesel and fuel oil. The price of this energy product will be the average price for the different qualities.

6.2.1.9. Liquefied Petroleum Gas (LPG)

Report the weighted value of LPG for each of the following sectors:

Import and export: Report the weighted average of CIF prices for imports or FOB prices for exports of liquefied gas in the year.

Residential: Use the weighted average of all prices for liquefied gas sold to households. Analyze this situation carefully, because liquefied gas is often sold by a multitude of companies in a deregulated market. If this is the case, determine the total average price through a survey, on a sample of either households or distributors.

Commercial, services and public: Use the weighted average price for liquefied gas sold to establishments in the sector, mainly restaurants and hotels. The total average price is usually very similar to that of the residential sector. If the market is deregulated, determine the total average price through a survey of establishments in the sector.

6.2.1.10. Gasoline

Record the weighted value of gasoline for each of the following consumption sectors:

Import and export: Report the weighted average price of gasoline in the year, using CIF for imports and FOB for exports.

Transportation: Use the average prices for the different qualities of motor gasoline sold in the market.

Note: Exclude aviation gasoline.

6.2.1.11. Kerosene and Turbo

Record the weighted value of kerosene and turbo for each of the following sectors:

Import and export: Report the weighted average price of residential kerosene in the year, using CIF prices for imports and FOB prices for exports.

Transportation: Use the average prices of the different qualities of jet fuel sold on the market.

Residential: Use the weighted average of the prices for kerosene sold to households. If the market is deregulated, determine the total average price through a survey, either of a sample of households or of a sample of distributors.

6.2.1.12. Diesel Oil

Record the weighted value of diesel oil for each of the following sectors:

Import and export: Report the weighted average prices of diesel oil in the year, using CIF for imports and FOB for exports.

Industrial: Use the average price of diesel oil sold to industries (usually in bulk).

Transportation: Use the average price of diesel oil sold in service stations, weighting by region or taking the most representative area.

Transformation: used for electricity generation. If the diesel oil used by power utilities is of the same quality and price as industrial diesel oil, use the same values as for the industrial sector. Otherwise, record the average price of diesel oil sold to the power industry, usually in bulk.

Commercial, services, utilities: there may be three cases:

- The country's tertiary sector purchases diesel oil primarily at service stations; consequently, the price is no different from the transportation sector.
- The country's tertiary sector buys in bulk from distribution companies; consequently, the price is that of the industrial sector.
- The situation in the country is mixed; take the weighted average of all values for transportation and industry.

6.2.1.13. Fuel Oil

Record the weighted value of fuel oil for each of the following sectors:

Imports and exports: Report the weighted average prices of fuel oil in the year, using CIF for imports and FOB for exports.

Industry: Use the average price for fuel oil sold to industries. If the market is deregulated, conduct survey with a fixed sample, either of consuming industries or of distributors.

Transportation: Use the average price for fuel oil and bunker sold to shipping companies or river service stations.

Transformation: record the fuel oil used by power utilities.

6.2.1.14. Charcoal

Record the weighted value of charcoal paid by households by consulting the most representative retail centers in the cities and towns where it is consumed, considering the residential sector as the only consumption sector.

6.2.1.15. Lubricants

Take the most representative lubricants used for vehicles in the country and keep that sample for all data before obtaining the weighted value for each of the following sectors:

Import and export: Report the weighted average of all lubricants prices in the year, using CIF for imports and FOB for exports.
Transportation: Take the average of the market prices for the sample.

6.2.1.16. Asphalt

Enter the weighted value of asphalt for each of the following sectors:

Import and export: Report the weighted average of all asphalt prices in the year, using CIF for imports and FOB for exports.

Construction, services and utilities: Use the average price of asphalt sold within the commercial or services sector. This includes the price of asphalt sold, taken at the refinery outlet or at importation, plus any refining margins, taxes and subsidies.

CHAPTER VII

Energy Infrastructure

7. Energy Infrastructure

7.1. HYDROCARBON SECTOR INFRASTRUCTURE

7.1.1. Oil and Gas Fields

An oil or gas field is an area with one or more oil and associated gas wells, or only non-associated gas wells. In addition to extraction infrastructure, these fields have facilities for separating and storing products.

Infrastructure variables

a) Oilfields

- ➢ Identifying data:
  - Field name
  - Location
  - Operating company
  - Site. C: Continent, A: Offshore
  - Depth [m]
  - API gravity. Input an average or range
  - Year of discovery
  - Activity. A: Active, I: Inactive
- ➢ Technical data
  - Reserves [Mbbl]
    - ❖ Proven
    - ❖ Probable
    - ❖ Possible
  - Number of wells
    - ❖ In production
    - ❖ Totals
  - Production volume (bbl/d)

b) Natural Gas Fields

- ➢ Identifying data
  - Field name
  - Location
  - Operating company
  - Site. C: Continent, A: Offshore
  - Depth [m]
  - Calorific power [BTU/ft^3 or J/m^3]
  - Year of discovery
  - Activity. A: Active, I: Inactive
- ➢ Technical data
  - Reserves [Gm^3]:
    - ❖ Proven
    - ❖ Probable
    - ❖ Possible

- Number of wells
    - In production
    - Totals
- Production volume (m^3/d)

7.1.2. Oil, Gas and Product Pipelines

Pipelines that transport crude oil from production sites to refineries or collection centers and marine terminals for export are called oil pipelines. Gas pipelines are pipelines for transporting natural gas and product pipelines are pipelines for transporting the different refined liquid petroleum products.

Infrastructure variables:

- Identifying data
    - Type of pipeline. P = Product pipelines, O = Oil pipelines, G = Gas pipelines
    - Name (Origin – Destination)
    - Operating company
    - First year of operation
    - Last year of operation
- Technical data
    - Diameter [cm]
    - Length [km]
    - Capacity (oil and product pipelines 10^3 bbl/d - Gas pipelines 10^6 m^3/d)
    - Average volume transported (oil and product pipelines 10^3 bbl/d – Gas pipelines 10^6 m^3/d)

7.1.3. International Pipelines

Oil pipelines, gas pipelines or product pipelines that connect two countries in order to exchange petroleum, natural gas or petroleum products.

Infrastructure variables:

- Name
- Country of origin
- Destination country
- Pipeline length (km)
- Pipe diameter (cm)
- Date of entry into operation
- Flow capacity (m^3/s for gases and bbl/s for liquids)

7.1.4. Refineries

A processing center where crude oil, natural gas liquids and other primary inputs are processed to transform them into refined products with better features for marketing and consumption.

Infrastructure variables:

- Identifying data
    - Name of the Refinery
    - Location
    - Operating company
    - Date of entry into operation
        - Last year of operation

    - Activity. A: Active, I: Inactive
- Technical data
    - Refining capacity [10^3 bbl/d]
        - Atmospheric distilling
        - Thermal operations
        - Catalytic cracking
        - Catalytic reforming

7.1.5. Gas Treatment Plants

A plant where natural gas is processed to extract its liquid components and some refined products such as LPG and gasoline.

Infrastructure variables:

- Identifying data
    - Name of the gas treatment plant
    - Location
    - Operating company
    - Last year of operation
    - Activity. A: Active, I: Inactive
- Technical data
    - Operational capacity [10^6 m^3/d]

7.1.6. Liquefaction and Regasification Plants

Liquefaction plants are centers where natural gas is cooled to cryogenic temperatures of about -161 °C to liquefy it and facilitate storage and transportation. Regasification plants on the other hand convert liquefied natural gas into a gas again in a controlled manner.

Infrastructure variables:

- Name of liquefaction or regasification plant
- Operating company
- Location
- Date of entry into operation
- Processing capacity (m^3 of natural gas per day)

7.1.7. Storage Facilities

Any facilities capable of storing energy sources, which can be solids, liquids or gases. Storage can take place at any stage in the energy chain, even at consumers' facilities. Infrastructure variables:

- Identifying data
    - Facility Name
    - Location
    - Operating company
- Technical data
    - Storage capacity [kbbl]
        - Oil
        - Liquefied gas
        - Gasoline
        - Kerosene
        - Diesel oil
        - Fuel oil
        - Alcohol
        - Others (specify)

7.2. COAL INFRASTRUCTURE

7.2.1. Deposits and Mines

Coal deposits are geological formations where this mineral is concentrated. When these deposits are exploited, they become coalmines. Depending on the location of the coal and the method of exploitation, coalmines are classified as underground mines and open pit mines. Underground mines are subterranean and the mineral is extracted through a tunnel. In open pit mines, the mineral is extracted by means of vast surface excavations that are progressively deeper.

Infrastructure variables:

- Identifying data
    - Field name
    - Location
    - Activity. A: Active, I: Inactive
- Technical data
    - Type of pipeline. AT = Anthracite, BT = Thermal Bituminous, BC = Metallurgical Bituminous, SB = Sub-bituminous, LG = Lignite, TB = Peat
    - Average Quality (ASTM Standards)
        - Calorific Power (cal/g). Input an average or range
        - Content (%). Input an average or range
            - Ash
            - Sulfur
            - Humidity
            - Volatile Material
    - Reserves [Mt]:
        - Proven
        - Probable
        - Possible
    - Production Volume (kt)
    - Number of Mines
    - Degree of Knowledge GSP = Surface Geology, GSS = Subsoil Geology, EG = Geological Survey,
    - EPM = Mine Pre-Feasibility Study, EFM = Mine Feasibility Study

7.2.2. Transportation Systems

Depending on the location of mines, coal can be transported to centers of consumption or to ports for export by road, railroad or waterway.

Infrastructure variables:

- Type of transportation system
- Location of origin
- Destination location
- Operating company
- Date of entry into operation
- Production capacity (t/d)

7.2.3. Coke Ovens

Industrial facilities that generally pertain to the metallurgical and steel sector, where coking (anaerobic destructive distillation or pyrolysis) of certain types of coal for coke production takes place. Coke is used as fuel and as a raw material in the process for reducing steel in blast furnaces.

Infrastructure variables:
- Name of the coking oven
- Location
- Operating company
- Date of entry into operation
- Coal processing capacity (t/d)

7.2.4. Blast Furnaces

Steel industry devices where steel (alloy of metallic iron, carbon and other minerals) is produced by high temperature reduction of iron ore with the basic intervention coke and limestone. They are considered part of the energy infrastructure because the gases produced in the process are generally used as fuel for heating the ovens themselves. Infrastructure variables:
- Name of the facility
- Location
- Operating company
- Date of entry into operation
- Coke processing capacity (t/d)

7.2.5. Storage Facilities

Coal is stored by piling the ore near the entrance or area near the mine, at river ports or seaports, or in specific collection centers.
Infrastructure variables:
- Name of the facility
- Location
- Operating company
- Date of entry into operation
- Storage processing capacity (t/d)

7.3. POWER SECTOR INFRASTRUCTURE

7.3.1. Power Plants

Facilities for electrical generation using different technologies and different energy inputs, such as: hydraulic power plants, steam thermal power plants, gas thermal power plants, internal combustion engines, nuclear power plants, geothermal power plants, wind power plants, photovoltaic power plants, and others.
Infrastructure variables:

- Identifying data
    - Type. HE = Hydro, TV = Thermal Steam, TG = Turbo Gas, DO = Diesel Oil, GE = Geothermal, NU = Nuclear, EO = Wind, SL = Solar, BM = Biomass
    - Plant name
    - Location
    - Operating company
    - Service. P: Public, A: Self producer
    - Owner. P: Public, R: Private
    - First year of operation
    - Last year of operation
    - Activity. A: Active, I: Inactive
- Technical data
    - Power [MW]

- Nominal
- Effective
- Delivered energy [GWh]
- Investment [US$/kW]
- Gross generation [GWh]
- Self consumption [GWh]
- Plant Factor [%]
- Thermal efficiency [%]
- Fuel Consumed
    - Fuel 1 [Unit]
        - Name
        - Amount used
    - Fuel 2 [Unit]
        - Name
        - Amount used

7.3.2. International Connections (foreign trade)

Electrical transmission lines that allow international trade in electricity by connecting the electrical systems of different countries. Infrastructure variables:

- Name of the transmission line
- Country and place of origin
- Destination country and location
- Operating company
- Date of entry into operation
- Number of phases
- Nominal voltage (kV)
- Transmission capacity 1-2 (MW)
- Transmission capacity 2-1 (MW)

7.3.3. Geothermal Fields

An area having wells for the exploitation of geothermal resources.

- Identifying data
    - Field name
    - Location
    - Operating company
    - Year of discovery
    - Activity. A: Active, I: Inactive
    - Development stage. F = Feasibility, D = Development, E = Exploitation
- Technical data
    - Geothermal potential
        - Power [MW]
        - Energy (GWh)
    - Capacity
        - Under construction (MW)
        - Installed (MW)
    - Number of wells

- ❖ Drilled
- ❖ In production
- Average depth of wells (m)
- Production volume (kt)
- Number of plants
- Production of:
  - ❖ Steam (t/h)
  - ❖ Water (t/h)

7.3.4. Hydropower Projects

- ➢ Identifying data
- ➢ Technical data
  - Reservoir capacity (Mm^3]
  - Average flow rate [m^3/s)
  - Hydropower potential
    - ❖ Power [MW]
    - ❖ Energy (GWh)
  - Capacity
    - ❖ Under construction (MW)
    - ❖ Installed (MW)

7.4. RENEWABLE ENERGY INFRASTRUCTURE

7.4.1. Bioenergy Plantations

Plantations of plant species for energy production, such as sugar cane for ethanol production and oil crops for biodiesel production.

<u>Infrastructure variables:</u>

- Name of the plantation
- Type of crop
- Location
- Operating company
- Cultivated area (km^2)
- Raw material production capacity for biofuels (t/d)

7.4.2. Charcoal Clamps

Facilities, usually artisanal, where wood is charred by anaerobic distillation (pyrolysis) to produce charcoal.

<u>Infrastructure variables:</u>

- Name of the charcoal clamp
- Location
- Charcoal production capacity(t/d)

7.4.3. Distilleries

Industrial facilities where alcohols, in particular ethanol, are produced by distilling plant materials rich in sugar, starch or cellulose. Only products that are intended for energy use will be considered within the energy infrastructure of the country.

Infrastructure variables:

- Name of the distillery
- Operating company
- Date of entry into operation
- Location
- Ethanol production capacity(bbl/d)

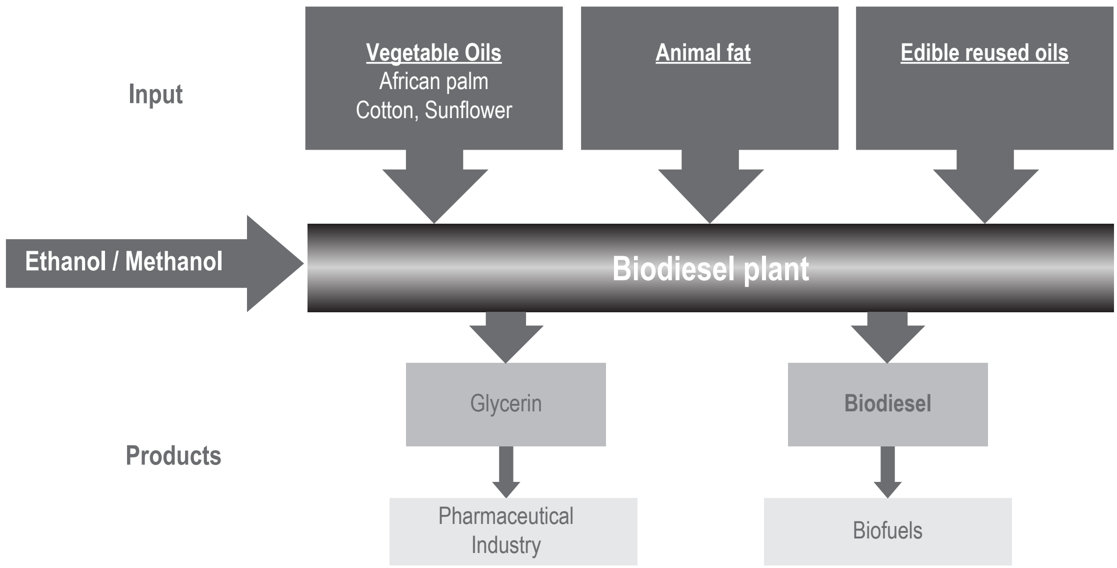
7.4.4. Biodiesel Plants

Facilities where biodiesel is produced, which is obtained through the transesterification of vegetable oils, animal fats and recycled oils to produce methyl or ethyl esters of fatty acids.

Infrastructure variables:

- Name of the plant
- Location
- Operating Company
- Biodiesel production capacity(bbl/d)

Figure 16. Biodiesel processing plants

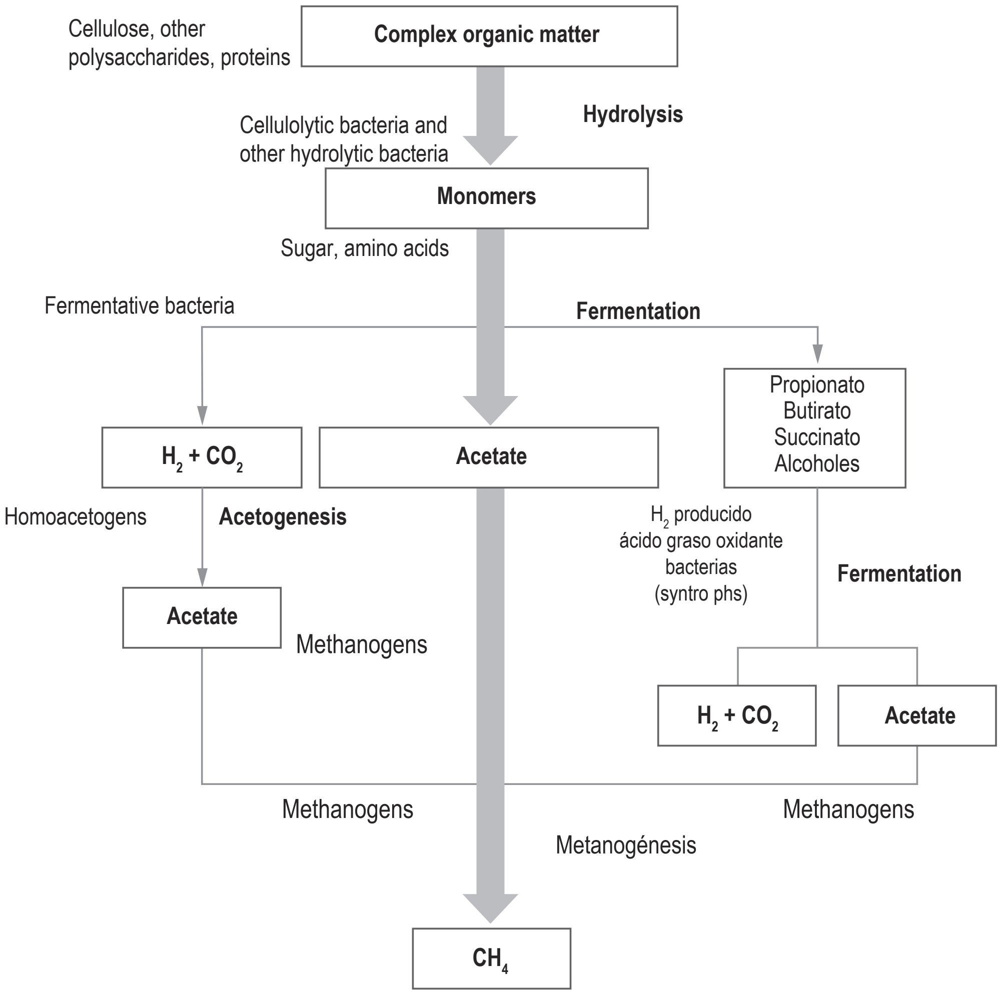


Source: SIEE-OLADE

7.4.5. Biogas / Biodigester Plants

Plants where fermentation takes place, which consist of a tank or pit called a digester and an airtight container whose function is to store the biogas produced.

Figure 17. Digestion process. Biodigesters



Source: SIEE-OLADE

7.4.6. Other Biomass Processing Centers

This category can include other facilities where plant or animal matter is processed for energy production, such as biodigesters used to obtain biogas from livestock manure, or municipal waste.

Infrastructure variables

- Name of the plant
- Location
- Operating company
- Biogas production capacity (m^3/d)

CHAPTER VIII

National Variables

8. National Variables

These are all economic, social, demographic, and energy variables that, when combined with energy flow variables, are useful for conducting a comprehensive analysis of a country's energy sector. Combinations of energy supply and demand variables and national variables are known as energy indicators.

8.1. NATIONAL POWER SECTOR VARIABLES

a) Installed power generation capacity: the sum of the rated capacities of all public power plants and large self-producers in the country. A large self-producer is an establishment that has an installed capacity of over one MW of power.

b) Electricity coverage: the percentage of households that have electricity, compared to the total number of households in the country.

Obtained by dividing the total observed units served by the total observed units in the country:

$$IC_j = 100 * \frac{j_{EE}}{j_T}$$

Where:
ICj Coverage ratio with reference to observed unit *j*
j Observed unit: dwellings, households or individuals
j_{EE} Total number of observed units
j_T Number of observed units with electricity

Coverage ratio with reference to observed unit j
Observed unit: dwellings, households or individuals
Number of observed units with electric utilities
Total number of observed units

Calculating the electricity coverage rate, then, depends on knowing the variables needed to obtain it, i.e., the information unit to be used as a reference, whether dwellings, households, customers, or individuals. All cases except for customers use surveys or censuses that collect the two parameters of the indicator in the same process. In the case of customers, this number should be provided by electric distribution companies or regulatory bodies having information with sufficient coverage and consistency, although a doubt remains as to the appropriate universe for calculating the indicator. Consider an estimate of potential customers added to existing customers or applying a correction factor to the number of dwellings to account for the fact that the number of customers is not equal to the number of electrified households.

According to OLADE's studies and estimates, this indicator was obtained by using variables such as total population, dwelling size, total number of occupied dwellings, and number of occupied dwellings that are electrified. Inter-census results were estimated using interpolation or extrapolation methods, considering that demographic variables such as population, housing, number of individuals per household and electrified homes fit asymptotic distributions, while the coverage ratio is adjusted to a logistic distribution.

c) Maximum power demand: the peak value recorded in the national load dispatch curve during the statistical period under study.

8.2. HYDROCARBONS INDUSTRY VARIABLES

a) Crude oil production capacity: the sum of all maximum petroleum production capacities for the country's oil fields, expressed in thousands of barrels per day.
b) Natural gas liquids production capacity: the sum of the maximum natural gas liquids production capacities for the country's oil and gas fields, expressed in thousands of barrels per day.
c) Natural gas production capacity: the sum of all associated and non-associated naturally gas production capacities for the country's oil and gas fields, expressed in millions of cubic meters per day.
d) Crude oil refining capacity: the sum of all crude oil capacities to feed into the country's processing refineries, expressed in thousands of barrels per day.
e) Natural gas processing capacity: the sum of all capacities to feed natural gas into gas treatment centers, expressed in millions of cubic meters.

8.3. COAL INDUSTRY VARIABLES

a) Coal production capacity: the sum of the production capacities of all coal mines in the country, expressed in tons per day.
b) Metallurgic coke production: the sum of all production capacities of the country's coking plants, which are usually installed in metal and steel industries.

8.4. RENEWABLE ENERGY SECTOR VARIABLES

a) Ethanol production capacity: the sum of all ethanol production capacities for energy use in the country's distilleries, expressed in thousands of liters.
b) Biodiesel production capacity: the sum of the production capacities of the country's biodiesel plants, expressed in thousands of liters.
c) Area of sugar cane crops: the total area planted with sugar cane in the country, expressed in hectares.
d) Annual sugarcane production: total annual sugarcane production in thousands of tons.
e) Oilseed crop area: the total area planted with oleaginous plants in the country, expressed in hectares.

8.5. ECONOMIC VARIABLES

a) Total GDP at constant prices (Base Year): the country's gross domestic product recorded in dollars at Base Year.
b) Primary GDP at constant prices (Base Year): the GDP of the primary economic sectors, such as agriculture, livestock, fisheries, and forestry, recorded in dollars at Base Year.
c) Secondary GDP at constant prices (Base Year): the industrial GDP, expressed in dollars at Base Year.
d) Tertiary GDP at constant prices (Base Year): the GDP of the commercial and services sectors, expressed in dollars at Base Year.
e) Minimum living wage: the minimum wage that a full-time worker can receive in the country, expressed in current dollars.

8.6. DEMOGRAPHIC VARIABLES

a) Total population: the number of inhabitants in the country, which can be projected from the last population and housing census conducted by the country, expressed in thousands of inhabitants.
b) Urban population: the number of people living in cities and other urban centers, expressed in thousands of inhabitants.
c) Rural population: the number of people living in the countryside, on plantations, farms and fields outside the city limits, expressed in thousands of inhabitants.
d) Economically Active Population (PEA): the population that performs or could perform paid or productive activities within the country, expressed in thousands of inhabitants.

CHAPTER IX

Environmental Impacts

9. Environmental Impacts

Energy production, processing and consumption are major sources of air pollution, and understanding and controlling them is a permanent commitment of the countries as a fundamental part of energy sector decision-making and planning.

SIEE as integrated system that provide important information on the energy sectors of OLADE member countries, also quantify pollutant emissions from energy production, processing and consumption.

To ensure the standardization and comparability of information presented in SIEE the procedure described below uses the methodologies proposed by the Intergovernmental Panel on Climate Change IPCC.

9.1. INTRODUCTION

The Greenhouse Gas (GHG) inventory accounts for gaseous and particulate emissions from human activities that increase the concentration of gases in the atmosphere above levels that occur naturally. Greenhouse gases are CO_2, CO, SO_x, NO_x and CH_4, and their ultimate effect would be global warming, causing changes in weather, rain and wind patterns and increasing sea levels, which would cause unpredictable disasters.

Detailed Greenhouse Gas (GHG) inventories identify the main causes of these emissions, their historical evolution and possible increase or future behavior, and facilitate the selection of alternatives for their control or mitigation.

The methodology for calculating GHG inventories caused by the energy sector is based on detailed knowledge of the amounts the different energy sources that are produced, transformed and consumed in the countries, based on information contained in energy balances.

From the energy balances and a general knowledge of the technical characteristics of the equipment used in energy production, processing and consumption activities, a set of emission factors for each pollutant, source of energy and activity is used to indicate the amount of pollutant emitted per unit of energy produced, processed or consumed.

Inventories are calculated using two methods to check the consistency of the results: The first is called the Reference Method and it is used only to estimate carbon dioxide emissions at an aggregate level. The second, called the Activities Method, yields emissions of other greenhouse gases in addition to CO_2.

9.2. CO_2 EMISSIONS BY THE REFERENCE METHOD

CO_2 emissions from combustion of fossil fuels, unlike other greenhouse gases, can be calculated with an acceptable degree of accuracy by calculating the amount of carbon in the fuels, while the volume of the remaining emissions depends on the technologies and combustion conditions.

The largest source of CO_2 emissions in the Energy Sector is the oxidation of carbon that occurs during the combustion of fossil fuels and represents 70% to 90% of total anthropogenic emissions.

Most of the carbon contained in fossil fuels is emitted into the atmosphere as CO_2 during combustion. The rest is emitted in the form of carbon monoxide (CO), methane (CH_4) and other hydrocarbons; within a few days or up to 10 or 11 years, the compounds are oxidized in the atmosphere to become CO_2.

For estimating CO_2 emissions associated with energy activities, the IPCC proposes a referential or *top-down* method. It consists of counting the amount of carbon contained in fossil fuels used in a country and assuming that CO_2 emissions depend primarily on the features of the fuel and not of the technologies using them, as in the case of other gases.

The calculation of CO_2 emissions from the combustion of fossil fuels is directly related to two factors: the amount of fuel consumed and the carbon content of each fuel. However, it is necessary to consider the following additional factors:

a) Common energy units: There is considerable variation in the energy content per unit of weight or volume of some fuels, especially coal. Therefore, energy data must first be expressed in a common energy unit before emission factors are applied. When estimating CO_2 emissions from energy balances, the problem of energy units is avoided because the balances are expressed in a common energy unit using conversion factors that are based on the caloric value of the fuels.
b) Changes in carbon content: For a given fuel, the amount of carbon per unit of useful energy can vary significantly, as in the case of coal, where the proportion of carbon depends on the type of fuel (anthracite, bituminous coal, lignite). Based on the sources of energy defined in the energy balance, the carbon content of fossil fuels and their derivatives must be known.
c) Unoxidized carbon: Not all carbon is oxidized to CO_2 in the process of fuel combustion. Incomplete oxidation occurs due to inefficiencies in the combustion, which determines that a part of the carbon does not burn.
d) Stored carbon: Not all fuels are consumed for energy purposes. Some of them are used as raw material in certain production processes or for other purposes, such as construction material or lubricants. In some cases (fertilizers), the carbon contained in the fuel is oxidized to CO_2 fairly rapidly when the product comes into contact with air. In other cases, the carbon is stored or sequestered in the product for long periods of time. This is called stored carbon, which should be deducted from the total carbon amounts contained in the fuels that are consumed.
e) Bunker: This category involves fuel used for international shipping and aircraft, so it is assumed that this consumption does not occur within the national territory, and therefore should not be taken into account in estimating GHG inventories.
f) Biomass: should not be included in CO_2 emissions because it is assumed that biomass is reproduced at the same rate as it is consumed, therefore the net flow of CO_2 is zero. However, IPCC recommends that it should be accounted for and presented separately from the inventories.

Thus, CO_2 emissions can be estimated by determining the carbon content of fossil fuels that can be effectively emitted as CO_2 through the combustion of an energy source. That amount of carbon is calculated by the following expression:

$$\text{C emitted as } CO_2 = \text{C content - unoxidized C – stored C}$$

To convert the amount of carbon (C) emitted into CO_2 emitted, it is multiplied by 44/12, which corresponds to the molecular weight ratio of CO_2 and C. Thus:

$$CO_2 \text{ emitted} = (\text{C Content - unoxidized C - stored C}) * 44/12$$

This expression should be applied to fossil fuel volumes that are actually consumed in the country, that is, quantities exported or stored should not be taken into account. The concept of Apparent Consumption arises from this.

9.2.1. Apparent Consumption

The reference method for estimating CO_2 emissions is based on the concept of apparent fuel consumption. This refers to a balance of primary energy produced in a country, plus imports of primary and secondary energy, minus exports, minus bunker and changes in inventories. Thus, carbon is 'transferred' to the country through production and energy imports (adjusted for changes in inventories), and transferred out of the country through exports and international bunker. The calculation of the apparent fuel consumption is defined by the following expression:

$$CA = PP – RI + IM - EX - BK – NA + VI + TR$$

Where:

PP = Production of primary energy
RI = Reinjection (if production in the case of hydrocarbons is wellhead)
IM = Import of primary and secondary energies
EX = Export of primary and secondary energies
BK = Bunker
NA = Unused
VI = Change in inventories (positive or negative)
TR = Transfers (positive or negative)

Secondary energy production is not taken into account, since the carbon contained in those energy sources is already reported in the primary energy from which they were obtained.

In some cases, the apparent consumption of secondary energy can result in negative values. This result is perfectly acceptable for computing CO_2 emissions, since it indicates a net export because domestic production is not counted.

9.2.2. CO_2 Emission Factors

The carbon content of a fossil fuel varies depending on its physical and chemical properties. In the case of natural gas, the emission factor depends on the composition of the gas, which may also include small quantities of ethane, propane, butane and heavy hydrocarbons in addition to methane. Emission factors will vary according to the proportion of each of these gases in the total mixture. For petroleum, the API grade is an indicator of the carbon/hydrogen ratio. The carbon content per unit of energy is lower for light products such as gasoline and higher for heavy products such as fuel oil. CO_2 emissions vary considerably in the case of coal, and depend on its hydrogen, sulfur, oxygen, nitrogen and ash content.

While emissions vary widely in terms of emissions per unit of mass, emissions per unit of energy are much lower. Lower quality products such as lignite or bituminous coal contain more carbon than other types of high-quality coal. Anthracite is an exception, as it generally has a higher carbon content than bituminous coal. If actual values of the carbon content of fuels are unavailable, it is suggested that the default values proposed by the IPCC methodology be used. These factors allow emissions to be estimated at an acceptable level of accuracy. However, each country should obtain their actual values from reports on the physical-chemical characteristics of fuels produced by refineries and from imports of coal, petroleum, natural gas and derivatives. The factors proposed by IPCC are presented in Table 5.

Table 5. CO_2 Emission Factors

Energy source	Emission factor (tons of carbon/TJ)
Oil	20.0
Gasoline	18.9
Kerosene	19.5
Diesel	20.2
Fuel Oil	21.1
LPG	17.2
Gases	15.3
Non energy sources	20.0
Coal	26.8
Coke	29.5
Natural gas	15.3

Source: IPCC

The basic procedure for estimating total carbon content is to multiply the apparent consumption of fossil fuels by the corresponding carbon emission factors:

Content of C = Apparent Consumption x Emission Factor C

9.2.3. Oxidized Carbon Fraction

As noted above, not all the carbon in fuels is oxidized during combustion. The amount of carbon that will not oxidize represents a small fraction of the total and it is assumed that this fraction remains stored indefinitely. The following default values are suggested by IPCC to calculate the carbon that is oxidized:

- For natural gas, more than 99% of the carbon content is oxidized during combustion.
- For petroleum and its derivatives, 1% to 1.5% is not oxidized, but is released to the environment as particulates or hydrocarbons.
- For coal, about 1% of the carbon content is stored in the form of ash.

The fractions of oxidized carbon suggested by the IPCC methodology are summarized in Table 6.

Table 6. Oxidized Carbon Fractions

Energy source	Oxidized carbon fraction
Petroleum	0.99
Gasoline	0.99
Kerosene	0.99
Diesel	0.99
Fuel Oil	0.99
LPG	0.99
Gases	0.99
Non-energy sources	
Coal	0.98
Coke	0.98
Natural Gas	0.995

Source: IPCC

9.2.4. Stored Carbon Volumes

The estimation of CO_2 emissions requires a determination of the amount of carbon that is stored (or sequestered) in non-energy sources as well as the non-energy use of fuels and their derivatives. The OLADE energy balance contains information broken down as non-energy sources originating from in energy transformation processes as well as energy sources consumed as raw materials in other production processes.

However, not all of the carbon contained in non-energy sources and fuels used for non-energy purposes remains stored indefinitely. A fraction of this carbon undergoes an oxidation process in a relatively short period of time. Based on the indications of the IPCC methodology, the following fractions of stored carbon are suggested for calculating actual CO_2 emissions (Table 7).

Table 7. Volume of carbon stored

Product	Fraction of stored carbon
Petroleum	1
Naphtha	0.8
Bitumen	1
Kerosene	0.8
Diesel	0.5
LPG	0.8
Natural gas	0.33
Other energy sources	1
Coke and coking products	0.75
Non-energy sources	0.625

Source: IPCC

The total amount of stored carbon (CAL) is calculated from the following relationship:

$$CAL = CNE \times FE \times FA$$

Where:

CNE = Non-energy consumption (TJ)
FE = Emission factor of the source (tC/TJ)
FA = Fraction of carbon stored

The complete formula for calculating total CO_2 emissions for each fuel is as follows:

$$CO_2 = FE*(CA*FO - CNE*FA)*(44/12)/1000$$

Where:

CO_2 = Amount of CO_2 emitted into the atmosphere in Gg (Gigagrams)
FE = Carbon emission factor (tC/TJ)
CA = Apparent fuel consumption (TJ)
FO = Fraction of oxidized carbon
CNE = Non-energy fuel consumption
FA = Fraction of carbon stored

9.2.5. Emissions from Biomass Consumption

The carbon content of firewood has been estimated at 45% to 50% while for vegetable waste these values range from 40% to 48%. The IPCC methodology recommends a figure of 29.9 tons of carbon per terajoule. For bagasse, a factor of 29.5 tons per terajoule is suggested.

The IPCC methodology recommends a value of 87% for the fraction of oxidized carbon, while some authors consider this fraction to be in a range of 60% to 80%. The OLADE methodology suggests an average value of 70%.

9.3. ACTIVITIES AND TECHNOLOGIES METHOD

This method involves estimating emissions of CO_2 and other gases (carbon monoxide, nitrogen oxides, hydrocarbons, sulfur oxides and particulate matter) according to the activity and technology with which energy is utilized. The aim is to quantify emissions that occur along the energy chains starting with primary energy use, passing through transformation processes, losses during transportation and distribution, until the final utilization of the energy.

Gas emissions are calculated using the expression:

$$Emissions = \sum (EF_{iJ} * Activity)$$

Where:

EF = emission factor Activity
Activity= energy consumption or production
i = type of fuel
j = sector or activity
k = type of technology

In addition to fuel characteristics, gas emissions other than carbon dioxide depend on the type of technology used for energy transformation and consumption. For example, nitrogen oxide emissions from natural gas-based thermal generation will be different from those of a steam turbine or a combined cycle process.

The following observations are necessary for an understanding of the scope of emissions estimation based on energy balances:

- In some cases, emission factors relate to levels of energy input for a specific use or activity (emissions per unit of diesel consumption in industry, emissions per unit of consumption of fuel oil for power generation, etc.). In other cases emissions relate to the amount of energy produced or processed (emissions per barrel of petroleum produced, emissions per ton of coke produced).
- The activity sectors used for calculating emissions correspond to the activity sectors identified in the energy balance, which result in gas and particulate emissions.
- In terms of technologies, the emission factors for each technology used in each activity should be identified, and the emission factor should be calculated as a weighted average of the amount of fuel produced or consumed with each technology. OLADE has selected emission factors of standard technologies for generic energy uses based on the corresponding methodology definitions used for preparing energy balances. These emission factors for each technology are presented in Annex III.

9.3.1. Information Sources

The selection of emission factors uses the following procedure:

a) A list of the most relevant technologies for Latin America and the Caribbean has been selected for each activity and fuel. The following databases were consulted:
   - Rapid Assessment of Sources of Air, Water, and Land Pollution"; World Health Organization, 1982.
   - Environmental Database - EDB; Stockholm Environment Institute, Boston Center- SEI-B. This database is part of the LEAP energy-planning model developed by SEI-B.
   - The IIASA CO_2 Technology Data Bank – CO_2DB; International Institute for Applied Systems Analysis; Laxenburg, Austria.
   - The Environmental Manual – EM; Oeko Institute – GTZ – The World Bank; Berlin, Germany.
   - Greenhouse Gas Inventory, The Reference Manual; Intergovernmental Panel on Climate Change – IPCC.

   For each activity and fuel, a representative technology was selected from this list and its emission coefficients should be used for calculating the emissions.

b) The emission coefficients have been converted to a common unit, kilograms per terajoule, based on the conversion factors used in SIEE.

Annex III presents a brief description of the selected technologies. For each technology the source of the information and the fuel associated with the technology are indicated.

9.3.2. Emission Factors

The emission factors for the energy flows defined in the energy balance are shown in Tables 19-24. The format of the factors tables correlates exactly to the SIEE balance format, so that the emissions of each energy activity are obtained by multiplying the figures in the boxes of the balance by the figures in the boxes of the coefficients table.

The following clarifications are needed to understand the scope of calculating emissions based on the energy balance:

a) Emissions from categories that define the energy supply sub-matrix are only for primary fossil fuel production (oil, natural gas and coal). The associated emission coefficients relate to the volume of emissions per unit of energy produced.

b) As for processing centers, in some cases (refineries, coke ovens and gas plants) emissions refer to self-consumption, i.e., the volume of emissions per unit of energy consumed in the transformation process. For each of these processes, the same coefficients as for industrial uses are assumed. Each country should obtain its own emission factors for transformation centers based on environmental impact studies or environmental audits, whether existing or to be conducted. If these data are not available, we suggest using the figures proposed by OLADE.

c) In the case of coal ovens and distilleries, the emission factors refer to the amounts of energy produced by these processing centers.

d) For other transformation centers, assume the emission factors used for those in which products are commonly obtained: refineries for hydrocarbons and coking ovens for coke.

e) The carbon dioxide emission factors for non-energy uses have been obtained using the IPCC methodology, as shown in Table 8.

Table 8. CO_2 emissions coefficients for non-energy uses

Energy product	Apparent emission coefficient (ton C/TJ)	Stored Carbon Fraction (%)	Oxidized Carbon Fraction (%)	Emission coefficient (ton CO_2/TJ)
Oil	20.0	0.50	0.99	36,300
Natural gas	15.3	0.33	0.995	37,399
Coal	26.8	0.75	0.98	24,075
Bagasse	29.0	1.00		
LPG	17.2	0.80	0.99	12,487
Gasoline/naphtha	20.0	0.80	0.99	14,520
Kerosene	19.5	0.80	0.99	14,157
Diesel	20.2	0.50	0.99	36,663
Fuel oil	21.1	0.50	0.99	38,115
Coke	29.5	0.75	0.98	26,501
Charcoal	29.0	0.70	1.00	8,700
Gases	15.3	0.33	0.995	37,399

Source: IPCC

To separate fossil fuel emissions from those for biomass, the emissions from distilleries and alcohol use are placed in the Sugarcane Products column.

Table 9. Emission Factors Carbon Dioxide (CO_2)

	kg/TJ	Primary energy sources													Secondary energy sources																	
		Primary hydrocarbons			Mineral sources		Direct energy				Biomass					Crude oil and natural gas products								Mineral sources products			Biomass products					
		Crude oil	Natural gas liquids	Natural gas	Coal	Nuclear	Hydroenergy	Geothermal	Wind	Solar	Firewood	Sugarcane products	Other biomass	Other primary sources	Electricity	LPG	Gasoline	Kerosene & Jet fuel	Diesel oil	Fuel oil	Refinery gas	Coke of petroleum	Other oil and gas products	Coke of coal	Industrial gas	Other coal products	Charcoal	Ethanol	Biodiesel	Biogas	Other secondary sources	Non energy
1	Primary Production	612		3.084	6																											
2	Reinjection or Recirculation GN																															
3	Import																															
4	Export																															
5	Change In Inventory																															
6	Unused																															
7	TRANSFERS																															
8	Bunkers																															
9	TOTAL SUPPLY																															
10	Refinery																															
11	Centers Gas																															
12	Power Plants	78.382		49.680	94.320			10.806			53.063	97.123		46.408		66.928	47.550	72.350	69.957	74.142	49.680	108.544					96.240					
13	Self-producers	78.382		53.314	91.245			10.806			53.063	97.123		46.408		66.366	47.550	71.881	69.025	75.886	53.314	108.544					96.240					
14	Coking Plant																															
15	Blast Furnace																															
16	Coal Mine																										49.850					
17	Ethanol distilleries																											26.930				
18	Biodiesel plants																															
19	Other Transformations																															
20	TOTAL TRANSFORMATION																															
21	Transport			63.517	91.245						92.893	41.937				67.674	72.864	73.731	76.651	75.886	63.517											36.300
22	Industry	76.385		49.721	94.428						92.893	97.123		46.408		67.674	47.550	69.229	69.925	74.134	49.721	108.544					96.240					27.500
23	Residential			53.314	87.186						92.893			80.949		67.674	50.307	69.975	75.497	76.385	53.314						96.240					
24	Commercial, services & public	76.385		53.314	87.186						92.893			46.408		67.674	47.550	69.975	75.016	75.886	53.314						96.240					
25	Farming, forestry & fishing	76.385		49.721	94.425						92.893	97.123		46.408		67.674	47.550	69.975	76.651	74.134	49.721	108.544					96.240					
26	Mining	76.385		49.721	94.425						92.893	97.123		46.408		67.674	47.550	69.975	76.651	74.134	49.721	108.544					96.240					
27	Construction and Other	76.385		63.517	91.245						92.893					67.674	72.864	69.229	76.651	75.886							96.240					17.967
28	ENERGY CONSUMPTION																															
29	Non Energy	36.300		37.399	24.075											12.487	14.520	14.157	36.663	38.115	37.399	26.501					8.700					33.250
30	FINAL CONSUMPTION																															
31	Own Consumption	76.385		49.721	94.425											67.269	47.550	69.229	69.965	74.134	49.721	90.629										
32	Losses																															
33	ADJUSTMENT																															

Source: SIEE-OLADE

Table 10. Emission Factors Monoxide Carbon (CO)

	kg/TJ	Primary energy sources													Secondary energy sources																	
		Primary hydrocarbons			Mineral sources		Direct energy				Biomass						Crude oil and natural gas products								Mineral sources products			Biomass products				
		Crude oil	Natural gas liquids	Natural gas	Coal	Nuclear	Hydroenergy	Geothermal	Wind	Solar	Firewood	Sugarcane products	Other biomass	Other primary sources	Electricity	LPG	Gasoline	Kerosene & Jet fuel	Diesel oil	Fuel oil	Refinery gas	Coke of petroleum	Other oil and gas products	Coke of coal	Industrial gas	Other coal products	Charcoal	Ethanol	Biodiesel	Biogas	Other secondary sources	Non energy
1	Primary Production	0,50		2	0																											
2	Reinjection or Recirculation GN																															
3	Import																															
4	Export																															
5	Change In Inventory																															
6	Unused																															
7	TRANSFERS																															
8	Bunkers																															
9	TOTAL SUPPLY																															
10	Refinery																															
11	Centers Gas																															
12	Power Plants	53		114	52						1.559	131		628		16	14.656	53	161	163	114	11					9.139				114	
13	Self-producers	53		197	86						1.559	131		628		646	14.656	354	226	322	197	11					9.139				197	
14	Coking Plant																															
15	Blast Furnace																															
16	Coal Mine																										5.585					
17	Ethanol distilleries																															
18	Biodiesel plants																															
19	Other Transformations																															
20	TOTAL TRANSFORMATION																															
21	Transport			143	86						173	6.418				1.523	7.410	122	524	349	143										143	
22	Industry	15		63	86						173	131		628		17	14.656	51	67	68	63	11					9.139				63	
23	Residential			281	3.583						8.029			7.299		65	12.887	134	18	17	281						9.139				281	
24	Commercial, services & public	15		281	3.583						819			628		9	14.656	134	337	322	281						9.139				281	
25	Farming, forestry & fishing	15		63	86						1.504	131		628		9	14.656	134	611	68	63	11					9.139				63	
26	Mining	15		63	86						1.504	131		628		9	14.656	134	611	68	63	11					9.139				63	
27	Construction and Other	15		143	86						173			628		1.523	7.410	51	524	349							9.139					
28	ENERGY CONSUMPTION																															
29	Non Energy																															
30	FINAL CONSUMPTION																															
31	Own Consumption	15		63	86											17	14.656	51	67	68	63	195									63	
32	Losses																															
33	ADJUSTMENT																															

Source: SIEE-OLADE

Table 11. Emission Factors Nitrogen Oxides (NOx)

	kg/TJ	Primary energy sources													Secondary energy sources																	
		Primary hydrocarbons			Mineral sources		Direct energy				Biomass					Crude oil and natural gas products								Mineral sources products			Biomass products					
		Crude oil	Natural gas liquids	Natural gas	Coal	Nuclear	Hydroenergy	Geothermal	Wind	Solar	Firewood	Sugarcane products	Other biomass	Other primary sources	Electricity	LPG	Gasoline	Kerosene & Jet fuel	Diesel oil	Fuel oil	Refinery gas	Coke of petroleum	Other oil and gas products	Coke of coal	Industrial gas	Other coal products	Charcoal	Ethanol	Biodiesel	Biogas	Other secondary sources	Non energy
1	Primary Production	17		78	3																											
2	Reinjection or Recirculation GN																															
3	Import																															
4	Export																															
5	Change In Inventory																															
6	Unused																															
7	TRANSFERS																															
8	Bunkers																															
9	TOTAL SUPPLY																															
10	Refinery																															
11	Centers Gas																															
12	Power Plants	233		265	414						119	79		32		66	379	234	322	327	265	246									265	
13	Self-producers	233		1.568	345						119	79		32		695	379	1.625	1.206	1.478	1.568	246									1.568	
14	Coking Plant																															
15	Blast Furnace																															
16	Coal Mine																										415					
17	Ethanol distilleries																											116				
18	Biodiesel plants																															
19	Other Transformations																															
20	TOTAL TRANSFORMATION																															
21	Transport			238	345						104	99				399	390	293	1.031	901	238										238	
22	Industry	166		126	274						104	79		32		66	379	224	188	191	126	246									126	
23	Residential			11	178						53			32		83	255	3	65	178	11										11	
24	Commercial, services & public	166		11	178						62			32		45	379	3	1.553	1.478	11										11	
25	Farming, forestry & fishing	166		126	274						115	79		32		45	379	3	1.527	191	126	246									126	
26	Mining	166		126	274						115	79		32		45	379	3	1.527	191	126	246									126	
27	Construction and Other	166		238	345						104			32		399	390	224	1.031	901												
28	ENERGY CONSUMPTION																															
29	Non Energy																															
30	FINAL CONSUMPTION																															
31	Own Consumption	166		126	274											66	379	224	188	191		488										
32	Losses																															
33	ADJUSTMENT																															

Source: SIEE-OLADE

Table 12. Hydrocarbon Emission Factors

	kg/TJ	Primary energy sources													Secondary energy sources																	
		Primary hydrocarbons			Mineral sources		Direct energy				Biomass					Crude oil and natural gas products								Mineral sources products			Biomass products					
		Crude oil	Natural gas liquids	Natural gas	Coal	Nuclear	Hydroenergy	Geothermal	Wind	Solar	Firewood	Sugarcane products	Other biomass	Other primary sources	Electricity	LPG	Gasoline	Kerosene & Jet fuel	Diesel oil	Fuel oil	Refinery gas	Coke of petroleum	Other oil and gas products	Coke of coal	Industrial gas	Other coal products	Charcoal	Ethanol	Biodiesel	Biogas	Other secondary sources	Non energy
1	Primary Production	1		1	2																											
2	Reinjection or Recirculation GN																															
3	Import																															
4	Export																															
5	Change In Inventory																															
6	Unused																															
7	TRANSFERS																															
8	Bunkers																															
9	TOTAL SUPPLY																															
10	Refinery																															
11	Centers Gas																															
12	Power Plants	16,40		5	2			500			131			5		1	554	17	4	4	5	1									5	
13	Self-producers	16,40		38	3			500			131					415	554	111	5	101	38	1									38	
14	Coking Plant																															
15	Blast Furnace																															
16	Coal Mine																															
17	Ethanol distilleries																											287				
18	Biodiesel plants																															
19	Other Transformations																															
20	TOTAL TRANSFORMATION																															
21	Transport			335	3						35	11				34	32	2	6	22	335										335	
22	Industry	3		5	259						35	131		5		1	554	16	3	3	5	1									5	
23	Residential			6	1						259			5		12	783	13	3	1	6										6	
24	Commercial, services & public	3		6	1						8			5		4	554	13	106	101	6										6	
25	Farming, forestry & fishing	3		5	259						15	131		5		4	554	13	11	3	5	1									5	
26	Mining	3		5	259						15	131		5		4	554	13	11	3	5	1									5	
27	Construction and Other	3		335	3						35			5		34	32	16	6	22												
28	ENERGY CONSUMPTION																															
29	Non Energy																															
30	FINAL CONSUMPTION																															
31	Own Consumption	3		5	259											1	554	16	3	3		1										
32	Losses	1.658		18.530													1.658	1.658	1.658	1.658	18.530										18.530	
33	ADJUSTMENT																															

Source: SIEE-OLADE

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Table 13.
Sulfur Dioxide (SO_2) Emission Factors

	kg/TJ	Primary energy sources												
		Primary hydrocarbons			Mineral sources		Direct energy				Biomass			
		Crude oil	Natural gas liquids	Natural gas	Coal	Nuclear	Hydroenergy	Geothermal	Wind	Solar	Firewood	Sugarcane products	Other biomass	Other primary sources
1	Primary Production	1		132	2									
2	Reinjection or Recirculation GN													
3	Import													
4	Export													
5	Change In Inventory													
6	Unused													
7	TRANSFERS													
8	Bunkers													
9	TOTAL SUPPLY													
10	Refinery													
11	Centers Gas													
12	Power Plants	482		0,40	730			53						
13	Self-producers	482		0,40	730			53						
14	Coking Plant													
15	Blast Furnace													
16	Coal Mine													
17	Ethanol distilleries													
18	Biodiesel plants													
19	Other Transformations													
20	TOTAL TRANSFORMATION													
21	Transport			23	730						19			
22	Industry	929		0	692						19			
23	Residential										27			
24	Commercial, services & public	929												
25	Farming, forestry & fishing	929		0	692						19			
26	Mining	929		0	692						19			
27	Construction and Other	929		23	730						19			
28	ENERGY CONSUMPTION													
29	Non Energy													
30	FINAL CONSUMPTION													
31	Own Consumption	929		0	692									
32	Losses													
33	ADJUSTMENT													

	kg/TJ	Secondary energy sources																	
			Crude oil and natural gas products								Mineral sources products			Biomass products					
		Electricity	LPG	Gasoline	Kerosene & Jet fuel	Diesel oil	Fuel oil	Refinery gas	Coke of petroleum	Other oil and gas products	Coke of coal	Industrial gas	Other coal products	Charcoal	Ethanol	Biodiesel	Biogas	Other secondary sources	Non energy
1	Primary Production																		
2	Reinjection or Recirculation GN																		
3	Import																		
4	Export																		
5	Change In Inventory																		
6	Unused																		
7	TRANSFERS																		
8	Bunkers																		
9	TOTAL SUPPLY																		
10	Refinery																		
11	Centers Gas																		
12	Power Plants		431	20	21	221	929	0	685					24				0,40	
13	Self-producers		2	20	21	175	487	0	685					24				0,40	
14	Coking Plant																		
15	Blast Furnace																		
16	Coal Mine																		
17	Ethanol distilleries														151				
18	Biodiesel plants																		
19	Other Transformations																		
20	TOTAL TRANSFORMATION																		
21	Transport							23										23	
22	Industry		433	20	21	221	929	0	685					24				0	
23	Residential			20	221	483								24					
24	Commercial, services & public			20	221	103								24					
25	Farming, forestry & fishing			20	221	103	929		685					24					
26	Mining			20	221	103	929		685					24					
27	Construction and Other				21									24					
28	ENERGY CONSUMPTION																		
29	Non Energy																		
30	FINAL CONSUMPTION																		
31	Own Consumption		433	20	21	221	929	0	0					0				0	
32	Losses																		
33	ADJUSTMENT																		

Source: SIEE-OLADE

Table 14. Particulate Emission Factors

	kg/TJ	Primary energy sources													Secondary energy sources																	
		Primary hydrocarbons			Mineral sources		Direct energy				Biomass					Crude oil and natural gas products								Mineral sources products			Biomass products					
		Crude oil	Natural gas liquids	Natural gas	Coal	Nuclear	Hydroenergy	Geothermal	Wind	Solar	Firewood	Sugarcane products	Other biomass	Other primary sources	Electricity	LPG	Gasoline	Kerosene & Jet fuel	Diesel oil	Fuel oil	Refinery gas	Coke of petroleum	Other oil and gas products	Coke of coal	Industrial gas	Other coal products	Charcoal	Ethanol	Biodiesel	Biogas	Other secondary sources	Non energy
1	Primary Production	3		2	2																											
2	Reinjection or Recirculation GN																															
3	Import																															
4	Export																															
5	Change In Inventory																															
6	Unused																															
7	TRANSFERS																															
8	Bunkers																															
9	TOTAL SUPPLY																															
10	Refinery																															
11	Centers Gas																															
12	Power Plants	17										1.050				1	24	17	7	41		123					83					
13	Self-producers	17		5								1.050				25	24	116	111	106	5	123					83				5	
14	Coking Plant																															
15	Blast Furnace																															
16	Coal Mine																										7.512					
17	Ethanol distilleries																											43				
18	Biodiesel plants																															
19	Other Transformations																															
20	TOTAL TRANSFORMATION																															
21	Transport			8																	8										8	
22	Industry											1.050				1	24	17				123					83					
23	Residential			1							756			2.322			23	117	9		1						83				1	
24	Commercial, services & public			1												1	24	117	111								83					
25	Farming, forestry & fishing											1.050				1	24	117				123					83					
26	Mining											1.050				1	24	117				123					83					
27	Construction and Other															8		17									83					
28	ENERGY CONSUMPTION																															
29	Non Energy																															
30	FINAL CONSUMPTION																															
31	Own Consumption															1	24	17														
32	Losses																															
33	ADJUSTMENT																															

Source: SIEE-OLADE

CHAPTER X

Indicators

10. Indicators

Indicators are metrics that usually comprise more than one basic variable to characterize an event through simple mathematical formulations. They expand the meaning of the component variables and make it easier to understand the causes, behavior and outcomes of an activity.

10.1. ENERGY SECTOR INDICATORS

The work done by OLADE and other agencies on this topic supports the United Nations proposals regarding the type of indicators to be developed, which in addition to energy, include social, economic and environmental dimensions.

The social dimension reflects the people's need for access to basic energy services in the form of commercial energy at affordable rates. Many social welfare parameters are related to energy use.

The economic dimension reflects the need for sufficient, reliable energy for all production activities. The availability and reliability of energy services is essential to ensure economic development. All economic sectors depend on secure, sufficient, efficient energy services. The availability of jobs, industrial productivity, urban and rural development, and all important economic activities are affected largely by energy availability. Electricity is an important and sometimes irreplaceable input for modern production activities, communication, dissemination of information, and other service industries. Energy services help economic development at the national level and help generate revenues, while interruption of energy supplies can lead to financial and economic losses. To support the goals of sustainable development, energy must always be available in sufficient quantities and at appropriate prices.

The environmental dimension includes the need to protect the environment without reducing the levels of other dimensions. Energy production and consumption are important factors that affect health and the environment. The environmental consequences of energy use can be seen at all levels wherever energy is produced and consumed. The health effects of air and water pollution and land degradation are some of the negative consequences.

Considering the social, economic, environmental and energy information to be input in the SIEE and its importance in assessing energy sector development, the following indicators are proposed as a minimum for consideration by all countries:

10.2. Classification of the Basic SIEE Indicators

- **General Indicator**
  - Growth rate (applicable to any variable or indicator)

- **Socio-Economic Indicators**
  - GDP per capita
  - Urban population to total population (%)
  - Economically active population to total population (%)
  - Sectoral makeup of the GDP (%)

- **Economic Energy Indicators**
  - Aggregate energy intensity
  - Energy intensity by economic sectors
  - Average energy prices to final consumers (US$/Toe)
  - Average price per energy source to final consumers (US$/Toe)

- Energy demand to GDP elasticity
- Energy demand to price elasticity
- Dependence on energy imports for energy consumption (%)

➢ **Per Capita Energy Indicators**
- Total energy consumption per capita (toe/Pop.)
- Per capita electricity consumption (GWh/Pop.)

➢ **Structural Energy Sector Indicators**
- Structure of primary energy production (%)
- Structure of energy consumption by energy source (%)
- Structure of energy consumption by sector (%)
- Structure of electricity generation by energy source (%)
- Structure of electricity consumption by sector (%)

➢ **Environmental Impact Indicators**
- Share of renewable resources in the total energy supply (%)
- Greenhouse gas emissions per capita (Ton/Pop.)
- Total emissions intensity relative to GDP (Ton/US$)
- Emissions per unit of electricity generated (Ton/GWh)

➢ **Energy Efficiency Indicators**
- Energy conversion efficiency (%)
- Power generation efficiency (%)
- Energy facility utilization factor (%)
- Energy transportation and distribution loss factor (%)

➢ **Potential and Reserve Energy Indicators**
- Percentage of unused exploitable hydroelectric potential (%)
- Scope of proven reserves of fossil resources (years)

10.3. Description and Formulation of Indicators

10.3.1. General Indicator

10.3.1.1. Growth Rate

Description:

It is defined as the percentage variation of a data item relative to an initial value.

Formulation:

The growth rate may be 'specific' when the data from two consecutive periods are compared, or 'average' when calculated using the first and last data items in a series of values.

Calculate the specific growth rate:

$$Tc = \frac{V_i - V_{i-1}}{V_{i-1}} * 100$$

Where:

Tc = growth rate (%)
i = time period
Vi = value of time period i
Vi-1 = value of period i-1

To calculate the average growth rate:

$$\bar{T}c = \left[\left(\frac{V_n}{V_1} \right)^{\frac{1}{n-1}} - 1 \right]$$

Where:

Tc = Average growth rate in the series from of 1 to n (%),
V_n = Value of time period n,
V_1 = File of the first time period in the series

Application: The growth rate is applicable to any periodic variable or indicator.

10.3.2. Socio-Economic Indicators

10.3.2.1. GDP per Capita

Description: It is defined as the ratio of the annual GDP value compared to the total population of the country. The GDP can be calculated at constant values or current values. In the case of constant values, take a basis year for price deflection. This year is usually 1990. Meanwhile, the population of a country in a given year is estimated using the growth rates from the last year in which a national census was taken.

Formulation:

$$PPC_i = \frac{PIB_i}{POB_i} * 100\%$$

Where:

PPC_i = Per capita GDP for year i (US$/Pop.)
PIB_i = GDP for year i (US$)
POB_i = Population in year i (Pop.)

Application:

This is a basic indicator of economic development for a country or region, as it reflects the production of goods and services per unit of population, which can also be seen as the inhabitants' individual contributions to economic development. Although not a direct indicator of sustainable development, it involves important aspects such as consumption patterns of the population and renewable resource use levels.

10.3.2.2. Urban Population to Total Population Ratio

Description: This consists of dividing the number of inhabitants living in cities or areas defined as urban by the total population of the country.

Formulation:

$$PPU_i = \frac{Pu_i}{POB_I} * 100$$

Where:

PPU_i = Percentage of urban population in year i (%)
PU_i = Urban population (Pop.)
POB_I = Total population of the country in year i (Pop.)

Application: This indicator is applicable in socio-economic studies to identify domestic migration from the countryside to urban centers, to analyze causes such as a lack of incentives for the farming sector, a lack of rural development programs, etc., and to anticipate consequences such as increased congestion, pollution and unemployment in urban centers.

10.3.2.3. Economically Active Population to Total Population

Description: This is the fraction of the total population that performs economically productive activities, expressed as a percentage.

Formulation:

$$PPEA_i = \frac{PEA_i}{POB_i} * 100$$

Where:

$PPEA_i$ = Economically active population to total population (%)
PEA_i = Economically active population (Pop.)
POB_i = Total population (Pop.)

Application: This indicator, when applied to a country's socio-economic analyses, can reveal problems such as unemployment, aging population, population explosion, etc. It can also be a measure of the economic capacity to supply goods and services relative to the demand for them.

10.3.2.4. Sectoral Composition of GDP

Description: The percentage share of each of the most representative sectors of the national economy in the total GDP. These sectors usually include: a) industry, b) commercial and services, and c) agriculture. To calculate these share percentages, all variables must be calculated either at constant values for the same reference year, or at current prices.

Formulation:

$$PPIBS_{ij} = \frac{PIB_{ij}}{PIB_i} * 100$$

Where:

$PPIBS_{ij}$ = Percentage of the sector GDP relative to the total GDP (%)
PIB_{ij} = GDP of sector j in year i (US$)
PIB_i = total GDP of year i (US$)

Application: It reveals the size and weight of each of the economic sectors in the country's total output.

10.3.3. Economic Energy Indicators

10.3.3.1. Aggregate Energy Intensity

Description: This is the ratio of energy consumption to the gross domestic product. The GDP can be calculated at constant values with a given base year or at current values. Note that to compare among countries, it is preferable to calculate the GDP at constant values based on a common year. Energy consumption is calculated using the final consumption of primary energy plus the input to processing centers.

Formulation:

$$IE_i = \frac{CE_i}{PIB_i}$$

Where:

IE_i = Aggregate energy intensity in year i (boe/10^3 US$)
CE_i = Total energy consumption in caloric units (10^3 boe)
PIB_i = total GDP (US$ 10^6)

Application: This indicator makes it possible to forecast the environmental and energy impacts that would be caused by economic growth in a country. Although energy is essential to the economic and social development of a country, intensive consumption of fossil fuels also means high levels of air pollution. Therefore, it is necessary to implement energy efficiency programs and try to decouple economic growth from increased energy consumption.

10.3.3.2. Energy Intensity by Economic Sectors

Description: This is the ratio of the energy consumption of an economic sector to the gross domestic product of that sector. The sectoral GDP can be calculated at constant values with a given base year or at current values. Energy consumption is calculated using the final consumption of primary energy in each of the economic sectors plus the final consumption of secondary energy sources including electricity.

Formulation:

$$IE_{ij} = \frac{CE_{ij}}{PIB_{ij}}$$

Where:

IE_{ij} = Energy intensity in year i for sector j (boe/10^3 US$)
CE_{ij} = Energy consumption in sector j expressed in caloric units (10^3 boe)
PIB_{ij} = GDP of sector j (US$ 10^6)

Application: This indicator makes it possible to identify which economic sectors are most energy-intensive and therefore cause the largest environmental impacts. Using the same criteria as in the previous indicator, it is necessary to implement programs and plans to reduce the energy intensity values for each of the economic sectors.

10.3.3.3. Average Energy Price to Final Consumers

Description: This is calculated by dividing total energy sale revenues for each sector and each commercial energy source, by the total caloric units of energy sold. Total revenues do not include those of distribution companies, as this data may be distorted by payment of arrears. Instead, it is calculated by multiplying the average price for the energy source in each consumption sector times the sales volume for that energy source to the sector.

Formulation:

$$\overline{PE_i} = \frac{\sum_{j-1}^{m} \sum_{k-1}^{n} PE_{iik} * V_{ijk}}{\sum_{j-1}^{m} \sum_{k-1}^{n} V_{ijk} * fc_{ijk}}$$

Where:

PE_i = Average energy price for period i (US$/Toe)
PE_{iik} = Price of the energy source in sector j for period i (US$/u.)
fc_{ijk} = Caloric factor for period i in sector j for energy source k (Toe/u.)
V_{ijk} = Volume sold of energy source k in sector j for period i (u.)
m = number of final consumption sectors
n = number of energy sources

Application: The average energy price is often used as a parameter to measure the energy sector's level of development, including efficiency and competitiveness, but given the marked differences between each sub-sector, an individualized analysis by energy source is more reliable. Although the indicator could also reveal socio-economic factors such as the cost of living in the country, this view may be distorted by the influence of political factors such as subsidies or taxes.

10.3.3.4. Average Energy Price per Energy Source

Description: This is a breakdown of the previous indicator, calculated by dividing the total energy sale revenues for each sector and for a given energy source, by the total energy sold for that energy source in caloric units. As with the previous indicator, total revenues are calculated by multiplying the average energy price in each consumption sector times the volume of that energy source sold to the sector.

Formulation:

$$= \frac{\sum_{j-1}^{m} PE_{iik} * V_{ijk}}{\sum_{j-1}^{m} V_{ijk} * fc_{ijk}}$$

Where:

Pe_{ik} = Average energy price source k in period i (US$/Toe)
PE_{iik} = Price of energy source k for sector j in period i (US$/u.)
fc_{ijk} = Caloric factor during period i in sector j for energy source k (Toe/u.)
V_{ijk} = Volume sold of energy source k to sector j in period i (u.)
m = number of end-use sectors

Application: As noted above for the previous indicator, the average energy price can reflect the energy sector's development level, including its efficiency and competitiveness. An individualized energy analysis, as in this case, is a way to assess the performance of each sub-sector.

For example, in the electricity sub-sector, high energy prices can mean intensive use of thermal energy with the resulting environmental impacts, due either to limited water resources or to a lack of investment in such projects.

In the hydrocarbons sub-sector, the indicator can reveal whether the country is a producer or importer of petroleum and its derivatives. However, often the prices in this sub-sector are influenced more by political conditions than by economic considerations.

10.3.3.5. Energy Demand to GDP Elasticity

Description: This is defined as the ratio of the energy demand variation rate to the GDP variation rate.
Formulation: To analyze an interval of two consecutive periods, a simplified equation for energy demand-GDP elasticity is as follows:

$$ED_i = \frac{\frac{D_i}{D_{i-1}} - 1}{\frac{PIB_i}{PIB_{i-1}} - 1}$$

Where:

ED_i = Energy demand - GDP elasticity (dimensionless)
D_i = Energy demand for period i (Toe)
D_{i-1} = Energy demand for period i-1 (Toe)
PIB_i = GDP for period i (US$)
GDP_{i-1} = GDP for period i-1 (US$)

Application: This indicator identifies the energy sector's degree of stability with regard to changes in the country's economic conditions.

A high elasticity index indicates that small variations in national incomes will produce large variations in energy demands, while a low elasticity index indicates that energy demand is a rigid parameter with regard to income variations. As in the case of the energy intensity indicator, a low demand-GDP elasticity index is environmentally friendly.

10.3.3.6. Energy Demand to Price Elasticity

Description: This is defined as the ratio of the energy demand variation rate to the energy price variation rate.

Formulation: To analyze an interval of two consecutive periods, the simplified equation for energy demand to price elasticity is as follows:

$$EDP_i = \frac{\frac{D_i}{D_{i-1}} - 1}{\frac{P_i}{P_{i-1}} - 1}$$

Where:

EDP_i = Energy demand to price elasticity (dimensionless)
D_i = Energy demand for period i (Toe)
D_{i-1} = Energy demand during period i-1 (Toe)
P_i = Average energy price for period i (US$/Toe)
P_{i-1} = Average energy price for period i-1 (US$/Toe).

Application: This indicator measures the sensitivity of energy demand with respect to energy price variations. Although an aggregate analysis may be valid, due to the features of each specific consumption sector and each energy source, an unbundled analysis for each of these items is more appropriate.

Formulation: The formula for a disaggregated analysis of the indicator would be expressed as follows:

$$EDP_{ijk} = \frac{\frac{D_{ijk}}{D_{(i-1)jk}} - 1}{\frac{P_i}{P_{(i-1)_{jk}}} - 1}$$

Where:

EDP_{ijk} = energy demand to price elasticity for period i in consumption sector j for energy source k (dimensionless)
D_{ijk} = Energy demand during period i in consumption sector j for energy source k (Toe)
$D_{(i-1)jk}$ = Energy demand for period i-1 in consumption sector j for energy source k (Toe)
P_{ijk} = Average price of energy source k in consumption sector j for period i (US$/Toe)
$P_{(i-1)jk}$ = Average price of energy source k in consumption sector j for period i-1 (US$/Toe)

In some energy source sub-sectors and energy consumption sectors, although demand is not actually rigid in relation to price variations, especially in the case of increases, its elasticity is manifest with some delays, due primarily to consumers' inability to adopt immediate measures to reduce demand through such measures as energy saving programs, energy substitution, equipment changeovers, etc.

10.3.3.7. Dependence of Energy Consumption on Energy Imports (%)

Description: This is the ratio of net energy import volumes to total domestic energy consumption, expressed as a percentage.

Formulation:

$$DIE_i = \frac{IMP_i - EXP_i}{CE_i} * 100$$

Where:

DIE_i = Energy consumption dependence on energy imports over period i (%)
IMP_i = Total energy import volume for period i (Toe)
EXP_i = Total energy export volume for period i (Toe)
CE_i = Total domestic energy consumption for period i (Toe)

Application: This indicator is used to measure the share of net energy imports in domestic supply.

10.3.4. Per Capita Energy Indicators

10.3.4.1. Total per Capita Energy Consumption

Description: This is the division of the country's total energy consumption by its population.

Formulation:

$$CEPC_i = \frac{CE_i}{POB_i}$$

Where:

$CEPC_i$ = Energy consumption per capita for period i (Toe/Pop.)
CE_i = Total energy consumption in period i (Toe)
POB_i = Population of the country in period i (Pop.)

Application: Traditionally, this indicator has been used as a measure of economic progress by relating energy consumption to the country's level of industrialization and to its inhabitants' quality of life. However, from a sustainable development viewpoint, it can also be taken as a warning parameter regarding the population's pressure on the environment.

10.3.4.2. Per Capita Electricity Consumption

Description:

Obtained by dividing the country's total electricity consumption by the number of inhabitants.

Formulation:

$$CELPC_i = \frac{CEL_i}{POB_i}$$

Where:

$CELPC_i$ = Electricity consumption per capita for period i (kWh/Inhab.)
Cel_i = Total electricity consumption during period i (GWh)
POB_i = Population of the country during period i (10^6 Inhab.)

Application:

Similar to the previous indicator, it is traditionally applied to measure the country's degree of industrial development and its inhabitants' standard of living. However, bear in mind that it is also a measure of the population's pressure on the environment.

10.3.5. Energy Sector Structure Indicators

10.3.5.1. Structure of Primary Energy Production

Description

This consists of determining the percentage share of each primary energy product in the total primary energy production.

Formulation

$$PPEP_{ik} = \frac{PEP_{ik}}{PTEP_i} * 100$$

Where:

$PPEP_{ik}$ = Percentage share of energy product k in primary energy production for period i (%)
PEP_{ik} = Production of primary energy product k during period i (Toe)
$PTEP_i$ = Total production of primary energy during period i (Toe)

Application

This indicator, in conjunction with that of the energy consumption structure, makes it possible to measure the sufficiency level of the energy industry for domestic supply, the import needs and the potential to export primary energy.

10.3.5.2. Structure of Energy Consumption by Energy Product

Description:

This is percentage that represents the final consumption of each energy product, both primary and secondary, in relation to the total final energy consumption.

Formulation

$$PPEC_{ik} = \frac{CEF_{ik}}{CE_i} * 100$$

Where:

$PPEC_{ik}$ = Percentage share of energy product k in primary energy consumption for period i (%)
CEF_{ik} = Final consumption of energy product k during period i (Toe)
CE_i = Total final energy consumption during period i (Toe)

Application

This indicator, in conjunction with that of the energy production structure, measures the sufficiency level of the energy industry for domestic supply, import needs and the potential to export energy. It can also be taken as a reference to project future consumption of each energy product.

10.3.5.3. Structure of Energy Consumption by Sector

Description

The percentage that represents the energy consumption in each final consumption sector in relation to the total final energy consumption.

Formulation

$$PPSC_{ij} = \frac{CES_{ij}}{CE_i} * 100$$

Where:

$PPSC_{ij}$ = Percentage share of consumer sector j in final energy consumption for period i (%)
CES_{ij} = Energy consumption of sector j for period i (Toe)
CE_i = Total final energy consumption during period i (Toe)

Application

Identifies the significance of each final consumption sector in the total energy consumption structure, and can be taken as the degree of responsibility that each consumer sector has for environmental impacts.

10.3.5.4. Structure of Electricity Generation by Energy Product

Description

The percentage that represents the electricity generated by each energy source used as a source for power plants, relative to total electricity generation. As for power plants, both public utilities and self-producers are considered. In the case of thermal biofuel plants, generation per energy source is calculated using the specific consumption data of each plant for each fuel.

Formulation

$$PGEE_{ik} = \frac{GEE_{ik}}{GET_i} * 100$$

Where:

$PGEE_{ik}$ = Percentage share of energy product k in generating electricity for period i (%)
GEE_{ik} = Electricity generation using energy product k during period i (GWh)
GET_i = Total electricity generation during period i (GWh)

Application

This indicator makes it possible to forecast the demand of energy sources for power supply and provides a parameter to measure the use of renewable resources. This indicator, combined with the emission factors, can also give a measure of the electricity sector's environmental impact.

10.3.5.5. Structure of Electricity Consumption by Sector

Description

The percentage that represents electricity consumption by each final use sector in relation to total electricity consumption.

Formulation

$$PCES_{ij} = \frac{CES_{ij}}{CET_i} * 100$$

Where:

$PCES_{ij}$ = Percentage share of sector j in total electricity consumption during period i (%)
CES_{ij} = Electricity consumption of sector j during period i (GWh)
CET_i = Total electricity consumption during period i (GWh)

Application

This indicator measures the weight of each final consumption sector in the power industry and makes it possible to project future consumption per sector. In combination with other environmental indicators, it can define the degree of each end-use sector's responsibility for environmental pollution.

10.3.6. Environmental Impact Indicators

10.3.6.1. Share of Renewable Resources in Total Energy Supply

Description

The percentage that represents the supply of primary renewable energy over the total energy supply. The total supply of primary renewable energy can be considered the total renewable energy entering processing centers, plus the final consumption of that energy supply.

The total energy supply is calculated by adding the total primary energy production to the net primary and secondary energy imports, plus or minus the total inventory change, minus the untapped primary and secondary energy. Net imports refer to the volume of imports minus the volume of exports.

Formulation

$$PPER_i = \frac{OER_i}{OTE_i} * 100$$

Where:

$PPER_j$ = Percentage share of the renewable energy supply over the total energy supply during period i (%)
OER_i = Renewable primary energy supply during period i (Toe)
OTE_i = Total energy supply during period i (Toe)

Application

This indicator measures the degree of penetration of renewable resources in the country's energy mix. In combination with emission factors, it can also assess environmental impact mitigation in the energy sector.

10.3.6.2. Greenhouse Gas Emissions per Capita

Description

Obtained by dividing the energy sector's total greenhouse gas emissions by the number of inhabitants. The method to calculate the volume of greenhouse gas emissions is detailed in Section 9 – Environmental Impact.

Formulation

$$GEIPC_i = \frac{GEI_i}{POB_i}$$

Where:

$GEIPC_i$ = Per capita greenhouse gas emissions during period i (Ton/Inhab.)
GEI_i = Greenhouse gas emissions during period i (Ton)
POB_i = Population during period i (Inhab.)

Application
This indicator makes it possible to forecast increased environmental impacts due to the country's population growth.

10.3.6.3. Total Emissions Intensity Relative to GDP

Description
Obtained by dividing the energy sector's total greenhouse gas emissions by the GDP. The GDP can be calculated at current or constant values for a given base year.

Formulation

$$IEGEI_i = \frac{GEI_i}{PIB_i}$$

Where:

$IEGEI_i$ = Intensity of greenhouse gas emissions during period I (Ton/US$)
GEI_i = Greenhouse gas emissions during period i (Ton)
PIB_i = Gross domestic product during period i (US$)

Application
This indicator makes it possible to measure the environmental impact of the country's economic development. This indicator should be minimized through sustainable development programs designed to decouple economic growth from increasing pollution.

10.3.6.4. Greenhouse Gas Emissions per Unit of Electricity Generated

Description
Obtained by dividing the electricity sector's total greenhouse gas emissions by the total electricity generated. The method to calculate the volume of greenhouse gas emissions is detailed in Section 9 – Environmental Impact.

Formulation

$$GEIGE_i = \frac{GEI_i}{GET_i}$$

Where:

$GEIGE_i$ = Greenhouse gas emissions per unit of electricity generated in period i (Ton/GWh)
GEI_i = Greenhouse gas emissions during period i (Ton)
GET_i = Total electricity generated during period i (GWh)

Application
This indicator makes it possible to measure environmental impact units per GWh of electricity generated. This indicator can be mitigated through greater use of renewable or clean energy sources for electricity generation.

10.3.7. Energy Efficiency Indicators

10.3.7.1. Efficiency of Energy Transformation

Description
The relationship between the energy coming out of processing centers as outputs and the energy entering those centers as inputs, measured in caloric units.

The energy input and output of transformation centers is calculated by multiplying the volumes of inputs and outputs in physical units by their respective caloric factor.

Formulation

$$ETE_{iJ} = \frac{ETP_{ij}}{ETI_{ij}} * 100$$

Where:

ETE_{ij} = Efficiency of energy transformation for center j during period i (%)
ETP_{ij} = Total energy content of outputs leaving processing center j during period i (Toe)
ETI_{ij} = Total energy content of inputs entering processing center j during period i (Toe)

Application

This indicator estimates the total supply of primary energy to be established, in order to meet the demand of all end-use sectors, through either domestic production or imports. The efficiency of energy transformation depends primarily on the technology used in the processes and on controlling flow and heat losses inside the facility.

10.3.7.2. Electricity Generation Efficiency

Description

This is a specific application for the electricity sector, from the transformation efficiency indicator. It is calculated by dividing the power generated at the plants by the energy content of the fuels or primary sources.

In some types of power plants that use non-conventional renewable energy sources such as solar and wind power, calculating transformation efficiencies can be highly complex because it is hard to accurately estimate the energy content of these sources, regardless of the plant characteristics. In these cases, standardized efficiency values are usually taken, or the energy content of the source is simply considered equal to the electricity produced (efficiency = 100%).

Formulation

$$EGE_i = \frac{GTE_i}{ETI_i} * 100$$

Where:

EGE_i = Efficiency of electricity generation for period i (%)
GTE_i = Total electricity generated, expressed in calorie units for period I (Toe)
ETI_i = Total energy content of the fuels and primary sources used in power plants during period i (Toe)

Application

It estimates the total primary energy supply to be established, for the power supply. This indicator can also serve to justify undertaking more efficient power generation projects.

10.3.7.3. Energy Facility Utilization Factor

Description

This indicator is also known as the plant factor or capacity factor, and its formulation depends on the energy chain activity and the energy products to which the facility is related.

In facilities that harness primary energy, particularly fossil resources, the capacity factor is defined as the net energy extracted during a given time period, over the maximum volume of that energy source that the facility may draw upon during that period, given the size of its infrastructure.

In transformation facilities, the capacity factor is calculated by dividing the volume of the energy source processed as an input during a given period by the maximum amount of energy processed in the same period.

In the specific case of power plants, the capacity factor is calculated by dividing the net electricity generation in a time period by the maximum generating capacity for the same period. The maximum generating capacity is the result of multiplying the installed capacity times the number of hours in the period. Calculations usually use the figure of 8,760 hours in a year and 730 hours in a month.

For electricity transport and transmission facilities, the capacity factor is the ratio between the volume of energy transported over a time period and the maximum energy that can be transported in the same period.

For storage facilities, the factor is calculated as the ratio between the absolute value of the inventory change in a time period and the maximum storage capacity of the facility.

For relatively long periods, the capacity factor of energy facilities may be affected by downtime, whether forced or due to scheduled maintenance.

Formulation for operating facilities

$$FP_{ijk} = \frac{PTE_{ijk}}{PMAX_{ijk}} * 100$$

Where:

FP_{ijk} = Capacity factor of facility j during period i for energy source k (%)
PTE_{ijk} = Net production of energy source k in facility j during period i (u.)
$PMAX_{ijk}$ = Maximum production capacity of energy source k for facility j during period i (u.)

Formulation for transformation facilities

$$FP_{ijk} = \frac{VTP_{ijk}}{VMAX_{ijk}} * 100$$

Where:

FP_{ijk} = Capacity factor of facility j during period i for energy source k (%)
VTP_{ijk} = Processed volume of energy source k in facility j during period i (u.)
$VMAX_{ijk}$ = Maximum energy source k that can be processed in facility j in period i (u.)

Formulation for power plants

$$FP_{ijk} = \frac{VTT_{ijk}}{VMAX_{ijk}} * 100$$

Where:

FP_{ij} = Capacity factor of facility j during period i (%)
GE_{ij} = Net electricity generated in facility j during period i (GWh)
PI_{ij} = Installed capacity of plant j during period i (MW)
Nh_{i} = The number of hours contained in period i

Formulation for transportation facilities

$$FP_{ijk} = \frac{VTT_{ijk}}{VMAXT_{ijk}} * 100$$

Where:

FP_{ijk} = The capacity factor of facility j during period i for energy source k (%)
VTP_{ijk} = Total transported volume of energy source k in facility j during period i (u.)
$VMAXT_{ijk}$ = Maximum volume of energy source k that can be transported by facility j during period i (u.)

Formulation for storage facilities

$$FP_{ijk} = \frac{|VI|_{ijk}}{VMAXA_{ijk}} * 100$$

Where:
FP_{ijk} = The capacity factor of facility j during period i for energy source k (%)
$|VI_{ijk}|$ = The absolute value of the inventory change for energy source K in facility j during period i (u.)
$VMAXA_{ijk}$ = The maximum storage capacity of energy source k in facility j during period i (u.)

Application
This indicator displays the percentage of the country's energy infrastructure that remains idle. Although a small capacity factor can mean a favorable long-term energy security situation, we must not lose sight of the negative consequences of over-investment and stagnant economic resources.

10.3.7.4. Energy Transmission and Distribution Loss Factor

Description

The ratio between the total energy lost in transmission and distribution facilities and the total supply of both primary and secondary energy.

Losses can be conceptualized as the difference between the amount of energy delivered to transmission and distribution facilities and the energy that actually reaches final consumption centers.

In the specific case of the electricity sector, losses in transmission and distribution systems are classified as technical losses and non-technical losses. Technical losses are caused by the physical properties of electric equipment, while non-technical losses are related to measurement errors, billing errors, power theft, etc.

Formulation

$$FPE_i = \frac{PTD_i}{OTE_i} * 100$$

Where:
FPE_i = The transmission and distribution energy loss factor in period i (%)
PTD_i = Total transmission and distribution energy losses in period i (Toe)
OTE_i = Total energy supply during period i (Toe)

Application
This indicator measures the energy sector's level of development, because one of the main goals pursued in expansion and upgrading plans is to minimize this factor.

10.3.8. Reserve and Potential Indicators

10.3.8.1. Unused Percentage of Usable Hydroelectric Potential

Description
The result of dividing the difference between the economically usable hydroelectric potential and the installed hydroelectric capacity by the economically usable installed hydroelectric potential, expressed as a percentage.

Formulation

$$PHNA_i = \frac{PHEA_i - CHI_i}{PHEA_i} * 100$$

Where:

$PHNA_i$ = Percentage of unused hydroelectric potential in period i (%)
$PHEA_i$ = The economically usable hydroelectric potential in period i (MW)
CHI_i = The installed hydroelectric capacity in period i (MW)

Application

This indicator measures the possibility of expanding the installed hydropower capacity.
From an environmental viewpoint, combined with the emission factors of thermoelectric plants, you can also assess the degree of environmental impact mitigation that could be achieved by leveraging the remaining hydro resources.

10.3.8.2. Scope of Proven Reserves of Fossil Resources

Description

The result of dividing the proven reserves of fossil resources in a given year by the production of that resource in the same year.

Formulation

$$ARF_{ik} = \frac{RPRF_{ik}}{PRF_{ik}}$$

Where:

ARF_{ik} = The scope of proven reserves of fossil resource k in period i (years)
$RPRF_{ik}$ = The proven reserves of fossil resource k measured in period i (u.)
PRF_{ik} = The production of fossil resource k during period i (u.)

Application

This indicator makes it possible to project the long-term production of fossil resources and to implement programs to substitute fossil fuels with renewable energy sources.

10.3.9. Sustainable Energy Development Indicators

Due to the interaction among energy systems in the different dimensions of development, a series of variables related to the structures and variables of these systems should be related to the sustainability dimensions.

The following figure shows a list of indicators used for energy analyses of the contributions the countries of Latin America and the Caribbean make to sustainable development, from a publication by OLADE-ECLAC-GTZ.

In this publication major patterns were identified, which highlight positive and negative aspects of the contributions that energy systems make to those countries' sustainable development.

Table 15. Sustainable energy development indicators

Indicator	High sustainability	Has the following goals
Energy autarky	Low share of imports in the energy supply	Security of foreign supply
		Sustainment, political maneuverability/leverage (high degree of political autonomy)
		Reduced risk of imbalances in the balance of payments
Resistance to external change	Low share of energy exports in GDP	Steady flow of export revenues
		Low share of the income variable in the budget
		Reduced risk of imbalances in the balance of payments
Energy productivity	High GDP per unit of energy	Production efficiency
		Energy efficiency
		Sufficient funding
		Reducing energy supply costs
		Sufficient supply
		High air quality
		Reducing greenhouse gas emissions
		Extending the durability of non-renewable energy sources
Electricity coverage	High percentage of electrified households	Energy diversification
		Sufficient supply
		Access to modern energy sources for production
		Provision of social services
Covering basic energy needs	Sufficient residential consumption of useful energy	Meeting basic needs
		Diversifying the energy mix
		Sustainable firewood management
Using renewable energy sources	High share of renewables in the energy supply	High air quality
		Reducing greenhouse gas emissions
Durability of fossil fuels and firewood	High reserves-production ratio for fossil fuels and firewood	Long-term resource reserves availability
		Long-term supply security
Relative purity	Low levels of CO_2 emissions	Improved air quality Reduction in climate change gas emissions

Source: OLADE-ECLAC-GT

Following this classification, below is an example that characterizes two countries: Colombia and Mexico.

Table 16. Example of using sustainable development indicators

Situations / Countries	Economy			Social Equity		Natural Endowment		
	Energy Autarky	Export Soundness	Energy Productivity	Electric Coverage	Coverage of basic energy needs	Purity of Consumption	Renewability	Durability Scope
CO, MX	High	High average	Low average	High average	Average	High average	Low average	High

CHAPTER XI

Systems of Units and Conversion Factors

11. Systems of units and conversion factors

11.1. INTERNATIONAL SYSTEM OF UNITS (S.I.)

After a series of proposals and amendments, scientists in the late eighteenth century managed to design the Metric Decimal System based on parameters related to physical phenomena and decimal notation, and struggled with resistance against the change to a modern system from the old medieval system of anthropological references and subdivisions in successive halves. The scientific community of the second half of the twentieth century dealt with the adoption of a new, more precise measurement system of fundamental units referenced to physical phenomena, adapted to the increasing advances in science. At the same time, it needed sufficient breadth and universality to cover the needs evidenced by the proliferation of subsystems that responded to a particular need of the various branches of science.

11.1.1. General Conference on Weights and Measures

At its 10th Conference (1954,) the General Conference on Weights and Measures had already established the Joule (J) and the energy unit (1 cal = 4.186 J) in 1948. It adopted the preexisting MKSA System (meter, kilogram mass, second, ampere), originally proposed by Professor G. Giorgi in 1902, which included the Kelvin (K) and Candle (cd) as units of temperature and light intensity respectively.

11.1.2. Dedication of the S.I.

The 11th General Conference on Weights and Measures held in October 1960 in Paris, home of the metric system, established the International System of Measures (SI), based on 6 fundamental units, meter, kilogram, second, ampere, Kelvin, candle, improved and later completed during the 12th, 13th and 14th Conferences. In 1971, the seventh fundamental unit, the mol, was added, which measures the amount of matter.

11.1.3. Coherent System

For proper and effective scientific communication, it is essential that each fundamental unit of magnitude of a system be specified and be reproducible as accurately as possible. The ideal way to define a unit is in terms of a constant and unchanging natural phenomenon that is reproducible, for example, the wavelength of a monochromatic light source. The units of each magnitude can be selected arbitrarily, as long as they are linked by mathematical relationships to the base unit, which must be defined uniquely. By limiting the number of base units, substantial simplicity is achieved in the system. The base units are called ‘fundamental’ and all others are ‘derived.’ A system of units with these features is called a ‘coherent system.’ S.I. prefixes do not apply to the units of angle or time other than seconds.

11.2. UNITS OF THE INTERNATIONAL SYSTEM OF UNITS

The following are the main units of the International System.

Table 17. Basic units of the International System of Units

Magnitude	Name	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	Ampere	A
Temperature	Kelvin	K
Amount of a substance	Mol	mol
Luminous intensity	Candle	cd

Table 18. Units of the International System of Units

Magnitude	Name	Symbol
Area	Square meter	m^2
Volume	Cubic meter	m^3
Velocity	Meters per second	m/s
Acceleration	Meters per second squared	m/s^2
Wave number	Reciprocal meters	m^{-1}
Mass density	Kilograms per cubic meter	kg/m^3
Angular velocity	Radians per second	rad/s
Angular acceleration	Radians per second squared	rad/s^2

Table 19. Units derived from the International System of Units

Magnitude	Name	Symbol	Expression in terms of other SI units	Expression in basic SI units
Frequency	Hertz	Hz		s^{-1}
Force	Newton	N		$m \cdot kg \cdot s^{-2}$
Pressure, stress	Pascal	Pa	N·m-2	$m^{-1} \cdot kg \cdot s^{-2}$
Energy, work, quantity of heat	Joule	J	N·m	$m^2 \cdot kg \cdot s^{-2}$
Power	Watt	W	J/s	$M^2.kg.s^{-3}$
Electric charge, amount of electricity	Coulomb	C	J·s-1	s.A
Electric potential difference, electromotive force	Volt	V	W/A	$M^2.kg.s^{-3}.A^{-1}$
Electric resistance	Ohm	W	V·A-1	$m^2 \cdot kg \cdot s\text{-}3 \cdot A^{-2}$
Capacitance	Faraday	F	C·V-1	$m^{-2} \cdot kg\text{-}1 \cdot s^4 \cdot A^2$
Magnetic flux	Weber	Wb	V·s	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$

Table 20. Non-metric units allowed by SI

Magnitude	Name	Symbol	S.I. Equivalent
Angle	Degree	°	1º=(pi/180)rad
	Minute		1’=(pi/10.8)rad=(1/60)°
	Second	“	1”=(1/60)”=(pi/648)rad
Time	Minute	min	1min=60s
	Hour	h	1h=60min=3600s
	Day	d	1d=24h=86400s
Volume	Liter	l	$1l=10dm^3=10^{-3}m^3$
Mass	Ton	t	$1t=10^3kg=1Mg$
Area	Hectare	Ha	$1ha=1hm^2=10^4m$

Source: UNAM, México

S.I. prefixes do not apply to angular or time units except for the second.

Synonyms

- **Liter:** a special name that may be given to the cubic decimeter as long as it does not express highly accurate volume measurement.
- **Degrees Celsius:** can be used to express a temperature interval. The intervals between degrees Kelvin and degrees Celsius are identical; however, zero Kelvin is absolute zero and zero Celsius is the melting point of ice.

Table 21. Prefixes of the International System

Factor	Prefix	Symbol
10^{24}	Yota	Y
10^{21}	Zeta	Z
10^{18}	Exa	E
10^{15}	Peta	P
10^{12}	Tera	T
10^{9}	Giga	G
10^{6}= 1,000,000	Mega	M
10^{3}= 1,000	Kilo	k
10^{2} = 100	Hecto	h
10 = 10	Deca	da

Factor	Prefix	Symbol
10^{-1} = 0.1	deci	d
10^{-2} = 0.01	centi	c
10^{-3} = 0.001	mili	m
10^{-6} = 0.000001	Micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	Femto	f
10^{-18}	Atto	a
10^{-21}	Zepto	z
10^{-24}	Docto	y

1 = (Basic unit without Prefix)

Source: UNAM, México

Written use of symbols and prefixes

- The names of units as well as their multiples and submultiples are written in lower case. Degrees Celsius is an exception.
- Symbols that represent units are written in lowercase, except when derived from proper names. The capital letter L is used for liter because 1 can be mistaken for l. When a two-letter symbol is derived from a proper name, the first letter is capitalized, for example, Pa (in honor of Blaise Pascal).
- Prefixes and submultiples are written in lowercase, except for mega and higher.
- Symbols are never written in plural, and are not followed by a period, unless they are at the end of a sentence.
- A space must be left between the number and the symbol except for angular measurements.
- The products of units are expressed by leaving a space between the symbols or leaving a space between the products.

11.3. EQUIVALENCE BETWEEN S.I. AND OTHER UNIT SYSTEMS

Although most of the countries of the world have adopted the international system, countries with a Saxon origin will take time to adopt the new units because their custom of using the old systems is very strong.

Table 22. Basic units in different systems of units

Dimension	SI	MKS	CGS	US
Length	m	m	Ccm	foot
Time	s	s	s	s
Mass	kg	UTM	g	lbm
Temperature	ºK	ºC	ºC	ºF
Heat	Joule	kcal	cal	Btu

Source: UNAM, Mexico

Table 23. Conversion factors of basic and derived units

Magnitude	Unit	Factor	S.I. Unit
Length	Inch	0.0254	Meters
	Foot	0.3048	
	Yard	0.9144	
	Mile	1609.34	
Volume	Gallon	0.003785	m^3
Mass	Ounce	0.02834	Kilogram
	Pound	0.45359	
Temperature	Kelvin	°Celsius + 273.5	
	Fahrenheit	°Celsius X 1.8+32	
Velocity	km/hour	0.27777	m/s
	Mile/hour	0.44704	
Acceleration	g (gravity)	9.80665	m/s^2
Force	Kilogram (weight)	9.80665	Newton
	Dyne	1.0 X 10-5	
Energy, Heat	kilocalorie	4186	Joule
	BTU	1054.35	

Magnitude	Unit	Factor	S.I. Unit
Power	Kilocalorie/hour	1.16222	Watt
	BTU/hour	0.29287	
	Horsepower (HP)	746	
Heat flow	BTU/hour ft^2 *	3.15248	Watt/m^2
Pressure	Atmosphere	1.01325×10^5	Newton/m^2 (Pascal)
	Millibar	100	
	mm Hg (Torr)	133.322	
	Psi (Lb/in^2)	6894.75	
Density	Lbm/Ft^3	16.0184	kg/m^3
Specific heat	BTU/Lbm*°F	4.18681	Joule/Kg*°K
Thermal conductivity	BTU*inc/Ft^2*hour	0.144131	Watt/m*°K
Thermal conductance	BTU/Ft^2 * hour	5.674466	Watt/m^2°K

Source: UNAM, Mexico

11.4. EQUIVALENCE BETWEEN COMMON ENERGY UNITS

OLADE has adopted barrels of oil equivalent (BOE) as a common unit for expressing energy balances based on the following considerations:

a) Is it consistent with the International System of Units (SI)
b) It acceptably expresses the physical reality of what it means
c) It is directly related to the most important energy source in the world today and therefore is easy to use
d) Its numerical value represents the dissimilarity in the magnitude of the values of the different energy sources among the Member Countries of the Organization

Based on the caloric value of 1 kg of petroleum, which is 10,000 kcal, the following equivalences are used:

Table 24. Equivalences between common energy units

1 boe = 0.13878	tons equivalent of petroleum (TOE)
1 TOE = 7.205649	barrels equivalent of petroleum (boe)
1 TOE = 10^7	kilocalories (kcal)
10^3 TOE = 41.84	terajoules (Tjoule)
10^3 boe = 1.3878	teracalories (Tcal)

Source: SIEE-OLADE

The database of OLADE's Energy Economic Information System, SIEE® uses information on the different energy sources in the supply/demand module in the physical units in which they are commonly measured as well as caloric units, and then transforms them into the common adopted heat unit, which is barrels of oil equivalent (boe). Thus:

Petroleum products such as oil, liquefied petroleum gas, gasoline, kerosene/jet fuel, diesel oil and fuel oil, are expressed in thousands of US barrels and are represented as 10^3 bbl.

Table 25. Conversion Factors of volume units

1 US barrel	5.614583	Cubic feet
	42	US gallons
	158.98	liters
	0.15898	Cubic meters
1 cubic meter	1000	liters
	35.3147	Cubic feet
	6.2898	US barrels
	264.172	US gallons
1 liter	1	Cubic decimeter

Source: SIEE-OLADE

If petroleum products are shown in mass units (tons), they must be converted into volume units using the density.

Table 26. Reference densities in ton/m³

Liquefied gas	0.55
Gasoline	0.75
Kerosene	0.82
Diesel Oil	0.88
Fuel Oil	0.94

Source: SIEE-OLADE

Solids products such as coal, charcoal, firewood and coke are expressed in metric tons, with the following equivalences:

Table 27. Conversion factors for mass units

1 ton	1000	Kilograms
	2204.62	Pounds
	1.10231	Short tons
	0.98421	Long tons

Source: SIEE-OLADE

Hydroelectricity, geothermal electricity and electricity are expressed in Gigawatt-hours (GWh). 1 GWh = 10^9 Wh.

For sources and products such as sugarcane products, other primary sources, gases, other secondary sources, and non-energy sources, the caloric value is used directly and expressed in barrels of oil equivalent (boe).

11.5. CONVERSION FACTORS FROM PHYSICAL TO CALORIC UNITS

In order to have a general unit for measuring energy flow through the various activities of the energy chain and to enable a consolidated analysis of the energy balance, both vertically and horizontally, the mass and volume units of energy sources need to be converted into caloric units using their lower caloric value. The lower caloric value not only depends on the type of substance, but also its specific physical and chemical characteristics, so there can be various caloric values for different qualities of the same substance. Lower caloric value units are conceptually energy or heat units over mass units, and the most common in the region is kcal/kg for liquid and solid fuels; however, for gaseous fuels such as natural gas, BTU/ft^3 or kJ/m^3 are usually used.

Table 28. Lower heating value of certain fuels

Fuel	(kcal/kg)
Coal	7,000
Crude oil	10,000
Gasoline	10,500
Diesel	10,200
Fuel oil	9,800
Natural Gas	8,300 (kcal/m^3)
Commercial butane	10,938
Commercial propane	11,082
Ethyl alcohol	6,500
Biogas	4,500

Source: SUPER-OLADE

Below are the conversion factors OLADE uses to convert energy sources from the original physical units to the common caloric unit BOE:

Table 29. Boe equivalence of some units used by OLADE

1 bbl	of oil	=	1.0015	boe
1 bbl	of gasoline	=	0.8934	boe
1 bbl	of diesel	=	1.0015	boe
1 bbl	of heavy fuels	=	1.0304	boe
1 bbl	of LPG	=	0.6701	boe
1 bbl	of kerosene	=	0.9583	boe
10^3 m^3	of natural gas	=	5.9806	boe
10^3 kWh	of hydro/geo electricity	=	0.6196	boe
1 ton	of firewood	=	2.5940	boe
1 ton	of charcoal	=	4.9718	boe
1 ton	of coal	=	5.0439	boe
1 ton	of coke	=	4.8998	boe
1 ton	of uranium	=	71.2777	boe
1 ton	of ethanol	=	0.5980	boe
1 ton	of biodiesel	=	0.9508	boe
1 ton	of bagasse	=	1.3114	boe

Source: SIEE-OLADE

Table 30. Conversion factors for common energy units of OLADE

	boe	toe	tce	Tcal	TJ	10^3 BTU	MWh	kg LPG	m^3 Natural Gas	pc Natural Gas
boe	1	0,13878	0,198259	0,00139	0,00581	5524,86	1,613944	131,0616	167,207304	5917,15976
toe	7,205649	1	1,428586	0,01	0,04184	39810,22	11,62951	944,3838	1204,83714	42636,9763
tce	5,0439	0,699992	1	0,007	0,029287	27866,85	8,14057	661,0616	843,376919	29845,5621
Tcal	720,5649	100	142,8586	1	4,184	3981022	1162,952	94438,38	120483,714	4263697,6
TJ	172,2191	23,90057	34,14404	0,239005	1	951487	277,9521	22571,31	28796,2988	1019048,19
10^3 BTU	0,00018	2,51E-05	3,59E-05	2,51E-07	1,05E-06	1,00E+00	0,00029	2,37E-02	0,030265	1,07101
MWh	0,6196	0,08599	0,1228	0,00086	0,0036	3423,2	1	81,20577	103,6016	3666,27219
kg LPG	0,00763	0,00106	0,001513	1,06E-05	4,43E-05	42,15469	0,012314	1	1,27579173	45,147929
m^3 Natural Gas	0,00598	0,00083	0,001186	8,30E-06	3,47E-05	33,04198	0,009652	0,783827	1	35,3881657
pc Natural Gas	0,00017	2,35E-05	3,35E-05	2,35E-07	9,81E-07	0,933701	0,022149	0,022149	0,02825803	1

Source: SIEE-OLADE

Needless to say, although the values shown in the above tables can serve as a reference for converting physical units to caloric units, each country should have its own table of conversion factors, which should be regularly updated, depending on the specific quality and composition of the energy sources handled in each of the periods of analysis.

Table 31. Caloric factors of OLADE Member Countries

a kboe	Oil	Natural gas	Coal	Nuclear	Hydroenergy	Geothermal	Firewood	Electricity	LPG	Gasoline	Kerosene	Diesel Oil	Fuel oil	Coke	Charcoal	Ethanol
Original Unit	kbbl	km^3	kt	kt	GWh	GWh	kt	GWh	kbbl	kbbl	kbbl	kbbl	kbbl	kt	kt	kbbl
Argentina	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Barbados	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Bolivia	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Brasil	1,020	6,182	3,457	71,278	0,618	0,620	2,228	0,618	0,698	0,900	0,939	0,969	1,096	4,960	4,643	0,598
Chile	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,623	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Colombia	1,000	5,988	4,710	71,278	0,620	0,620	2,609	0,620	0,688	0,884	0,964	1,000	1,075	3,478	4,710	0,598
Costa Rica	0,994	5,981	5,263	71,278	0,620	0,620	3,100	0,620	0,699	0,894	0,944	0,994	1,066	4,614	4,939	0,598
Cuba	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Ecuador	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
El Salvador	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Grenada	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Guatemala	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Guayana	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Haiti	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Honduras	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Jamaica	1,002	5,981	5,044	70,187	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Mexico	1,099	7,617	3,461	71,278	0,620	0,620	2,594	0,62	0,648	0,839	0,900	0,934	1,037	4,925	4,972	0,598
Nicaragua	1,006	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,698	0,891	0,954	0,986	1,068	5,788	2,786	0,598
Panama	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Paraguay	1,002	5,981	5,260	71,278	0,620	0,620	2,594	0,620	0,670	0,879	0,958	0,994	1,059	4,612	4,972	0,598
Peru	0,997	7,356	5,044	71,278	0,620	0,620	2,594	0,620	0,685	0,893	0,958	1,002	1,030	4,900	4,684	0,598
Dominican Republic	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Suriname	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Trinidad & Tobago	1,002	5,981	5,044	71,278	0,620	0,620	2,594	0,620	0,670	0,893	0,958	1,002	1,030	4,900	4,972	0,598
Uruguay	0,997	5,981	5,044	71,278	0,620	0,620	1,946	0,620	0,692	0,902	0,951	0,988	1,102	4,900	5,404	0,598
Venezuela	1,107	7,586	5,260	71,278	0,617	0,620	2,594	0,620	0,670	0,925	1,014	1,067	1,133	4,900	5,627	0,598

2009 Reference Year

Source: SIEE-OLADE

11.6. Efficiency factors of energy facilities

11.6.1. Useful Thermal Energy

The second law of thermodynamics underscores the impossibility of converting 100% of the thermal energy of a source into useful work, and also explains that all heat extraction processes are irreversible. This law also introduces the concept of thermal efficiency, defined as the ratio of the useful work produced by a system to the heat input.

$$Et = \frac{\Delta W}{\Delta Q} * 100$$

The remaining portion, i.e. 100 – Et, is the percentage of losses, either the dissipation of heat to the environment or the absorption of heat by the system itself. The efficiency of the various facilities of the energy chain, processing as well as final consumption, will depend on the characteristics of the heat source and the technology used to utilize the energy.

11.6.2. Efficiency in Conventional Thermal Power Plants

Thermal power plants use the heat released by the combustion process to produce mechanical work, and then convert it into electrical energy in the generator. The thermal efficiency of the thermal power plant is calculated by dividing the amount of electrical energy produced, expressed in caloric units, by the heat produced by combustion. The heat produced by combustion is obtained by multiplying the mass of fuel burned by its respective net lower caloric value. The following a table shows the typical thermal efficiencies of some types of power plants.

Table 32. Thermal Efficiencies of Some Power Plants.

Type of plant	Fuel	Efficiency (%)
Internal combustion engines	Fuel Oil	35%
Internal combustion engines	Diesel	30%
Gas turbine	Diesel	40%
Gas turbine	Natural Gas	45%
Steam turbines	Fuel Oil	45%
Steam turbines	Diesel	40%
Steam turbines	Coal	40%
Combined cycle turbines	Natural Gas	55%

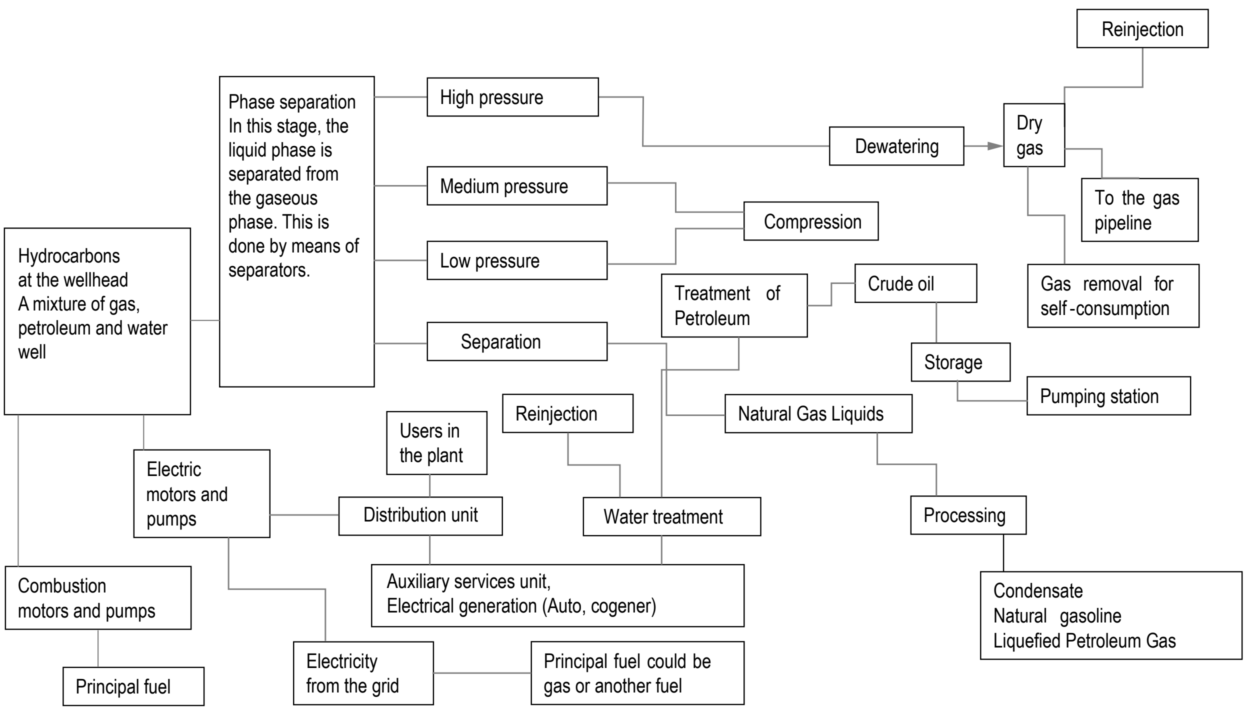
Source: SUPER-OLADE

Annex

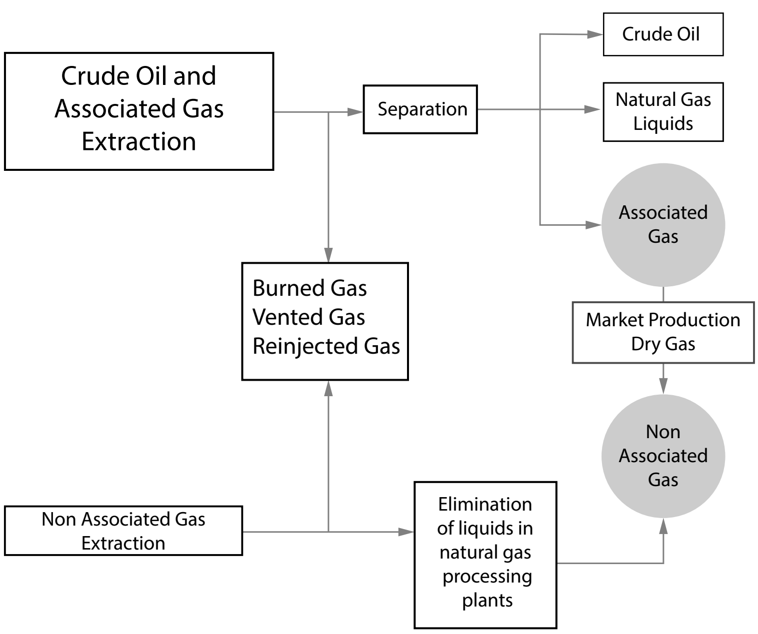
ANNEX

ANNEX I. Process Diagrams

Process Diagram of Petroleum Extraction



ANNEX II. Flow Chart Of Natural Gas Extraction



ANNEX III. Technologies

Production and processing

Emissions factors related to the production of primary energy (petroleum, natural gas and coal) are expressed in kilograms of pollutant per unit of energy produced.

Unused energy is the amount not utilized due to technical and/or economic conditions of exploitation. The most significant categories are spilled crude oil and unused natural gas. According to the equilibrium equations that define the balance, it is not possible to distinguish between energy losses and energy wasted. Due to a lack of detailed information, emissions from these two categories are only associated with the category 'Losses.'

Emissions related to petroleum refining and coke production are expressed in terms of the fuel consumed in these transformative processes and the emissions factors are thus associated with consumption itself.

In the case of the charcoal clamps and distilleries, emissions factors are expressed in terms of the amount of energy produced.

Table 33. Energy production and processing methodology

	Energy source	Source	Technology
A1	Petroleum	EDB	Onshore production (emissions per unit of energy produced)
A2	Natural gas	EDB	Production (emissions per unit of energy produced)
A3	Coal	EDB	Production: open pit mine (emissions per unit of energy produced)
K18	Charcoal	EDB	Charcoal clamp (emissions per unit of energy produced)
P17	Coke	EDB	Coke oven/blast furnaces (emissions per unit of energy produced)
M13	Ethanol	EDB	Distilleries (emissions per unit of energy produced)
P13	Gasoline	EDB	Refineries (emissions per unit of energy consumed in the refining process)
P14	Kerosene	EDB	Refineries (emissions per unit of energy consumed in the refining process)
P15	Diesel	EDB	Refineries (emissions per unit of energy consumed in the refining process)
P16	Fuel Oil	EDB	Refineries (emissions per unit of energy consumed in the refining process)
Q1	Petroleum	EDB	Petroleum losses
Q2	Natural gas	EDB	Natural Gas Losses
Q13	Gasoline	EDB	Gasoline Losses
Q14	Kerosene	EDB	Kerosene losses
Q15	Diesel	EDB	Diesel Losses
Q16	Fuel Oil	EDB	Fuel oil losses
Q19	Gases	EDB	Gas losses

Electricity Generation

The technologies selected for calculating emissions from thermal power generation are generic. Not included are technologies that incorporate emissions control or cutting-edge technologies through which high yields decrease the volume of emissions.

Table 34. Electricity generation technologies

	Energy source	Source	Technology
H1	Oil	EDB	Steam turbine. Generic technology. Light crude oil
H2	Natural gas	EM	Gas turbine. Simple technology
H3	Coal	EM	Steam turbine. Generic technology
H5	Geothermal	CO_2DB	Dry steam geothermal. Generic technology
H7	Firewood	IPCC	Boiler. Generic technology
H8	Bagasse	EDB	Boiler. Generic technology
H9	Others	EDB	Biomass. Waste. Boiler
H12	LPG	EDB	LPG steam. Generic technology
H13	Gasoline	EDB	Gasoline. Motor
H14	Kerosene	EDB	Steam turbine. Generic technology
H15	Diesel	EM	Steam turbine. Diesel 1 and 2. Generic Technology
H16	Fuel Oil	EM	Gas turbine. Simple
H17	Coke	EDB	Coke. Boiler. Generic technology
H18	Charcoal	EDB	Boiler. Generic technology
H19	Gases	EM	Gas turbine. Generic technology

For electricity self-production, small-scale technologies are assumed, and in some cases (petroleum products), it has been assumed that generation involves internal combustion motors.

Table 35. Electricity generation technologies for self-production

	Energy source	Source	Technology
I1	Petroleum	EDB	Steam turbine. Generic technology. Light crude oil
I2	Natural gas	EDB	Natural gas. Motor. Generic technology
I3	Coal	EM	Steam turbine. Small scale
I5	Geothermal	CO_2DB	Geothermal. Dry steam. Generic technology
I7	Firewood	IPCC	Boiler. Generic technology
I8	Bagasse	EDB	Boiler. Generic technology
I9	Others	EDB	Biomass (waste). Boiler
I12	LPG	EDB	Small-scale motor. Generic technology
I13	Gasoline	EDB	Gasoline. Motor
I14	Kerosene	EDB	Gasoline. Motor

I15	Diesel	EM	Generator. Small scale
I16	Fuel Oil	EDB	Motor. Small scale
I17	Coke	EDB	Coke. Boiler. Generic technology
I18	Charcoal	EDB	Boiler. Generic technology
I19	Gases	EDB	Natural gas. Motor. Generic technology

Technologies selected for energy end use are summarized in tables 12 to 17. In all cases, these are standard technologies.

Table 36. Final energy consumption technologies in transportation

	Energy source	Source	Technology
S2	Natural Gas	IPCC	Passenger vehicles
S3	Coal	EM	Boiler. Small scale
S7	Firewood	EM	Boiler. Standard technology
S12	LPG	IPCC	Passenger Vehicles.
S13	Gasoline	IPCC	Light vehicles. No catalyst
S14	Kerosene	IPCC	Air transportation. Jet
S15	Diesel	IPCC	Heavy vehicles. No catalyst
S16	Fuel Oil	EDB	River transportation

Table 37. Final energy consumption technologies in industry

	Energy source	Source	Technology
T1	Petroleum	EDB	Light oil. Additional boiler
T2	Natural gas	EM	Boiler. Standard technology
T3	Coal	EM	Boiler. Conventional technology
T7	Firewood	EM	Firewood. Boiler. Standard technology
T8	Bagasse	EDB	Bagasse. Standard boiler
T9	Others	EDB	Plant waste. Standard boiler
T12	LPG	EDB	Standard boiler
T13	Gasoline	EDB	Motors
T14	Kerosene	EDB	Turbines. Small scale
T15	Diesel	EM	Standard boiler
T16	Fuel oil	EM	Standard boiler
T17	Coke	EDB	Boiler. Generic technology
T18	Charcoal	EDB	Thermal uses. Ovens
T19	Gases	EM	Standard boiler

Table 38. Final energy consumption technologies in the residential sector

	Energy source	Source	Technology
U2	Natural gas	EDB	Cooking. Standard stove
U3	Coal	EDB	Cooking. Standard stove
U7	Firewood	EDB	Cooking. Open hearth
U9	Others	EDB	Plant waste. Cooking. Hearth
U12	LPG	EM	Cooking. Standard stove
U13	Gasoline	EDB	Small scale motors
U14	Kerosene	EM	Cooking. Standard stove
U15	Diesel	EDB	Heating. Standard equipment
U16	Fuel Oil	EDB	Oven/dryer. Standard equipment
U18	Charcoal	EDB	Cooking. Stove. Standard equipment
U19	Gases	EDB	Cooking. Standard stove

Table 39. Final energy consumption technologies in the business and services sector

	Energy source	Source	Technology
V1	Petroleum	EDB	Light oil. Conventional boiler
V2	Natural gas	EDB	Generic uses
V3	Coal	EDB	Used for cooking
V9	Others	EDB	Plant waste. Used for cooking
V12	LPG	EDB	Various applications
V13	Gasoline	EDB	Motor. Small scale
V14	Kerosene	EDB	Used for cooking
V15	Diesel	EDB	Motor. Small scale
V16	Fuel Oil	EDB	Motor. Small scale
V18	Charcoal	EDB	Used for cooking
V19	Gases	EDB	Various applications

Table 40. Energy consumption technologies in the agriculture and fisheries sectors

	Energy source	Source	Technology
W1	Petroleum	EDB	Light oil. Conventional boiler
W2	Natural gas	EM	Boiler. Generic technology
W3	Coal	EM	Boiler. Standard technology
W7	Firewood	IPCC	Boiler. Standard technology

W8	Bagasse	EDB	Boiler. Standard technology
W9	Others	EDB	Plant waste. Boiler. Standard technology
W12	LPG	EDB	Various applications
W13	Gasoline	EDB	Motors. Small scale
W14	Kerosene	EM	Cooking uses
W15	Diesel	IPCC	Farm Equipment
W16	Fuel Oil	EM	Boilers. Standard technology
W17	Coke	EDB	Boilers. Standard technology
W18	Charcoal	EDB	Cooking uses
W19	Gases	EM	Boilers. Standard technology

Table 41. Technologies that consume energy in the construction industry and others

	Energy product	Source	Technology
X1	Oil	EDB	Light oil conventional boilers
X2	Natural gas	IPCC	Combustion engines
X3	Coal	EM	Boilers Small scale
X7	Firewood	EM	Boiler. Standard technology
X9	Others	EDB	Plant waste. Standard boilers
X12	LPG	IPCC	Vehicles. Combustion engines
X13	Gasoline	IPCC	Vehicles
X14	Kerosene	EDB	Turbines. Small scale
X15	Diesel	IPCC	Heavy vehicles
X16	Fuel oil	EDB	Internal combustion engines
X18	Charcoal	EDB	Thermal uses. Furnaces

ANNEX IV. Nuclear Energy

Nuclear Fuel Processing Plants

The process begins with the extraction of uranium ore that, once freed from the waste rock, is concentrated to obtain pure U_3O_8. It goes through a purification stage to obtain pure UO_3 or U_3O_8, and from there is sent to a conversion plant where UO_2 oxide is produced. Here the process differs depending on the type of reactor that will use the nuclear fuel. For gas-cooled reactors (GCR) with natural uranium, the UO_2 is fluorinated and reduced to obtain uranium metal, from which the fuel elements are manufactured. The different fuels elements obtained are used in reactors to produce steam that ultimately drive a turbine and alternator like in a conventional power plant, which is treated separately in power plants.

Nuclear Energy Treatment

Countries wishing to include nuclear energy in their balances are recommended to adopt similar criteria as for hydropower, i.e., the primary nuclear energy produced will be equal to the amount of heat obtained from the fissile fuel that is 'burned' in a reactor. Take the following as a reference:

a) The caloric equivalent of 1 ton of natural uranium enriched to 3 percent and 'burned' in a 30,000 MWD PWR reactor is 1 ton natural U = 4.24×10^{14} J
b) The caloric equivalent of 1 ton of natural uranium usable in a 7500 MWD HWR reactor is:1 ton natural U = 6.48×10^{14} J[6].

ANNEX V. Non-Commercial Energy

In many countries, people in rural areas and small towns gather firewood, animal waste and other products directly from the field to meet their cooking needs. That is why they are called 'non-commercial' energy sources, even though consumers often pay a price to those who collect them for sale. In any case, production is never recorded.

Some cottage industries such as brickyards, limekilns, bakeries, beverage distilleries, etc. consume firewood gathered in the surrounding area.

Finally, charcoal consumed non-commercially by rural households or purchased by the low- and high-income urban population is often not produced commercially.

Many publications are publically available on the theory and practice of non-commercial energy. For the energy balance, a good rule of thumb is as follows.

First, try to detect all non-commercial flows that may be of significance in the country and locate studies and estimates on the subject. Only then, plan a survey to gather any missing data.

You can use: 1) censuses when the entire universe is studied; 2) surveys if a sample is 'statistically chosen' from the universe and reliability calculated using the standard error; and 3) inquiry when the sample is arbitrary and reliability is undetermined.

ANNEX VI. Treatment of Cogeneration

This paper aims to provide technicians responsible for preparing energy balances with criteria for calculating the amounts of fuel used to generate electricity in cogeneration processes. Cogeneration involves the combined use of steam for power generation, driving force and heat. That is, superheated steam from the boiler goes through a turbine coupled to a generator to produce electricity, and the resulting (saturated) steam is used in the industrial process as additional driving force and heat for drying, centrifugation, grinding, distillation, sanitation, etc. Cogeneration is used primarily by Industrial Self-producers, as they generally require electricity, driving force and heat, although some countries (with high rates of thermal generation) have public cogeneration, and saturated steam is used in cities (commonly known as district heat).

In energy balances, self-producers are designated as transformation centers, in which some forms of energy (hydro, coal, fuel oil, diesel, bagasse, etc.) produce electricity through certain processes (hydro plants, steam plants, diesel turbine, gas turbine, etc.). In conventional thermal generation, the steam from the turbine (exhaust steam) is not used but passes through condensers and returns by water lines to the boilers. The yield of the process in this case is determined by dividing the calories of electricity generated by the calories of fuel consumed in the boiler. Normally, the yield is low, i.e., not above 30%. The data on the fuel consumption and electricity produced by these generation processes are usually known, so it is possible to build electricity balances using the inputs, outputs and transformation losses.

Although cogeneration is a steam-driven thermal process, the steam is used in the industrial process after turbo generation, so it is essential to determine the portion of the fuel burned in the boiler that actually generated the electricity. The other part will be designated as final consumption by the respective industry. Incorrectly calculating these portions can compromise the specific energy consumption of a given industrial product, since final consumption may be underestimated or overestimated.

Usually self-producers only report the fuel burned in the boiler and the electricity that is generated, so persons responsible for calculating the energy balance have to calculate the portion used for generation and the portion used for final consumption. It is common to make the mistake of assigning all the fuel burned in the boilers to electricity generation, which results in low yields (not more than 10%) for self-production, and the underestimation of final consumption by the industry. Sometimes available data are fuel oil and electricity sales to a certain self-producer or a percentage of its own generation. Sometimes a self-producer consumes more than one fuel in the boiler, and the quantities and the electricity generated are known. In practice, different situations arise regarding self-producers' data, and as long as they are properly treated, the energy balance will be more representative of the energy situation.

Based on actual data from seven industries that self-produce electricity in a typical steam flow configuration for a sugar mill, a methodology is proposed below for handling the topic. The basic idea is to determine the additional boiler fuel consumption required to increase the pressure, superheat the steam and consequently generate electricity. The resulting fuel would effectively be what the industry would require to produce saturated steam, if all electricity were bought from the grid.

Case 1:

The industry provides thermodynamic cogeneration data: p1 = steam pressure (superheated) before turbine; t1 = Steam temperature before the turbine; p2 = steam pressure (saturated) after the turbine; t2 = steam temperature after the turbine; C = Fuel consumption in the boiler; E = Electricity produced by the generator; y = Percentage of the steam that passes through the generator. With the pressure and temperature data, a steam diagram can be used to determine enthalpies 'i1' and 'i2' of the steam in Kcal/kg, before and after the turbine.

The difference between the enthalpies is the thermal energy provided by electricity generation. So dividing this difference by the enthalpy before the turbine gives percentage 'x,' and when it is multiplied by 'y' (percentage of steam passing through the turbine generator) and 'C' (total fuel), we obtain the portion of the fuel that was actually supplied to the boiler to generate electricity.

i1 – i2	steam enthalpy difference
x = (i1 – i2)/i1	% of steam calories used to generate electricity
Ce = C*y*x	Total fuel supplied to the boiler to generate electricity
Cc = C – Ce	Total fuel supplied to the boiler to generate process heat

Case 2:

The industry provides only fuel consumption data 'C' for the boiler and electricity generated 'E.'

Here it is necessary to introduce the following concepts: "Total yield of cogeneration" (RTC), "Equivalent electrical yield of cogeneration" (REE) and "Reference thermal yield" (RTR).

The total cogeneration yield is the total amount of energy from the cogeneration system that is used (electricity 'E' + process heat 'Cp'), divided by the energy supplied back to 'C.'

a) RTC = (E + Cp)/C
   Equivalent electrical yield of cogeneration is obtained by dividing the electricity generated 'E' by the heat supplied to the boiler to generate electricity 'Ce'.

b) REE = E/Ce
   The reference thermal yield is the yield that a process heat production system would have without electricity generation (conventional boiler).

c) RTR = Cp/Cc

Where Cc is the heat that should be supplied to the boiler to generate process heat (steam) in a conventional system.
Assuming that the total heat supplied to the boiler in the cogeneration system is equal to the sum of the heat supplied for generating electricity and the heat supplied for process heat, we have the following equations:

d) Ce = C – Cc

e) Cc = Cp/RTR

f) REE = E/(C – Cp/RTR)

Conclusion:

If the amount of heat required by the industrial process ‘Cp’ is known, a value could be assumed for RTR (between 70% and 90%) and the heat supplied to generate electricity ‘Ce’ could be calculated.

If ‘Cp’ is not known, it is recommended that the equivalent electrical yield of the cogeneration system be estimated directly as 50% to 60% (a yield that incorporates boiler losses proportionally) and that equation b) be used to calculate ‘Ce.’

Calculating Energy Savings from Cogeneration

The energy savings through cogeneration are given by the difference between the total energy that would have to be supplied to separate processes of electricity generation and process heat, and the energy supplied to the cogeneration system to obtain the same results in useful energy. It is calculated with the following formula:

Ea = (E/RER + Cp/RTR) – C

Where:

Ea = Energy saved
E = electricity obtained
REE = Reference electrical yield of a conventional electric generator (without waste heat utilization)
Cp = Process heat obtained
RTR = Reference thermal yield of a conventional steam system (without electricity generation)
C = Energy supplied to the cogeneration system

Practical examples

1. A self-producer consumed 150,000 tons of bagasse in the boilers and generated 20,000 MWh of electricity. Calculate the portion of the fuel used for cogeneration and for final consumption.

   PC of bagasse = 1900 kcal/kg = 1.9 Gcal/ton; PC of electricity = 860 kcal/kWh = 0.86 Gcal/MWh 0.86 * 20000 * 17200 Gcal ==> electricity in Gcal; taking 50% as the equivalent electrical yield for cogeneration we have: 17200/0.50 = 34400 Gcal of bagasse; dividing the Gcal of bagasse by its caloric value: 34400/1.9 = 18105 tons of bagasse for generation; and: 150000–18105 = 131,895 tons of bagasse for final consumption

2. A self-producer consumed 40,000 tons of fuel oil, 20 million cubic meters of natural gas and 30,000 tons of coal in the boiler to generate 15,000 MWh of electricity. All the boilers produced superheated steam for the steam turbine generator. Calculate the amount of fuel for self-generation and for final consumption.

   PC of fuel oil = 10100 kcal/kg = 10.1 Gcal/ton; PC of natural gas = 9000 kcal/m^3 = 9000.0 Gcal/million m^3; PC of coal = 7000 kcal/kg = 7.0 Gcal/ton; PC of electricity = 860 kcal/kWh = 0.86 Gcal/MWh

ANNEX VII. Coal Classification

Table 42. Coal

Class/group		Fixed coal (%)	Volatile matter (%)	Caloric value (BTU/lb)
Anthracite	Meta-anthracite	>98	<2	-
	Anthracite	92 – 98	2 – 8	-
	Semi-anthracite	86 – 92	8 – 14	-
Bituminous	Low volatility	78 – 86	14 – 22	-
	Medium volatility	69 – 78	22 – 31	
	High volatility A	<69	>31	> 14,000
	High volatility B	-	-	13,000 – 14,000
	High volatility C	-	-	10,500 – 13,000
Sub-bituminous	Sub-bituminous A	-	-	10,500 – 11,500
	Sub-bituminous B	-	-	9,500 – 10,500
	Sub-bituminous C	-	-	8,300 – 9,500
Lignite	Lignite A	-	-	6,300 – 8,300
	Lignite B	-	-	< 6,300

ANNEX VIII. Wind Energy

Wind energy is energy contained in the wind, which is used primarily in turbine-generator groups to produce electricity. This type of energy is a clean, renewable source with low environmental impacts.

The main applications for a wind energy system include electrification of remote villages, pumping water for irrigation, pumping oil, energizing remote communication systems, etc.

Types of Wind Turbines

Low-Power Generators

With power between 180 and 3000 Watts, lower-power generators produce currents of 12 to 24 volts, and higher-power generators produce 120 to 240 volts. They are used to supply electricity to low-consumption, off-grid homes and also in marine vessels.

High-Power Generators

These are generators that currently reach an individual power of up to 1300 kW (in Latin America) and installed in wind farms can jointly reach several tens of megawatts of power.

The first wind turbines had yields of 10%, but more modern ones use control systems and always operate with maximum aerodynamic efficiency, reaching yields close to 50%.

The energy fraction captured by a wind turbine is given by the Cp (power coefficient) factor. This power coefficient has a maximum value of 59.3%, called the Betz limit.

Power Produced by Wind Turbines

The power output of a wind turbine is directly proportional to the area swept by the “S” blades and the cube of the wind speed “v”.

$$P = k.S.v^3$$

It is necessary to raise the height of the wind turbine to get higher wind speeds. They are usually installed in mountain or waterfront areas. In the case of high mountains, the decline in air density negatively affects power.

The more blades, the lower the yield, although less startup torque is needed. The three-bladed turbine is considered the optimal choice. The blade pitch and orientation are variable.

Wind turbines are designed for a range of specific wind speeds.

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