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Technical guidelines for the evaluation of energy savings of thermal power plants

Lignes directrices techniques pour l'évaluation des économies d'énergie des centrales électriques thermiques

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso .org/iso/foreword.html.

This document was prepared by ISO/TC 301, *Energy management and energy savings*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document provides a general and practical framework for evaluating energy savings of thermal power plants, including steam power plants based on the Rankine cycle, gas turbine plants and combined cycle systems. These power plants mainly comprise one or several thermal power generating units (TPGUs) to produce electricity only or both electricity and heat (i.e. cogeneration facilities and combined heat and power systems) by burning coal, oil products, natural gas and/or other fuels.

This document covers principles, procedures, evaluation indexes and calculation methods when determining the potential of energy savings of an existing TPGU before (an) energy performance improvement action(s) (EPIAs) or evaluating the contract guarantees of its energy savings after the EPIA(s) (e.g. energy performance contracting).

This document can be used by any interested party that intends to evaluate energy savings of a thermal power plant.

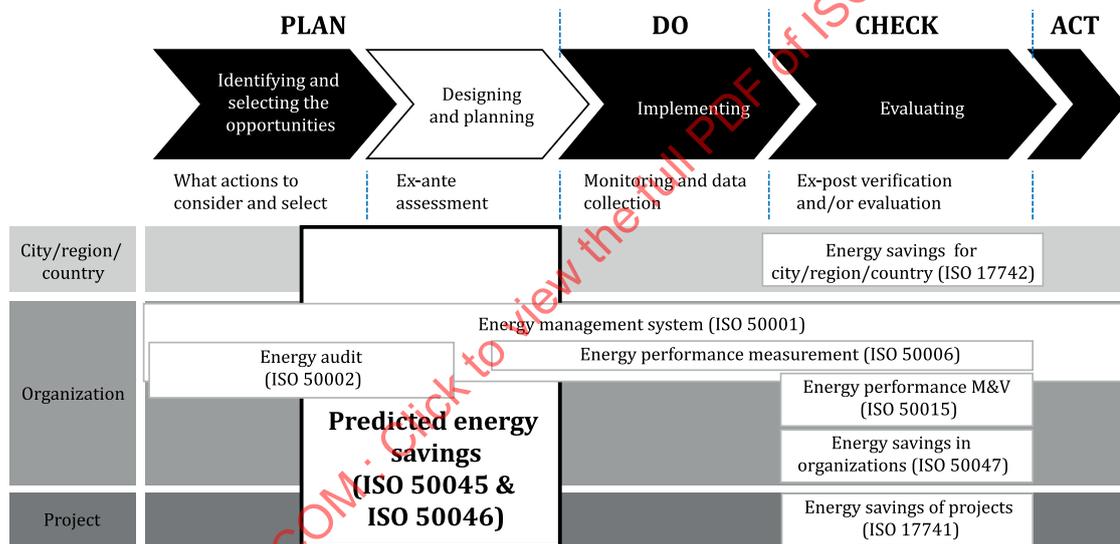The relationship of this document with related standards and the Plan-Do-Check-Act cycle is shown in Figure 1.

Figure 1 — General process for iterative improvement

Technical guidelines for the evaluation of energy savings of thermal power plants

1 Scope

This document gives general technical guidelines for evaluating energy savings of thermal power plants before and/or after implementing energy performance improvement action(s) (EPIAs). It includes evaluation, unit component efficiency, indexes calculation, analyses and reporting.

This document is applicable to existing thermal power generating units (TPGUs), where fossil fuels (e.g. coal, oil, natural gas) are combusted to generate electricity only or to supply thermal energy with the additional production of electricity (i.e. combined cycle power plants).

NOTE   A typical thermal power plant encompasses at least one TPGU. If there is more than one, the TPGUs can run independently.

Results obtained in accordance with this document can be used either to evaluate the potential of energy savings or to determine fulfilment of contract guarantees. They do not provide a basis for comparison of the energy savings between TPGUs.

This document does not prescribe performance tests or measurements for TPGU equipment components/systems, the sampling and analysis of the fuels used, substances added for control of emissions (e.g. halide, limestone) and by-products (e.g. ash, gypsum), and instruments to be employed, but it does specify parameters of interest in the determination of energy savings. Applicable procedures can be found in relevant documents (published or to be published).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
energy savings
ΔE
reduction of energy consumption compared to an energy baseline

Note 1 to entry: Energy savings can be actual (realized) or expected (predicted).

Note 2 to entry: Energy savings can be the result of implementation of an *EPIA* (3.4).

[SOURCE: ISO 17743:2016, 3.8, modified — "or autonomous progress" has been deleted from Note 2 to entry.]

3.2
fossil fuel
organic material, other than biomass, used as fuel

Note 1 to entry: In this document, the term fossil fuel primarily refers to coal, oil and natural gas used for *electricity generation* (3.11) or both electricity generation and heating supply.

[SOURCE: ISO 6707-3:2017, 3.5.8, modified — Note 1 to entry has been added.]

3.3
thermal power generating unit
TPGU
facility that consists of all the equipment necessary for the production of electricity or heat energy, or both, by combusting *fossil fuels* (3.2)

Note 1 to entry: In a typical fossil fuel-fired thermal power plant, for example, a TPGU would normally consist of one or more boilers, where coal, oil or natural gas is burned to create steam, one or more turbine generators, which convert the steam's heat energy into electricity, and other plant equipment, which supports both boiler and turbine generators.

Note 2 to entry: A TPGU usually operates independently and can be brought online or taken offline as demand fluctuates.

3.4
energy performance improvement action
EPIA
action or measure (or group of actions or measures) implemented or planned within a project intended to achieve energy performance improvement through technological, management, behavioural, economic or other changes

[SOURCE: ISO 17741:2016, 3.8]

3.5
combined heat and power
CHP
system that uses waste heat associated with electricity production, to provide heat for industrial, building space or other uses such as hot water and space heating for neighbouring buildings

[SOURCE: ISO 14452:2012, 2.16, modified — "associated with" has replaced "from" and "heat for industrial, building space or other uses such as" has been added.]

3.6
steam generating unit
furnace, boiler or heat recovery steam generator used to produce steam in the process of combusting *fossil fuels* (3.2) or waste heat

3.7
gas turbine generating unit
system combined with a gas turbine and all the essential equipment necessary for producing electricity or/and both electricity and useful heat

3.8
energy efficiency
effectiveness of converting chemical energy into electric energy or heat energy into electric energy, or both

[SOURCE: ISO 10987:2012, 3.11, modified — "chemical energy" has replaced "energy" and "electric energy or heat energy into electric energy, or both" has replaced "useful work".]

3.9
heating value
amount of heat released by the complete combustion in air of a specific quantity of fuel when the reaction takes place at constant pressure

Note 1 to entry: The heating value may be expressed as higher heating value (also known as gross calorific value or gross energy) or lower heating value (also known as net calorific value).

[SOURCE: ISO 2314:2009, 3.5, modified — "fuel" has replaced "gas or liquid fuel" and Note 1 to entry has been replaced.]

3.10
fuel equivalent
accounting unit of the fuel *heating value* (3.9) that represents the energy released by burning a specified amount of the fuel (e.g. coal, natural gas, oil)

Note 1 to entry: Fuel equivalent is a reference unit for the evaluation of various energy types.

3.11
electricity generation
process whereby electrical energy is obtained from some other form of energy

[SOURCE: IEC 601-01-06:1985, modified — The term has been changed from "generation of electricity".]

3.12
internal electricity consumption
amount of electricity consumed by a single *TPGU* (3.3) itself during the process of generation of electricity and/or heat over a given *period* (3.25)

3.13
electric energy supply
Q
amount of electricity exported by a single *TPGU* (3.3), which is transmitted and distributed to customers, typically through a power grid over a given *period* (3.25)

3.14
fuel equivalent consumption rate of electricity generation
amount of *fuel equivalent* (3.10) consumed by a single *TPGU* (3.3) for producing a unit of electricity

3.15
fuel equivalent consumption rate of electric energy supply
F_e
amount of *fuel equivalent* (3.10) consumed by a single *TPGU* (3.3) for supplying a unit quantity of electricity to customers

3.16
heat to power ratio
ratio of the heat utilized for purposes (e.g. district heating, water desalination) to the *electric energy supply* (3.13)

Note 1 to entry: This is different to "heat rate", which is the ratio of fuel energy input to electricity output.

3.17
pipe efficiency
η_p
thermal efficiency of a continuous enclosed passageway for the transmission of steam generated from a boiler to a steam turbine within a single *TPGU* (3.3), including steam chests, valves, etc.

3.18
reference value
set of parameters that can represent the status of a *TPGU* (3.3) in a certain operating mode

3.19
measurement and verification
M&V
process of energy measurement to reliably determine data in relation to the performance of *energy savings* (3.1) for defined system boundaries

[SOURCE: ISO/IEC 13273-1:2015, 3.3.5, modified — "the performance of energy savings" has replaced "energy performance".]

3.20
auxiliary equipment
equipment or devices of a *TPGU* (3.3) that are typically used for supplementing and assisting unit systems

Note 1 to entry: Typical auxiliary equipment may include boiler cleaning equipment, fuel preparation and burning equipment, economizers and air heaters, ash handling systems, turbine auxiliaries, turbine cycle equipment and balance of plant equipment.

3.21
conversion factor
C_f
ratio of two measurement units for quantities of the same kind

[SOURCE: ISO 80000-1:2009, 3.24, modified — "between units" in the term and the examples have been deleted.]

3.22
energy savings income
income resulting from implementing an *EPIA* (3.4) over a defined *period* (3.25)

3.23
rated operating condition
operating condition requiring fulfilment during measurement in order that equipment performs as designed or determined

[SOURCE: ISO 4064-1:2014, 3.4.4, modified — "equipment performs as designed or determined" has replaced "a meter perform as designed".]

3.24
rated operation
operation under *rated operating condition* (3.23)

3.25
period
time duration where predicting or measuring results can be obtained

4   Symbols, units and abbreviations

For the purposes of this document, the following symbols, units and abbreviations apply.

The user should either adjust all units or adopt suitable conversion factors to ensure unit consistency. For example, GJ might be used for large plants, kJ for small plants.

C_f	conversion factor	
ΔE	energy savings	kJ
F_e	fuel equivalent consumption rate of electric energy supply	g/kWh
I_{nc}	energy-saving income	monetary unit

Q	electric energy supply	kWh
$Q_{o,b}$	energy at the output of a boiler boundary	kJ
$Q_{i,b}$	energy at the input of a boiler boundary	kJ
$Q_{l,b}$	energy losses at a boiler boundary	kJ
$Q_{eg,st}$	electric energy generated at a steam turbine boundary	kJ, kWh
$Q_{s,b}$	energy entering into the steam turbine from the boiler	kJ
Q_h	energy extracted for heating applications	kJ
$Q_{eg,gt}$	electric energy generated by a gas turbine	kJ, kWh
Q_f	heating energy of the fuel used	kJ
$Q_{eg,TPGU}$	electricity generation of a TPGU	kWh
$Q_{iec,TPGU}$	internal electricity consumption of a TPGU	kWh
$Q_{ees,TPGU}$	electric energy supply of a TPGU	kWh
U_p	unit price of the fuel used	monetary unit
$W_{f,gt}$	quantity of the equivalent fuels used by a gas turbine	kg
$W_{f,TPGU}$	quantity of the equivalent fuels used by a TPGU	kg
η_b	boiler efficiency	%
η_{st}	efficiency of the steam turbine	%
η_{gt}	efficiency for a simple cycle gas turbine unit	%
η_{CCPP}	efficiency for a CCPP	%
η_p	pipe efficiency	%
EPIA	energy performance improvement action	
CCPP	combined cycle power plant	
CHP	combined heat and power	
M&V	measurement and verification	
TPGU	thermal power generating unit	

5 Evaluation of energy savings

5.1 General

Energy savings evaluation in the TPGU before/after implementing an EPIA can be categorized as:

a) evaluation before implementation of an EPIA;

b) evaluation after implementation of an EPIA.

In a), estimated energy savings can be determined by using historical data before the action, with modelling as appropriate to reflect changes in equipment and operating conditions once the EPIA is implemented.

In b), energy savings are determined by measurement and verification (M&V) using measured values (before and after the actions) or with and without an action. When evaluating a thermal power plant, the rated operation and plant conditions should be considered.

Energy savings by an EPIA(s) in a TPGU are calculated using Formulae (1) to (5).

Prior to implementation of an action:

$$\Delta E_{\text{before}} = E_p - E_b + v_{\text{adj}} \tag{1}$$

After implementation of an action:

$$\Delta E_{\text{after}} = E_r - E_b + v_{\text{adj}} \tag{2}$$

where

ΔE is the energy savings;

E_p is the energy consumption of the prediction period;

E_b is the energy consumption of the baseline period;

E_r is the energy consumption of the reporting period;

v_{adj} is the adjusted quantity to align the conditions of the prediction (reporting) period and baseline period.

$$E_p = C_f \times F_{ep} \times E_{\text{out}} \tag{3}$$

$$E_b = C_f \times F_{eb} \times E_{\text{out}} \tag{4}$$

$$E_r = C_f \times F_{er} \times E_{\text{out}} \tag{5}$$

where

F_{ep}, F_{eb} and F_{er} are the fuel equivalent consumption rate of electric energy supply for the prediction period, baseline period and reporting period, respectively;

E_{out} is the output of electric energy;

C_f is the conversion factor.

5.2 Principles

The following principles should be followed.

— The appropriate measurement boundary for the EPIA should be determined, and interactive effects should be taken into account.

— The relevant variables affecting energy performance should be identified for the equipment involved in the EPIA.

— The appropriate baseline measurement period should be determined to effectively represent energy performance under expected operating conditions.

— The appropriate modelling approach (e.g. thermodynamic or statistical) should be determined to account for changes in relevant variables for the baseline case.

— The appropriate ex-ante modelling approach should be determined for the EPIA during the reporting period.

— The calculation of ex-ante savings should be informed, appropriate load forecasts and other operating conditions for the EPIA determined, and historical loads, market demand cycles and expected changes in market demand considered.

— The appropriate measurement or modelling approach should be determined to quantify reporting period performance under changing conditions.

— The baseline and/or reporting period modelling should be calibrated based on actual measured data, where applicable.

— Any static factors that may require non-routine adjustments to be made should be determined.

— Appropriate indexes should be chosen and reference values should be determined using operating or test data of the TPGU before an EPIA.

> NOTE   Design data is used in case the test data is not available.

— Relevant curves or formulae should be obtained using statistical analyses, according to the effects of operating parameters on equipment efficiency and output generation or fuel consumption of the TPGU.

— The selected indexes using operating or test data after an EPIA should be determined for comparing with the reference values.

— Data comparison, calculation and analyses should be conducted under the same unit load and adjusted conditions.

— The reference values should be adjusted when the operating time and equipment conditions have been changed.

— The cause of quantitative deviation should be determined between the reference values and the operating data.

5.3   Evaluation indexes

The evaluation system introduces the key indexes that can reflect the technical and economical performance of the TPGU as a whole, including operating and test data, field operation reports, unit performance test reports, unit reports for pre- and post-overhauls, regular or specialized reports for analysing energy savings, etc.

Figure 2 shows the index structure of evaluation of energy savings for the TPGU. Saving fuels and electricity is the main target for energy savings of the TPGU, and its amount of energy savings can be evaluated using the fuel equivalent consumption rate. The primary index can be subdivided into the secondary indexes relevant to the boilers, steam/gas turbines, duct, the fuels used, electricity generation and the internal electricity consumption. Based on the indexes calculated from the operating data during a certain period and the reference values set, the evaluation of energy savings can be achieved by determining the causes of the variation of the primary index. If the TPGU is used for supplying heat energy with producing electricity (i.e. cogeneration and CHP), the heat to power ratio and other indexes could be used.
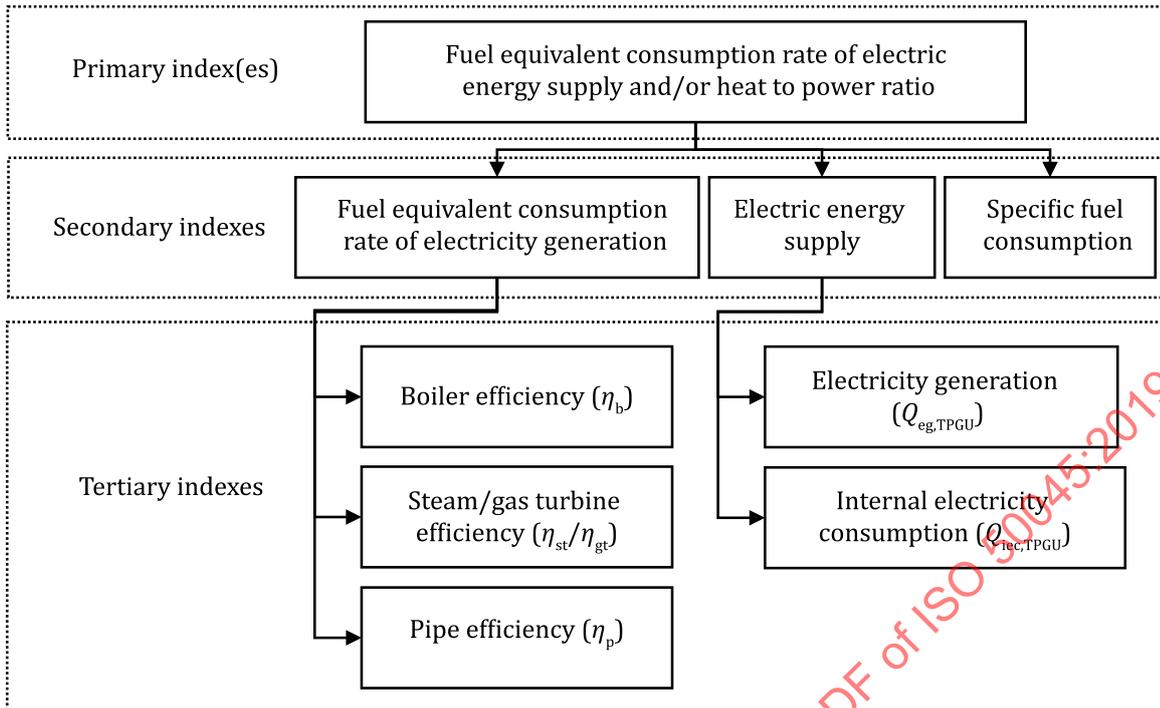
Figure 2 — Index structure of evaluation of energy savings for a TPGU

## 6 Unit component efficiency

6.1 Boilers

6.1.1 Boundary

Boilers are custom designed with a specific arrangement to supply steam by burning fossil fuels to the steam turbine. Their boundaries encompass the equipment relevant to the furnace, fuel/air supply, flue gas circulation, steam/water conversion and other miscellaneous equipment (e.g. pumps, fans), as shown in Figure 3.

6.1.2 Boiler energy balance

The efficiency of the energy conversion of boilers can vary with their steam cycle design (e.g. natural circulation, forced circulation, subcritical and supercritical once-through boilers) and chemical additives (sorbents) added for control of emissions. Accuracy is primarily dependent on:

— the type of fuel (e.g. coal, natural gas);

— the steam cycle design;

— the boiler operating load condition;

— the efficiency calculation method selected;

— energy that should be taken into account for input, output and losses;

— the choice of the basis of the fuel heating value, whether higher or lower heating value;

— parameters to be measured, e.g. ambient temperature and humidity;

— estimated values to be used for unmeasured parameters.
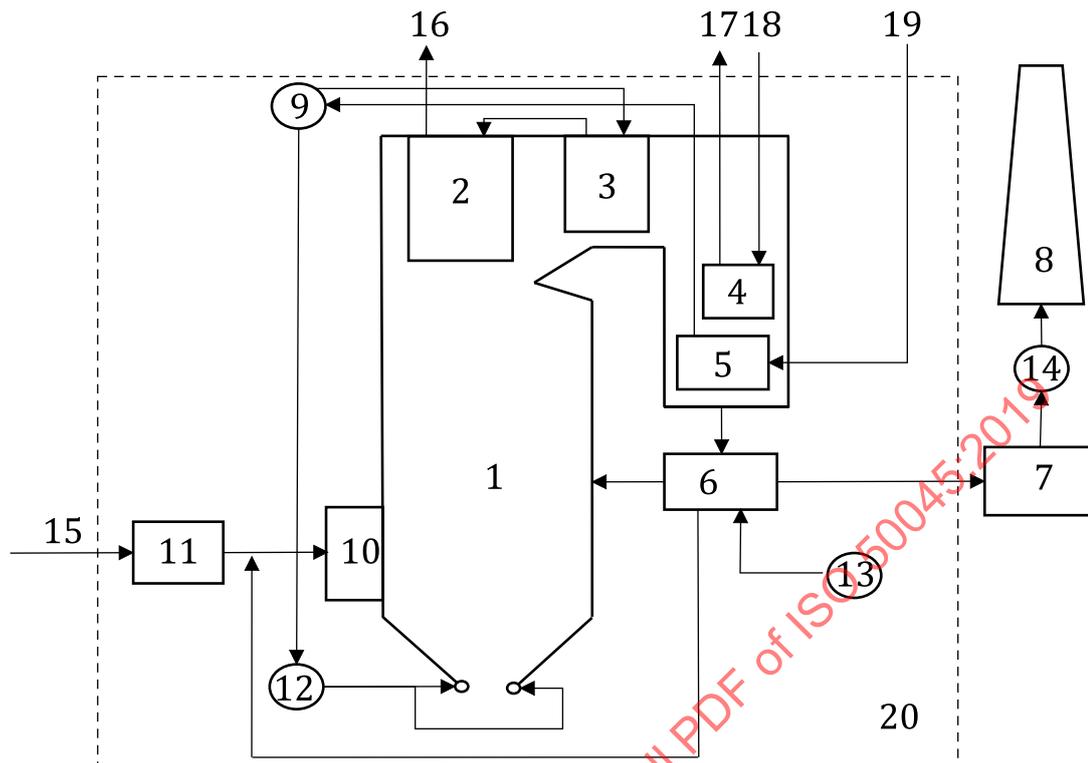
Key

|			
1	furnace	11	fossil fuel pretreater
2	secondary superheater	12	circulating pumps
3	primary superheater	13	forced draft fans
4	reheater	14	induced draft fans
5	economizer	15	fossil fuels
6	air preheater	16	main steam
7	air quality control device(s)	17	hot reheat
8	stack	18	cold reheat
9	drum	19	feedwater
10	burners	20	boiler boundary

NOTE 1   The selection of the fossil fuel pretreater (key 11) is dependent on the type of the fuel being burned, e.g. the pulverisers/crushers for coals and the filers/heaters for burning oil/natural gas.

NOTE 2   Oil and gas fired boilers cannot have primary air, which generally flows into the furnace (key 1), with crushed coals through the burners (key 10) for coal-fired boilers.

NOTE 3   This figure only considers the input and output of heat energy within the boundary, without the energy consumed by mechanical movement driven by electricity in auxiliary equipment (keys 6, 11, 12 and 13).

Figure 3 — Boundary for a typical thermal power plant boiler

[Figure 4](#) shows a schematic diagram for the energy balance of the boiler.
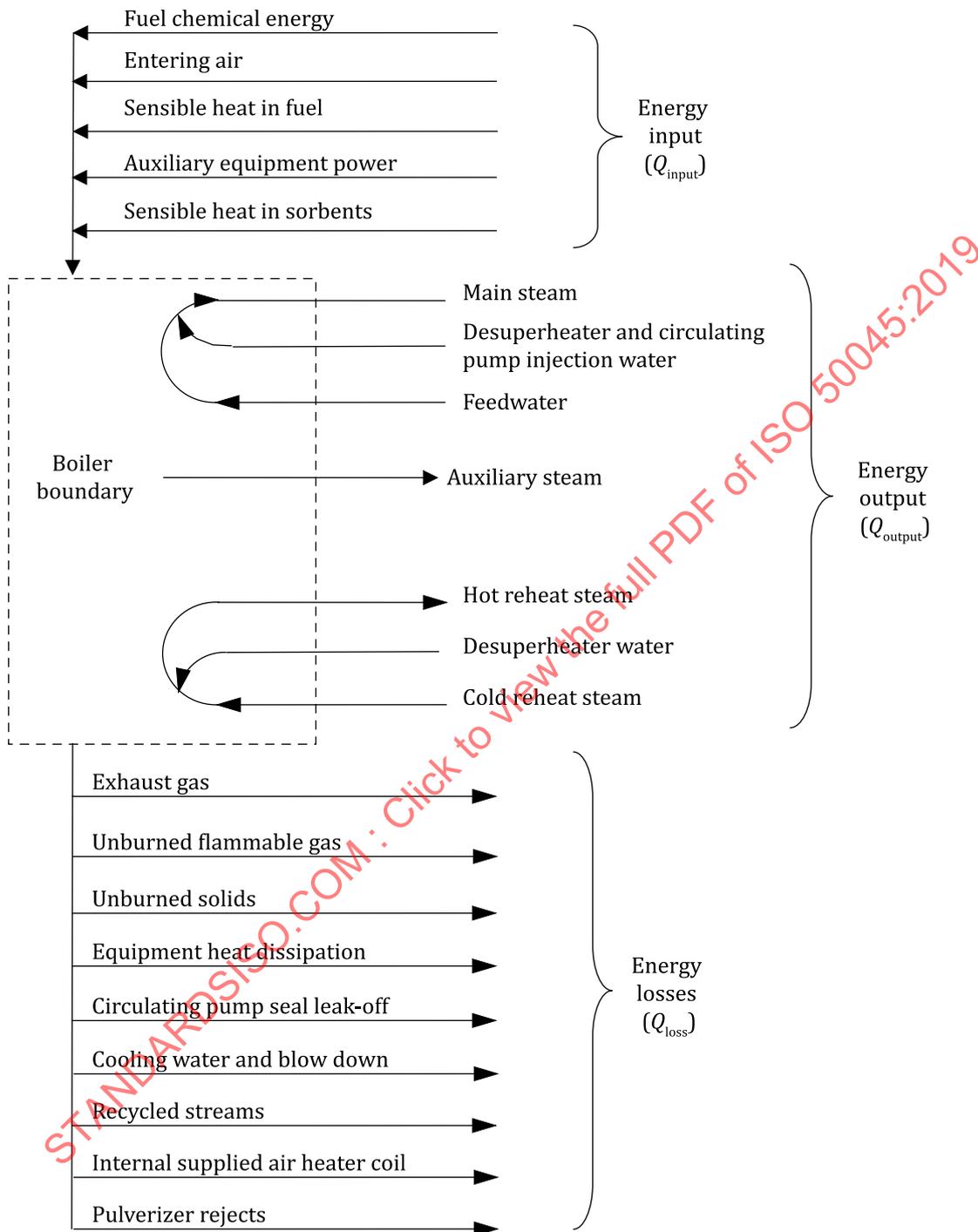
NOTE   Source: ASME PTC 4-2013, modified.

Figure 4 — Energy balance for a boiler boundary

6.1.3 Boiler efficiency calculations

There are two methods for determining the boiler efficiency. Accuracy, practicability and availability should be taken into consideration to select a method.

a) Input-output method.

The input-output method, also known as the direct method, can be expressed as Formula (6) and used when direct and accurate measurements of all the inputs and outputs of energy are available:

$$\eta_b = \frac{Q_{o,b}}{Q_{i,b}} \times 100\,\%$$

(6)

where

$Q_{o,b}$ is the energy, in kJ, at the output of a boiler boundary;

$Q_{i,b}$ is the energy, in kJ, at the input of a boiler boundary;

η_b is the boiler efficiency.

NOTE   The primary measurements include the flue flow rates, the flow of feedwater entering the boiler boundary, desuperheating water and all secondary output streams (e.g. boiler blow down and auxiliary steam), pressure and temperature of all working fluid steam (e.g. entering feedwater, superheater outlet and auxiliary steam), and higher (lower) heating value of the fuel used as well as reheat flows.

b) Energy balance method.

The energy balance method, also known as the indirect method, can be expressed as Formula (7) and used when all losses of energy can be identified and measured (or estimated):

$$\eta_b = \left(1 - \frac{Q_{l,b}}{Q_{i,b}}\right) \times 100\,\%$$

(7)

where

$Q_{l,b}$ is the energy, in kJ, losses at a boiler boundary;

$Q_{i,b}$ is the energy, in kJ, at the input of a boiler boundary;

η_b is the boiler efficiency.

Tables 1 and 2 give a comparison between the input-output and energy balance methods.

Table 1 — Input-output method

Advantages	Disadvantages
Primary parameters from the efficiency definition (input, output) are directly measured.	Fuel flow and fuel heating value, steam flow rate and steam properties need to be measured very accurately to minimize uncertainty.
Requires fewer measurements.	Does not aid in locating source of possible inefficiency.
Does not require estimation of unmeasurable losses.	Requires the use of energy balance calculation method for correction of test results to standard or guarantee conditions.
	Corrections to standard or guarantee conditions can only be made using the energy balance method.
NOTE Source: ASME PTC-4:2013.	

Table 2 — Energy balance method

Advantages	Disadvantages
The primary measurements (flue gas analyses and flue gas temperature) can be made very accurately.	Requires more measurements.
Permits corrections of test results to standard or guarantee conditions.	Does not automatically yield capacity and output data.
The as-tested efficiency often has lower uncertainty because the measured quantities (losses) represent only a small fraction of the total energy.	Some losses are practically unmeasurable and value has to be estimated.
The effects of fairly substantial errors in secondary measurements and estimated values are minimal.	
Sources of large losses are identified.	
NOTE Source: ASME PTC-4:2013.	

#### 6.1.4   Others

There are many potential maintenance and operational changes that can improve boiler system performance, such as online boiler tube cleaning, flue-gas waste heat recovery, optimization of crushers, or improvements in feedwater pump and fan performance.

Such improvements may not be easily quantifiable from overall boiler system performance, but may be modelled or simulated using engineering principles based on expected operating conditions. For details of the evaluation, see References [21] and [22].

6.2   Steam turbine/generator efficiency

Figure 5 shows a typical boundary for a steam turbine. For a typical TPGU, steam turbines are directly coupled with an electric generator(s), and thus a mechanical rotation is created when the steam produced in the boilers passes through the turbine and drives the generator(s) to produce the electricity.
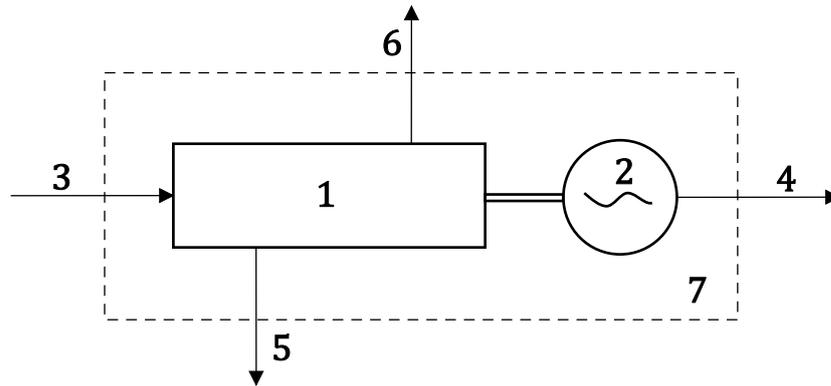
Key

1 steam turbine
2 electric generator
3 main steam from a boiler
4 electric power

5 heat sink
6 extracted steam used for heating application
7 steam turbine generator train boundary

NOTE   This figure only considers the input and output of heat energy within the boundary, without the energy consumed by auxiliary equipment out of the boundary.

Figure 5 — Typical boundary for a steam turbine

The thermodynamic efficiency, or first-law efficiency, of the steam turbine can be calculated based on Formulae (8) and (9).

For producing electric energy only:

$$\eta_{st} = \frac{Q_{eg,st}}{Q_{s,b}} \times 100\,\%$$

(8)

For cogeneration and CHP:

$$\eta_{st} = \frac{Q_{eg,st} + Q_h}{Q_{s,b}} \times 100\,\%$$

(9)

where

$Q_{eg,st}$ is the electric energy generated at a steam turbine boundary, in kJ (1 kWh = 3 600 kJ);

$Q_{s,b}$ is the energy entering into the steam turbine from the boiler, in kJ;

Q_h is the energy extracted for heating applications, in kJ;

η_{st} is the efficiency of the steam turbine.

6.3   Gas turbine efficiency

6.3.1   General

TPGUs can be either simple cycle (see 6.3.2) or combined cycle (see 6.3.3), thus far. Simple cycle systems consist only of successive compression, combustion and expansion. Combined cycle systems combine a simple gas turbine cycle with a steam or other fluid Rankine cycle for heat recovery applications (e.g. electricity generation, heat supply). Both systems can be evaluated by their thermodynamic efficiency or first-law efficiency.

6.3.2 Simple cycle gas turbine systems

Simple cycle gas turbine power units mainly consist of a gas turbine and an electric generator, as shown in Figure 6. The thermodynamic efficiency can be calculated by the ratio of the usable power produced to the fuel energy supplied per unit of time.

For a simple cycle gas turbine unit, the thermodynamic efficiency, or first-law efficiency, can be calculated using Formula (10):
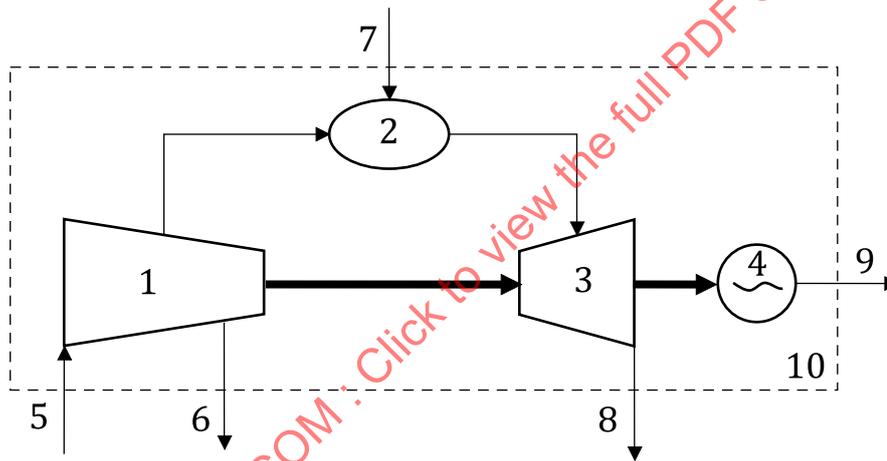
$$\eta_{gt} = \frac{Q_{eg,gt}}{Q_f} \times 100\,\% \tag{10}$$

where

$Q_{eg,gt}$ is the electric energy generated by a gas turbine, in kJ (1 kWh = 3 600 kJ);

Q_f is the heating energy of the fuel used, in kJ;

η_{gt} is the efficiency for a simple cycle gas turbine unit.

Key

1	compressor	6	extracted air
2	combustor	7	gas/liquid fuels
3	gas turbine	8	exhaust gas
4	electric generator	9	electric power
5	inlet air	10	gas turbine train boundary

Figure 6 — Typical train boundary for a simple open gas turbine generating unit

6.3.3 Combined cycle power plants

Combined cycle power plants (CCPPs) mainly consist of a gas turbine, a heat recovery system and a steam turbine. Steam is created by the exhaust heat captured from the gas turbine in the heat recovery system and is sent to the steam turbine for delivering additional electricity or supplying heat, as shown in Figure 7.

The thermodynamic efficiency, or first-law efficiency, for a CCPP can be calculated using Formula (11) when all extracted by gas turbine is used to drive the steam turbines to generate electricity:
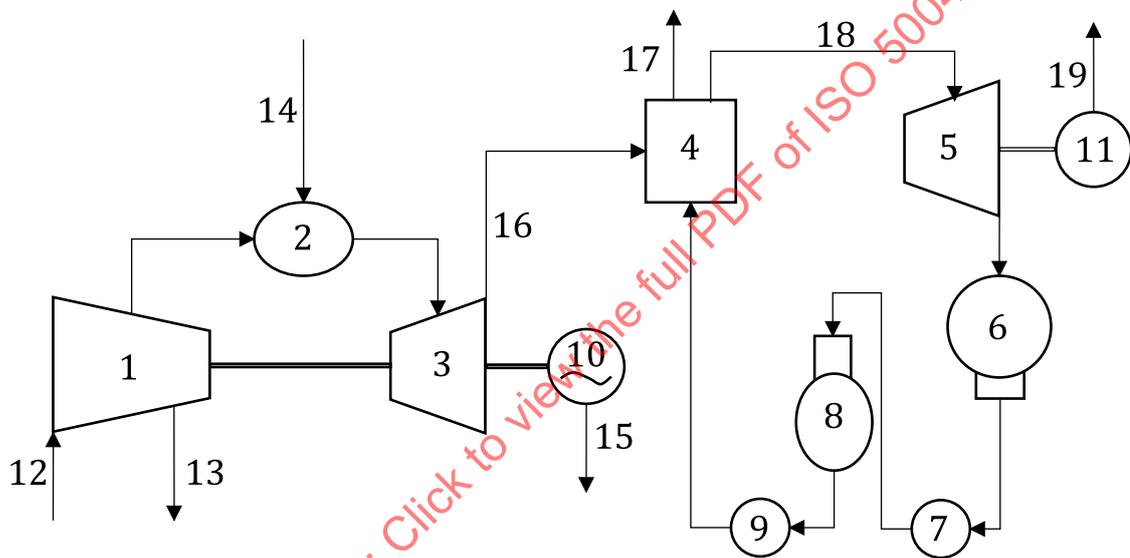
$$\eta_{CCPP} = 1 - \left(1 - \eta_{gt}\right)\left(1 - \eta_{st}\right) \tag{11}$$

where

η_{CCPP} is the efficiency for a CCPP;

η_{gt} is the efficiency for a gas turbine;

η_{st} is a measure of the efficiency of transforming gas turbine exhaust heat into mechanical shaft power, not isentropic turbine efficiency based on a steam flow.

Key

1	compressor	11	electric generator or heat supplying
2	combustor	12	inlet air
3	gas turbine	13	extracted air
4	heat recovery boiler	14	gas/liquid fuel
5	steam turbine	15	electric power
6	condenser	16	exhaust gas
7	condensate pump	17	stack gas
8	deaerator	18	high/low pressure steam
9	feedwater pump	19	electric power or heating power
10	electric generator		

NOTE 1   This figure only considers the boundary of the system, rather than its configuration.

NOTE 2   For CHP, heating energy (key 19) is used for heating supply.

NOTE 3   The electric energy required to drive the CCPP can be taken into the calculation.

Figure 7 — Process flow diagram for a typical combined cycle power plant

7 Calculation of evaluation indexes

7.1 Fuel equivalent

When conducting an economic comparison, the fuels used should be converted to common units due to the difference of the heat (calorific) values measured in fuels, e.g. the equivalent of coal used in China or the equivalent of oil in Japan and Korea.

7.2 Fuel equivalent consumption rate

Table 3 shows the calculation formulae associated with this document.

Table 3 — Calculation of evaluation indexes

	Steam generating units	Simple gas turbines	CCPPs
Fuel equivalent consumption rate of electricity generation	$$\dfrac{1}{\eta_\text{b} \cdot \eta_\text{st} \cdot \eta_\text{p}}$$ where η_b is the boiler efficiency; η_st is the efficiency of the steam turbine; η_p is the pipe efficiency.	$$\dfrac{W_\text{f,gt}}{Q_\text{eg,gt}}$$ where $W_\text{f,gt}$ is the quantity of the equivalent fuels used by a gas turbine; $Q_\text{eg,gt}$ is the electric energy generated by a gas turbine.	$$\dfrac{1}{\eta_\text{CCPP}}$$ where η_CCPP is the efficiency for a CCPP.
Electric energy supply	$Q_\text{ees,TPGU} = Q_\text{eg,TPGU} - Q_\text{iec,TPGU}$ where $Q_\text{eg,TPGU}$ is the electricity generation of a TPGU; $Q_\text{iec,TPGU}$ is the internal electricity consumption of a TPGU.		
Fuel equivalent consumption rate of electric energy supply	$W_\text{fe,TPGU} = k \cdot W_\text{f,TPGU}$, $k = \dfrac{Q_\text{fhhv}}{Q_\text{fe}}$ $\text{FE} = \dfrac{W_\text{fe,TPGU}}{Q_\text{ees,TPGU}}$ where $W_\text{f,TPGU}$ is the quantity of the equivalent fuels used by a TPGU; k is a conversion factor; Q_fhhv is the higher heating value of the fuel used; Q_fe is the heating value of the fuel equivalent; $W_\text{fe,TPGU}$ is the consumption of the fuel equivalent; $Q_\text{ees,TPGU}$ is the electric energy supply of a TPGU.		

8 Analyses and performance evaluation

8.1 Procedure for evaluation

When conducting an evaluation of energy savings, a team led by the top management of a power plant should be established, which has the responsibility and authority to:

a) develop an action plan for energy savings;

b)   approve energy savings planning and measures;

c)   guide the implementation of energy savings evaluation activities;

d)   coordinate activities within different departments;

e)   examine the progress of work regularly;

f)   circulate a notice of checking the work;

g)   examine and verify measures and planning of the energy savings proposed.

A group should be established in each department (or workshop) and should have the responsibility and authority to:

—   conduct a thorough and comprehensive check for the generating units and auxiliary equipment that it operates and manages;

—   categorize, sort and analyse the data collected by means of checking, inquiring, field testing and information consulting;

—   investigate, assess and record indexes relevant to fuel, boilers, turbines, water and metering;

—   develop a practical plan for retrofit projects.

Rigorous and comprehensive assessments require the involvement of people who have the skills and knowledge to identify and investigate energy efficiency improvements. Top management should ensure that the assessment team has sufficient in-house (or externally supplemented) resources and the necessary skills and influence both to undertake assessments and to ensure the uptake of any cost-effective opportunities.

The organization should ensure that the assessment involves people with specific knowledge, skills and responsibilities in the following areas:

—   professional engineers with knowledge of design and operating principles relevant to the plant being assessed;

—   engineers and technicians from operations and maintenance functions;

—   environment/sustainability;

—   corporate, trading and commercial areas with knowledge of electricity output demand and market strategies;

—   managers and operators with responsibility for production scheduling and control;

—   business development and asset management/engineers.

NOTE   Electricity output is a critical factor for determining energy savings because efficiency gains from opportunities can vary with output (e.g. for variable speed drives). In addition, most EPIAs will only be feasible if the plant load and capacity utilization are sufficient.

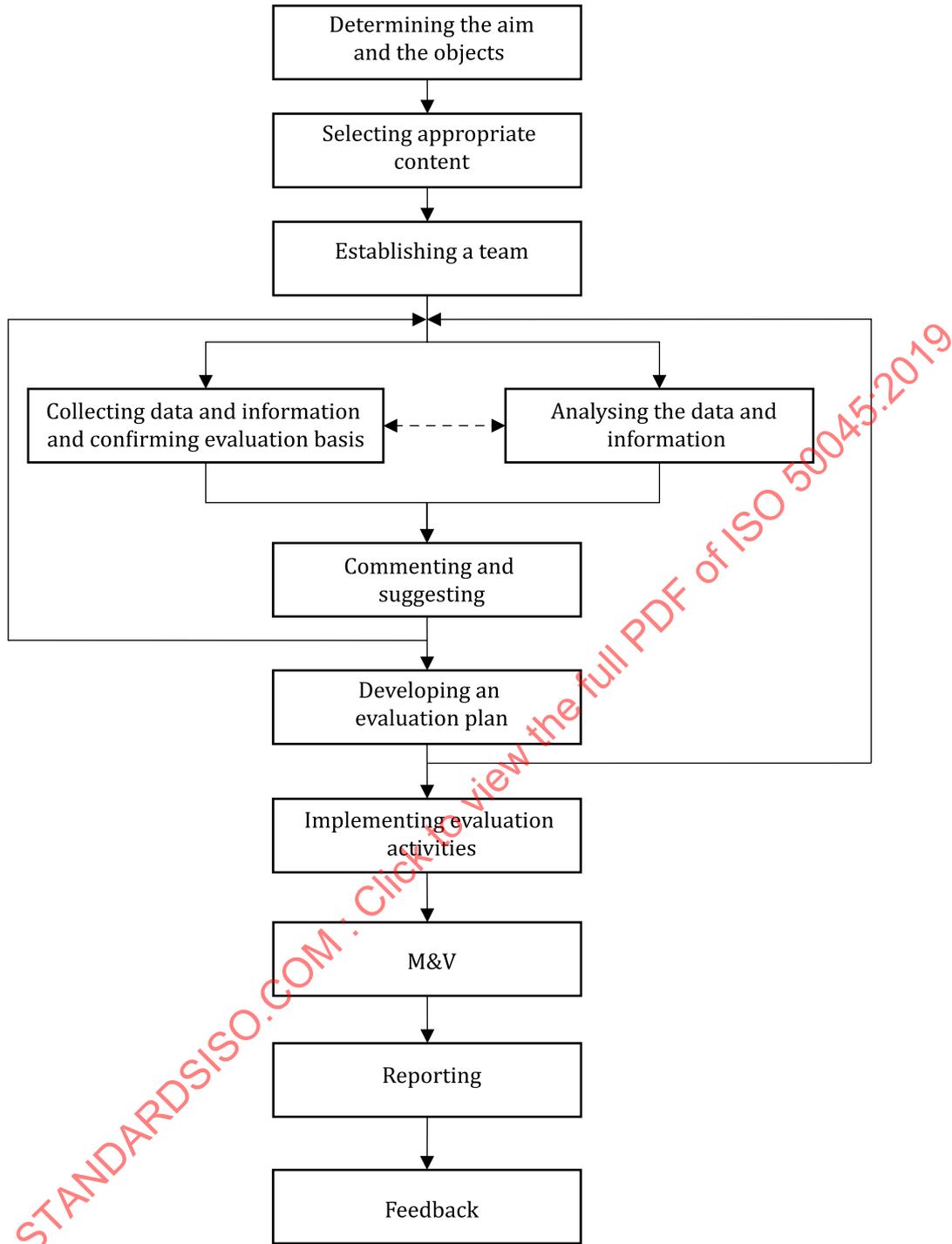Figure 8 shows the procedure for the evaluation of energy savings of a TPGU.

Figure 8 — Energy-savings evaluation flow chart

8.2 Evaluation of energy savings

8.2.1 Determination of energy savings income

When selecting an investment plan for saving energy of a TPGU, a financial quantitative (qualitative) analysis, calculation and comparison, based on the energy savings results obtained, can be used to a) establish the possible financial and social benefits for a pre-evaluation, and b) confirm income and