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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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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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.

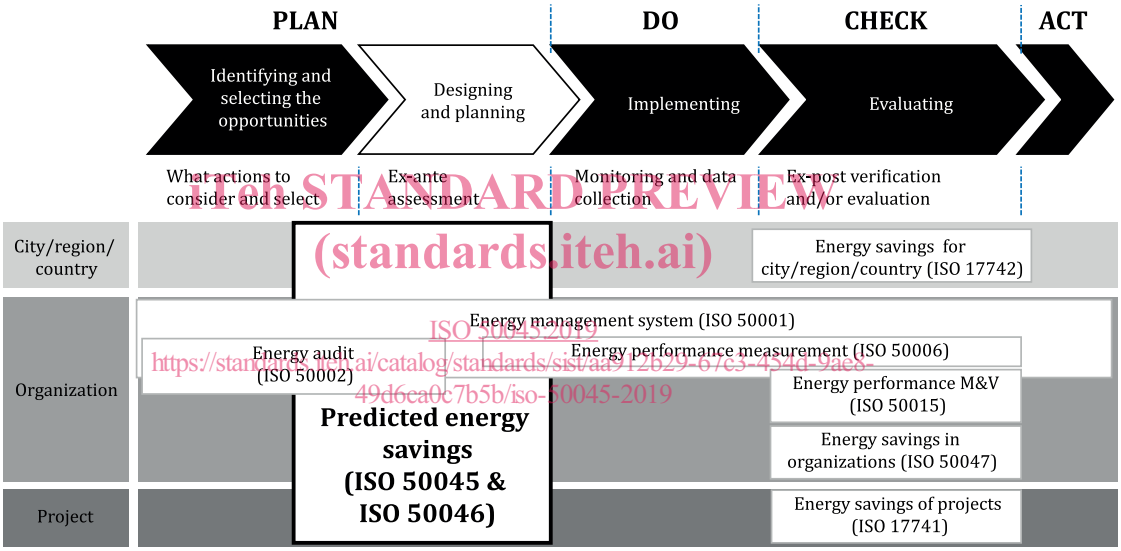

Figure 1 — General process for iterative improvement

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:

$$\Delta E_{\text{before}} = E_{\text{p}} - E_{\text{b}} + v_{\text{adj}} \tag{1}$$

After implementation of an action:

$$\Delta E_{\text{after}} = E_{\text{r}} - E_{\text{b}} + v_{\text{adj}} \tag{2}$$

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.

$$E_{\text{p}} = C_{\text{f}} \times F_{\text{ep}} \times E_{\text{out}} \tag{3}$$

$$E_{\text{b}} = C_{\text{f}} \times F_{\text{eb}} \times E_{\text{out}} \tag{4}$$

$$E_{\text{r}} = C_{\text{f}} \times F_{\text{er}} \times E_{\text{out}} \tag{5}$$

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.

