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Priroļ nik za soļ asno generacijo toplote in energije (CHP) (IEC 61472:2004)

Manual for Determination of Combined Heat and Power (CHP)

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CEN/CENELEC WORKSHOP AGREEMENT

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Manual for Determination of Combined Heat and Power (CHP)

This CEN/CENELEC Workshop Agreement has been drafted and approved by a Workshop of representatives of interested parties, the constitution of which is indicated in the foreword of this Workshop Agreement.

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Foreword

This CEN/CENELEC Workshop Agreement has been drafted and approved by a Workshop of representatives of interested parties on 2004-06-16, the constitution of which was supported by CEN and CENELEC following the public call for participation made in January 2003.

A list of the individuals and organizations which supported the technical consensus represented by the CEN/CENELEC Workshop Agreement is available to purchasers from the CEN Management Centre. These organizations were drawn from the following economic sectors: national and international energy (electricity, gas) and in particular CHP/DHC associations[1], municipalities owning/operating CHP/DHC systems, utilities owning/operating CHP/DHC systems, industries owning/operating CHP plants, manufacturers of CHP and/or DHC plants and equipment, engineering and consulting companies, industrial CHP and/or DHC users (pulp and paper industry, sugar industry).

The final review/endorsement round for this CWA was started on 2004-05-24 and was successfully closed on 2004-06-16.The final text of this CWA was submitted to CEN for publication on 2004-06-28.

This CEN/CENELEC Workshop Agreement is publicly available as a reference document from the National Members of CEN and CENELEC.

Comments or suggestions from the users of the CEN/CENELEC Workshop Agreement are welcome and should be addressed to the CEN Management Centre.

[1] CHP/DHC = Combined heat and power / district heating and cooling

Symbols and Indices

Latin symbols	Description	unit
f	fuel energy	MWh
p	electrical/mechanical energy	MWh
q	heat energy	MWh

Greek symbols	Description	units
η	efficiency	MWh/MWh
β	power loss	MWh/MWh
σ	power-to-heat ratio	MWh/MWh

Indices	Description
CHP	combined heat and power
non-CHP	non combined heat and power
q	heat energy
p	electrical/mechanical capacity, electrical/mechanical energy
m	mechanical
e	electrical

1 Objective and Scope

CHP can make significant fuel and emissions savings over conventional, separate forms of power generation and heat-only boilers. The generation of electricity from power stations is generally at efficiencies in the range 30-55%, based on the Net Calorific Value (NCV) or Lower Heating Value (LHV) of the fuel. Further losses occur in the transmission and distribution of electricity to customers. This means that 45-70% of the energy content of the fuel is not usefully employed. This unutilised energy content is rejected as heat directly to the atmosphere or into seas or rivers. The generation of electricity and the recovery of heat in CHP plants typically achieve overall efficiencies of 70-90% and above, corresponding to efficiencies of heat only boilers. The higher the overall efficiency and the power to heat ratio, the more effective the CHP process.

Unlike conventional methods of electricity generation, in order to achieve such high overall efficiencies, some of the heat cogenerated in a CHP Scheme is usefully employed in industrial processes or for heating and hot water in buildings. The heat used in this way displaces heat that would otherwise have to be supplied by burning additional fuel in boilers or other direct-fired equipment and so also leads directly to a reduction in CO_2-emissions. The development of CHP plays a crucial role in the European energy policy for reducing CO_2-emissions.

The determination of CHP products (heat and power outputs) is important not only for the CHP Directive [1] but also for the European Emissions Trading Scheme [2], State Aid guidelines for environmental improvement and the energy taxation Directive [3].

The objective of the CEN/CENELEC Workshop Agreement is to present a set of transparent and accurate formulae and definitions for determination of CHP (cogeneration) energy products and the referring energy inputs. The CEN/CENELEC Workshop Agreement shall simply formulate the procedure for quantifying CHP output and inputs, such as CHP electrical energy, CHP mechanical energy, CHP heat energy and CHP fuel energy. It does not include quality rankings such as assessments of fuel savings or environmental impact.

Gathering statistics and monitoring developments in the combined heat and power sector is difficult and can contain a considerable number of uncertainties. Some CHP plants may decouple the generation of heat and power at certain times or to a certain extent and thus CHP and NON-CHP electricity and heat may be generated in the same plant.

The lack of reliable information and transparency may be considered in itself as a barrier to the further development of the technology and negatively affects the image of the CHP sector. To remove the ambiguity resulting from a lack of standardised procedures across Europe, a set of widely accepted determination rules is needed. Such rules will create greater certainty that the basic concept of CHP is understood and determined in the same way.

As a result of this requirement the CEN[2] /CENELEC[3] Workshop on "Manual for Determination of Combined Heat and Power (CHP)" was initiated. It ran in parallel to the discussions on the Directive on the promotion of cogeneration based on a useful heat demand in the internal energy market [1].

1.1 Relation to Annex II of CHP Directive 2004/8/EC 11 February 2004

The resulting CEN Workshop Agreement (CWA) is to provide guidance for the implementation of Annex II of the CHP-Directive and the determination of the power-to-heat ratio (see section 5).

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2) European Committee for Standardization (http://www.cenorm.be)

3) European Committee for Electrotechnical Standardization (http://www.cenelec.org)

Whereas the amount of CHP electrical/mechanical energy defined as p_{CHP} in the CWA equals E_{CHP} in the CHP Directive.

Whereas total useful heat in the CWA (q) covers heat for a justified demand regardless of the possible CHP character, in the Directive the concept of useful heat implies useful heat from CHP only.

Whereas the amount of CHP useful heat energy defined as q_{CHP} in the CWA equals H_{CHP} in the CHP Directive.

Whereas the electrical/mechanical energy-to-heat energy ratio defined as σ_{CHP} in the CWA equals the power-to-heat ratio C in the CHP Directive.

2 Reading Instructions (Route Map)

This chapter is a route map through the manual. The manual is prepared/designed to handle all kind of plants and is therefore to some extent complicated when the plant is simple.

2.1 Instructions

Start to read chapter 3 where all the expressions used in the manual are defined and chapter 4 where the plant is defined and your plant can be classified. The chapter describes the CHP-plant, the CHP-process and the non-CHP generation of heat and electrical/mechanical energy. For small and simple plants read Annex A where useful simplifications are presented. For all other plants try to find the example in Annex C which corresponds to your plant as close as possible and follow the procedure step by step.

A schematic picture of the principles of the manual is given in chapter 5. The figure 5, 6 and 7 show the principles from a general overview to detailed equations. To simplify your classification and your determination of the CHP plant see Annex C.2 for instructions to draw a CHP scheme line diagram.

In chapter 6 the CHP plant boundaries are drawn. The principle is to keep the boundaries around the CHP process itself. Here all inputs and outputs are determined. Fuel input in 6.2, electrical and mechanical energy output in 6.3 and useful heat output in 6.4. Measurements are default. In case of lack of such measurement, indirect methods for determination of energy flows can be used provided they supply the adequate accuracy. Indirect methods are described in chapter 6.2.3 and 6.4.2.

Chapter 7 gives instructions how to separate non-CHP heat and the corresponding fuel. This is necessary in plants with live steam extraction and/or auxiliary/supplementary firing.

In chapter 8 determination of CHP overall efficiency is described. How to act when the plant can not run in complete back pressure mode and how to handle the cooling steam in a extraction steam turbine on minimum load.

Chapter 9 gives instructions how to separate non-CHP electricity and the corresponding fuel.

2.2 Annexes

Read Annex A to learn about how to simplify the determinations for small and simple plants.

Read Annex B to learn about determination of the power loss coefficients for CHP processes with steam turbines.

In Annex C.1 determination examples are presented. In C.2 instruction for describing of the CHP plant is given. Here also the Tag notation used in the manual is presented.

When the principles for determination are clear collecting data is the next step. In Annex C.3 and C.4, CHP plant monitoring and metering requirements as well as how to treat uncertainties is presented.

3 Definitions

For further explanations see section 4 and subsequent sections..

Combined heat and power (CHP) or "cogeneration" is the simultaneous conversion of primary energy into mechanical and/or electrical energy and useful heat energy in one (the same) plant. Simultaneously means that the energy content of a the fuel is used for the generation of both heat and electrical/mechanical power at the same time within a thermodynamic process (the CHP process) (see Article 3 (a) in [1]).

CHP plants are plants that simultaneously can generate electrical/mechanical power as well as useful heat power. Thereby all or least at a certain extent of generated useful heat power and electrical/mechanical power can be CHP useful heat power and cogenerated (CHP) electrical/mechanical power.

Reporting Period is the period of time used for reporting and determination of data for the CHP plant.

Heat rejection facilities are devices for the diversion of heat energy by means of which heat energy is discharged unused into the environment, e.g.:

- Waste heat condensers
- Compression air coolers not connected to a heat recovery system
- Bypass facilities
- Steam condensers not connected to a heat recovery system
- Radiators
- Cooling air coolers not connected to a heat recovery system
- Lube oil coolers not connected to a heat recovery system
- Charge air coolers not connected to a heat recovery system
- Stacks
- Auxiliary coolers not connected to a heat recovery system

The term "bypass" is used for the direct diversion of the flue gases into the environment, avoiding the waste heat boiler / flue gas heat exchanger. The consequence is incomplete use of the heat in the flue gas.

3.1 Energies

Total useful heat energy (q) is the heat energy (thermal energy) supplied by a plant in a reporting period. It is heat energy supplied by a plant that would otherwise demonstrably be supplied from other sources.

Change in total useful heat energy (Δq).

Total electrical/mechanical energy (p) is defined as gross electrical/mechanical energy output of a plant in a reporting period.

Change in total electrical/mechanical energy (Δp).

Total fuel energy (f) is the total fuel energy based on lower heating value (LHV) needed in a CHP plant to generate electrical/mechanical energy and useful heat in a reporting period.

CHP useful heat energy (q_{CHP}) is the heat energy (thermal energy) supplied by a CHP process to a network or a production process in a reporting period. It is heat energy that would otherwise be supplied from other sources (see Article 3 (b) in [1]).

CHP electrical/mechanical energy (p_{CHP}) is defined as the gross electrical/mechanical energy, which is generated in direct relation to the generation of CHP useful heat (see Article 3 (d) in [1]) in a reporting period.

CHP fuel energy (f_{CHP}) is the fuel energy based on lower heating value (LHV) needed in a CHP process to co-generate CHP electrical/mechanical energy and CHP useful heat energy in a reporting period.

Non-combined useful heat energy ($q_{non\text{-}CHP}$) is the heat energy (thermal energy) supplied by a CHP plant to a network or a production process, which is not generated in direct relation to the generation of CHP electrical/mechanical energy in a reporting period.

Non-combined electrical/mechanical energy ($p_{non\text{-}CHP}$) is defined as the gross electrical/mechanical energy, which is generated in a reporting period at times when no or insufficient heat energy is required. Thus this electrical/mechanical energy is not generated in direct relation to the generation of useful heat.

Non-combined fuel energy ($f_{non\text{-}CHP} = f_{non\text{-}CHP,q} + f_{non\text{-}CHP,p}$) is the fuel energy based on lower heating value (LHV) needed in a CHP plant for non-combined generation of useful heat energy and non-combined electrical/mechanical energy generation in a reporting period.

3.2 Dimensionless Figures of Energies

Total overall efficiency of energies ($\eta_{tot} = \eta_{CHP+non\text{-}CHP,q+non\text{-}CHP,p}$) is the ratio of all energy outputs to all energy inputs of a plant in a reporting period.

Overall efficiency of energies ($\eta = \eta_{CHP+non\text{-}CHP,p}$) is the ratio of energy outputs to energy inputs of a plant excluding non-CHP heat energy and the referring non-CHP fuel energy for generation of non-CHP heat energy in a reporting period (see Article 3 (g) in [1]).

CHP overall efficiency of energies (η_{CHP}) is the ratio of CHP energy output to CHP energy inputs of the CHP plant in a reporting period.

Electrical/mechanical power-to-heat ratio (σ_{CHP}) is the ratio between gross electrical/mechanical CHP energy (p_{CHP}) to CHP useful heat energy (q_{CHP}) in a reporting period (see Article 3 (k) in [1]).

Electrical/mechanical power loss coefficient (β) is the balance between increasing heat energy recovery (Δq) and reducing electrical/mechanical energy (Δp) of CHP plants with power loss in a reporting period.

Efficiency of non-combined electrical/mechanical energy generation ($\eta_{non\text{-}CHP,p}$) is the efficiency of the electrical/mechanical energy generation, which is not generated in direct relation to the generation of useful heat energy in a reporting period.

Efficiency of non-combined heat energy generation ($\eta_{non\text{-}CHP,q}$) is the efficiency of the heat energy generation, which is not generated in direct relation to the generation of CHP electrical/mechanical energy in a reporting period.

4 Description of CHP and Non-CHP Processes

In a combined heat and power (CHP) process high overall efficiencies can be achieved whereby a share of the energy output is electrical/mechanical power.

4.1 CHP Plant

CHP power plants may generate electrical/mechanical energy as well as useful heat energy at the same time (simultaneously, see Figure 1 — Transformation of Fuel Energy in a CHP Plant). Thereby not all useful heat energy and all electrical/mechanical energy has to be generated in CHP mode. Thus:

$p = p_{CHP} + p_{non\text{-}CHP}$

$q = q_{CHP} + q_{non\text{-}CHP}$

$f = f_{CHP} + f_{non\text{-}CHP,p} + f_{non\text{-}CHP,q}$

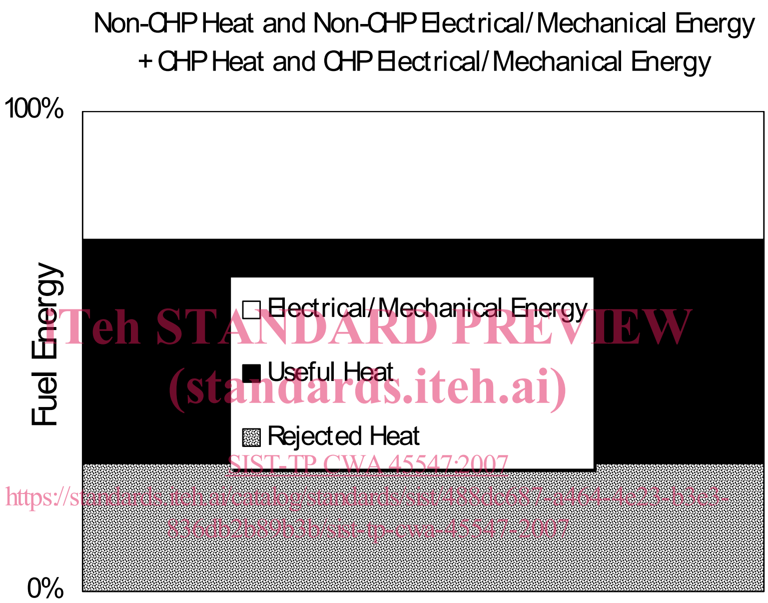

Figure 1 — Transformation of Fuel Energy in a CHP Plant

4.2 CHP Process

CHP electrical/mechanical energy is defined as the share of electrical/mechanical energy, which is at the same time generated in direct relation to the generation of useful heat energy, thus being CHP useful heat energy. Together the CHP electrical/mechanical energy and the CHP useful heat energy is the output from the CHP process as shown in (Figure 2 — Subdivision of a CHP Plant in Combined and Non-Combined Processes).

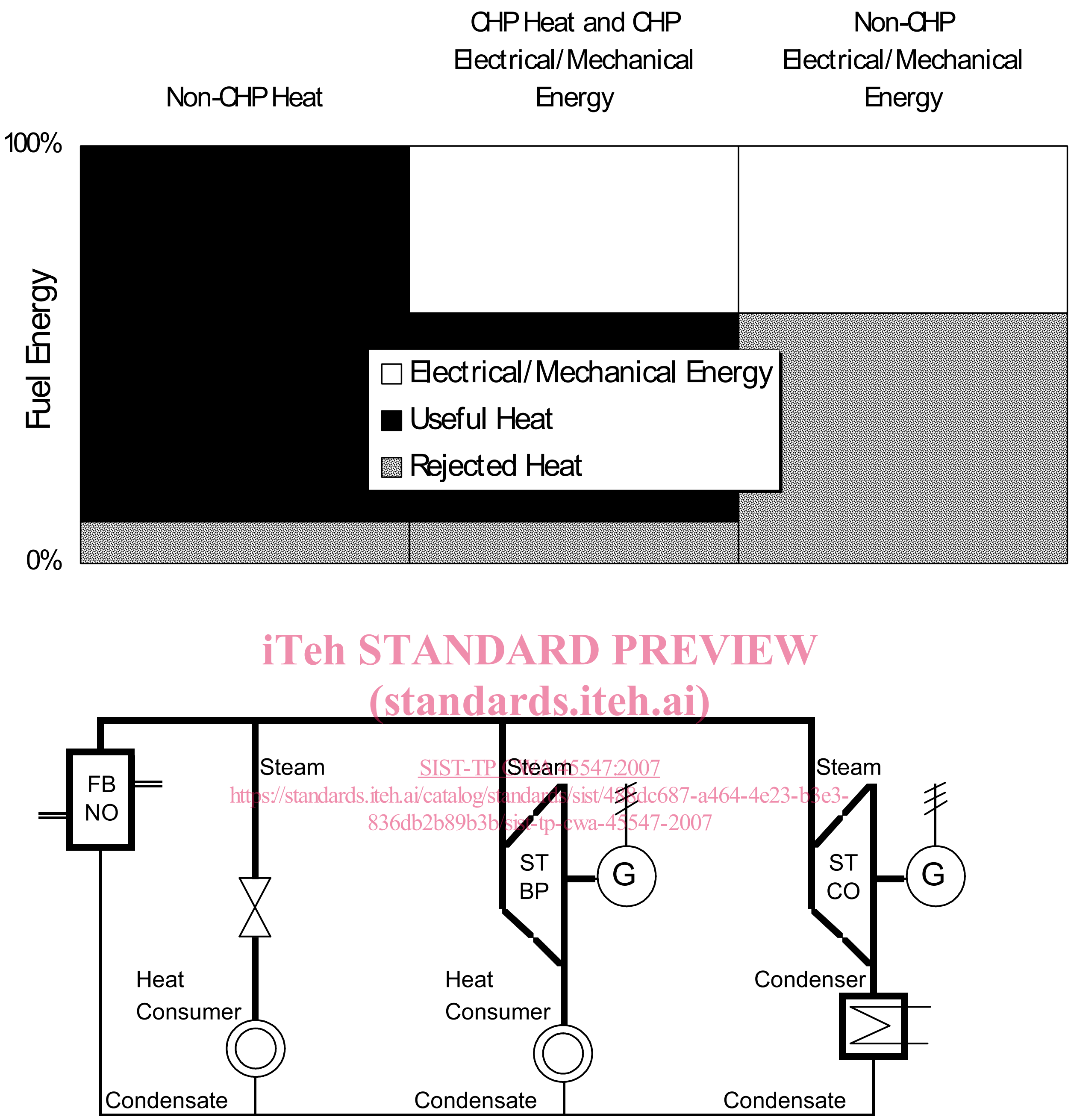

Figure 2 — Subdivision of a CHP Plant in Combined and Non-Combined Processes

4.2.1 Electrical/Mechanical Energy-to-Heat Energy Ratio

$\sigma_{CHP} = p_{CHP} / q_{CHP}$ Electrical/mechanical energy-to-heat energy ratio in MWh/MWh

4.2.2 CHP Overall Efficiency

The overall efficiency of the CHP process is defined as follows:

η_{CHP} overall efficiency of energies of CHP process in a reporting period in MWh/MWh

$\eta_{CHP} = (p_{CHP} + q_{CHP}) / f_{CHP}$

4.3 Non-Combined Heat Energy Generation

Non-Combined useful heat energy generation occurs in processes with generation of useful heat energy without upstream generation of electrical/mechanical energy (see Figure 3 — Non-Combined Heat Energy Generation with Additional Boilers), e.g. applying:

— Live steam extraction (steam extraction prior to generation of electrical/mechanical energy)

— Steam boilers without downstream (back-pressure or extraction-condensing) steam turbines

— Waste-heat boilers with auxiliary / supplementary firing without downstream (back-pressure or extraction-condensing) steam turbines However the waste heat (recovered heat) recovered from the GT exhaust gases in such boilers is an integral part of the CHP.

The heat efficiency of non-CHP processes is defined as:

$\eta_{non\text{-}CHP,q}$ Efficiency of non-combined heat energy generation in MWh/MWh

$\eta_{non\text{-}CHP,q} = q_{non\text{-}CHP} / f_{non\text{-}CHP,q}$

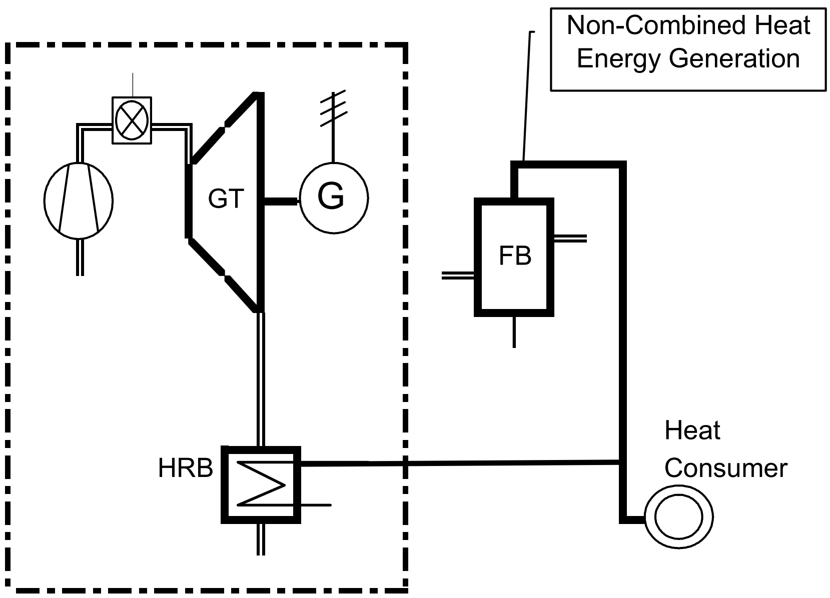

Figure 3 — Non-Combined Heat Energy Generation with Additional Boilers