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Cogeneration systems — Technical declarations for planning, evaluation and procurement

Systèmes de cogénération — Déclarations techniques pour la planification, l'évaluation et l'acquisition

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 26382 was prepared by Technical Committee ISO/TC 192, *Gas turbines*.

Cogeneration systems — Technical declarations for planning, evaluation and procurement

1 Scope

This International Standard describes the technical declarations for a cogeneration system (CGS) that simultaneously supplies electric power and heating and/or cooling, for planning, evaluation and procurement.

It applies to the identification of investigation items for project evaluation, CGS evaluation, and primary information works for CGS procurement.

It also specifies necessary check items in CGS planning, provides a procedure to obtain the satisfactory configuration of the CGS for each project, and includes a detailed process diagram of the key development steps.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15663-2:2001, *Petroleum and natural gas industries — Life-cycle costing — Part 2: Guidance on application of methodology and calculation methods*

3 Terms and definitions

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

3.1
asset
resource owned by an organization, normally for the purpose of generating income or increasing value

3.2
auxiliary heating and/or cooling sources
equipment installed in the CGS which supply additional heating and/or cooling, as required

EXAMPLE Steam and/or hot water boilers, direct-fired absorption chillers/heaters, and motor-driven machines.

3.3
availability
share of the total time that the CGS is available to produce electric power, heating and/or cooling as required during a defined period, normally a calendar year

3.4
capital expenditure
money used to purchase, install and commission a capital asset

[ISO 15663-1:2000, definition 2.1.6]

3.5
cogeneration system
CGS
facility which simultaneously generates electric power and heating and/or cooling using exhaust gas or waste heat from engines or prime movers

3.6
conventional system
system or equipment which supplies electric power (including imported electric power from an external grid) and heating and/or cooling independently without using exhaust gas or waste heat from engines or prime movers

3.7
fuel supply agreement
agreement entered into with a fuel supplier which provides the basis of ensuring the fuel supply requirements of the facility over a defined period

3.8
internal rate of return
IRR
discount rate that gives a net present value equal to zero

NOTE For more information on this time-discounted measure of investment desirability, see ISO 15663-2:2001, 4.1.4.

3.9
life cycle
all development stages of an item of equipment or function, from when the study commences up to and including disposal

[ISO 15663-1:2000, definition 2.1.14]

3.10
life-cycle cost
LCC
discounted cumulative total of all costs incurred by a special function or item of equipment over its life cycle

[ISO 15663-1:2000, definition 2.1.15]

NOTE Life-cycle cost means the sum of all the expenditures associated with the project during its entire service life. A method for calculating the life-cycle cost is shown in Annex B.

3.11
net present value
NPV
sum of the total discounted costs and revenues

[ISO 15663-1:2000, definition 2.1.18]

3.12
operating expenditure
money used for operation and maintenance, including associated costs such as logistics and spares

[ISO 15663-1:2000, definition 2.1.19]

3.13
payback period
period after which the initial capital invested has been paid back by the accumulated net revenue earned

[ISO 15663-1:2000, definition 2.1.20]

NOTE The payback-period method is not equivalent to the internal-rate-of-return method. The payback-period method is recommended only as a secondary method of measuring investment worth. In particular, it is suggested that the payback-period method be used in addition to a method based on the time value of money.

3.14
reliability
share of the time outside of planned maintenance and other planned shut-downs that the CGS can produce electric power and heat as required during a defined period, normally a calendar year

3.15
scheduled maintenance
maintenance of the CGS at regularly scheduled times

NOTE Scheduled maintenance includes planning times for the inspection, adjustment and exchange of equipment to prevent the CGS from malfunctioning and to recover efficiency and performance.

3.16
sensitivity analysis
analysis for determining the effects of the uncertainties in estimating parameter values, which is tested by independently varying one parameter at a time to determine how sensitive each parameter is to the project analysis and, therefore, the project risk

NOTE The testing process for any item under evaluation establishes whether or not the final conclusion is sensitive to a change in assumption. The variables subjected to sensitivity analysis will usually include capital costs, overall conversion efficiency, completion time, fuel costs and the escalation of costs.

3.17
system design
design of the CGS

4 Key project information and analysis for evaluation

4.1 General

In order to carry out the proper evaluation of the CGS, the following items shall be accurately analysed at each stage of the investigation. The important investigation items are listed in 4.2 through 4.4, and descriptions on detailed parameters are provided. Items included in this category should basically be provided by the purchaser.

4.2 Site conditions and energy demands

4.2.1 Site conditions

The purchaser of a CGS shall identify the installation site and related conditions necessary for the planning of the CGS. The following environmental conditions and various regulatory requirements which may affect the planning of the CGS shall be considered:

— weather conditions, average and maximum (predominant wind direction, wind speed, precipitation of rain and snow, etc.);

— general air quality (industrial emissions, sand, salt, soil, pollen, etc.);

- ambient conditions (temperature, pressure and humidity) including annual averages, maximum and minimum conditions;
- water supply temperature, its quality and quantity (hot-water supply, cooling water, de-mineralised water, water processing, etc.);
- land-use classification (business district, rural area, etc.);
- environmental air and effluent emission regulations (CO, CO_2, NO_X, SO_X, particulate matters, unburned hydrocarbon, visible smoke, cooling tower plume, etc.);
- regulations for vibration and noise (influence on neighbourhood);
- input fuel [type of fuel, specific energy, chemical composition, temperature (maximum and minimum), pressure (maximum and minimum), other properties];
- installation site (indoor, outdoor, seismic zone, site history, load-bearing capacity of soil, ground water level, frost line, snow load, sandstorms, transportation conditions, grid voltage, regulations for health and safety, etc.).

4.2.2 Energy demands

4.2.2.1 Investigation items for specifying energy demand

Maximum and minimum values, as well as data about variations in energy demand, shall be investigated carefully by the purchaser, including the demands for electric power and heating and/or cooling.

The following conditions related to energy demands shall also be clarified:

- electric power demand and voltage, frequency and power factor to be delivered;
- restrictions from the electrical grid, maximum power output, frequency variations, etc.;
- thermal demand, flow rate, pressure, temperature and quality requirements for heating and/or cooling to be delivered and to be returned;
- electrical and/or thermal load profile over a weekday and a weekend day (24 hours) allowing for process or seasonal demand variation.

4.2.2.2 Investigation of energy demand pattern

When a CGS is installed at a given site, it is important to identify the site classification because requirements for electric power and heating and/or cooling differ among various types of sites.

Typical types of facilities are as follows:

- office;
- hotel (resort, city, business, etc.);
- hospital (general, independent, etc.);
- store (retail, restaurant, department, supermarket, etc.);
- public site (government, hall, library, museum, etc.);
- sport, health or leisure facilities (swimming pool, gym, aquarium, etc.);
- computer centre;

- residence (apartment, detached house, etc.);
- welfare facility;
- educational institution (university, elementary or junior/senior high schools, etc.);
- compound facility (integrated building including different categories);
- district heating and/or cooling facility (facility which supplies heating and/or cooling to buildings located in a district);
- industrial factory (food, chemical and pharmaceutical machinery, electrical equipment, iron and metal, textile, pulp and paper, gas/oil and/or other energy, glass soda and ceramics, etc.).

If the facility is a building, it is important to know the total floor space, number of floors, area classification for each usage, and both the total area and the lay-down areas which are available during the construction.

4.3 Related policies and regulations

Related government policies and regulations, both local and national, are applicable to the installation of a CGS.

A detailed consideration of such policies is necessary. These policies may include:

- business assistance policies (tax reduction, financial loans, subsidy system, etc.);
- deregulations for power supply (liberalization, etc.).

4.4 CGS planning

4.4.1 General

When considering the planning of the CGS, the items included in this category shall be decided by the purchaser with reference to technical data proposed by the manufacturers.

4.4.2 System diagrams

Examples of the types of systems to be considered are shown in the diagram and flowcharts provided for guidance purposes in Annex C.

4.4.3 Type of prime mover

The type of prime mover shall be examined and selected by taking into consideration the specified or desired electric power and heat demands, heat-to-electric power ratio and other particular requirements of the project.

The type to be examined may include:

- gas turbine[1)];
- reciprocating internal combustion engines (gas engine, diesel engine);
- steam turbine.

See the related flowcharts in Annex C.

1) A CGS using one or more gas turbine(s) is called a “gas turbine CGS”.

4.4.4 Electric power output

Electric power output and generating efficiency vary with the type of prime mover, operating loads and ambient conditions.

Considerations shall include:

— output at electric generator terminal;

— output at export delivery point;

— rated and partial load efficiencies.

4.4.5 Heat recovery

Exhaust heat from the prime mover is recovered as heating and/or cooling outputs.

Quantities of heating and/or cooling outputs will vary depending upon the load conditions and the ambient conditions.

Considerations shall include:

— type of heat recovery medium (hot and/or chilled water, steam, hot oil and/or direct use in drying or thermally activated equipment);

— thermal process demand (mass flow rate, supply pressure, supply temperature, total rated thermal demand, other specific requirement);

— heat recovery rate;

— heating medium return flow and condition (e.g. condensate).

4.4.6 Fuel

The CGS input fuel may be gas, liquid or solid and shall be selected after careful consideration of availability and economics. Some prime movers may have strict limitations affecting the selection of gas and liquid fuels such as residual oil, heavy fuel oils, blast furnace gas or gases with high hydrogen content. The types of fuel shall be selected by taking into consideration service conditions (supply temperature, pressure), environmental factors and the cost at the time the prime mover is being selected.

Other considerations shall include:

— serviceable fuels, their properties and variability (composition, net specific energy, Wobbe index, sulfur content, etc.);

— fuel handling, delivery steam for pipe heating of heavy oil, fuel treatment and storage (if applicable); including the clarification of the storage capacity, supply pressure and supply temperature;

— standby or alternative fuel; when the CGS is used for both continuous and intermittent uses, it is advisable to consider the necessity of a standby (or alternative) fuel; there can be certain special conditions attached to the fuel supply agreement that require a standby fuel;

— fuel consumption rate;

— net specific energy;

— reliability of main fuel supply.

4.4.7 Planning of electric power use

Electric power systems shall be designed from economic and reliability viewpoints taking into account items that will affect the electric power demand's pattern and factors, such as:

— factors concerning introduction of a CGS (peak shaving, base load, common use together with emergency service, back-up for temporary electric power failure);

— whether it will be grid-connected or independently operated;

— the possibility of exporting electric power back to the grid;

— allowable minimum importing power to minimize operating costs;

— operation of the CGS if there is a grid-failure accident (shutdown, shutdown and automatic re-start without shutdown);

— number of cogeneration units;

— contracted electric power, including terms of agreement;

— possibility of importing electric power from the commercial grid during the failure or maintenance of the CGS;

— type of operation (electric power or heat-oriented);

— type of control of electric power system (such as constant import/export control);

— load factor of electric generator (maximum, minimum);

— necessary auxiliary electric power.

4.4.8 Planning of recovered heat use

The energy flow of air-conditioning, export steam, hot and/or chilled water supply shall be planned by taking into consideration the pattern of the heat-use equipment and the order of the recovered heat use.

The heat balance between the demands for heat and the capacity of the water equipment shall be confirmed. Heat balances shall be prepared for a number of defined operational modes and plant configurations to ensure compatibility between production and off-take, taking into account factors such as:

— type of recovered heat use (space heating and/or cooling, hot water and/or steam supply);

— auxiliary heat source (for supplemental use and/or usage in case of CGS outage);

— storage tank;

— order of recovered heat use (space heating and/or cooling and hot water and/or steam supply);

— efficiency of heat-use equipment;

— return of condensate;

— existing process equipment such as steam turbines, boilers and heat exchangers.

4.4.9 Planning of operation and maintenance

The operational stage of the CGS is planned by taking into account annual, monthly and daily maintenance schedules through a one-year period. Consideration shall be given to the planning of maintenance between major overhauls, which may occur over a number of years. Typical considerations include:

— operational planning (continuous, intermittent, seasonal usage, days on standby, maintenance months and days required considering operational and process restrictions of customer site);

— number of generators possible to operate under normal circumstances;

— daytime, night-time, weekday and weekend considerations.

4.5 System's operational simulation

4.5.1 General

After determining the factors or parameters in 4.2 through 4.4, the system's operational simulation shall be performed to obtain detailed figures for the evaluation of the CGS.

This operational simulation shall take into account monthly, hourly, weekly and holiday patterns of electric power and heating and/or cooling. In addition, the long-term energy-demands profile shall be considered. The relevant time period used in the evaluation of the CGS shall be decided after considering all these terms.

4.5.2 Operational patterns

Operational patterns shall be compiled for performing the system's operational simulations. Typical patterns include:

— operational pattern of electric power through more than one year (electric generator, auxiliary units, electric power from and to the grid);

— operational pattern of recovered heat through more than one year (hot and/or chilled water, and/or steam);

— operational pattern of auxiliary heat through more than one year;

— operational pattern of fuel consumption through more than one year (gas, oil);

— operating days through more than one year.

4.5.3 Energy costs and incomes

Calculated costs and incomes are based on the result of an operational simulation for economic evaluation of the CGS.

These costs and incomes are calculated with parameters, such as:

— electric power and heating and/or cooling through more than one year (electric generator, auxiliary units, electric power from and to the grid);

— necessary fuel consumption through one year (gas, oil) for the prime mover during normal operation, and for the auxiliary heat source during maintenance;

— contracted electric power;

— charge rate (electric power from and to the grid, gas, oil);

— maintenance cost;

— standby charge rate (electric power).

4.6 Planning of comparison with a target comparable to the CGS

To evaluate the effectiveness of the CGS, economic and technical data for a conventional system are required for comparison. It is necessary to calculate the energy costs and incomes for the conventional system in the same way that the CGS is evaluated.

In addition to this comparison, other factors necessary for planning targets shall be investigated according to the purchaser's request. Typical factors include:

— requirements by national or regional standards and/or regulations (if applicable for the installation site);

— targets for comparison requested by the purchaser, such as carbon credit, tax reduction, and other financial incentives, etc.

5 CGS evaluation

5.1 Economic evaluation

5.1.1 General

A CGS is most effective when supplies for both electric power and heating and/or cooling are well balanced with demands.

In the first instance, projects may be evaluated using the payback-period method (see 5.1.2.1) and/or the procedure in Annex D.

After that, it will be necessary to carry out a more detailed evaluation such as LCC, IRR, and NPV.

5.1.2 Preliminary economic evaluation steps

5.1.2.1 Payback period

The payback period is a simple method for determining the desirability of the CGS, based on the number of years required to recover the initial investment outlay (I_0) from the CGS's future cash flow (see ISO 15663-2:2001, 4.1.6). The payback period, t_{PP}, is calculated as follows:

$$t_{PP} = I_0 / R_{AC} \quad (1)$$

where

I_0 is the initial investment outlay;

R_{AC} is the annual cash receipts.

When the receipts fluctuate over time, the payback period is calculated by summing the receipts until the initial investment outlay (I_0) is covered.

To compare the CGS with the conventional system, two calculation methods are used: one for the compensation period (see Annex D), and the other for the total profit during the plant life (see Annex E).

5.1.2.2 Assumption

The economic assumption shall be based on selected decision criteria and should be used in different partnerships with suppliers.

Economic evaluation methods and assumptions should be decided early in the iterative procedures for the evaluation (see ISO 15663-2:2001, 3.2.3.3).

Table 1 — Assumption

— Timing — Investment year — Start of operation — Lifetime of plant — Fuel cost — Discount rate — Pre-tax/after-tax calculations	How costs are weighed against the initial investment during operation	Which is the best system solution/equipment alternative?
— Output requirement over time — Cost of power	The impact of improving efficiency	
— Production profile — Criticality	The potential cost of failures	

5.1.3 Secondary economic evaluation steps

The detailed economic evaluation is usually carried out with long-term economic indicators for both the CGS and the conventional system. The indicators to be evaluated may include:

a) life-cycle cost (LCC);

b) internal rate of return (IRR);

c) net present value (NPV);

d) sensitivity analysis.

The life-cycle cost method is a very important economic evaluation; a typical life-cycle cost analysis of a CGS, including related elements, is shown in Annex B (see ISO 15663-2:2001, 4.1.3).

In addition, IRR and NPV are shown in 4.1.4 and 4.1.2 of ISO 15663-2:2001.

5.2 Energy saving evaluation

The amount of energy used is to be determined in the operational simulation of the CGS and of the conventional system.

The amount of fuel needed by different systems shall be determined, and the equivalent energy content of the fuels shall be computed for comparison of the total energy input.

The energy savings can then be calculated and compared with possible targets for the investment in the CGS.

5.3 Environmental evaluation

Based on the result of the system's operational simulation, impacts on the environment shall be evaluated by comparing the CGS with the conventional system and/or with factors necessary for targets of planning.

The emission levels shall be evaluated for costs, impact on health, and safety for workers and the environment. The emission levels shall at least meet the requirements from applicable regulations and codes for the project site, such as:

— emission into the atmosphere and the environment (CO, CO_2, NO_X, SO_X, particulate matter, unburned hydrocarbon, dioxin, etc.);

— noise;

— vibration;

— land use;

— waste (chemicals, oil, effluent, etc.).

5.4 Availability and reliability evaluation

For both the CGS and the conventional system, the following parameters for availability and reliability evaluation shall be taken into account:

— planning of proper maintenance (standard procedure for maintenance, education for personnel, etc.);

— manufacturer's experiences and demonstrated level of support (manufacturer's machine-specific reference list, operating hours and starts on lead machine, statistic data of availability and reliability, etc.);

— scheduled maintenance (inspection outage type, inspection interval, inspection duration, etc.);

— supervisory control (remote control, manufacturer's condition monitoring services, etc.);

— proven technical solutions and reliable proven component design (technical support and manufacturer's senior service team at project location, etc.);

— plant redundancy and back-up systems (e.g. auxiliary firing and auxiliary boilers).

Internationally recognized definitions for availability and reliability should be used to allow direct comparisons.

5.5 Total evaluation

The most desirable CGS is obtained by investigation with the procedure in 5.6.

For the total evaluation, all the identifiable cost impacts of the evaluation items in 5.2, 5.3 and 5.4, which change depending on the scope of each project, should be included in the economic evaluation in 5.1.

The final decision for approval or rejection of the CGS project should be based on the following results:

— comparison with the conventional system;

— judgment of the impact of the legal, technical and environmental issues identified in 4.1 through 4.5 on the viability of CGS projects.

5.6 Evaluation procedure

The flowchart in Figure 1 shows the evaluation procedure for introducing a CGS. It defines the evaluation steps needed to optimize the CGS configuration, including the selection of the prime mover.

The investigation is performed based on the various conditions supplied by the purchaser through each planning stage and the results obtained by operational simulation and calculation of evaluation parameters. Finally, the total evaluation of introducing the CGS shall be judged by comparing the results with comparable targets.

The evaluation loop shown in Figure 1 shall be iterated by changing parameters in planning stages and operational simulation until the expected results are obtained.

For guidance purposes, an example of a typical evaluation procedure is provided in Annex A. It shows the necessary actions and division of works by the purchaser (or purchaser's consultant) and manufacturer.

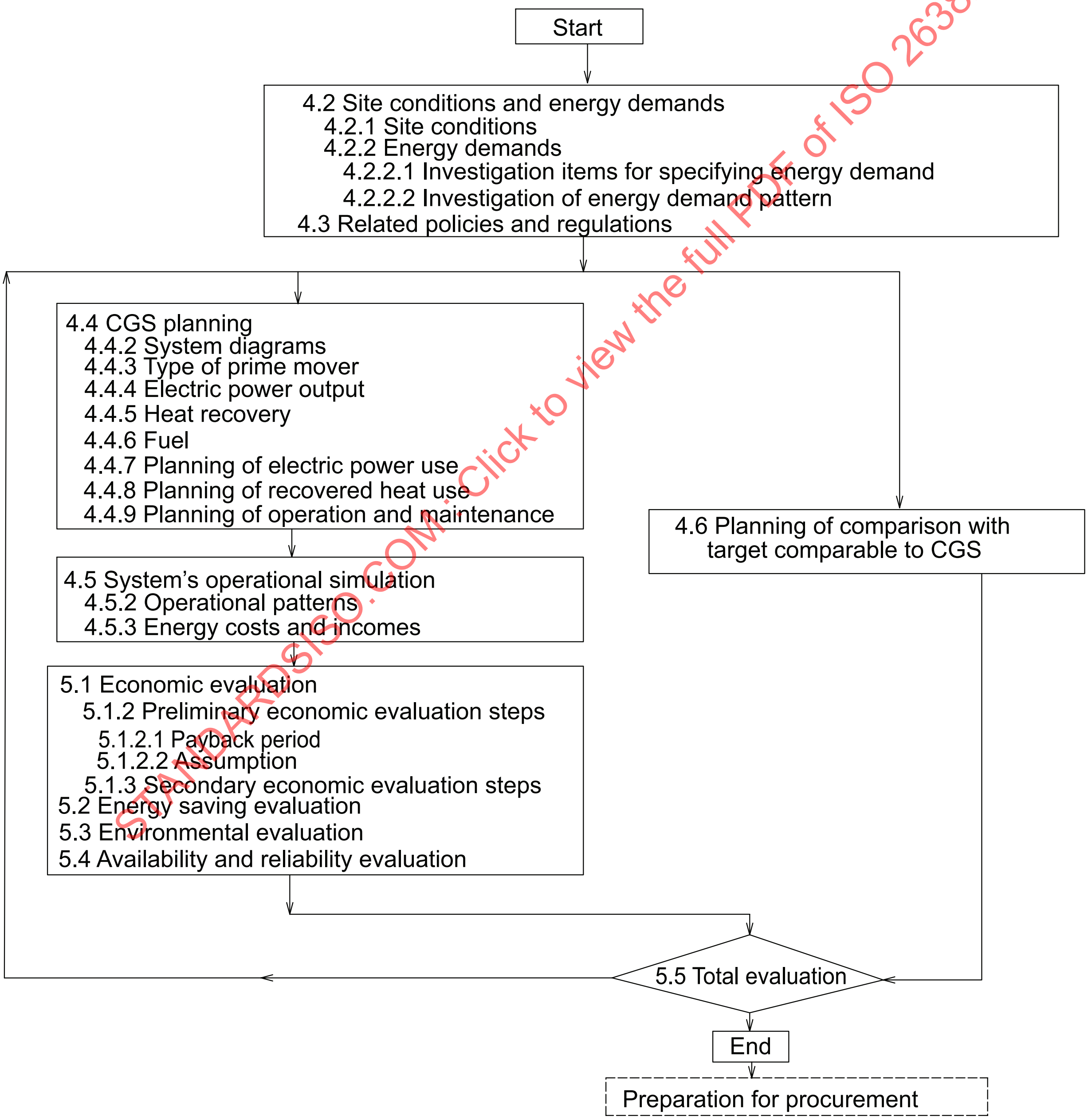


Figure 1 — Flowchart for the evaluation of a CGS

6 Primary information and works for CGS procurement

6.1 Inquiry phase

The inquiry phase shall start early enough to obtain the pricing (budgetary) information needed to support the evaluation phase.

A typical job classification of primary information and works for CGS procurement is shown in Annex F.

Appropriate standards should be used as the basis for an inquiry. Available standards for inquiry may include:

— ISO 15663-1:2000 and ISO 15663-2:2001 for life-cycle costs;

— ISO 3977-1 through ISO 3977-9 for gas turbines;

— ISO 8528-1 through ISO 8528-10 for reciprocating internal combustion engine driven alternating current generating sets;

— ISO 14661 and IEC 60953-1 for steam turbines.

6.2 Formal procurement

The formal procurement phase involves the actual contracting of hardware and services to support the construction of a CGS. This phase may start following the completion of the evaluation phase.

Annex A
(informative)

Typical evaluation procedure for CGS planning

A typical evaluation procedure for CGS planning at the execution stage is shown in Figure A.1. The sequence shown on the following page should be followed.

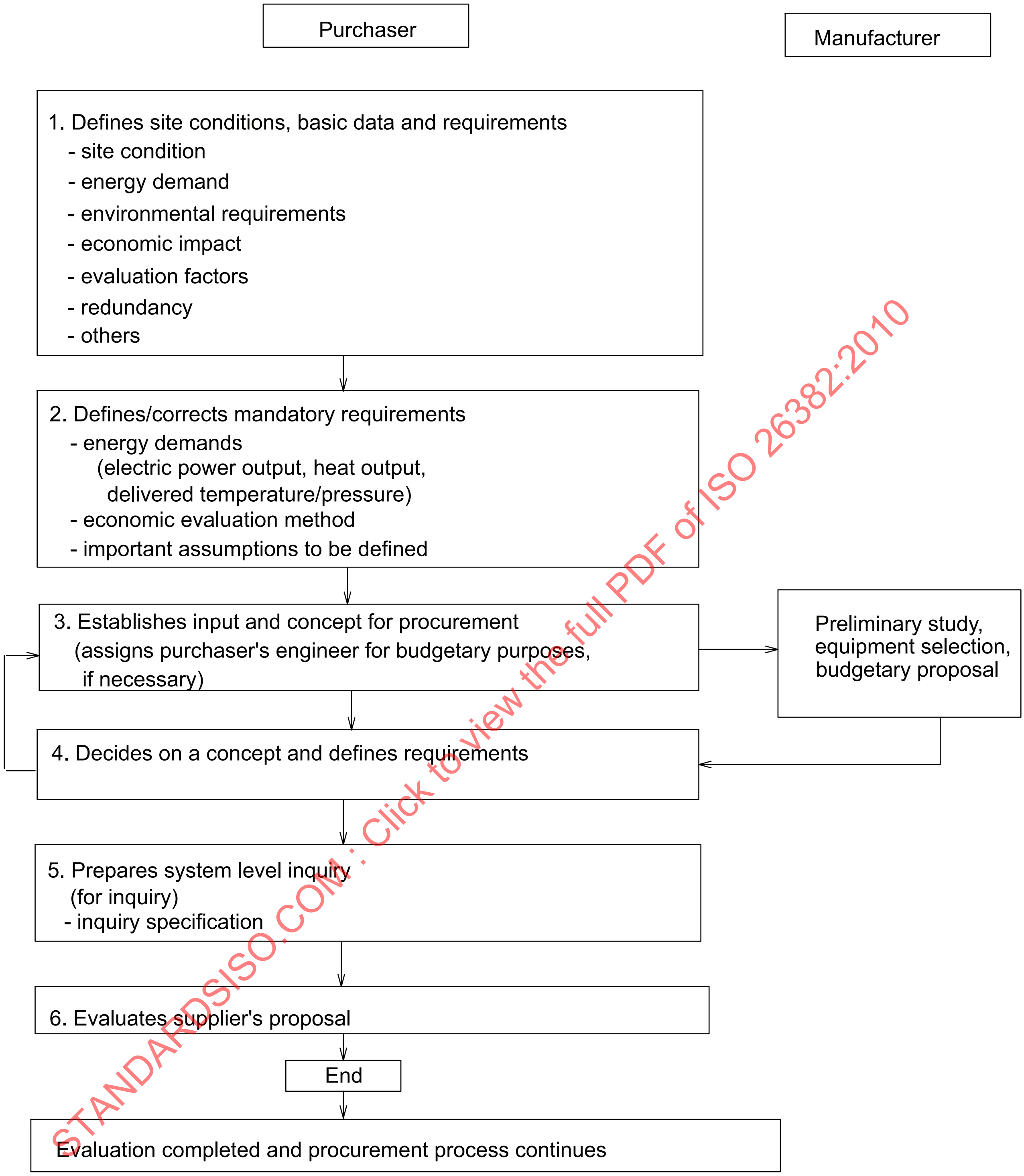


Figure A.1 — Typical evaluation procedure for CGS planning

Annex B
(informative)

Typical life-cycle cost analysis

A typical detailed economic evaluation is shown in this annex.

Life-cycle cost (L_{CC}) can be calculated using Equation (B.1).

$$L_{CC} = C_e F_{pe} + \sum_{j=1}^{n} F_{pj} \left(C_{oj} + C_{rj} + C_{mj} \right) + S F_{ps} \tag{B.1}$$

where

L_{CC} is the life-cycle cost;

C_e is the capital expenditure, including financing costs and interest during construction for planning, designing and construction;

C_{oj} is the operating expenditure[2)] in period j;

C_{rj} is any contingency for repair and/or renewal in period j;

C_{mj} is the maintenance expenditure in period j;

F_{pe} is the correction rate for capital expenditures to present value;

F_{pj} is the correction rate for expenditures in period j to present value;

F_{ps} is the correction rate for expenditures for disposition after closing the plant to present value;

j is the duration of certain periods or of one set period, usually a fiscal year;

n is the lifetime;

S is the expenditure for disposition after closing the plant.

2) Excluding expenditures for repair and/or renewal related to the facility and maintenance in period j, including expenditures for using fuel energy and environmental costs.

Annex C
(informative)

Typical CGS diagram and flowcharts

A typical CGS diagram and typical flowcharts are shown in this annex.

The CGS may include conventional reciprocating internal combustion engine (gas engine and diesel engine), gas turbine and steam turbine cycles.

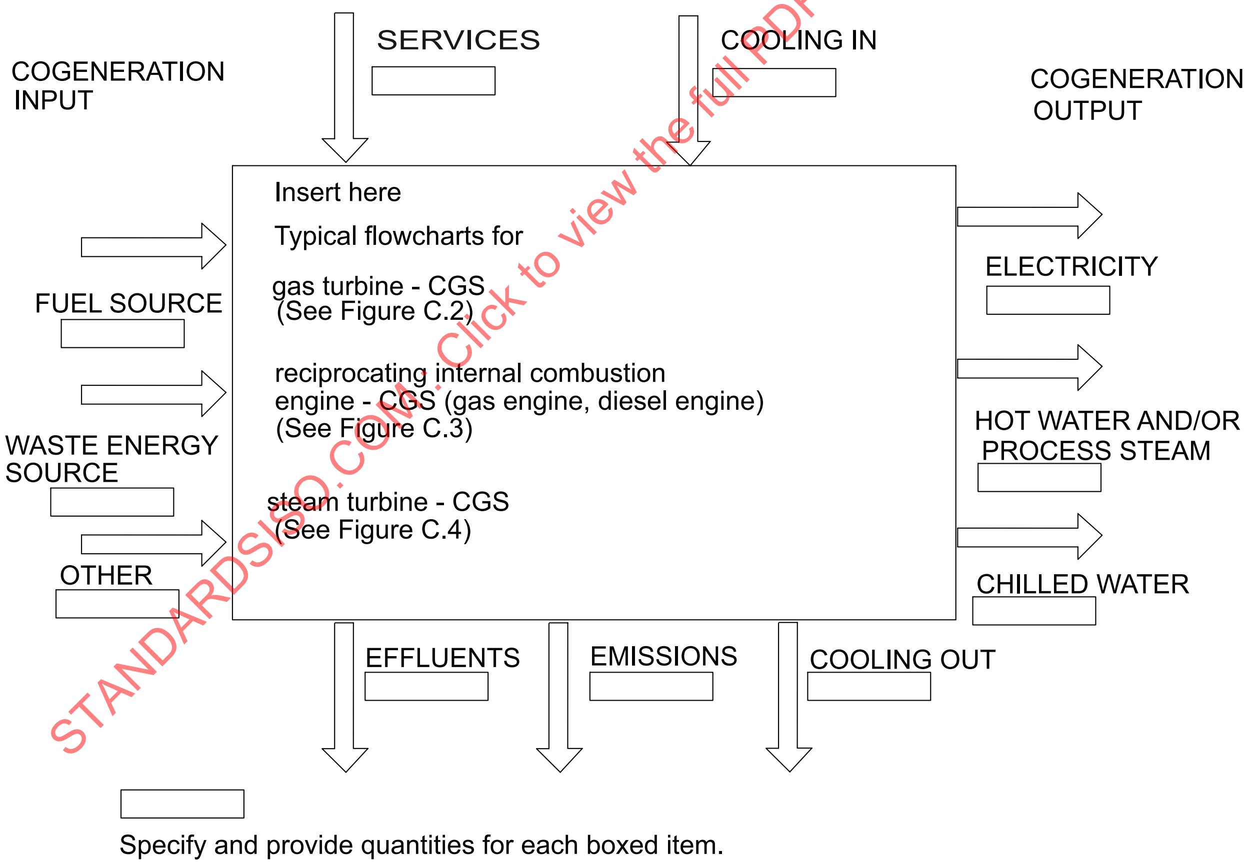
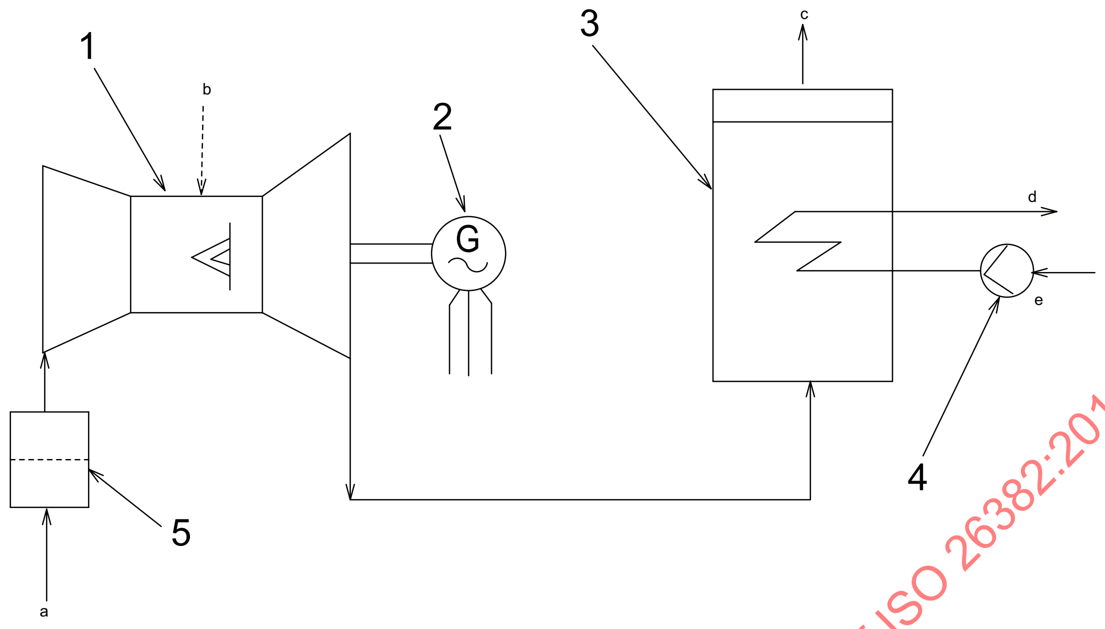


Figure C.1 — Typical CGS diagram

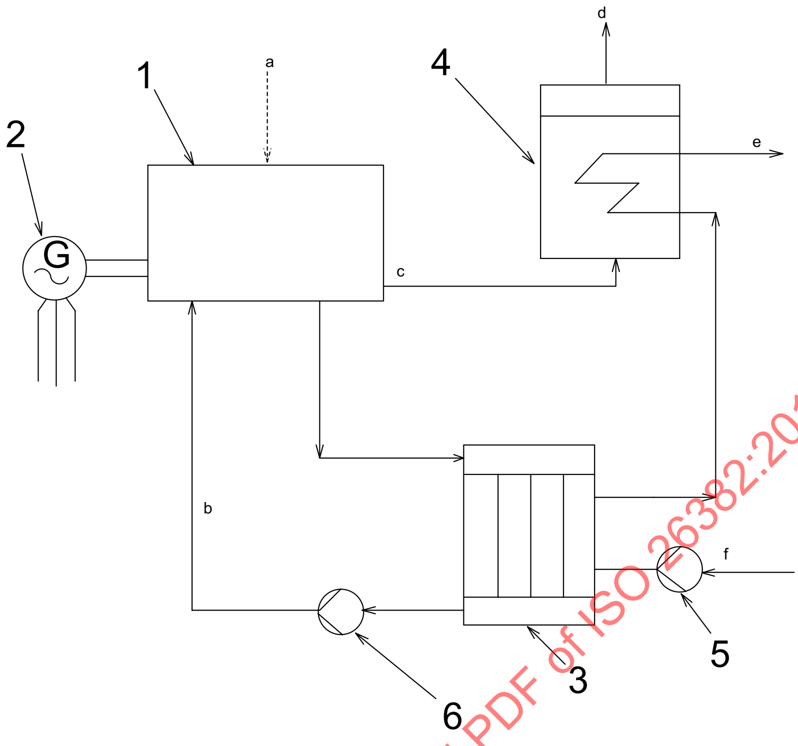


Key

1 gas turbine
2 electric generator
3 heat recovery steam generator
4 feed water pump
5 air filter

a Air.
b Fuel supply.
c To stack.
d Process steam export.
e Water supply.

Figure C.2 — Typical flowchart for gas turbine-CGS
(Gas turbine-CGS with process steam)

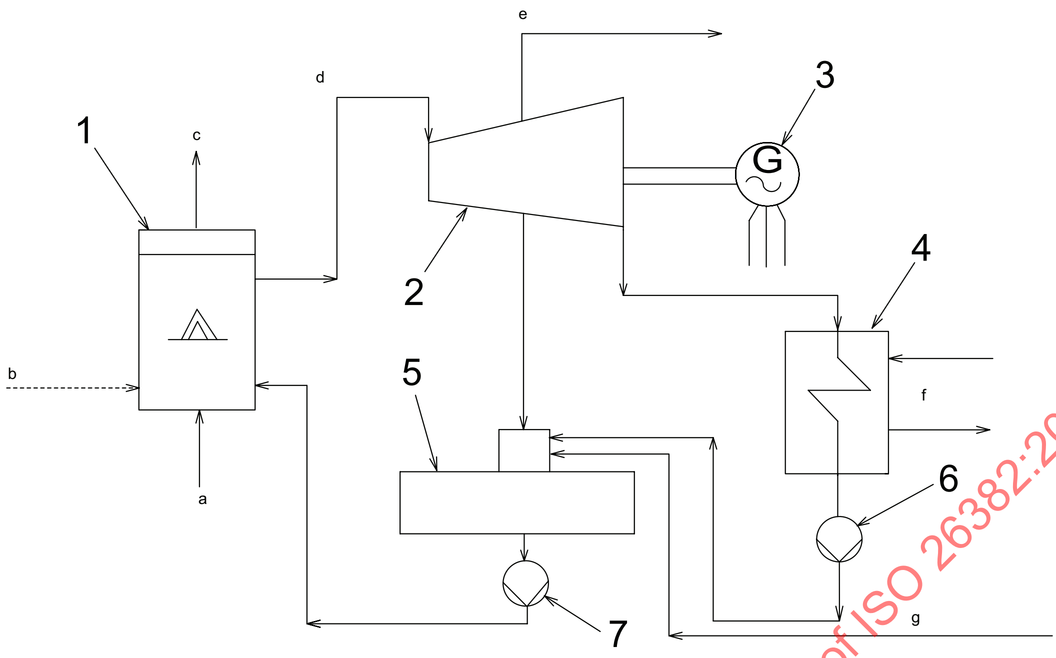


Key

1 packaged reciprocating internal combustion engine (gas engine, diesel engine)
2 electric generator
3 low temperature heat exchanger (LTHX)
4 high temperature heat exchanger (HTHX)
5 hot water pump
6 engine cooling water pump

a Fuel supply.
b Engine cooling water.
c Exhaust gas.
d To stack.
e Hot water supply.
f Water supply.

Figure C.3 — Typical flowchart for reciprocating internal combustion engine-CGS
(Reciprocating internal combustion engine-CGS with hot water)



Key

1 conventional fired steam generator
2 steam turbine
3 electric generator
4 condenser
5 feed water heater
6 water pump
7 feed water pump

a Air.
b Fuel supply.
c To stack.
d High-pressure steam.
e Process steam export.
f Cooling water.
g Condensate return.

Figure C.4 — Typical flowchart for steam turbine-CGS
(Condensing extraction steam turbine with process steam)

Annex D
(informative)

Calculation method for the period of time during which the CGS and the conventional system have equal expenditures

D.1 The calculation method for the period of time (i.e. compensation period) during which the CGS and the conventional system have equal expenditures is shown in Equation (D.1). This compensation period, t_c, is calculated by summing up the expenditures until they are equal for both the CGS and the conventional system.

$$t_c = (C_{GS.CE} - C_{S.CE})/(C_{S.OE} - C_{GS.OE}) \quad (D.1)$$

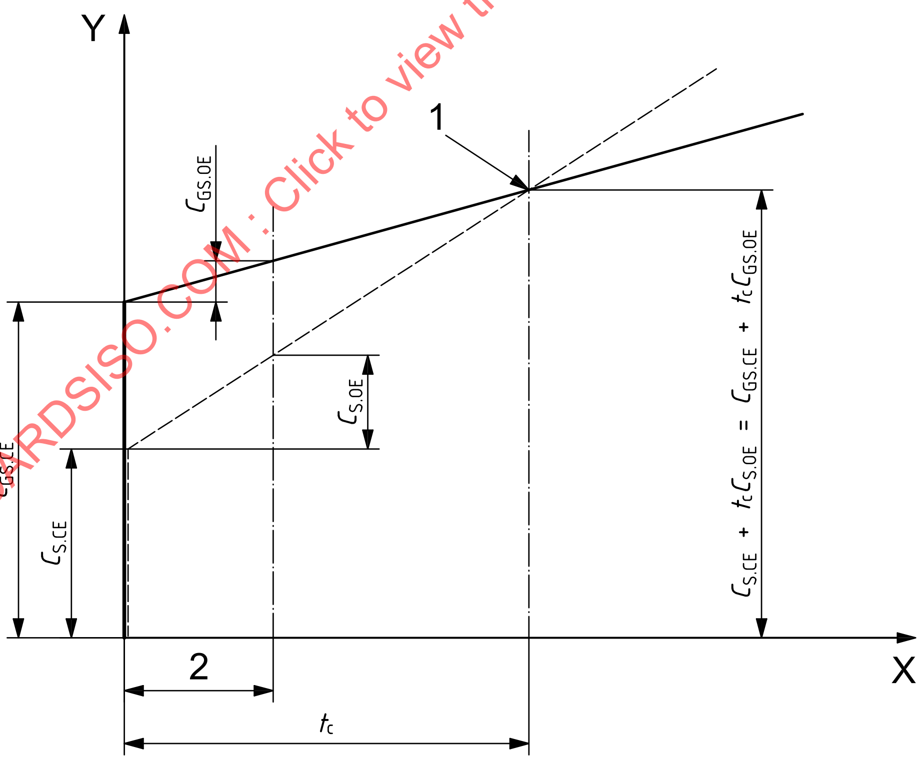
where

$C_{GS.CE}$ is the capital expenditure necessary for introducing the CGS;

$C_{S.CE}$ is the capital expenditure for the conventional system;

$C_{S.OE}$ is the operational expenditure for using the conventional system during certain periods or for one set period, usually for a fiscal year;

$C_{GS.OE}$ is the operational expenditure for using the CGS during certain periods or for one set period, usually for a fiscal year.



Key

X period of time
Y expenditure
1 break even point
2 fiscal year

Figure D.1 — Map of compensation period

