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Use of reclaimed water in industrial cooling systems —

Part 2: Guidelines for cost analysis

Utilisation de l'eau recyclée dans les systèmes de refroidissement industriels —

Partie 2: Lignes directrices relatives à l'analyse des coûts

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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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This document was prepared by Technical Committee ISO/TC 282, *Water reuse*, Subcommittee SC 4, *Industrial water reuse*.

A list of all parts in the ISO 22449 series can be found on the ISO website.

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

Large amounts of water resources are used in industrial development. Industrial cooling water use accounts for a high proportion of industrial water use. Industrial water reuse is one of the promising ways to solve water shortages and to provide a new water source for cooling systems. The quality of reclaimed water is of great importance for the design and operation of industrial cooling systems. Industrial wastewater must meet the requirements of the cooling systems before it can be used as make-up water. Consequently, the primary cost consideration is related to the costs of treating industrial wastewater. In addition, for new-built cooling systems based on life-cycle consideration, the capital cost, operating cost and maintenance cost need to be considered.

This document provides a comparative cost analysis method for cooling systems using reclaimed water. It will be conducive to establishing an effective and unified cost analysis method in different countries for further cost comparison. This document is intended to lead the use of reclaimed water in industries worldwide, promoting the reuse of water resources, improving water-use efficiency and putting into practice the concept of the industrial circular economy.

Use of reclaimed water in industrial cooling systems —

Part 2: Guidelines for cost analysis

1 Scope

This document provides guidelines for cost analysis of the use of reclaimed water in industrial cooling systems.

This document is intended for new-built industrial cooling systems using reclaimed water as make-up water, in which the reclaimed water originates from industrial wastewater and is generated through wastewater treatment systems for reuse. The source of industrial wastewater is from all the production plants inside the enterprise.

In this document, the levelized cost of cooling water (LCOCW) is used to compare and determine which industrial cooling system is more expensive per-kilowatt-hour heat removed.

Use of reclaimed water will have a direct impact on the operating cost of cooling systems and the environment. External benefits, including positive externalities and negative externalities, are provided in Annex A, which considers environmental, social and financial elements.

This document is intended for all types of stakeholders involved in reclaimed water use in new-built industrial cooling systems.

This document aims to ensure consistency within any organization engaged in reclaimed water reuse.

This document provides a broad framework within which costs for new-built industrial cooling systems using reclaimed water can be assessed. The currency used is local currency (LCY).

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 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/

3.1.1
capital cost
capital expenditure
money used to purchase, install and commission a capital asset

[SOURCE: ISO 15663-3:2001, 2.1.3, modified — preferred term changed from capital expenditure to capital cost.]

3.1.2
disposal cost
money used to demolish and rehabilitate a capital asset at the end of its life

3.1.3
heat rejection capacity
amount of heat which can be rejected by a cooling system

Note 1 to entry: Measured in kW (1 000 Watts, thermal or electric).

3.1.4
operation and maintenance cost
cost incurred in running and managing the facility, plus labour, material and other related costs incurred to retain a building or its parts in a state in which it can perform its required functions

[SOURCE: ISO 15686-5:2017, 3.1.9 and 3.1.11]

3.1.5
replacement cost
anticipated cost to major system components that are required to maintain the operation of a facility

3.2 Abbreviated terms

The abbreviated terms in Table 1 apply.

Table 1 — Abbreviated terms

Abbreviation	Full term
EPCM	engineering procurement construction management
LCY	local currency
LCOCW	levelized cost of cooling water

4 Guidelines for the cost analysis

4.1 General

The scope of the costs includes the costing associated with wastewater treatment systems and industrial cooling systems.

This document includes:

— principles of the cost analysis;

— cost calculation method;

— cost analysis indexes.

The flow diagram and components of a cooling system using solely reclaimed water as make-up water are shown in Figure 1.

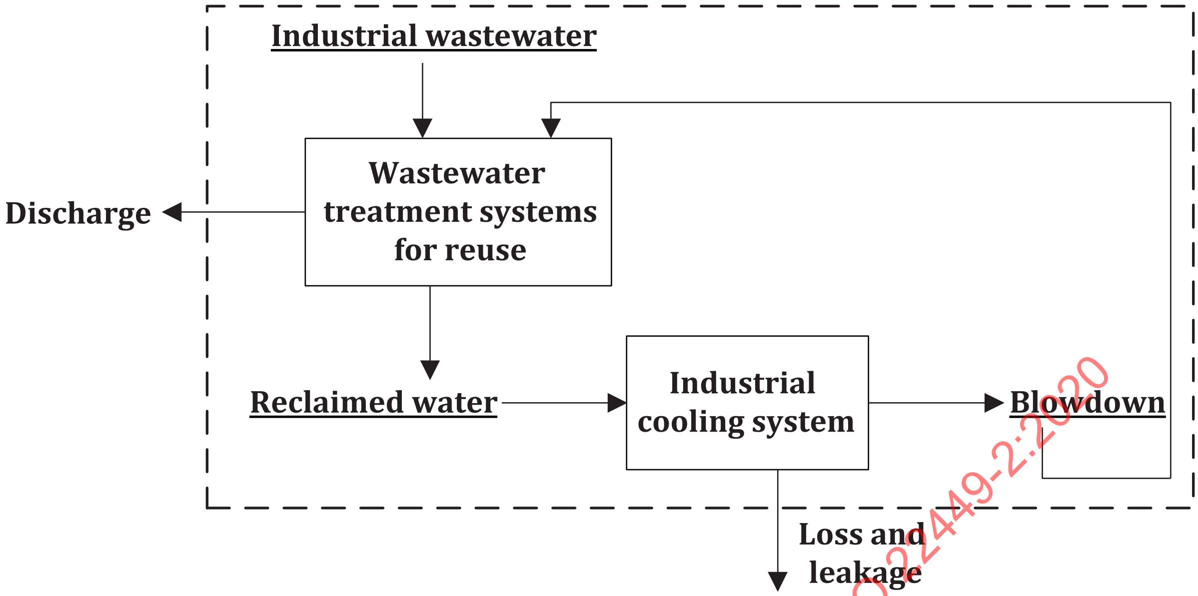

Figure 1 — Flow diagram and components of a cooling system using reclaimed water

4.2 Principles of the cost analysis

Cost analysis should observe the following principles[5]:

a) Life-cycle cost analysis should be used as the cost analysis method, and the calculation period for the analysis should include the construction period, operation period and disposal period.

b) The cost analysis should take the following items into account: the capital cost during the construction period; the operation, maintenance and replacement cost during the operation period; and the disposal cost during the disposal period.

c) The scope of cost includes the costs associated with the wastewater treatment system and industrial cooling system.

4.3 Cost calculation method

4.3.1 Capital cost

4.3.1.1 Principles of capital cost calculation

Capital cost calculation should observe the following principles:

a) The scope of capital cost covers the relevant equipment, buildings and supporting facilities of the industrial cooling system and the wastewater treatment system.

b) The capital cost calculation should be based on the whole system, and the cost should cover the whole construction period from initial work to the completion of construction and commissioning.

c) The capital cost should be annualized based on the construction schedule during the construction period.

4.3.1.2 Capital cost calculation

4.3.1.2.1 Construction and building cost

The construction and building cost includes:

a) construction labour cost (all salaries and wages paid to construction workers, supervisory staff and overhead personnel);

b) construction material cost (all construction material purchased by the contractor or the owner for use on the construction project);

c) construction equipment usage cost (the construction contractor’s equipment usage operating cost for the installation of all bulk materials and equipment).

4.3.1.2.2 Equipment cost

Equipment cost consists of the purchase cost of all process, non-process or fixed equipment purchased by the contractor or owner, but excludes freight cost and duties. It is calculated according to the equipment list and the quotations from vendors.

A good choice of material for equipment can deal with complex water quality of reclaimed water for new-built cooling water systems. It can affect the operation regarding the required amount of direct energy consumption, the occurrence of controlled (wastewater treatment) and uncontrolled (leakage) emissions to the environment and the direction of heat emissions. The selected materials will require a certain level of investment. Annex B, Table B.1, describes materials commonly used in cooling systems and the effects of water quality on the material.

4.3.1.2.3 Subcontract cost

Subcontract cost includes all lump sum/unit rate subcontracts let by the contractor or the owner which are not included in the engineering procurement construction management (EPCM).

4.3.1.2.4 Indirect cost

The indirect cost consists of the EPCM cost, the cost for temporary construction facilities and temporary utilities, catering and lodging cost, vendor representatives cost, spare parts for start-up, pre-commissioning and commissioning, first fills, third-party engineering services/testing/inspection, freight and duties/taxes.

4.3.1.2.5 Owner's cost

The owner's cost consists of the owner’s labour cost and expenses during construction, consultants' costs, payment of licenses and royalties, land acquisition costs, environmental evaluation cost, insurance, tests and study cost.

4.3.1.2.6 Contingency cost

Contingency cost is a provision of funds for unforeseen or inestimable costs within the defined project scope relating to the level of engineering effort undertaken and estimate/engineering accuracy. Contingency cost of each sub-item of the system is determined according to the risk level, and the total contingency cost is summarized finally.

4.3.1.2.7 Capital cost of the system

The capital cost of the system is the total of the above-mentioned items, calculated according to Formula (1):

$$C = C_1 + C_2 + C_3 + C_4 + C_5 + C_6 \quad (1)$$

where

C is the capital cost, in LCY;

C_1 is the constructing and building cost, in LCY;

C_2 is the equipment cost, in LCY;

C_3 is the subcontract cost, in LCY;

C_4 is the indirect cost, in LCY;

C_5 is the owner’s cost, in LCY;

C_6 is the contingency cost, in LCY.

4.3.2 Operation and maintenance cost

4.3.2.1 Principles of operation and maintenance cost calculation

a) The scope of operation and maintenance cost calculation covers all costs for the operation of the wastewater treatment system and the industrial cooling system.

b) The operation and maintenance cost calculation should include the cost of the whole cooling system and the calculation period should cover the whole period from the operation to the end of life of the system.

c) The operation and maintenance cost should be calculated annually.

4.3.2.2 Operation and maintenance cost calculation

4.3.2.2.1 Electricity cost

Electricity cost is the cost incurred due to the electricity consumption during system operation. The electricity of common electrical equipment in Table 2 consumed for the wastewater treatment system and the industrial cooling system is included in the consumption. The cost for electricity is calculated according to Formula (2) and Formula (3).

$$O_1 = A \cdot f_1 \quad (2)$$

where

O_1 is the electricity cost, in LCY/a;

f_1 is the unit price of electricity, in LCY/(kW·h);

A is the electricity consumed by the system, in kW·h/a.

$$A = \sum_{j=1}^{n} \left(N_j \cdot P_j \cdot T_j \right) \quad (3)$$

where

N_j is the number of electrical equipment j;

P_j is the total power of electrical equipment j, in kW;

T_j is the operation time of electrical equipment j, in h/a;

n is the number of types of electrical equipment.

Table 2 — Common electrical equipment in cooling water system using reclaimed water

	Power kW	Operating time h	Number	Power consumption kW·h
Pump	P_1	T_1	N_1	A_1
Lighting	P_2	T_2	N_2	A_2
Compressor	P_3	T_3	N_3	A_3
Fan	P_4	T_4	N_4	A_4
Electrical service/generation	P_5	T_5	N_5	A_5
Heat exchanger	P_6	T_6	N_6	A_6

4.3.2.2.2 Chemical cost

To meet the quality requirements of reused water, chemicals such as coagulants, scale inhibitors, corrosion inhibitors and antiseptics need to be added into the wastewater treatment system and the industrial cooling system. The cost of the consumption of these chemicals should be included in the operation cost. Annex C, Table C.1 and Table C.2 describe the chemical cost elements for the wastewater treatment system and the industrial cooling system, respectively.

The cost for chemicals is calculated according to Formula (4):

$$O_2 = \sum_{i=1}^{k} (G_i \cdot f_{2i}) \quad (4)$$

where

O_2 is the chemical cost, in LCY/a;

G_i is the consumption of chemical type i, in kg/a;

f_{2i} is the unit price of chemical type i, in LCY/kg;

k is the number of chemicals used.

4.3.2.2.3 Labour cost

The labour cost includes salaries and wages paid to all employees for the wastewater treatment system and the industrial cooling system, including all operating workers, maintenance staff, inspection staff, supervisory staff and administrative personnel. The labour cost includes not only salaries, wages and allowance, but also welfare such as social insurance paid on behalf of the employees.

4.3.2.2.4 Maintenance cost

The maintenance cost includes the payment for maintenance and repair of the wastewater treatment system and the industrial cooling system, such as spare parts, maintenance materials and expense of maintenance contractors (if any), but excluding maintenance labour costs, which are included in the labour cost.

4.3.2.2.5 Management cost

The management cost includes the payment for operating management, such as expenses for office, travelling, work protection, water-quality monitoring, rent (if any), technical services (if any), insurance (if any), waste discharge fee (tax), duties (if any) and other costs excluded from the above items.

4.3.2.2.6 Operation and maintenance cost of the system

The operation and maintenance cost of the system is the sum of the items mentioned above, which is calculated according to Formula (5):

$$O = O_1 + O_2 + O_3 + O_4 + O_5 \quad (5)$$

where

O is the operation and maintenance cost, in LCY/a;

O_1 is the electricity cost, in LCY/a;

O_2 is the chemical cost, in LCY/a;

O_3 is the labour cost, in LCY/a;

O_4 is the maintenance cost, in LCY/a;

O_5 is the management cost, in LCY/a.

4.3.3 Replacement cost

4.3.3.1 Principles of replacement cost calculation

a) Replacement cost calculation includes the cost incurred during the operation period for the wastewater treatment system and the industrial cooling system.

b) Replacement cost is typically generated by replacement of a system or component that has reached the end of its useful life.

c) The replacement cost should be calculated on replacement schedule.

4.3.3.2 Replacement cost calculation

Replacement cost includes the cost for components and demolition and any alterations of existing systems required for new components, see Formula (6).

$$R = R_1 + R_2 \quad (6)$$

where

R is the replacement cost, in LCY;

R_1 is the component cost, in LCY;

R_2 is the cost of any alterations of existing systems required for new components, in LCY.

4.3.4 Disposal cost

4.3.4.1 Principles of disposal cost calculation

a) Disposal cost calculation includes the cost incurred during the disposal period for the wastewater treatment system and the industrial cooling system.

b) Disposal cost calculation should calculate all of the costs occurred in the system, and the cost calculation period should range from the end of life of the system to the completion of demolition and rehabilitation of the system.

c) The disposal cost should be annualized based on the disposal schedule during the disposal period.

4.3.4.2 Disposal cost calculation

Disposal cost includes the cost for the demolition of the system and the rehabilitation cost for the land used by the system (if applicable) at the end of the system's useful life, including all labour cost, material cost and construction equipment usage cost related to the demolition and rehabilitation of the system, see Formula (7).

$$D = D_1 + D_2 \quad (7)$$

where

D is the disposal cost, in LCY;

D_1 is the demolition cost, in LCY;

D_2 is the rehabilitation cost, in LCY.

4.4 Cost analysis indexes

4.4.1 General

For the sake of comparison, costs also have to be expressed in terms of the heat capacity the system is designed for (kW_{th} or MW_{th})[6]. This method is not accurate in absolute terms, therefore it is not meant to be used for accurate investment estimates. It is, however, suitable for comparing investment costs of different cooling systems. Cost analysis indexes are used as detailed in 4.4.2.

4.4.2 Levelized cost of cooling water (LCOCW)

LCOCW[7] is the unit cost of the industrial cooling system considering all the costs during the whole life cycle of the system. It is often cited as a convenient summary measure of the overall competitiveness of different technologies[8], which is calculated according to Formula (8):

$$C_{\mathrm{L}} = \frac{\sum_{j=1}^{n} \frac{\left(C_j + O_j + R_j + D_j\right)}{(1+r)^n}}{\sum_{j=1}^{n} \frac{H \cdot t_j}{(1+r)^n}} \tag{8}$$

where

C_{L}	is the levelized cost of cooling water, in LCY/(kW_{th}·h);
C_j	is the capital cost in year j, in LCY;
O_j	is the operation and maintenance cost in year j, in LCY;
R_j	is the replacement cost in year j, in LCY;
D_j	is the disposal cost in year j, in LCY;
H	is the heat rejection capacity of the cooling system, in kW_{th};
t_j	is the running time of the system in year j, in h;
n	is the calculation period corresponding to the lifetime of the system, in years;
r	is the discount rate.

Annex A
(informative)

External benefit elements

Table A.1 helps companies make better decisions based on balancing the benefits and costs of using reclaimed water for industrial cooling water systems.

Table A.1 — External benefit elements for reclaimed water used in industrial cooling systems[6] [9][10][11][12]

Positive externalities	Notes
Reducing the industrial wastewater discharge fees	Discharge fees are usually charged by the government or the state when an industry discharges its wastewater into public rivers or water.
Health impacts	In most cases, reuse of industrial wastewater means reducing toxic pollutants which threaten aquatic organisms and humans.
Raising social awareness of a new water culture	Industrial wastewater reuse helps many industries become aware of the importance of resource recycling and find a new way to reduce cost. Communication policies may also need to be created to draw public attention to the new water culture.
Reduced pollutants in industrial wastewater discharge	There is a risk of industrial wastewater discharged into rivers directly without treatment threatening the biological organisms in the aquatic environment. However, this also depends on how discharges are regulated in the country concerned and specific cases.
Reduce declining ground water level	Using ground water as make-up water could save water resources by reusing industrial wastewater.
Financial subsidies	Reusing industrial wastewater is a requirement for sustainable development and is often encouraged by financial subsidies all over the world.
Negative externalities	**Notes**
Heat emission to the air and surface water	The cooling water in recirculating systems releases the majority of its heat via a cooling tower into the air. Meanwhile, the emission heat through leakage to the surface water influences the aquatic environment, especially fish. The temperature has a direct effect on all life forms and their physiology and an indirect effect by affecting the oxygen balance.
Process chemicals and their reactants due to leakage to the surface water	A large number of biocides used for inhibiting microorganism growth in the cooling system may have an adverse impact on the aquatic environment due to leakage to the surface water.

Table A.1 *(continued)*

Emissions of CO_2	Emissions of CO_2 into the air due to the operation of industrial cooling systems.
Emissions of noise	Noise emissions are generally an issue of both mechanical draught cooling towers and large natural draught wet cooling towers.