T.R.
MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF WATER MANAGEMENT

Water Efficiency Campaign

# Water Efficiency Guidance Documents Series

# 35.11 ELECTRICAL ENERGY GENERATION

It was commissioned by the Ministry of Agriculture and Forestry, General Directorate of Water Management to the Contractor io Environmental Solutions R&D Ltd. Şti.

# Contents

# Abbreviations

| | |
|---|---|
| WTP | Wastewater Treatment Plant |
| EU | European Union |
| SSM | Suspended Solid Matter |
| BREF | Best Available Techniques Reference Document |
| EMS | Environmental Management System |
| MoEUCC | Republic of Turkey Ministry of Environment, Urbanization and Climate Change |
| NOM | Natural Organic Matter |
| EMAS | Eco Management and Audit Program Directive |
| EPA | United States Environmental Protection Agency |
| IPPC | Industrial Pollution Prevention and Control |
| ISO | International Organization for Standardization |
| BAT | Best Available Techniques |
| NACE | Statistical Classification of Economic Activities |
| GSWM | General Directorate of Water Management |
| RO | Reverse Osmosis |
| MAF | Ministry of Agriculture and Forestry of the Republic of Turkey |
| TurkStat | Turkish Statistical Institute |
| NF | Nanofiltration |
| MF | Microfiltration |
| UF | Ultrafiltration |
| GW | Groundwater |
| SW | Surface Water |

# 1 Introduction

Türkiye is located in the Mediterranean basin, where the effects of global climate change are felt intensely, and is considered to be among the regions that will be most affected by the negative effects of climate change. Projections on how our water resources in our basins will be affected in the future due to climate change show that our water resources may decrease by up to 25 per cent in the next hundred years.

For the year 2022, the annual amount of water available per capita in Türkiye is 1,313 $m^3$ and it is expected that the annual amount of water available per capita will fall below 1,000 cubic metres after 2030 due to human pressures and the effects of climate change. If the necessary measures are not taken, it is obvious that Türkiye will become a country suffering from water scarcity in the very near future and will bring many negative social and economic consequences. As can be understood from the results of future projections, the risk of drought and water scarcity awaiting our country necessitates the efficient and sustainable use of our existing water resources.

The concept of water efficiency can be defined as *"using the least amount of water in the production of a product or service"*. The water efficiency approach is based on the rational, sharing, equitable, efficient and effective use of water in all sectors, especially in drinking water, agriculture, industry and household use, in a way that protects water in terms of quantity and quality and takes into account not only the needs of humans but also the needs of all living things with ecosystem sensitivity.

With the increasing demand for water resources, changes in precipitation and temperature regimes as a result of climate change, increasing population, urbanisation and pollution, fair and balanced allocation of usable water resources among users is becoming more and more important every day. For this reason, it has become a necessity to create a road map based on efficiency and optimisation in order to protect and use limited water resources through sustainable management practices.

In the vision of sustainable development set by the United Nations, Goal 7: Ensuring Environmental Sustainability from the Millennium Development Goals and Goal 9: Industry, Innovation and Infrastructure and Goal 12: Responsible Production and Consumption from the Sustainable Development Goals include issues such as efficient, fair and sustainable use of resources, especially water, environmentally friendly production and consumption with the concern of future generations.

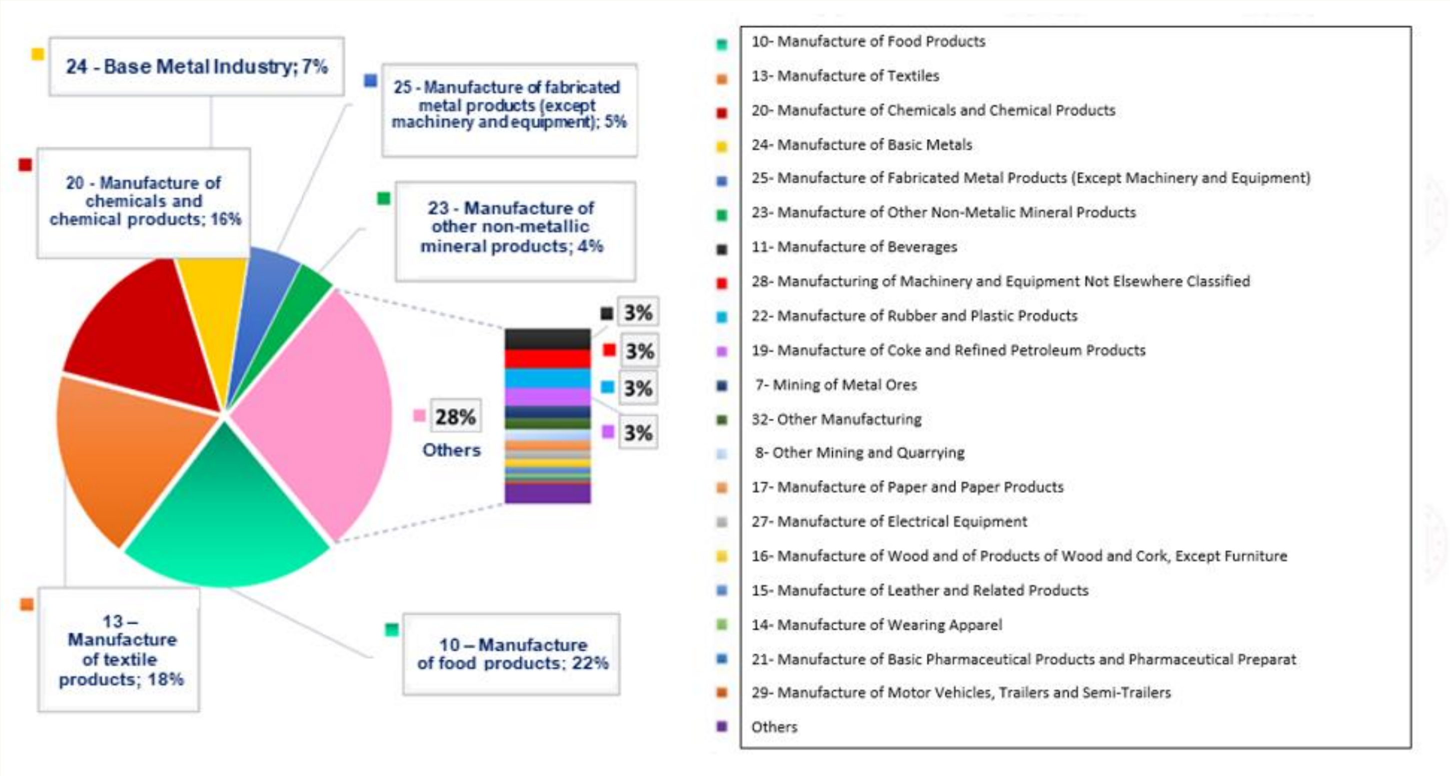
In the European Green Deal Action Plan prepared by our country within the scope of the European Green Deal Action Plan, in which member countries agreed on the objectives such as implementing a clean, circular economy model with a carbon neutral target, expanding the efficient use of resources and reducing environmental impacts, actions emphasising water and resource efficiency in production and consumption in various fields, especially in industry, have been determined.

The "Industrial Emissions Directive (EED)", which is one of the most important components of the European Union environmental legislation in terms of industry, includes measures to be taken for the control, prevention or reduction of discharges/emissions from industrial activities to the receiving environment, including air, water and soil, with an integrated approach. In the Directive, Best Available Techniques (BAT) are presented in order to systematise the applicability of cleaner production processes and to eliminate difficulties in implementation. BATs are the most effective implementation techniques for a high level of environmental protection, taking into account their costs and benefits. In accordance with the Directive, Reference Documents (BAT-BREF) have been prepared for each sector in which BATs are explained in detail. In BREF documents, BATs are presented in a general framework such as good management practices, techniques as general measures, chemical use and management, techniques for various production processes, wastewater management, emission management and waste management.

The Ministry of Agriculture and Forestry, General Directorate of Water Management carries out activities aimed at disseminating efficient practices in urban, agricultural, industrial and individual water use and raising social awareness. Water efficiency action plans addressing all sectors and stakeholders were prepared within the scope of ***the "Water Efficiency Strategy Document and Action Plan (2023-2033) within the Framework of Adaptation to a Changing Climate"***, which entered into force with the Presidential Circular No. 2023/9. In the Industrial Water Efficiency Action Plan, a total of 12 actions have been determined for the period 2023-2033 and responsible and relevant institutions have been assigned for these actions. Within the scope of the Action Plan, the General Directorate of Water Management is responsible for carrying out studies to determine specific water use ranges and quality requirements on the basis of sub-sectors in industry, organising technical training programmes and workshops on sectoral basis and preparing water efficiency guidance documents.

On the other hand, with the ***"Industrial Water Use Efficiency Project by NACE Codes"*** carried out by the General Directorate of Water Management of the Ministry of Agriculture and Forestry, the best sectoral techniques specific to our country were determined within the scope of studies on improving water efficiency in industry. As a result of the study, sectoral guidance documents and action plans categorised by NACE codes, including the measures recommended for improving water use efficiency in sectors with high water consumption operating in our country, were prepared.

As in the world, the sectors with the highest share in water consumption in our country are food, textile, chemical and basic metal sectors. Within the scope of the studies, field visits were carried out in enterprises representing 152 sub-sectors in 35 main sectors, especially food, textile, chemical and basic metal industries, which represent production areas with different capacities and diversity within the scope of NACE Codes operating in our country and with high water consumption, and data on water supply, sectoral water use, wastewater generation, recycling were obtained and information was provided on best available techniques (BAT) and sectoral reference documents (BREF), water efficiency, clean production, water footprint, etc. published by the European Union.




Sectoral distribution of water use in industry in Türkiye

As a result of the studies, specific water consumption and potential saving rates for the processes of enterprises for 152 different 4-digit NACE codes with high water consumption were determined, and water efficiency guidance documents were prepared by taking into account the EU best available techniques (BAT) and other cleaner production techniques. Within the guidelines, 500 techniques (BAT) for water efficiency;
(i) Good Management Practices, (ii) General Measures, (iii) Measures Related to Auxiliary Processes and (iv) Sector Specific Measures.

Within the scope of the project, environmental benefits, operational data, technical specifications-requirements and applicability criteria were taken into consideration during the determination of BATs for each sector. In the determination of BATs, not only BREF documents were not limited, but also different data sources such as current literature data on a global scale, real case analyses, innovative practices, reports of sector representatives were examined in detail and sectoral BAT lists were created. In order to evaluate the suitability of the BAT lists created for the local industrial infrastructure and capacity of our country, the BAT lists prepared specifically for each NACE code were prioritised by the enterprises by scoring them on the criteria of water saving, economic savings, environmental benefit, applicability, cross-media impact and the final BAT lists were determined using the scoring results. Water and wastewater data of the facilities visited within the scope of the project and the final BAT lists, which were prioritised by sectoral stakeholders and determined by taking into account the local dynamics specific to our country, were used to create sectoral water efficiency guides on the basis of NACE code.

# 2 Scope of the Study

Guidance documents prepared within the scope of water efficiency measures in industry cover the following main sectors:

- Crop and animal production and hunting and related service activities (including sub-production area represented by 6 four-digit NACE codes)
- Fisheries and aquaculture (including sub-production area represented by 1 four-digit NACE Code)
- Coal and lignite extraction (including sub-production area represented by 2 four-digit NACE codes)
- Service activities in support of mining (including sub-production area represented by 1 four-digit NACE Code)
- Metal ores mining (including the sub-production area represented by 2 four-digit NACE codes)
- Other mining and quarrying (including the sub-production area represented by 2 four-digit NACE codes)
- Manufacture of food products (including 22 sub-production areas represented by four-digit NACE codes)
- Manufacture of beverages (including the sub-production area represented by 4 four-digit NACE codes)
- Manufacture of tobacco products (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of textile products (including 9 sub-production areas represented by four-digit NACE codes)
- Manufacture of articles of clothing (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of leather and related products (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of wood, wood products and cork products (except furniture); manufacture of articles made of thatch, straw and similar materials (including sub-production area represented by 5 four-digit NACE Codes)
- Manufacture of paper and paper products (including sub-production area represented by 3 four-digit NACE codes)
- Manufacture of coke and refined petroleum products (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of chemicals and chemical products (including 13 sub-production areas represented by four-digit NACE codes)
- Manufacture of basic pharmaceutical products and pharmaceutical ingredients (including sub-production area represented by 1 four-digit NACE Code)
- Manufacture of rubber and plastic products (including sub-production area represented by 6 four-digit NACE codes)
- Manufacture of other non-metallic mineral products (including 12 sub-production areas represented by four-digit NACE codes)
- Basic metal industry (including 11 sub-production areas represented by four-digit NACE codes)
- Manufacture of fabricated metal products (except machinery and equipment) (including 12 sub-production areas represented by four-digit NACE codes)
- Manufacture of computers, electronic and optical products (including sub-production area represented by 2 four-digit NACE codes)
- Manufacture of electrical equipment (including sub-production area represented by 7 four-digit NACE codes)
- Manufacture of machinery and equipment not elsewhere classified (including sub-production area represented by 8 four-digit NACE codes)
- Manufacture of motor vehicles, trailers (semi-trailers) and semi-trailers (semi-trailers) (including sub-production area represented by 3 four-digit NACE codes)

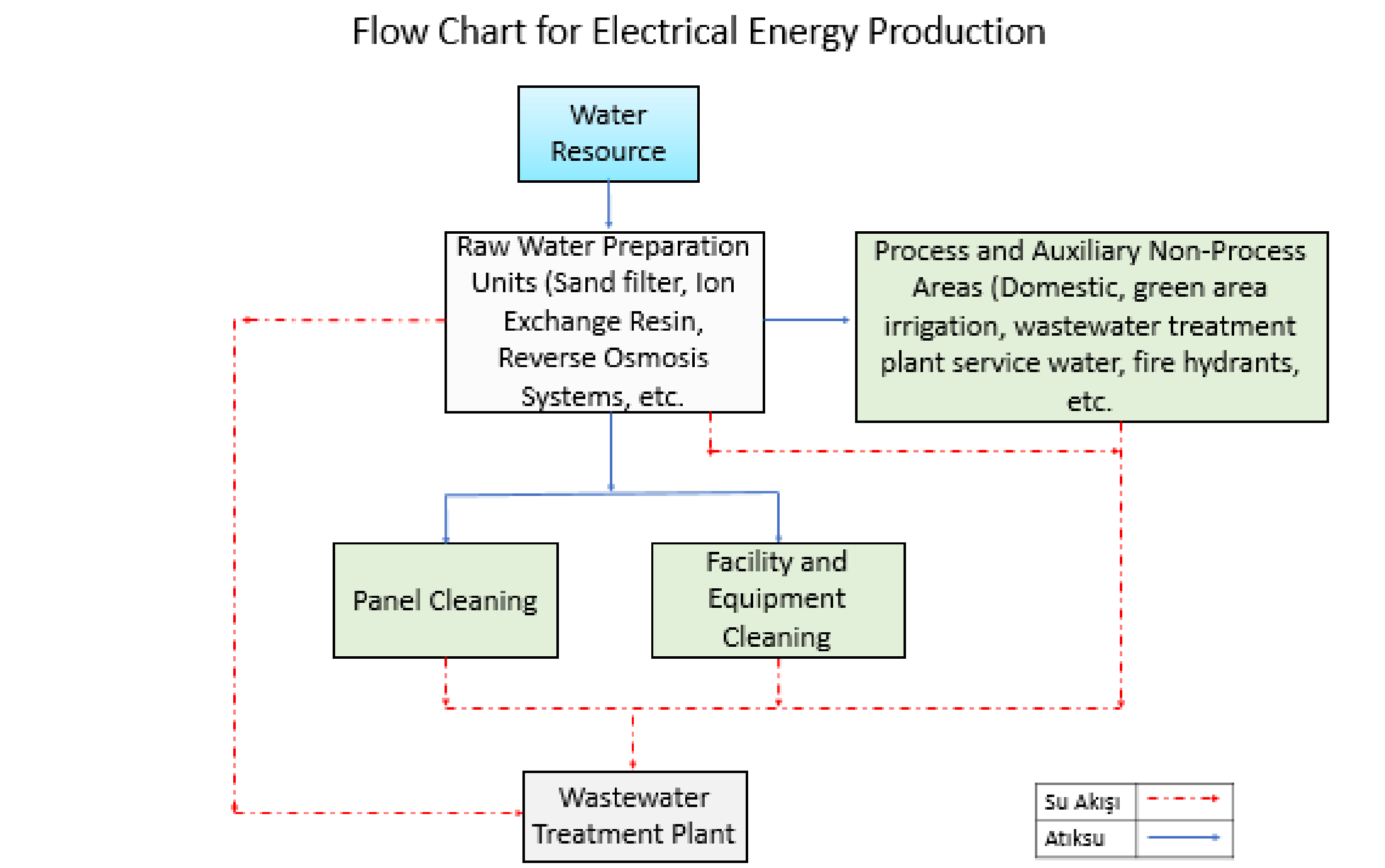
- Manufacture of other transport equipment (including sub-production area represented by 2 four-digit NACE codes)
- Other manufacturing (including 2 sub-production areas represented by four-digit NACE codes)
- Installation and repair of machinery and equipment (including sub-production area represented by 2 four-digit NACE codes)
- Electricity, gas, steam and ventilation system production and distribution (including sub-production area represented by 2 four-digit NACE codes)
- Waste collection, reclamation and disposal activities; recovery of materials (including sub-production area represented by 1 four-digit NACE Code)
- Construction of non-building structures (including sub-production area represented by 1 four-digit NACE Code)
- Warehousing and supporting activities for transport (including sub-production area represented by 1 four-digit NACE Code)
- Accommodation (including sub-production area represented by 1 four-digit NACE Code)
- Educational Activities (Higher Education Campuses) (including sub-production area represented by 1 four-digit NACE Code)
- Sporting activities, leisure and recreation activities (including sub-production area represented by 1 four-digit NACE Code)

## Electricity, gas, steam and ventilation system production and distribution

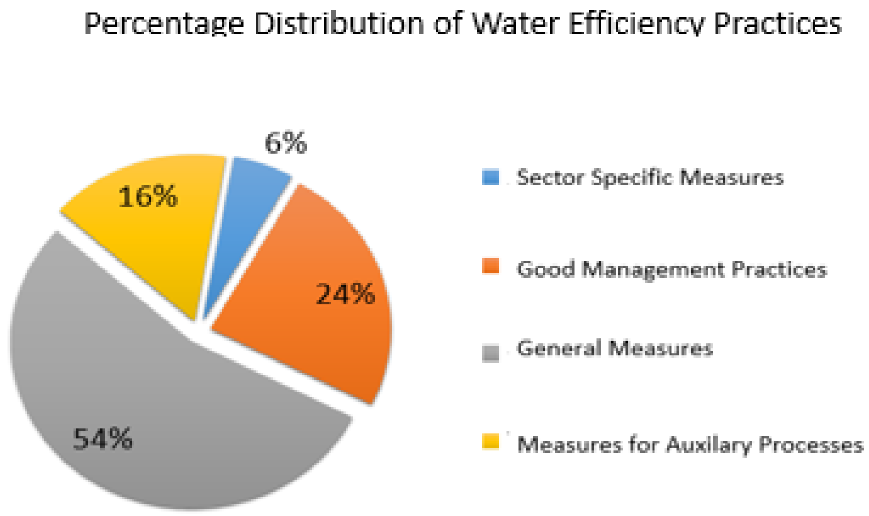
Under the electricity, gas, steam and ventilation system production and distribution sector, the sub-production branches for which guidance documents were prepared are as follows

| | |
|---|---|
| 35.11 | Electric power generation |
| 35.30 | Steam and air conditioning supply |

# 2.1 Electric Power Generation (NACE 35.11)




| | Minimum | Maksimum |
|---|---|---|
| Proje Kapsamında Ziyaret Edilen Tesislerin Spesifik Su Tüketimi (L/person.day) | 0,004 | 3,2 |
| Referans Spesifik Su Tüketimi (L/person.day) | 0,05 | 0,75 |



Methods such as coal and natural gas fuelled thermal power plants, nuclear power plants, hydroelectric power plants, wind energy, solar energy are used to generate electrical energy. The water supplied to thermal, nuclear and hydroelectric power plants from water sources such as sea and river is returned to the same receiving environment. For this reason, the water used for energy generation or cooling within the scope of the project and returned to the same source is not considered as consumption. However, since water consumption occurs for purposes such as panel cleaning in solar power plants, solar energy production is analysed.

In the production of electricity from solar energy, photovoltaic batteries convert the energy incident on them into electrical energy. When sunlight hits the panel, photovoltaic batteries absorb this light, take the photon and convert it into electricity. The converted electricity is not at the voltage value that we can use in our homes and converters are used.

Although there are dry methods for panel cleaning in electrical energy generation, cleaning is generally carried out with water in the facilities. Panels are usually cleaned at the beginning of the season to remove dust and dirt. Deionised water is needed to prevent stains and corrosion on the panels. If there are raw water preparation units such as activated carbon filter, ion exchange resin, reverse osmosis used to produce soft water to be used in production processes in the sector, significant water consumption is also realised for filter washing, resin regeneration and membrane cleaning processes.

The reference specific water consumption in the electric power generation sector is in the range of 0.05 - 0.75 L/kWh. The specific water consumption of the production branch analysed within the scope of the study is 0.004 - 3.2 L/kWh. With the implementation of sector-specific measures, good management practices and general measures, it is possible to achieve water savings of 39 - 59% in the sector.

35.11 Priority water efficiency implementation techniques recommended within the scope of Electrical Energy Generation NACE code are presented in the table below.

| NACE Code | NACE Code Description | | Sectoral Prioritisation Best Available Techniques |
|---|---|---|---|
| 35.11 | Electric power generation | | **Sector Specific Measures** |
| | | 1. | Hybrid dry and wet cleaning in panel cleaning, determining the need for cleaning with drone systems or with sensors that allow intervention only in dirty areas |
| | | | **Good Management Practices** |
| | | 1. | Use integrated wastewater management and treatment strategy to reduce wastewater quantity and pollutant load |
| | | 2. | Establishment of environmental management system |
| | | 3. | Preparation of water flow diagrams and mass balances for water |
| | | 4. | Preparing a water efficiency action plan to reduce water use and prevent water pollution |
| | | 5. | Providing technical trainings to personnel for the reduction and optimisation of water use |
| | | 6. | Good production planning to optimise water consumption |
| | | 7. | Determination of water efficiency targets |
| | | 8. | Monitoring the quantity and quality of water used in production processes and auxiliary processes and the wastewater generated and adapting this information to the environmental management system |
| | | | **Measures in the nature of General Measures** |
| | | 1. | Minimising spillages and leakages |
| | | 2. | Recovery of water from rinsing solutions and reuse of recovered water in processes appropriate to its quality |
| | | 3. | Use of automatic hardware and equipment (sensors, smart hand washing systems, etc.) that will save water at water usage points such as showers/toilets etc. |
| | | 4. | Use of pressure washing systems for equipment cleaning, general cleaning, etc. |
| | | 5. | Reducing water consumption by reusing filter wash water in filtration processes, reusing relatively clean cleaning water in production processes and using clean-in-place systems (CIP) |
| | | 6. | Avoiding the use of drinking water in production lines |
| | | 7. | Use of cooling water as process water in other processes |
| | | 8. | Identification and minimisation of water losses |
| | | 9. | Use of automatic control-close valves to optimise water use |
| | | 10. | Documented production procedures are kept and used by employees to prevent water and energy wastage |
| | | 11. | Reuse of pressurised filtration backwash water prior to water softening at appropriate points |
| | | 12. | Optimising the frequency and duration of regeneration (including rinses) in water softening systems |
| | | 13. | Construction of closed storage and impermeable waste/scrap sites to prevent the transport of toxic or hazardous chemicals for the aquatic environment |
| | | 14. | Storage and storage of substances (such as oils, emulsions, binders) that pose a risk in the aquatic environment and prevention of their mixing with wastewater after use |

| NACE Code | NACE Code Description | Sectoral Prioritisation Best Available |
|---|---|---|
| 35.11 | Electric power | 15. Where technically feasible, treatment of suitable wastewater and use as steam boiler feed water |
| | | 16. Prevention of mixing of clean water streams with polluted water |
| | | streams Preventing the quantity and quality of wastewater at all wastewater generation points |
| | | 17. characterisation of wastewater streams that can be reused with or without treatment |
| | | 18. Use of closed loop water cycles in appropriate processes |
| | | 19. Use of computer aided control systems in production processes |
| | | 20. Untreated reuse of relatively clean wastewater from washing, rinsing and equipment cleaning in production processes |
| | | 21. Determination of the scope of reuse of washing and rinsing water |
| | | 22. Separate collection and treatment of grey water in the facility and its use in areas that do not require high water quality (green area irrigation, floor washing, etc.) |
| | | 23. Implementation of time optimisation in production and arrangement of all processes to be completed as soon as possible |
| | | 24. Collecting rainwater and utilising it as an alternative water source in facility cleaning or in suitable areas |
| | | 25. Preventing the need for rinsing between activities by using compatible chemicals in sequential processes |
| | | 26. Reuse of nanofiltration (NF) or reverse osmosis (RO) concentrates with or without treatment depending on their characterisation |
| | | **Precautions for Auxiliary Processes** |
| | | 1. Saving water by reusing steam boiler condensate |
| | | 2. Increasing the number of cycles by using corrosion and scale inhibitors in systems with closed water cycle |
| | | 3. Use of air cooling systems instead of water cooling in cooling systems |
| | | 4. Reducing the amount of blowdown by using degassers in steam boilers |
| A total of 39 techniques have been proposed in this sector. | | |

For Electrical Energy Generation NACE Code;

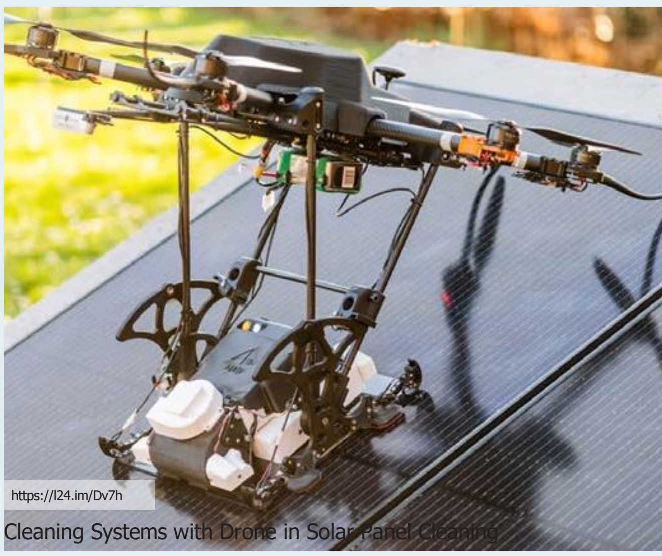
(i) Sector Specific Measures,
(ii) Good Management Practices,
(iii) General Precautions and
(iv) Precautions for Auxiliary Processes
are given under separate headings.

# 2.1.1 Sector Specific Measures

- ***Hybrid dry and wet cleaning in panel cleaning, determining the need for cleaning with drone systems or with sensors that allow intervention only in dirty areas***

Dust and debris accumulated on solar panels reduce efficiency in energy production and adversely affect power output. For this reason, the panels are regularly cleaned, especially during seasonal transitions. In systems that provide panel cleaning with drone systems, drones fly over the panel and detect the pallet to be cleaned with sensors. The robotic system connected to the drone is released from the drone platform onto the panel and cleans the panel with equipment such as rotating brushes etc. by spraying cleaning fluid. The helicopter returning to the station picks up the robot that has completed the cleaning process on the panel. In this way, the areas in need of cleaning are identified and water use is reduced as dry cleaning is performed at possible points (Coxworth, 2022).

Dry cleaning methods can also be applied with equipment such as compressed air sprays, synthetic dust cloths and mechanical rollers. Especially the Middle East regions, which have a high potential to utilise solar energy, are under high impact in terms of sand and dust. In addition, in these regions where water scarcity is experienced, cleaning of solar panels becomes a costly and challenging issue. Dry methods are recommended for panel cleaning in these regions (Aly, Gandhidasan, Barth, & Ahzi, 2015).




Cleaning Systems with Drone in Solar Panel Cleaning


Dry Cleaning Robot for Solar Panel Cleaning

## 2.1.2 Good Management Practices

***Establishment of environmental management system***

Environmental Management Systems (EMS) include the organisational structure, responsibilities, procedures and resources required to develop, implement and monitor the environmental policies of industrial organisations. The establishment of an environmental management system improves the decision-making processes between raw materials, water and wastewater infrastructure, planned production process and different treatment techniques. Environmental management organises how resource supply and waste discharge demands can be managed with the highest economic efficiency, without compromising product quality and with the least possible impact on the environment.

The most widely used Environmental Management Standard is ISO 14001. Alternatives include the Eco Management and Audit Scheme Directive (EMAS) (761/2001). It has been developed for the assessment, improvement and reporting of the environmental performance of enterprises. It is one of the leading practices within the scope of eco-efficiency (cleaner production) in EU legislation and voluntary participation is provided (TUBITAK MAM, 2016; MAF, 2021). The benefits of establishing and implementing an Environmental Management System are as follows:

- Economic benefits can be obtained by improving business performance (Christopher, 1998).
- International Standards Organisation (ISO) standards are adopted to ensure greater compliance with global legal and regulatory requirements (Christopher, 1998).
- While the risks of penalties related to environmental responsibilities are minimised, the amount of waste, resource consumption and operating costs are reduced (Delmas, 2009).
- The use of internationally recognised environmental standards eliminates the need for multiple registrations and certificates for businesses operating in different locations around the world (Hutchens Jr., 2017).
- Especially in recent years, the improvement of the internal control processes of companies is also considered important by consumers. The implementation of environmental management systems provides a competitive advantage against companies that do not adopt the standard. It also contributes to the better position of organisations in international areas / markets (Potoski & Prakash, 2005).

The above-mentioned benefits depend on many factors such as the production process, management practices, resource utilisation and potential environmental impacts (MAF, 2021). Practices such as preparing annual inventory reports with similar content to the environmental management system and monitoring inputs and outputs in terms of quantity and quality in production processes can save 3-5% of water consumption (Öztürk, 2014). The total duration of the development and implementation phases of the EMS takes an estimated 8-12 months (ISO 14001 User Manual, 2015).

Industrial organisations also carry out studies within the scope of ISO 14046 Water Footprint Standard, an international standard that defines the requirements and guidelines for assessing and reporting water footprint. With the implementation of the relevant standard, it is aimed to reduce the use of fresh water required for production and environmental impacts. In addition, ISO 46001 Water Efficiency Management Systems Standard, which helps industrial organisations to save water and reduce operating costs, helps organisations to develop water efficiency policies by conducting monitoring, benchmarking and review studies.

- ***Use integrated wastewater management and treatment strategy to reduce wastewater quantity and pollutant load***

Wastewater management should be based on a holistic approach from wastewater generation to final disposal and includes functional elements such as composition, collection, treatment including sludge disposal and reuse. The selection of the appropriate treatment technology for industrial wastewater depends on integrated factors such as land availability, desired treated water quality and compliance with national and local regulations (Abbassi & Al Baz, 2008).

On-site reuse of treated wastewater not only improves the quality of water bodies, but also reduces the demand for freshwater. It is therefore very important to identify appropriate treatment strategies for different reuse objectives.

In integrated industrial wastewater treatment, different aspects such as wastewater collection system, treatment process and reuse target are evaluated together (Naghedi et al., 2020). For industrial wastewater recovery, methods such as SWOT method (strengths, weaknesses, opportunities and threats), PESTEL method (political, economic, social, technological, environmental and legal factors), decision tree can be combined with expert opinions to determine the integrated wastewater management framework (Naghedi et al., 2020). The integration of Analytic Hierarchy Process (AHP) and CoCoSo techniques can be used to determine priorities based on multiple criteria for industrial wastewater management processes (Adar et al., 2021).

The implementation of integrated wastewater management strategies can lead to an average reduction of up to 25% in water consumption, wastewater quantity and pollution loads of wastewater. The potential payback period of the implementation varies between 1-10 years (MAF, 2021).

http://www.asw-eg.com/en/images/products/116567Water-Sewage-Treatment-System-With-Plant-And-Facility.jpg

Industrial Wastewater Treatment Plant

- ***Providing technical trainings to personnel for the reduction and optimisation of water use***

  With this measure, water saving and water recovery can be achieved by increasing the training and awareness of the personnel, and water efficiency can be achieved by reducing water consumption and costs. In industrial facilities, problems related to high water consumption and wastewater generation may arise due to the lack of necessary technical knowledge of the personnel. For example, it is important that cooling tower operators, which represent a significant proportion of water consumption in industrial operations, are properly trained and have technical knowledge. Determination of water quality requirements in production processes, measurement of water and wastewater quantities, etc. It is also necessary for the relevant personnel to have sufficient technical knowledge (MAF, 2021). Therefore, it is important to provide training to staff on water use reduction, optimisation and water saving policies. Practices such as involving the staff in water saving studies, creating regular reports on the amount of water use before and after water efficiency initiatives, and sharing these reports with the staff support participation and motivation in the process. The technical, economic and environmental benefits to be obtained through staff training yield results in the medium or long term (TUBITAK MAM, 2016; MAF, 2021).

- ***Monitoring the water used in production processes and auxiliary processes and the wastewater generated in terms of quantity and quality and adapting this information to the environmental management system*** There is resource utilisation in industrial facilities and there is resource utilisation as a result of resource utilisation.
  Inefficiency and environmental problems may arise from input-output flows. For this reason
  Water and wastewater used in production processes and auxiliary processes should be monitored in terms of quantity and quality (TUBITAK MAM, 2016; MAF, 2021). Process-based quantity and quality monitoring together with other good management practices (personnel training, establishment of an environmental management system, etc.) can reduce energy consumption by 6-10%, water consumption and wastewater quantities by
  It can provide a reduction of up to 25% (Öztürk, 2014).

  The main stages for monitoring water and wastewater in terms of quantity and quality are as follows

  - Use of monitoring equipment (such as counters) to monitor water, energy, etc. consumption on a process basis,
  - Establishment of monitoring procedures,
  - Determining the use/exit points of all inputs and outputs (raw materials, chemicals, water, products, wastewater, sludge, solid waste, hazardous waste and by-products) related to the production process, monitoring, documenting, comparative evaluation and reporting in terms of quantity and quality,
  - Monitoring raw material losses in production processes where raw materials are transformed into products and taking measures against raw material losses (MoEU, 2020e).

- ***Good production planning to optimise water consumption***

  In industrial production processes, planning by using the least process in the process from raw material to product is an effective practice for reducing labour costs, resource use costs and environmental impacts and ensuring efficiency (TUBITAK MAM, 2016; MAF, 2021). Production planning in industrial plants, taking into account the water efficiency factor, reduces water consumption and wastewater amount. Modification of production processes in industrial plants or combining some processes provides significant benefits in terms of water efficiency and time planning (MAF, 2021).

- ***Preparing a water efficiency action plan to reduce water use and prevent water pollution***

  It is important for water efficiency to prepare an action plan that includes short, medium and long term actions to be taken in order to reduce water-wastewater quantities and prevent water pollution in industrial facilities. At this point, determination of water needs throughout the facility and in production processes, determination of quality requirements at water use points, wastewater generation points and wastewater characterisation should be carried out (MAF, 2021). At the same time, it is necessary to determine the measures to be implemented to reduce water consumption, wastewater generation and pollution loads, to make their feasibility and to prepare action plans for the short-medium-long term. In this way, water efficiency and sustainable water use are ensured in the facilities (MAF, 2021).

- ***Determination of water efficiency targets***

  The first step in achieving water efficiency in industrial facilities is to set targets (MAF, 2021). For this, a detailed water efficiency analysis should be carried out on the basis of processes. In this way, unnecessary water use, water losses, wrong practices affecting water efficiency, process losses, reusable water-wastewater sources with or without treatment, etc. can be determined. It is also very important to determine the water saving potential and water efficiency targets for each production process and the plant as a whole (MAF, 2021).

- ***Preparation of water flow diagrams and mass balances for water***

  Determination of water use and wastewater generation points in industrial plants, establishment of water-wastewater balances in production processes and auxiliary processes other than production processes constitute the basis of many good management practices in general. Establishing process profiles throughout the plant and on the basis of production processes facilitates the identification of unnecessary water use points and high water use points, evaluation of water recovery opportunities, process modifications and determination of water losses (MAF, 2021).

## 2.1.3 General Measures

- ***Identification and minimisation of water losses***

Water losses occur in equipment, pumps and pipelines in industrial production processes. Firstly, water losses should be identified and leakages should be prevented by regular maintenance of equipment, pumps and pipelines to keep them in good condition (IPPC BREF, 2003). Regular maintenance procedures should be established, paying particular attention to the following points:

- Adding pumps, valves, level switches, pressure and flow regulators to the maintenance checklist,
- Carrying out inspections not only in the water system, but also in particular in the heat transfer and chemical distribution systems, broken and leaking pipes, barrels, pumps and valves,
- Regular cleaning of filters and pipework,
- Calibrate, routinely check and monitor measuring equipment such as chemical measuring and dispensing devices, thermometers, etc. (IPPC BREF, 2003).

With effective maintenance-repair, cleaning and loss control practices, savings ranging from 1-6% in water consumption can be achieved (Öztürk, 2014).

- ***Minimising spillages and leakages***

Both raw material and water losses can occur due to spills and leaks in enterprises. In addition, if wet cleaning methods are used to clean the areas where spillage occurs, water consumption, wastewater amounts and pollution loads of wastewater may also increase (MAF, 2021). In order to reduce raw material and product losses, spill and splash losses are reduced by using splash guards, flaps, drip trays, sieves (IPPC BREF, 2019).

- ***Prevention of mixing of clean water flows with polluted water flows***

By determining the wastewater generation points in industrial facilities and characterising the wastewater, wastewater with high pollution load and relatively clean wastewater can be collected in separate lines (TUBITAK MAM, 2016; MAF, 2021). In this way, wastewater streams with appropriate quality can be reused with or without treatment. With the separation of wastewater streams, water pollution is reduced, treatment performances are improved, energy consumption can be reduced in relation to the reduction of treatment needs, and emissions are reduced by providing wastewater recovery and recovery of valuable materials. In addition, heat recovery from separated hot wastewater streams is also possible (TUBITAK MAM, 2016; MAF, 2021). Separation of wastewater streams generally requires high investment costs, and where it is possible to recover large amounts of wastewater and energy, costs can be reduced (IPPC BREF, 2006).

- ***Use of pressure washing systems for equipment cleaning, general cleaning, etc.***

  Water nozzles are widely used in equipment plant cleaning. Effective results can be achieved by using correctly placed, appropriate nozzles to reduce water consumption and wastewater pollution loads. The use of active sensors and nozzles at points where high water consumption occurs and where possible is very important in terms of efficient use of water. It is possible to achieve significant water savings by replacing mechanical equipment with pressurised nozzles (TUBITAK MAM, 2016). Reducing water consumption, wastewater generation and wastewater pollution load through the use of water pressure optimised nozzles in technically appropriate processes are the main environmental benefits of the application.

- ***Use of automatic control-close valves to optimise water use***

  Monitoring and controlling water consumption using flow control devices, meters and computer-aided monitoring systems provide significant technical, environmental and economic advantages (Öztürk, 2014). Monitoring the amount of water consumed in the plant and in various processes prevents water losses (TUBITAK MAM, 2016). It is necessary to use flow meters and counters in the plant in general and in production processes in particular, to use automatic shut-off valves and valves in continuously operating machines, and to develop monitoring-control mechanisms according to water consumption and some determined quality parameters by using computer-aided systems (TUBITAK MAM, 2016). With this application, it is possible to save up to 20-30% of water consumption on process basis (DEPA, 2002; LCPC, 2010; IPPC BREF, 2003). By monitoring and controlling water consumption on a process basis, 3-5% savings can be achieved in process water consumption (Öztürk, 2014).

- ***Avoiding the use of drinking water in production lines***

  In different sub-sectors of the manufacturing industry, waters with different water quality can be used for production purposes. In industrial plants, raw water supplied from groundwater sources is generally used in production processes after treatment. However, in some cases, although it is costly in production processes, drinking water can be used directly or raw water is disinfected with chlorinated compounds and then used in production processes. These waters containing residual chlorine can react with organic compounds (natural organic substances (NOM)) in water in production processes and form disinfectant by-products harmful to living metabolisms (Özdemir & Toröz, 2010; Oğur et al.) The use of drinking water containing residual chlorine compounds or raw water disinfected with chlorinated compounds should be avoided as much as possible. Highly oxidising disinfection methods such as ultraviolet (UV), ultrasound (US) or ozone can be used instead of chlorine disinfection for disinfection of raw water. In order to increase the technical, economic and environmental benefits of the application, the determination and use of the water quality parameters required in each production process helps to reduce unnecessary water supply and treatment costs. With this application, it is possible to reduce water, energy and chemical costs (TUBITAK MAM, 2016).

- ***Storage and storage of substances that pose a risk in the aquatic environment (such as oils, emulsions, binders) and prevention of their mixing with wastewater after use***

  In industrial plants, water recovery is achieved by using dry cleaning techniques and preventing leaks to prevent the mixing of chemicals that pose a risk to the aquatic environment such as oils, emulsions and binders into wastewater streams (TUBITAK MAM, 2016).

- ***Construction of closed storage and impermeable waste/scrap sites to prevent the transport of toxic or hazardous chemicals for the aquatic environment***

  In industrial facilities, closed and impermeable waste/scrap storage sites can be constructed to prevent the transport of toxic or hazardous chemicals for the aquatic environment to receiving environments. This practice is already being implemented in our country within the scope of existing environmental regulations. Within the scope of the field studies carried out, a separate collection channel can be constructed in the storage areas of toxic or hazardous substances in industrial facilities and the leachate can be collected separately and prevented from mixing into natural water environments.

- ***Use of computer aided control systems in production processes***

  Since inefficient resource utilisation and environmental problems in industrial facilities are directly related to input-output flows, it is necessary to define the process inputs and outputs in the best way for production processes (TUBITAK MAM, 2016). Thus, it becomes possible to develop measures to improve resource efficiency, economic and environmental performance. The organisation of input-output inventories is considered as a prerequisite for continuous improvement. While such management practices require the participation of technical staff and senior management, they pay for themselves in a short time with the work of various experts (IPPC BREF, 2003). It is necessary to use measurement equipment on the basis of application processes and to carry out some routine analyses/measurements specific to the processes. Utilising computerised monitoring systems as much as possible in order to maximise the efficiency of the application increases the technical, economic and environmental benefits to be obtained (TUBITAK MAM, 2016).

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Computer Aided Control System

- ***Documented production procedures are kept and used by employees to prevent water and energy wastage***

  In order to ensure efficient production in an enterprise, effective procedures should be implemented to identify and evaluate potential problems and resources and to control production stages (Ayan, 2010). Determining and implementing appropriate procedures in production processes ensures more efficient use of resources (such as raw materials, water, energy, chemicals, personnel and time) and ensures reliability and quality in production processes (Ayan, 2010). The existence of documented production procedures in production processes contributes to the evaluation of business performance and the development of the ability to develop immediate reflexes to solve problems (TUBITAK MAM, 2016; MAF, 2021). Effective implementation and monitoring of the procedures created specifically for production processes is one of the most effective ways to ensure product quality, receive feedback and develop solutions (Ayan, 2010). Documentation, effective implementation and monitoring of production procedures is a good management practice and an effective tool in structuring and ensuring the continuity of the cleaner production approach and environmental management system. In addition to the potential benefits, the cost and economic gains of the application may vary from sector to sector or depending on the facility structure (TUBITAK MAM, 2016; MAF, 2021). Although establishing and monitoring production procedures is not costly, the payback period may be short considering the savings and benefits it will provide (TUBITAK MAM, 2016; MAF, 2021).

- ***Implementation of time optimisation in production and arrangement of all processes to be completed as soon as possible***

  In industrial production processes, planning the process from raw material to product by using the minimum number of processes is an effective practice for reducing labour costs, resource use costs and environmental impacts and ensuring efficiency. In this context, it may be necessary to revise the production processes so that the minimum number of process steps is used (TUBITAK MAM, 2016). In cases where the desired product quality cannot be achieved due to some inefficiencies, inefficiency and design errors in basic production processes, production processes may need to be renewed. Therefore, in this case, the resource utilisation and the amount of waste, emission and solid waste generated in the production of unit amount of product increases. Time optimisation in production processes is an effective application (TUBITAK MAM, 2016).

- ***Recovery of water from rinsing solutions and reuse of recovered water in a process appropriate to its quality***

  Rinsing wastewater in industrial plants can be reused without treatment in relatively clean wastewater, floor washing and garden irrigation processes that do not require high water quality (Öztürk E. , 2014). Thanks to this reuse, savings between 1-5% in raw water consumption can be achieved. The initial investment cost required for the application consists of the installation of new pipelines and reserve tanks. The estimated initial investment cost can vary between 1000-5000 TL.

- ***Avoid the need to rinse between activities by using compatible chemicals in sequential processes***

  Chemical compatibility is a measure of how stable a substance is when mixed with another substance. If two substances can mix together and undergo a chemical reaction, they are considered incompatible.

  Various chemicals are used in industrial plants to increase washing and rinsing efficiency. The fact that these chemicals are compatible and act as solvents has a positive effect on increasing the efficiency. Therefore, the dirt on the material can be removed in a shorter time and more effectively and the amount of water used in washing processes can be significantly reduced. In this case, even if the amount of wastewater can be reduced, the chemical loads carried by wastewater may increase. These negative effects can be minimised by reusing the solvent-containing wash water used in washing and rinsing processes.

  Water savings of 25-50% can be achieved by reusing wash water. The application may require reserve tanks and new pipelines. In some cases, the washing solution is kept directly in the system and can be used repeatedly until it loses its properties. The investment costs required for both cases can be variable. However, the initial investment cost of the applications can be between 5.000 - 30.000 TL.

- ***Reuse of nanofiltration (NF) or reverse osmosis (RO) concentrates without or after treatment, depending on their characterisation***

  Depending on the wastewater characterisation and the appropriate point of use, the reuse potential of other wastewater from membrane processes (backwashes without or with chemicals, CIP cleaning, module cleaning, cleaning of chemical tanks, etc.) should be evaluated.

  Nanofiltration is a membrane-based liquid separation technique with low energy consumption and low operating pressures suitable for the treatment of well water and surface water. Reverse osmosis is also a membrane-based liquid separation technique and can remove smaller substances than nanofiltration (AKGÜL, 2016).

  Depending on the characterisation of nanofiltration or reverse osmosis concentrates, savings can be achieved by reusing them without treatment or after treatment. Measures should be taken to reduce water consumption by reusing clean water in the production processes of filter backwash water in filtration processes and using cleaning systems (MAF, 2021).

- ***Use of cooling water as process water in other processes***

  Water cooling systems are widely used in processes where thermal energy is used intensively and cooling is required. It is possible to recover heat by using heat exchangers in cooling water return, prevent contamination of cooling water, and save water and energy by increasing cooling water return rates (TUBITAK MAM, 2016; MAF, 2021). In addition, in case of separate collection of cooling water, it is often possible to use the collected water for cooling purposes or to reuse it in appropriate processes (EC, 2009). Reuse of cooling water can save 2-9% of total water consumption ( Greer et al., 2013). Energy consumption can be saved up to 10% (Öztürk E. , 2014; MAF, 2021).

- ***Reuse of filter washing water in filtration processes, reuse of relatively clean cleaning water in production processes, reduction of water consumption by using on-site cleaning systems***

The wastewater from backwashing of activated carbon filters and softeners usually contains only a high content of suspended solids (TSS). Backwash water, which is one of the easiest types of wastewater to recover, can be recovered by filtration with ultrafiltration plants. In this way, water savings of up to 15% can be achieved. This investment can pay itself back within 1-2 months (URL - 1, 2021).

Regeneration wastewater generated after the regeneration process are soft waters with high salt content and constitute approximately 5-10% of total water consumption. Regeneration wastewater can be collected in a separate tank and utilised in processes with high salt requirements, plant cleaning and domestic use. For this purpose, a reserve tank, water installation and a pump are required. By reusing regeneration wastewater, approximately 5-10% reduction in water consumption, energy consumption, wastewater amounts and salt content of wastewater can be achieved (Öztürk E. , 2014). The initial investment cost for the application is expected to be around 250-350 USD/m³ (TUBITAK MAM, 2016; MAF, 2021). The payback period varies depending on whether the regeneration water is consumed in production processes, in the plant system or for domestic use. The potential payback period is estimated to be less than one year in case of reuse of regeneration waters in production processes that require high salt (since both water and salt will be recovered). For facility and equipment cleaning and domestic use, the payback period is estimated to be over one year (MAF, 2021).

In our country, reverse osmosis (RO) concentrates are combined with other wastewater streams and discharged to the wastewater treatment plant channel. It is possible to use the concentrates formed in TO systems used for additional hardness removal for garden irrigation, in-plant and tank-equipment cleaning (TUBITAK MAM, 2016; MAF, 2021). In addition, with the configuration of continuous monitoring of raw water quality applications, it is possible to feed TO concentrates back to the raw water reservoirs and re-evaluate them by mixing (MAF, 2021).

- ***Where technically feasible, treatment of suitable wastewater and use as steam boiler feed water***

Although it is quite difficult to implement in industrial plants, it can be ensured that suitable wastewater is treated to process water quality and reused in production processes, including steam boilers. In this way, savings ranging from 20-50% in total water consumption and wastewater generation can be achieved (Öztürk E. , 2014; TUBİTAK MAM, 2016). The initial investment cost required for the application is the treatment system to be used. Considering the amount of water to be recovered, the amount of economic savings, unit water-wastewater costs applied, treatment system operation-maintenance costs, payback periods vary. However, it is estimated that the payback period will be long due to the extra costs of treatment (MAF, 2021). In this context, a combination of membrane systems (ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) systems can be used. For example, in some industrial plants, it may be possible to treat cooling system blowdown water and reuse it as process water (MAF, 2021).

- ***Reuse of pressurised filtration backwash water prior to water softening at appropriate points***

  Today, there is a need for softened process water with low calcium and magnesium concentrations. With water softening systems, calcium, magnesium and some other metal cations in hard water are removed from the water and soft water is obtained.

  Various savings can be achieved by reusing pressurised filtration backwash water at appropriate points before water softening. This measure is similar in content with practices such as "Reuse of filter backwash water in filtration processes, reuse of relatively cleaning water in production processes, reduction of water consumption by using on-site cleaning systems".

- ***Optimising the frequency and duration of regeneration (including rinses) in water softening systems***

  Cationic ion exchange resins, which are one of the most frequently used methods for softening raw water in industrial plants, are routinely regenerated. In regeneration, pre-washing of the resin using raw water, regeneration with salt water and final rinsing processes are carried out respectively. Regeneration time is set to certain days and hours according to the hardness of the water. If the hardness is high, regeneration should be done more frequently in water softening systems.

  In regeneration processes, washing, regeneration and rinsing wastewaters are usually removed directly. However, if the washing and final rinsing waters are of raw water quality, they can be sent to raw water storage or reused in processes that do not require high water quality such as plant cleaning and green area irrigation (MAF, 2021). Regeneration wastewater has high conductivity and high salt and calcium content. For this reason, although it is not reused in areas requiring sensitive water quality, it can be reused in some industries such as yeast industry (TUBITAK MAM, 2016).

  It is very important to determine the optimum regeneration frequency in regeneration systems. Although regeneration in water softening systems is adjusted according to the frequencies recommended by the supplier or depending on the flow rate and time entering the softening system, this frequency may also vary depending on the calcium concentration in the raw water. For this reason, online hardness measurement is applied when determining the regeneration frequency. Thus, regeneration frequencies can be optimised and excessive washing rinsing or backwashing with salt water can be avoided by using online hardness sensors.

- ***Untreated reuse of relatively clean wastewater from washing, rinsing and equipment cleaning in production processes***

  In industrial plants, relatively clean wastewater such as washing-final rinse wastewater and filter backwash wastewater can be reused without treatment in floor washing and garden irrigation processes that do not require high water quality, saving between 1-5% in raw water consumption. The initial investment costs required for the application are the installation of new pipelines and reserve tanks (Öztürk, 2014).

- ***Use of closed loop water cycles in appropriate processes***

Refrigerants are chemical compounds with certain thermodynamic properties that take heat from the substances to be cooled and cool them, affecting the performance of the cooling process (Kuprasertwong et al., 2021).

Water is used as a refrigerant in many processes in the manufacturing industry and in many processes led by the product cooling process. During this cooling process, water can be reused through cooling tower or central cooling systems. If unwanted microbial growth occurs in the cooling water, it can be controlled by adding chemicals to the recirculation water (TUBITAK MAM, 2016).

By reusing cooling water in processes such as cleaning, water consumption and the amount of wastewater generated are reduced. However, the need for energy for cooling and recirculation of cooling water is a side interaction.

Heat recovery is also provided by the use of heat exchangers in cooling water. Generally, closed loop systems are used in plants where aqueous cooling systems are used. However, cooling system blowdowns are discharged directly to the wastewater treatment plant channel. These blowdown waters can be reused in appropriate production processes.

- ***Collecting rainwater and utilising it as an alternative water source in facility cleaning or in suitable areas***

Nowadays, when water resources are decreasing, rainwater harvesting is frequently preferred especially in regions with low rainfall. There are different technologies and systems for rainwater collection and distribution systems. Cistern systems, ground infiltration, surface collection and filter systems are used. Rainwater collected by special drainage systems can be used for production processes, garden irrigation, tank and equipment cleaning, surface cleaning, etc. if it meets the required quality requirements (Tanık et al., 2015).

In various examples, roof rainwater collected in industrial facilities was stored and used inside the building and in landscape areas, resulting in 50% water saving in landscape irrigation (Yaman, 2009). Perforated stones and green areas can be preferred in order to increase the permeability of the ground and to allow rainwater to pass and absorb into the soil on the site (Yaman, 2009). Rainwater collected on building roofs can be used for car washing and garden irrigation. It is possible to recover and reuse 95% of the collected water by biological treatment after use (Şahin, 2010).

- ***Determination of the scope of reuse of washing and rinsing water***

In industrial plants, relatively clean wastewaters such as washing-final rinse wastewaters and filter backwash wastewaters can be reused without treatment in floor washing and garden irrigation processes that do not require high water quality (Öztürk, 2014). Thus, it is possible to save between 1-5% in raw water consumption (MAF, 2021).

- ***Use of automatic hardware and equipment (sensors, smart hand washing systems, etc.) to save water at water usage points such as showers/toilets etc.***

  Water is very important in many sectors of the manufacturing industry, both for production processes and for personnel to meet the necessary hygiene standards. Water consumption in the production processes of industrial facilities can be provided in various ways, as well as water consumption savings can be achieved by using equipment such as sensor faucets and smart hand washing systems in the water usage areas of the personnel. Smart hand washing systems provide resource efficiency in addition to water saving while adjusting the mixture of water, soap and air at the right rate.

- ***Separate collection and treatment of grey water in the facility and its use in areas that do not require high water quality (green area irrigation, floor washing, etc.)***

  Wastewater generated in industrial facilities is not only industrial wastewater from production processes, but also includes wastewater from showers, sinks, kitchens, etc. Wastewater from shower, sink, kitchen etc. areas is called grey water. Water savings can be achieved by treating this grey water with various treatment processes and using it in areas that do not require high water quality.

- ***Determination of wastewater flows that can be reused with or without treatment by characterising wastewater quantities and qualities at all wastewater generation points***

  Determination and characterisation of wastewater generation points in industrial facilities
  It is possible to reuse various wastewater streams with or without treatment (Öztürk, 2014; TUBİTAK MAM, 2016; MAF, 2021). In this context, filter backwash waters, TO concentrates, blowdown waters, condensate waters, relatively clean washing and rinsing waters can be reused without treatment in the same/different processes and in areas that do not require high water quality (such as facility and equipment cleaning). In addition, wastewater streams that cannot be directly reused can be reused in production processes after treatment using appropriate treatment technologies.

  Membrane filtration processes are an integral part of many wastewater reuse systems. Nanofiltration (NF) and reverse osmosis (RO) filtration systems are used for industrial wastewater recovery. Microfiltration (MF) and ultrafiltration (UF) are generally used for pre-treatment of water before it goes to NF or TO (Singh et al., 2014).

## 2.1.4 Precautions for Auxiliary Processes

**BATs for steam generation**

- ***Saving water by reusing steam boiler condensate***

  When steam indirect heating techniques are used to transfer thermal energy in production processes, it is an effective practice to return the condensed steam (condensate) as much as possible to reduce water consumption (IPPC BREF, 2009). An average of 5% reduction in water consumption can be achieved by recovering condensate water (Greer et al., 2013). In addition, the potential payback period varies between 4-18 months (considering energy savings) (Öztürk E. , 2014; TUBİTAK MAM, 2016).

- ***Reducing the amount of blowdown by using degassers in steam boilers***

  Carbon dioxide gases formed by the decomposition of carbonates in the boilers with free oxygen dissolved in the feed water of steam boilers and hot water boilers can cause corrosion in the form of pores, rusting and melting in steam boilers, steam appliances and especially in installations. The effects of these gases increase as the fresh feed water ratio and system operating pressure increase. If the boiler feed water is not purified from these dissolved gases, the useful life of these systems is shortened, corrosion and various deformations may occur. In addition, carbon dioxide causes excessive corrosion in coils, steam devices and condensate pipes. Boiler feed water must be purified from dissolved gases such as oxygen and carbon dioxide by passing through a degasser. Degasser systems are mechanical systems that provide the evaporation of dissolved gases from the water by supplying air to the water with a fan. Dissolved gas removal can be increased by increasing the water and air contact surface in the degasser system. In this way, corrosion formation is reduced and boiler efficiency is increased. The unit cost of a vacuum degasser with a capacity of approximately 2,000 L/hour varies between 2,200-10,000 USD (TUBITAK MAM, 2016; MAF, 2021).

***BATs for cooling systems***

- ***Use of air cooling systems instead of water cooling in cooling systems***

  Industrial cooling systems are used to cool heated products, processes and equipment. Closed and open circuit cooling systems can be used for this purpose, as well as industrial cooling systems where a fluid (gas or liquid) or dry air is used (IPPC BREF, 2001b; MAF, 2021). Air cooling systems consist of finned pipe elements, condensers and air fans (IPPC BREF, 2001b; MAF, 2021). Air cooling systems may have different operating principles. In industrial air cooling systems, the heated closed circuit cooler is cooled with air in condensers and heat exchangers (IPPC BREF,2001b; MAF, 2021). In water cooling systems, the heated water is taken to a cooling tower and the water is cooled in drip systems. However, despite the closed circuit operation of water-cooled systems, a significant amount of evaporation occurs. In addition, some water is discharged as blowdown in cooling systems. In this way, water is lost (IPPC BREF,2001b; MAF, 2021). Using air cooling systems instead of water in cooling systems is effective in reducing evaporation losses and also in reducing the risk of contamination of the cooling water (IPPC BREF, 2001b; MAF, 2021). However, the capacity of air cooling systems is low. On the other hand, although there is no water use in air cooling systems, electricity is consumed to operate the air fans. Air cooling systems have a very wide area of use. In addition, air cooling systems require a larger surface area than water cooling systems and may have higher costs (IPPC BREF,2001b; MAF, 2021).

- ***Increasing the number of cycles by using corrosion and scale inhibitors in systems with closed water cycle***

  Cooling towers and evaporative condensers are efficient and low-cost systems that remove heat from air conditioning and industrial process cooling systems (IPPC BREF, 2001b; MAF, 2021). In these systems, more than 95% of the circulating water can be recovered (TUBITAK MAM, 2016). In cooling systems, impurities remain in the recirculating water due to the evaporation of a portion of the recirculating water, and impurity concentrations gradually increase in each cycle. Impurities that can be included in the cooling system together with air can cause contamination in recirculation water (TUBITAK MAM, 2016). If impurities and contaminants are not effectively controlled, they can cause scaling and corrosion, unwanted biological growth and sludge accumulation. This can become a chronic problem leading to reduced efficiency of heat transfer surfaces and increased operating costs. In this case, it is necessary to implement a water treatment programme specifically designed for the quality of the feed water supplied to the cooling system, the cooling water system construction material and operating conditions. In this context; blowdown control, control of biological growth, corrosion control, avoidance of hard water, use of sludge control chemicals, filtration and screening systems may be appropriate (TUBITAK MAM, 2016). The establishment and periodic implementation of an effective cleaning procedure and programme is also a good management practice for the protection of cooling systems. Corrosion is one of the most important problems in cooling systems. In tower recirculation water, dissolved solids (sulphate, chloride, carbonate, etc.) that cause corrosion as a result of the formation of limestone and deposits on the walls as the degree of hardness increases will cause corrosion on the surface over time. In addition, the formation of deposits reduces energy efficiency by negatively affecting heat transfer. In order to prevent these problems, chemical treatment programme should be applied to prevent scale and corrosion, disinfection with biological activation inhibitor biocide, cooling towers in use should be subjected to chemical and mechanical cleaning at least twice a year to remove deposits, hardness and conductivity values of the make-up water should be as low as possible (IPPC BREF, 2001; Kayabek et al., 2005). In order to improve the quality of the makeup water, it may be necessary to treat (condition) it using an appropriate treatment system. In addition, unwanted microbial growth should be kept under control (IPPC BREF, 2001b; MAF, 2021). Blowdown occurs in cooling systems as well as in steam boilers due to micro-residues and deposits in the cooling water. The deliberate draining of the cooling system to stabilise the increasing concentration of solids in the cooling system is called cooling blowdown. By pre-treatment of cooling water with appropriate methods and continuous monitoring of cooling water quality, biocide usage and blowdown amounts can be reduced (TUBITAK MAM, 2016). Although the investment cost depends on the scale of the application, the payback period for the expected investment costs varies between 3 and 4 years (IPPC BREF, 2001).

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