PUB'S STIPULATED STANDARD & REQUIRMENTS ON MANDATORY WATER EFFICIENCY REQUIREMENTS

PUB SINGAPORE'S NATIONAL WATER AGENCY

First Edition – Jan 2024

CONTENTS

INTRODUCTION

Singapore's water consumption was about 440 million gallons water per day (mgd) in 2022, and the total water demand is expected to almost double by 2065. A major source of demand growth is expected to come from the non-domestic sector which is projected to increase from half of total consumption today to more than two-thirds in the future. To conserve our water resources, we must raise water efficiency in the non-domestic sector, especially promoting water recycling among the large water users.

The wafer fabrication, electronics, biomedical and pharmaceutical industries are among the largest water users in Singapore, accounting for about 20% of the current non-domestic water demand. There is also high potential for water recycling in these industries, as their used water streams can be effectively recycled when segregated at source. In addition, some wastewater streams are fairly clean, making them both technically feasible and commercially viable to recycle with minimal treatment required.

PUB's Stipulated Standards & Requirements on Mandatory Water Efficiency Practices is issued under Section 40 of Public Utilities Act (PUA) and under Public Utilities (Water Supply) Regulations. It specifies the recycling requirements for new facilities in the Wafer Fabrication, Electronics, Biomedical and Pharmaceutical industries, at both the design stage and operation stage. The person proposing to build the new facility shall ensure that all aspects of water recycling are considered during the planning, design, and implementation of the facility.

PUB, Singapore's National Water Agency

PART 1
-
GENERAL REQUIREMENTS

1 Mandatory Water Efficiency Requirements

1.1 Water Efficiency Requirements

1.1.1 The following requirements will apply to new projects (including expansion of existing plants) that will consume at least 60,000m^3 of water* annually from 1 January 2024:

Industry	Water Efficiency Requirements
Front-end Wafer Fabrication	Achieve a minimum recycling rate of 50%.
Electronics	Recycle all specified waste streams
Biomedical and Pharmaceutical	Recycle all specified waste streams

*At design stage, the annual water consumption is based on the declared demand in the projected water balance chart. At operation stage, the annual water consumption is based on the actual water use on site.

1.1.2 New project (including expansion of existing plant) refers to a new facility for which an application is made on or after 1 January 2024

(i) for planning permission under the Planning Act 1998; or

(ii) for approval of plans for building works under the Building Control Act 1989.

1.1.3 At Design Stage, a new facility that meets the conditions in Section 1.1.1 must obtain Board's approval for a projected water balance chart before starting any building works for the new facility.

1.1.4 At Operation stage, a new facility that

a) meets the conditions specified in Section 1.1.1; and
b) is a qualified consumer (i.e., consumes at least 60,000m^3 of water for that year)

must achieve the specified water efficiency requirements from the fourth calendar year after the year in which the temporary occupation permit for the new facility is granted.

1.2 Front-End Wafer Fabrication

1.2.1 Wafer Fabrication process typically involves front-end wafer fabrication and back-end wafer fabrication.

1.2.2 Front-end wafer fabrication plant refers to a facility whose business activity is fabrication of semiconductor wafers, circuits, devices or products from blank wafers, before separating into individual chips. This includes the deposition of thin films of material onto the wafer, patterning the films using photolithography, and etching away the unwanted material to create the desired circuit patterns.

1.2.3 For a facility whose activities involve both front-end wafer fabrication and back-end wafer fabrication, only the front-end wafer fabrication must achieve a minimum recycling rate of 50%. Refer to Clause 3 for the computation of a front-end wafer fabrication Recycling Rate.

1.3 Electronics

1.3.1 Electronics plant refers to a facility whose business activities involve one of the following: -

a) Manufacture of semiconductor wafers from ingots;

b) Back-end testing and assembly of semiconductor chips;

c) Manufacture or assembly of semiconductor products such as diodes, radio frequency filters and photomasks.

d) Manufacture or assembly of electronic products or components such as hard disks, sensors, capacitors, batteries, PCBs and display screens .

1.4 Biomedical and Pharmaceutical

1.4.1 Biomedical and pharmaceutical plant refers to a facility whose business activities involve one of the following: -

a) Manufacture of health products, including medical devices, contact lenses, cosmetic, therapeutic, oral dental gum, cell/ tissue/gene therapy products, quasi-medicinal and medicated oil or balm products [as defined in the Health Products Act 2007]

b) Examples of such products include Active Pharmaceutical Products (APIs), biologics, new modalities, medical equipment and nutritional products such as milk powder, proteins, supplements, cream, syrup, tablets etc.

2 Water Balance Chart

2.1 Water Balance Chart Requirements

2.1.1 Water Balance Chart (WBC) is a chart providing a clear and concise overview of the annual water demand and usage in a facility. It should show:

(a) the amount of water entering a facility;
(b) the amount of water used for each activity at the facility; and
(c) the amount of water leaving the facility.

2.1.2 Water Balance Chart typically includes components such as:

(a) Annual Water Use
(b) Alternate Source of Water
(c) Recycled Water

2.2 Annual Water Use

2.2.1 Annual Water Use is the amount of water that is required at a facility in a year.

2.2.2 This includes all water that will be supplied by PUB and any other third-party suppliers, but excludes any alternative source of water that are collected at the facility, for example rainwater, AHU condensate, seawater etc.

2.2.3 Water from third-party suppliers may include, but not limited to, the following: steam condensate, demineralised water, high grade industrial water, treated wastewater for reuse, etc.

2.3 Recycled Water

2.3.1 Recycled water refers to water that has been used for a specific process or application within the facility and then reused again (with or without further treatment to a level that makes it suitable for use) within the same facility.

2.3.2 The use of recycled water within a facility will result in a reduction of the annual water use required for that facility.

2.3.3 The amount of recycled water in a year is total amount of water in a year that is used for the processes or applications within the facility and reused again within the same facility.

2.4 Alternate Source of Water

2.4.1 Alternate source of water refers to water that is collected within or in the close vicinity to the facility and used for a specific process or application within the same facility (with or without further treatment to a level that makes it suitable for use).

2.4.2 The collection of alternate sources of water will result in a reduction of the annual water use required for that facility.

2.4.3 The amount of alternate source of water in a year is determined as follows:

Type of water	**Calculation method**
AHU Condensate	The amount of condensate collected in a year before any further treatment, if required.
Rainwater	The amount of rainwater collected in a year before any further treatment, if required.

Seawater	The amount of seawater after further treatment to a level that makes it suitable for use. Seawater that is collected and used without further treatment (e.g., once-through use for cooling purpose) must be converted to an equivalent amount of NEWater required for the same cooling needs, to be included as an alternate source of water.

3 Recycling Rate

3.1 Recycling Rate Formula

3.1.1 Recycling rate of a facility (or part of a facility) refers to the ratio of the amount of water reused from recycling and from alternate sources of water, against the total water demand by the facility (or part of a facility).

3.1.2 The Recycling Rate Formula shall be used to compute the recycling rate of a facility (or part of a facility):

$$\mathrm{RR} = \frac{\mathrm{R} + \mathrm{AS}}{\mathrm{AWU} + \mathrm{R} + \mathrm{AS}} \times 100$$

where RR = recycling rate

AWU = annual water use (m^3)

R = recycled water in a year (m^3)

AS = alternate sources of water in a year (m^3)

3.2 Facility with only Front-End Wafer Fabrication Process

3.2.1 The water balance chart of a facility with only front-end wafer fabrication process should show the quantity of each of the sources of water that enters and leaves the facility, and the quantity of each of the recycled streams within the facility. **Figure 1** shows an example of a water balance chart for a typical front-end wafer fabrication plant.

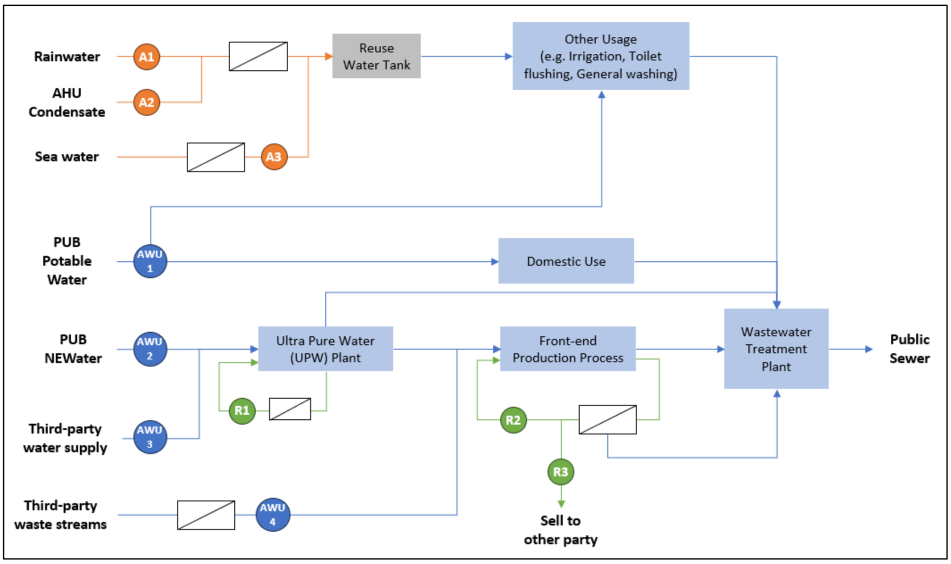


Figure 1: *Water Balance Chart for a Front-End Wafer Fabrication Plant*

3.2.2 The recycling rate formula of a front-end wafer fabrication plant may vary depending on the various streams that enter, leave and is recycled within the facility. The formula below shows the calculation for the recycling rate for a front-end wafer fabrication plant with the water balance chart shown in Figure 1.

$$\mathbf{RR} = \frac{(\mathbf{R1} + \mathbf{R2}) + (\mathbf{A1} + \mathbf{A2} + \mathbf{A3})}{(\mathbf{AWU1} + \mathbf{AWU2} + \mathbf{AWU3} + \mathbf{AWU4}) + (\mathbf{R1} + \mathbf{R2}) + (\mathbf{A1} + \mathbf{A2} + \mathbf{A3})}$$

where:

RR	=	recycling rate
AWU1 AWU2	=	annual water use supplied by PUB (m^3)
AWU3 AWU4	=	annual water use supplied by third parties (m^3)
R1	=	UPW recycled water in a year (m^3)
R2	=	process recycled water used within the facility in a year (m^3)
R3	=	process recycled water used outside of the facility in a year (m^3)
A1, A2, A3	=	alternate source of water in a year (m^3)

3.3 Facility with both Front-End and Back-End Wafer Fabrication

3.3.1 The water balance chart of a facility with both front-end and back-end wafer fabrication process should show:

a) the breakdown quantity of each of the sources of water that enter and leave the front-end and back-end wafer fabrication process separately; and

b) the breakdown quantity of each the recycled streams within front-end and back-end wafer fabrication processes separately.

3.3.2 As only front-end wafer fabrication facility is required to achieve a minimum recycling rate of 50%, it is important to monitor the breakdown for front-end and back-end wafer fabrication processes separately.

3.3.3 Companies are advised to consult PUB during the design stage for the correct application of recycling rate formula and for the installation of private meters to monitor these streams.

3.3.4 Depending on the design of the recycling plants for both front-end and back-end wafer fabrication process, the water balance chart and recycling rate formula for the front-end process may vary. **Figure 2** shows an example of a water balance chart for a typical front-end wafer fabrication plant.

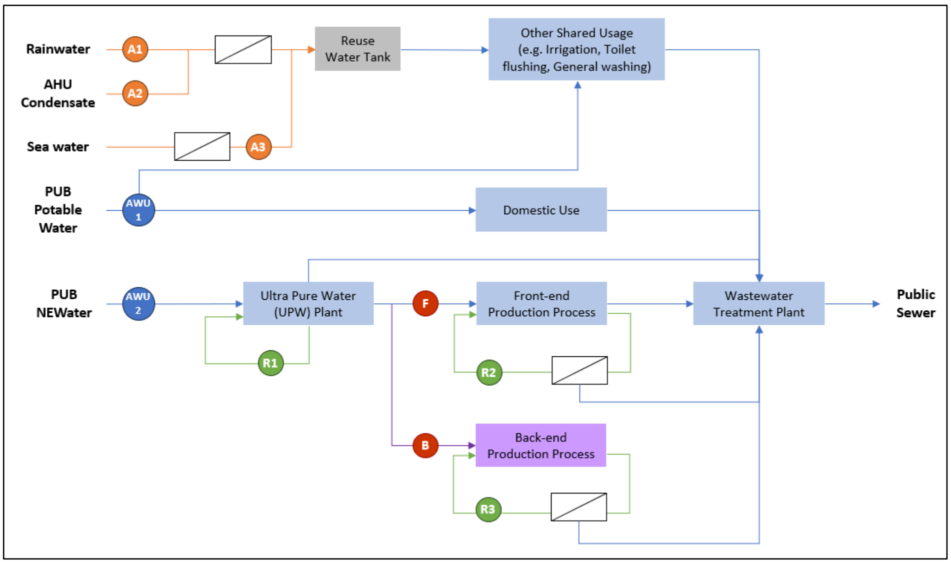


Figure 2: *Water Balance Chart for a Facility with both Front-End and Back-End Wafer Fabrication*

3.3.5 The formula below shows the calculation for the recycling rate for the front-end wafer fabrication in a facility with both front-end and back-end production with the water balance chart shown in Figure 2.

$$RR_{front.end} = \frac{(R1_{front.end} + R2) + (A_{front.end})}{(AWU_{front.end}) + (R1_{front.end} + R2) + (A_{front.end})} x100$$

where:

RR	=	recycling rate
AWU1, AWU2	=	annual water use supplied by PUB to the facility (m^3)
$AWU_{front.end}$	=	annual water use supplied by PUB to front-end wafer fabrication (m^3) $AWU_{front.end} = (AWU1 + AWU2)x\frac{F}{F+B}$
R1	=	UPW recycled water in a year (m^3)
$R1_{front.end}$	=	UPW recycled water in a year, to be supplied to front end wafer fabrication (m^3) $R1_{front.end} = R1x\frac{F}{F+B}$
R2	=	front-end wafer fabrication recycled water used within front-end production in a year (m^3)
R3	=	back-end wafer fabrication recycled water used within back-end production in a year (m^3)
A1, A2, A3	=	alternate source of water in a year (m^3)
$A_{front.end}$	=	alternate source of water apportionment to front-end wafer fabrication in a year (m^3) $A_{front.end} = (A1 + A2 + A3)x\frac{F}{F+B}$
F	=	output of UPW plant supplied to front-end production process in a year (m^3)
B	=	output of UPW plant supplied to back-end production process in a year (m^3)

4 Specified Waste Streams

4.1 List of Specified Waste Streams Mandated to Recycle

4.1.1 A new facility as described in Section 1.1.1 of this document must collect for recycling all water from the following specified waste streams, if available within the facility. These specified waste streams are fairly clean and require minimal or no treatment for reuse.

a) **Microfiltration (MF)** – Microfiltration is a type of physical filtration process where a contaminated fluid is passed through a special pore-sized membrane filter to separate microorganisms and suspended particles from process liquid.

b) **Ultrafiltration (UF)** – Ultrafiltration is a type of membrane filtration in which forces such as pressure or concentration gradients lead to a separation through a semipermeable membrane.

c) **Electrodeionisation (EDI)** – Electrodeionisation is a continuous, chemical-free process of removing ionized and ionizable species from feedwater using DC power.

d) **Reverse osmosis (RO)** – Reverse osmosis is a water purification process that uses a partially permeable membrane to separate ions, unwanted molecules and larger particles from drinking water.

4.1.2 The water balance chart should show how the rejects of all specified streams are reused in the facility, and indicate if there is a collection tank for all the streams or a direct reuse of any specific streams.

4.1.3 The water balance chart should show all the water end use that receive the rejects from the specified streams. Any amount of these specified streams that are not collected shall be indicated clearly in the water balance chart.

PART 2
-
DESIGN STAGE REQUIREMENTS

5 Board's Approval for Projected Water Balance Chart

5.1 No Building Works Prior to Board's Approval

5.1.1 No building works for a new facility shall commence without Board's approval in writing for the projected water balance chart of the facility.

5.1.2 The approval by the Board is only valid for the projected water balance chart for the facility submitted at that point of time. For any change in design or projected annual water end use which results in the new facility unable to meet the mandatory water efficiency requirements, the person proposing to build the facility must obtain a fresh approval for the updated projected water balance chart.

6 Design Considerations for Recycling

6.1 Segregation of Waste Streams

6.1.1 The new facility shall adopt a design with effective segregation of various waste streams to maximise its recycling potential.

6.1.2 The design for the segregation of various waste streams should take into consideration the water quality of each of the waste streams, as follows:

a) Waste streams of high purity level and containing easy to remove contaminants should be segregated for recycling or reuse within the facility with minimal or no further treatment.

b) Waste streams of high concentration and containing hard to remove contaminants should be segregated for (1) further treatment with advanced water technologies to a suitable level for reuse or (2) for disposal if no recycling potential.

c) Waste streams of contaminants which are of concern for environmental regulatory compliance should be segregated to allow for a more sustainable and cost-effective treatment/ disposal solution.

6.1.3 Refer to **Appendix 1** for the potential reusable water from a typical semiconductor facility and its potential end usage.

6.1.4 Refer to **Appendix 2** for the classification of various recycling technologies.

6.2 Space Allocation for Recycling Systems

6.2.1 The design of the new facility shall allow adequate space for the construction of the proposed recycling systems to achieve the water efficiency requirements specified in Clause 1.1.1 when the facility operates at its full design capacity.

6.2.2 For facility which business activities will ramp up in phases and not all recycling systems are required when it obtains the Temporary Occupation Permit (TOP) to start operation, additional empty space must be reserved for the construction of the remaining recycling systems required at when it operates at its full design capacity.

7 Submission for Board's Approval

7.1 Mode of Submission and Approval

7.1.1 The submission for Board's approval shall be made online via a webpage or any other mode as described in PUB website.

7.2 Project Information

The following information shall be provided to the Board for design stage approval:

7.2.1 BCA Project Reference Number refers to the number which is assigned to the project to build the new facility when it is registered with the Building and Construction Authority (BCA) of Singapore.

7.2.2 BCA Project Title refers to the project title which is corresponding to the Project Refence Number in Clause 7.2.1.

7.2.3 Company Name refers to the registered name of the organisation proposing to build the new facility.

7.2.4 Projected Annual Water Use refers to the amount of water that is required from PUB and third-party suppliers at the facility in a year when it operates at full design capacity. The computation of water end use can be found in Clause 2.2.

7.2.5 Projected Recycling Rate refers to the recycling rate that the facility can achieve when it operates at full design capacity. The computation of recycling rate can be found in Clause 3.1.

7.3 Supporting Documents

The following supporting documents could be provided to the Board for facilitation of design stage approval:

7.3.1 Projected Water Balance Chart

- refers to the water balance chart of the facility when it operates at full design capacity.
- shows the projected water end use at the facility when it operates at full design capacity.
- to be prepared and endorsed by a certified Water Efficiency Manager.
- to be signed off by chief executive or equivalent of the proposed new facility.

7.3.2 Production Ramp-up Plan

- refers to the timeline showing when the proposed new facility will operate at its design capacity and require the projected water end use indicated in the projected water balance chart.
- shows the timeline for the increase of its business activities corresponding to the increase of annual water use.
- to be submitted using template in **Annex 1**.

7.3.3 List of Drain Segregation and Recycled Streams

- refers to the list of all reject streams from the processes that can be recycled
- indicates the recycling technology to be used for each of the recycled streams if further treatment is required.
- to be submitted using template in **Annex 2**.

7.3.4 Water Efficiency Manager Certificate

- refers to the certificate issued by an authorised body for the completion of the "Water Efficiency Manager (WEM) Course" by the person who prepares and endorse the projected water balance chart.

7.3.5 Cooling Tower Information (if applicable)

- details the types of water used and the projected cycles of concentration for their cooling tower.
- for cooling tower using Potable Water and NEWater, the cycles of concentration shall be minimal at 7 and 10 respectively.
- to be submitted using template in **Annex 3**.
- Reference:
    - **Appendix 3** recommends design consideration to optimise cooling tower operations and increase water efficiency.

7.3.6 Floor Plan (if applicable)

- details the floor layout of the proposed new facility and the water recycling systems indicated in the projected water balance chart.
- shows the gross floor area of the proposed new facility and the estimated area to be used for the water recycling systems indicated in the projected water balance chart.

8 Exception Cases at Design Stage

8.1 If, subject to approval of the Board, the water efficiency requirements as specified in Clause 1.1.1 cannot be met at the design stage, any of the following conditions must be met and proven to the Board's satisfactory:

(a) The land allocated for the new facility is not sufficient for the construction of the necessary recycling systems.

(b) Limited or no potential end use for the recycled water.

(c) Waste streams cannot be reuse due to either hazardous water quality or international regulations/guidelines.

(d) Insufficient volume of the reject streams to effectively recycle.

(e) Any other conditions deemed as reasonable by the Board.

8.2 The person in charge of the new facility that meets any of the conditions in Clause 8.1 shall submit for Board's review and acceptance the following supporting documents, but not limited to:-

(a) construction plans or drawings,

(b) water quality of the reject streams of concern, and

(c) any relevant international regulations/ guidelines.

PART 3
-
OPERATION STAGE REQUIREMENTS

9 Operation Requirements

9.1 Installation of Private Meters

9.1.1 Private meters to be installed at respective streams at operation stage to monitor and track if the mandatory water efficiency requirements are met.

9.1.2 For front-end Wafer Fabrication facility, private meters shall be installed to measure each and every recycled stream and alternate water source. Any water sources that are not monitored shall be excluded from the recycling formula.

9.1.3 For electronics, biomedical and pharmaceutical facility, private meters shall be installed to monitor:

(a) the amount of each and every specified stream mentioned in Clause 1.4, and

(b) the amount of each and every water end use stream that receive the recycled water from the specified streams.

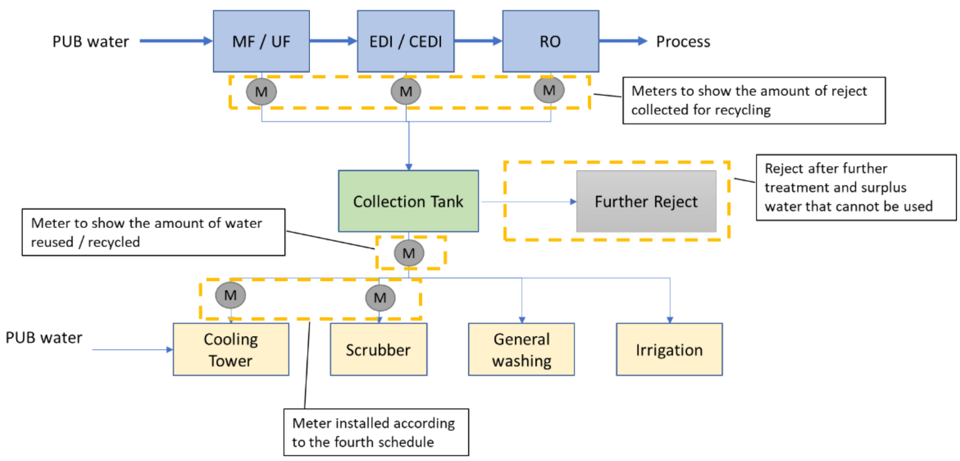


***Figure 3**: Water Balance Chart of a Facility that Centrally Collects Rejects from Specified Streams for Reuse*

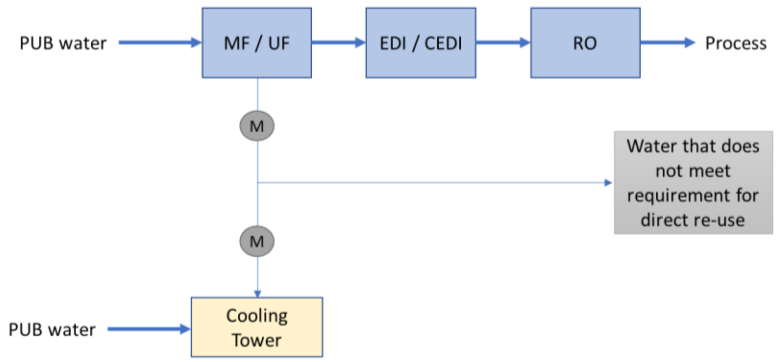
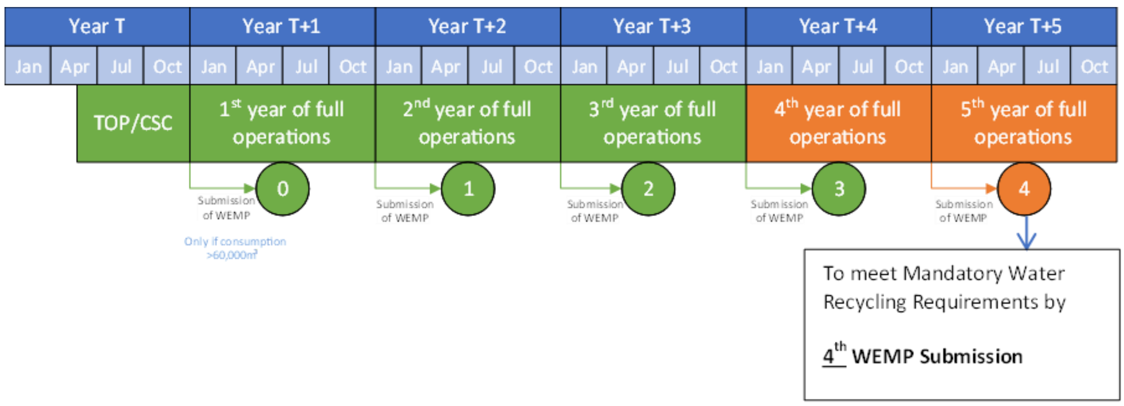


Figure 4: *Water Balance Chart of a Facility that Directly Reuse Specified Streams*

9.2 Submission of Water Efficiency Management Plan

9.2.1 From the fourth calendar year after the Temporary Occupation Permit (TOP) is obtained, the new facility is required to meet the mandatory recycling requirements as specified in Clause 1.1.1. This shall be demonstrated as part of the annual submission of the Mandatory Water Efficiency Management Plan (MWEMP).

9.2.2 The diagram below illustrates the timeline for MWEMP and at which submission, compliance to the mandatory recycling requirements is required.



9.2.3 Companies are advised to monitor their water consumption closely to ensure full compliance. In any cases that the recycling requirements cannot be fulfilled, justifications with supporting documents shall be provided for the Board's review.

10 Exception Cases at Operation Stage

10.1 If, subject to approval of the Board, the water efficiency requirements as specified in Clause 1.1.1 or any other approved levels at design stage by the Board cannot be met at the operation stage, any of the following conditions must be met and proven to the Board's satisfactory:

(a) Disruption in planned operations due to external factors.

(b) Change in production technologies, products compared to initial design resulting in different water quality to be treated.

(c) Lower product demand resulting in lower water consumption compared to the optimal design.

(d) Any other conditions deemed as reasonable by the Board.

10.2 The person in charge of the new facility that meets any of the conditions in Clause 10.1 shall submit for Board's review and acceptance the following supporting documents, but not limited to:-

(a) Proof of operation disruptions indicating the duration and reasons.

(b) Proof if changes to the technologies/ products/ demand and reasons why this affects the compliance.

(c) Water quality of the reject streams of concern.

ANNEX 1 – PRODUCTION RAMP-UP PLAN

Year	**1**	**2**	**…**	**N**
	CY xxxx	**CY xxxx**	**CY xxxx**	**CY xxxx**
Annual NEWater demand (m^3)				
Annual Potable Water demand (m^3)				
Total Annual Water Demand (m^3)				
Business Activity Indicator (BAI)				

(to add more columns and rows where necessary)

ANNEX 2 – LIST OF DRAIN SEGREGATION & RECYCLING STREAMS

S/N	Streams	To Be Recycled? (Yes/ No)	If Yes, provide the Water-End use point	If No, provide reason
1	Acid Rinse			
2	Air Handling Unit / Heat Ventilation and Air Conditioning (AHU/HVAC)			
3	Chemical Mechanical Polishing (CMP)			
4	De-ionised (DI) Reclaim			
5	Dilute Hydrofluoric (HF)			
6	Dilute Organic Rinse			
7	Electro-Deionization (EDI/CEDI) Reject			
8	First Rinse			
9	Last Rinse			
10	Rainwater			
11	Reverse Osmosis (RO) Reject			
12	Tetramethylammonium hydroxide (TMAH)			
13	Ultrafiltration (UF) Reject			
14	Others			

ANNEX 3 – COOLING TOWER INFORMATION

Heat Source		Type of water used (NEWater/Potable Water/Other sources of water)	Cycles of concentration (COC)	COC based on which limiting parameters
System	System Description			

APPENDIX 1 – RECYCLING POTENTIAL IN A SEMICONDUCTOR FACILITY

A – List of streams with high recycling potential

S/N	Streams	Remarks
1	UPW System Rinse Water	• Water used in the maintenance and upkeep of the UPW system, such as polish resin or filter rinses, is of high quality after initial discharge may be suitable for a wide range of applications based on the diversion criteria used with little or no treatment. • Flows from analytical stations may also be considered for collection with this stream.
2	Idle Tool Water	• Fab tools consume significant amounts of water when idle to maintain tool cleanliness. • Collection of this water requires no treatment for reuse if such segregation is available.
3	Wafer Rinse Water	• The second and third rinses from wafer cleaning processes are sufficiently high quality to be reused without further treatment either for facilities systems, make-up water in a UPW system, or directly for use in a lower grade application such as CMP cleaning. • Use of this stream requires sophisticated segregation capability, as well as additional monitoring and control to mitigate the risks.
4	Specialty Waste Treatment System Effluent	• Many semiconductor fabs now contain segregated treatment systems for wastewaters such as those containing high concentrations of fluoride or copper. • The effluent of these treatment systems may be reclaimed and considered for reuse, subject to being permitted by local hazardous waste regulations.
5	General Fab Waste	• All effluent from a range of tools and sources that includes both high and low pH, high TDS, TOC, and solids content. • This effluent is not suitable for direct reuse without treatment. In such a case, centralized reclamation approach can be considered.

B - List of potential end-use points

S/N	End-use Points	Remarks
1	Cooling Tower Makeup	• Cooling towers (condenser system) is typically the 2nd largest water end-use after UPW system. This demand varies seasonally and in some areas the variation can be significant and have a major impact on the water balance. • Chemical treatment is the recommended method of corrosion and fouling prevention in condense loops as opposed to chemical free solutions due to criticality of the cooling systems in semiconductor applications. • The water treatment vendors can propose treatment schedules capable of utilizing a wide range of waters. It is important to work closely with water treatment specialists to identify the correct chemical dosing regimen. • It is important to note that sending a higher salinity/hardness water stream to the cooling towers will necessitate changing the cycles of concentration and thus increase blowdown. Conversely providing a softer water stream may have greater water savings decreasing the quantity reclaimed due to reduced cooling tower makeup.
2	Facilities Scrubber	• General exhaust scrubber systems can consume relatively large volume of water because of treatment of significant flow of the air from the fab. • Scrubber systems can run on water of similar quality to cooling tower makeup; however, operation and maintenance will be a challenge. • Preferred water should be low hardness to prevent scale formation.
3	POU Abatement Units	• Fab tool exhaust can contain high concentrations of contaminants that require treatment before the air can be sent to the house scrubbers.

		• These systems have a similar requirement for low hardness water due to elevated temperature and high scaling potential. • The low and distributed water consumption of POU abatement units justifies use of soft water and to avoid monitoring and treatment of scale.
4	Chemical Preparation System for non-process system	• Some fabs purchase chemical of high consumption and for non-process uses in the form of powder instead of liquid form and may have their own chemical preparation system.
5	Drain Primers and Flushes	• Small quantities of water are used to maintain p-traps and to flush drains to ensure lines are free of clogging or for cooling in some cases.
6	Aspirator Pumps	• Many fab process tools use aspirators to move chemicals or wastewater from self-contained tanks to downstream collection points or to waste drains. • Aspirator motive water is a viable POU for non-process reclaimed water.
7	Toilets/ Pantries/ Domestic Uses	• Cleaning and flushing purposes.

APPENDIX 2 – CLASSIFICATION OF RECYLICNG TECHNOLOGIES

Principles of treatment	Recycling Technologies
Separation	• Clarification • Media filtration • Micro-, nano- and ultrafiltration • Reverse osmosis • Electrodialysis • Ion-exchange • Degasification • Thermal distillation • Crystallization • Filter-press • Centrifuge, • Etc.
Oxidation	• Chlorination • Ozonation • Advanced oxidation • Photolysis • Catalysis • Etc.
Adsorption	• Activated carbon • Zeolite, or other media • Etc.
Biological	• Activated sludge (Membrane Bioreactor Reactor or conventional), • Anaerobic solvent or sludge digestion • Bio-polishers (often using activated carbon or other adsorption media) • Moving bed bioreactors • Etc.

APPENDIX 3 – DESIGN CONSIDERATIONS FOR COOLING TOWER

Cooling Towers are large consumers of water due to high evaporation and drift losses. By adopting water-efficient design at the cooling towers and water-efficient practices during building operations, it is able to reduce the use of the makeup water.

The following design criteria can be considered to optimise Cooling Tower operations and increase water efficiency:

- Minimization of drift through the installation of high-efficiency drift eliminators and an enclosure of the area above the cooling tower to reduce the windage that cause the drift to escape through the sides.

- Reduction in the blowdown rates and/or chemical by-products via the installation of side stream water filters to remove the suspended solids.

- Maximization of total chiller plant chiller plant efficiency by the installation of variable drive speed fans which can match fan speed to actual cooling load

- Monitoring of water use by installation of water meters on make-up and blowdown lines

- Achieving high cycles of concentration while meeting water -quality requirements

- Adoption of energy-efficiency measures to reduce cooling load such as setting the temperature of air-conditioning systems or switching off air-conditioning system when not in use