HKIE Associate Member Committee (AMC), 18 Nov 2023

Seminar on
Sustainable Plumbing Design

Ir Dr. Sam C. M. Hui
Department of Mechanical Engineering
The University of Hong Kong
E-mail: cmhui@hku.hk

Nov 2023

About the Lecturer

- ***Ir Dr. Sam C. M. Hui*** 許俊民 博士 工程師 http://ibse.hk/cmhui
  - Adjunct Assistant Professor 客席助理教授, HKU Dept of Mech Engg
  - PhD, BEng(Hons), CEng, CEM, BEMP, HBDP, MASHRAE, MCIBSE, MHKIE, MIESNA, LifeMAEE, AssocAIA
    - CEng = Chartered Engineer
    - CEM = Certified Energy Manager
    - BEMP = Building Energy Modeling Professional
    - HBDP = High-performance Building Design Professional
    - LifeMAEE = Life Member, Association of Energy Engineers
    - AssocAIA = Associate Member, American Institute of Architects
  - ASHRAE Distinguished Lecturer (2009-2011)
  - President, ASHRAE Hong Kong Chapter (2006-2007)

Contents

- 1. Introduction
- 2. Basic principles
- 3. Important considerations
- 4. Key aspects
- 5. Sustainable practices
- 6. Conclusions

1. Introduction

- Sustainable Plumbing Design
  - Specify the installation of eco-friendly systems that minimise the environmental impacts & improve building performance with sustainable practices

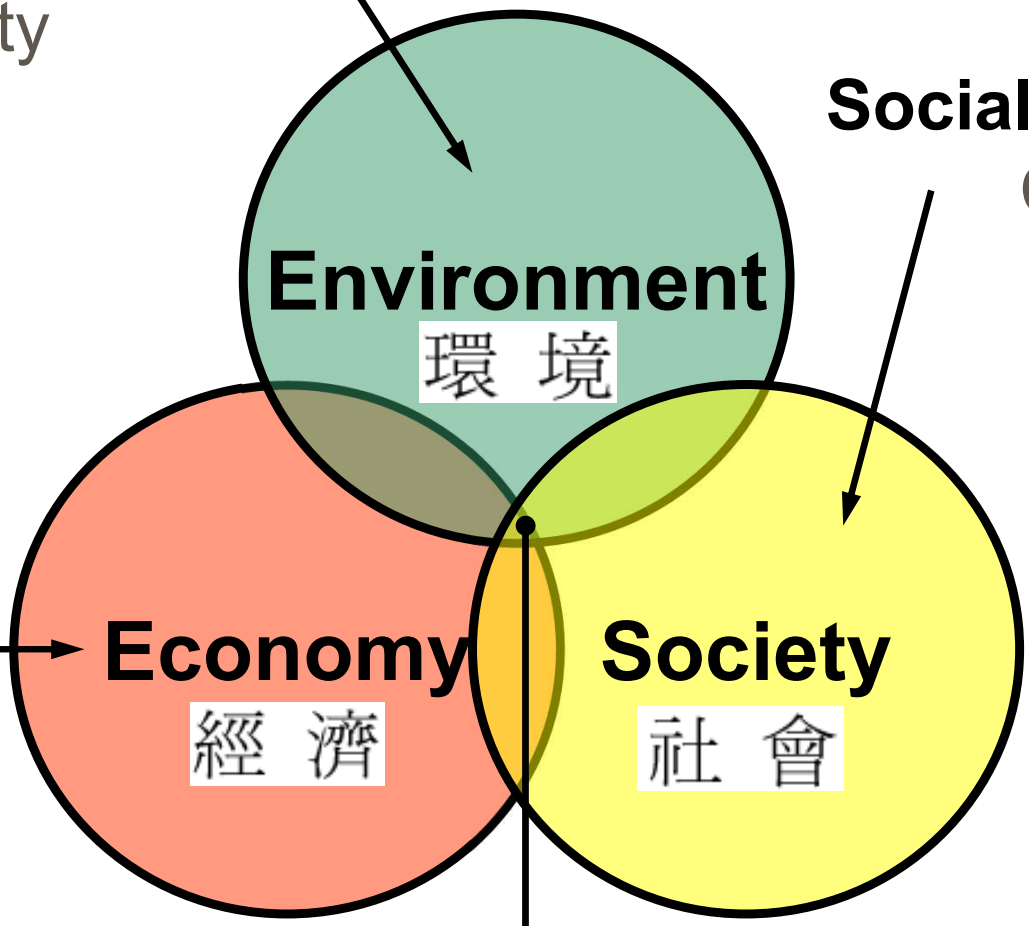
- The need for sustainable design
  - To minimise environmental effects, preserve resources & promote social equality
  - Can cut carbon emissions & waste, and save resources by implementing sustainable design

可持續給排水設計

Three dimensions of sustainability

Environmental Sustainability

Ecosystem integrity
Carrying capacity
Biodiversity



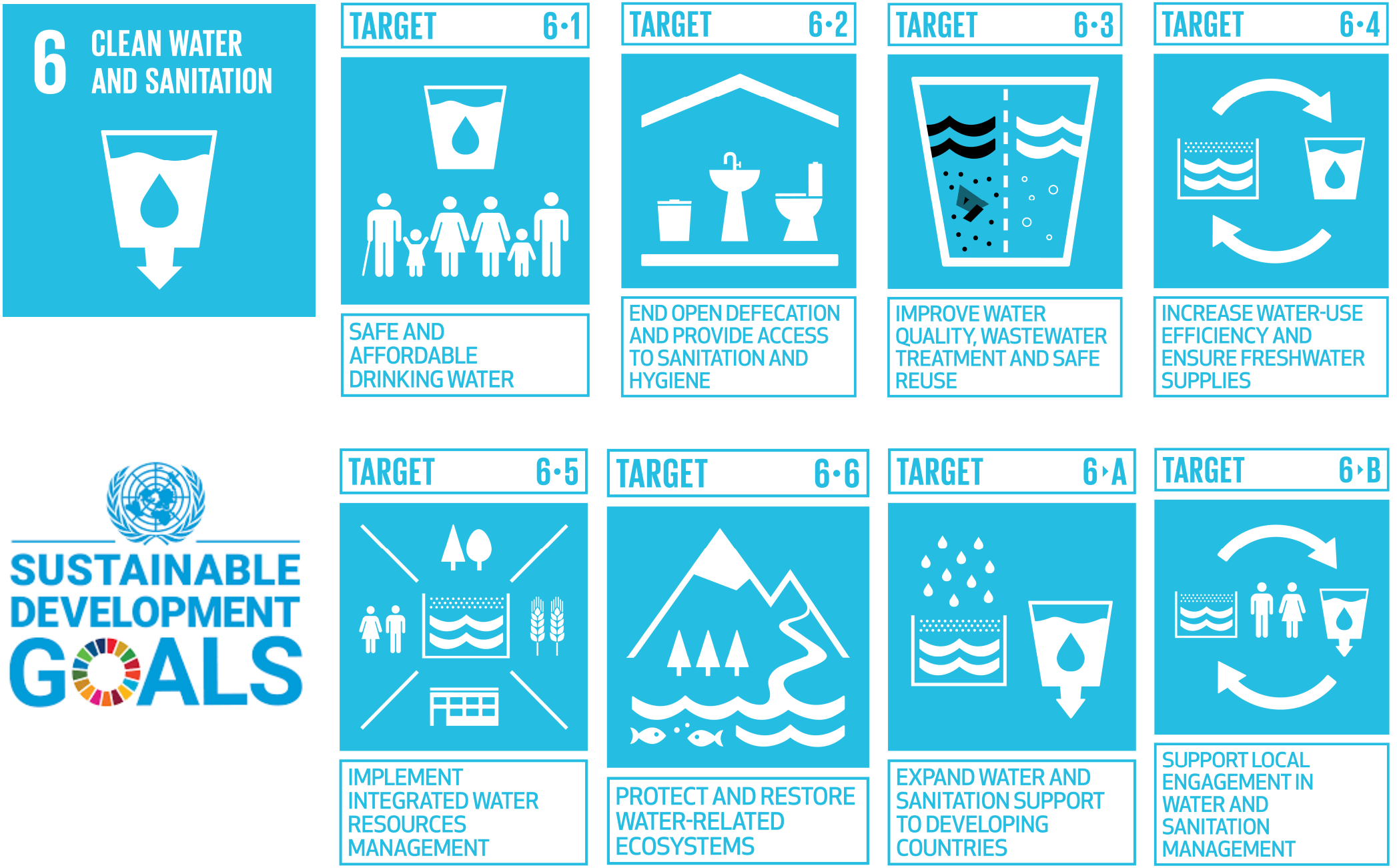
Social Sustainability

Cultural Identity
Empowerment
Accessibility
Stability
Equity

Economic Sustainability

Growth
Development
Productivity
Trickle-down

United Nations (UN) Sustainable Development Goals (SDGs)
Goal 6: Clean water and sanitation

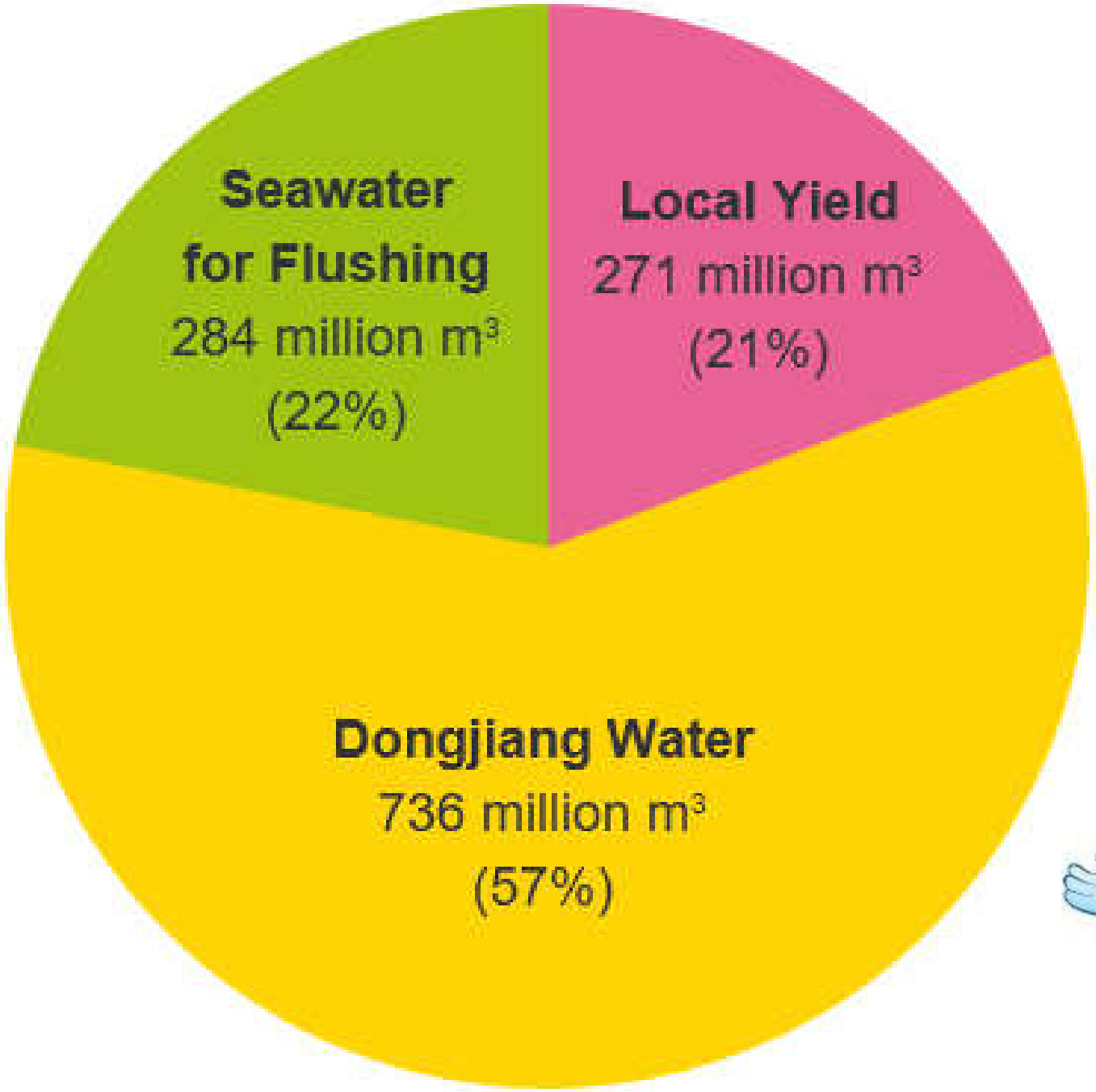


(Source: https://www.globalgoals.org/goals/6-clean-water-and-sanitation/)

1. Introduction

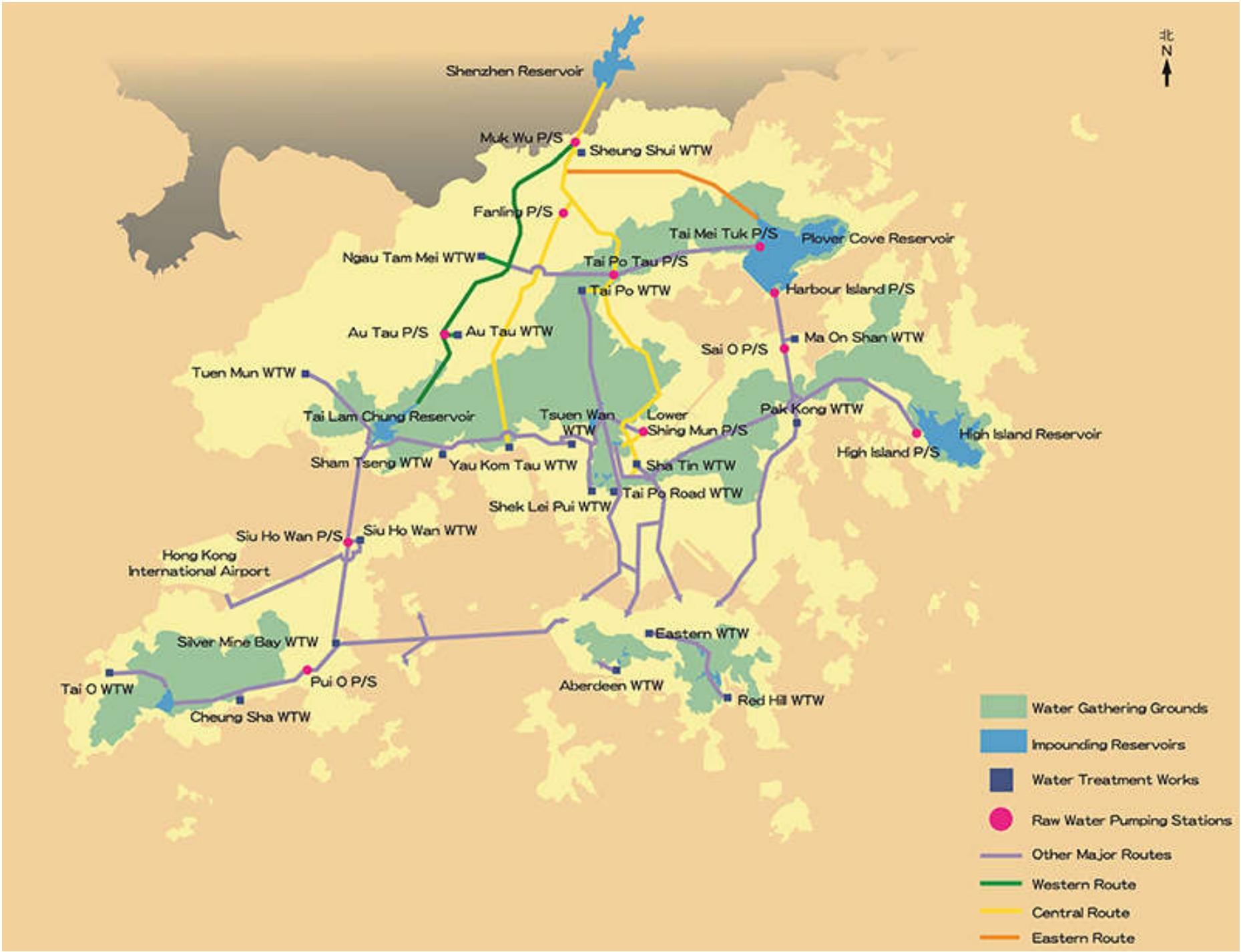
- Hong Kong situation:
  - Subtropical climate
  - Population > 7.4 million, land area 1,106 km^2
  - Hilly & mountainous terrain
  - High-rise, high density urban areas
  - Building-related activities account for 90% of Hong Kong's total electricity consumption & 60% of the city's greenhouse gas emissions
  - Rely on import of fresh water from Guandong

Water consumption in Hong Kong in 2018 (1.292 billion m^3)



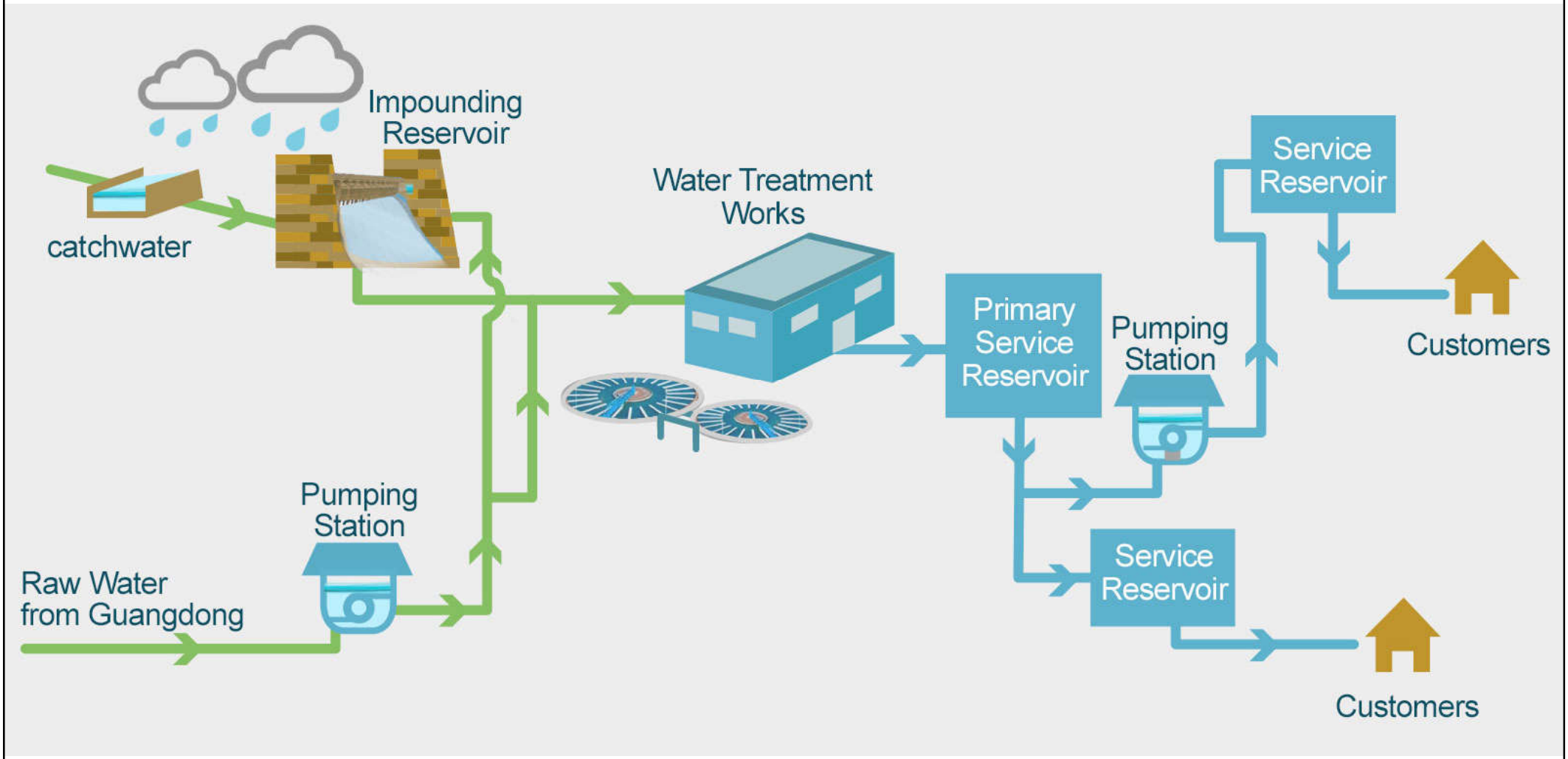
(Source: Water Supplies Department www.wsd.gov.hk)

Principal water supply system in Hong Kong



(Source: Water Supplies Department www.wsd.gov.hk)

Water treatment & supply process in Hong Kong



(Source: Water Supplies Department, www.wsd.gov.hk)

1. Introduction

- Total Water Management (TWM) strategy

全面水資源管理策略

  - Water demand management
    - To enhance public education on water conservation
    - To promote use of water saving devices
    - To enhance water leakage control
    - To extend use of seawater for toilet flushing
  - Water supply management
    - To strengthen protection of water resources
    - To actively consider water reclamation (reuse of greywater & rainwater harvesting)
    - To develop the option of seawater desalination

(Source: https://www.wsd.gov.hk/en/core-businesses/total-water-management-strategy/)

Outlook of the future water resources in Hong Kong

Future fresh water resources in Hong Kong*:

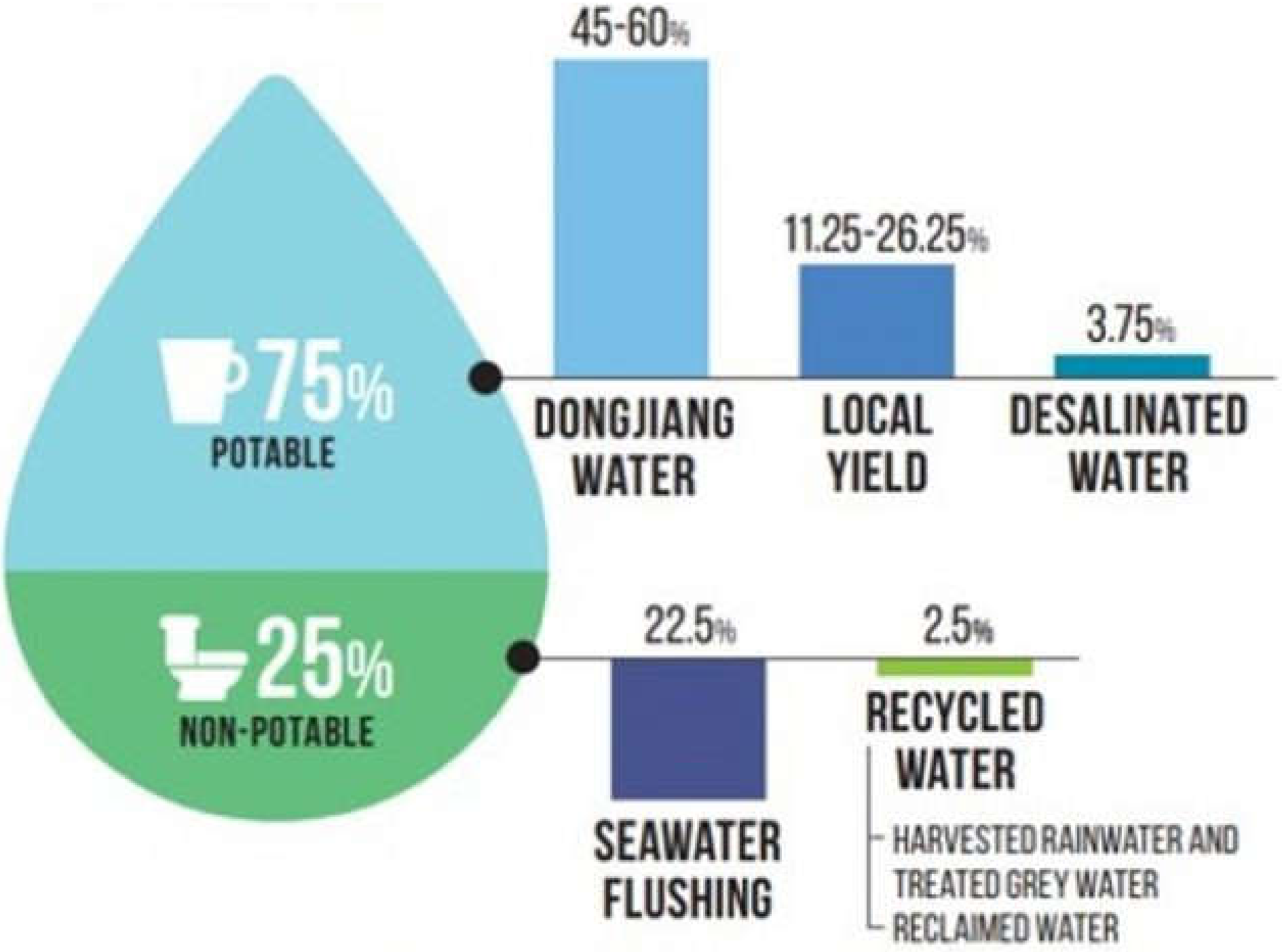
Dongjiang water with water supply ceiling of 820 mcm per annum	~ 60% - 80% depending on the amount of local yield
Local yield	~ 15% - 35%
Desalinated water up to 50 mcm per annum	~ 5%

* While the above fresh water resources will account for about 75% of the total water consumption in Hong Kong, the lower grade water (namely seawater and recycled water) for non-potable uses will account for the remaining 25%.

- Dongjiang Water 東江水
- Local Yield 本地集水
- Desalination 海水化淡
- Seawater for Flushing 海水沖廁
- Recycled Water 循環再用水

(Source: https://www.wsd.gov.hk/en/core-businesses/total-water-management-strategy/twm-review/)

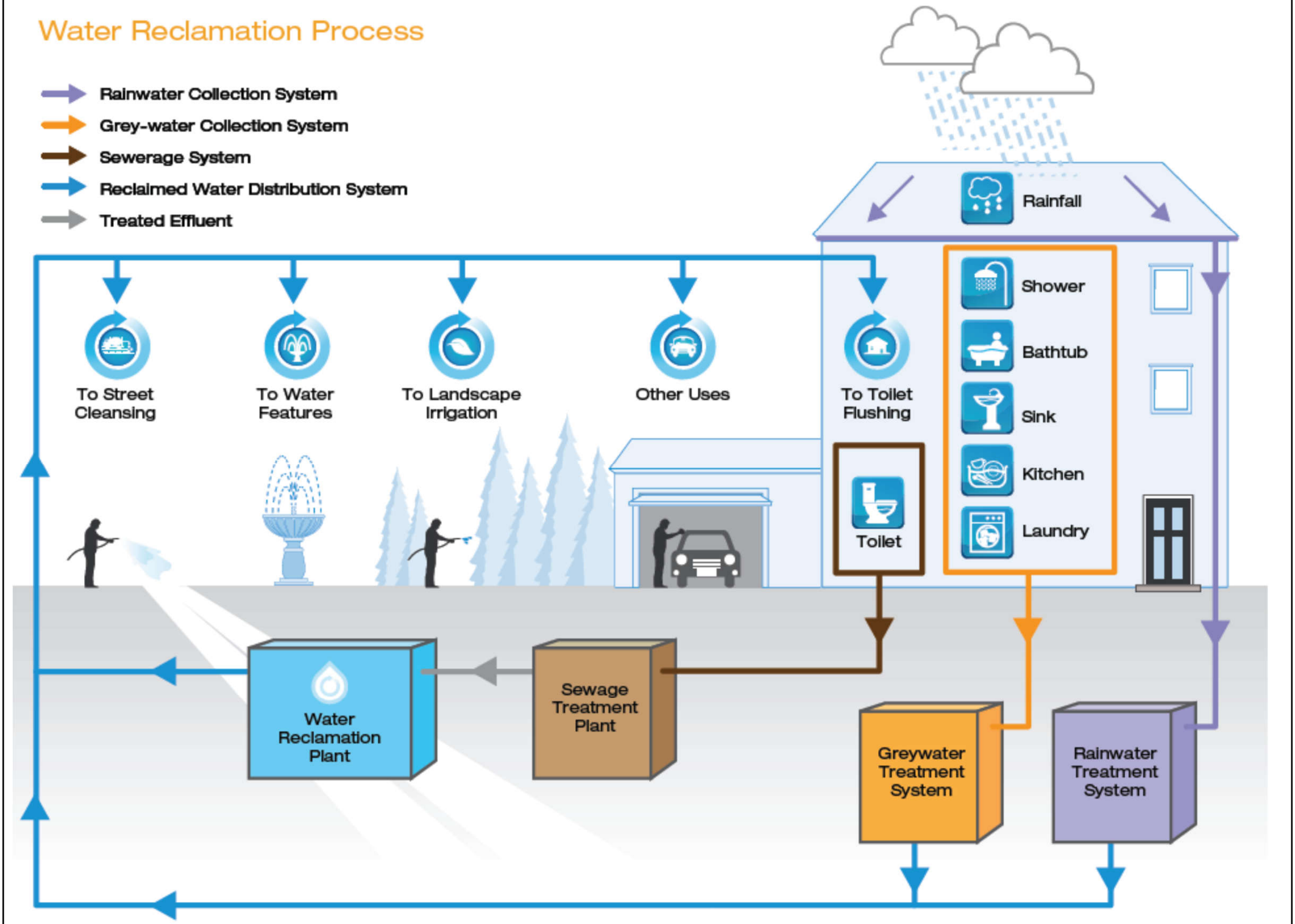
Diversification of water resources in Hong Kong



(Source: https://chinawaterrisk.org/opinions/sustainable-infrastructure-towards-a-diversified-hk-water-supply/)

1. Introduction

- Development of new water supply sources
  - Seawater desalination
    - Using reverse osmosis (RO) technology
  - Reclaimed water
    - Primarily for non-potable uses
    - Convert the tertiary treated sewage effluent into reclaimed water for toilet flushing
  - Grey water reuse & rainwater harvesting
  - Stormwater management & harvesting

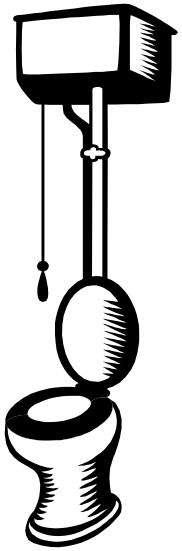


(Source: Water Supplies Department www.wsd.gov.hk)

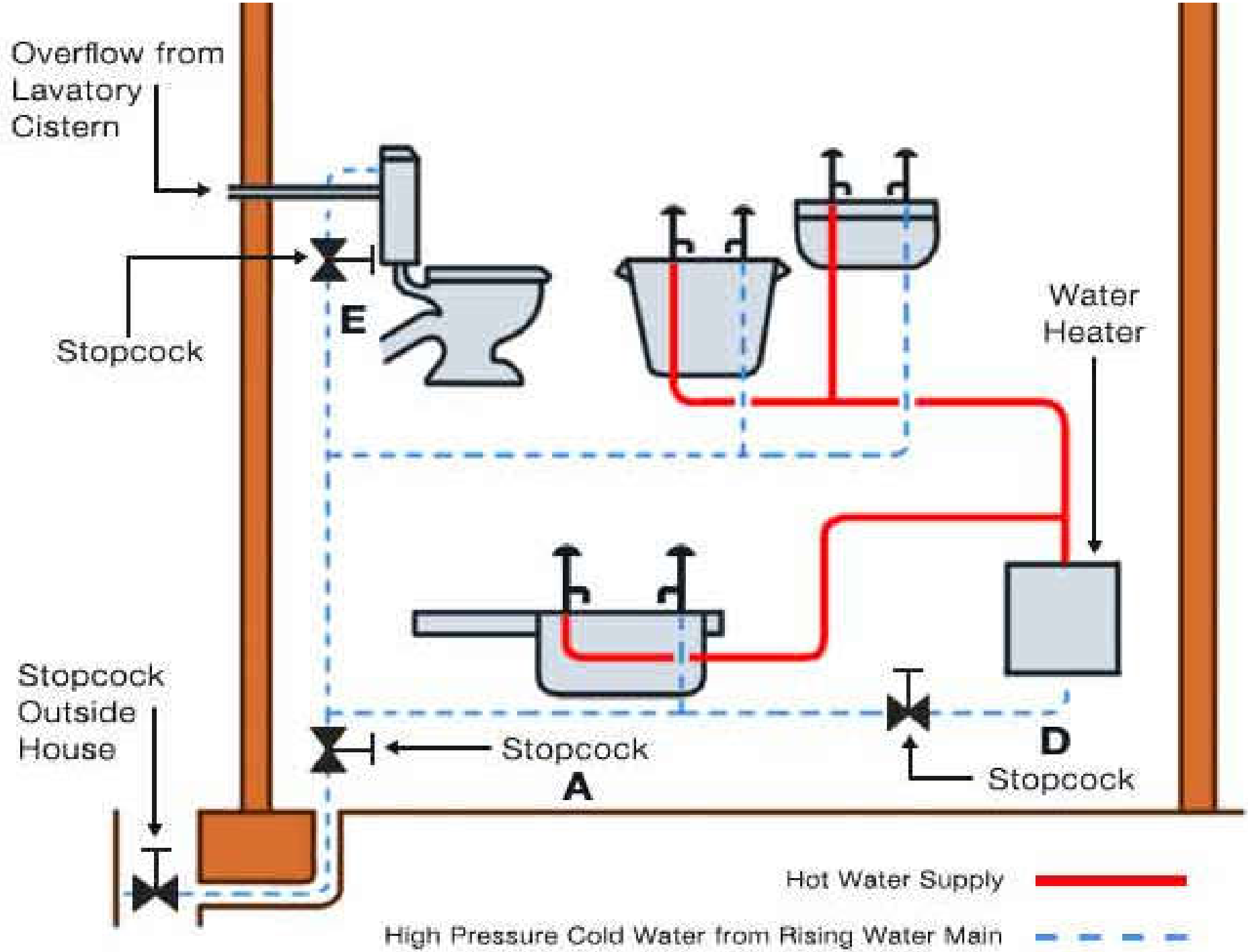
2. Basic principles

- Plumbing & drainage systems
  - Cold water supply
    - Fresh water supply (potable)
    - Flush water supply (non-potable)
  - Hot water supply
  - Stormwater drainage
    - Rainwater drainage & disposal
  - Wastewater (sanitary) drainage
    - Greywater & blackwater
  - Fuel gas supply (e.g. town gas, LPG)




An example of cold & hot water supply system

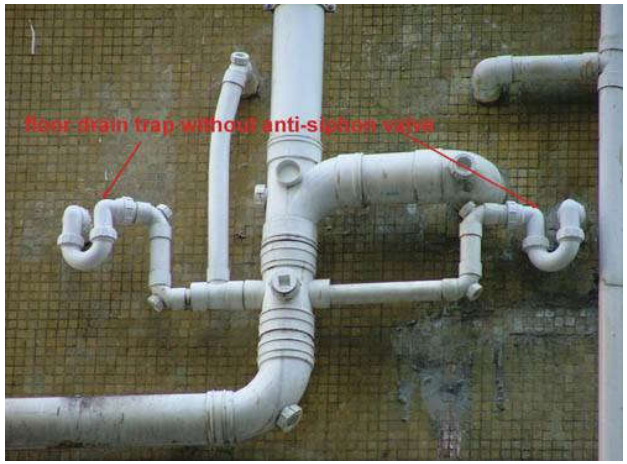


Basic concepts of sanitary plumbing & drainage systems

Plumbing system (water supply)

Sanitary fitments

Rainfall, surface water & stormwater



Above ground drainage

Sometimes, sump & pump system is required for disposal e.g. in basement

Below ground drainage

Sewage disposal (and treatment)

2. Basic principles

- What is **sustainable building**?
  - It involves a *holistic* approach to the design & operation of buildings. It considers:
    - *1) Economy and efficiency of resources*
    - *2) Life cycle design*
    - *3) Human well-being*
  - Main objectives
    - Be environmentally friendly & responsible
    - Improve the quality of built environment

2. Basic principles

- **Definition of Sustainable Building** [by an OECD project]
  - Have minimum adverse impacts on the built & natural environment, in terms of the buildings themselves, their immediate surroundings & the broader regional and global setting
  - Apply practices which strive for integral quality (economic, social & environmental performance) in a very broad way

(Source: OECD Work on Sustainable Buildings http://www.oecd.org/env/consumption-innovation/oecdworkonsustainablebuildings.htm)

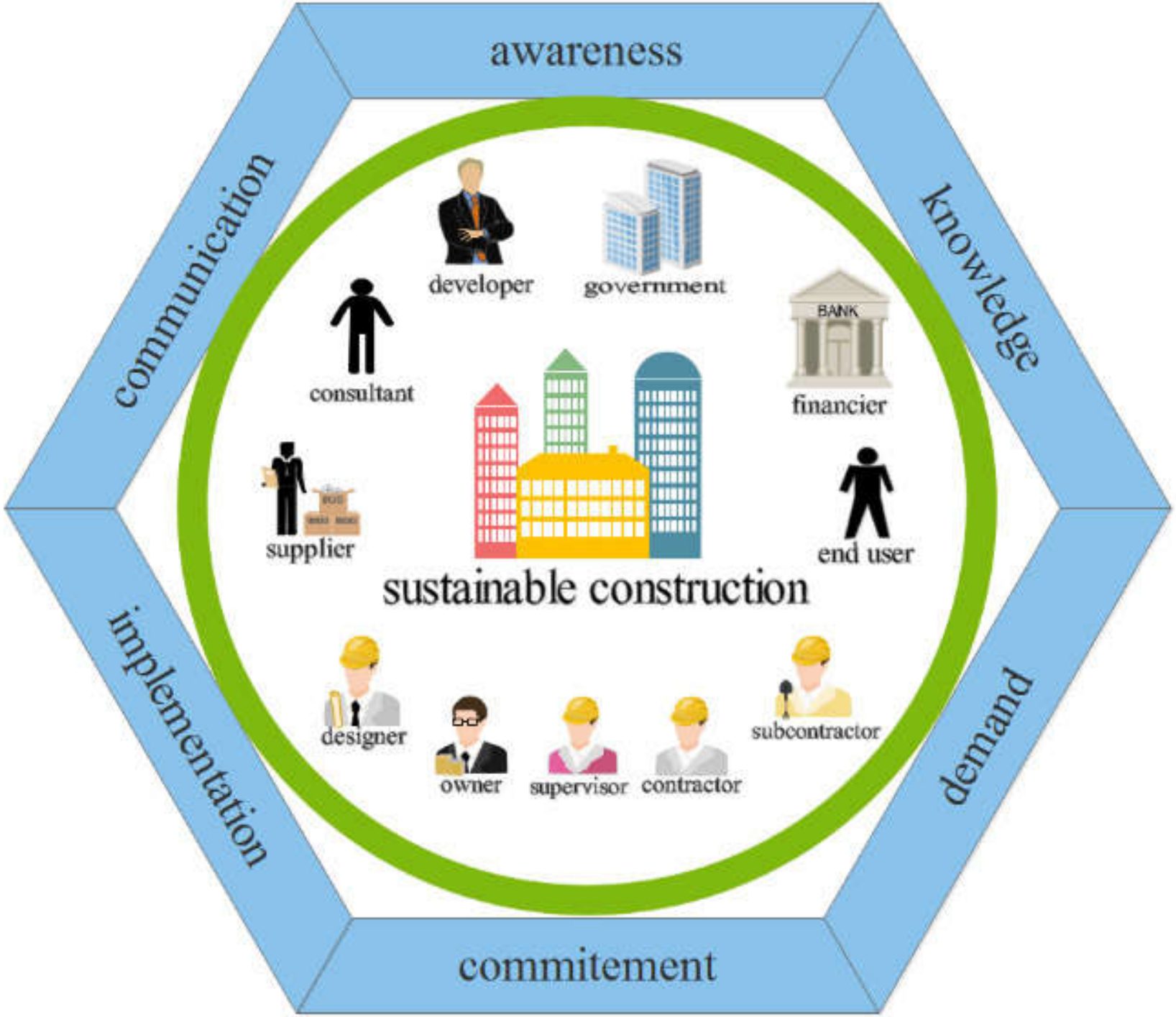
What factors determine whether a building is sustainable?

(Source: https://ibu-epd.com/en/what-factors-determine-whether-a-building-is-sustainable/)

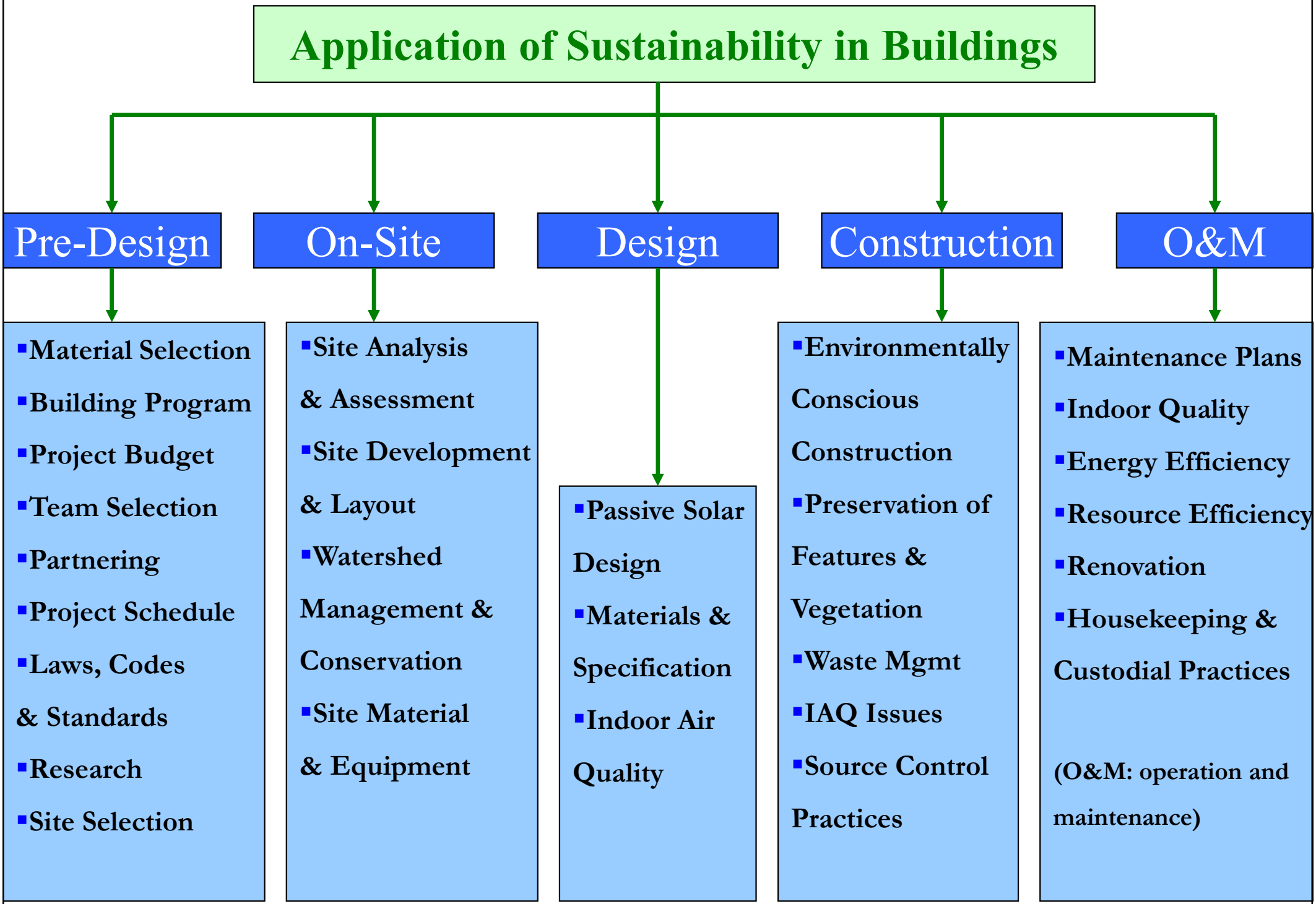
Eco sustainable building practices

(Source: https://www.transbuildwa.com.au/green-architecture)

Stakeholders & factors surrounding sustainable construction



(Source: https://www.researchgate.net/figure/Stakeholders-and-factors-surrounding-sustainable-construction_fig1_318253082)


Application of Sustainability in Buildings
Pre-Design
On-Site
Design
Construction
O&M
▪Material Selection
▪Building Program
▪Project Budget
▪Team Selection
▪Partnering
▪Project Schedule
▪Laws, Codes & Standards
▪Research
▪Site Selection
▪Site Analysis & Assessment
▪Site Development & Layout
▪Watershed Management & Conservation
▪Site Material & Equipment
▪Passive Solar Design
▪Materials & Specification
▪Indoor Air Quality
▪Environmentally Conscious Construction
▪Preservation of Features & Vegetation
▪Waste Mgmt
▪IAQ Issues
▪Source Control Practices
▪Maintenance Plans
▪Indoor Quality
▪Energy Efficiency
▪Resource Efficiency
▪Renovation
▪Housekeeping & Custodial Practices
(O&M: operation and maintenance)

Main principles of sustainable design

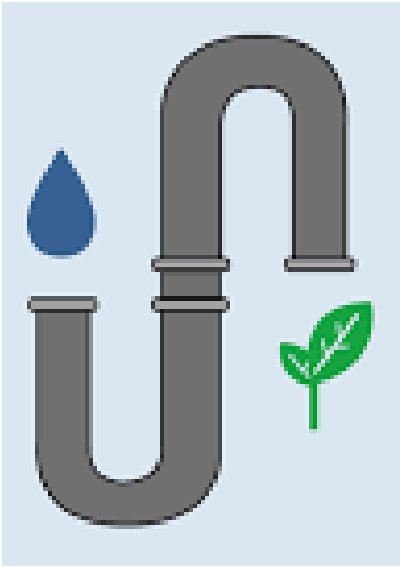
(Source: Sustainable design https://claudiaportelli.weebly.com/blog/january-04th-2015)

Green Features

Manufacturing Process (MP)	Building Operations (BO)	Waste Mgmt. (WM)
Waste Reduction (**WR**)	Energy Efficiency (**EE**)	Biodegradable (**B**)
Pollution Prevention (**P2**)	Water Treatment & Conservation (**WTC**)	Recyclable (**R**)
Recycled (**RC**)	Nontoxic (**NT**)	Reusable (**RU**)
Embodied Energy Reduction (**EER**)	Renewable Energy Source (**RES**)	Others (**O**)
Natural Materials (**NM**)	Longer Life (**LL**)	

2. Basic principles

- Essential component of sustainable plumbing:
  - Water efficiency
    - Water conservation, leakage reduction
  - Water reuse
    - Rainwater harvesting, greywater reuse
  - Sustainable wastewater management
    - Sanitation & sewage disposal
  - Renewable energy (biomass, biofuel, solar)
    - Hot water systems (solar water heating, heat pump)
  - Energy efficiency (plumbing equipment)
  - Materials, installation & cleaning practices

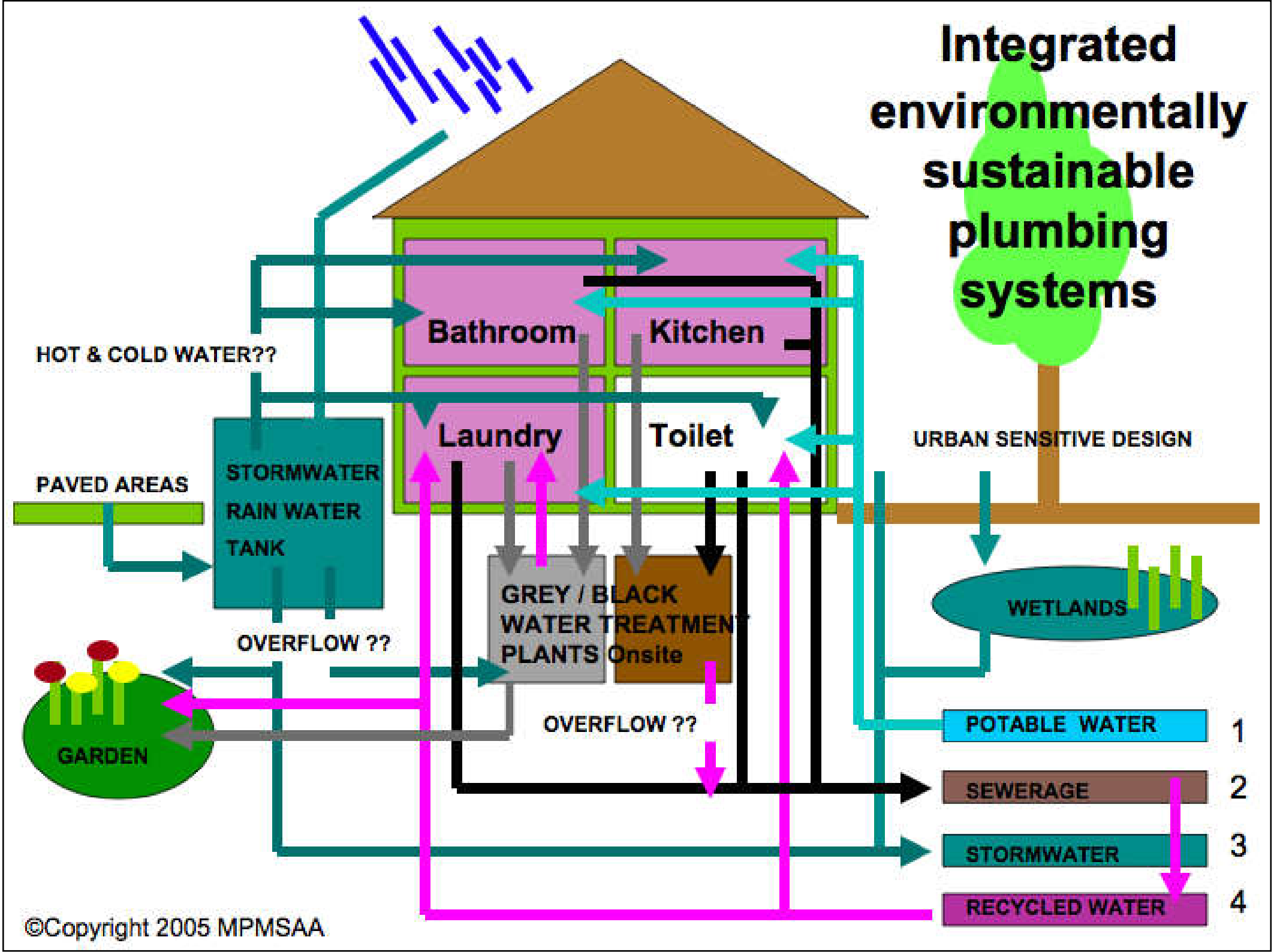


3. Important considerations

- Stormwater or watershed protection
  - Control rainwater runoff, flooding & erosion
    - Preservation of soils & drainage ways
    - Porous paving materials
    - Drainage of concentrated runoff
  - Avoid pollution & soil disturbance

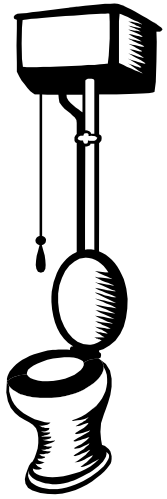
- Water efficiency & conservation
  - Saving of water & money: water-use charge, sewage treatment costs, energy use, chemical use

>>> Make the best use of water resources.

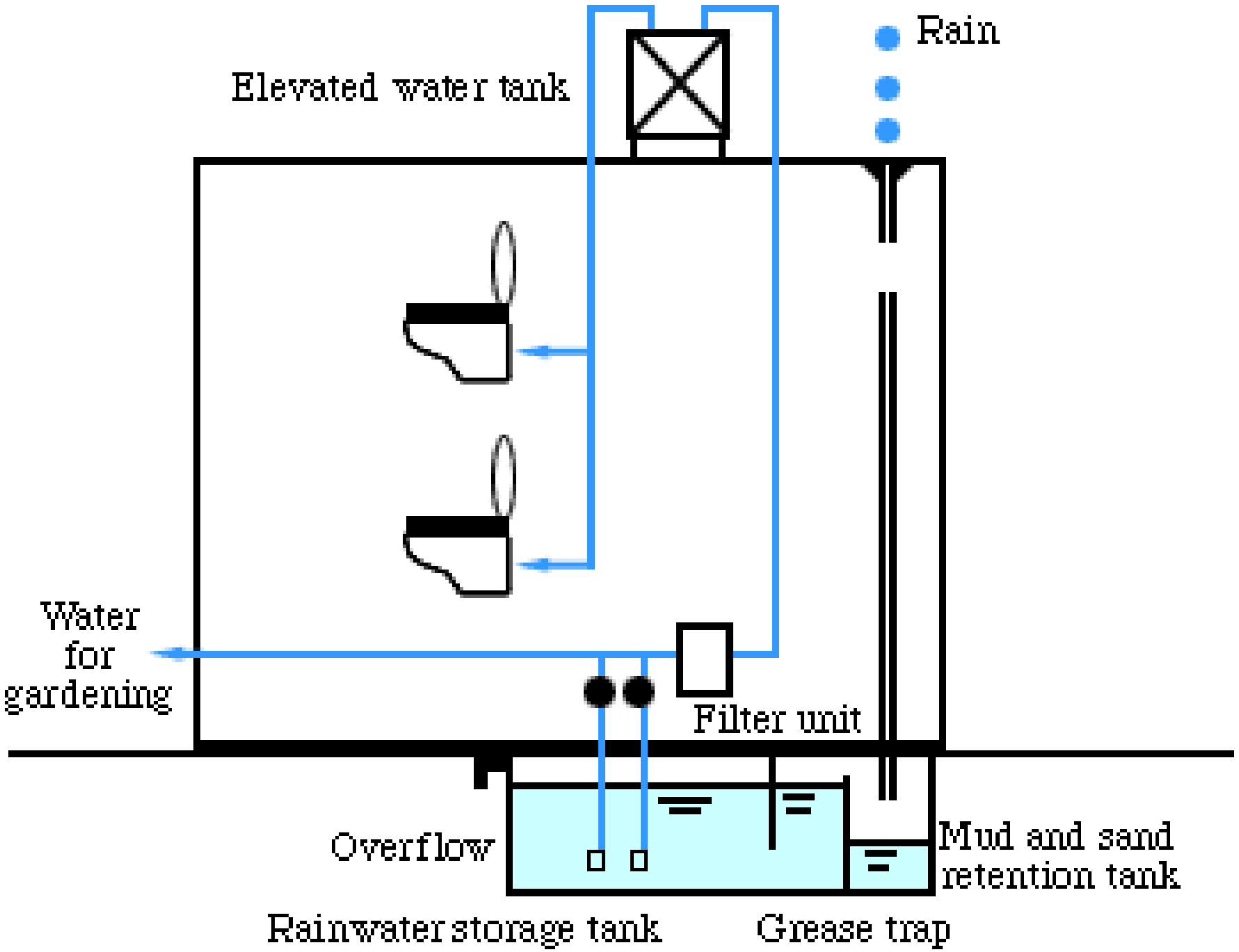

Integrated environmentally sustainable plumbing systems
Bathroom
Kitchen
Laundry
Toilet
HOT & COLD WATER??
PAVED AREAS
STORMWATER
RAIN WATER
TANK
OVERFLOW ??
GREY / BLACK
WATER TREATMENT
PLANTS Onsite
OVERFLOW ??
GARDEN
URBAN SENSITIVE DESIGN
WETLANDS
POTABLE WATER
1
SEWERAGE
2
STORMWATER
3
RECYCLED WATER
4
©Copyright 2005 MPMSAA

3. Important considerations

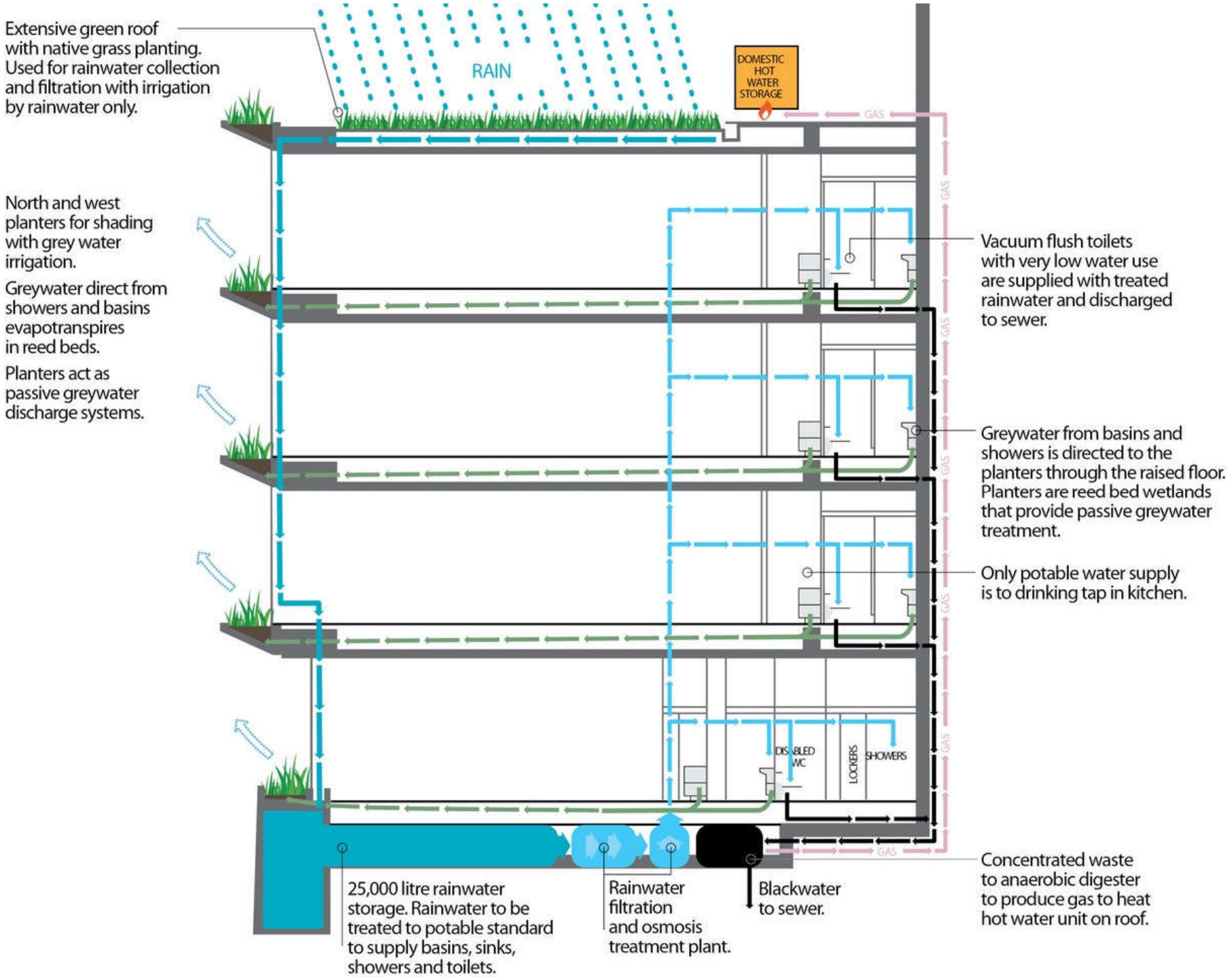
- Design strategy for water efficiency
  - Reduce water consumption
    - Low-flush toilets & showerheads
    - Leak detection & prevention
  - Correct use of appliances (e.g. washing machine)
  - Reuse and recycle water onsite
    - Rainwater collection & recycling
    - Greywater recycling (e.g. for irrigation)
  - No-/Low-water composting toilet



Rainwater recycling system

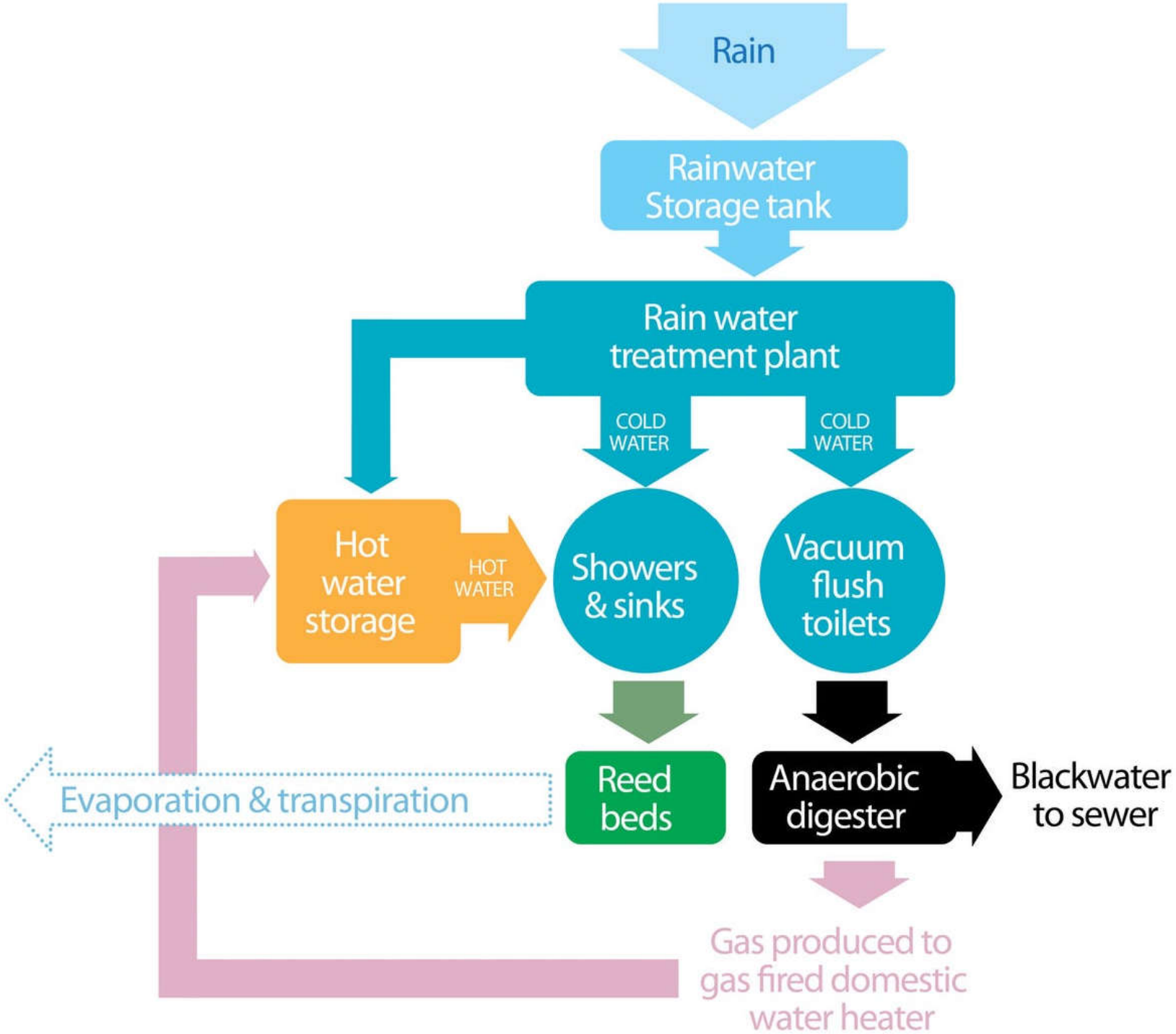


Pixel Building water cycle (Melbourne, Australia)



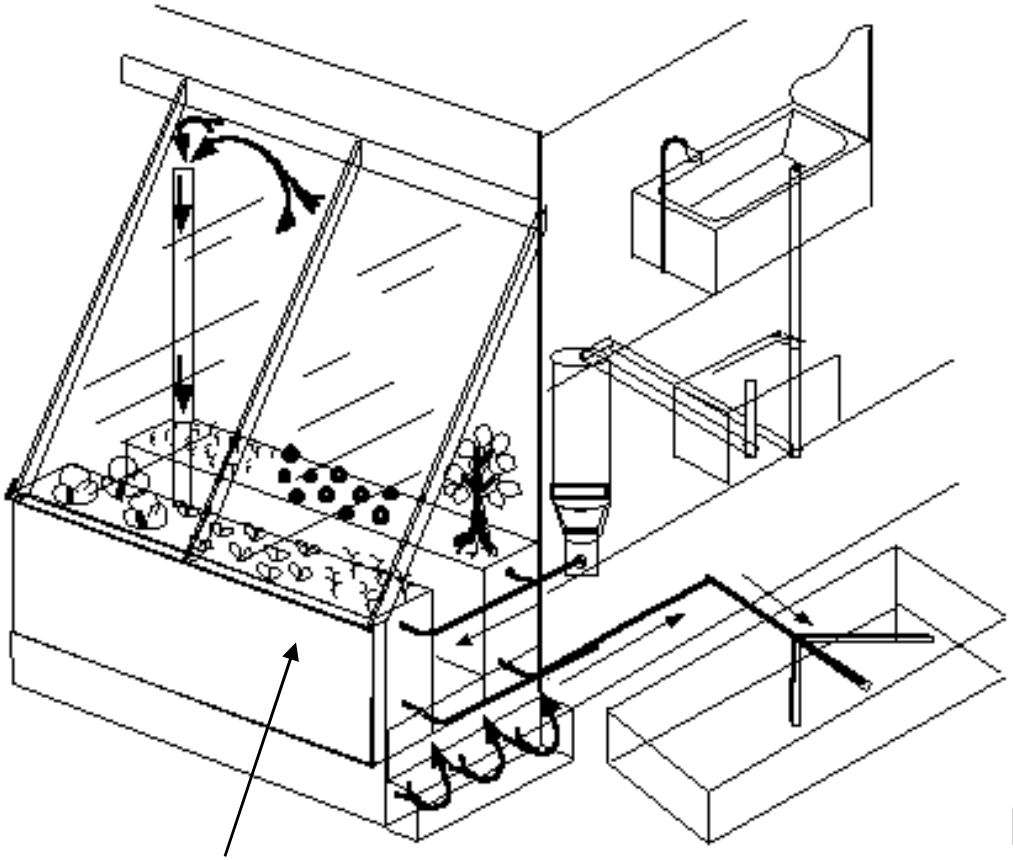
(Source: https://www.livinspaces.net/projects/architecture/pixel-office-building-australia-studio-505/)

Pixel Building rainwater harvesting (Melbourne, Australia)

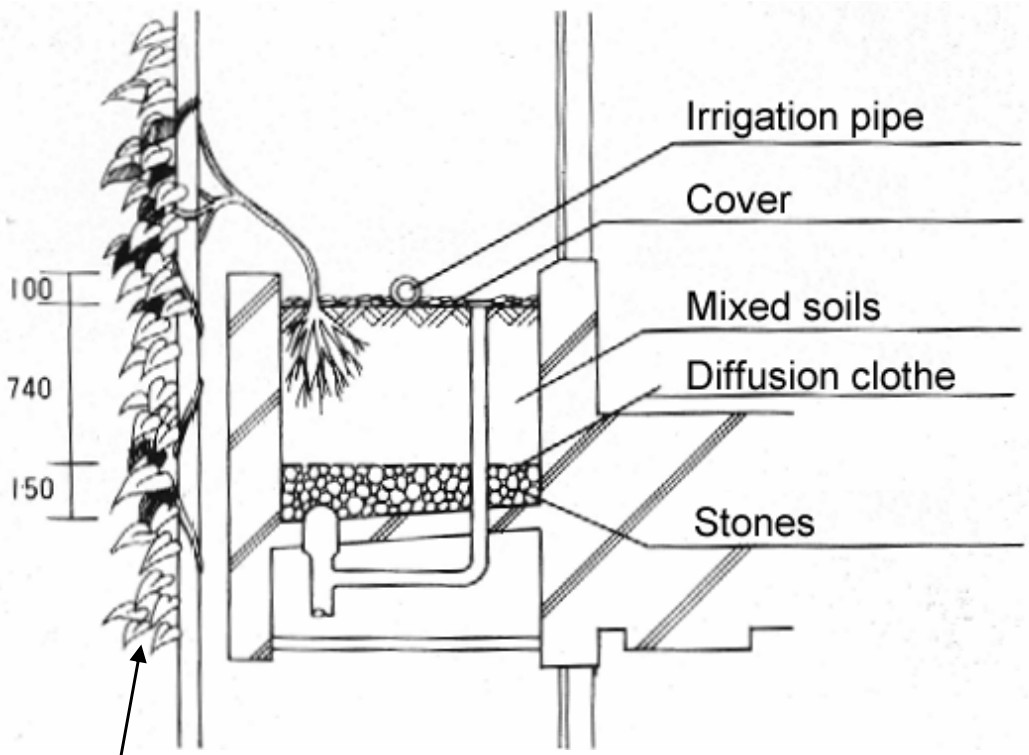


(Source: https://www.livinspaces.net/projects/architecture/pixel-office-building-australia-studio-505/)

Using greywater for crops & landscape irrigation

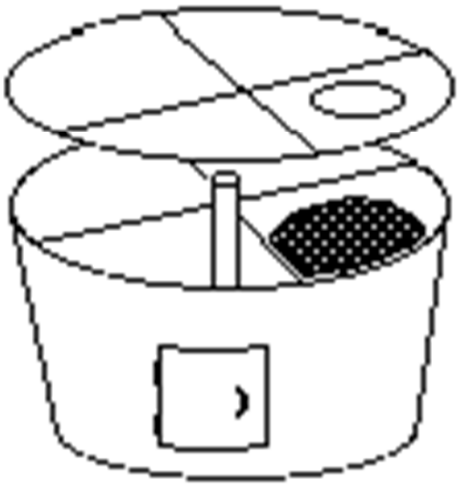


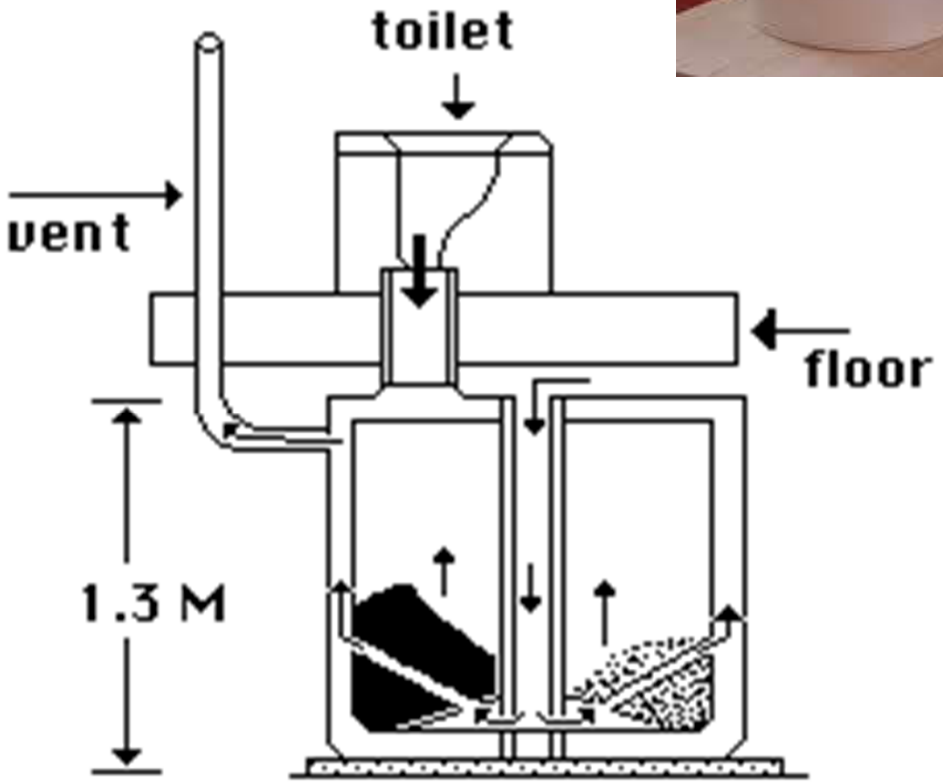
Crops growing
(for food or flowers)



Espalier

Composting toilets 堆肥式廁所 (use no or less water)





3. Important considerations

- Water Safety Plan (WSP)
  - Developed by WSD in 2007 in accordance with WHO's recommendations
  - Launched an integrated Drinking Water Quality Management System (DWQMS) in 2017
    - Water quality policy
    - Principle of water quality management
    - Health-based targets
    - Water safety plans
    - Surveillance

(Source: https://www.wsd.gov.hk/en/core-businesses/water-quality/action-plan-for-enhancing-of-drinking-water-safety/water-safety-plans/)

Drinking Water Quality Management System

(Source: Water Supplies Department www.wsd.gov.hk)

3. Important considerations

- Quality Water Supply Scheme for Buildings
  - https://www.wsd.gov.hk/en/core-businesses/water-quality/buildings/
  - To encourage building owners to maintain their plumbing systems properly
    - Fresh Water (Management System)
    - Fresh Water (Plus)
    - Flushing Water
  - There are 3 grades of certificates:
    - Blue Certificates: New application or renewal with < 3 years
    - Silver Certificates: Continuous participation 4-6 years
    - Gold Certificates: Continuous participation >= 6 years

(Source: https://www.wsd.gov.hk/en/core-businesses/water-quality/buildings/)

3. Important considerations

- Promoting water conservation
  - Water Efficiency Labelling Scheme (WELS)
  - Automatic meter reading
  - Public education
  - Water use efficiency guidelines
  - Water loss management (reduce leakages)
  - Water intelligent network (WIN) (monitor water loss)
  - Underground asset (water mains) management
  - Expand the use of low grade water (e.g. seawater flushing)

(See also: https://www.waterconservation.gov.hk/)

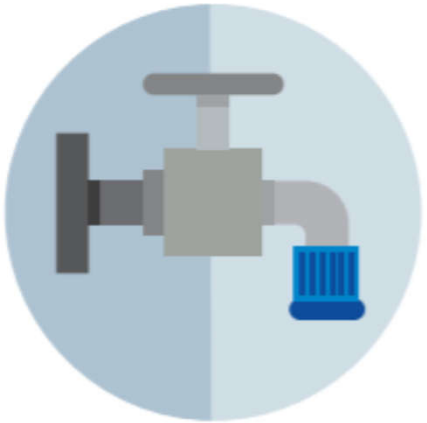
Voluntary Water Efficiency Labelling Scheme (WELS)

Showers for Bathing

Water Taps

Urinal Equipment

Washing Machines

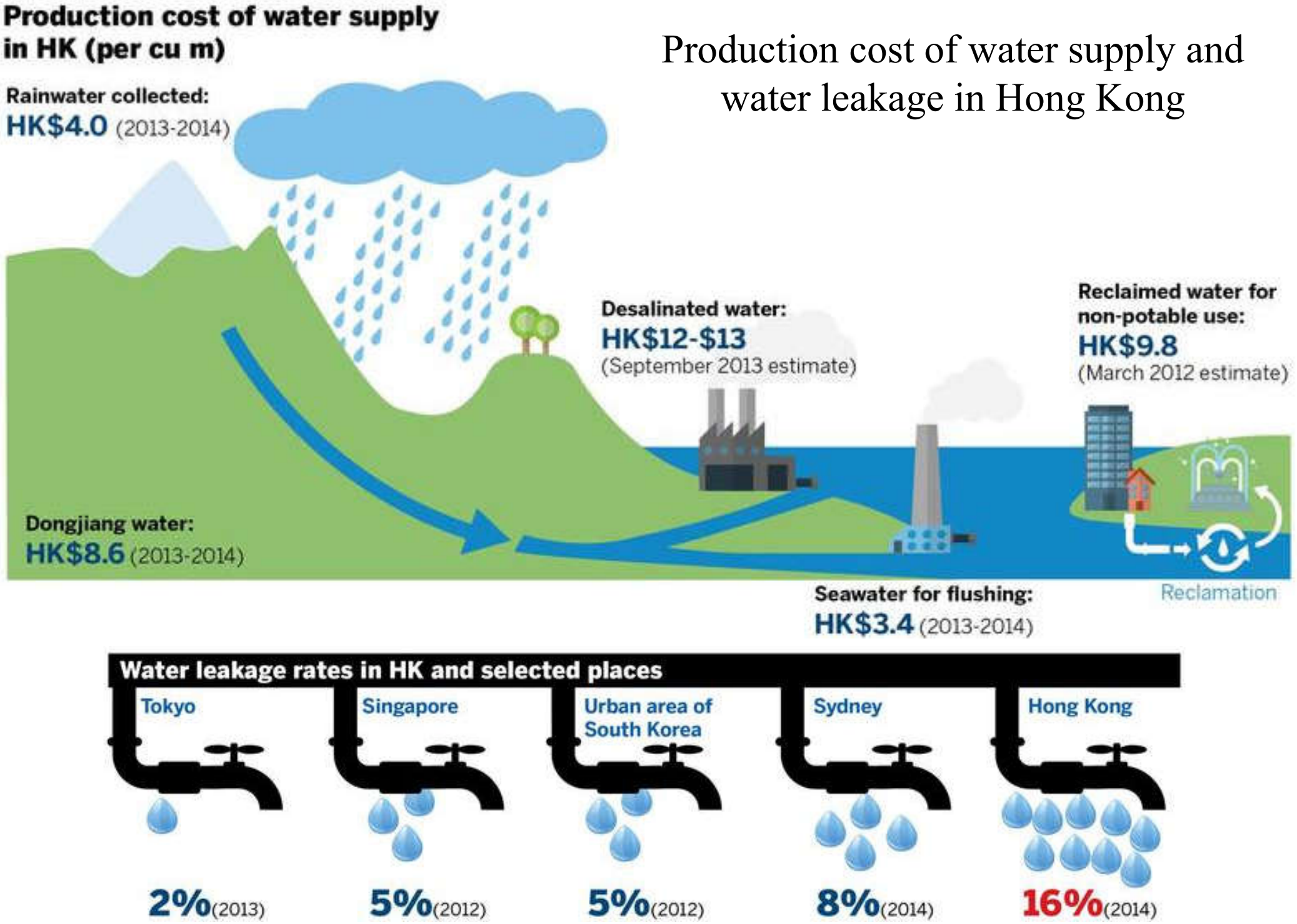


Flow Controllers

Water Closets

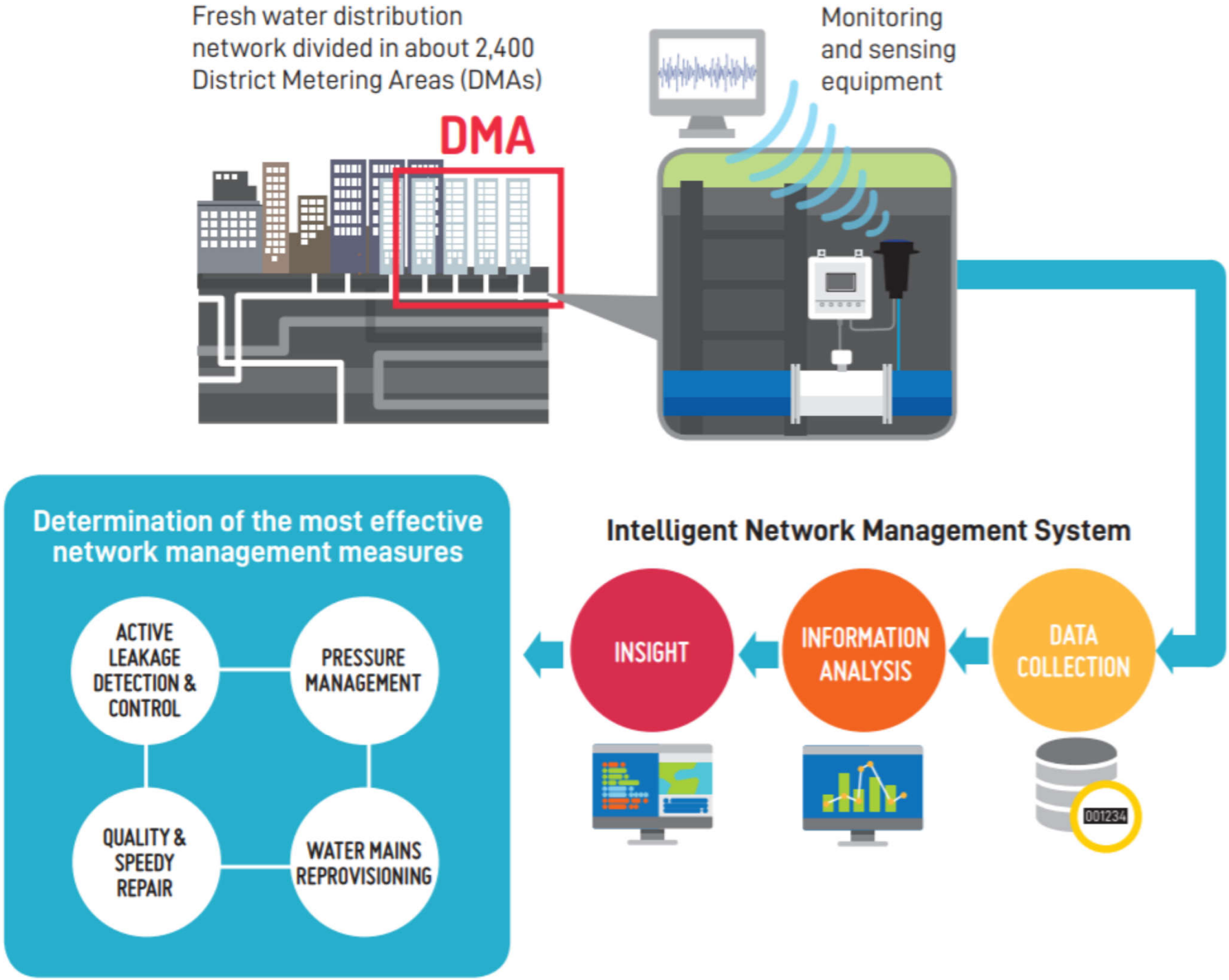
(Source: https://www.wsd.gov.hk/en/plumbing-engineering/water-efficiency-labelling-scheme/)

Production cost of water supply and water leakage in Hong Kong



(Source: https://www.chinadailyhk.com/articles/70/137/218/1509961687569.html)

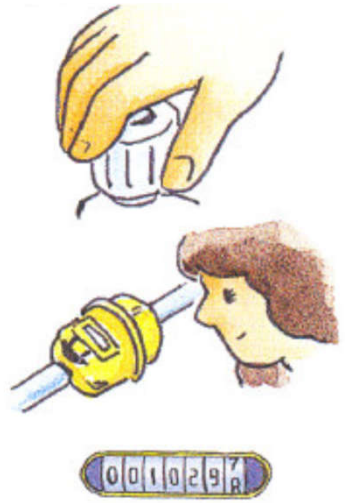
Water intelligent network (WIN) (monitor water loss)



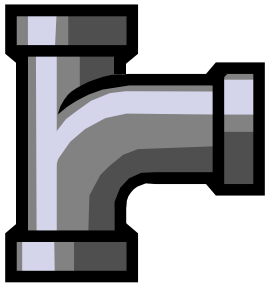
(Source: https://www.wsd.gov.hk/en/core-businesses/operation-and-maintenance-of-waterworks/reliable-distribution-network/)

3. Important considerations

- Inspect & maintain plumbing to prevent water leaks
- Checking of water leakage: simple method
  - Turn off all water taps
  - Compare the water meter reading over a 30-minutes period
  - If the water meter registers flow when all water taps are turned off, it implies leaking
- However, this method cannot detect very small leakage (seepage)



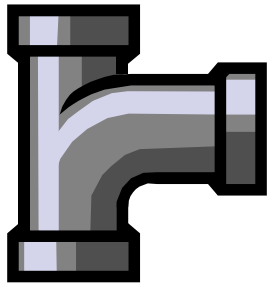
4. Key aspects



- Water conservation & energy efficiency
  - Water conservation
    - A key factor in the design (to conserve water)
    - Measures:
      - Detect water leakage
      - Reduce water consumption
      - Reuse or recycle water

  - Energy efficiency
    - Adopt pumps of better energy efficiency
    - Insulation of hot water pipe, fittings & vessels
    - Use of fresh water for cooling tower make-up

4. Key aspects



- Pipes & fittings for plumbing systems in HK
  - Water supply pipes & fittings with valid General Acceptance (GA)
  - Applicable standards
  - Voluntary GA labelling scheme for plumbing products
  - Voluntary quality assurance information scheme (GA+)
  - Voluntary low metal leaching rate pipes and fittings scheme (GA*)

水務署
Water Supplies Department

(Source: https://www.wsd.gov.hk/en/plumbing-engineering/pipes-and-fittings-to-be-used-in-inside-service-or/)

Voluntary GA (General Acceptance) Labelling Scheme for plumbing products

water taps and mixers

soldering materials

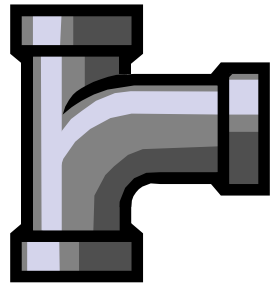
pipes

pipe fittings

valves

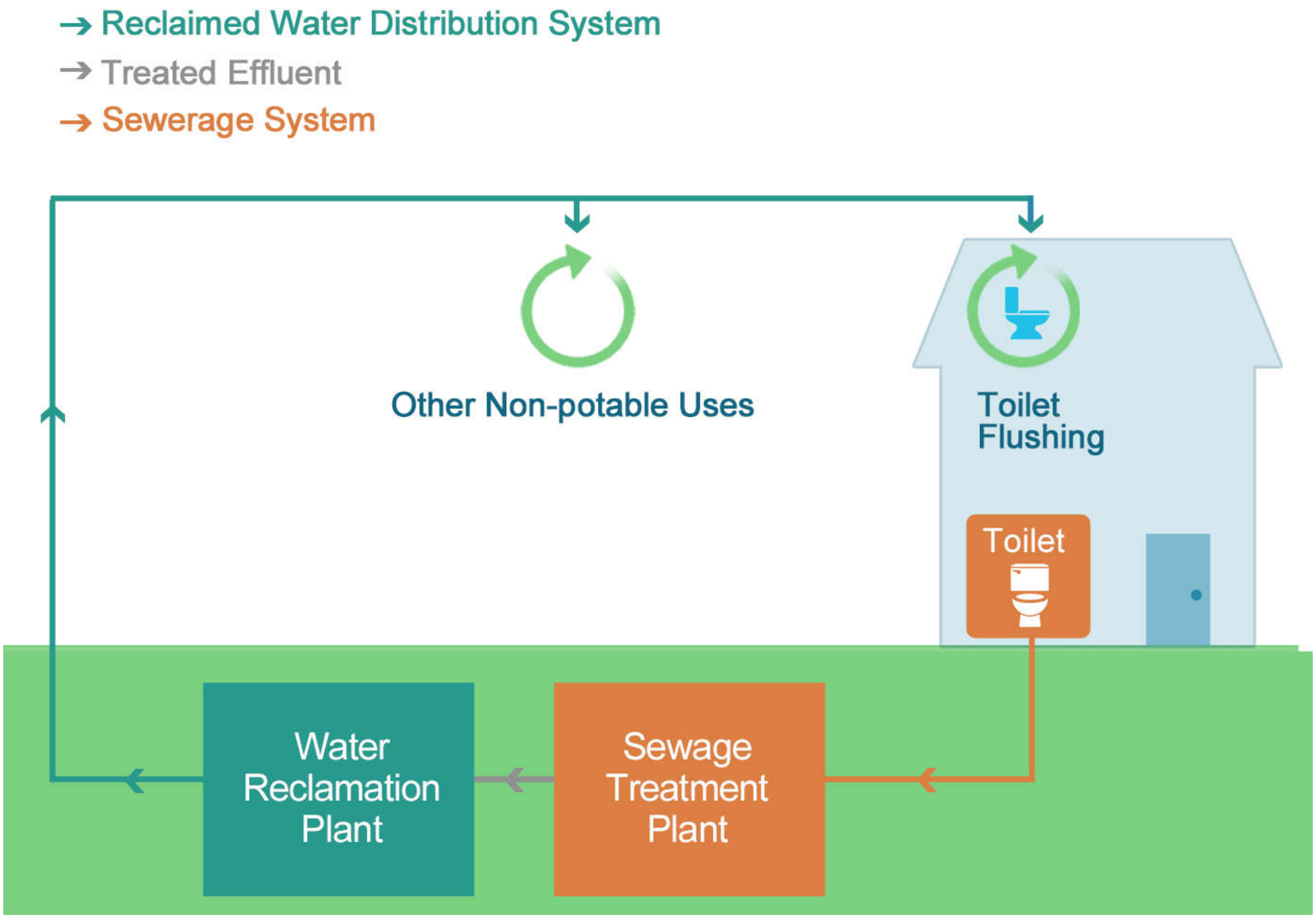
(Source: https://www.wsd.gov.hk/en/plumbing-engineering/pipes-and-fittings-to-be-used-in-inside-service-or/voluntary-ga-shop-scheme/)

4. Key aspects



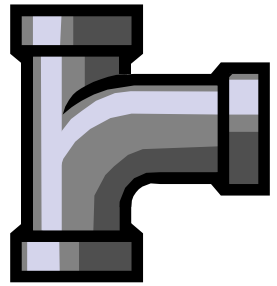
- Reclaimed water (再造水) trial scheme in HK
  - For flushing at public toilets in Ngong Ping & cable car terminal; at Shek Wu Hui, for toilet flushing & non-potable uses
  - Highly treated wastewater:
    - Clear in appearance, odourless & is safe for use
    - Contains a low level of nutrients (nitrogen & phosphorus)
    - Can be beneficial to plant growing (reduce fertilizer use)

Water reclamation process in Hong Kong



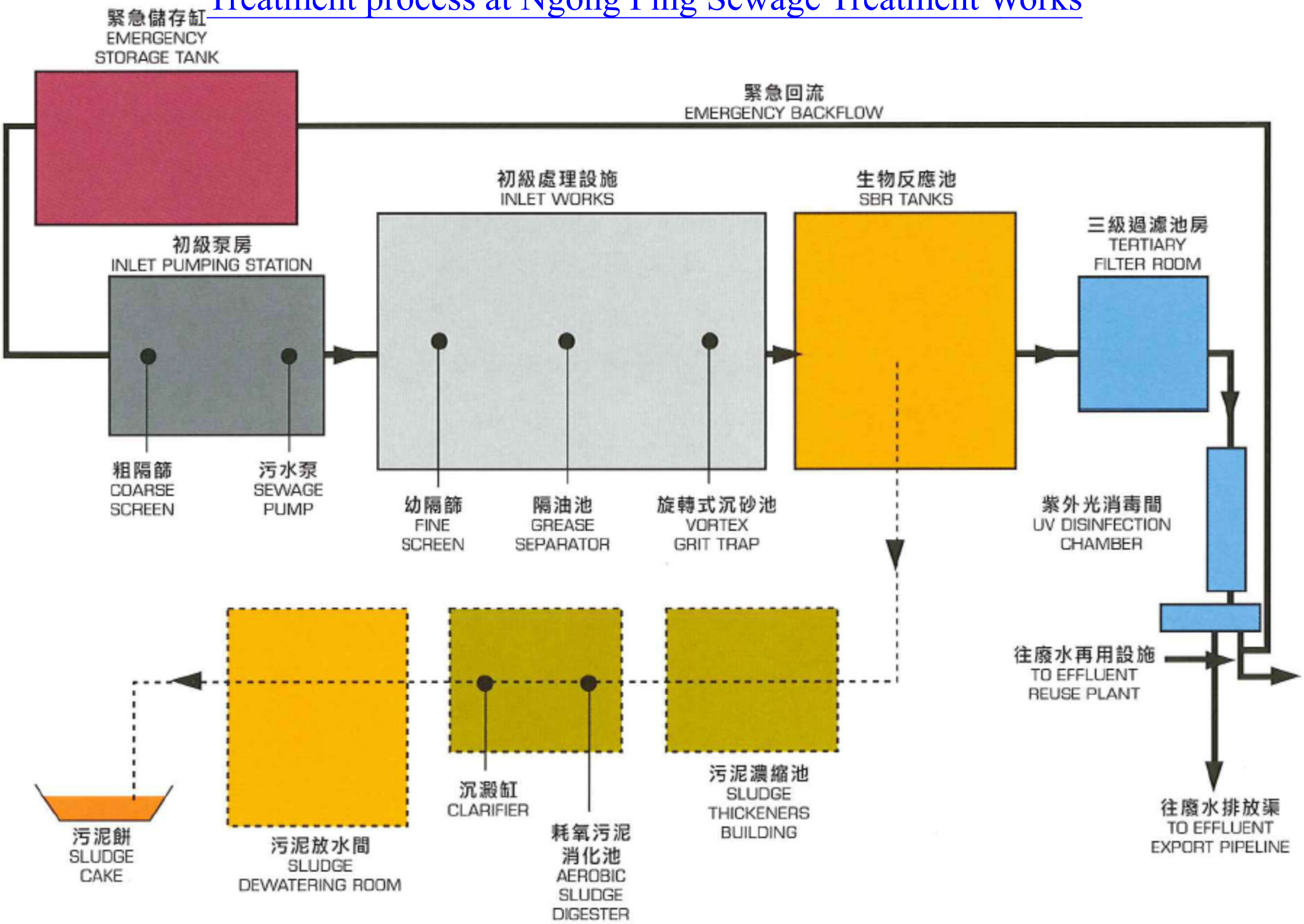
(Source: https://www.wsd.gov.hk/en/core-businesses/water-resources/recycled-water/)

4. Key aspects



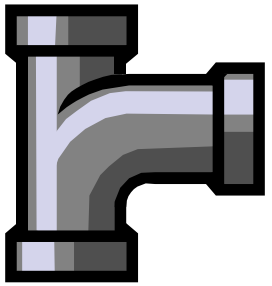
- Ngong Ping Sewage Treatment Works
  - https://www.dsd.gov.hk/EN/HTML/20517.html
  - For Ngong Ping cable car & surrounding areas (environmentally sensitive)
  - The first tertiary sewage treatment plant with reclaimed water facilities in Hong Kong
    - High quality effluent good for reuse
    - Adopt the technology of Sequencing Batch Reactor (SBR), dual media filter and disinfection process to reduce organic pollutants, suspended solids, nutrients & pathogenic organisms

Treatment process at Ngong Ping Sewage Treatment Works



(Source: Drainage Services Department, www.dsd.gov.hk)

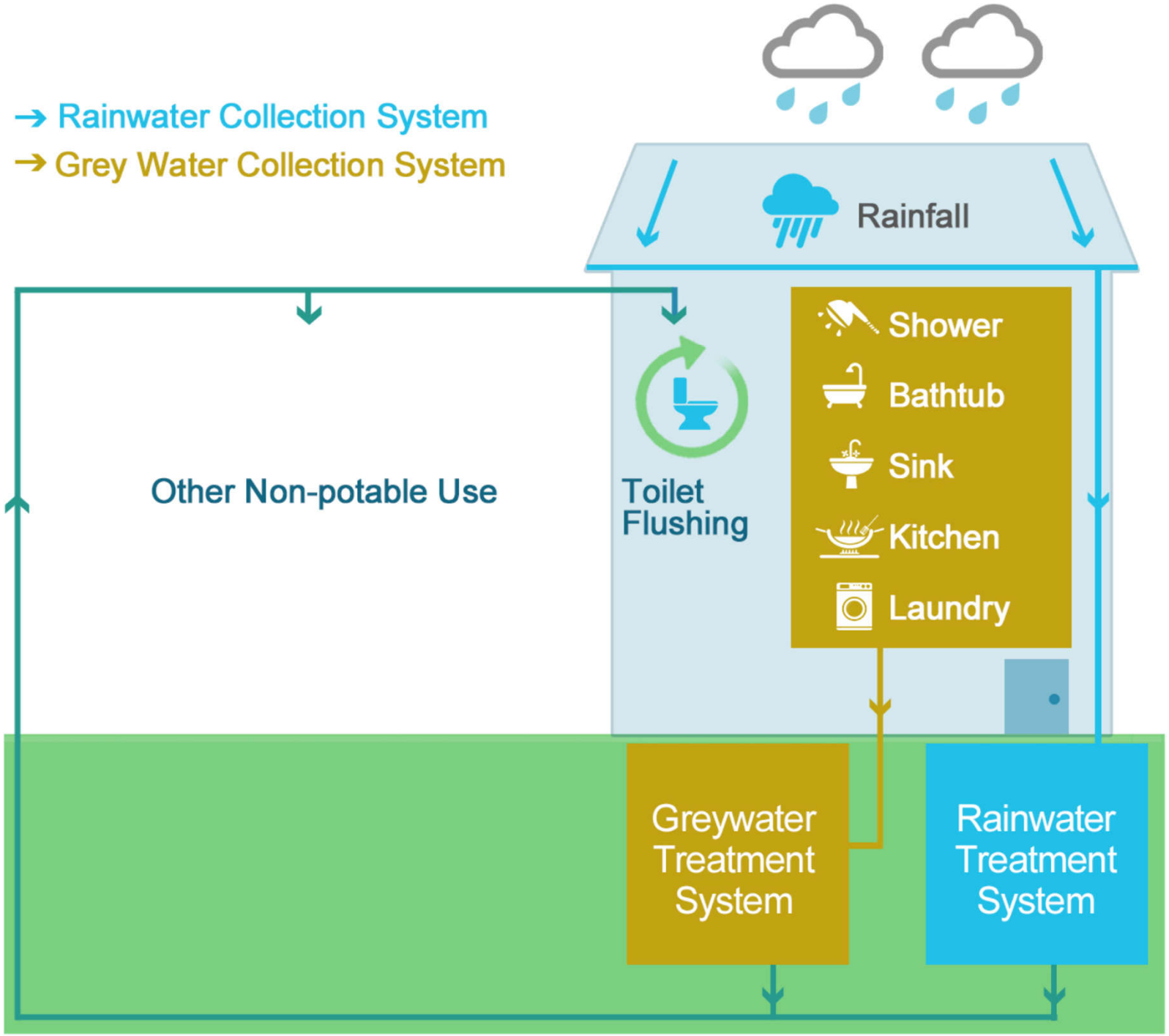
4. Key aspects



- Grey water reuse & rainwater harvesting
  - Collection of grey water & rainwater
  - Collection & storage tanks, pumps
  - Treatment of grey water & rainwater
  - Assess quantity of supply & demand
    - Yield of grey water & rainwater
    - Estimate grey water & rainwater demand
  - Installation, operation & maintenance
  - Marking & proper use of treated reclaimed water

(Source: Technical Specifications on Grey Water Reuse and Rainwater Harvesting 重用洗盥污水及集蓄的雨水技術規格
https://www.wsd.gov.hk/filemanager/en/content_1459/technical_spec_grey_water_reuse_rainwater_harvest.pdf)

Grey water recycling and rainwater harvesting system



(Source: https://www.wsd.gov.hk/en/core-businesses/water-resources/recycled-water/)

Grey water & rainwater sources and end uses

Grey Water Sources	Rainwater Sources	Potential End Use After Treatment
• Wash basins • Baths • Showers • Dishwashers • Laundry machines • Kitchen sinks • Air conditioning condense	• Roofs • Permeable paving • Non-permeable paving • Surface runoff from grass and landscaped areas	• Toilet flushing • Drip irrigation • Sprayed irrigation • Water features • Car washing • External cleaning • Fire fighting • Industrial processes

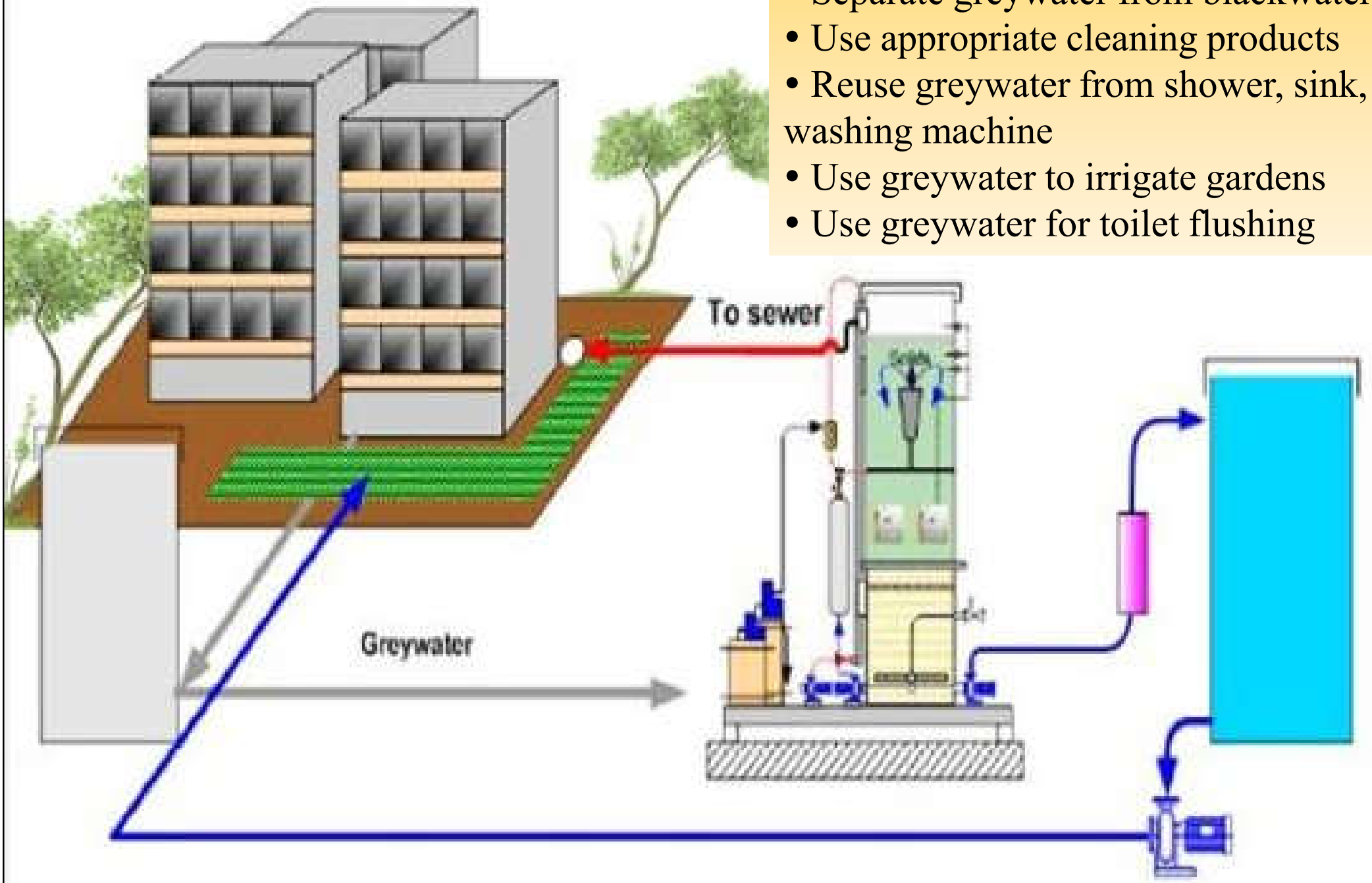
Treated grey water and rainwater (hereafter referred to as "reclaimed water") shall be prohibited from the following uses:

(a) Consumed by humans or animals
(b) Used for bathing or showering
(c) Used to top-up swimming pools or spas
(d) Used for food preparation or washing dishes or kitchen appliances
(e) Used for irrigating in a way that will contact edible parts of herbs, fruit, or vegetables
(f) Piped to hot water services

(Source: Technical Specifications on Grey Water Reuse and Rainwater Harvesting 重用洗盥污水及集蓄的雨水技術規格 https://www.wsd.gov.hk/filemanager/en/content_1459/technical_spec_grey_water_reuse_rainwater_harvest.pdf)

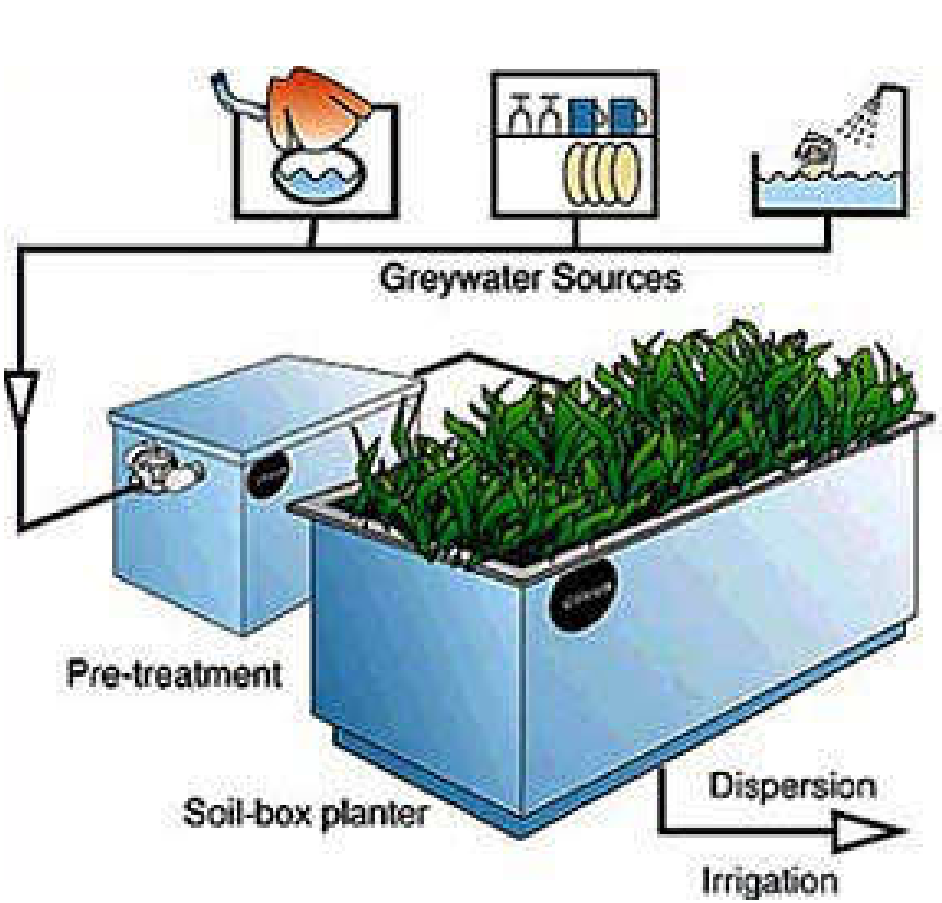
Effective greywater management: reuse, irrigation & toilet flushing

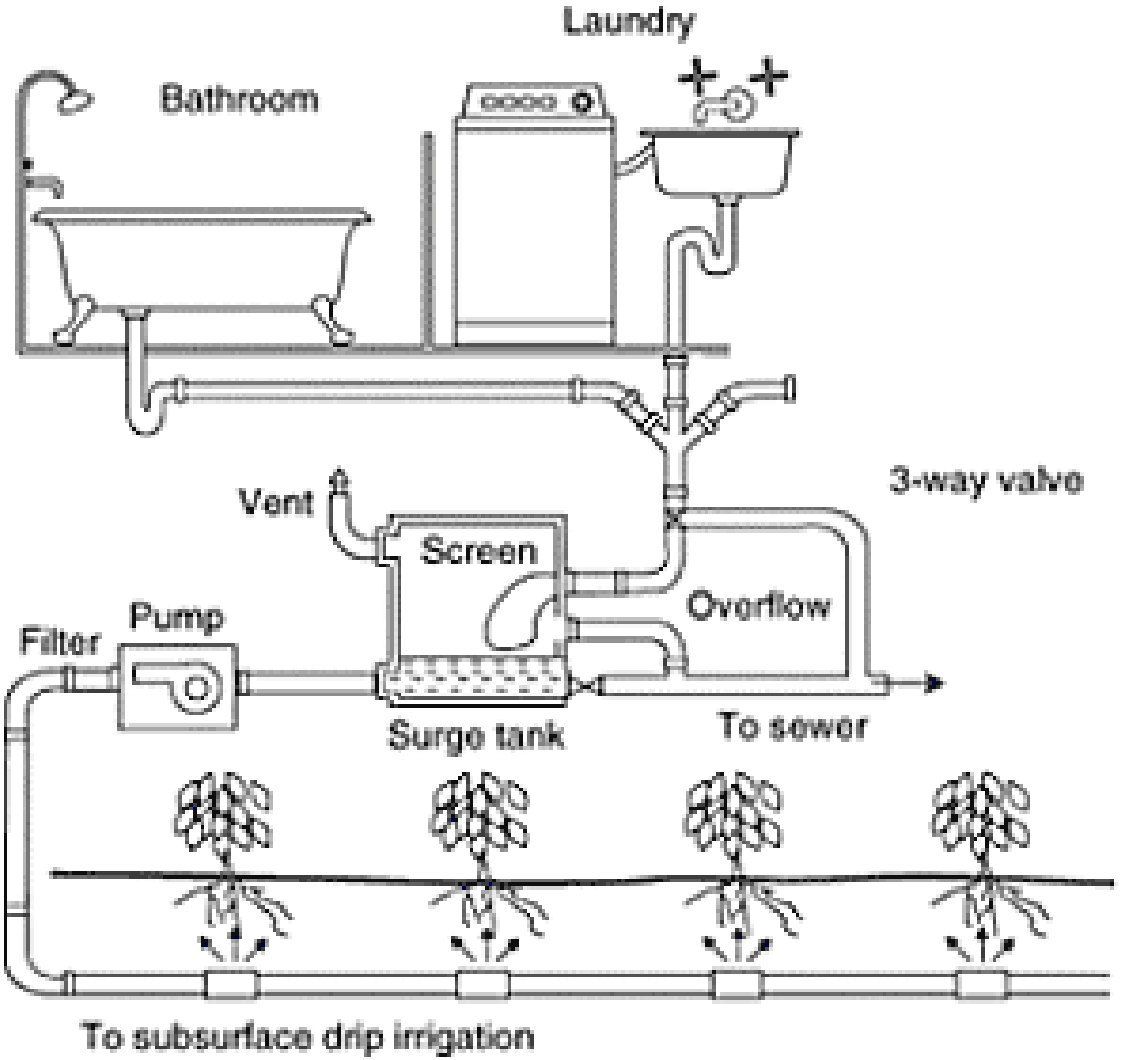
- Separate greywater from blackwater
- Use appropriate cleaning products
- Reuse greywater from shower, sink, washing machine
- Use greywater to irrigate gardens
- Use greywater for toilet flushing



(Source: https://sanicon.in/)

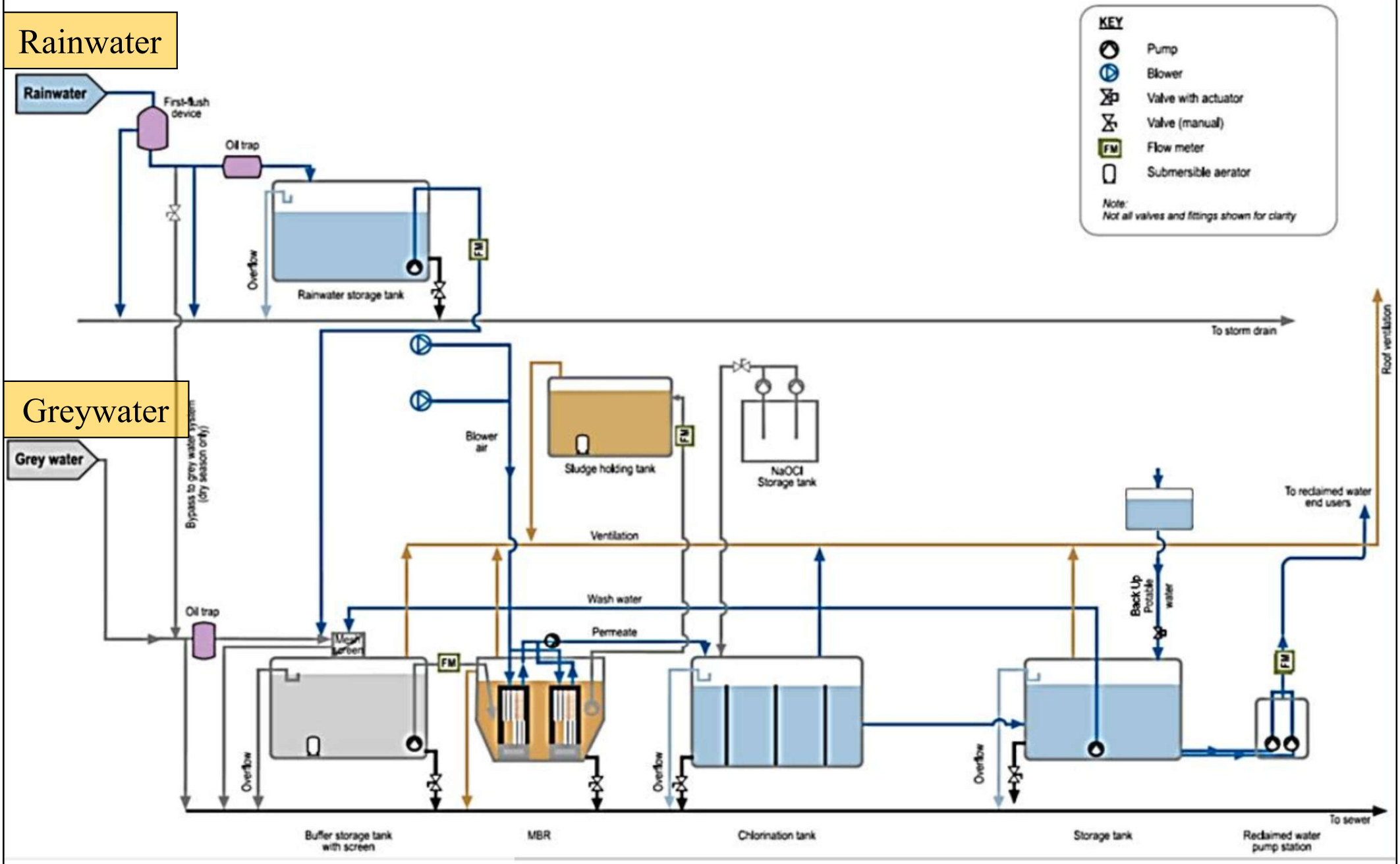
Greywater reuse and/or dual plumbing system (greywater + pretreatment + planter + irrigation)





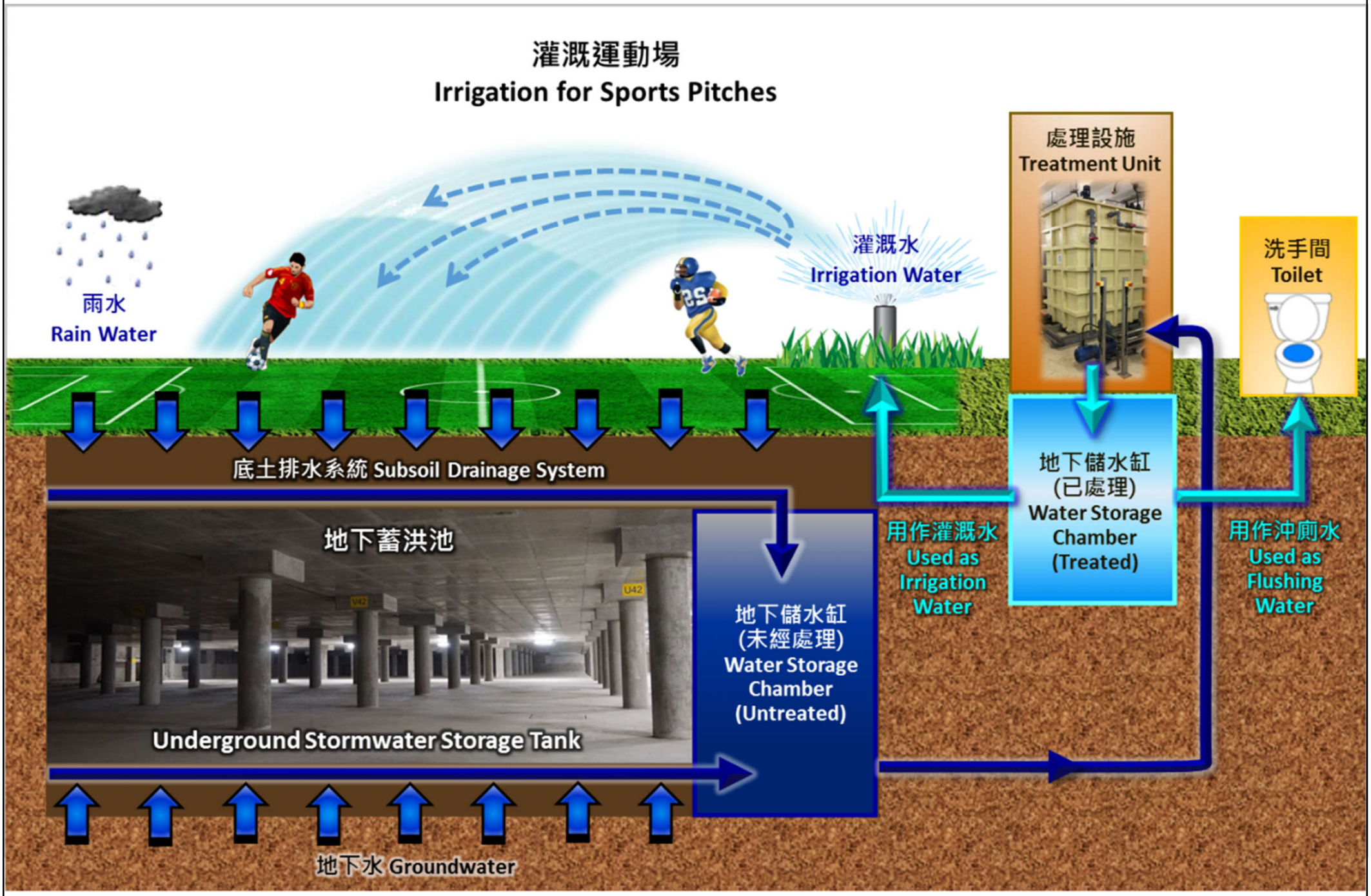
(Source: https://www.h2ouse.org/greywater-system-installation-tips/)

Schematic diagram for combined grey water & rainwater treatment



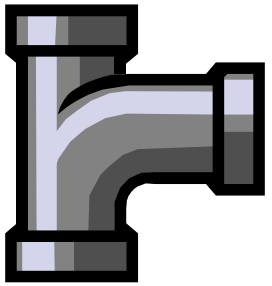
(Source: Technical Specifications on Grey Water Reuse and Rainwater Harvesting 重用洗盥污水及集蓄的雨水技術規格
https://www.wsd.gov.hk/filemanager/en/content_1459/technical_spec_grey_water_reuse_rainwater_harvest.pdf)

Happy Valley water harvesting system



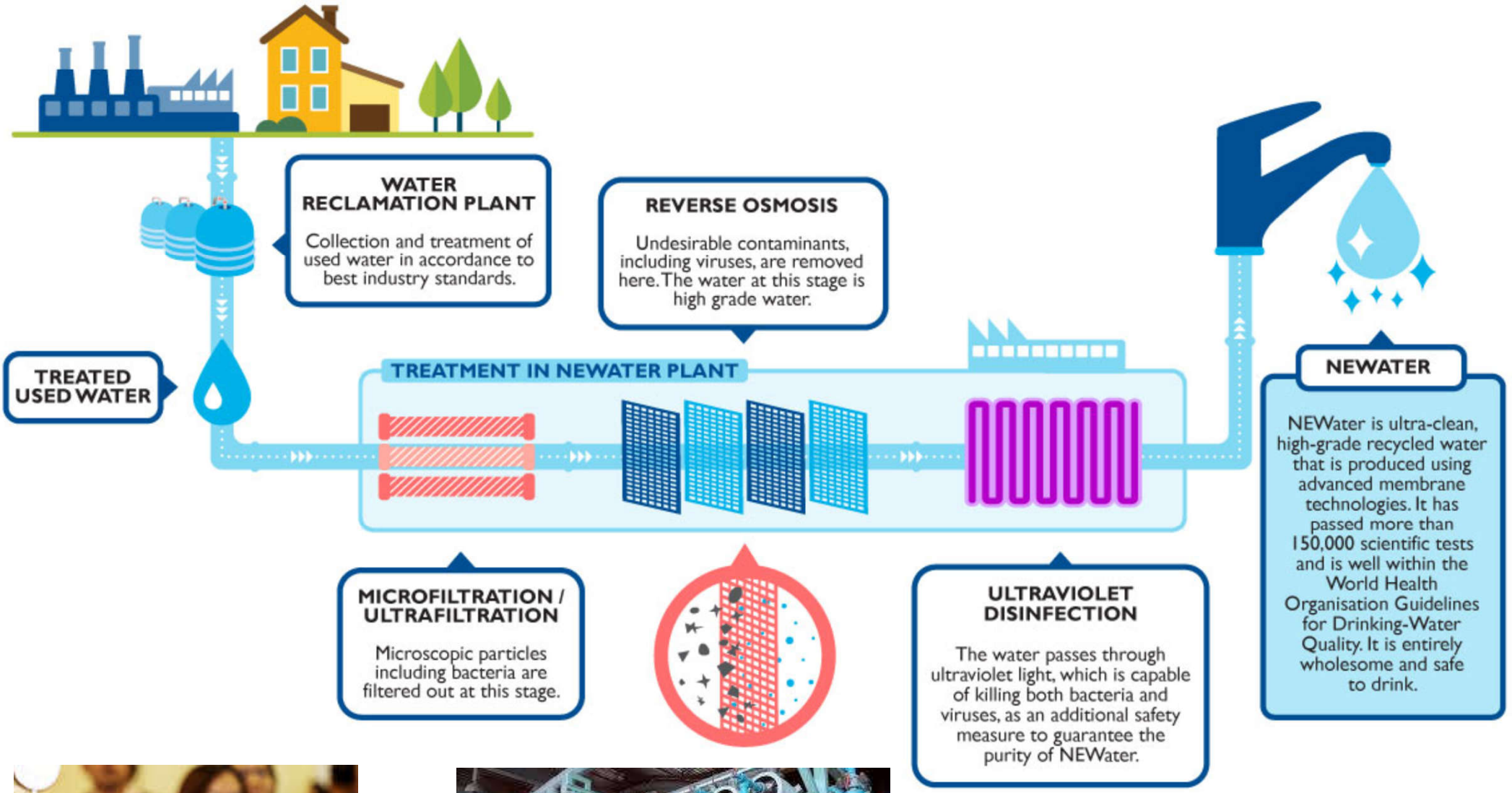
(Source: https://www.dsd.gov.hk/EN/HTML/20515.html)

4. Key aspects



- Reclaimed water (再造水)
  - Benefits: better use of treated wastewater, save water, protect our environment, better quality water for irrigation
- In Singapore, the brand name is NEWater (新生水)
  - High-purity reclaimed water
  - Treated wastewater purified using dual-membrane (via microfiltration and reverse osmosis) and ultraviolet technologies, in addition to the water treatment processes
    - The water is potable and is consumed by humans
    - But is mostly used for industry requiring high purity water

NEWater technology in Singapore



(Source: https://www.pub.gov.sg/watersupply/fournationaltaps/newater)

Green Plumbing Design Certificate (GPD) by American Society of Plumbing Engineers (ASPE) & International Association of Plumbing and Mechanical Officials (IAPMO)

https://www.aspe.org/education-credentialing/gpd/

GREEN PLUMBING DESIGN™


GREEN PLUMBING DESIGN

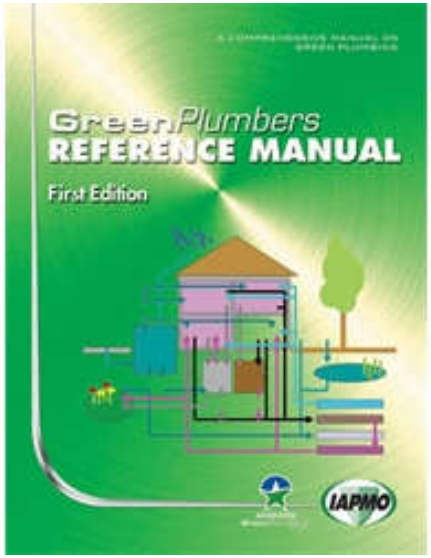
THIS CERTIFIES THAT

HAS SUCCESSFULLY COMPLETED THE GREEN PLUMBING DESIGN CERTIFICATE PROGRAM AND HAS DEMONSTRATED A HIGH LEVEL OF COMPETENCE AND KNOWLEDGE IN GREEN PLUMBING THEORY AND CONCEPTS.

IAPMO

ASPE

IAPMO GREEN PLUMBERS TRAINING



(Source: https://www.aspe.org/education-credentialing/gpd/)

5. Sustainable practices

- LEED Green Building Rating System
  - Evaluates & recognizes performance in accepted green design categories, including:
    - Sustainable sites
    - Water efficiency
    - Energy and atmosphere
    - Materials and resources
    - Indoor environmental quality
    - Innovation credits
  - Website: http://www.usgbc.org/leed

Different versions of LEED NC: v.1.0, v.2, v.2.1, v.3, v.4

Plumbing related credit points in LEED v4.1 Building Design +Construction

Sustainable Site (SS): - Rainwater Management **Water Efficiency (WE):** - Outdoor Water Use Reduction - Indoor Water Use Reduction - Building-Level Water Metering - Optimize Process Water Use - Water Metering	**Energy and Atmosphere (EA):** - Commissioning and Verification - Renewable Energy **Materials and Resources (MR):** - Environmental Product Declarations - Sourcing of Raw Materials - Material Ingredients & Recycled Content **Indoor Environmental Quality (EQ):** - Low Emitting Materials

LEED v4.1

(Source: https://www.usgbc.org/leed/v41)

5. Sustainable practices

- The BEAM Plus Family
  - https://www.hkgbc.org.hk/eng/beam-plus/introduction/

- Neighbourhood (ND): Masterplanning stage of building development projects

- New Buildings (NB): New building projects and major renovation/alteration works on existing buildings

- Existing Buildings (EB): Operation and maintenance performance of existing buildings

- Interiors (BI): Fit-out works of premises
- Data centres and existing schools

Development of BEAM Plus in Hong Kong

Strong link to government policy and requirements (e.g. Climate Action Plan HK2030+ and Energy Saving Plan)

(Source: HKGBC)

Plumbing related credit points in BEAM Plus v2.0 New Building

Integrated Design and Construction Management (IDCM):
- IDCM 1 Sustainability Champions Design
- IDCM 17 Design for Engagement & Education on Green Buildings

Sustainable Site (SS):
- SS P1 Minimum Landscaping Requirements
- SS 11 Stormwater Management

Materials and Waste (MW):
- MW 4 Design for Durability & Resilience
- MW 6 Recycled Materials
- MW 8 Regional Materials
- MW 9 Use of Certified Green Products

Energy Use (EU):
- EU 5 Renewable & Alternative Energy Systems

Water Use (WU):
- WU P1 Minimum Water Saving Performance
- WU 1 Annual Water Use
- WU 2 Water Efficient Irrigation
- WU 3 Water Efficient Appliances
- WU 4 Water Leakage Detection
- WU 5 Twin Tank System
- WU 6 Cooling Tower Water
- WU 7 Effluent Discharge to Foul Sewers
- WU 8 Water Harvesting & Recycling

Health and Wellbeing (HWB):
- HWB 8 Indoor Air Quality
- HWB 12 Biological Contaminations

Innovations and Additions (IA)

(Source: https://www.hkgbc.org.hk/eng/beam-plus/file/BEAMPlus_New_Buildings_v2_0.pdf)

5. Sustainable practices

- Sustainable landscape:
  - Designed to be both attractive & in balance with the local climate & environment and requires minimal resource inputs, e.g. fertilizer, pesticides, gasoline, time, & water
  - The design must be functional, cost-efficient, visually pleasing, environmentally friendly & maintainable
  - Preserve limited & costly resources, reduce waste and prevent air, water & soil pollution

5. Sustainable practices

- Components of sustainable landscaping:
  - Compost, fertilization, grass cycling, pest control measures that avoid or minimize the use of chemicals
  - Integrated pest management
  - Using the right plant in the right place
  - Appropriate use of turf
  - Irrigation efficiency
  - Xeriscaping or water-wise gardening

10 principles of sustainable landscape construction

1. Keep sites healthy
2. Heal injured sites
3. Favour living, flexible materials
4. Respect the waters of life
5. Pave less
6. Consider the origin and fate of materials
7. Know the costs of energy over time
8. Celebrate light, respect darkness
9. Quietly defend silence
10. Maintain to sustain

(Source: Salat, S. (ed.), 2006. *The Sustainable Design Handbook: China: High Environmental Quality Cities and Buildings*, CSTB, Cedex, France)

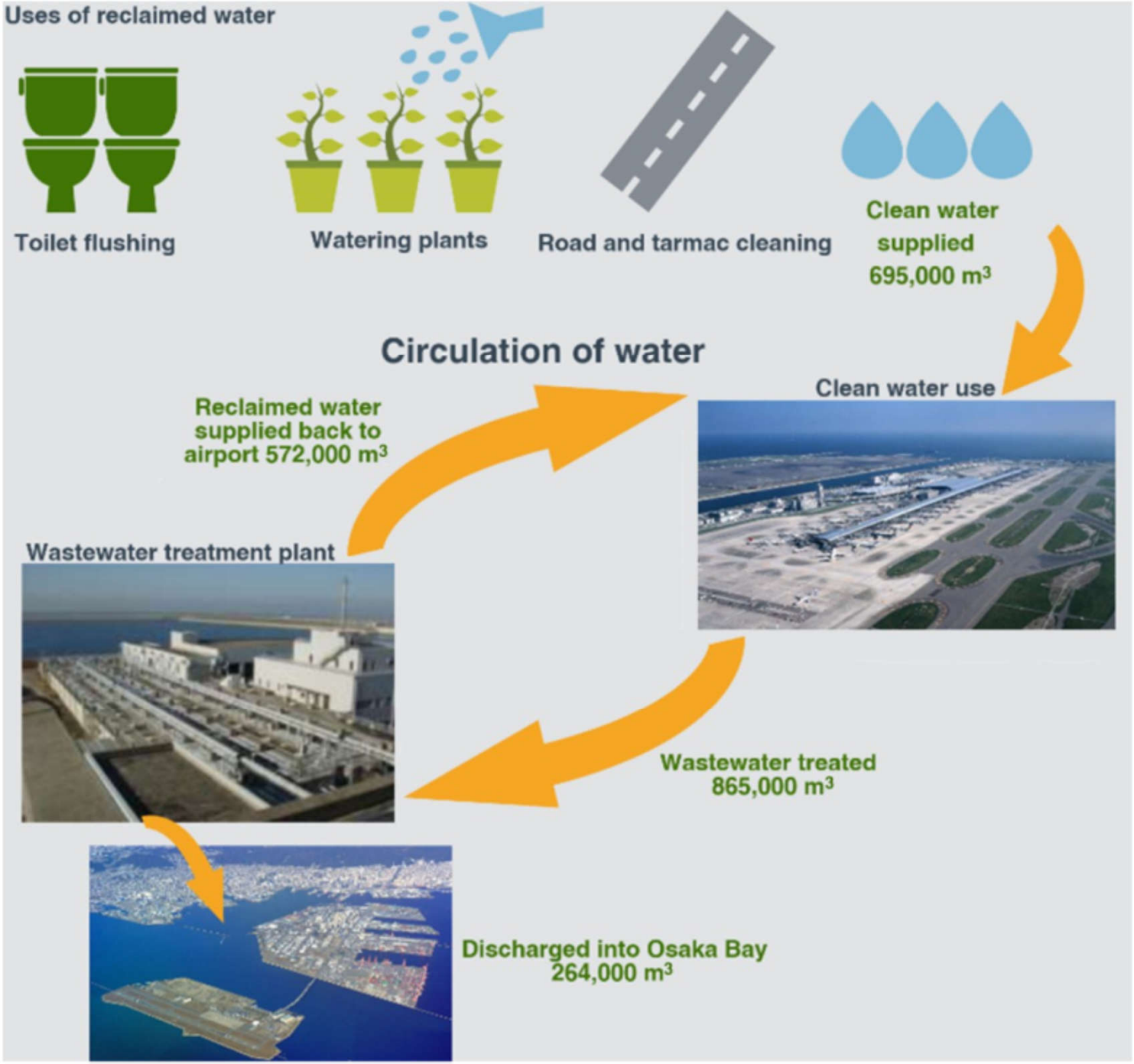
5. Sustainable practices

- Environmental management of the water cycle
  - Aims: reduce water consumption, avoid potential pollution & flood risks
- Recommended planning strategies:
  - Retention: control & manage stormwater drainage
  - Infiltration: percolation of rainwater into the soil to maintain the water cycle
  - Treatment: recuperate runoff water from risk surfaces (car parks, circulation areas, etc.) & treat it prior to discharge

5. Sustainable practices

- Manage the water cycle: good practices
  - Water management & landscaping
    - e.g. residential housing with water scene
  - Respect groundwater tables & storm drainage
    - e.g. minimise the extent of impervious surfaces
  - Rainwater recuperation (and reuse)
  - Rainwater management using valleys, percolation wells, roadways & roofs
  - Planted (green) roofs

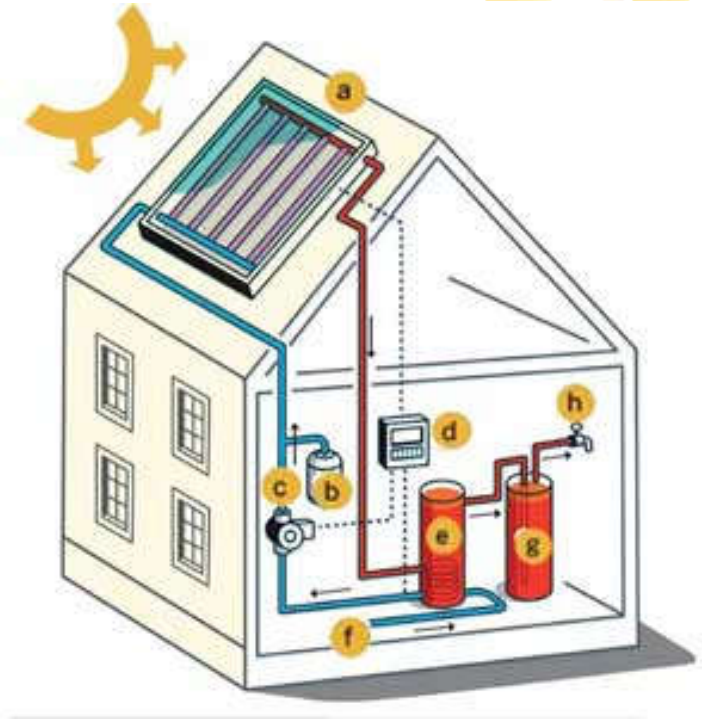
Circulation of water resources at Kansai International Airport



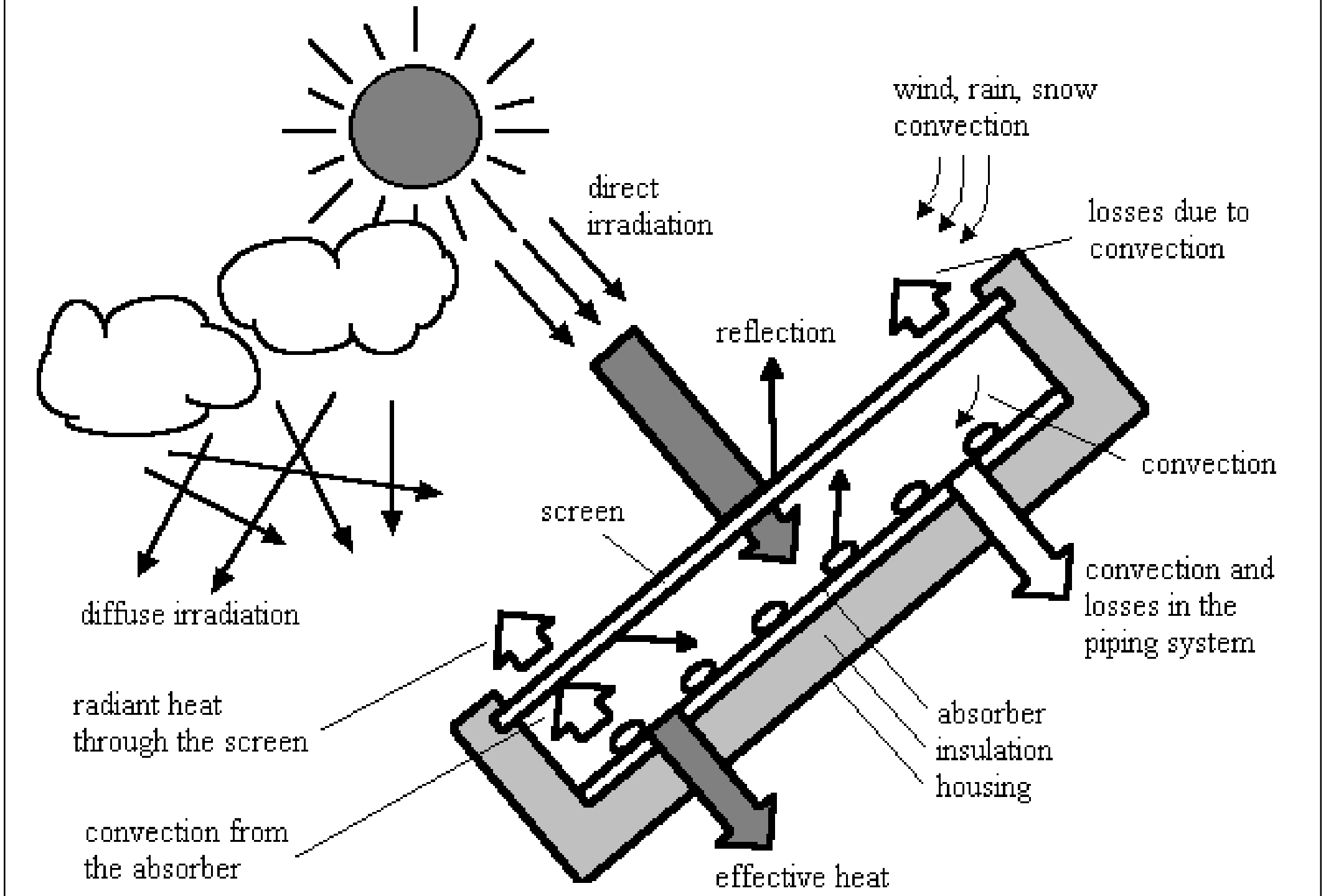
(Source: Baxter G., Srisaeng P. & Wild G., 2018. An assessment of sustainable airport water management: The case of Osaka's Kansai International Airport, Infrastructures, 3 (4) 54. http://dx.doi.org/10.3390/infrastructures3040054)

5. Sustainable practices

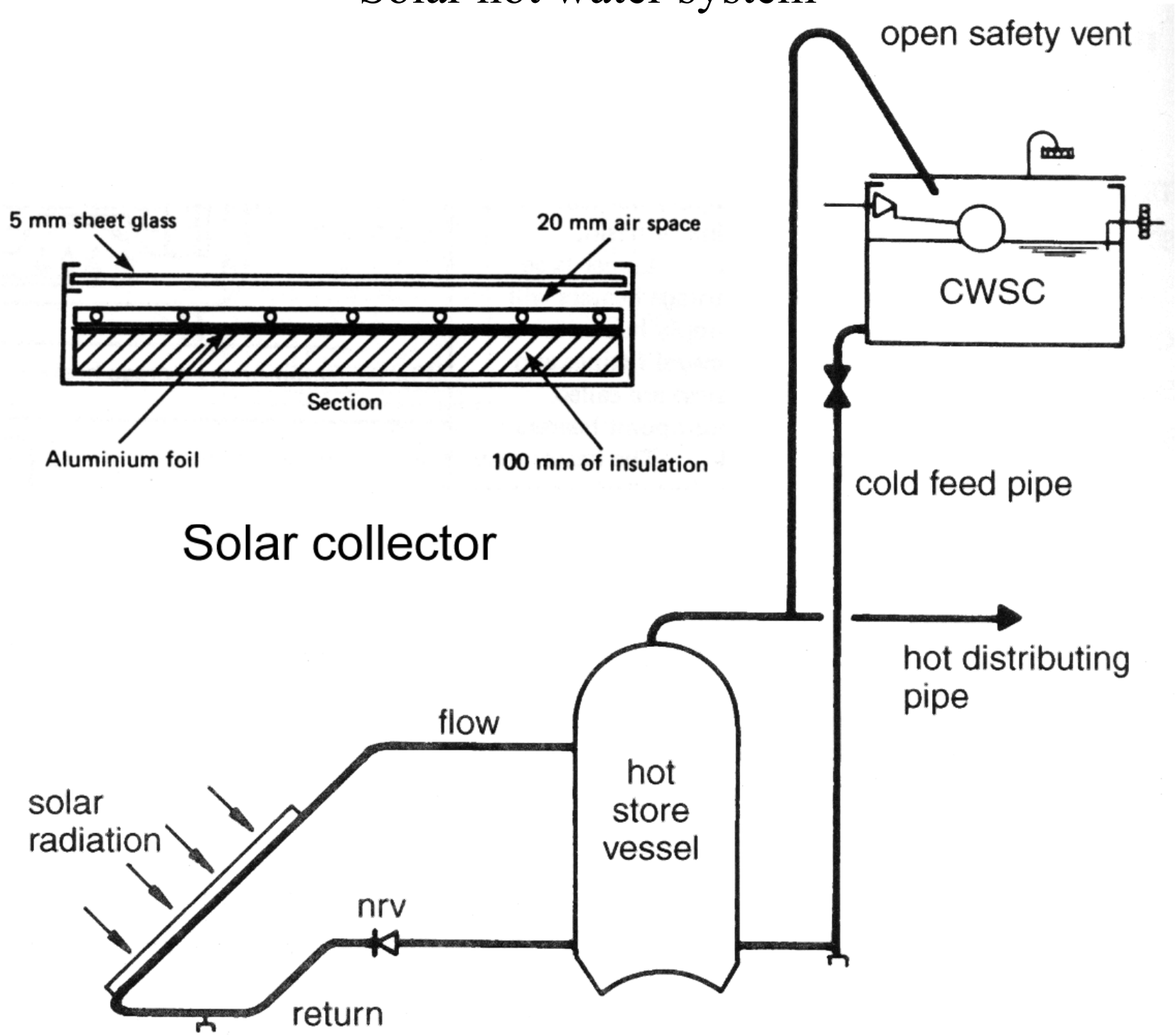
- Solar water heating
  - ‘Renewable’ or green energy
  - Simple system (e.g. domestic):
    - Solar collector + direct feed gravity
- Types of solar collectors:
  - Formed plastic
  - Flat plate
  - Evacuated tube (heat pipe)
- Supplemented by gas/electric heating



Heat transfer processes at a flat-plate solar collector



Solar hot water system



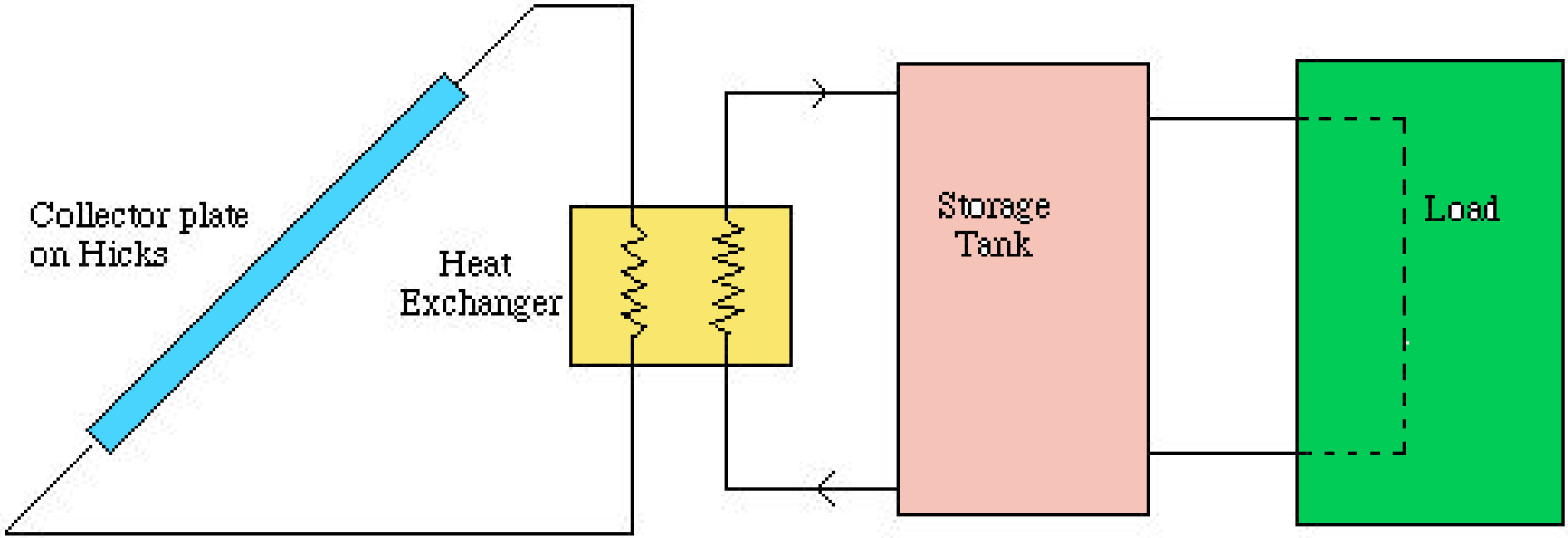
(Source: Garrett, R. H., 2008. *Hot and Cold Water Supply*)

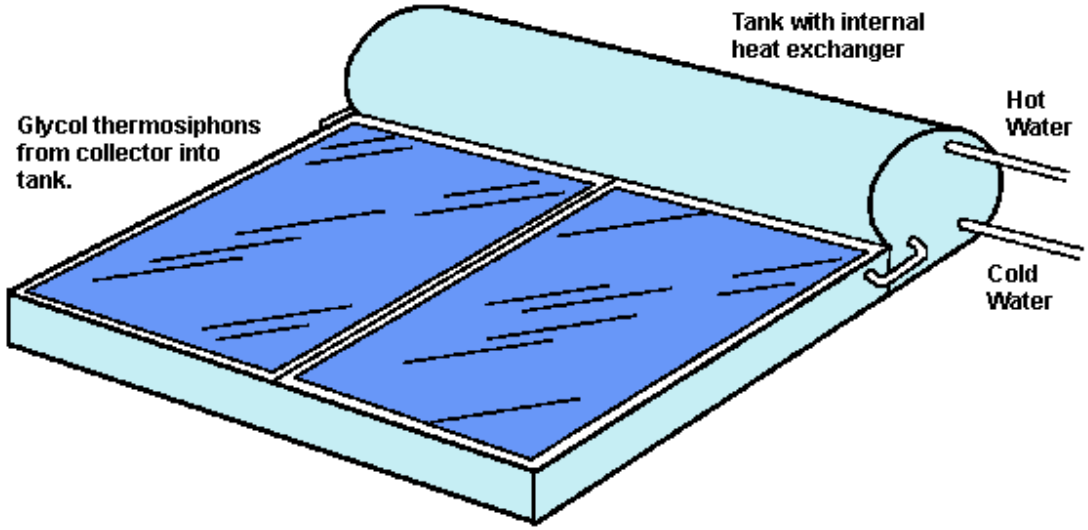
Solar thermal systems in Hong Kong

Solar heating for a swimming pool complex in Kwai Chung (313 sq.m solar collectors)

Solar hot water system at Sheung Shui Slaughter House (882 sq.m solar collectors)

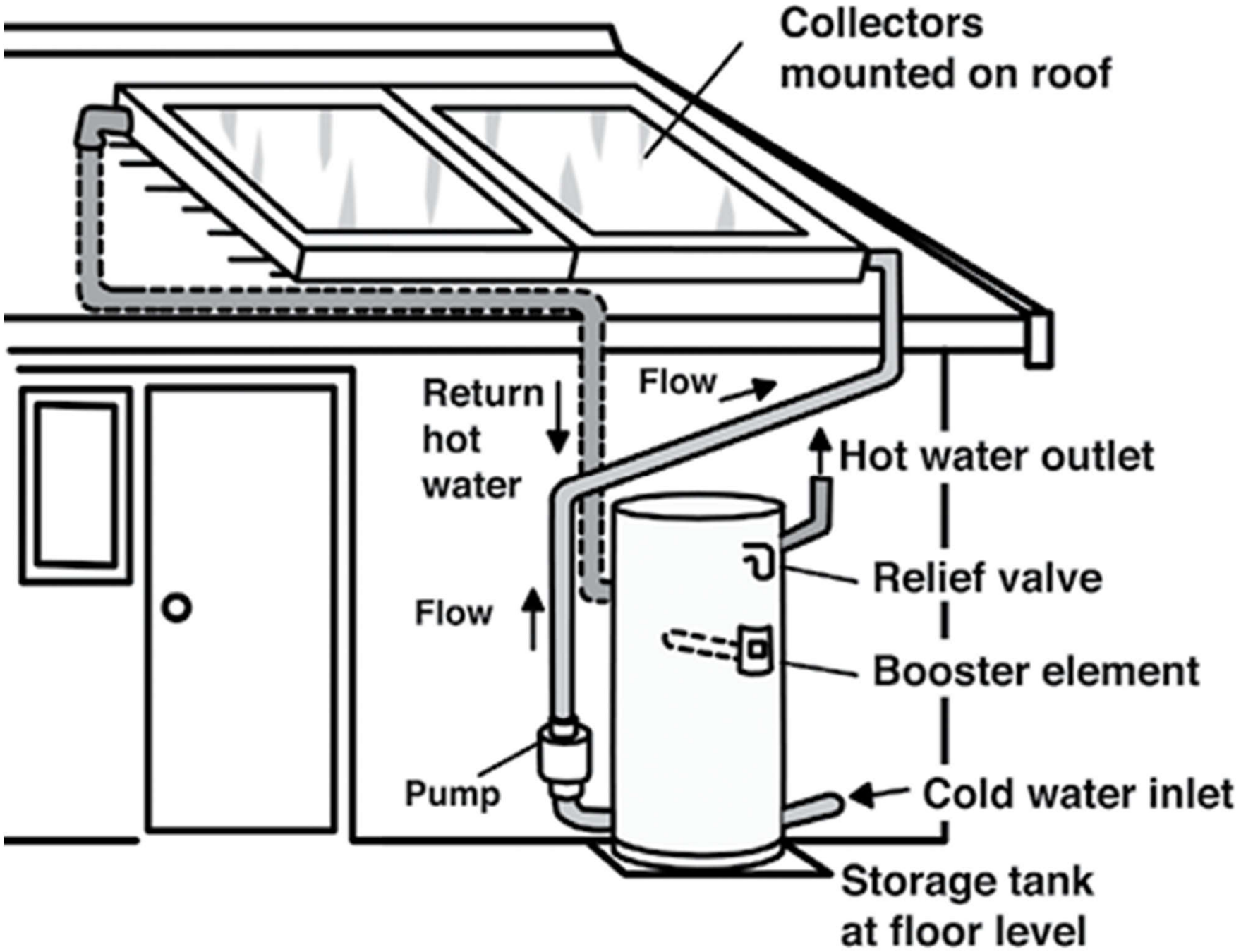
Solar hot water systems





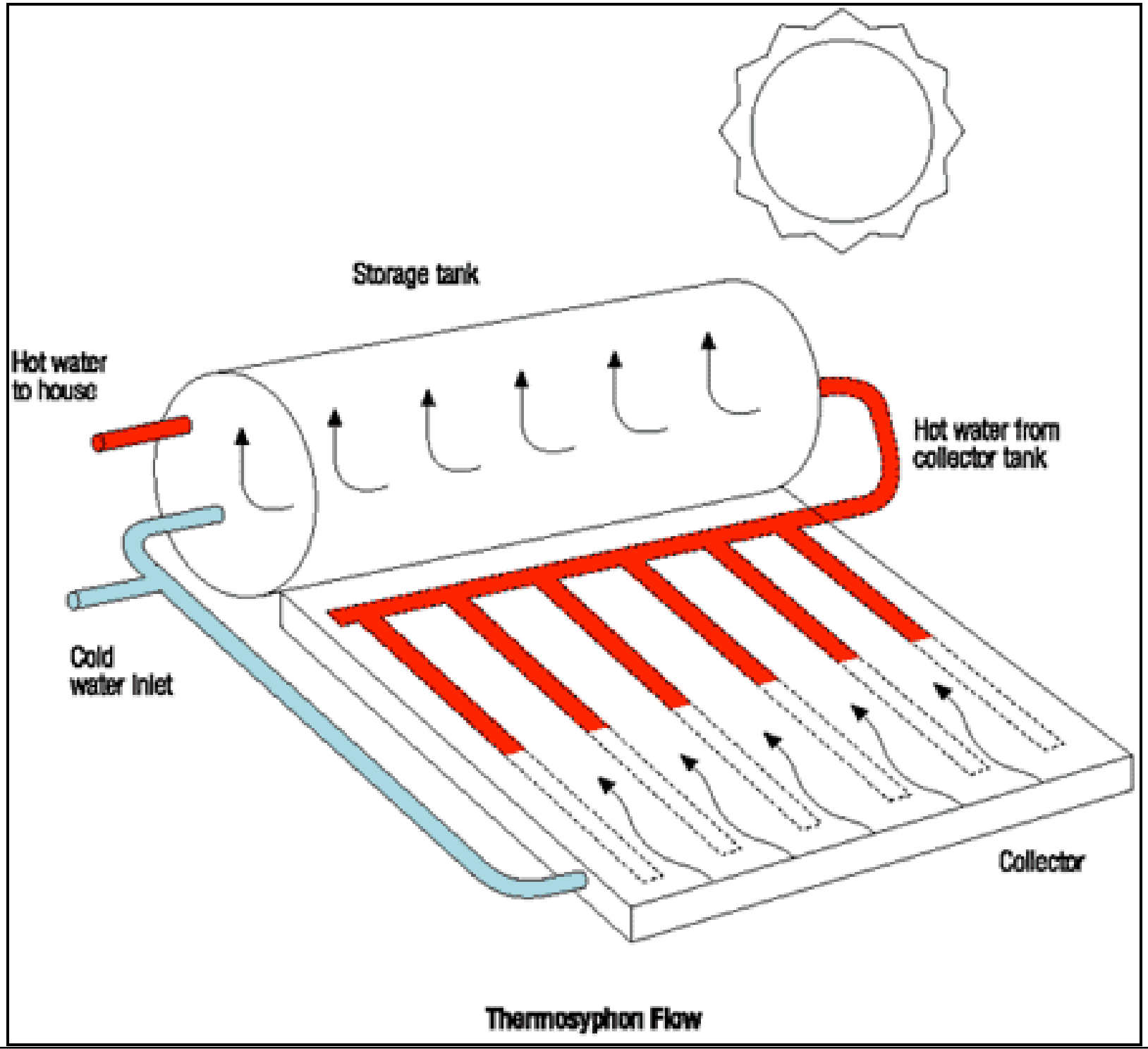
Simple domestic system
(with integral storage tank)

Active (or pumped) solar hot water system

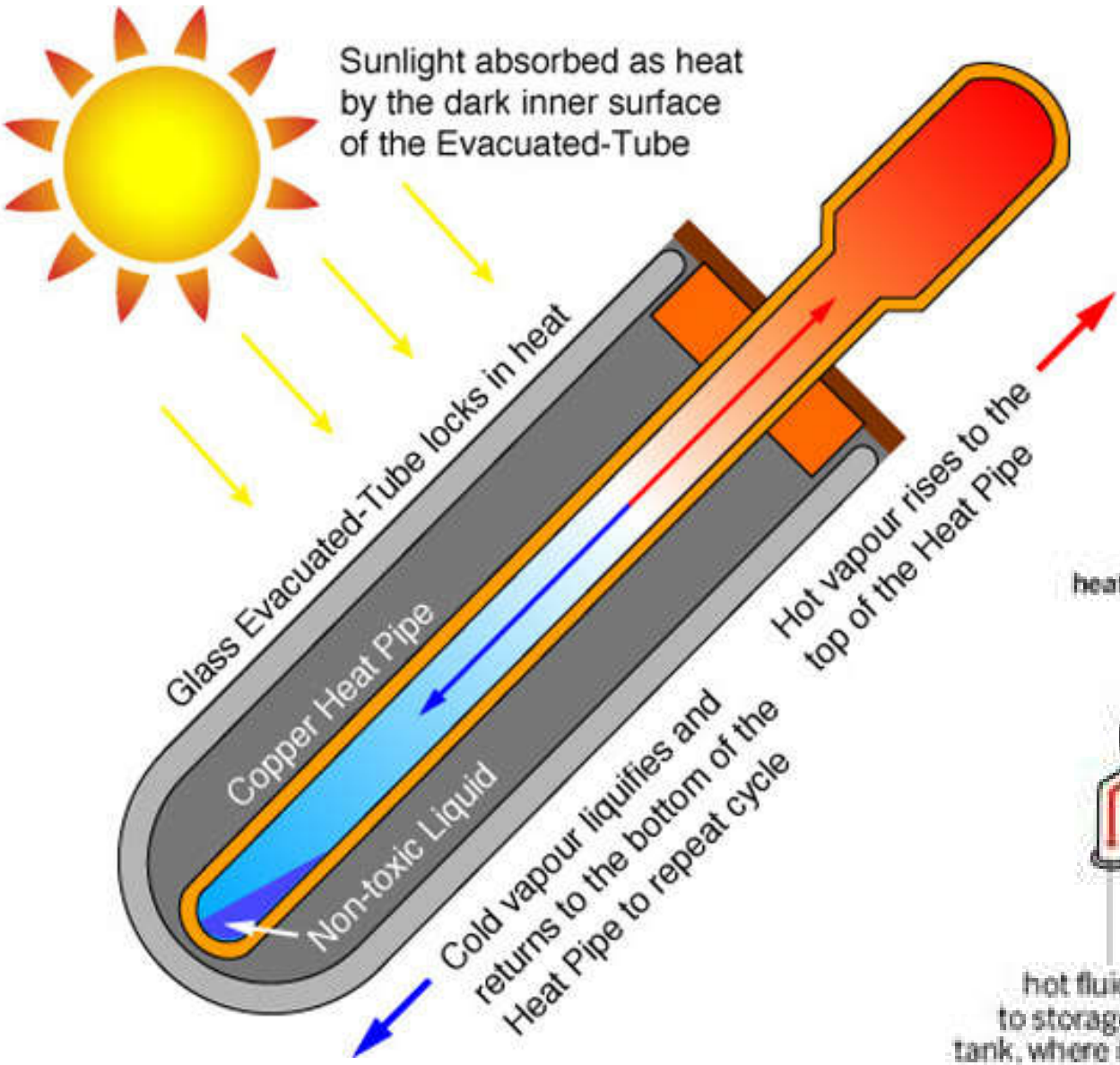


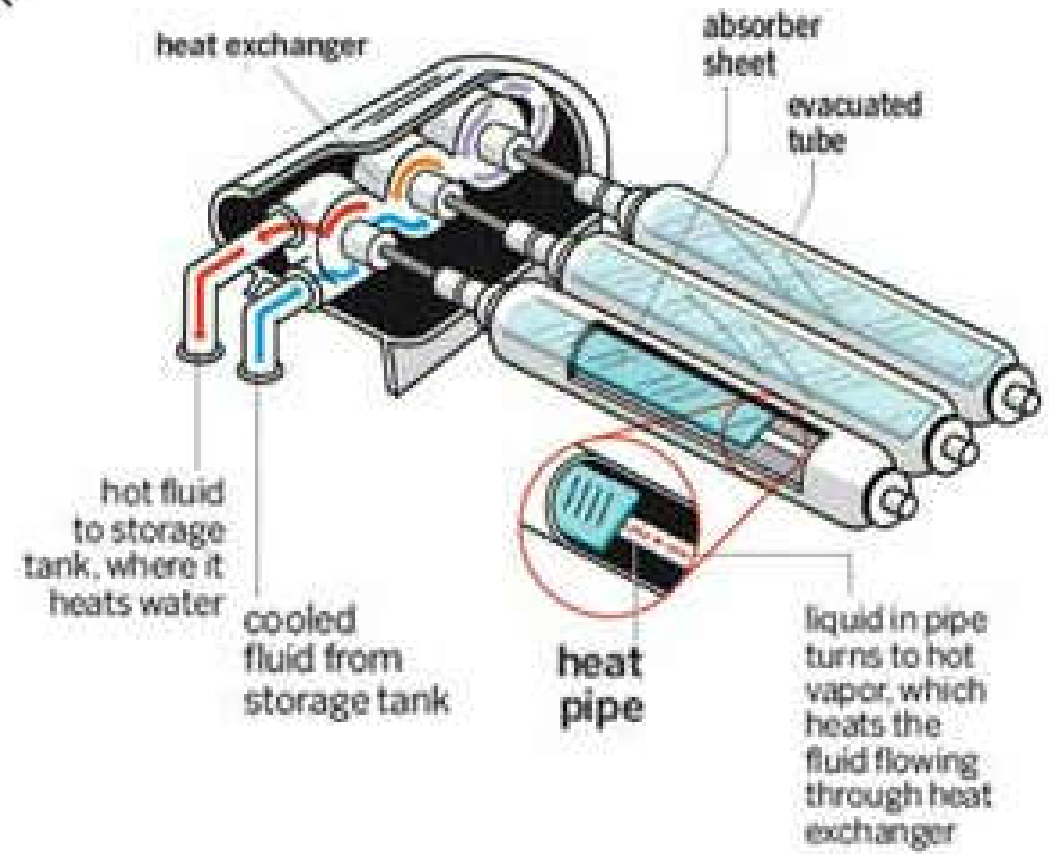
(Source: https://www.yourhome.gov.au/energy/hot-water-service)

Solar collector with thermosyphon flow



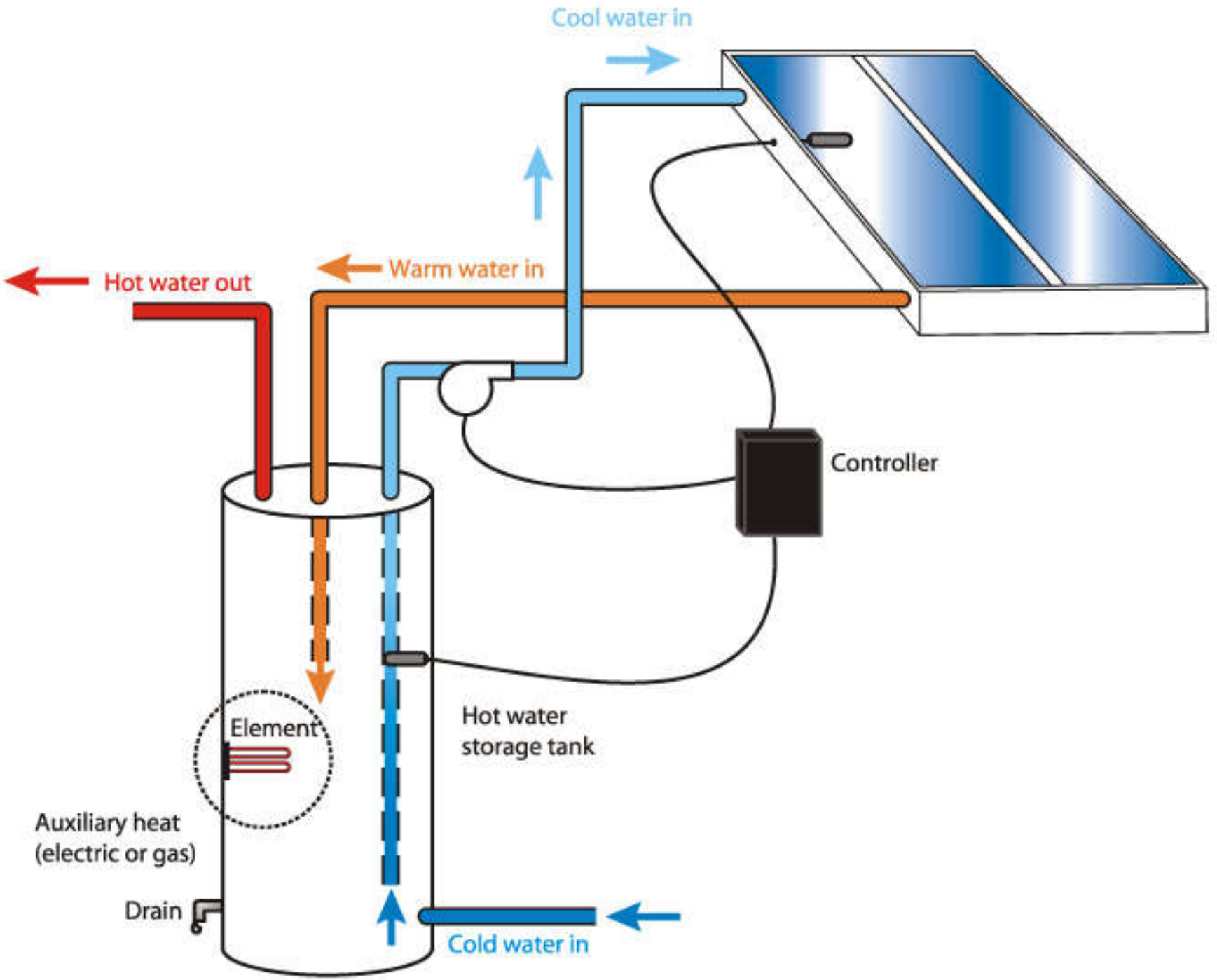
Heat pipe evacuated-tube solar collector





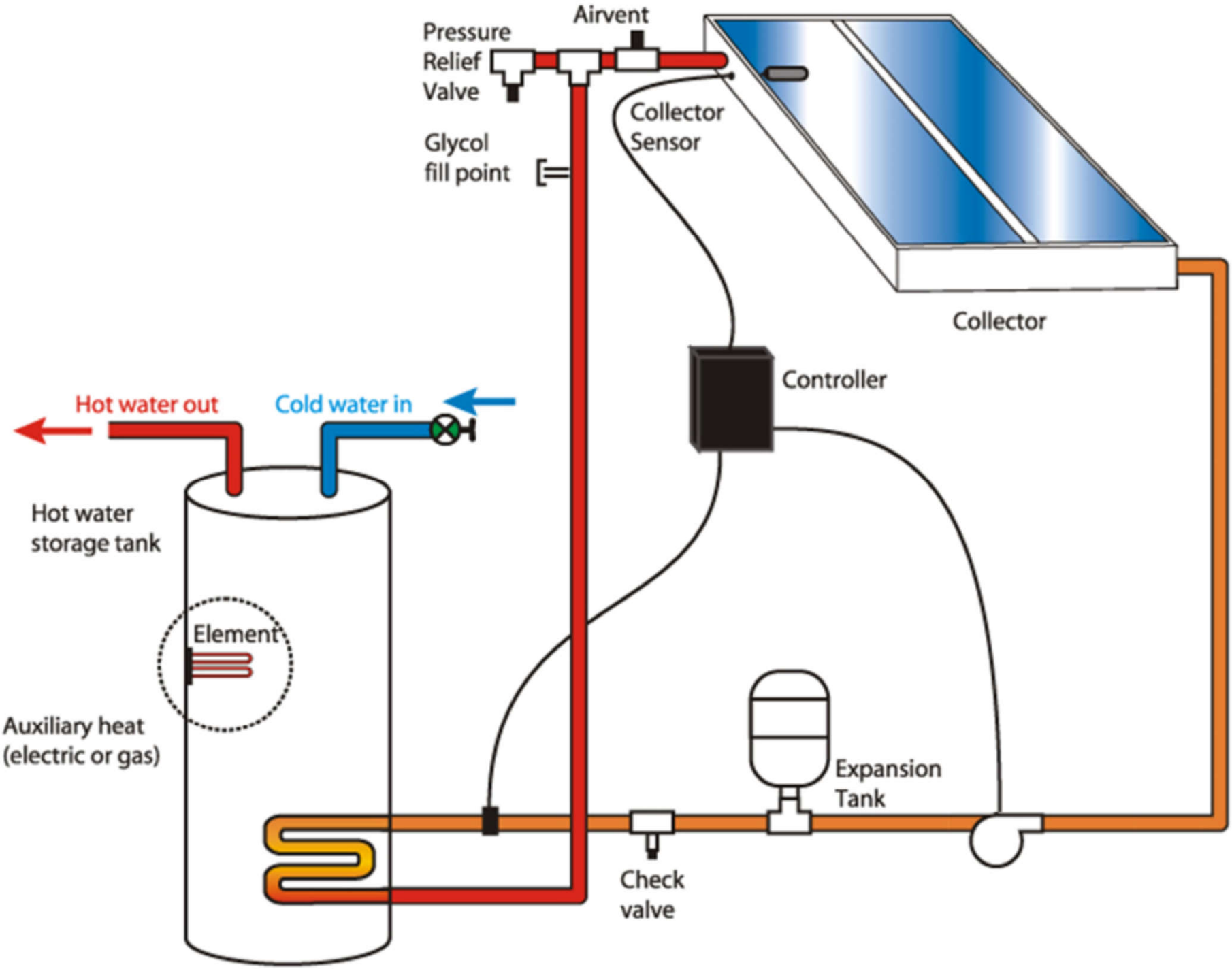
Evacuated-tube solar hot water system

Direct type (open-loop) solar hot water heating system



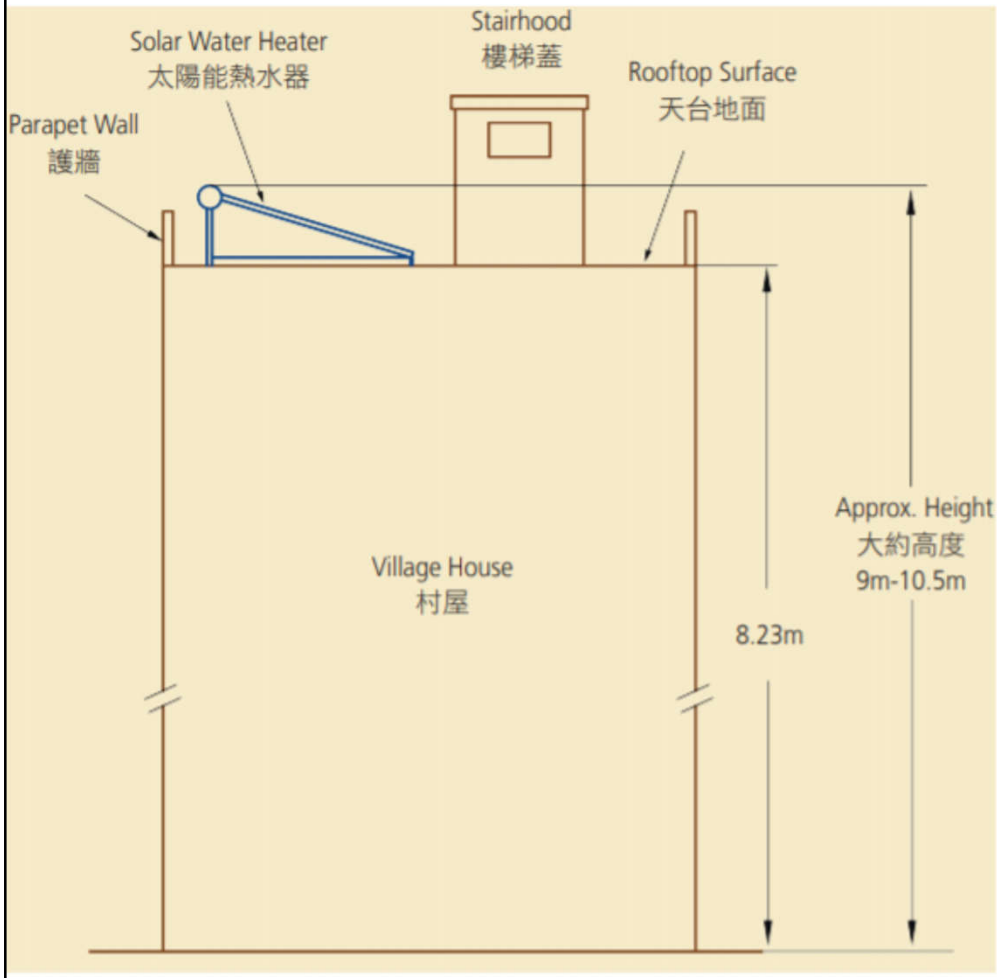
(Source: https://re.emsd.gov.hk/english/solar/solar_wh/Common_Types_of_Solar_Water_Heating_System.html)

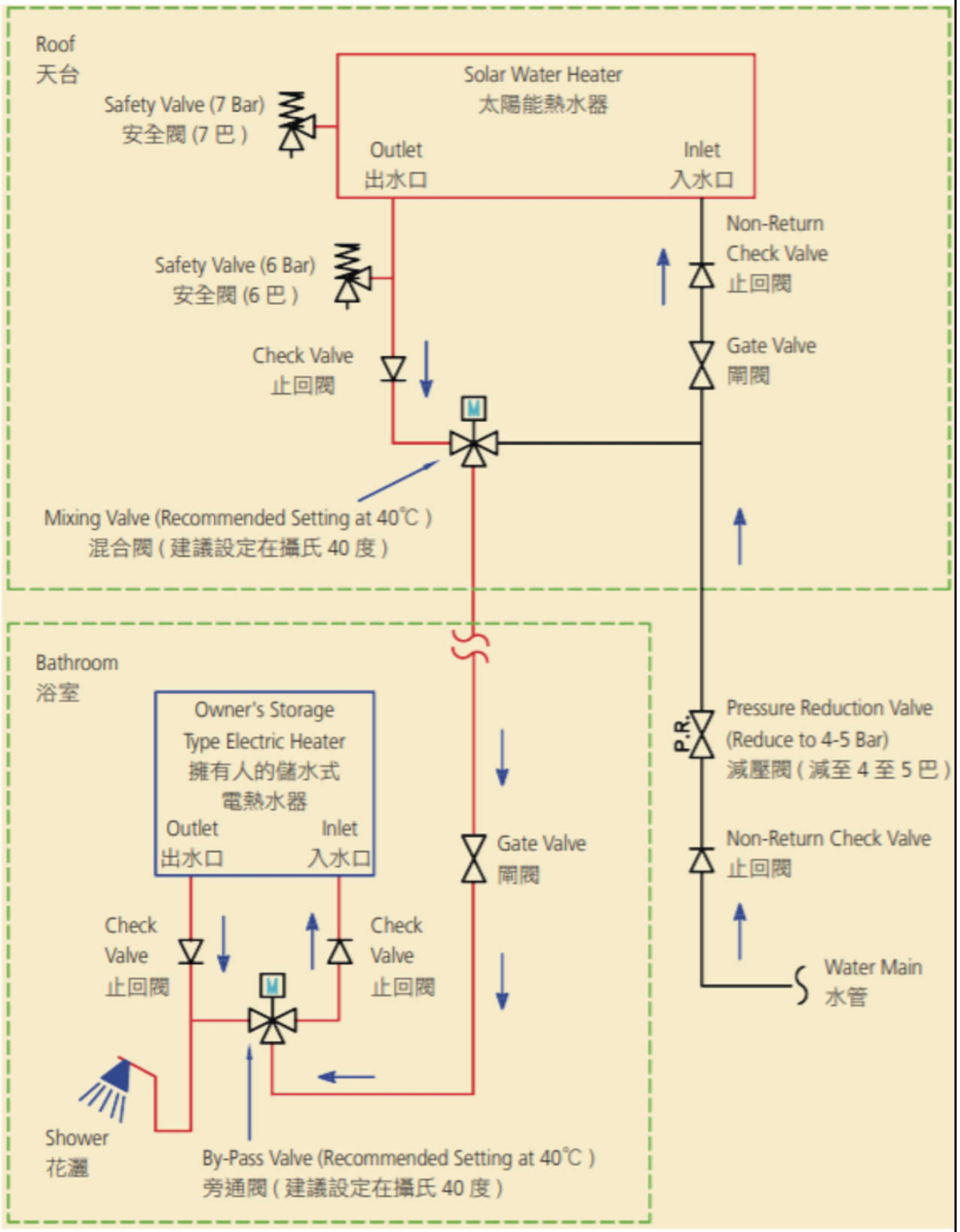
Indirect type (closed-loop) solar hot water heating system (freeze protection)



(Source: https://re.emsd.gov.hk/english/solar/solar_wh/Common_Types_of_Solar_Water_Heating_System.html)

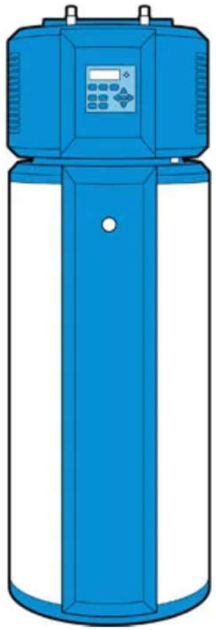
Household-scale solar water heating system at village houses





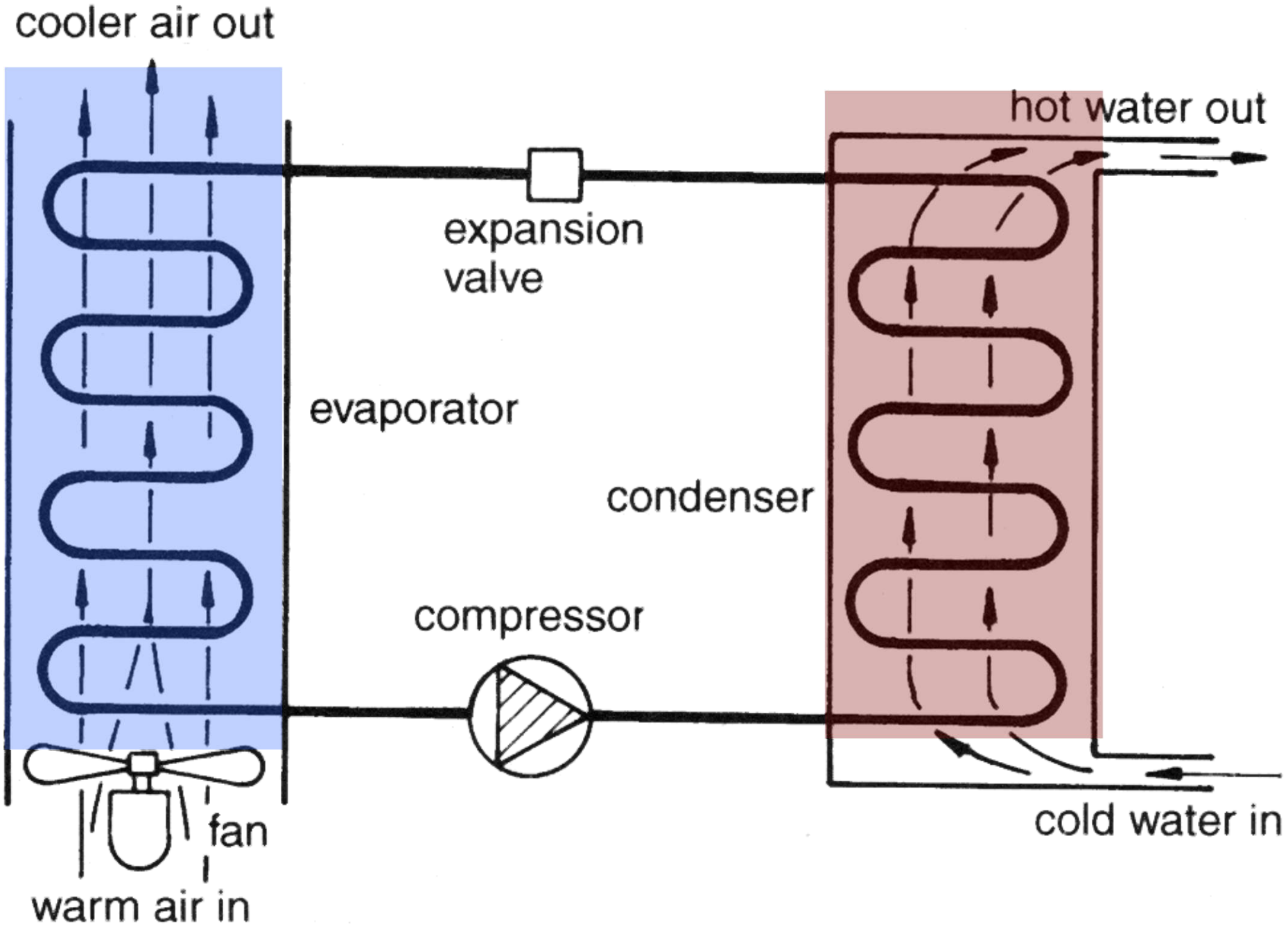
(Source: https://www.emsd.gov.hk/filemanager/en/content_299/Guidance_Notes-solar_water_heating_system.pdf)

5. Sustainable practices



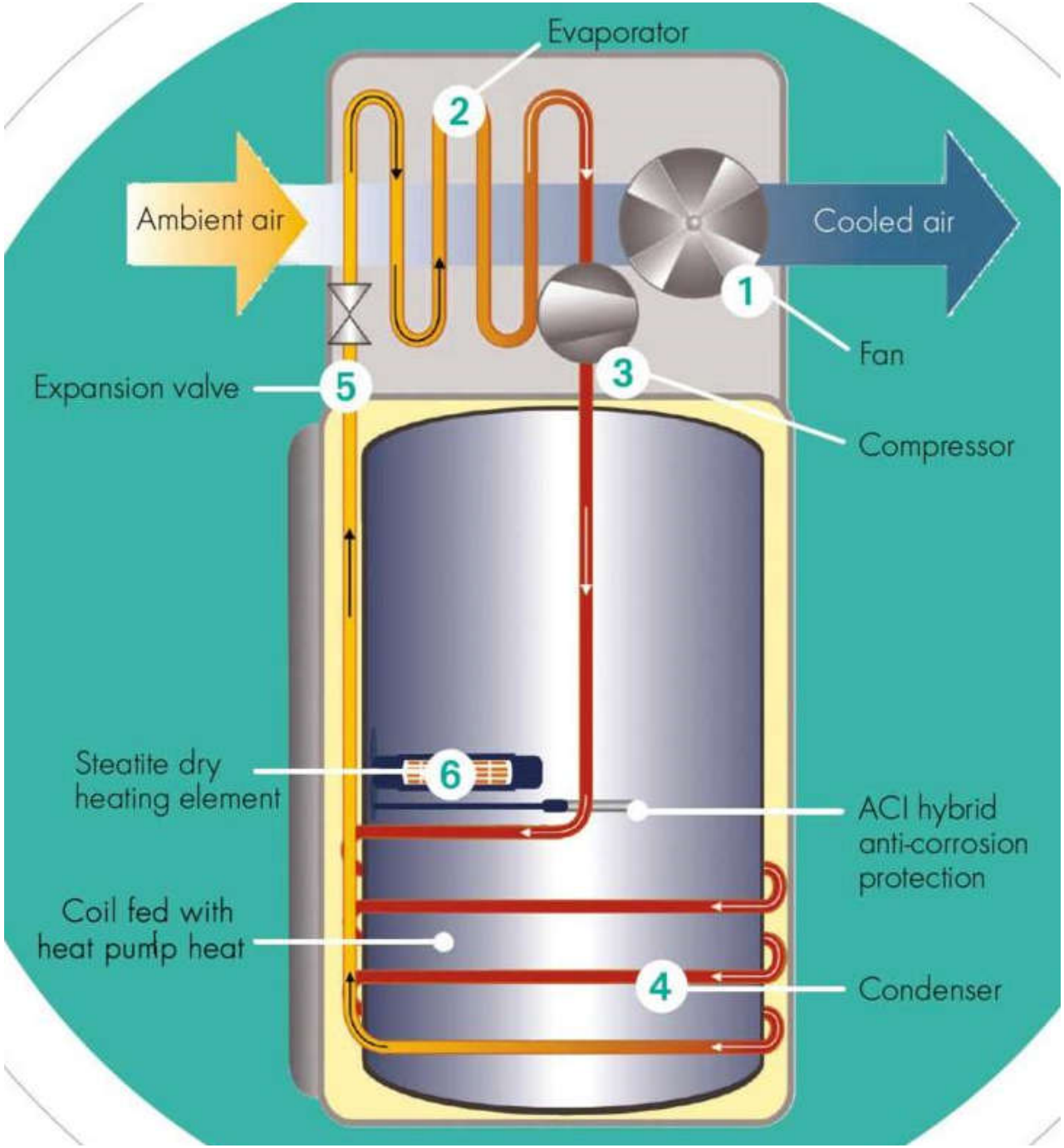
- Heat pump water heaters (HPWH)
  - An effective tool to produce hot water
  - Extract energy from ground, water, or ambient air
  - Typical applications:
    - To preheat conventional hot water systems
    - To augment existing systems
    - To supply full hot water
  - Reverse of the normal refrigeration cycle

Basic principles of heat pump



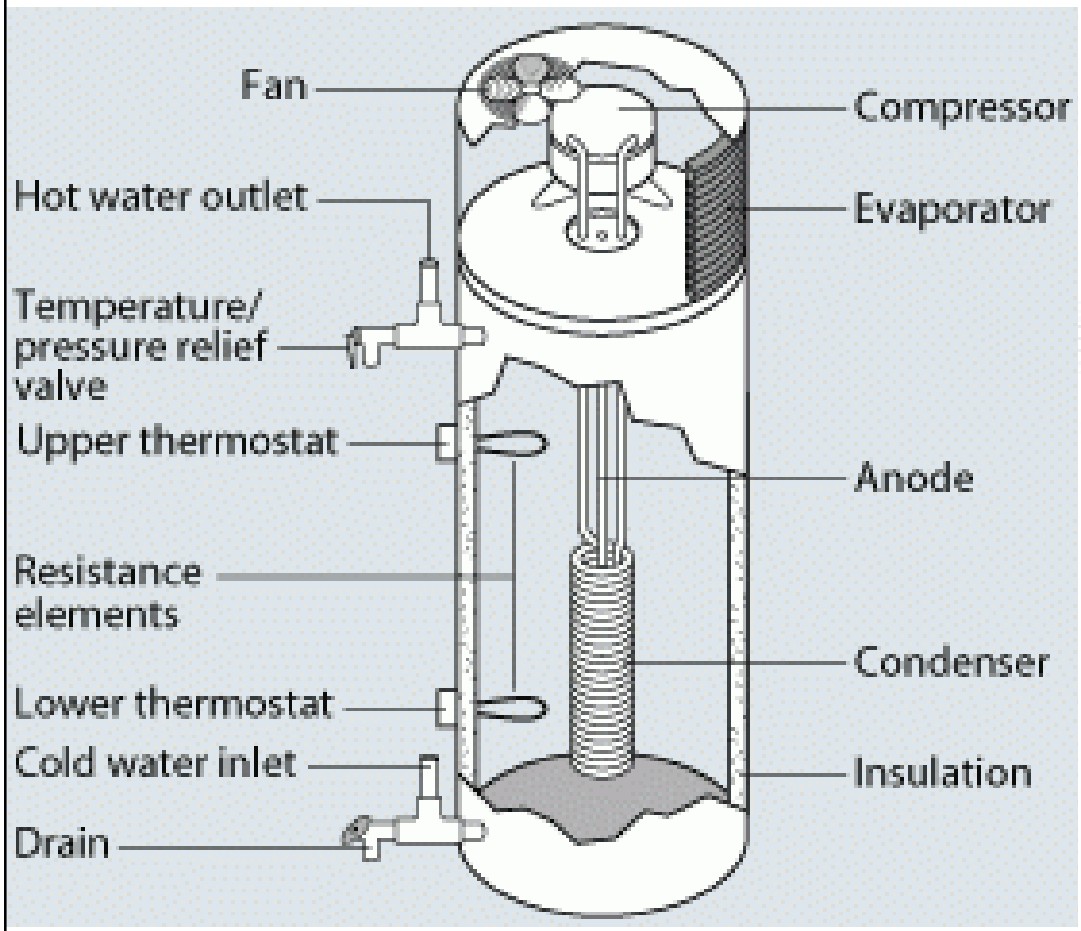
(Source: Garrett, R. H., 2008. *Hot and Cold Water Supply*)

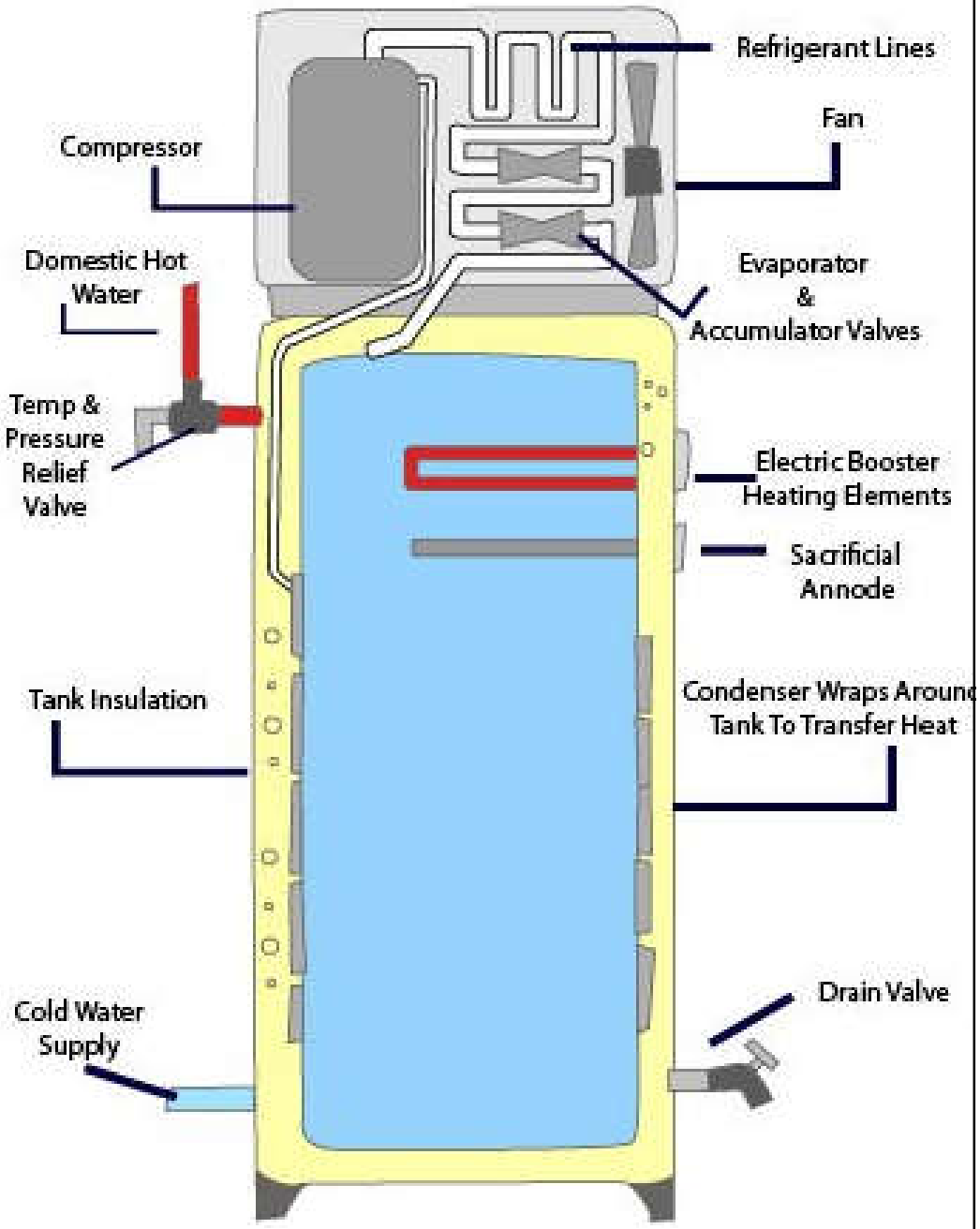
Working principle of heat pump water heater



(Source: https://www.atlantic-comfort.com/How-to-choose/Choosing-your-water-heater/Water-heating-technologies/Heat-pump-water-heaters-working-principle)

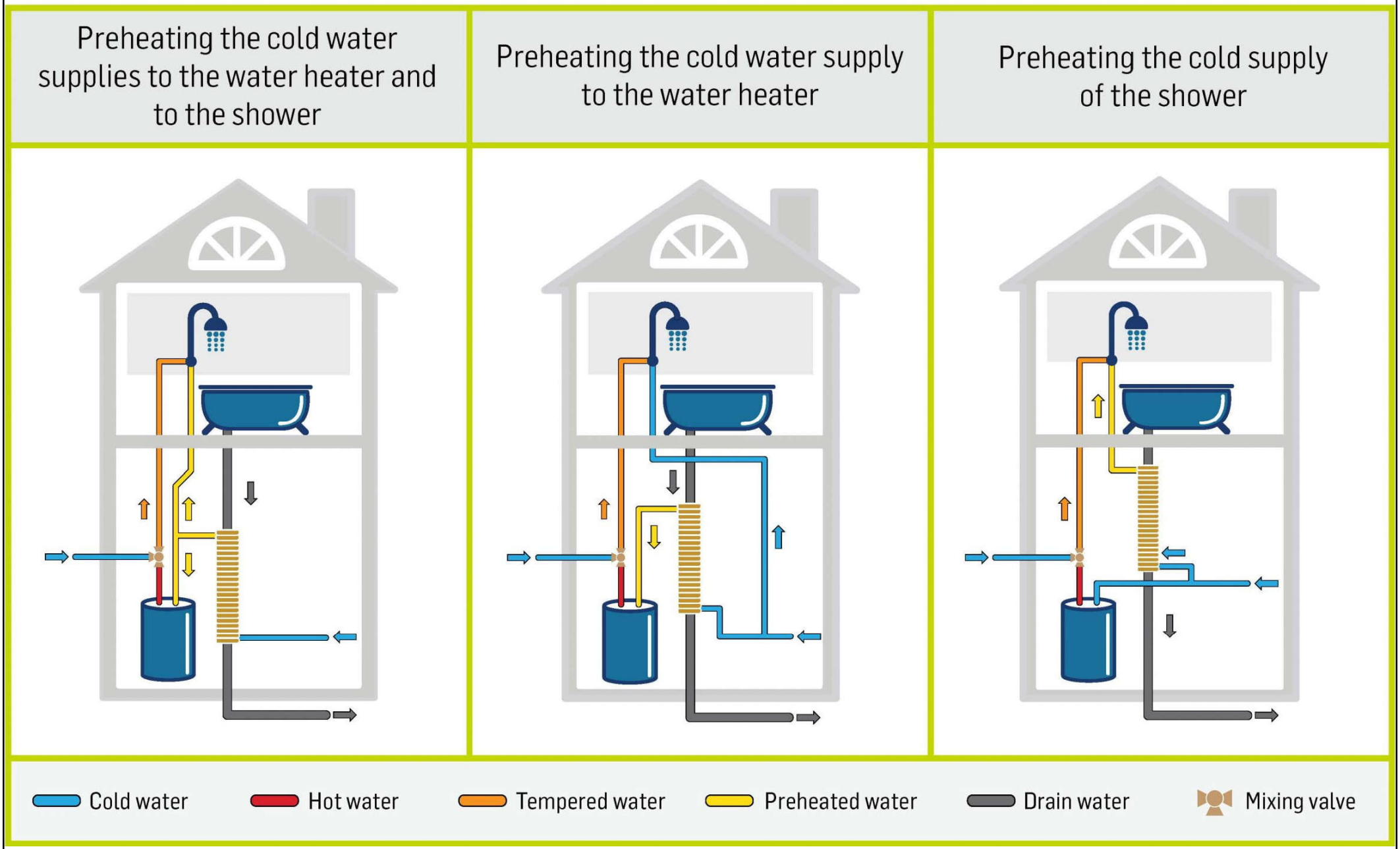
Heat pump water heaters





(Image sources: https://www.energy.gov/energysaver/water-heating/heat-pump-water-heaters; https://cdn2.hubspot.net/hubfs/91341/waterHeaterModals/waterHeater002a.html)

Drain water heat recovery (for preheating the cold water)

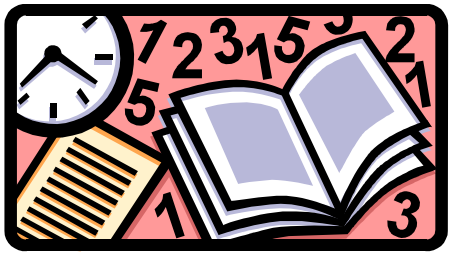


(Source: https://zeroenergyproject.com/product-category/heat-recovery/)

6. Conclusions

- Sustainable plumbing measures:
  - Rainwater harvesting & greywater reuse
  - Efficient plumbing fixtures
  - Plumbing materials
  - Holistic design of water heating & distribution
  - Proper installation techniques
  - Green cleaning practices
  - Enhanced durability
  - Education & awareness

Useful references



- Adeyeye K. (ed.), 2014. *Water Efficiency in Buildings: Theory and Practice*, Wiley-Blackwell, Chichester, West Sussex, United Kingdom & Malden, MA.
- BuildingGreen, 2015. *BuildingGreen's Guide to Green Plumbing Products*, BuildingGreen, Inc., Brattleboro, VT. https://www.buildinggreen.com/sites/default/files/ebn/EBN_24-9.pdf
- CIBSE, 2014. *Public Health and Plumbing Engineering*, CIBSE Guide G, Chartered Institution of Building Services Engineers (CIBSE), London.
- IAPMO, 2012. *Green Plumbers Reference Manual*, First Edition, International Association of Plumbing and Mechanical Officials (IAPMO). https://www.amazon.com/GreenPlumbers-Reference-International-Association-Mechanical/dp/1938936345
- IOP, 2002. *Plumbing Engineering Services Design Guide*, [New ed.], Institute of Plumbing (IOP), Hornchurch, Essex, UK.