

H2E Enterprise resource series · 2nd edition

Climate-Smart Sanitation

A practitioner's guide from the field, for donors, NGOs, water utilities and municipalities



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Contents

Executive summary

1 Sanitation and climate: a two-way problem

2 Designing for climate resilience

3 Counting emissions

4 Market-Based WASH Products: Toilet-in-a-Box · Septic tank · Safe pit emptying · Biosand filter

5 DEWATS: Constructed wetland · Anaerobic baffled reactor

6 Resource Recovery: Co-composting · Biogas digester

7 Choosing the right option

8 From the field: two case studies

9 Financing and monitoring climate-smart sanitation

A Appendix: hygiene technologies

References

About this guide. H2E Enterprise designs sanitation, wastewater and resource recovery solutions and builds the local ecosystems that deliver them. This guide shows how each of our solutions copes with climate hazards and how much it emits, and helps decision-makers choose, finance and monitor climate-smart sanitation. It replaces the 1st edition (2024).

Executive summary

Climate change and sanitation are locked in a two-way relationship. Floods, droughts, heavy rain and heat damage toilets, tanks and treatment systems, spreading waste into homes and water sources. At the same time, waste decomposing without oxygen in pits, tanks and drains releases methane: in Kampala, sanitation was found to cause more than half of the city's greenhouse gas emissions.

Key messages

1. **Choose for the worst season.** The right option is the one that keeps working through the local flood, drought or cold season, can be maintained by local businesses, and never sends untreated waste into drains.
2. **Containment is where the emissions are.** A dry twin pit that is emptied emits about 22 kg CO₂e per person per year; a shared pit never emptied about 109; a pit in groundwater about 153.
3. **Treat what leaves the tank.** A constructed wetland after a septic tank cuts system emissions by about a third compared with an open drain, and protects drains and rivers.
4. **Capture the gas.** Anaerobic systems are among the highest emitters if they vent methane and among the lowest if they capture and burn it.
5. **Plan emptying and treatment from day one.** Without a service, every pit and tank eventually fails, under climate stress first.

How H2E solutions perform against climate hazards

Technology	Flooding	Heavy rain	Drought	Extreme heat	Cold	Power cuts
Toilet-in-a-Box	●	●	●	●	●	●
Septic tank	●	●	●	●	●	●
Safe pit emptying	●	●	●	●	●	●
Household water treatment: biosand filter	●	●	●	●	●	●
Constructed wetland	●	●	●	●	●	●
Anaerobic baffled reactor	●	●	●	●	●	●
Co-composting of faecal sludge and organic waste	●	●	●	●	●	●
Biogas digester	●	●	●	●	●	●

● Resilient ● Needs adaptation ● Vulnerable

1

Sanitation and climate: a two-way problem

Why climate change matters for sanitation, and why sanitation matters for climate change.

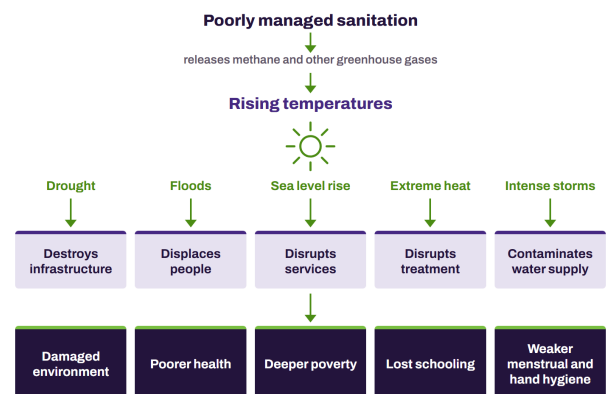
Climate damages sanitation

- **Floods** release pit and tank contents into homes, streets and water sources, and block emptying trucks.
- **Heavy rain** collapses unlined pits and overloads sewers and treatment systems.
- **Drought** leaves flush toilets without water, blocking pipes and tanks.
- **Heat and cold** change how fast waste breaks down and how treatment performs.
- **Displacement** pushes people into high-risk areas with little sanitation.

The result is more cholera, typhoid and diarrhoea, and costly rebuilding after each disaster.

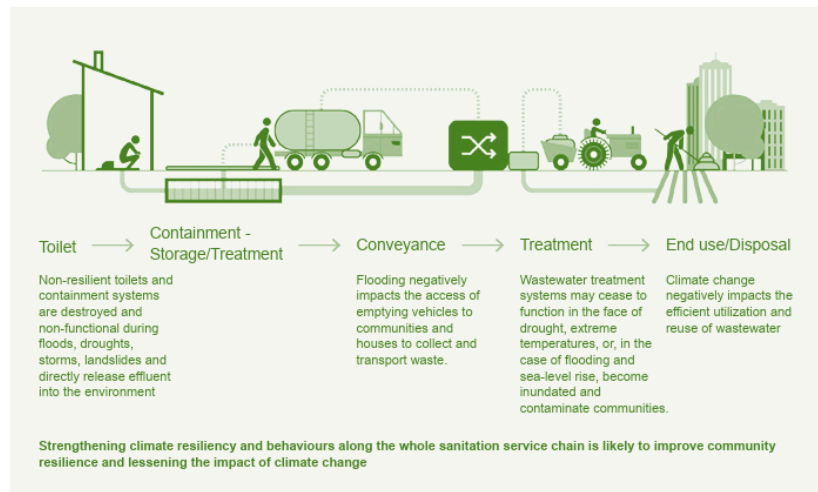
Sanitation drives climate change

When excreta breaks down without oxygen, in pits, septic tanks, drains and untreated sludge, it releases methane, a gas about 27 times more warming than CO₂ over 100 years. Energy for pumping and treatment and fuel for sludge trucks add more. A whole-city study of Kampala estimated about 189 kilotonnes of CO₂e a year from sanitation, over half the city's emissions, mostly from containment.



How poorly managed sanitation and climate change feed each other. Adapted from GWP and UNICEF, Climate-Resilient Sanitation in Practice.

Every step of the service chain is exposed



The sanitation service chain and the climate impacts at each step. Source: GWP and UNICEF.

Adaptation means keeping the service working when climate hazards hit: avoiding exposure, withstanding it, and recovering fast.

Mitigation means cutting the greenhouse gases released along the chain: mainly methane from containment and treatment, plus energy and transport.

2

Designing for climate resilience

A simple framework for programmes, and the design features that make sanitation hold up under climate stress.



Strategic framework for climate-resilient WASH. Source: GWP and UNICEF (2022).

Four steps for programmes

- 1. Understand the problem:** assess climate hazards, who and what is exposed, vulnerabilities and local capacity. Involve communities and utilities.
- 2. Identify and appraise options:** list responses to the known risks, favouring options that also cut emissions (Chapters 4 to 7).
- 3. Deliver solutions:** build climate features into policies, plans, training for artisans and masons, finance products and demand creation.
- 4. Monitor and move forward:** track whether systems keep working through extreme events and how emissions change (Chapter 9).

Seven groups of resilience design features

#	Feature group	What it means in practice
1	Avoid exposure	Site above flood levels; raise slabs, vents and manholes.
2	Withstand exposure	Lined, sealed pits and tanks that keep their shape in waterlogged soil.
3	Enable flexibility	Twin pits, bypasses and overflows that let the system keep running.
4	Contain failures	Sealed covers and non-return valves so a failure does not spread waste.
5	Limit the consequences of failure	Keep systems away from drinking-water sources.
6	Recover fast	Standard parts that local artisans can replace in days.
7	Benefits beyond resilience	Reuse of treated water, compost and biogas.

Feature groups based on the Institute for Sustainable Futures, University of Technology Sydney, ClimateFIRST How-to Guide.

How to read the hazard scorecards

Each technology profile in Chapters 4 to 6 rates six hazards (flooding, heavy rain, drought, extreme heat, cold and power cuts):

- **Resilient:** works as designed.
- **Needs adaptation:** works with the design response given.
- **Vulnerable:** high risk of failure or pollution unless redesigned.

3

Counting emissions

How much greenhouse gas each sanitation option produces, calculated the same way for every technology so they can be compared fairly.

Why it matters

Most sanitation emissions come from methane, released when excreta breaks down without oxygen in pits, tanks and drains. Methane traps about 27 times more heat than CO₂ over 100 years. In Kampala, a whole-city study found sanitation causes more than half of the city's greenhouse gas emissions, and most of it comes from **containment**: pits and tanks (Johnson et al., 2022). This makes sanitation design a climate decision, not just a health one.

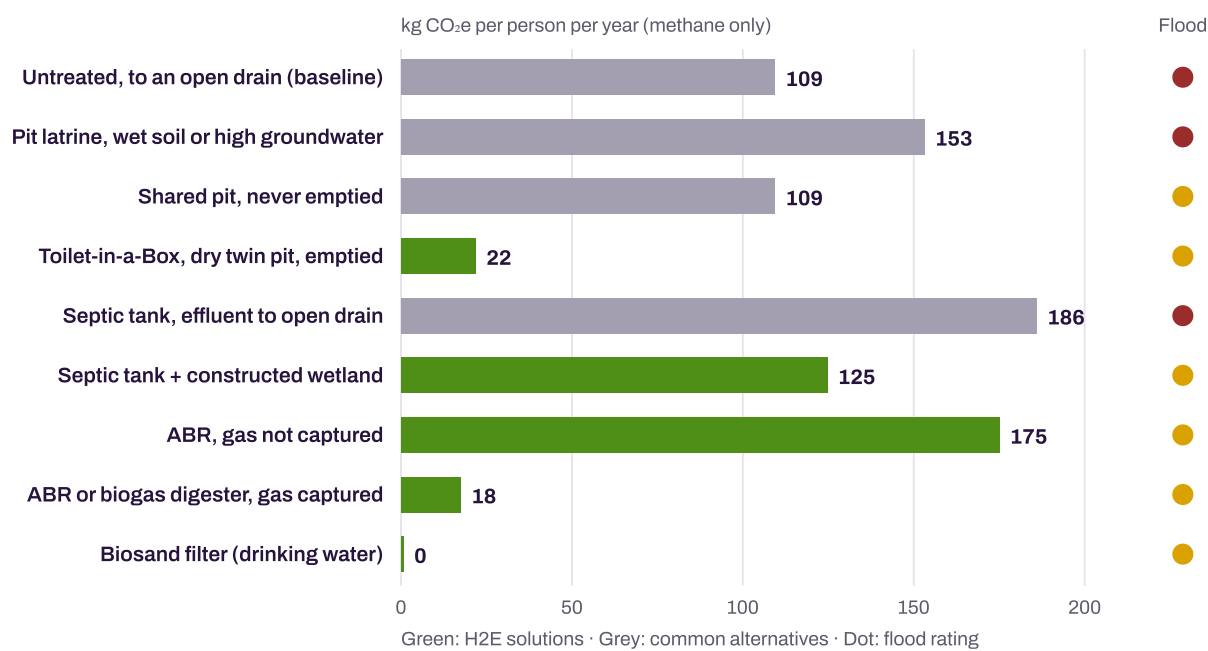
The method in one line

$$\text{Emissions} = \text{BOD per person} \times \text{maximum methane yield} \times \text{methane correction factor (MCF)} \times 27$$

The MCF is the key number: it describes how much of the waste breaks down without oxygen. A dry, shallow pit that is emptied regularly has an MCF of 0.1; a wet pit sitting in groundwater has 0.7; a sealed anaerobic reactor has 0.8. We use the IPCC Tier 1 defaults that governments use for national greenhouse gas inventories.

BOD produced per person	37 g/day = 13.5 kg/year (IPCC default for Africa)
Maximum methane yield (Bo)	0.6 kg CH ₄ per kg BOD (IPCC)
Global warming potential	Methane 27, nitrous oxide 273 (IPCC AR6, 100 years)
Methane correction factors (MCF)	Dry household pit or emptied pit 0.1 · shared pit 0.5 · wet pit or high groundwater 0.7 · septic tank 0.5 · stagnant open drain 0.5 · anaerobic reactor 0.8 · horizontal subsurface flow wetland 0.1
Septic tank BOD removal	30% (assumption); the rest flows on with the effluent
Gas capture in a digester or gas-tight ABR	90% captured and burned (assumption); 10% escapes
Not included	Nitrous oxide from excreta (small, highly uncertain), construction materials, transport, and avoided emissions from fuel savings

Results: kilograms of CO₂e per person per year



Option	kg CO ₂ e / person / yr	Basis
Untreated, to an open drain (baseline)	109	MCF 0.5
Pit latrine, wet soil or high groundwater	153	MCF 0.7
Shared pit, never emptied	109	MCF 0.5
Toilet-in-a-Box, dry twin pit, emptied	22	MCF 0.1
Septic tank, effluent to open drain	186	0.5 + 0.7 x 0.5
Septic tank + constructed wetland	125	0.5 + 0.7 x 0.1
ABR, gas not captured	175	MCF 0.8
ABR or biogas digester, gas captured	18	0.8 x 10% escaping
Biosand filter (drinking water)	0	no excreta

For reference: if all the BOD a person produces turned into methane, it would equal 219 kg CO₂e per year. Co-composting is measured per tonne of waste instead: about 174 kg CO₂e per tonne treated (IPCC defaults), far less than the same waste left to rot in pits or dumps.

What the numbers tell decision-makers

5×

Dry, emptied pits emit about five times less than shared pits that are never emptied, and seven times less than pits sitting in groundwater. Toilet-in-a-Box twin pits, used in turn and emptied, are a low-emission option.

–33%

Treating septic effluent in a constructed wetland cuts the emissions of a septic system by about a third compared with letting the effluent run into an open drain, and also protects drains and rivers.

–90%

Capturing the gas changes everything for anaerobic systems. An ABR or digester that vents its methane is one of the highest emitters; one that captures and burns it, as cooking gas or flared, is one of the lowest.

0

Biosand filters have no direct emissions and avoid the firewood or charcoal used to boil drinking water; the size of that saving depends on local fuel use.

Five levers to cut sanitation emissions

1. **Keep pits dry and above groundwater:** raised, lined pits and twin pits.
2. **Empty regularly** and take sludge to treatment, not drains or fields.
3. **Never discharge untreated effluent** to open drains: follow septic tanks and ABRs with a wetland.
4. **Capture methane** wherever waste is digested on purpose: biogas, gas-tight ABRs.
5. **Turn sludge and organic waste into compost** with good aeration, instead of dumping.

How to read these numbers. They are indicative Tier 1 estimates for comparing options, not measurements. Real emissions depend on climate, groundwater, how often systems are emptied and how they are operated, and can differ by a factor of two or more. Nitrous oxide and construction emissions are not included. For project reporting or carbon credits, site measurements or an approved methodology are needed.

4

Market-Based WASH Products

Products households buy, made and installed by local enterprises and artisans.

- **Toilet-in-a-Box** proven, scaled to 2 regions
- **Septic tank** built in H2E programmes
- **Safe pit emptying** pilot
- **Biosand filter** in development

Toilet-in-a-Box (VIP and twin pit)

A complete household toilet, pit lining, slab and walls, made from interlocking precast panels by local enterprises.

H2E stage: proven, scaled to 2 regions

Rural and peri-urban households

Schools and health posts

Dry or pour-flush

How it works

Small concrete enterprises cast standard interlocking panels with steel molds. Trained artisans line the pit, place the slab and build the walls from the same panels, in days rather than weeks. Twin pits are used in turn: when one fills, it is closed and left to decompose while the other is used, so the contents can be emptied safely later.

Best for

Areas without sewers, where families build their own toilets and loose soils make unlined pits collapse.

Avoid where

High groundwater or shallow drinking-water wells nearby, unless the pit is sealed or raised.



Interlocking panels forming a twin-pit toilet (H2E design drawing).

Key facts

Days, not weeks

To build a complete toilet

No power or water

Needed for operation (dry VIP option)

Emptyable

Twin pits allow safe emptying and reuse

Climate hazard scorecard

Hazard	Rating	Why, and the climate-proof design response
Flooding	● Needs adaptation	Flood water can enter pits and carry waste into homes and wells. Response: raise the slab and first panel rows above flood level; seal the pit top; avoid low-lying plots.
Heavy rain	● Resilient	The precast lining does not collapse when soil is waterlogged, unlike unlined or stone-lined pits. Divert runoff away from the slab.
Drought and water scarcity	● Resilient	Dry VIP version uses no water. Pour-flush version needs only 1 to 2 litres per flush.
Extreme heat	● Resilient	Higher temperatures speed up drying and decomposition in the resting pit.
Cold	● Needs adaptation	In cold highlands, the resting pit takes longer to become safe. Response: allow a longer resting period before emptying.
Power cuts	● Resilient	No electricity needed.

Mitigation

Direct emissions (Scope 1)	Methane from waste decomposing in the pit, lower in shallow, dry pits that are emptied regularly. About 22 kg CO₂e per person per year for a dry twin pit that is emptied; up to 153 if the pit sits in wet soil or groundwater.
Indirect emissions (Scope 2)	Mainly cement in the panels; local production and hand-carrying keep transport emissions low. Not quantified in this edition.
Compared with the alternative	Replaces unlined pits that collapse and are abandoned full, and open defecation near water sources.

Indicative IPCC Tier 1 estimates, methane only. Method and assumptions: Chapter 3.

Enterprise and market model

Local concrete enterprises sell panels and installation as one package; trained artisans install; households pay directly or through loans from local microfinance institutions. Programmes fund molds, training and demand creation rather than subsidising each toilet.

H2E field experience



- Piloted in Adama, then scaled across four to five zones of the Oromia region and into the Amhara region.
- Produced by local enterprises with H2E molds; installed by trained artisans; financed through local lenders.
- Featured at the Ethiopian Innovation Centre; 2nd place in the CCRDA National Development Award.
- **Climate lesson:** a lined pit keeps its shape when the soil is waterlogged, where unlined pits are at risk of collapse.

Septic tank

A sealed underground tank that settles and partly treats wastewater from flush toilets, with the effluent going to a soak pit or onward treatment.

H2E stage: built in H2E programmes

Urban households

Condominiums

Institutions

How it works

Wastewater flows into a watertight tank with two or more chambers. Solids settle to the bottom and are slowly digested; the partly treated liquid flows out to a soak pit, a drain field, or better, a constructed wetland or ABR. The settled sludge must be emptied every few years and taken to treatment.

Best for

Flush toilets in towns without sewers, where there is space for safe disposal of the effluent and a desludging service.

Avoid where

High groundwater, flood-prone plots, or where the effluent would go straight into open drains.



A two-chamber septic tank under construction.

Key facts

Water-based

Needs water for flushing

Partial treatment

Effluent needs further treatment

Regular desludging

Frequency depends on size and users

Climate hazard scorecard

Hazard	Rating	Why, and the climate-proof design response
Flooding	● Vulnerable	Floods can push water back into toilets, wash out soak pits and spread untreated sludge. Response: raise covers and vents above flood level, seal lids, add a non-return valve, send effluent to a raised wetland instead of a soak pit.
Heavy rain	● Needs adaptation	Saturated soil stops soak pits from draining. Response: keep stormwater out of the tank; size disposal for wet-season soils.
Drought and water scarcity	● Needs adaptation	Too little flushing water can block pipes. Response: low-flush toilets, reuse greywater for flushing, regular maintenance.
Extreme heat	● Resilient	Warmth improves digestion in the tank.
Cold	● Needs adaptation	Treatment slows in cold conditions. Response: larger tank volume in highland towns.
Power cuts	● Resilient	Works by gravity; no electricity needed.

Mitigation

Direct emissions (Scope 1)	Methane from sludge digesting in the tank, one of the larger sources in on-site sanitation, especially if never emptied. About 109 kg CO₂e per person per year from the tank; about 186 in total if the effluent runs to an open drain, or 125 if it is treated in a constructed wetland.
Indirect emissions (Scope 2)	Concrete construction and fuel for desludging trucks. Not quantified in this edition.
Compared with the alternative	Regular emptying and onward treatment (wetland or ABR) cut emissions compared with tanks left to overflow into drains.

Indicative IPCC Tier 1 estimates, methane only. Method and assumptions: Chapter 3.

Enterprise and market model

Built by local masons or contractors and paid for by households or building owners; desludging by private operators or the utility, ideally on a scheduled service.

H2E field experience

- Built alongside Toilet-in-a-Box in market-based programmes.
- Combined with constructed wetlands for condominium wastewater in Adama and Shashemene.

Safe pit emptying (PuPu pump)

A portable, hand-operated pump that lets trained local operators empty pits and tanks safely where vacuum trucks cannot reach.

H2E stage: pilot

Dense informal settlements

Narrow lanes

Service business

How it works

The PuPu pump is a portable, manually operated pump. An operator lowers the hose into the pit and pumps the sludge into sealed barrels, which are carried or carted to a transfer point or treatment site. Operators wear protective equipment and follow a safe procedure.

Best for

Dense settlements where lanes are too narrow for trucks, and where pits are otherwise emptied by hand.

Avoid where

Very dry, solid sludge or pits with lots of rubbish, unless water is added and waste is screened.



A trained operator emptying a pit with a PuPu pump.

Key facts

Manual

No fuel or electricity

Portable

Reaches pits trucks cannot

2 to 3 operators

Per team, with protective equipment

Climate hazard scorecard

Hazard	Rating	Why, and the climate-proof design response
Flooding	● Needs adaptation	Flooded streets block transport to treatment. Response: empty pits before the rainy season; use transfer stations close to settlements.
Heavy rain	● Needs adaptation	Muddy lanes slow carting. Response: sealed barrels, handcarts and local transfer points.
Drought and water scarcity	● Resilient	Unaffected; very thick sludge may need a little water added.
Extreme heat	● Needs adaptation	Heat stress for operators in protective gear. Response: work early in the day, rest breaks, drinking water.
Cold	● Resilient	Not affected.
Power cuts	● Resilient	Manual pump; no electricity.

Mitigation

Direct emissions (Scope 1)	Emptying limits methane from full, overflowing pits. Regular emptying can bring a shared pit from about 109 to about 22 kg CO₂e per person per year, provided the sludge is treated.
Indirect emissions (Scope 2)	No fuel for the pump; emissions only from carting or trucking sludge onward. Not quantified in this edition.
Compared with the alternative	Replaces manual emptying and dumping into drains and fields, and the methane from untreated sludge.

Indicative IPCC Tier 1 estimates, methane only. Method and assumptions: Chapter 3.

Enterprise and market model

Run as a small business by trained local operators who charge per emptying; municipalities license operators and provide a transfer or treatment point.

H2E field experience



- Theory and practical training and testing of the PuPu pump at the sludge treatment plant of Adama University, Ethiopia.

Household water treatment: biosand filter

A household filter that cleans drinking water through sand and a natural biological layer, with no chemicals or electricity.

H2E stage: in development

Rural households

Unsafe water sources

Local product line

How it works

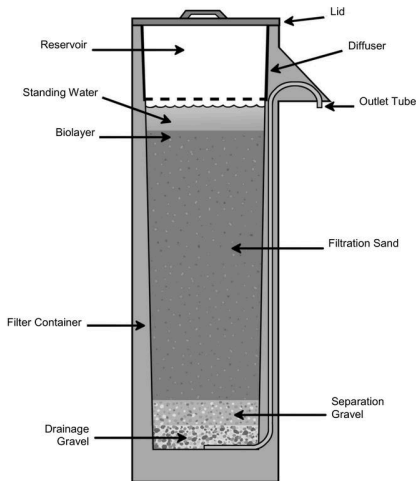
Water is poured into the top of the filter and flows slowly through fine sand. A biological layer that forms on the sand surface, together with the sand itself, removes most pathogens and turbidity. Clean water flows out of a pipe into a safe storage container. The filter is used every day and needs only simple cleaning.

Best for

Households using rivers, ponds or unprotected wells, where boiling with firewood or charcoal is common.

Avoid where

Water with chemical contamination (for example fluoride or arsenic) unless an adapted design is used.



Parts of a biosand filter. Diagram: CAWST, Biosand Filter for Technicians (CC BY 3.0).

Key facts

No power or chemicals

Gravity and biology only

Daily use

Keeps the biological layer alive

Climate hazard scorecard

Hazard	Rating	Why, and the climate-proof design response
Flooding	● Needs adaptation	Floods make source water muddier and more contaminated. Response: let water settle first; place the filter above flood level; protect safe storage.
Heavy rain	● Needs adaptation	High turbidity after storms clogs the sand faster. Response: pre-settling bucket; train users to clean the surface.
Drought and water scarcity	● Needs adaptation	The biological layer needs regular water. Response: keep daily use even with small volumes; store water safely.
Extreme heat	● Resilient	Works in hot climates; keep stored treated water covered and shaded.
Cold	● Needs adaptation	The biological layer slows in cold weather and can freeze. Response: keep indoors.
Power cuts	● Resilient	No electricity needed.

Mitigation

Direct emissions (Scope 1)	None from the filter itself. 0 kg CO ₂ e per person per year.
Indirect emissions (Scope 2)	Mainly cement and sand for a concrete filter, made locally. Not quantified in this edition.
Compared with the alternative	Avoids firewood or charcoal used to boil drinking water, a direct cut in emissions and in deforestation.

Indicative IPCC Tier 1 estimates, methane only. Method and assumptions: Chapter 3.

Enterprise and market model

Local producers make and sell filters with installation, user training and follow-up visits; households buy them, with programmes supporting demand creation and producer training.

H2E field experience



- In development: H2E will apply the Toilet-in-a-Box delivery model (local producers, trained installers, finance links) to biosand filters.
- Photo: a biosand filter in a home in Bihar, India. Photo: CAWST (CC BY-SA 4.0).

5

DEWATS: Decentralised Wastewater Treatment

Robust, low-energy treatment for institutions, housing and small towns.

- **Constructed wetland** proven, 3 built
- **Anaerobic baffled reactor** design service

Constructed wetland (horizontal subsurface flow)

Nature-based treatment of settled wastewater in a planted gravel bed: no electricity, no chemicals, simple upkeep.

H2E stage: proven, 3 built

Institutions

Condominium housing

Small towns

After a septic tank or ABR

How it works

Wastewater is first settled in a septic tank or ABR. It then flows slowly through a lined bed of gravel, below the surface, so there is no standing water, odour or mosquito breeding. Bacteria on the gravel and plant roots break down pollution. Treated water collects at the outlet and can be reused. Because the water stays below the surface, the wetland can sit close to homes and doubles as green space.

Best for

Condominiums, schools, hospitals and small towns with land available and no sewer connection.

Avoid where

Very limited land, or sites in flood plains that cannot be protected.



Constructed wetland, Shashemene.

Key facts

Gravity-fed

No electricity or pumps once running

Needs land

Size depends on users and climate

Low-skill upkeep

Inlet cleaning, plant cutting

Climate hazard scorecard

Hazard	Rating	Why, and the climate-proof design response
Flooding	● Needs adaptation	Flood water can wash out the bed and spread untreated wastewater. Response: site above the flood line, raise bed walls or add a bund, divert runoff around the cell.
Heavy rain	● Needs adaptation	Stormwater in the sewer can overload the bed. Response: keep stormwater out; add an overflow at the settler.
Drought and water scarcity	● Resilient	Treated water becomes a resource for flushing and gardens. Response: keep a minimum water level for the plants.
Extreme heat	● Resilient	Warmth speeds up treatment; vegetation cools the surroundings.
Cold	● Needs adaptation	Treatment slows at low temperatures. Response: size the bed for the coldest month.
Power cuts	● Resilient	No electricity needed where gravity flow is possible.

Mitigation

Direct emissions (Scope 1)	Small amounts of methane and nitrous oxide from the bed and settler. About 15 kg CO2e per person per year for the wetland stage; with the septic tank before it, about 125 in total, compared with 186 when the effluent goes to an open drain.
Indirect emissions (Scope 2)	Close to zero for operation; gravel, liner and concrete for construction. Not quantified in this edition.
Compared with the alternative	Avoids methane from untreated wastewater in open drains and energy for mechanical treatment; plants and soils store some carbon.

Indicative IPCC Tier 1 estimates, methane only. Method and assumptions: Chapter 3.

Enterprise and market model

Built with the water utility and local contractors; run by residents' committees or institution staff with utility support; reuse of treated water gives the community a reason to maintain it.

H2E field experience



- Three wetlands: a pilot phase in 2022 in Adama and Shashemene, then the Dembela wetland in Adama, opened on 9 October 2024.
- Dembela serves about 700 residents of three condominium blocks; run by the community with the Adama Water Utility; treated water reused for toilet flushing and gardens.

Sources: World Waternet and Dutch Water Authorities (2024); WASTE case study.

Anaerobic baffled reactor (ABR)

A compact, buried tank with a series of chambers where bacteria break down wastewater without oxygen, energy or moving parts.

H2E stage: design service

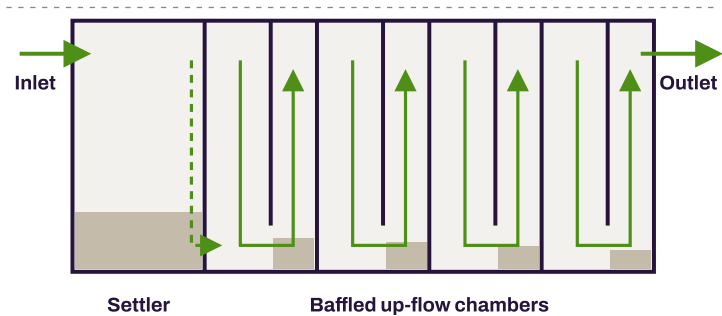
Institutions

Housing estates

Before a constructed wetland

How it works

Wastewater first enters a settling chamber, then flows down and up through a row of chambers separated by baffle walls. In each chamber it passes through a blanket of active sludge, where bacteria digest the organic load. ABRs handle variable flows well and take little space because they are buried. The effluent is usually polished further in a constructed wetland.



How an anaerobic baffled reactor works (H2E schematic).

Best for

Institutions and housing estates producing a steady flow of wastewater, where land is limited.

Avoid where

Very small flows (a septic tank is simpler) or where nobody is responsible for desludging.

Key facts

No power

Gravity flow, no moving parts

Small footprint

Buried; land above can be used

Regular desludging

Main maintenance task

Climate hazard scorecard

Hazard	Rating	Why, and the climate-proof design response
Flooding	● Needs adaptation	Flood water entering through manholes can wash out the sludge blanket. Response: raise manholes and vents above flood level; seal covers.
Heavy rain	● Needs adaptation	Stormwater surges flush out the active sludge. Response: keep stormwater out of the sewer; overflow at the inlet.
Drought and water scarcity	● Resilient	Lower flows are handled well.
Extreme heat	● Resilient	Warmer temperatures improve treatment.
Cold	● Needs adaptation	Treatment drops in cold conditions. Response: larger volume; insulate by burying deeper.
Power cuts	● Resilient	No electricity needed.

Mitigation

Direct emissions (Scope 1)	Methane is produced in the chambers; it can be captured as biogas in larger systems instead of venting. About 175 kg CO₂e per person per year if the methane is vented; about 18 if 90% is captured and burned.
Indirect emissions (Scope 2)	Close to zero for operation; concrete for construction. Not quantified in this edition.
Compared with the alternative	Replaces untreated discharge and energy-intensive mechanical plants.

Indicative IPCC Tier 1 estimates, methane only. Method and assumptions: Chapter 3.

Enterprise and market model

Designed for utilities, institutions and developers; built by local contractors; operated by the institution or utility, with private desludging.

H2E field experience

- Designed as part of H2E's decentralised wastewater treatment services, usually combined with a constructed wetland.

6

Resource Recovery

Turning sludge and organic waste into fertiliser and energy.

- **Co-composting** field-tested
- **Biogas digester** research

Co-composting of faecal sludge and organic waste

Turning treated faecal sludge and organic market or household waste into a safe soil conditioner that farmers can buy.

H2E stage: field-tested

Towns with sludge treatment

Market waste

Farmers as customers

How it works

Dewatered faecal sludge is mixed with organic waste such as market and food waste in boxes or long piles (windrows) under a simple roof. The mix heats up as it decomposes; regular turning keeps air flowing and high temperatures kill pathogens. After curing, the compost is screened, tested and sold as a soil conditioner.

Best for

Towns with a sludge treatment site and a steady supply of organic waste, close to farming areas.

Avoid where

Sites without a roof or drainage, or where sludge contains heavy industrial waste.



Compost curing under a roofed co-composting hall.

Key facts

Manual turning

No electricity needed

Weeks to months

From mixing to finished compost

Tested product

Pathogen and quality checks

Climate hazard scorecard

Hazard	Rating	Why, and the climate-proof design response
Flooding	● Needs adaptation	Floods can wash sludge and leachate into the surroundings. Response: raised, roofed site with drainage and leachate collection.
Heavy rain	● Needs adaptation	Rain makes piles too wet and cold. Response: roof over piles; cover finished compost.
Drought and water scarcity	● Needs adaptation	Piles can dry out. Response: add water or wet waste to keep moisture right.
Extreme heat	● Resilient	Heat helps the piles reach safe temperatures.
Cold	● Needs adaptation	Piles struggle to heat up. Response: larger piles, insulation with finished compost.
Power cuts	● Resilient	No electricity needed.

Mitigation

Direct emissions (Scope 1)	Some methane and nitrous oxide if piles are poorly aerated; well-turned piles release far less. About 174 kg CO2e per tonne of waste composted, far less than the same waste left in pits or dumps.
Indirect emissions (Scope 2)	Fuel for transporting sludge and waste. Not quantified in this edition.
Compared with the alternative	Avoids methane from dumped sludge and organic waste in landfills; replaces synthetic fertiliser; stores carbon in soil.

Indicative IPCC Tier 1 estimates, methane only. Method and assumptions: Chapter 3.

Enterprise and market model

Run by a municipality, utility or private enterprise; income from compost sales and waste collection fees; farmers and nurseries as customers.

H2E field experience



- Co-composting trials and training with field teams.

Biogas digester

A sealed digester that turns faecal sludge, manure and food waste into cooking gas and a nutrient-rich fertiliser.

H2E stage: research

Institutions

Farms

Communal toilets

How it works

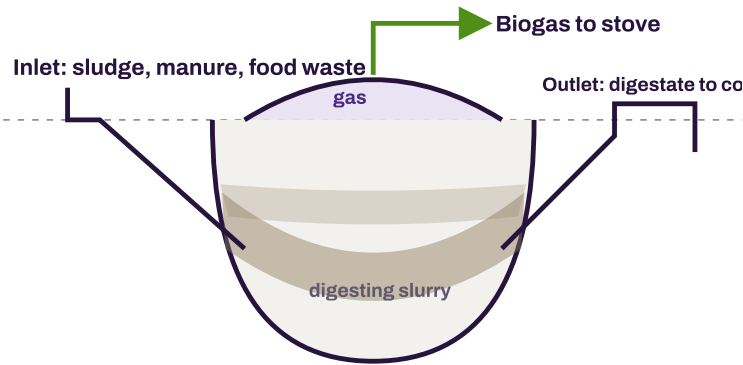
Organic material is fed into a sealed, usually underground digester. Without oxygen, bacteria break it down and release biogas, mostly methane, which collects under the dome and is piped to a stove. The digested slurry flows out and can be composted or used as fertiliser. Toilets can be connected directly to the digester.

Best for

Schools, prisons, farms and communal toilets with a steady supply of waste and a use for cooking gas.

Avoid where

Places without a reliable daily feed, or without anyone responsible for operation.



How a fixed-dome biogas digester works (H2E schematic).

Key facts

Cooking gas

Replaces firewood and charcoal

Fertiliser

Digestate for fields

Climate hazard scorecard

Hazard	Rating	Why, and the climate-proof design response
Flooding	● Needs adaptation	Flood water can enter the inlet and outlet and disrupt digestion. Response: raise inlet and outlet above flood level; seal the dome.
Heavy rain	● Needs adaptation	Runoff can dilute the digester. Response: divert surface water; cover inlets.
Drought and water scarcity	● Needs adaptation	Needs water to mix the feed. Response: use urine, greywater or wet waste to mix.
Extreme heat	● Resilient	Higher temperatures increase gas production.
Cold	● Vulnerable	Gas production drops sharply in cold conditions. Response: bury deeper, insulate, use a greenhouse cover in highland sites.
Power cuts	● Resilient	No electricity needed.

Mitigation

Direct emissions (Scope 1)	Leaks of methane from the dome or unburnt gas are the main risk; a well-sealed digester captures it. About 18 kg CO₂e per person per year if 90% of the gas is captured and burned; leaks quickly erase the benefit.
Indirect emissions (Scope 2)	Construction materials; low operating emissions. Not quantified in this edition.
Compared with the alternative	Captures methane that would otherwise escape from waste and replaces firewood and charcoal for cooking.

Indicative IPCC Tier 1 estimates, methane only. Method and assumptions: Chapter 3.

Enterprise and market model

Built by trained masons for institutions or farms; owners pay through savings on fuel and fertiliser; carbon credit programmes can co-finance.

H2E field experience

- Research stage, linked with sanitation and co-composting work.

7

Choosing the right option

A quick guide for programme designers, utilities and municipalities: which solutions fit which context, and the questions to ask before choosing.

Which solution fits which context

Context	Toilet-in-a-Box	Septic tank	Pit emptying	Biosand filter	Constructed wetland	ABR	Co-composting	Biogas
Flood-prone areas	Possible	Avoid	Good fit	Possible	Possible	Possible	Possible	Possible
Drought-prone, water-scarce	Good fit	Avoid	Good fit	Possible	Possible	Possible	Possible	Possible
High groundwater, shallow wells	Possible	Avoid	Good fit	Good fit	Good fit	Possible	Good fit	Possible
Dense urban or informal settlement	Possible	Possible	Good fit	Good fit	Possible	Good fit	Good fit	Possible
Rural, scattered households	Good fit	Possible	Possible	Good fit	Avoid	Avoid	Possible	Possible
Schools, health posts, institutions	Good fit	Good fit	Possible	Good fit	Good fit	Good fit	Possible	Good fit
Condominiums and housing estates	Avoid	Good fit	Possible	Possible	Good fit	Good fit	Possible	Possible
Cold highlands	Possible	Possible	Good fit	Possible	Possible	Possible	Possible	Avoid

Good fit: works well as designed. Possible: works with the climate-proof design responses in the profiles. Avoid: high risk of failure or pollution in this context. Ratings are general guidance; local conditions always need checking.

Five questions before you choose

1

What is the main climate hazard here?

- **Floods or high groundwater:** favour sealed or raised containment and emptying services; avoid septic tanks with soak pits.
- **Drought:** favour dry or low-flush toilets and reuse of treated water.
- **Cold highlands:** allow longer resting times and larger tanks; avoid relying on biogas alone.

2

Is there water for flushing all year round?

- **No:** dry Toilet-in-a-Box (VIP or twin pit).
- **Yes:** pour-flush Toilet-in-a-Box, or septic tank with a wetland or ABR after it.

3

Who will empty and treat the sludge?

- Without a service, every pit and tank eventually fails or overflows. Plan safe emptying (for example PuPu pump operators) and a treatment or composting site **from the start**.

4

Is the wastewater from one household or many?

- **Household:** on-site toilets with emptying.
- **Many households or an institution:** shared treatment, such as a septic tank or ABR followed by a constructed wetland.

5

Can something be recovered and sold?

- **Steady organic waste and nearby farms:** co-composting.
- **Steady feed and a use for cooking gas:** biogas, with gas-tight design.
- **Drinking water from unsafe sources:** biosand filters avoid boiling with firewood or charcoal.

Rule of thumb: choose the option that keeps working in the worst season, can be emptied and maintained by local businesses, and does not send untreated waste into drains or water sources. That option is usually also the lowest in emissions.

8

From the field: two case studies

Two H2E-supported solutions, proven in Ethiopia and ready to scale.

Case study 1: Constructed wetlands in Adama and Shashemene



3

Wetlands built

2 cities

Adama and Shashemene

~700

Residents served by the
Dembela wetland

9 Oct 2024

Dembela wetland opened

The problem

Condominium blocks in growing towns had no sewer connection. Wastewater from septic tanks and drains ran into open channels, close to where people live.

The solution

Horizontal subsurface flow wetlands treat the settled wastewater in planted gravel beds. A pilot phase in 2022 built wetlands in Adama and Shashemene; the Dembela wetland in Adama followed in 2024, serving about 700 residents of three condominium blocks.

Who runs it

Residents manage the wetland together with the Adama Water Utility, with partners monitoring water quality.

The climate angle

- **Adaptation:** treated water is drawn by hand pump for toilet flushing and vegetable gardens, a resource in dry seasons; no power to fail.
- **Mitigation:** treating effluent in a wetland cuts system emissions by about a third compared with an open drain (Chapter 3), with near-zero energy use.

Lessons

- Involve the community and the utility from planning onwards.
- Settle solids well before the bed.
- Make reuse visible so residents see the benefit.

Sources: World Waternet and Dutch Water Authorities (2024); WASTE case study on constructed wetlands.

Case study 2: Toilet-in-a-Box across Oromia and Amhara



2 regions

Oromia and Amhara

Days

To build a complete toilet

One package

Pit lining, slab and walls

The problem

Families wanted decent toilets, but the market offered only slabs. Each household had to organise diggers, materials and masons alone, and unlined pits collapsed in the rains.

The solution

A complete modular toilet made from interlocking precast panels: pit lining, slab and walls. Local concrete enterprises produce the panels with steel molds, trained artisans install them, and households can pay through local lenders.

Scale

A pilot in Adama, then four to five zones of the Oromia region and on to the Amhara region. Featured at the Ethiopian Innovation Centre and 2nd in the CCRDA National Development Award.

The climate angle

- **Adaptation:** lined pits do not collapse when soils are waterlogged; slabs can be raised above flood level; dry version needs no water.
- **Mitigation:** a dry twin pit that is emptied emits about 22 kg CO₂e per person per year, against 109 for a shared pit never emptied and 153 for a pit in groundwater (Chapter 3). Local production cuts transport.

Lessons

- A complete product removes the burden from families.
- Design every part so one artisan can handle it.
- Photo-based monitoring keeps quality consistent across many enterprises.

9

Financing and monitoring climate-smart sanitation

How to make the climate case to funders, which finance channels exist, and what to monitor.

Building the climate rationale

Climate funds finance what is clearly linked to climate change. A strong sanitation proposal shows the link in four steps, following the GWP and UNICEF strategic framework for climate-resilient WASH:

Step	What to show	Where this guide helps
1. Climate risk	Which hazards (floods, drought, heavy rain, heat) affect sanitation in the area, now and in projections.	Chapter 1; hazard scorecards
2. Vulnerability	How current toilets, tanks and drains fail under those hazards, and who is affected.	Chapter 2; profiles
3. The response	Why the chosen solutions reduce that risk (adaptation) and cut emissions (mitigation).	Profiles; Chapters 3 and 7
4. Measurable results	Indicators that track resilience and emissions over time.	Indicator set below

Finance channels

Channel	What it can fund	Fits best with
Multilateral climate funds (for example Green Climate Fund, Adaptation Fund)	Larger adaptation and mitigation programmes with a clear climate rationale, usually through accredited entities and national governments.	City-wide programmes, DEWATS, faecal sludge management
Bilateral climate and development funding	Programmes that combine WASH, resilience and local economic development.	Market-based WASH with enterprise development
Results-based finance	Payments per verified result, for example per household with safely managed sanitation or per tonne of sludge treated.	Toilet-in-a-Box, pit emptying, co-composting
Carbon markets	Credits for verified emission reductions, under approved methodologies (for example for methane avoided through composting, methane recovered in biogas, or fuel saved by not boiling water).	Biogas, co-composting, biosand filters
Utility and municipal budgets, climate-labelled loans	Infrastructure that utilities own and operate.	Constructed wetlands, ABRs, treatment sites

Who pays for what

Climate finance works best when it strengthens the everyday finance that keeps sanitation running. Each actor needs its own source:

Actor	Typical sources
Households	Microfinance loans (individual or group) from public or private lenders, savings cooperatives, own savings.
Schools, health posts and institutions	Government budgets, parent contributions, company social programmes.
Local enterprises	Credit from local lenders; bridge funding from programmes while sales build up.
Lenders	Loanable funds from banks and development finance; guarantee schemes that share the risk and unlock more credit. Programmes can reserve part of their funds as a guarantee.

Carbon credits need care. They require an approved methodology, baseline data, monitoring and independent verification. Check current eligibility rules with the standard and the national authority before planning on this income. The indicative figures in Chapter 3 are not enough on their own.

What to monitor

A short indicator set that works for both climate funders and WASH programmes. Collect data with simple digital tools; photo-based monitoring, as used for Toilet-in-a-Box, keeps it affordable.

Area	Indicator	How
Adaptation	Share of toilets and treatment systems still working after the rainy season or an extreme event	Post-season visit or photo check
	Days of service disruption during floods or drought	Operator and utility records
	Share of facilities built with climate-proof design (raised slabs, lined pits, flood protection)	Construction checklist
	Volume of treated water reused in dry seasons	Simple meter or log
Mitigation	Share of pits and tanks emptied on schedule	Emptying service records
	Volume of sludge safely treated or composted, rather than dumped	Treatment site records
	Methane captured and used (biogas, gas-tight reactors)	Gas use records
	Estimated emissions avoided, using the Chapter 3 method	Annual calculation
Service and equity	Households with safely managed sanitation (JMP definition)	Household survey
	Local enterprises and artisans active, including women-led businesses	Enterprise register
	Households in the poorest groups reached	Survey or loan records

References: GWP and UNICEF (2022), WASH Climate Resilient Development: Strategic Framework; GWP and UNICEF (2017), Technical Brief: Monitoring and evaluation for climate-resilient WASH; WHO/UNICEF JMP definitions (washdata.org).

Appendix: hygiene technologies

Handwashing options that keep working when water and power are disrupted.

Technology		How it works	Climate notes
Foot-operated handwashing station		Pedals open the tap and the soap dispenser, so hands never touch them. Low water use.	Resilient to storms, drought and heat. Raise the base and storage in flood areas. No emissions.
Splash handwashing and drinking stations		Separate, colour-coded stations for handwashing and filtered drinking water in schools and institutions.	Storms and floods can damage pipes and tanks: elevate storage and protect from flooding. No emissions.
Solar-powered automated hand washer		Touch-free unit with a sensor that releases soap, then rinse water, over a 25-second cycle; solar powered.	Keeps working during power cuts after storms and floods. No emissions from energy use.

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