BILFINGER WATER TECHNOLOGIES

Vacuum Sewerage & Water Management Systems

Regional Workshop on
Integrated Resource Management in Asian Cities:
The Urban Nexus
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Session 2: Urban Nexus Approach in Practice

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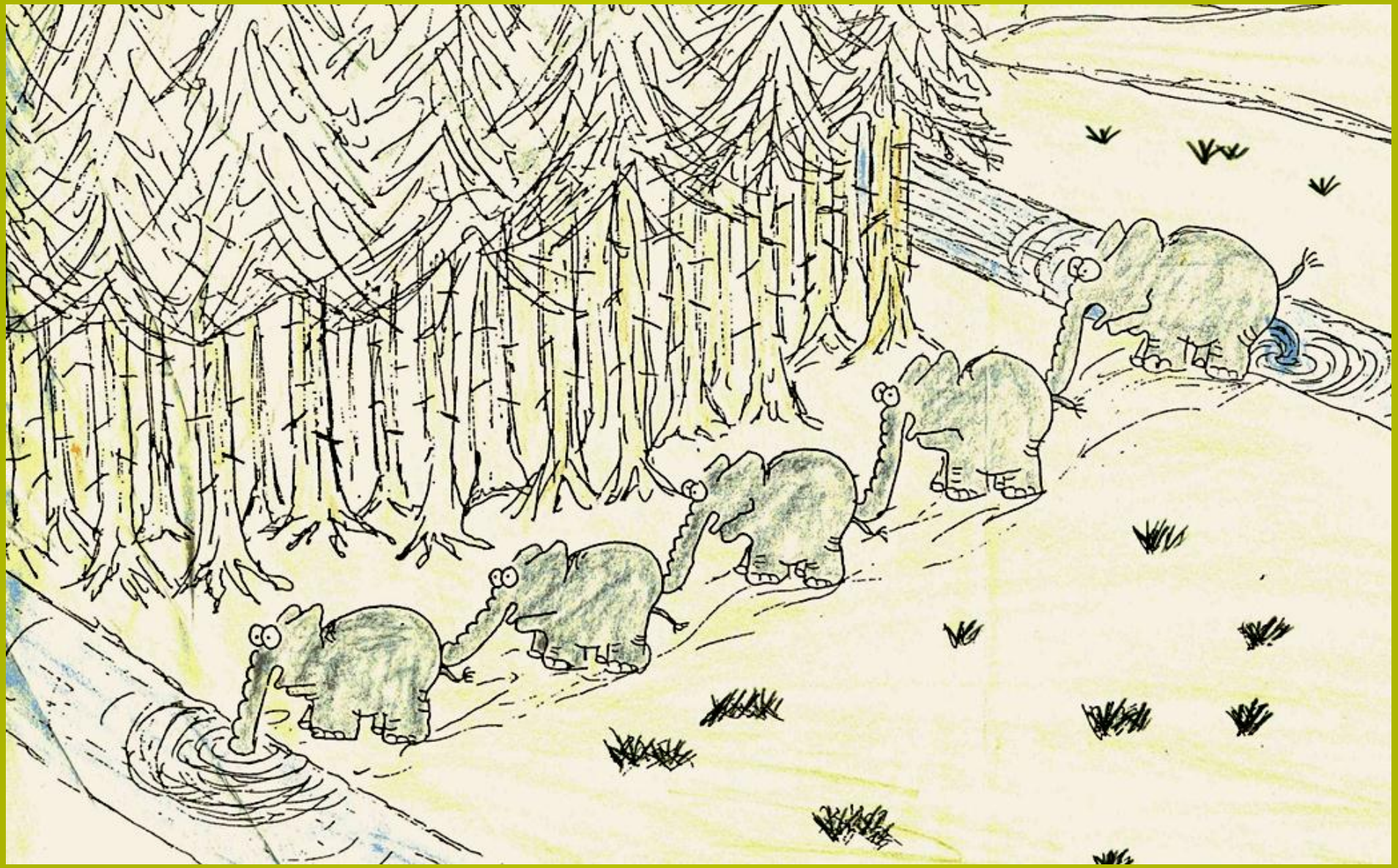
Vacuum Sewerage Principle

Collection > Transport > Discharge



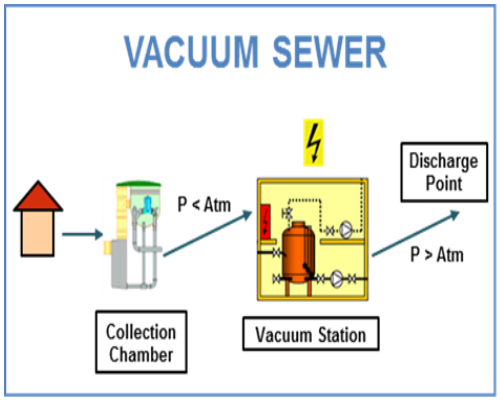
Brief Introduction of Sewer Systems

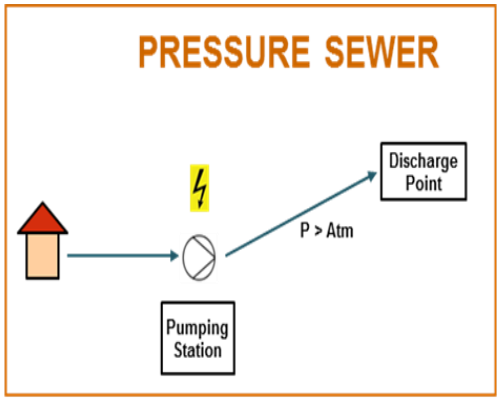
Background

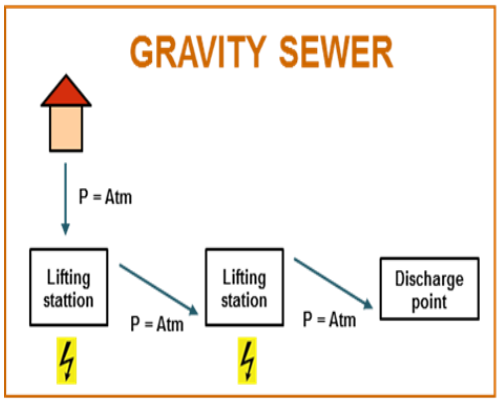
- Sewers are hydraulic conveyance structures that carry wastewater to a treatment plant or other authorized point of discharge.
- Most sewage collection systems are conventional gravity (CG) types, unless local factors dictate the use of alternatives, e.g. vacuum sewerage systems.

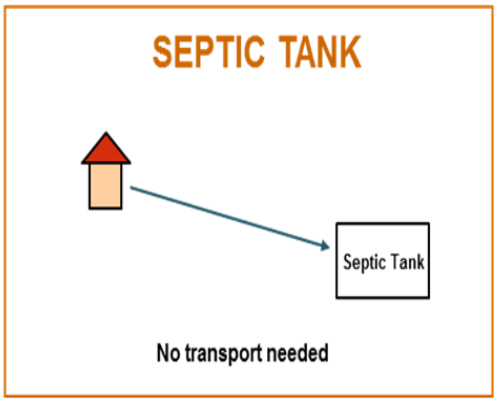
Major Collection Systems:

- Conventional Gravity
- Pressure Sewers
- Septic Tank
- Vacuum Sewers

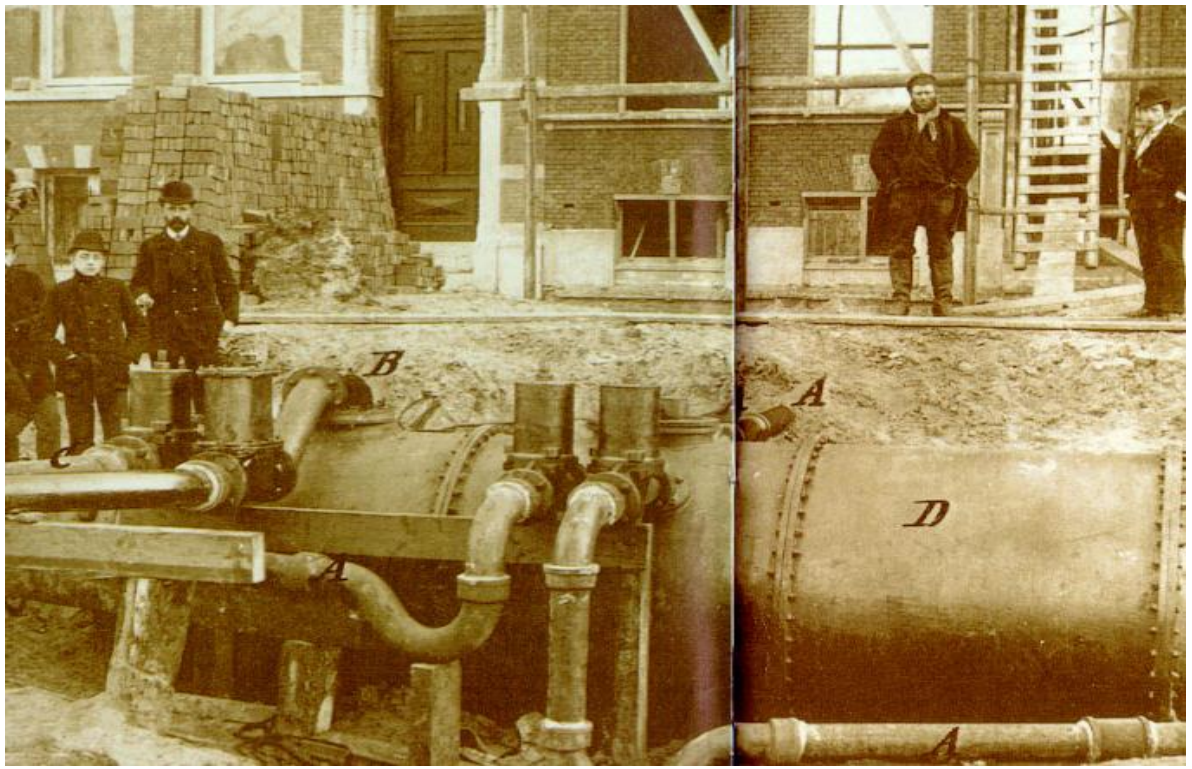


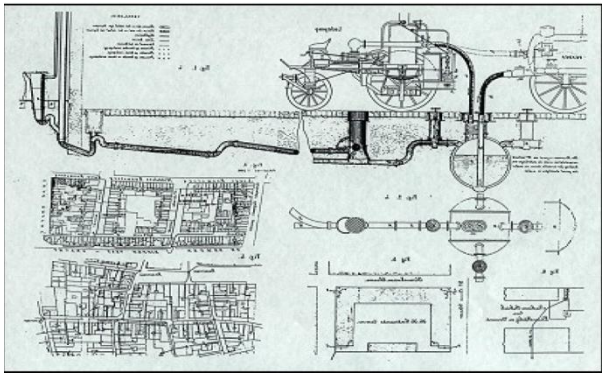






Brief History of Vacuum Sewerage Systems





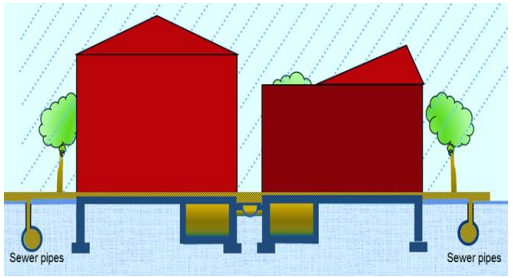
First Vacuum Sewerage System End of 19th Century

- Amsterdam, Netherlands (1870)
- Dordrecht, Netherlands (1870)
- Dordrecht, Netherlands (1871)
- Hanau, Germany (1871)
- Trouville-sur-mer, France (1897)

Septic Tank Limitations – Some Facts

SOME FACTS ABOUT SEPTIC (COLLECTION) TANKS

- **SEPTIC = anaerobic bacterial environment which ideally decomposes waste discharged into the tank;**
- **However, preventive maintenance is required to remove irreducible solids that gradually fill the tank, reducing greatly its efficiency;**
- **Black-water constitutes only around 10% of domestic waste-water being discharged;**
- **However, this modest volume contains about approx.. 99% of pathogens (that cause typhoid, bilharzias, and diarrhea);**
- **Black-water contains 90% of nitrogen, 80% of phosphorus and 40-75% of organic matter (BOD);**
- **Septic tanks are not at all efficient, only 30% of organic matter are removed prior to discharge;**
- **Even an optimal functioning septic tank is one of the most significant sources of organic matter (BOD);**
- **Even if all of the septic tanks in Da Nang were functioning properly:**
  - **The discharge of BOD will still be very high;**
  - **The discharge of nitrogen and phosphorus are not reduced at all.**



Comparison: Septic Tank – Vacuum Sewerage System

SEPTIC TANK	VACUUM SEWERAGE SYSTEM
• Pollution of groundwater and rivers - risk of infection (coliform bacteria) - exfiltration from septic tanks due to fissures and/or cracks in tank walls and bottom;	• Completely tight and contained system: no ex-filtration or in-filtration possible – protection of groundwater and surroundings; no impact on environment;
• Biological hazards due to ex-filtration: germs, bacteria, pathogenic organisms, insects, rodents;	• No biological hazards: completely tight and contained system;
• Very heavy rainfall and flooding (rainy season) is preventing the normal operation of the tank, causing: overflowing of tank waste-water, risk of infection, bad smell;	▪ Completely tight and contained system: no overflowing, no leakage, no risk of infection, no smell;
• Periodic preventive maintenance is required to remove the irreducible solids that settle and gradually fill the tank, reducing its efficiency;	▪ No maintenance of collection chambers needed – annual control of chambers and vacuum station only;
• Tank has to be opened for maintenance and emptying – causing destruction of floor on top of septic tank, direct contact with hazardous waste-water;	▪ No contact with hazardous effluents when opening collection chambers, separation of waste-water sump and valve-controller unit;
• Some cubic meters of underground space required for each house;	▪ Little space required for collection chamber: 4 houses = 1 collection chamber;
• Sensitive system – foreign objects/solids are greatly reducing the efficiency of the septic tank;	▪ System is still functioning when certain solids (e.g. napkins, food items, small toys, etc.) are contained in wastewater;
• Efficiency greatly reduced due to waste water composition (solids), temperature, blockages, etc.;	▪ Self-cleaning of the system due to high velocities of waste-water transport;
• Leakage detection almost impossible;	▪ Immediate detection of leakages at the vacuum station (extended pump-run causes alarm);

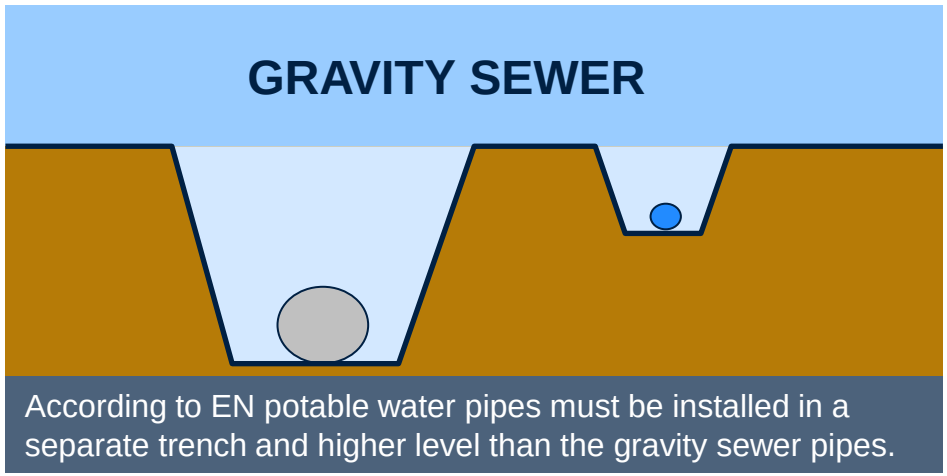
Vacuum Sewerage – How does it work?

VacuumSewerage – How does it work?

Vacuum Sewerage – Leakage Test

Sustainable Solution for a Green Future

Same Trench Installation



- **Potable water pipes and storm-water pipes can be installed together in ONE trench with the vacuum sewer pipe !**

Sustainable Solution for a Green Future

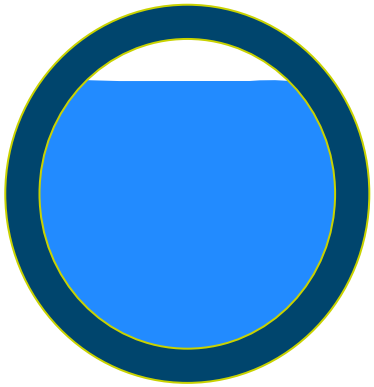
No Undetected Infiltration Possible !

- There will be **no undetected infiltration of rain-/storm- or groundwater** into the vacum sewage pipe network, diluting the biological condition of the Sewerage Treatment Plant (STP);

- Knowing that STP's are responsible for up to 40% of the energy consumption of small communities, the pressing question is: **"Why spending a lot of money for treating just little polluted rain water ?"**

Vacuum Sewerage Advantages – Operation

Tolerating Fluctuating Flows



100% peak flow

or

< 10 % peak flow

- **Self cleaning system;**
- **High velocities (4-6 m/s);**
- **No sedimentation even during low-flow periods;**
- **Suitable for holiday resorts (seasonal occupancy);**

Vacuum Sewerage Advantages – Cost

WHAT DOES IT COST $$$?

Vacuum Sewerage Advantages – Cost

What does it cost ?

- Costs vary depending of network size and project specifications;
- The cost saving factor is the network itself, so a minimum project size is required to be competitive;
- Vacuum sewerage systems can achieve up to **25 - 40% cost savings** compared to gravity sewerage systems, considering all aspects of construction;

Again !

- Vacuum sewerage systems do not require manholes;
- Trenching is limited to average depth of 0.9 - 1.2 m;
- No interim pumping station for large networks in flat terrain;
- Central Vacuum Station and Odour Control;

Vacuum Sewerage Advantages – Cost

Real Case Study Middle East (Fujairah)

- **Project perfectly suitable for a vacuum sewer system :**
- **Flat terrain, no natural slopes;**
- **Sandy, unstable soils;**
- **Coastal area with high ground water table;**
- **Long stretched development with a long pipe network;**
- **Low-density area with 7.500 PE;**

Vacuum Sewerage Advantages – Cost

Vacuum Sewer Lines (S&I)	500.000 €
Inspections pipes and division valves (S&I)	40.000 €
Collection chambers (S&I) (350 nos. G75 3")	700.000 €
Vacuum station (S&I)	350.000 €
Customs and transport costs	90.000 €
TOTAL approx.	1.680.000 €

S&I: Supply & Installation / Length of the pipe-lines: 18.000 meter

VacuumSewerage Advantages – Cost

Gravity Sewer Lines (S&I)	**1.600.000 €**
Manholes (S&I)	**1.000.000 €**
5 pumping stations (civil + M&E) (estimated S&I)	**180.000 €**
Odour control unit for manholes and pump stations	**50.000 €**
TOTAL approx.	**2.830.000 €**

S&I: Supply & Installation / Length of the pipe-lines: 18.000 meter

Vacuum Sewerage – Advantages – Cost

Gravity Total	**2.830.000 €**
Vacuum Total	**1.680.000 €**
Cost savings	***1.150.000 € or ~ 40 %***

Vacuum Sewerage Systems
Summary of Advantages

1. Closed (contained) system: no leakage, no ex-/infiltration, no biological hazards (no risk of infection), no smell along sewer network;

2. No manholes; no lifting (pump-) stations, also no rubbish can be thrown into vacuum sewer lines (closed system);

3. No sedimentation due to high velocity transport of waste-water in the vacuum sewer pipes, no flushing (cleaning) required;

4. Toleration of fluctuating flows (seasonal occupancy);

5. Flexible system, easy design adaption of profiles during construction phase (obstacles can be over-/under-/by-passed);

6. Only one central vacuum station: no lifting (pump-) stations required;

7. No electrical connections at collection chambers, only at the central vacuum station;

8. Small diameter pipes (d90 to d250); HDPE (SDR11) or PVC (PN10);

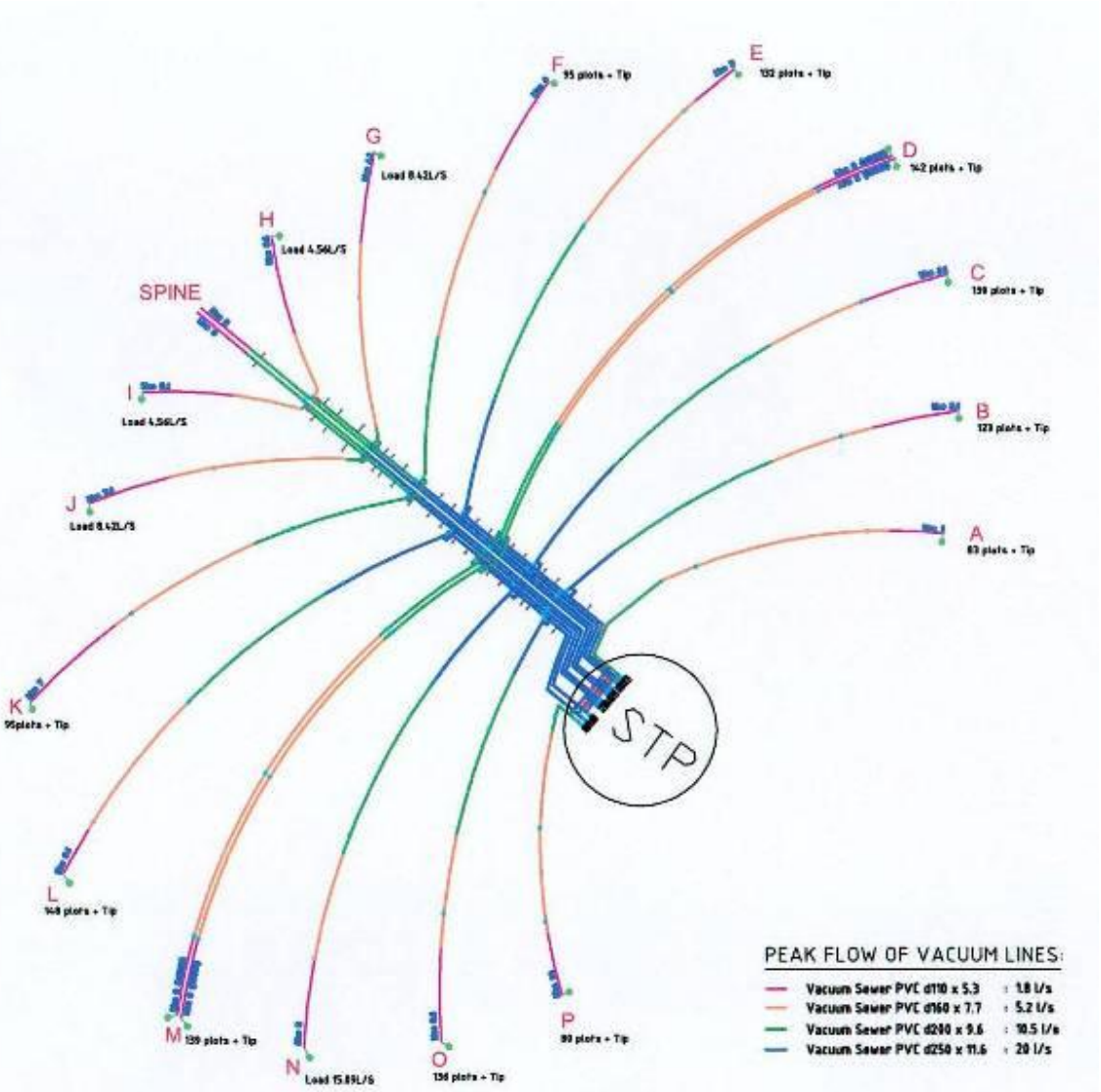
9. Shallow, fast and easy trenching (cost saving);

10. Reduced Operation & Maintenance equipment/cost; greatly reduced H_2S (hydrogen sulfide) and other fouling gases;

Bilfinger Water Technologies

REFERENCES Middle East – Asia - Africa

Middle East
The Palm Jumeirah, Dubai



- **Technical data:**
- Number of inhabitants: 23.000 PE
- Number of villas: 2.300
- Water consumption: 100 l/PE/d
- Peak flow: 200 l/s
- Length of the vacuum network: 40 km
- Number of collection chambers: 1.200
- Number of vessels: 4 x 25 m^3
- Type of vacuum pumps: 16 x 15 kW
- Type of discharge pumps: 6 x 18.5 kW

Middle East
The Palm Jumeirah, Dubai

Middle East
Durrat Al Bahrain, Bahrain

- **Technical data:**
- Number of inhabitants: 11.000 PE
- Number of islands: 11
- Water consumption: 250 l/PE/d
- Length of the vacuum network: 28 km
- Number of collection chambers: 460
- 3 Vacuum Stations

Middle East
A´Seeb, Sultanate of Oman

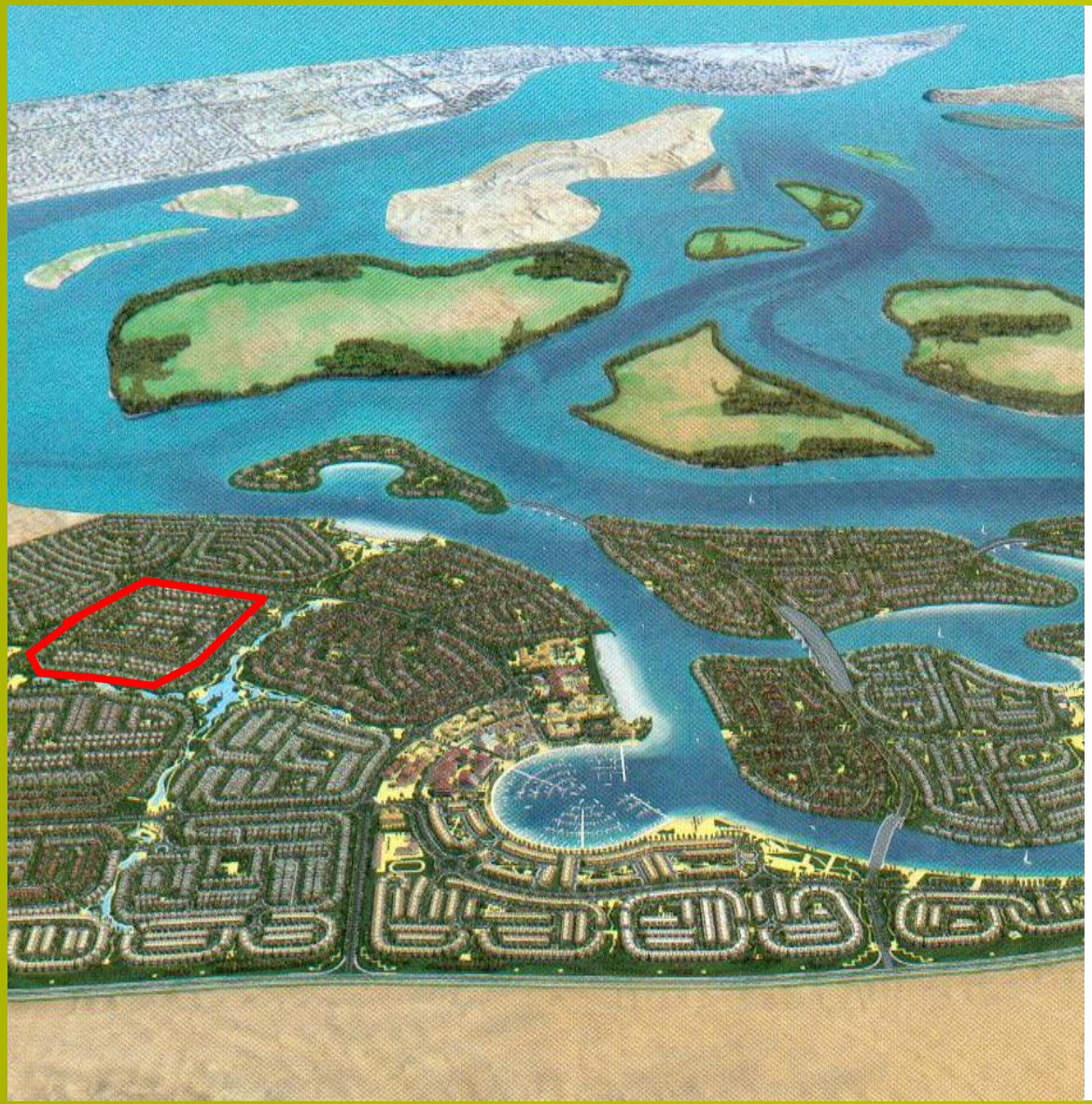
- **Technical data:**
- Number of inhabitants: 100.000 PE
- Water consumption: 150 l/PE/d
- Length of the vacuum network: 100 km
- Number of collection chambers: 2.000
- Number of VS: 5
- Construction time: 3.5 years
- Replacement of existing septic tanks
- Connection of new developments

Middle East
A´Seeb, Sultanate of Oman





Middle East
Umm Al Quwain Marina, U.A.E.

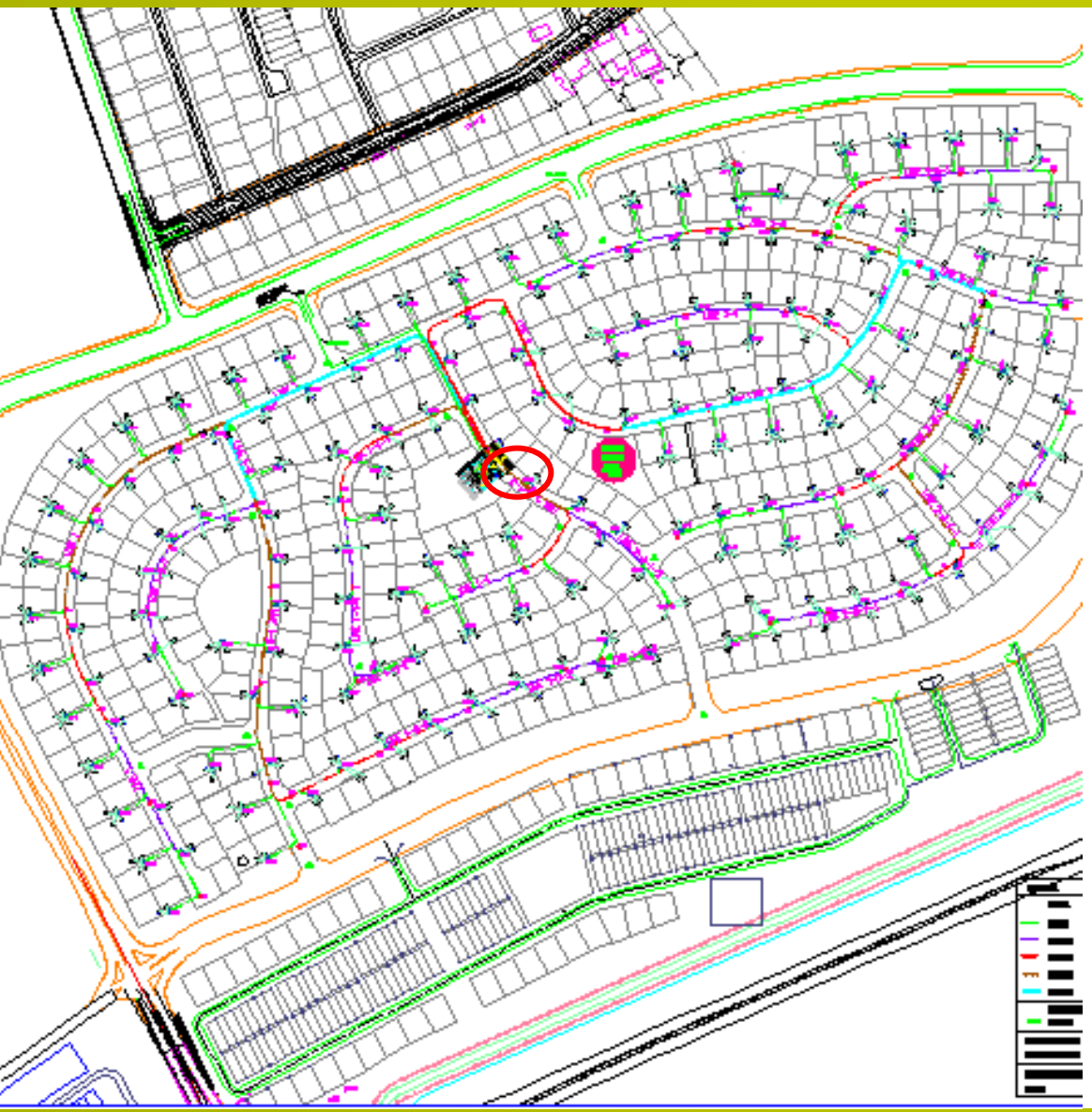


- **Technical data:**
- Number of villas: 277
- Length of the vacuum network: 5 km
- Number of collection chambers: 50
- Number of vessels: 1 x 20 m³
- Type of vacuum pumps: 3 x 11 kW
- Type of discharge pumps: 2 x 4.7 kW
- Construction time: 6 months

Asia
Brunei National Housing, Brunei

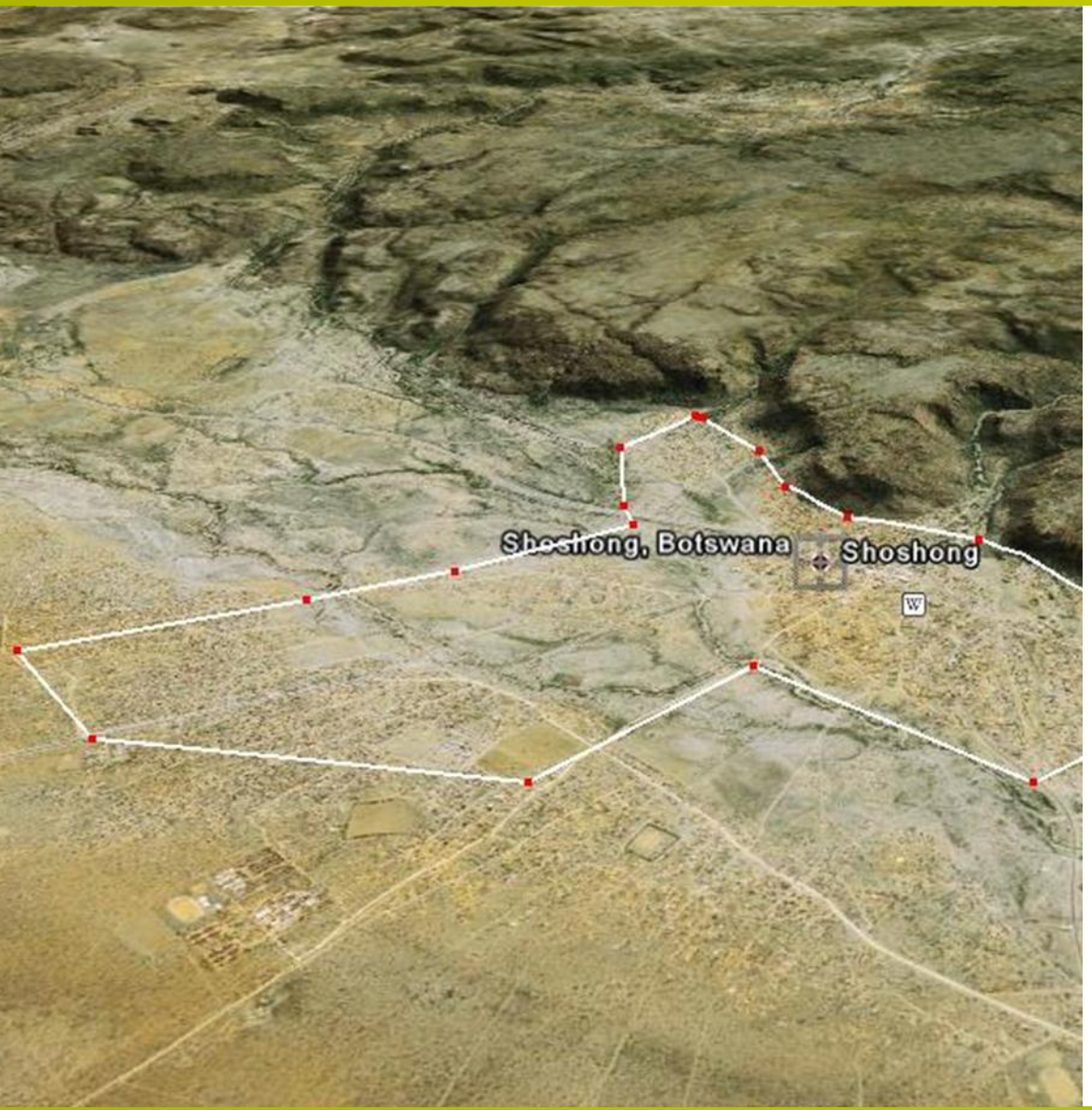
- **Technical data:**
- Number of inhabitants: 13.000 PE
- Number of houses: 2.000
- Water consumption: 300 l/PE/d
- Length of the vacuum network: 22 km
- Number of collection chambers: 402
- Number of vessels: 3 x 25 m³
- Type of vacuum pumps: 12 x 15 kW
- Type of discharge pumps: 2 x 22 kW

Asia
Kg Lumut, Brunei



- **Technical data:**
- Number of inhabitants: 3.000 PE
- Water consumption: 350 l/PE/d
- Length of the vacuum network: 8.2 km
- Number of collection chambers: 164
- Number of vessels: 2 x 10 m³
- Type of vacuum pumps: 3 x 15 kW
- Type of discharge pumps: 2 x 9 kW
- Start-up: May 2011

Africa
Shoshong, Botswana



- **Technical data:**
- Number of inhabitants: 8.000 PE
- Total length of the network: 55 km
- Number of collection chambers: 550
- Number of VS: 2
- Number of vessels: 2 x 7m³ at each VS
- Type of vacuum pumps: 3 x 5.5 kW at each VS

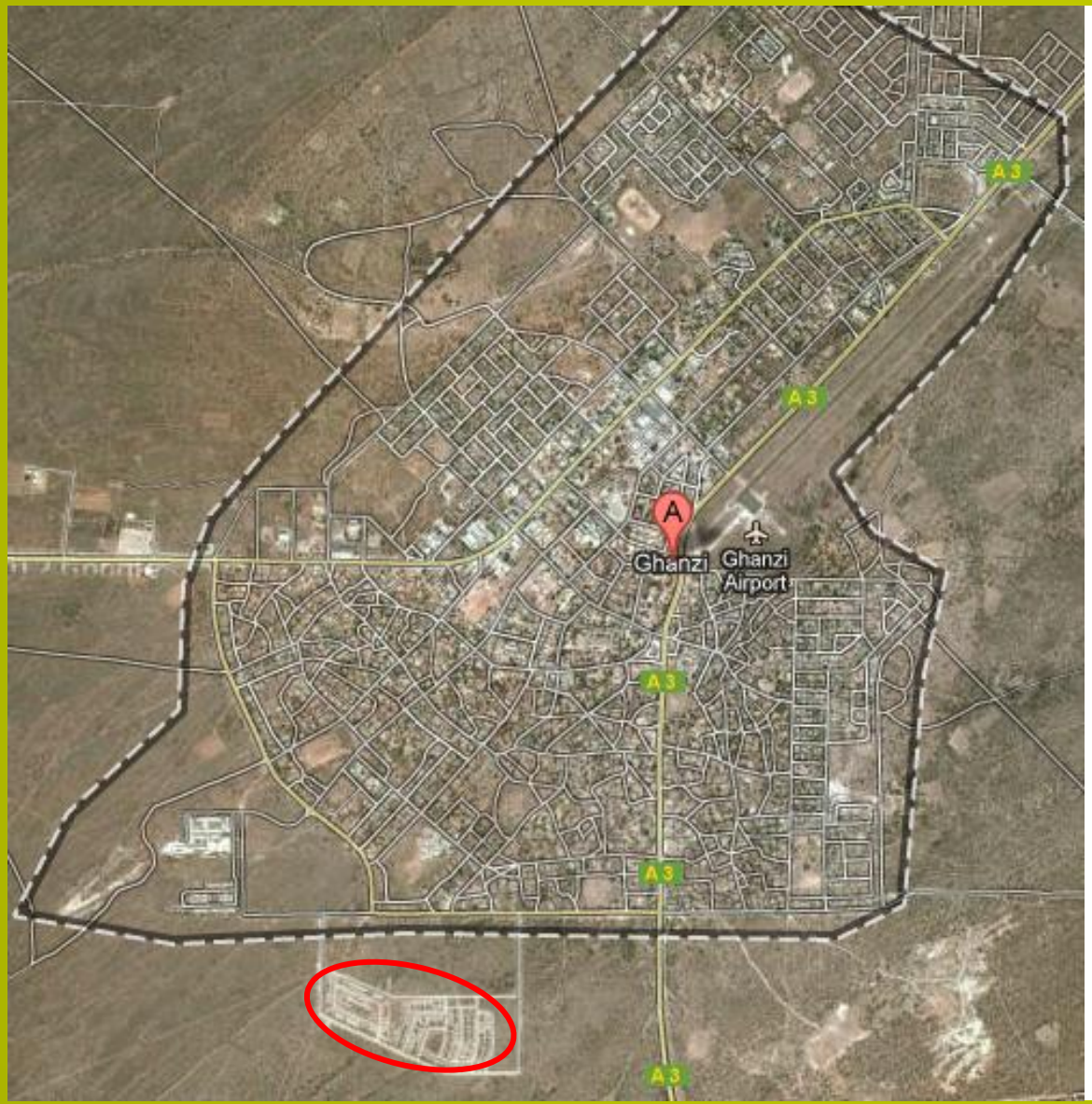
Africa
Good Hope, Botswana

- **Technical data:**
- Number of inhabitants: 1.500 PE
- Water consumption: 150 l/PE/d
- Total length of the network: 11.300 km
- Number of collection chambers: 400
- Number of vessels: 2 x 7m³
- Type of vacuum pumps: 3 x 5.5 kW
- Type of discharge pumps: 2 x 9.2 kW
- Start-up: October 2010

Africa
Jwaneng unit 8, Botswana

- **Technical data:**
- Number of inhabitants: 1.050 plots
- Total length of the network: 16 km
- Number of collection chambers: 350
- Number of vessels: 2 x 10m³
- Type of vacuum pumps: 4 x 7.5 kW
- Type of discharge pumps: 2 x 7.5 kW
- Start-up: spring 2010
- Construction time: 1 year

Africa
Ghanzi, Botswana



- **Technical data:**
- Number of inhabitants: 864 PE
- Total length of the network: 2.6 km
- Number of collection chambers: 75
- Number of vessels: 1 x 7 m³
- Type of vacuum pumps: 2 x 5.5 kW
- Type of discharge pumps: 2 x 7.5 kW

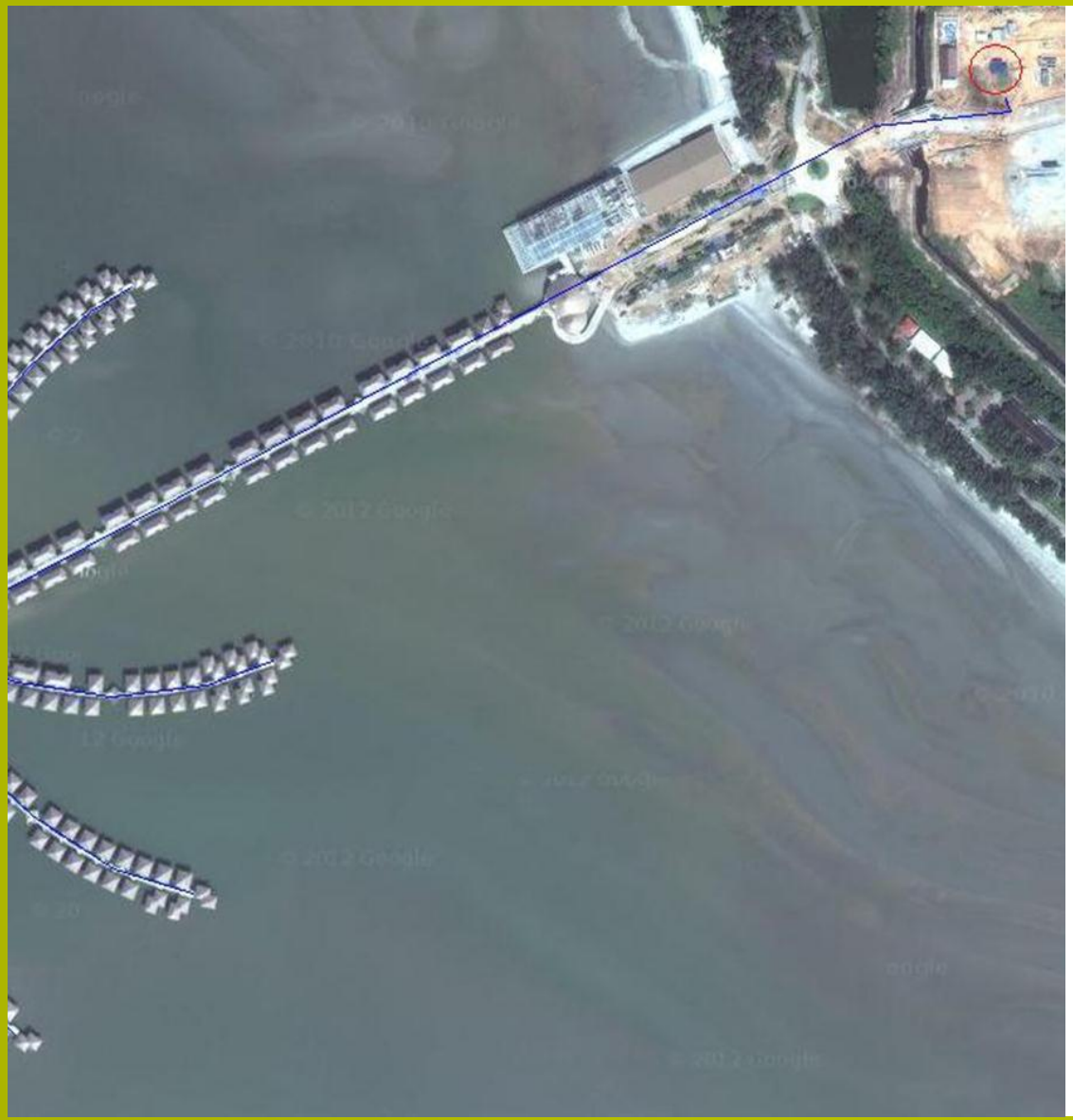
Africa
Kosovo-Township, Cape Town, South Africa

- **Technical data:**
- Number of inhabitants: 6.700 PE
- Water consumption: 50 l/PE/d
- Length of the vacuum network: 3.5 km
- Number of collection chambers: 148
- Number of vessels: 1 x 16 m³
- Type of vacuum pumps: 3 x 5.5 kW
- Type of discharge pumps: 2 x 4.7 kW
- Modular vacuum station

Africa
Buena Vista, parcel A, Nigeria

- **Technical data:**
- Number of inhabitants: 2.085 PE
- Water consumption: 180 l/PE/d
- Total length of the network: 4.0 km
- Number of collection chambers: 60
- Number of vessels: 1 x 16 m³
- Type of vacuum pumps: 4 x 5.5 kW
- Type of discharge pumps: 2 x 4.2 kW

Asia
Sepang Gold Coast , Malaysia

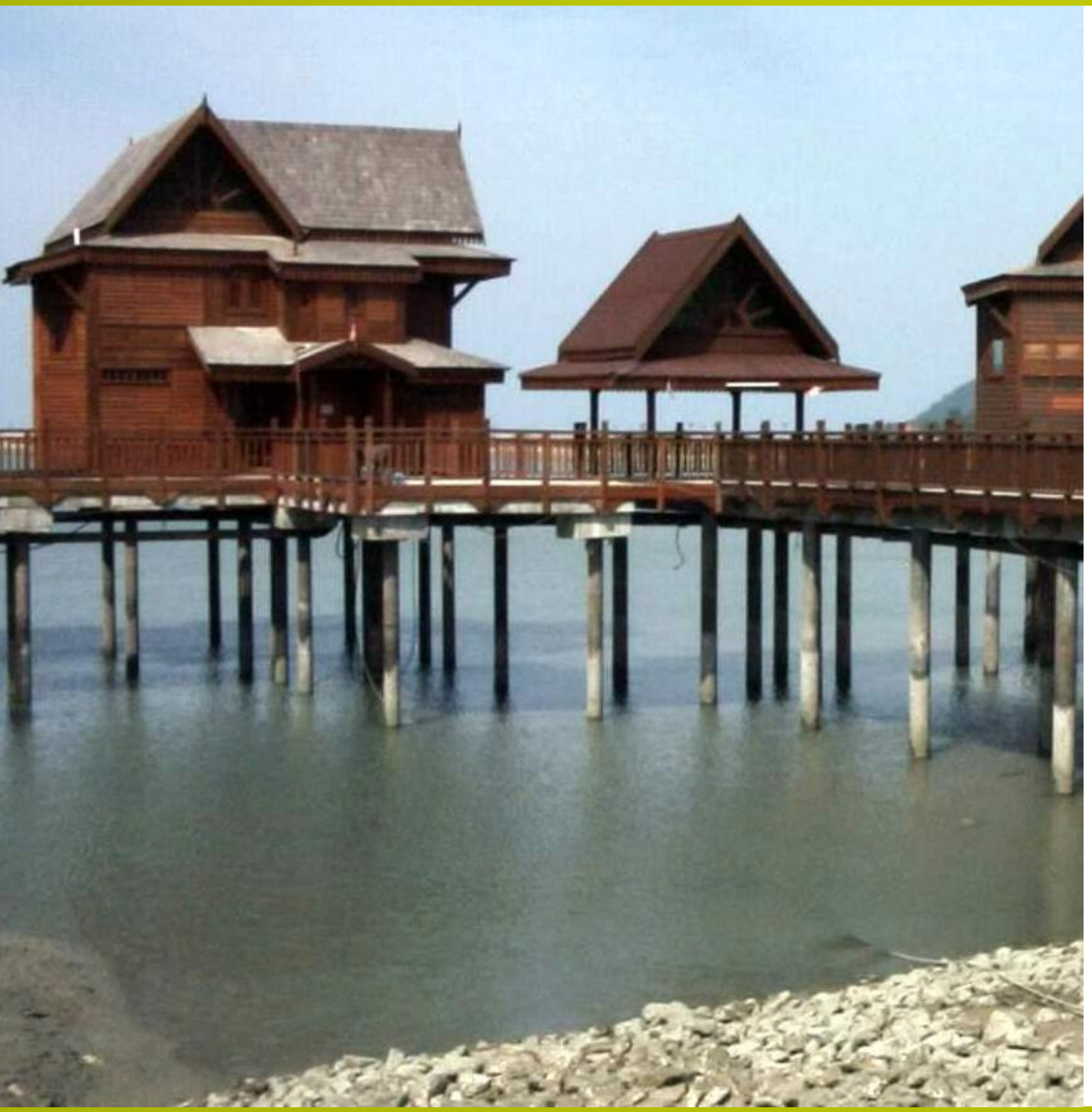


- **Technical data:**
- Number of inhabitants: 5.500 PE (phase 1)
- Vacuum network length: 6 km
- Number of collection chambers: 78
- Number of vessels: 2 x 23 m³
- Type of vacuum pumps: 4 x 15 kW
- Type of discharge pumps: 2 x 13.5 kW
- Discharge point: app. 50 m

Asia
Landaa Giraavaru, Maldives

- **Technical data:**
- Number of inhabitants: 2.000 PE
- Vacuum network length: 3 km
- Number of collection chambers:
  - G65 with single valves: 46 units
  - G65 with double valves: 3 units
  - Water villa chambers with 2“ valve: 56 units
- Number of vessels: 1 x 16 m³
- Type of vacuum pumps: 3 x 5.5 kW
- Type of discharge pumps: 2 x 4.7 kW

Asia
Langkawi, Malaysia



- **Technical data:**
- Number of inhabitants: 700 PE
- vacuum network length: 3 km
- Number of collection chambers: 30 units
- Number of vessels: 1 x 20 m^3
- Type of vacuum pumps: 2 x 15 kW
- Type of discharge pumps: 2 x 4.7 kW

Asia
Jimah power station, Malaysia

- **Technical data:**
- Peak flow: 1.85 l/s
- Total length of the vacuum network: 1.000 m
- Number of collection chambers: 8
- Number of vessels: 1 x 5 m³
- Type of vacuum pumps: 2 x 4.0 kW
- Type of discharge pumps: 2 x 3.0 kW, dry-mounted

Middle East
Occidental Worker‘s Camp, Oman

- **Technical data:**
- Number of inhabitants: 5.000 PE
- Number of collection chambers: 127
- Number of vessels: 1 x 25 m³
- Type of vacuum pumps: 4 x 15 kW
- Type of discharge pumps: 3 x 9 kW

Middle East

Yas island Formula 1 race track, Abu Dhabi

- **Technical data:**
- Total amount of visitors: up to 60.000 PE
- Length of the vacuum network: 20 km
- Number of collection chambers: 127
- Number of vessels: 2 x 20 m³
- Type of vacuum pumps: 6 x 15 kW
- Type of discharge pumps: 2 x 22 kW, dry-mounted

Bilfinger Water Technologies

Water Management for Hotels/Resorts and Coastal Areas Resources Saving – Sustainable Application

Facts about Water and Tourism

- **Only 1% of the entire water stocks on Earth is fresh water**
- **With increasing population and industrial growth, fresh water is getting even more scarce**
- **Wastewater is increasingly considered as a resource**
- **Tourism sector accounts for about 5-10% of the world economy and of global employment, it is growing faster than GDP and doubling in size every decade (*ITB World Travel Trends Report 2011/2012*)**
- **There was 1 billion international tourist arrivals in 2012 (*UNWTO*)**

There is a need to decrease the pressure of tourism on water consumption and discharge of wastewater !

Water Management Challenges facing Hotel/Resort Projects

High Water Consumption:

- Specific water consumption at hotels and resorts is high in the range of 300 to 1,300 l/person per night. Water heating alone requires 3-6 kWh/person per night
- Limits development or expansion potential of hotel
- Can lead to significant operating costs for potable water supply and wastewater treatment
- Environmental costs (decreasing fresh water resources, wastewater discharge to environment)

Wastewater Treatment:

- Increasing environmental standards worldwide has created a need for on-site wastewater treatment at many hotels
- Increasing costs for off-site wastewater treatment

Increasing Water/Wastewater Tariffs:

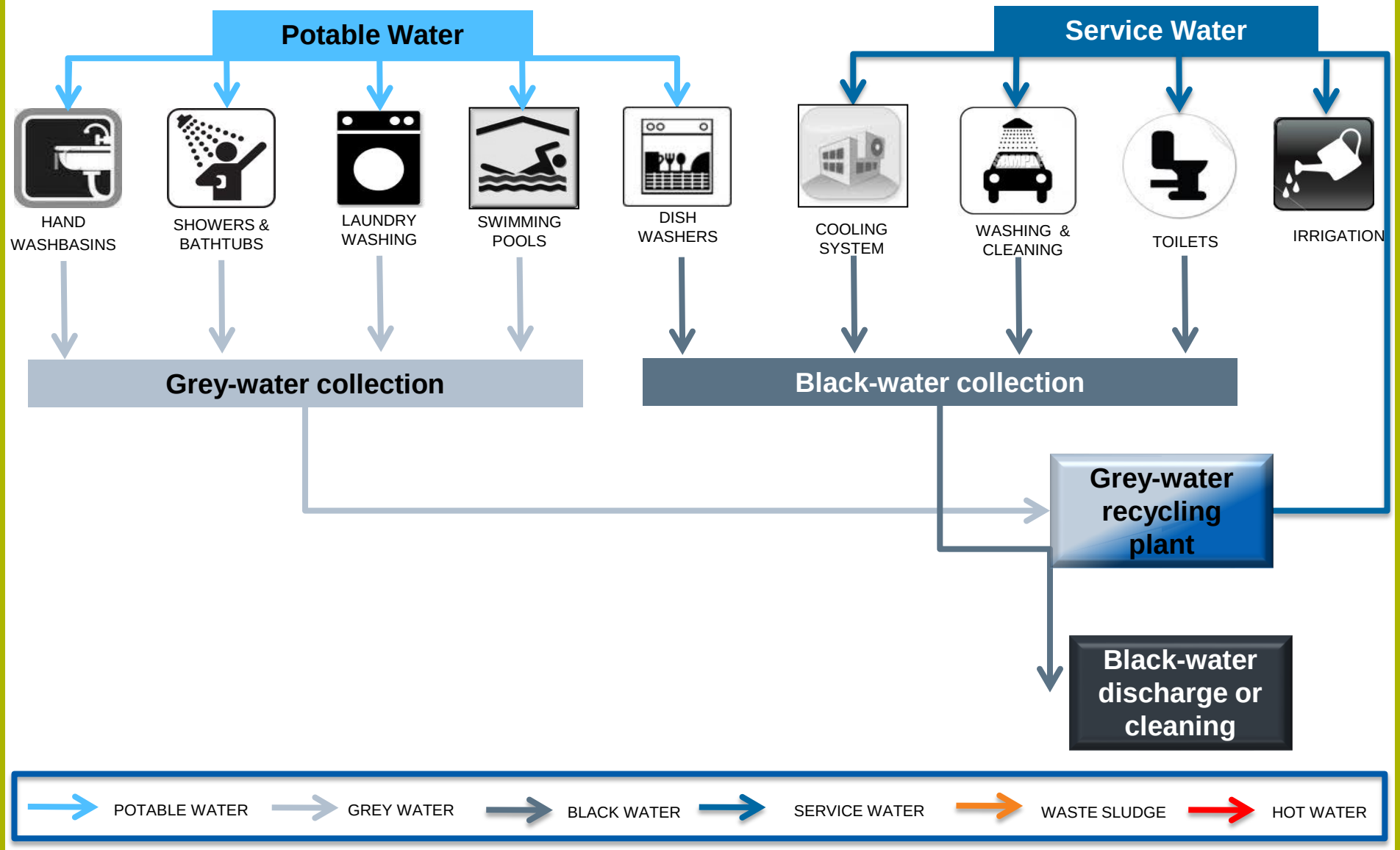
- Water scarcity leads to rising water tariffs due to production of water from lower quality water, which requires higher investment and operating costs (e.g. reverse osmosis desalination)
- Water and wastewater tariff increases due to increasing cost of energy, especially for energy intensive water desalination systems

Sustainable Development:

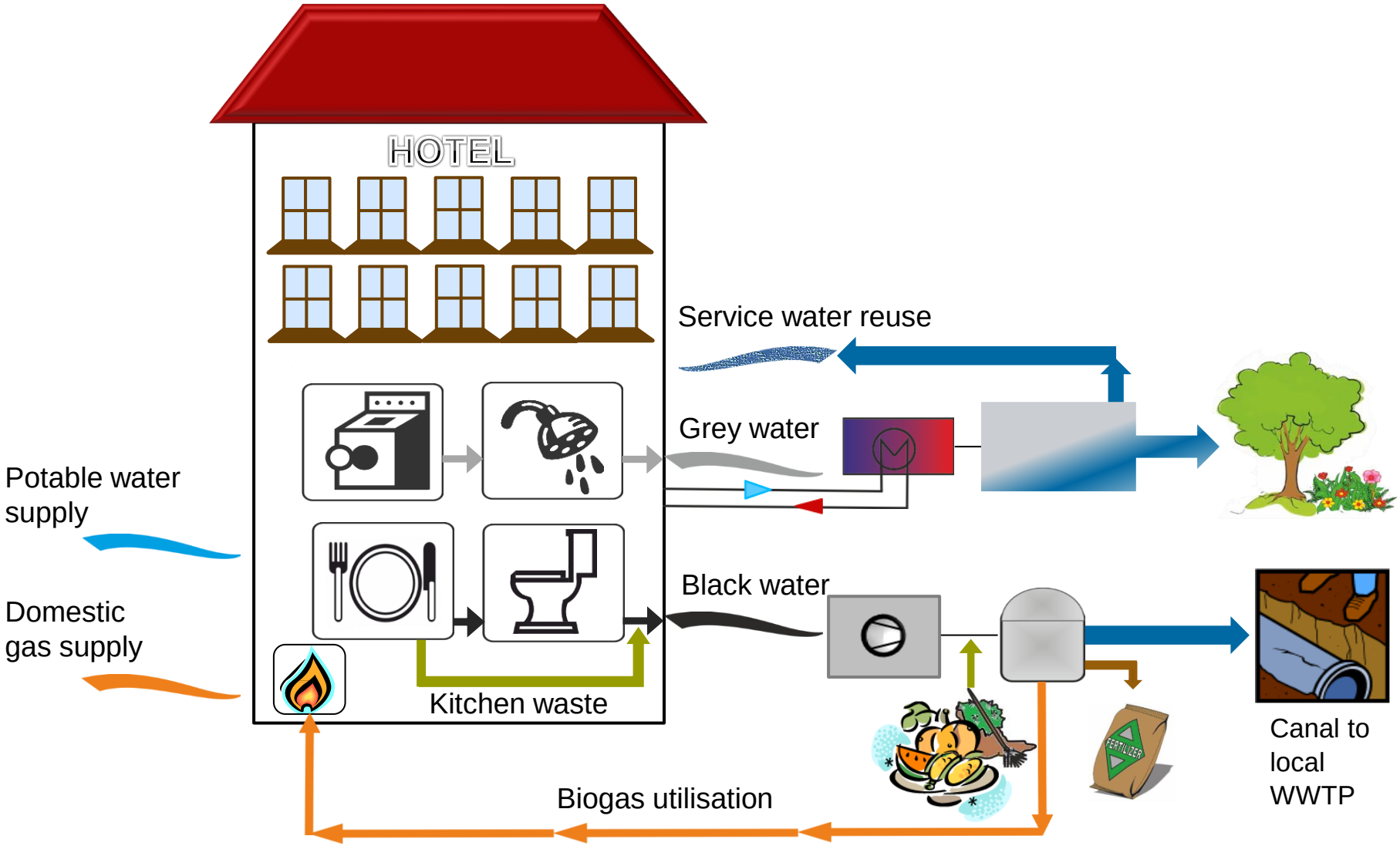
- Increasing pressure for Triple Bottom Line (TBL) approach to achieving company growth i.e. people, planet, profit
- Reduction in greenhouse gas emissions, water consumption, waste production are subject to sustainability principles of green tourism certification systems

Make Wise Use of Your Water

Separation Enables the Exploitation of Resources in Sanitation



Eco Park Solution

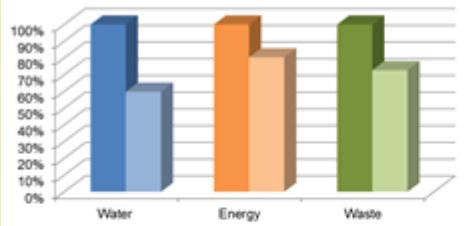


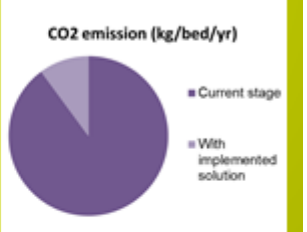
The Filled-in Questionnaire Serves As Basis For Mass & Energy Balance And Budget Cost Estimation For Hotel/Resorts Projects

Input Data	Value	Unit	Value	Unit
Basic data				
Year of data collection				
Country				
City or locality				
Name of hotel				
Number of guest beds		beds		
Occupancy		%		
Hotel closes in winter		yes/no		months/yr
Technically skilled personnel in house		yes/no		
Hotel specific water consumption data				
Toilet flushing				
Number of toilets connected				
Toilet water consumption per flush conventional		l/flush		
Toilet water consumption per flush vacuum		l/flush		
Number of flushes per bednight				
Specific water consumption for toilet flushing conventional		l/bed night		m^3/d
Specific water consumption for toilet flushing vacuum		l/bed night		m^3/d
Irrigation				
Irrigated green area		m^2		
Specific application rate		l/m^2 d		l/m^2 yr
Irrigation water from drinking water		yes/no		
Irrigation water from ground water or other source		yes/no		
Irrigation water consumption from ground water		m^3/yr		m^3/d
Specific water consumption for irrigation		l/bed night		m^3/d

Particular saving potential in Your hotel by implementing "Eco Park" solution

	€/yr	€/bed/yr
Investment	839,210.00	1,678.42
Operation and maintenance expenses	44,606.86	89.81
Financial savings	257,178.38	514.38
- Fresh water costs savings from grey water reuse (toilet + irrigation)	105,981.25	211.96
- Waste water costs savings from grey water reuse	63,588.75	127.18
- Grey water heat recovery	29,137.34	58.27
- Savings calorific value of biogas production	11,375.35	22.75
- Savings from solid waste disposal (kitchen waste, green area)	47,096.67	94.19
ROI		**4.4 years**





	Current stage (per bed/day)	With implemented solution (per bed/day)	%
Water	577 l	345 l	-40.2%
Energy	1,400 kWh	1,126 kWh	-19.8%
Waste	2 kg	1.45 kg	-27.8%

	Current stage (per bed/yr)	With implemented solution (per bed/yr)
CO_2 emission	12 kg	10.65 kg (-1.35 kg)

Roediger® Systems/Components

Sustainable Urban Water Management Systems

Principle of Grey Water Treatment
From Grey-Water to Service Water

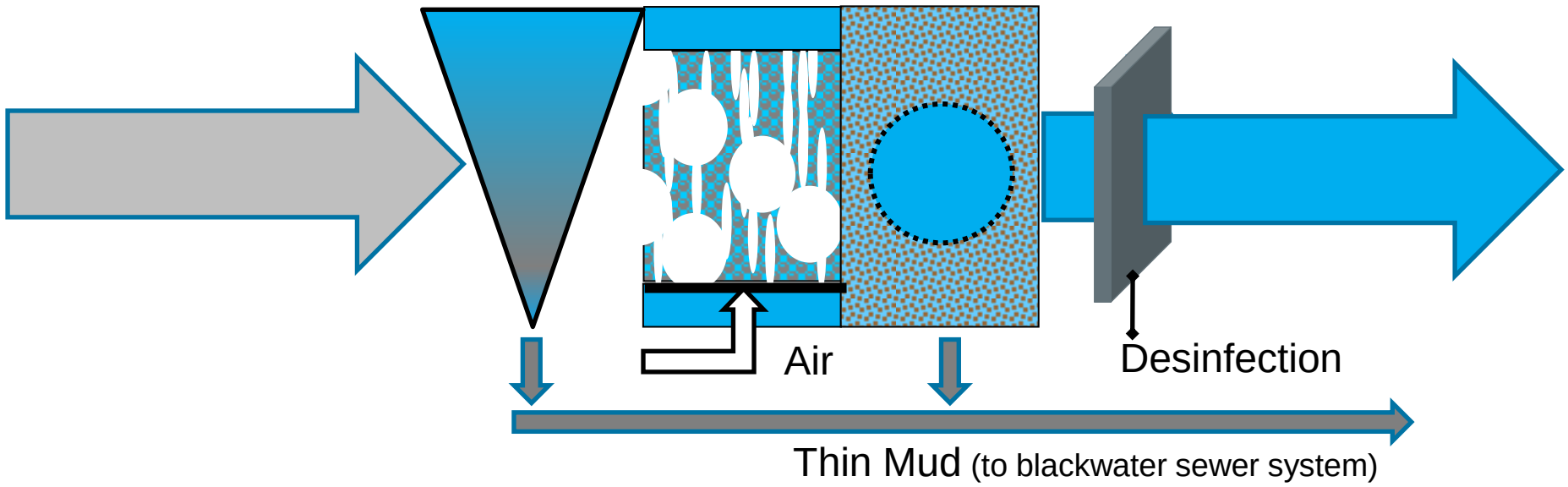
Grey Water

15-30% Solids
15-20% Organics
<0,1% Coliforms

Buffer Screen/Sed.	Biological Contactor	Mechanical Filtration

Service Water

Visually clear
Biologically stable
≤ Bathwater quality



Energy Recovery From Hot Water

- Hot water generation consumes approx. 21 kWh/m³ (Germany) and is the largest energy consumer of a household after general heating.
  - 17 % of power consumption
  - 14 % of methane consumption (BDEW 2008)
- The hot waste-water from shower etc. is usually directly discharged into the sewer line and foregoes a potential recovery.

Option:

Heat recovery from shower, bathroom, washing machine and dish-washer by using a heat exchanger system.

Recovery potential > 50% !

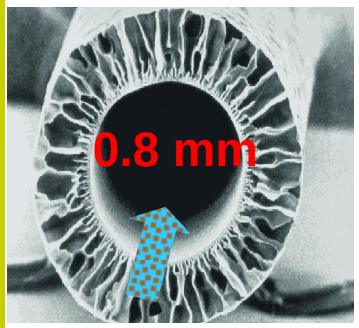
Roediger® Membrane Bio Reactor & Hollow Fibre Systems

System MBR (Membrane Bio Reactor)

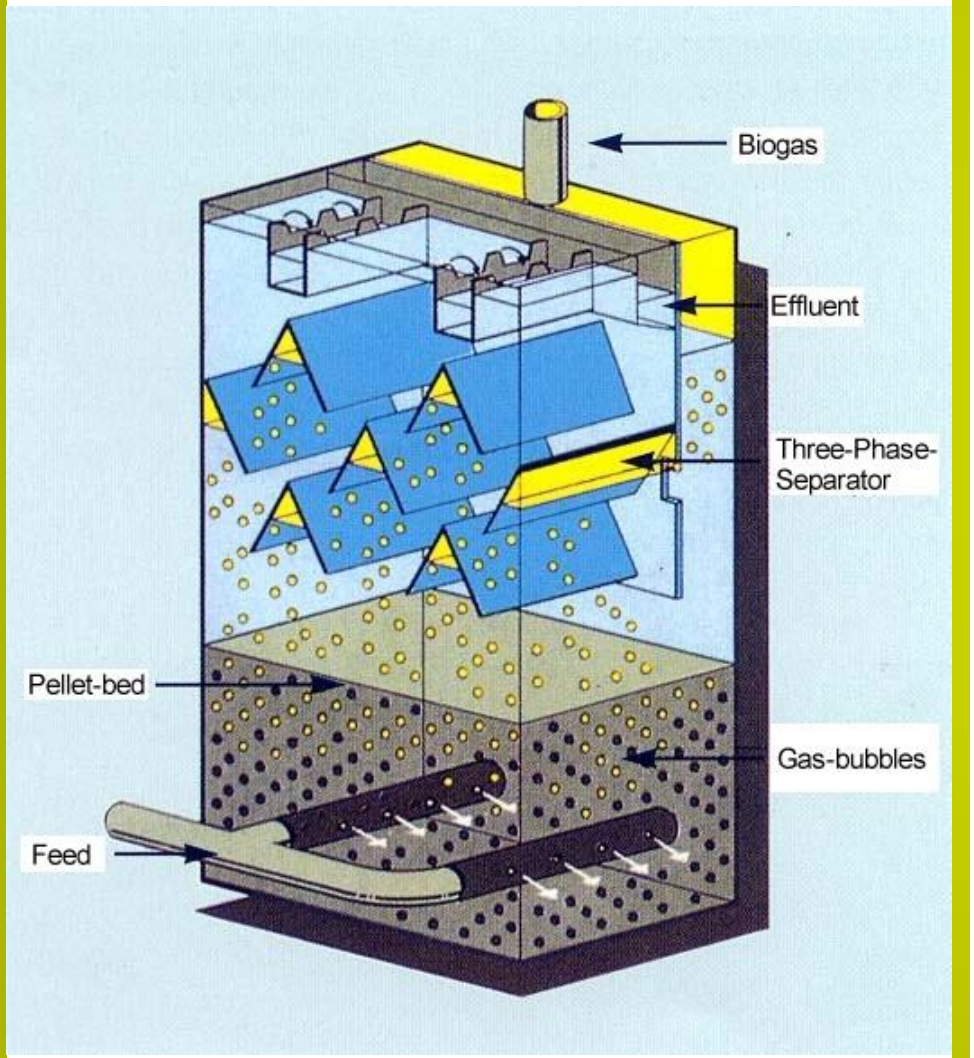
- Submerged low-rate filtration system
- Combines biological activated sludge treatment with final ultra filtration
- Requires up-stream mechanical or UASB pre-treatment

System HF10 (Hollow Fibre)

- Pressurized high-rate filtration system
- Used as final treatment with ultra filtration
- Requires up-stream biological-mechanical pre-cleaning



ROEDIGER® UASB Reactor (Upflow Anaerobic Sludge Blanket)



Application

- Proven and reliable technology for anaerobic primary treatment of wastewater.
- Wastewater can also contain grinded kitchen waste.
- Suitable for concentrated wastewater and preferably for av. water temperatures of >15°C, ideal >20 °C.
- Effluent wastewater provides reduced loading to secondary treatment and saves aeration energy.
- Separated sludge is very suitable for final digestion.

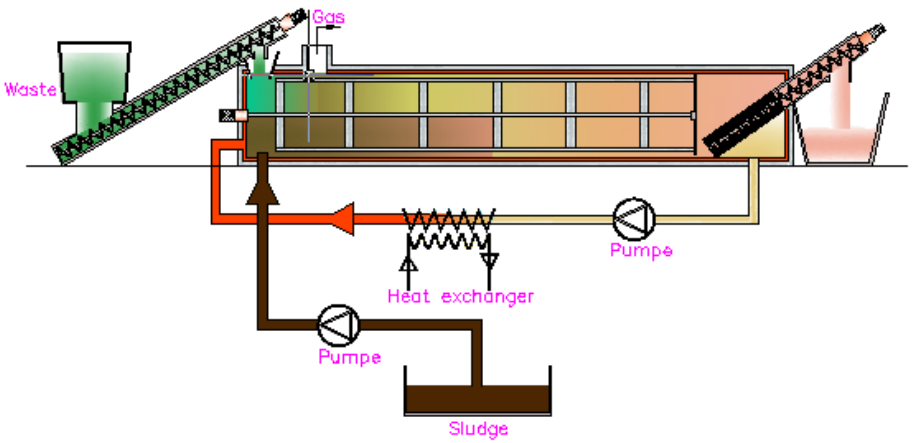
Process Characteristics

- **U**pflow **A**naerobic **S**ludge **B**lanket reactor.
- Simultaneous three-phase separation of generated biogas, pre-treated wastewater and grown/settled sludge.
- Dual solid and hydraulic (liquid) retention time.
- High organic loading capacity (up to10kg COD/m^3/day)
- No heating required. High-efficient, low volume and low energy consuming bio reaction process.

ROEDIGER® Hybrid Fermentation For Sludge & Biomass

Application

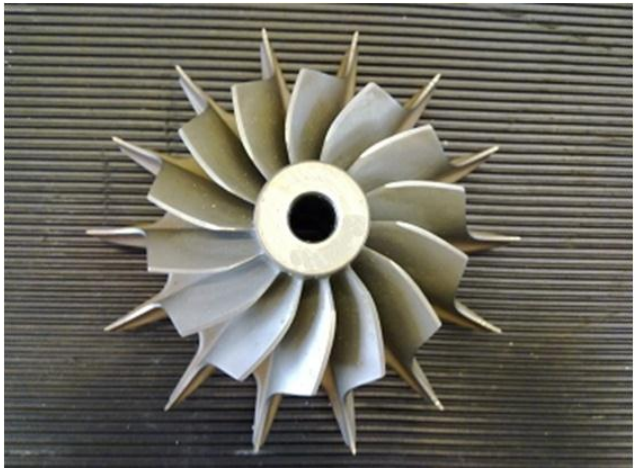
- Co-fermentation of fluid and solid matter.
- Fluid matter shall be rich in organic content like black water, primary or UASB sludge, secondary sludge, manure.
- Solid matter shall be low-ligneous biomass like food leftover, kitchen waste, waste from food industry, lawn-clippings.
- Flexible input between fluid/solid matter.
- Output is fermented and stabilized digestate and thin sludge, which can both be used in agriculture for fertilization.



Process Characteristics

- Simultaneous fluid and solid plug-flow, but decoupled hydraulic (liquid) and solid retention time.
- Common seeding mixer, improved heat and mass transport, combined homogenization and slow agitation,
- Mesophilic and thermophilic digestion applicable according to requirements. Thermophilic secures hygienization.
- Compact containerized solution with separate modules for fermentation and biogas utilization for power generation.
- One fermentation module suits for 500-1000 kg/d bio waste and 2.5 m³/d sludge (5% DS). Several modules can be operated in parallel in connection to one biogas utilization module.

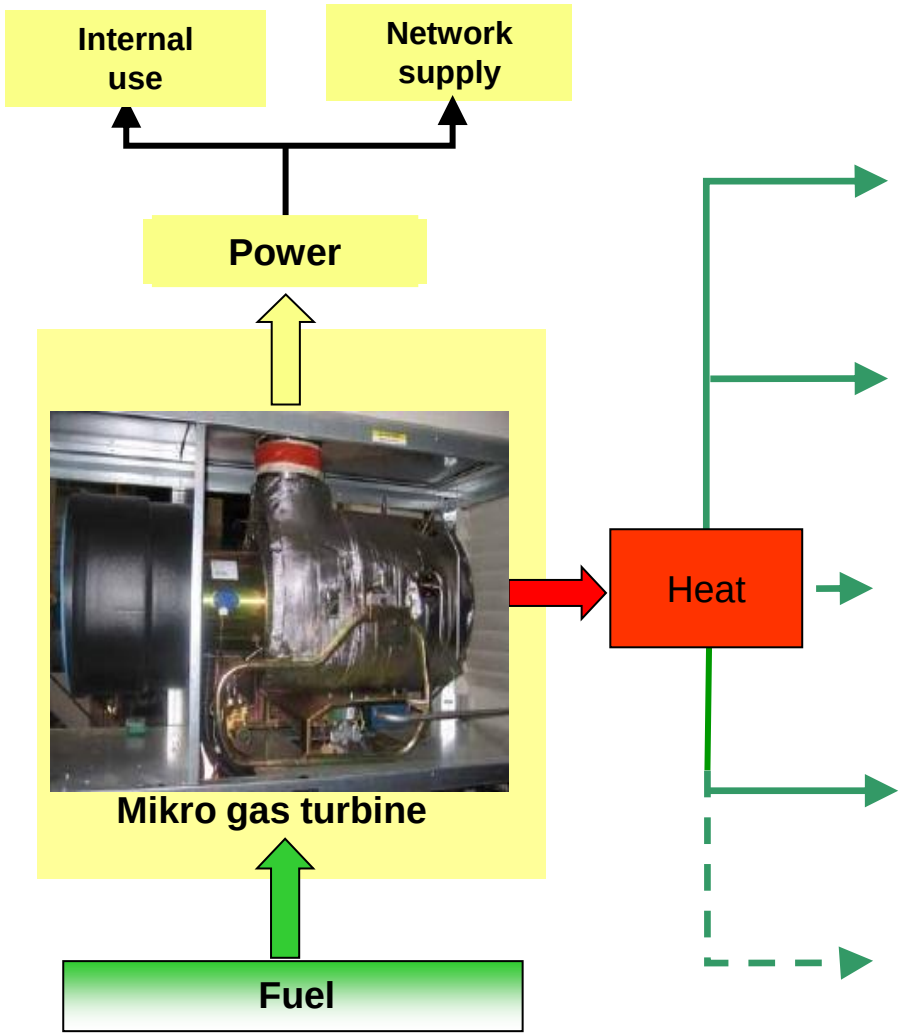
Micro Gas Turbines MGT
Modern Decentralized Energy Generation



- CO_2 Release
- Primary Energy Requirement
- Maintenance Expenses

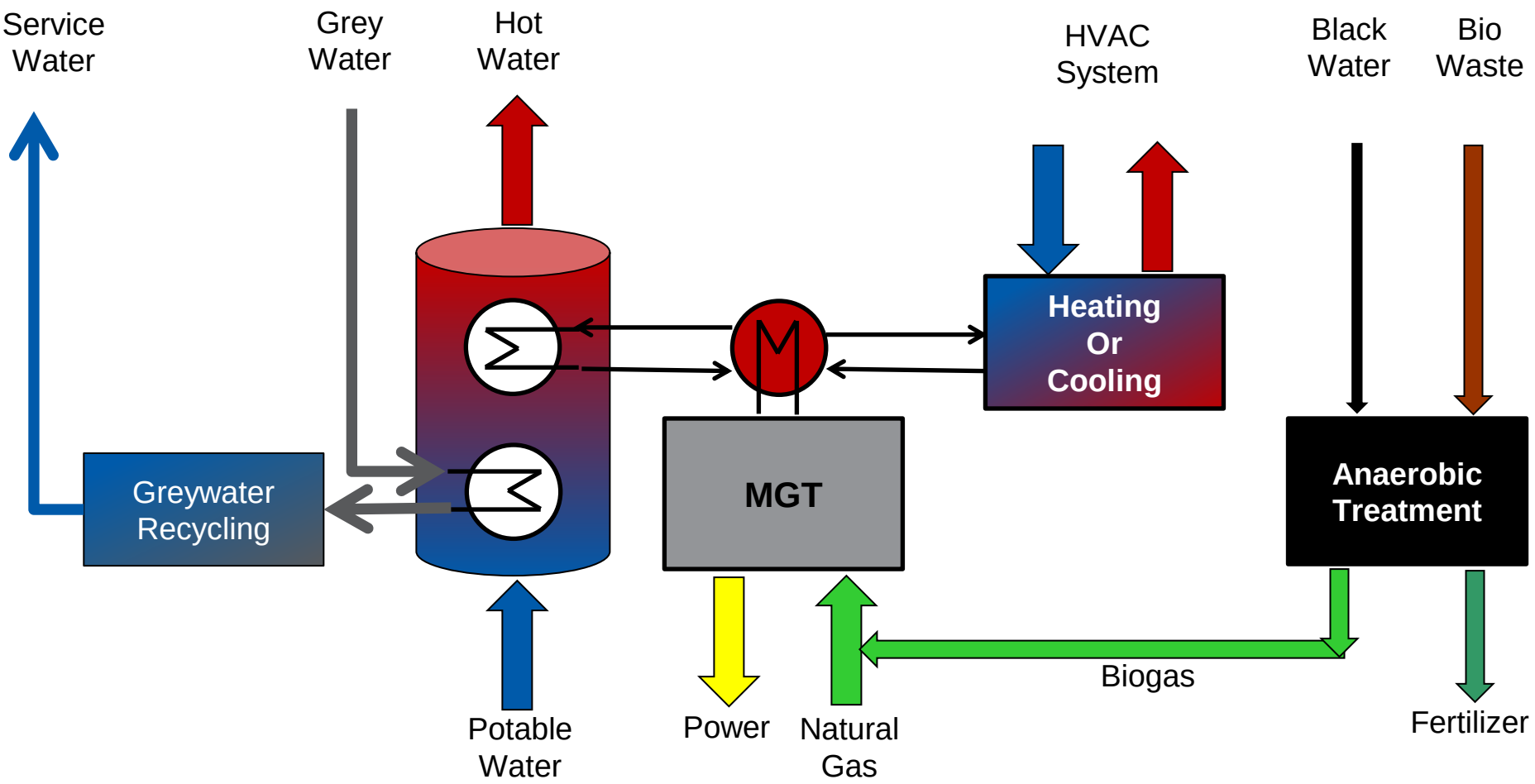
- Energy Efficiency (>85%)
- Increased Lifetime (>100,000 h)
- Flexibility > Fuel/Gas
- Improved Image

Application Of MGT Plants



	Application	Clients
Heating	Supply to building heating system	▪ Agriculture ▪ Hotels/restaurants ▪ Industry ▪ Housing developments
Hot water	Supply to building hot water system	▪ Hotels
Drying	Direct drying by hot offgas	▪ Agriculture ▪ Industry ▪ Sewage plants
Cooling	Heat for absorption refrigeration devices	▪ Super markets ▪ Hotels/restaurants ▪ Computer centers ▪ Housing developments
“Surplus heat using”	Additional power generation using waste heat	▪ Agriculture ▪ Hotels/restaurants ▪ Industry ▪ Housing developments

Decentralized Heating/Cooling System Using Interconnection Synergy



"You're not allowed to use the sprinkler system to keep your audience awake."

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