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Integration of Green Energy and Energy–Efficient Technologies for Wastewater Treatment Plants

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OUTLINES

- 1. Introduction
- 2. Energy–Efficient Technologies for WWTPs
- 3 Green Energy Utilized in WWTPs
- 4. Integration of Green Energy and Energy–Efficient Technologies
- 5. Challenges and Perspectives

1. Introduction

- **1.1 Wastewater Treatment Plants**

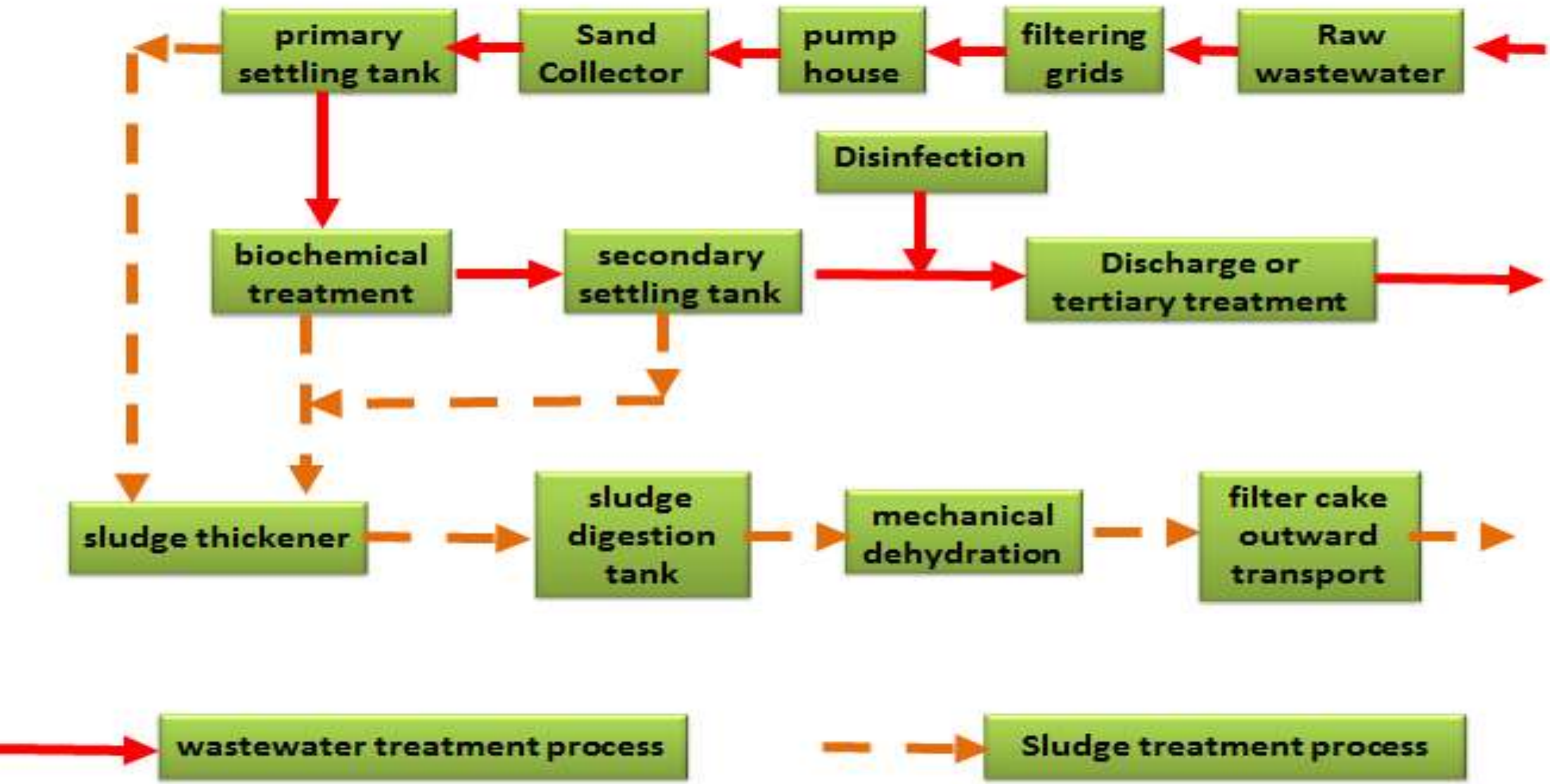
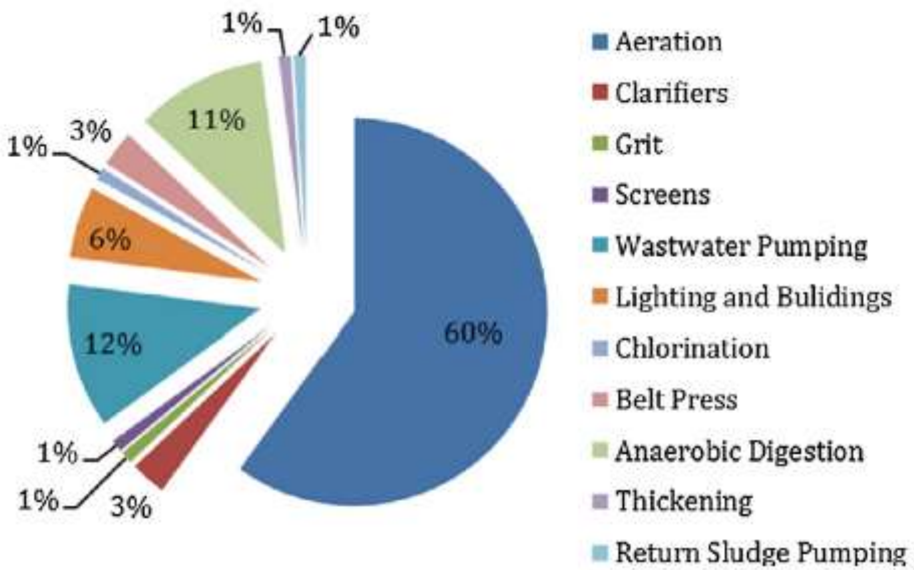


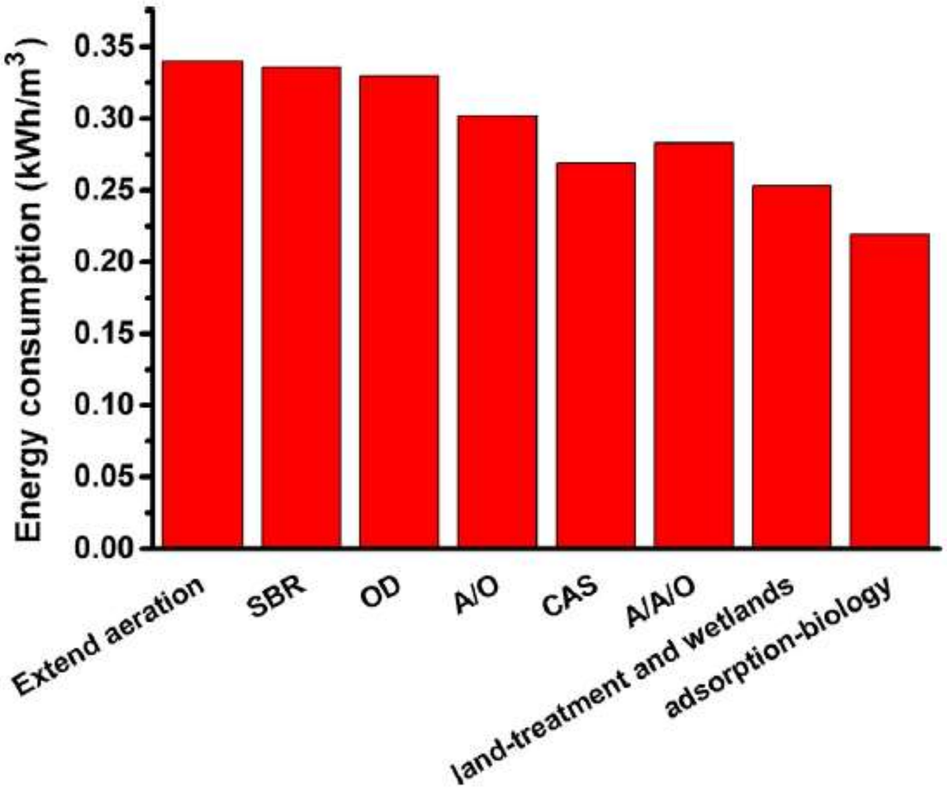
Figure Typical process overview of wastewater treatment plant

1.2 Water Treatment Plants

Figure Energy Intensity of Each Stage In The Water Use Cycle, With Key Opportunities For Energy Efficiency, Renewable Energy, And Water Efficiency.

1.3 Current Energy Consumption in WWTPs





The proportion of energy use associated with different components of a CAS treatment system

Energy consumption of secondary treatment plants with different treatment technologies

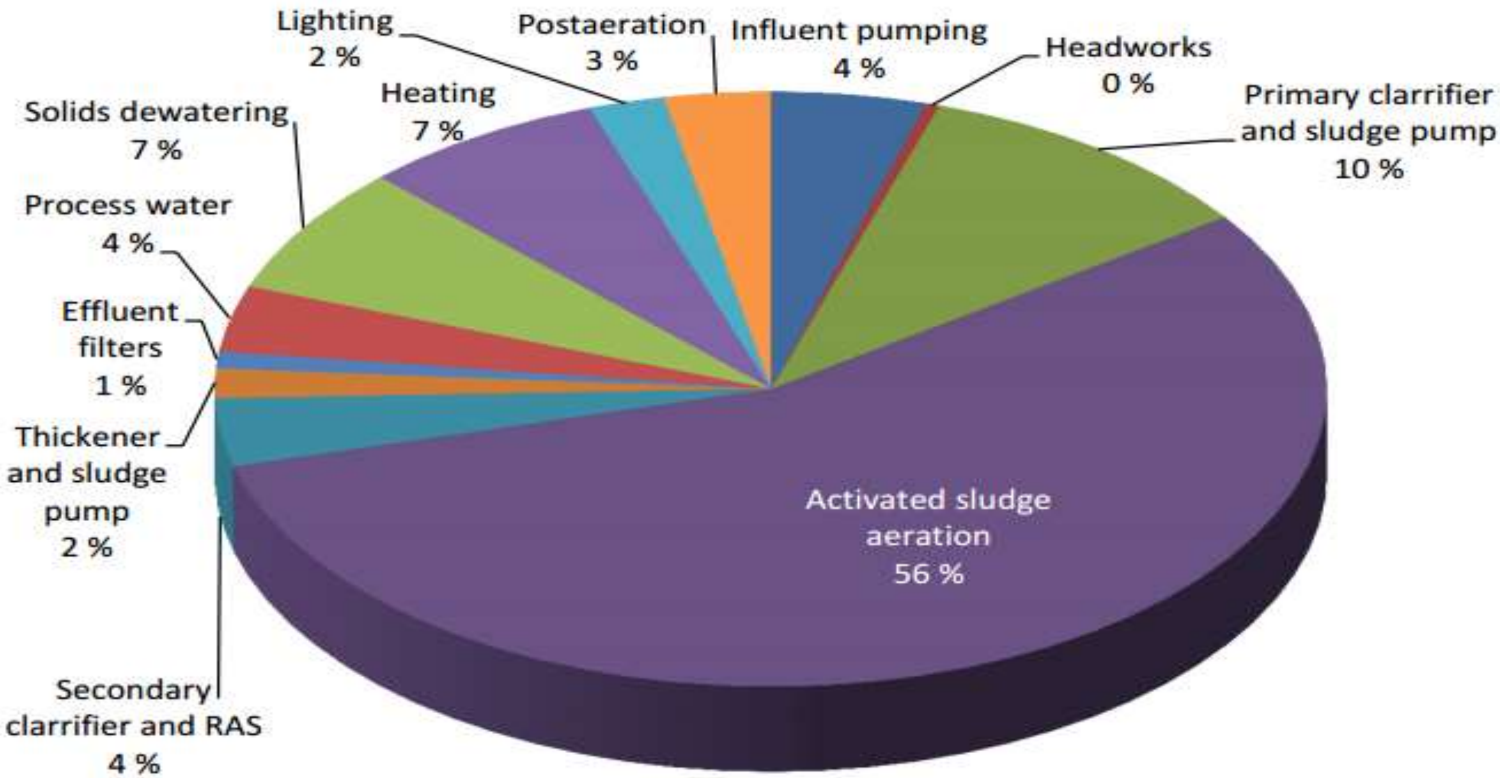


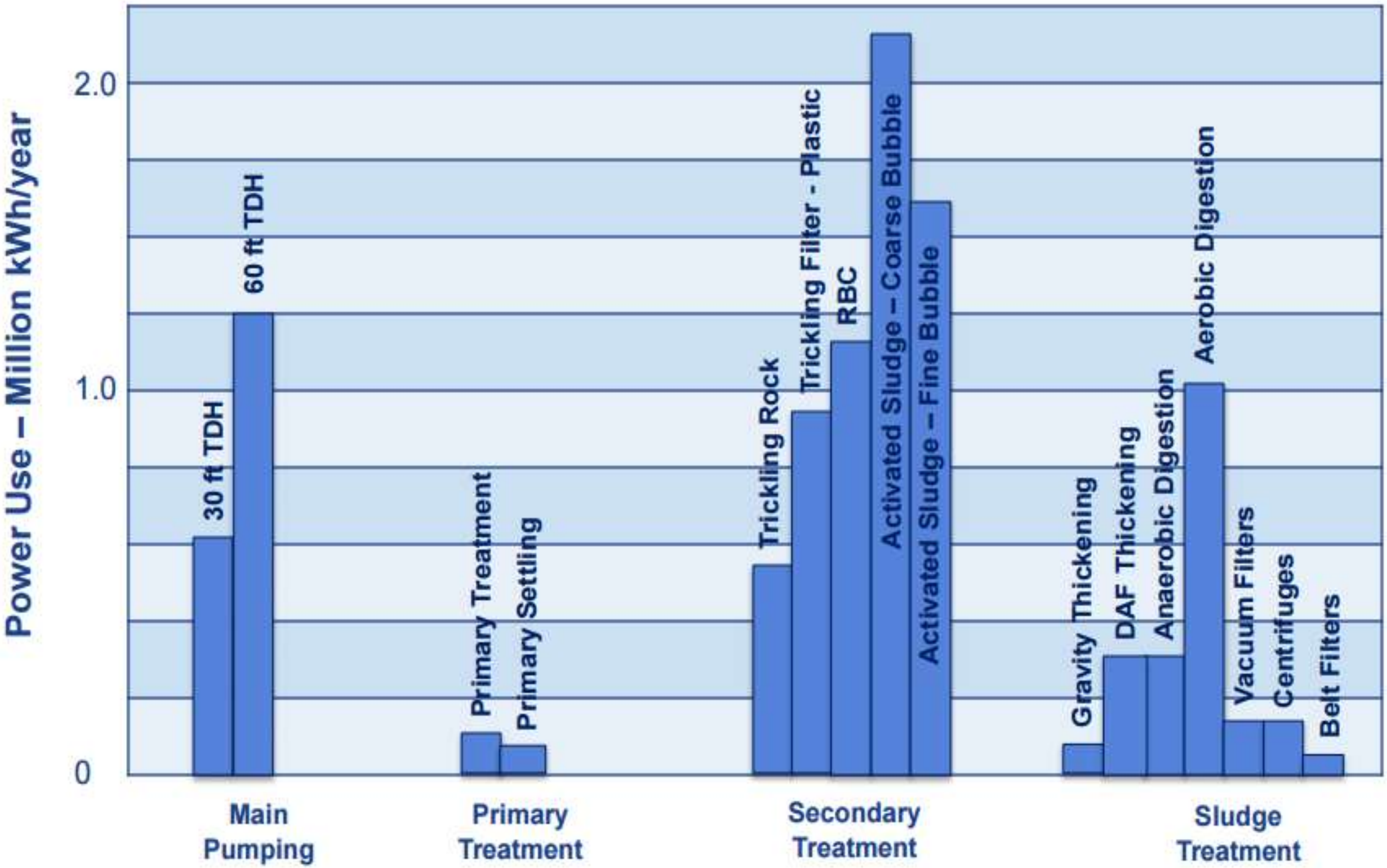
Table 1. The energy intensity proportion and energy consumption in WWTPs at national level in different countries

Regions/Countries	Energy intensity (kWh/m^3)	Proportion of energy consumption national level (%)	Reference
USA	0.52	0.6	[48]
China	0.31	0.25	[48]
Germany	0.40-0.43	0.7	[48]
South Africa	0.079-0.41	-	[48]
Japan	0.304[a]	-	[35]
Korea	0.243	0.5	[49]
Sweden	0.42	1	[50]
Israel	-	10	[50]

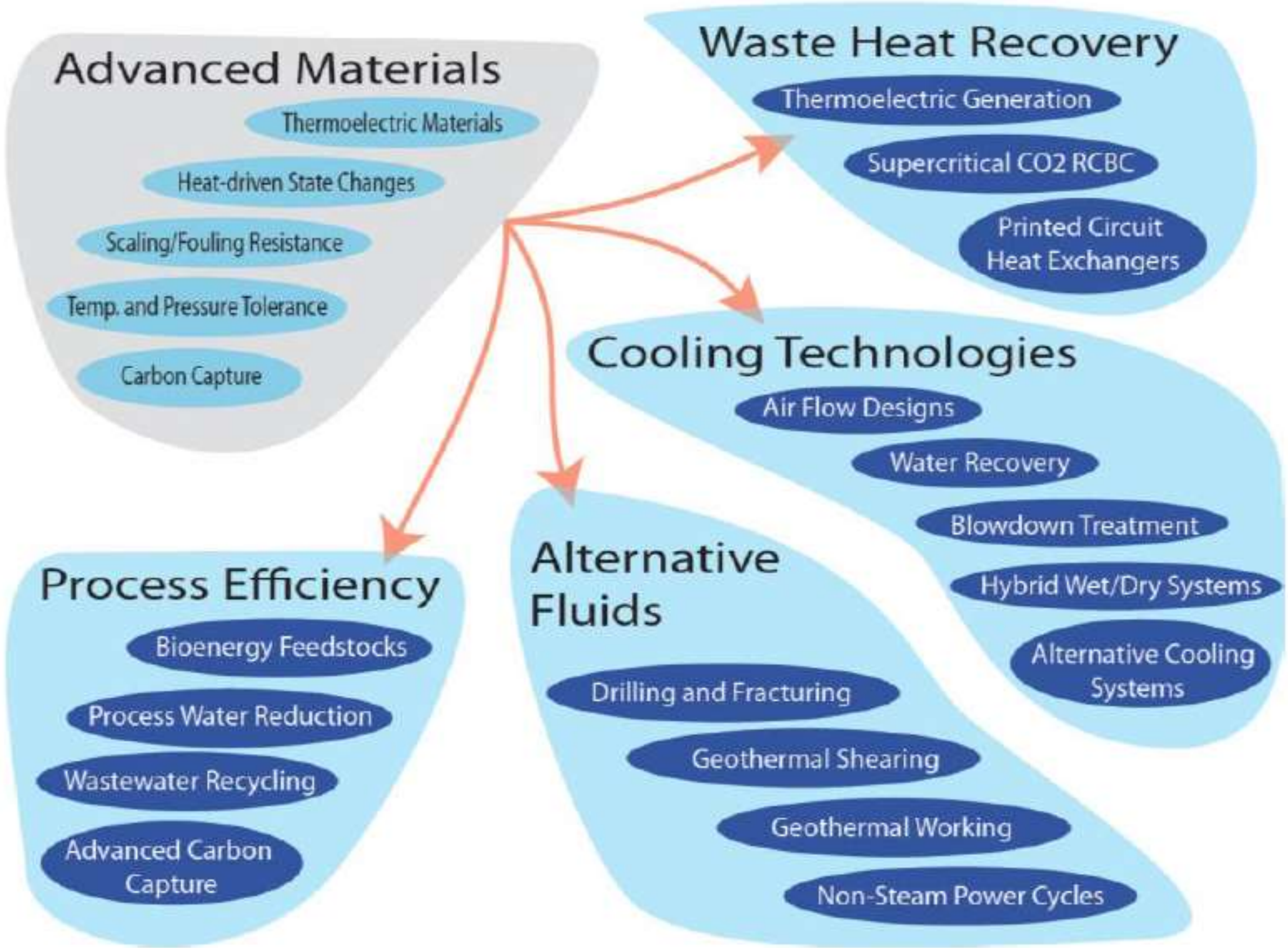
Note: *a* including effluent disinfection and sludge digestions

Typical Energy Use Profile

(for 10-mgd secondary treatment processes)



- **Water for Energy**



Possibilities for efficiency improvements include biofuels production, forest products, food processing, and refining and chemical manufacturing, among others.

Energy For (and From) Water

2. Energy–Efficient Technologies in WWTPs

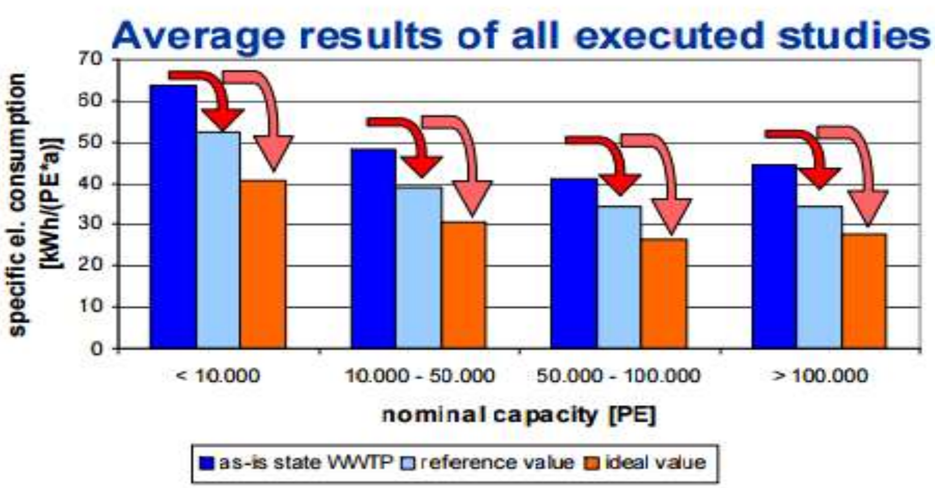
- **2.1 Advanced Energy-efficient Systems**

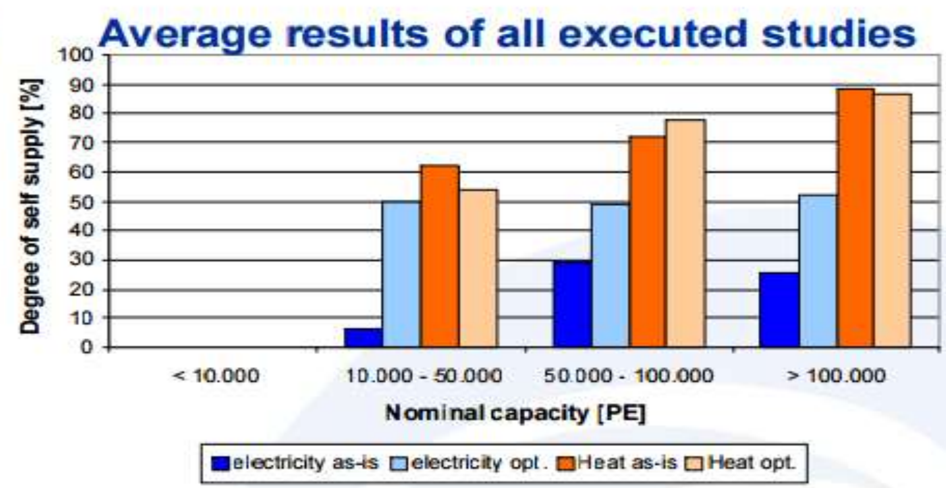
General results

Measures:

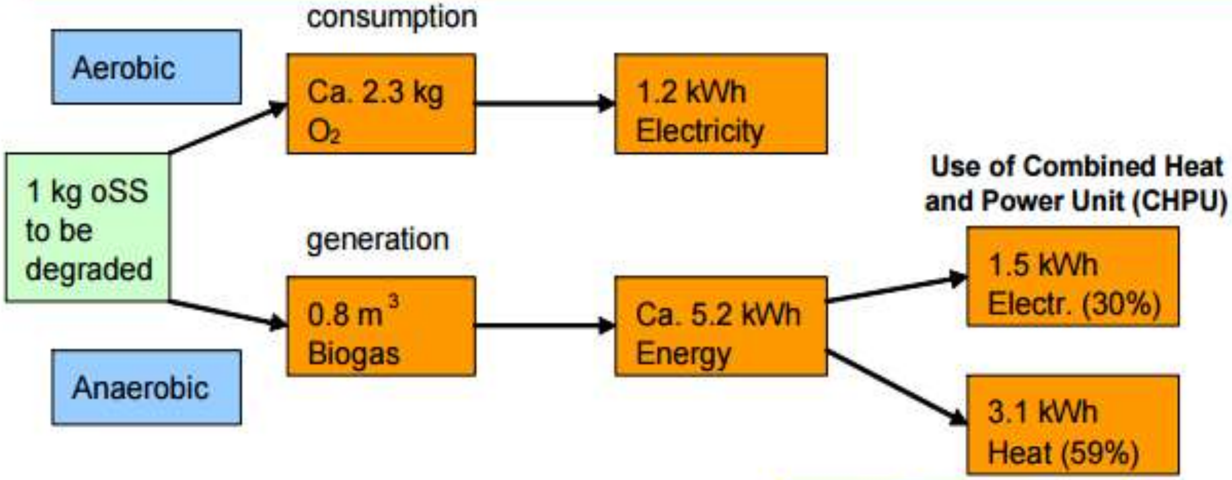
- Reduction of energy consumption
  - Improvement of efficiency of individual units/aggregates
  - Adjustment of the process
  - Optimization of operating methods
  - Adapted measurement and control technology

- Improvement of the degree of self-supply in energy





Recommended measures – Change from aerobic to anaerobic sludge stabilization



Process	Option A Biological BOD, N and P removal	Option B Biological BOD, N and P removal	Option C Biological BOD, N and P removal	Option D Biological BOD, N and P removal
Primary Settling	yes	yes	no	no
Sludge stabilization	no	yes, anaerobic	no	yes, aerobic
Total investment costs				
	15 Mio USD	19 Mio USD	17 Mio USD	18 Mio USD
Effective yearly costs				
Cost of Capital	1,4 Mio USD/a	1,7 Mio USD/a	1,5 Mio USD/a	1,6 Mio USD/a
Energy costs	0,8 Mio USD/a	0,5 Mio USD/a	0,8 Mio USD/a	1,3 Mio USD/a
Personnel costs	0,1 Mio USD/a	0,1 Mio USD/a	0,1 Mio USD/a	0,1 Mio USD/a
Chemical costs	0,4 Mio USD/a	0,4 Mio USD/a	0,5 Mio USD/a	0,3 Mio USD/a
Disposal costs	0,5 Mio USD/a	0,3 Mio USD/a	0,5 Mio USD/a	0,4 Mio USD/a
Maintenance costs	0,2 Mio USD/a	0,2 Mio USD/a	0,2 Mio USD/a	0,2 Mio USD/a
Total yearly costs	**3,4 Mio USD/a**	**3,2 Mio USD/a**	**3,5 Mio USD/a**	**3,8 Mio USD/a**
Ratio	100%	94%	103%	112%

Advanced Energy-Efficient Systems -Aeration

Aeration introduces air into waste water, providing an aerobic environment for microbial degradation of organic matter.

- Supply the required oxygen to the metabolizing microorganisms
- Provide mixing so that the microorganisms come into intimate contact with the dissolved and suspended organic matter.

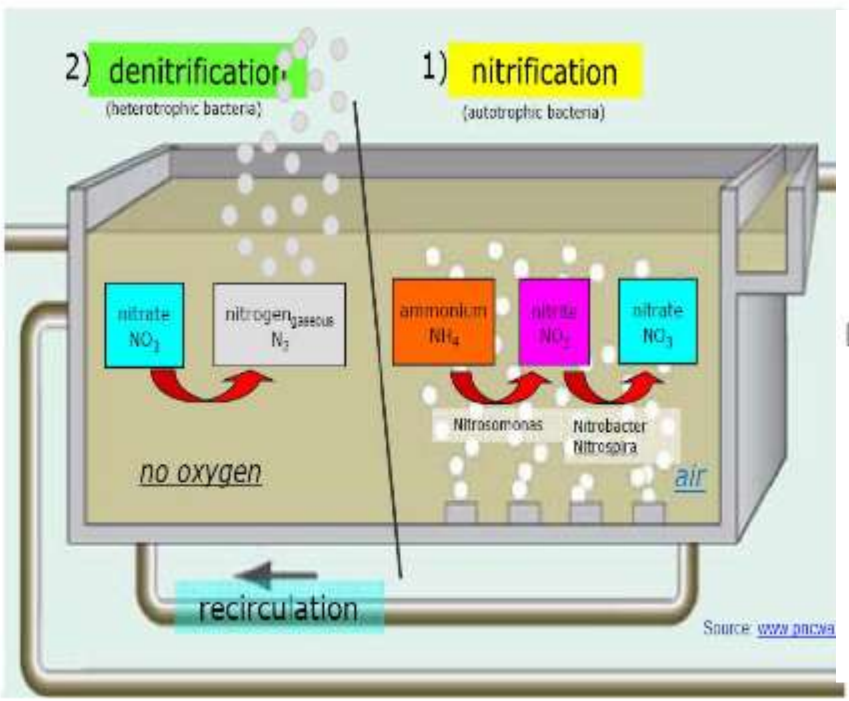
Surface/Mechanical Aeration

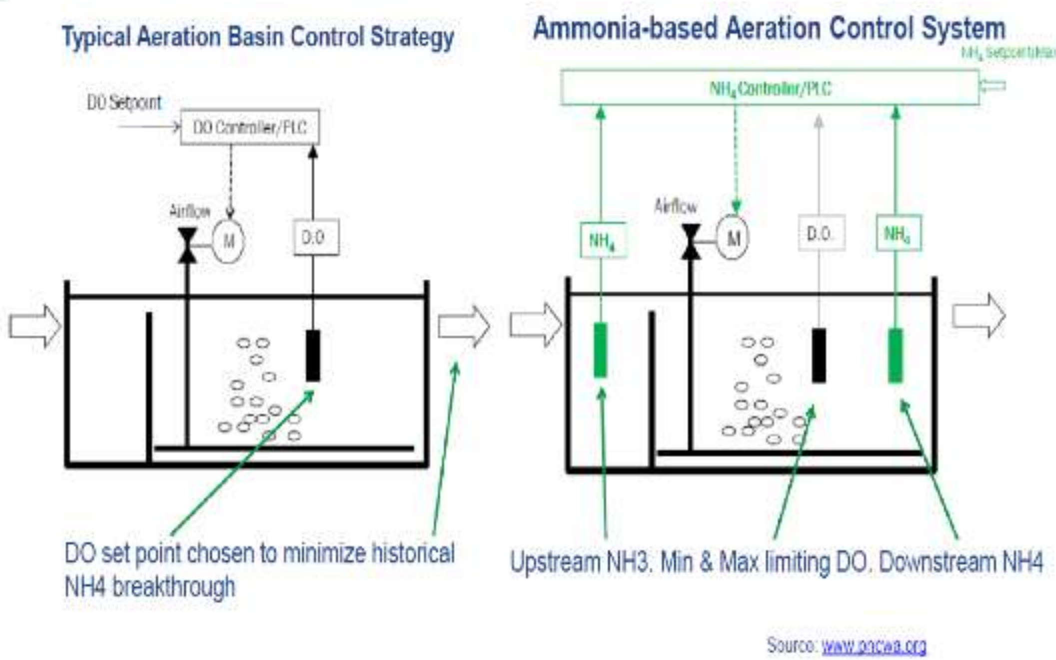
Sub Surface Aeration

Recommended measures – Optimization of Aeration

- Reduction of necessary aeration energy
- Exchange of destroyed aerators

Advanced Energy-Efficient Systems– Biological Nitrogen Removal





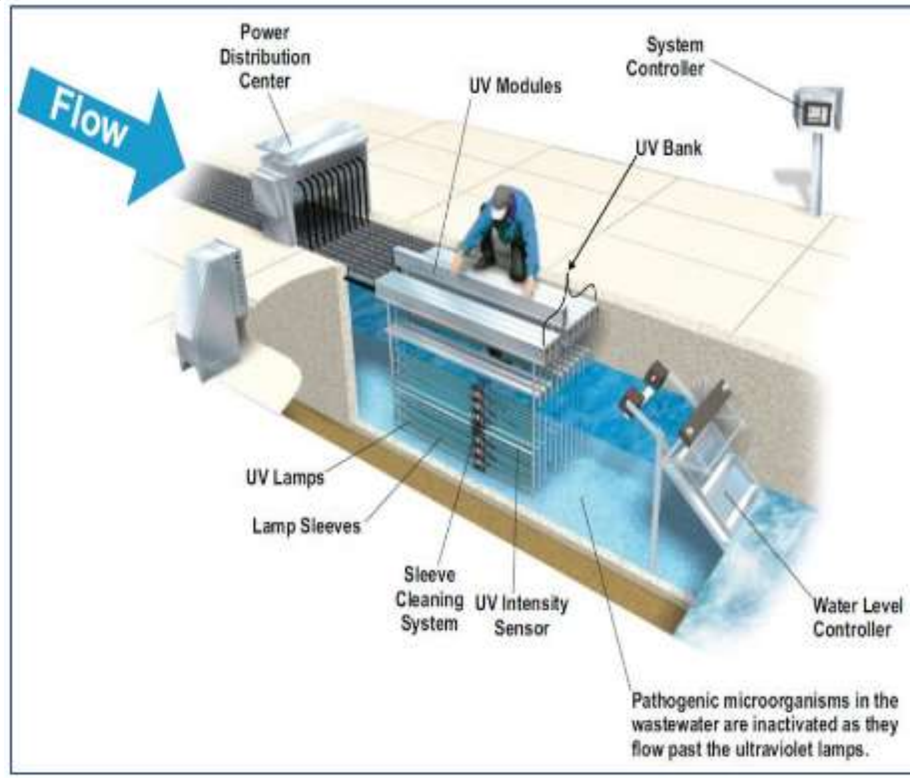
Advanced Energy-Efficient Systems–Disinfection

Ways to save energy

- Modulate UV system output to the level required for disinfection (dose-pacing control) and system turndown (number of operating lamps and lamp output)
- Properly sizing disinfection stage pumps and UV lamps

- Use electronic ballasts instead of electromagnetic ballasts. Electronic ballasts are ~10% more energy efficient than electromagnetic ballasts.

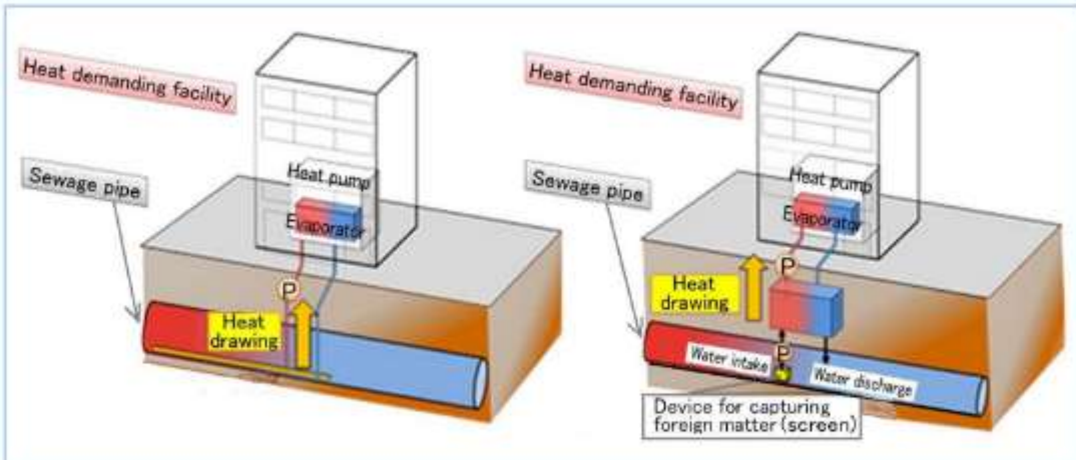
- LED UV emerging

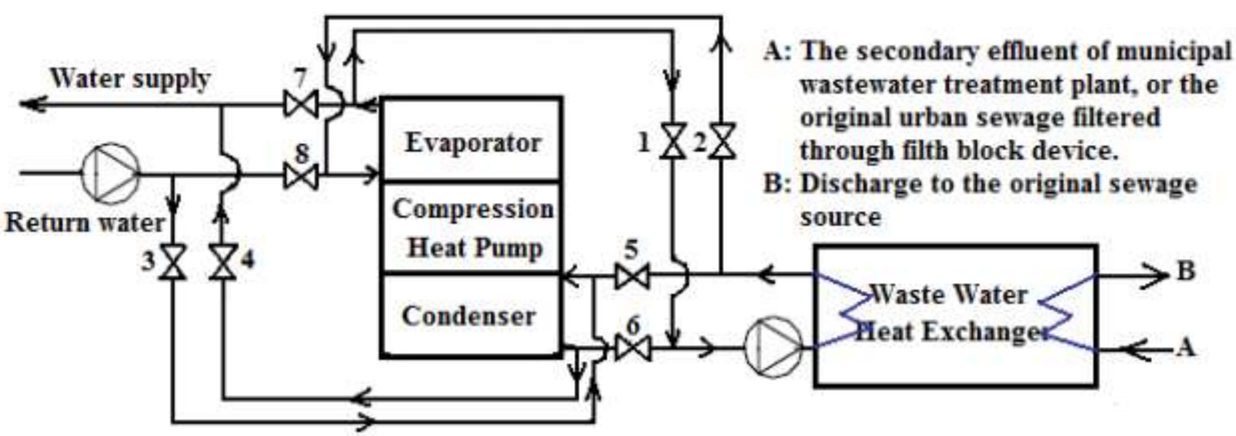


Source: U.S. Department

2.2 Low Water-demanding Power Generation Technologies

- **2.2.1 Sewage Water Source Heat Pump Technology**





Advanced Heat Pump Systems Using Urban Waste Heat "Sewage Heat"

2.2.2 High Temperature Anaerobic Sludge Digestion Technology and Biogas Power Generation Technology

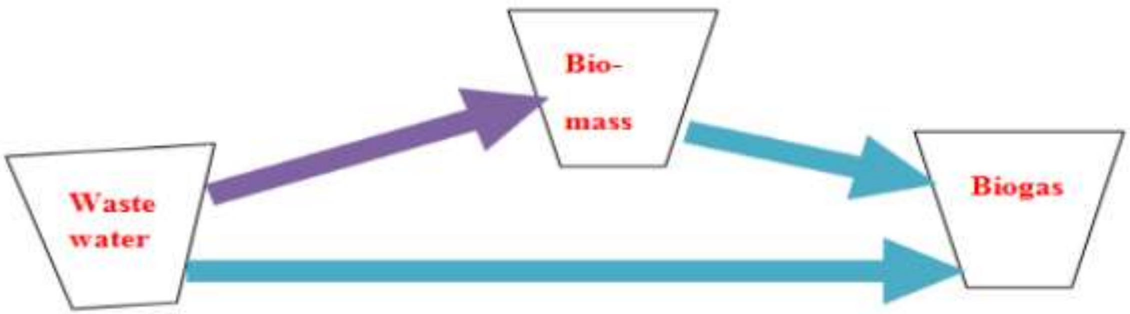


Figure 2. The possible route to biogas production during biological wastewater treatment.

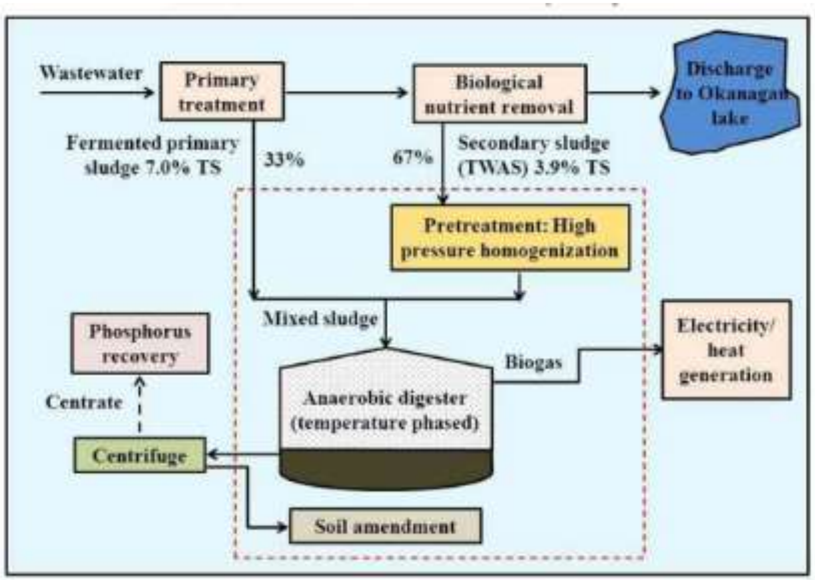


Figure 1.2: Schematic of proposed alternative management option involved anaerobic digester

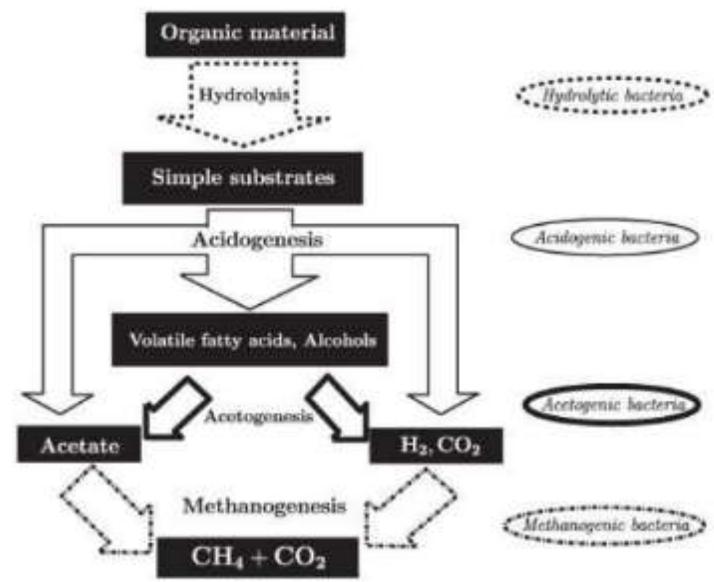
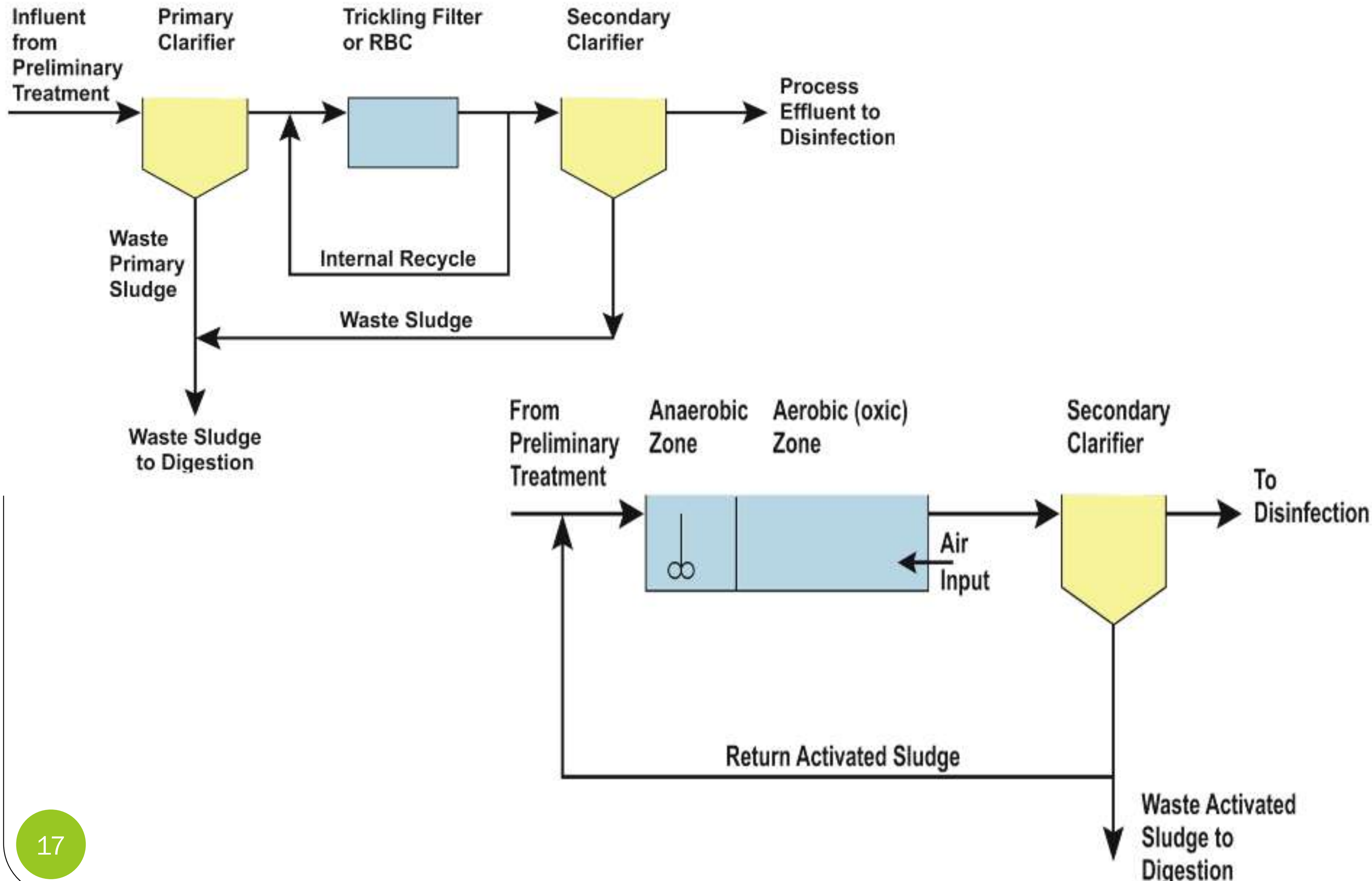
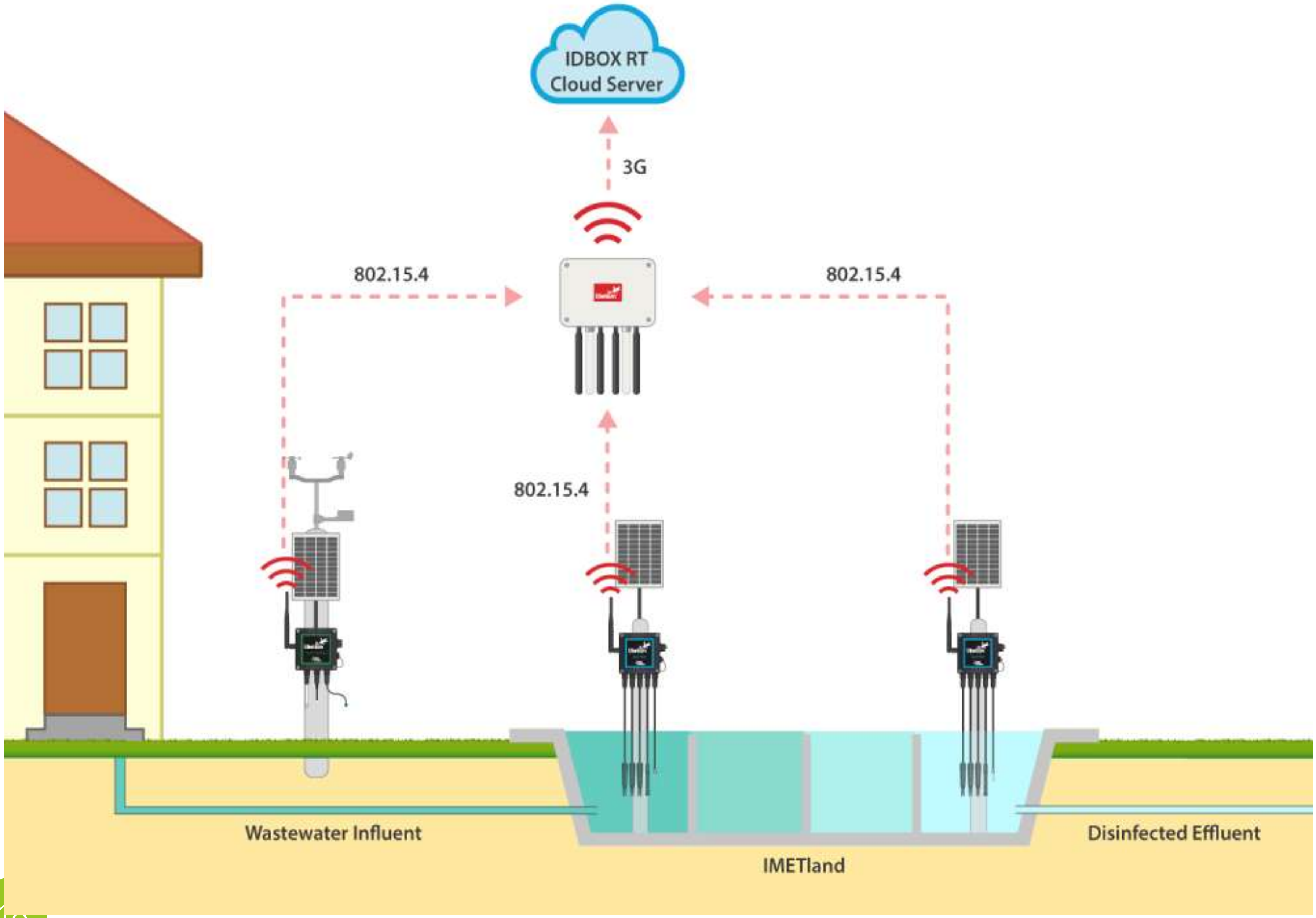


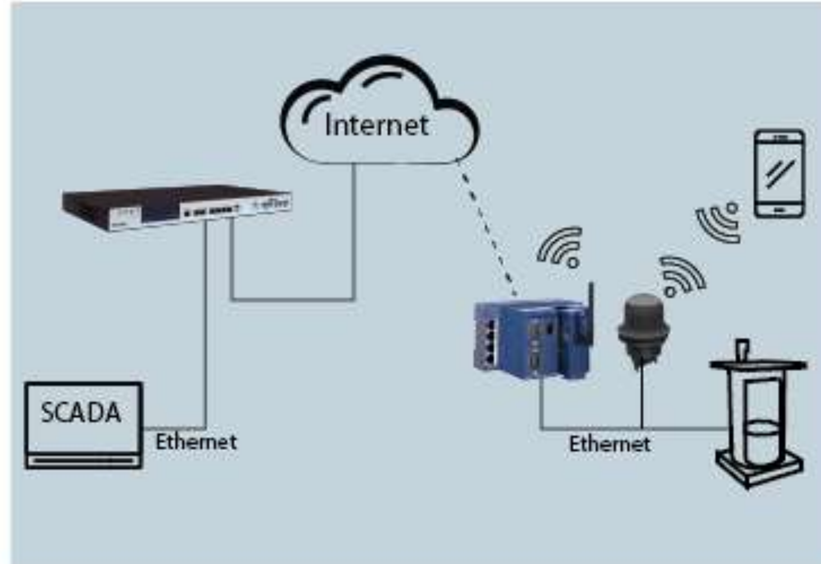
Figure 3. Schematic view of the various stages of anaerobic digestion processes. Source: [16].

2.3 Process Control in WWTPs




IDBOX RT
Cloud Server
3G
802.15.4
802.15.4
802.15.4
Wastewater Influent
Disinfected Effluent
IMETland

Lift Station Application Example



Wastewater treatment plant operations

Industrial IoT Blog

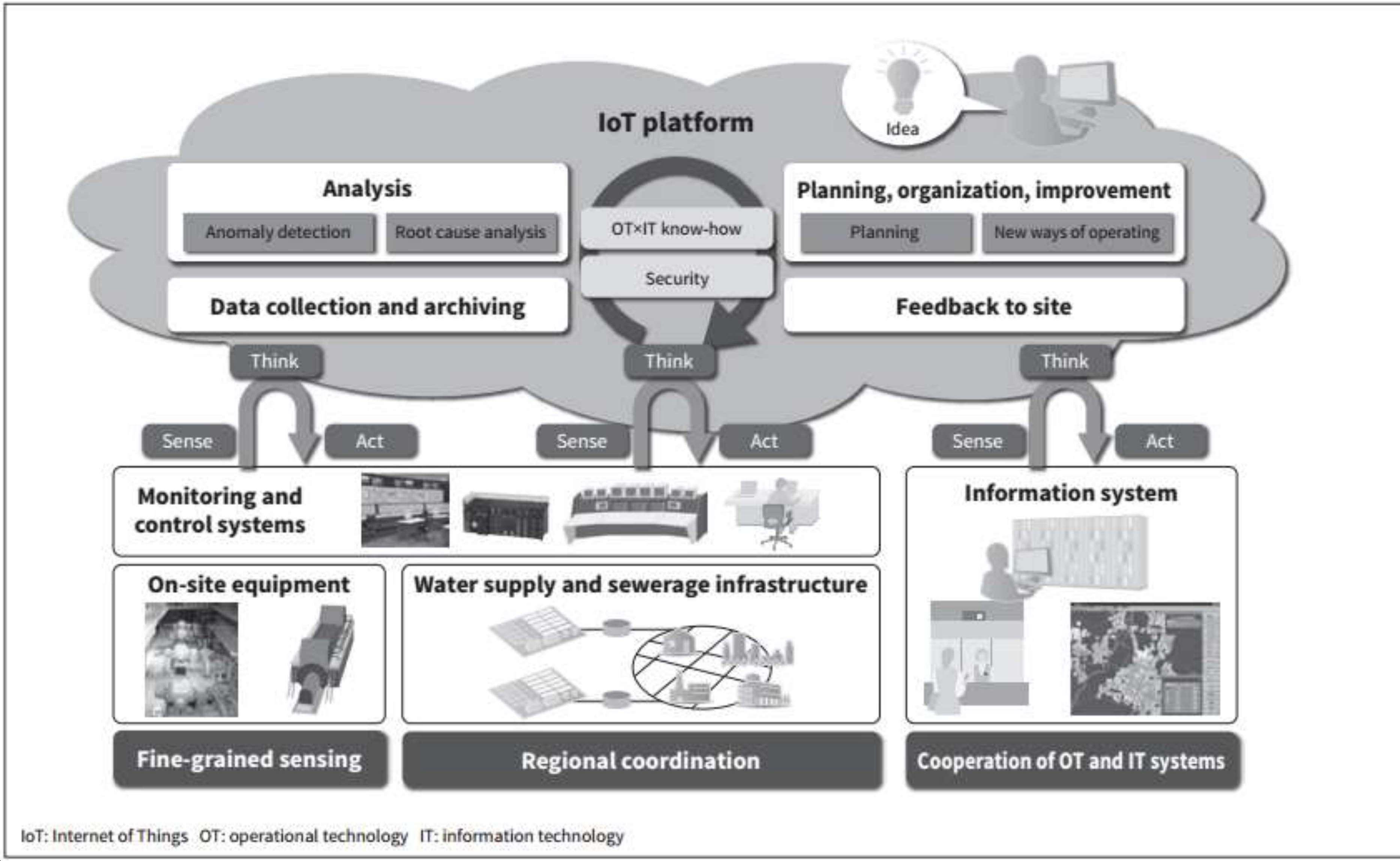
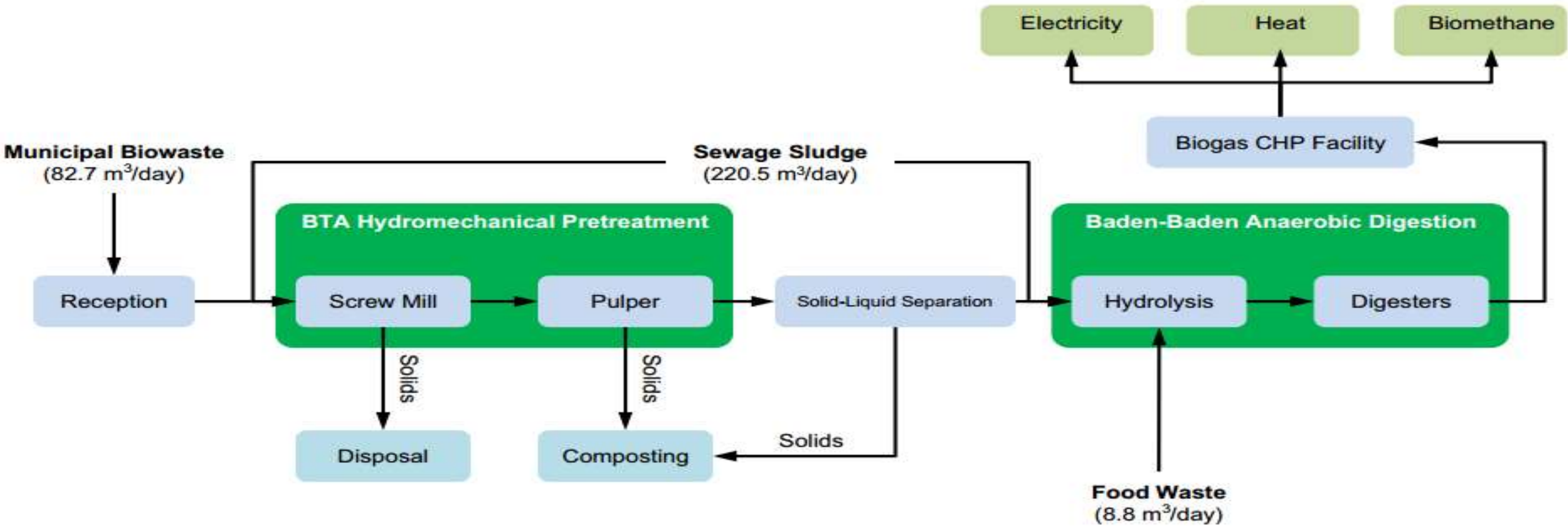


Figure —Monitoring and Control System for the IoT Era



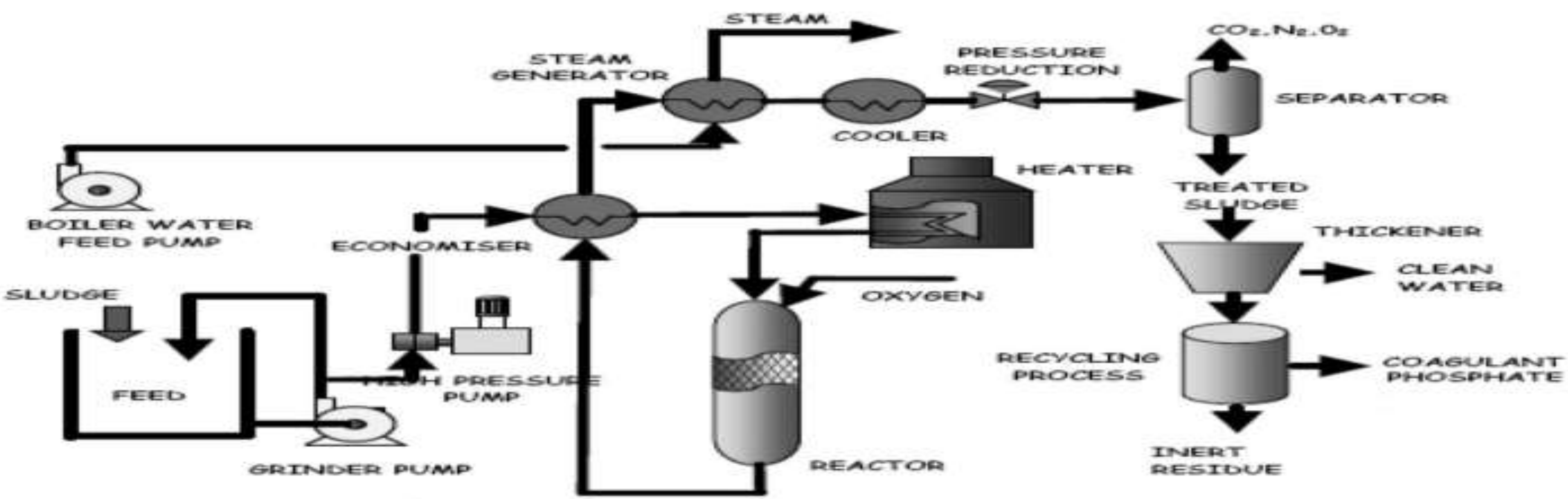
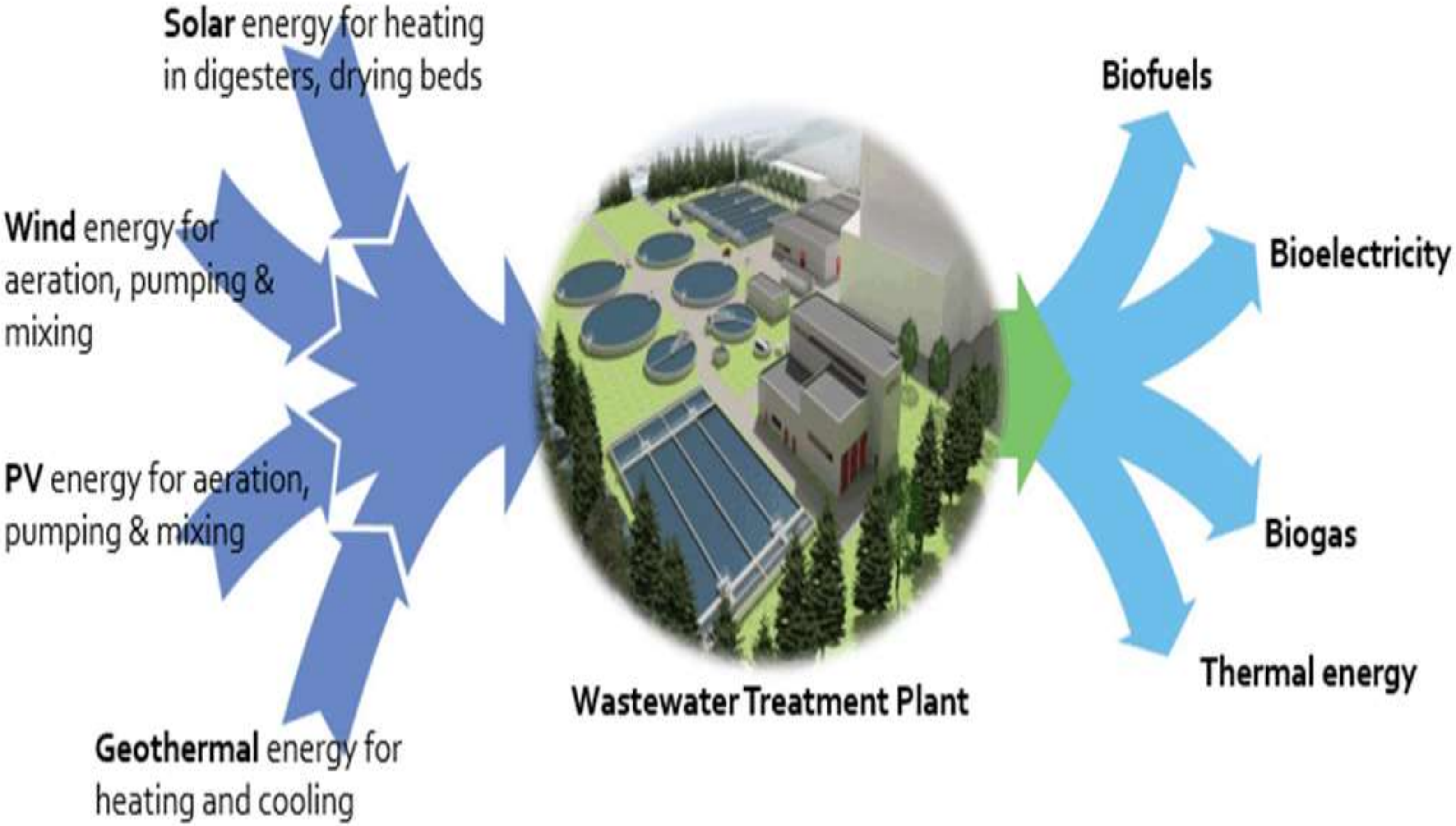


Figure 3. Aqua Critox® process schematic [11]. Source: J O'Regan, S. Preston, A. Dunne: Supercritical Water Oxidation of Sewage Sludge.

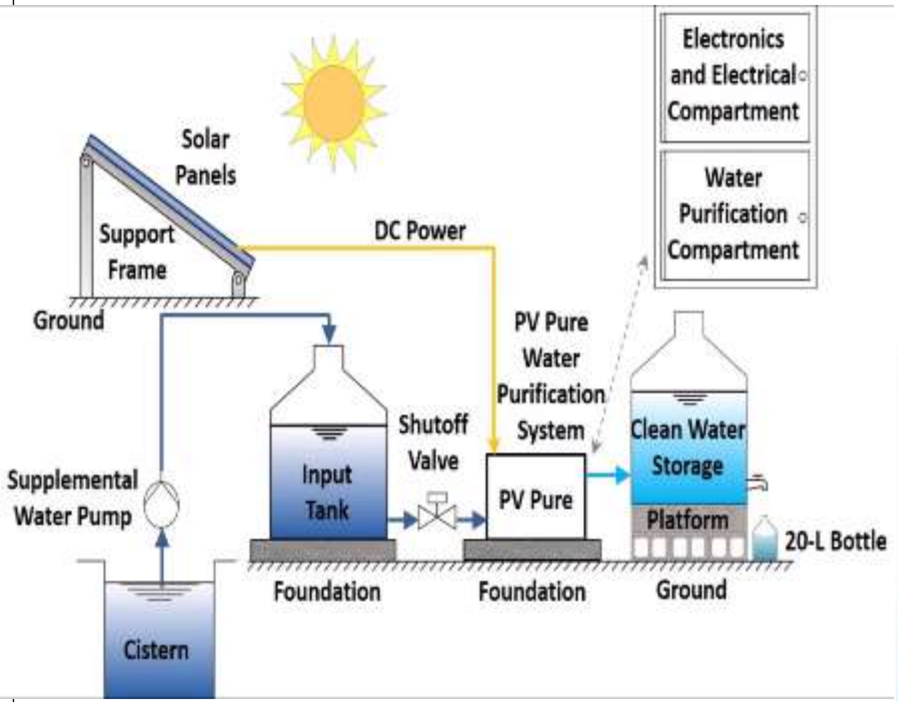
Figure. Baden–Baden WWTP: schematic of solid pretreatment process (BTAs Process), two-stage AD system (hydrolysis reactor and digesters) and biogas utilization system

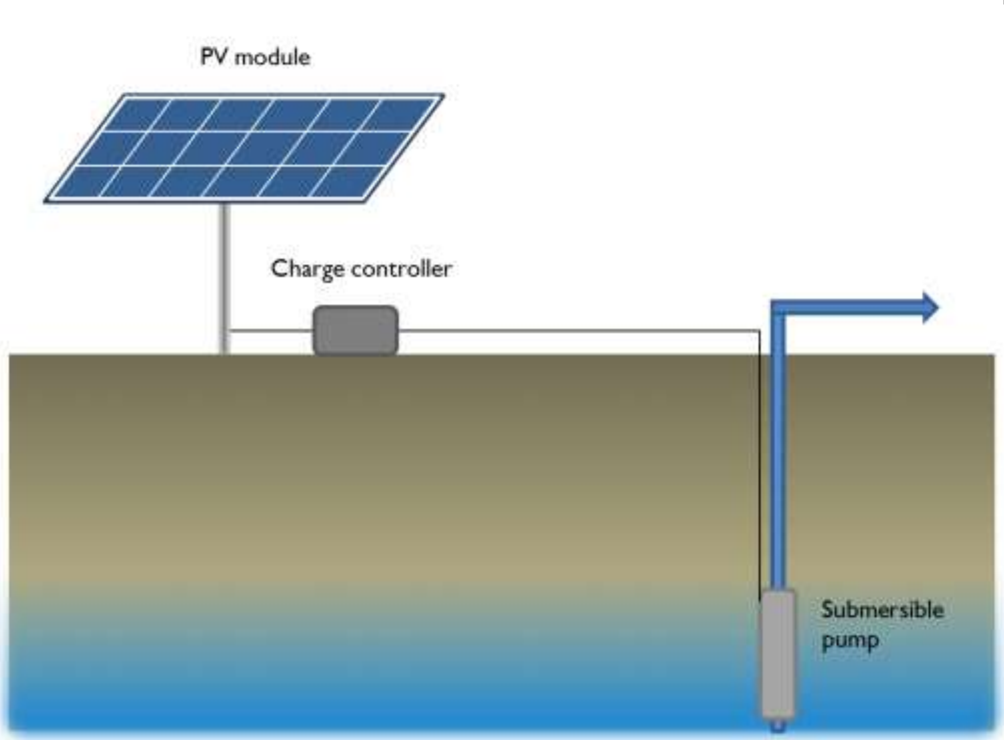
3. Green Energy and Energy Production in WWTPs

- **3.1 Green Energy Implementation**



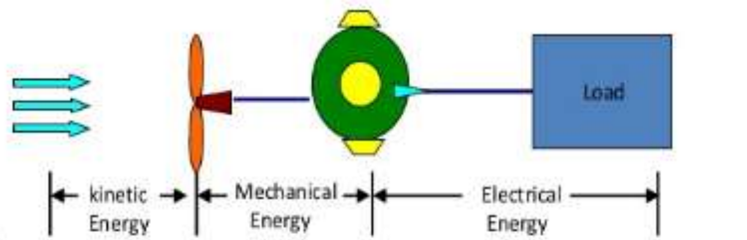
3.2 Solar Energy

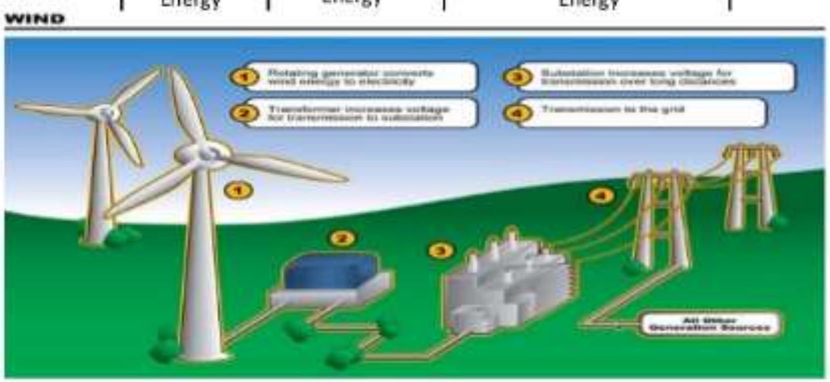


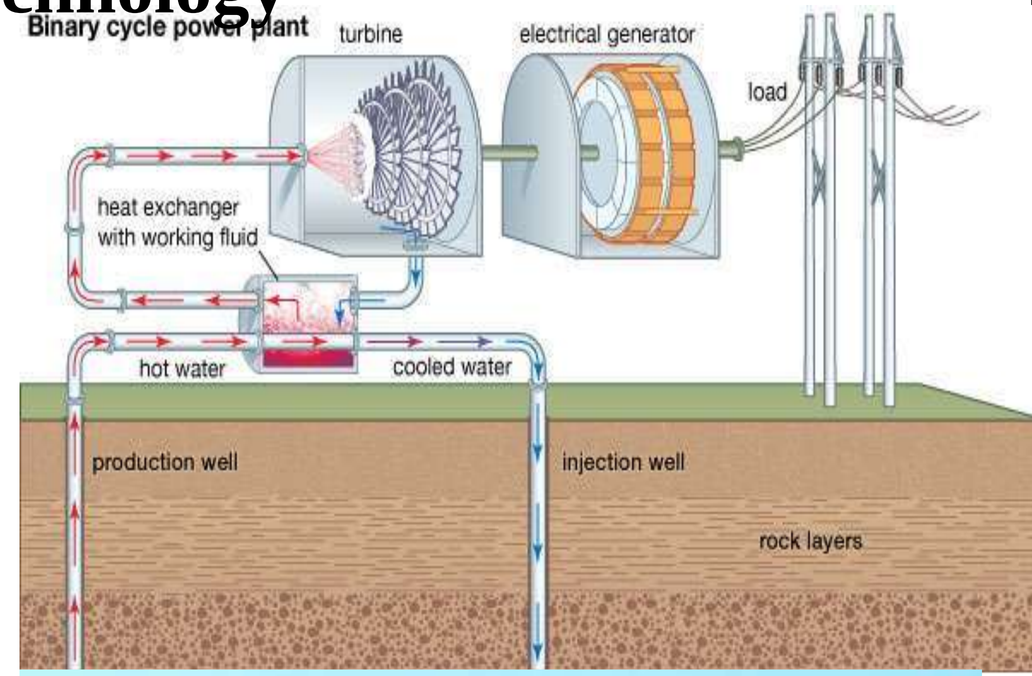


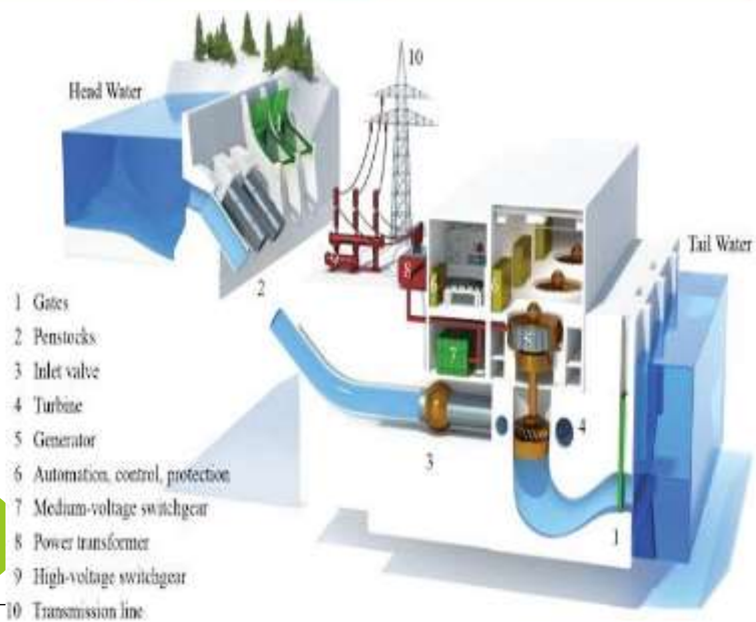
Photovoltaic Power Generation Technology

3.3 Wind Energy Technology

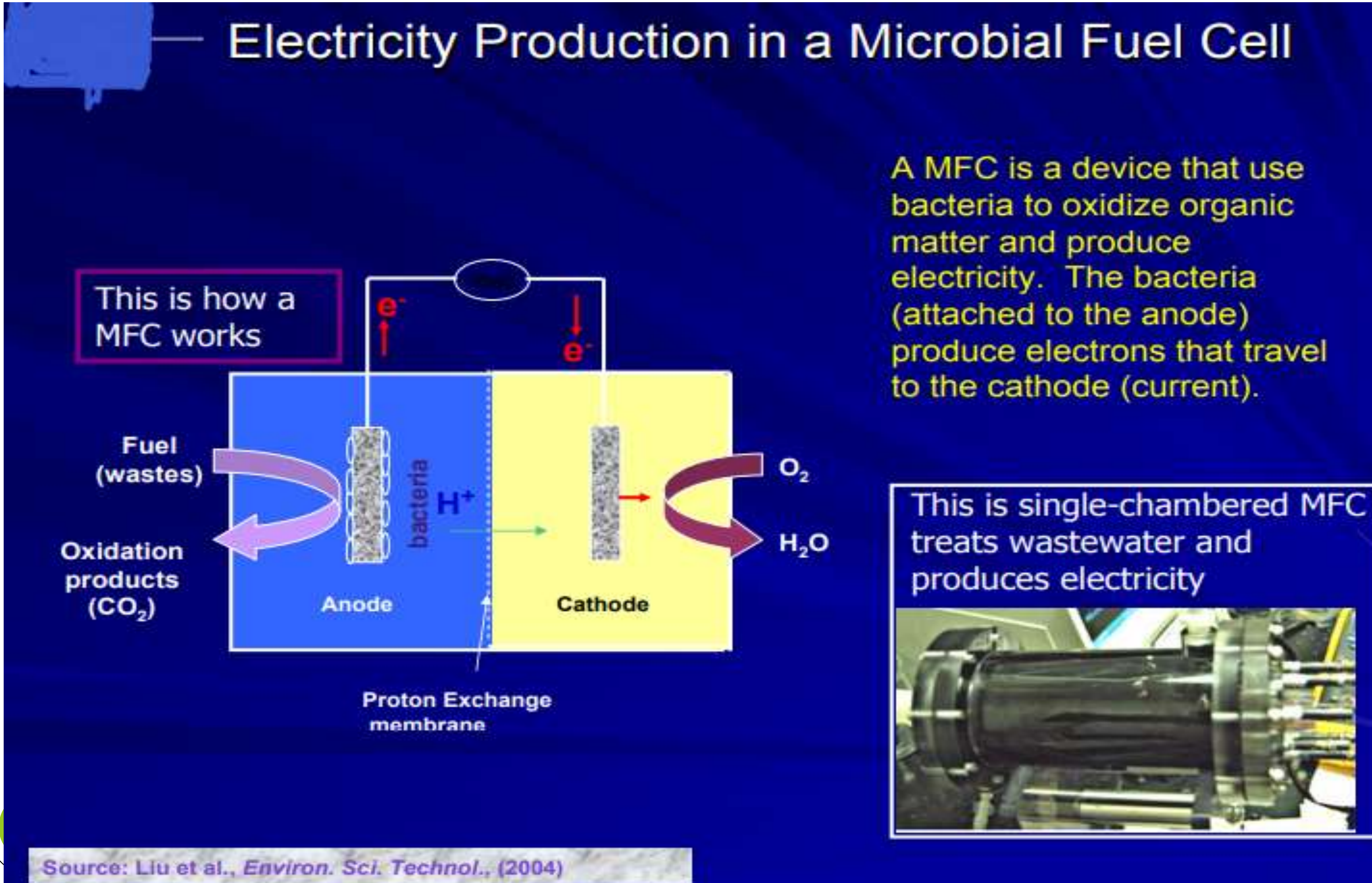








3.4 Biomass Energy Production



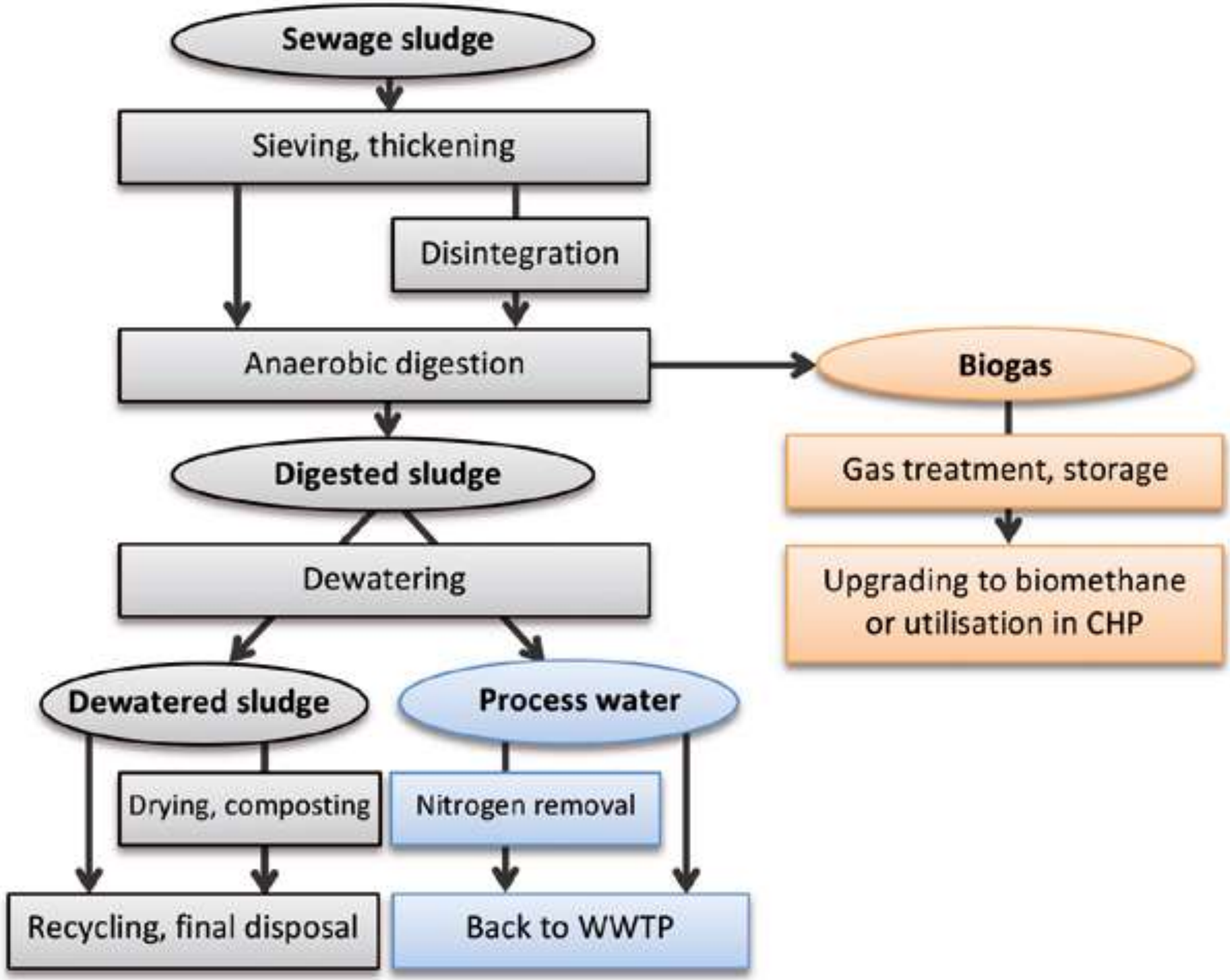


Figure Main steps of Anaerobic digestion in WWTP

Table 1 The conventional utilization of digesting biogas

Utilization method	Equipment
Digestive tank heating	Boiler, heat recovery equipment, heat exchanger
Power generation	Biogas purification equipment, biogas generator
Building heating	Heat recovery equipment
Air conditioning	Heat recovery equipment
Sludge drying	Dryer, heat recovery equipment
Sludge pasteurization	Boiler, heat recovery equipment
Thermal hydrolysis	Boiler, heat recovery equipment
Methane sales	Biogas treatment equipment
Drive pump and blower	Biogas generator set
Combustion	Burner

4. Integration of Green Energy and Energy–Efficient Technologies

- **4.1 Energy Audit System**

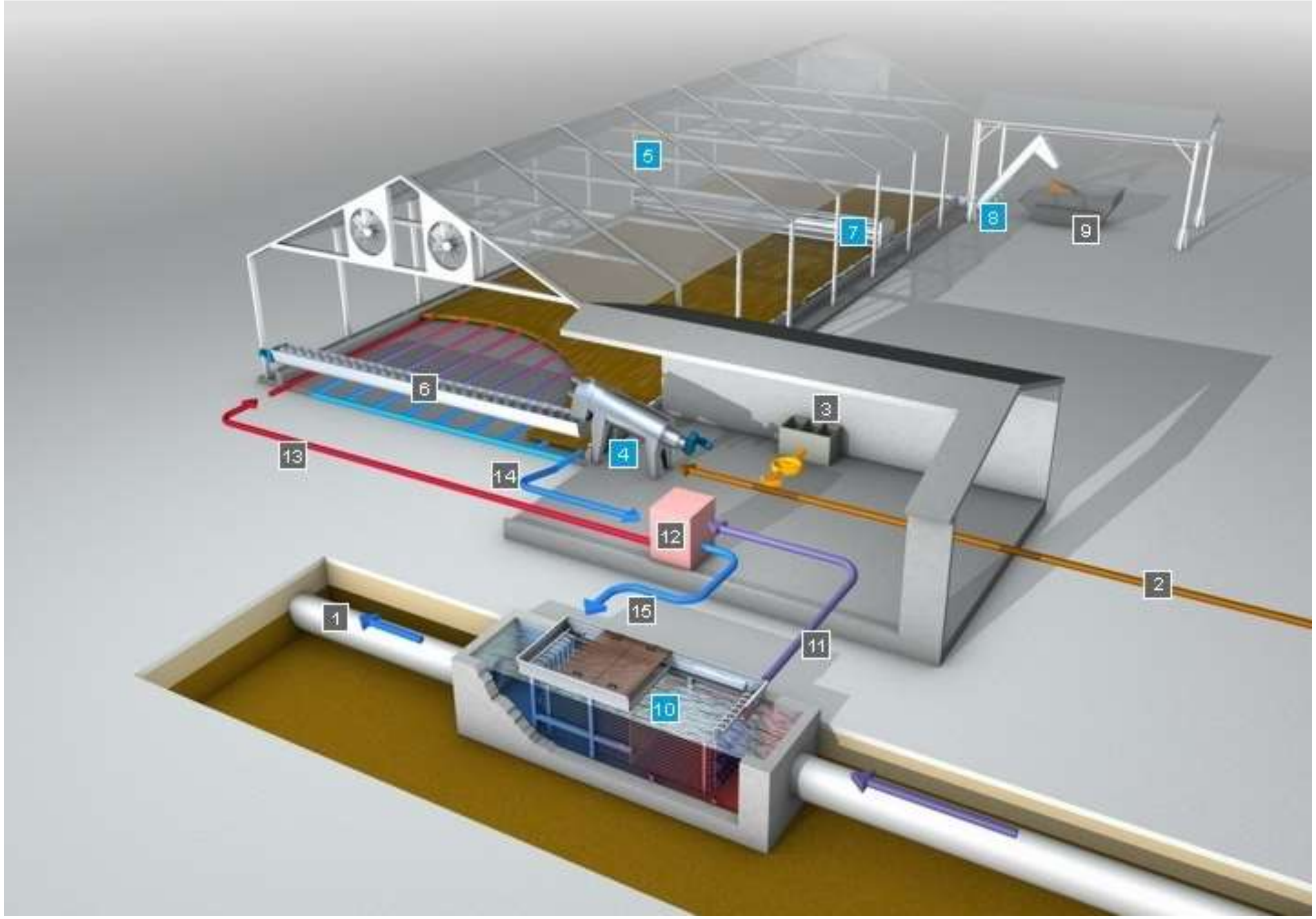
Plan	*Step 1. Get Ready* ▪ Establish the facility's energy policy and overall energy improvement goals ▪ Secure and maintain management commitment, involvement and visibility ▪ Choose an energy "fenceline" ▪ Establish energy improvement program leadership ▪ Secure and maintain employee and management buy-in *Step 2. Assess Current Energy Baseline Status* ▪ Establish a baseline and benchmark facilities ▪ Perform an energy audit ▪ Identify activities and operations that consume the most energy or are inefficient *Step 3. Establish an Energy Vision and Priorities for Improvement* ▪ Identify, evaluate, and prioritize potential energy improvement projects and activities *Step 4. Identify Energy Objectives and Targets* ▪ Establish energy objectives and targets for priority improvement areas ▪ Define performance indicators
Do	*Step 5. Implement Energy Improvement Programs and Build a Management System to Support Them* ▪ Develop action plans to implement energy improvements ▪ Get top management's commitment and approval ▪ Develop management system "operating controls" to support energy improvements ▪ Begin implementation once approvals and systems are in place

Check	***Step 6. Monitor and Measure Results of the Energy Improvement Management Program*** ▪ Review what the facility currently monitors and measures to track energy use ▪ Determine what else the facility needs to monitor and measure its priority energy improvement operations ▪ Develop a plan for maintaining the efficiency of energy equipment ▪ Review the facility's progress toward energy targets ▪ Take corrective action or make adjustment when the facility is not progressing toward its energy goals ▪ Monitor/reassess compliance status
Act	***Step 7. Maintain the Energy Improvement Program*** ▪ Continually align energy goals with business/operation goals ▪ Apply lessons learned ▪ Expand involvement of management and staff ▪ Communicate success

Figure Steps For Designing, Implementing, And Sustaining Energy Efficiency Improvements In Water And Wastewater Facilities

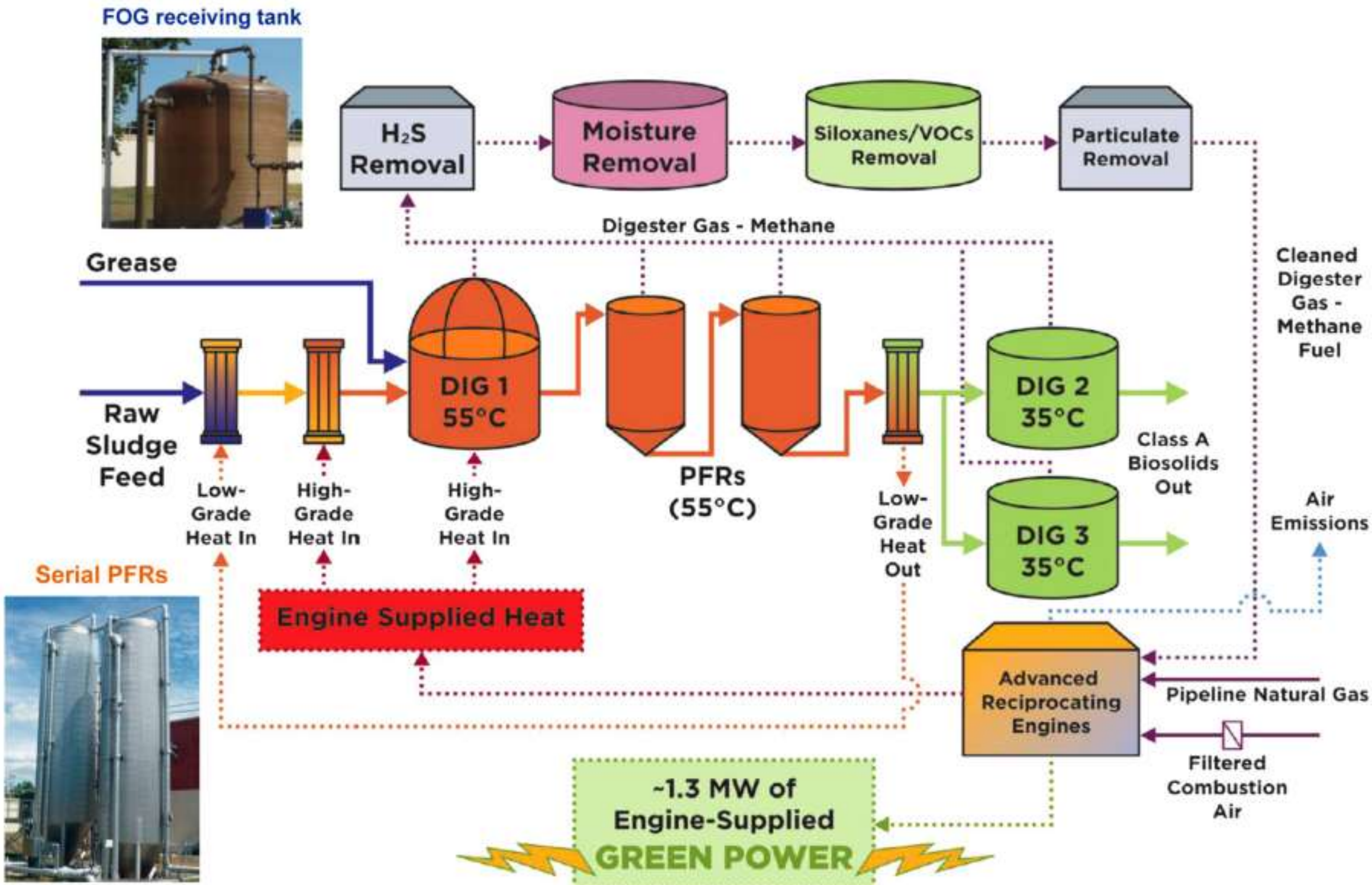
4.2 Integration of Green Energy and Energy–Efficient Technologies

Solar Energy Combined With Water Source Heat Pump For Sludge Drying

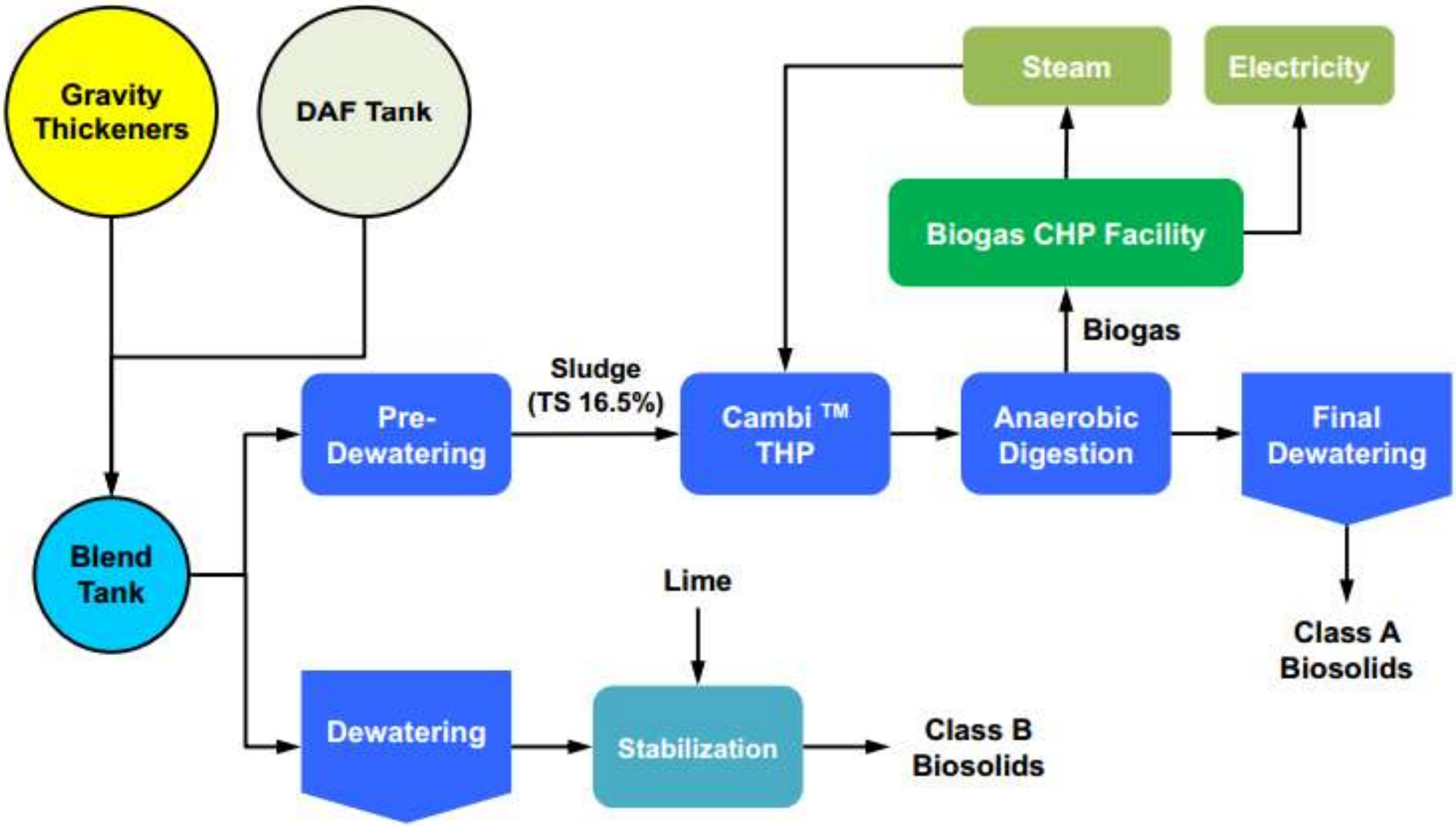


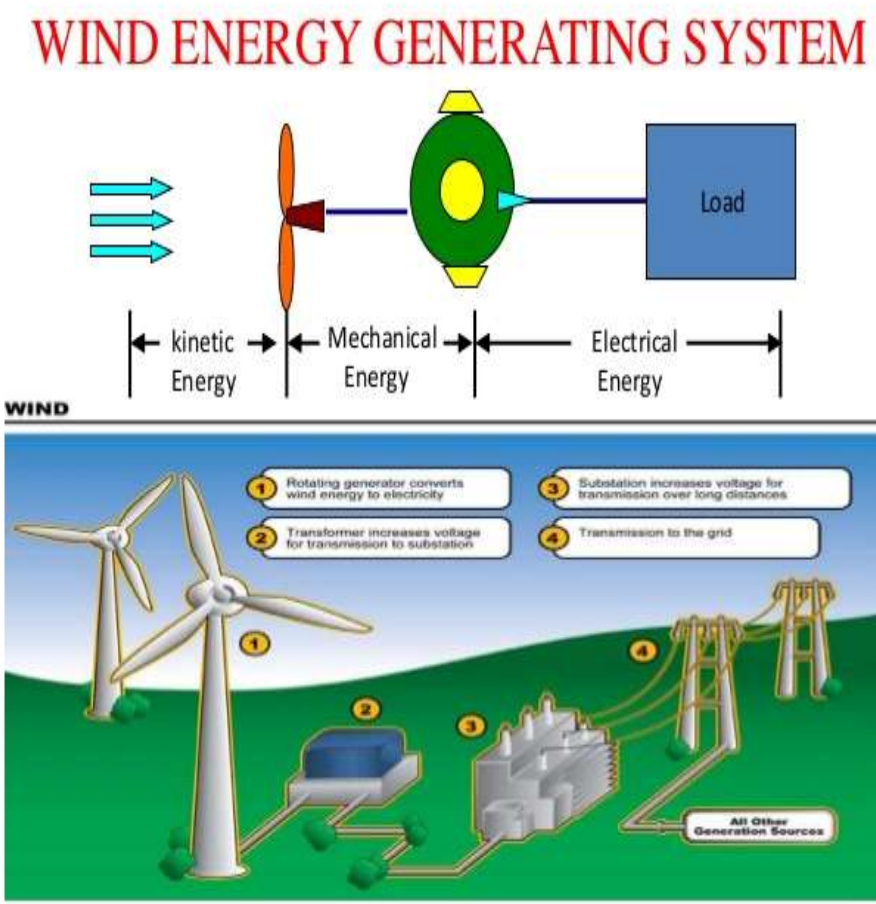
Sludge Drying with Solar and Renewable Energy

Co-digestion with sludge for Production of Biogas



schematic of the new Biosolids Management Plan .




WIND ENERGY GENERATING SYSTEM
Load
kinetic Energy
Mechanical Energy
Electrical Energy
WIND
1 Rotating generator converts wind energy to electricity
2 Transformer increases voltage for transmission to substation
3 Substation increases voltage for transmission over long distances
4 Transmission to the grid
All Other Generation Sources

5. Challenges and Perspectives

5.1 Challenges

- The water-energy nexus is an important focus area for the nation and the world.
- The water-energy nexus is a complex network of problems, actors, and contexts.
- Utilization of storage capacity in an intelligent way
- The scheduling of some operations (dewatering, filter back-washing) to off-peak periods.
- Requires real-time data analysis and forecasting systems that will inform process control strategies on public-health risk assessment.

5.2 Perspectives

- Implication of IoT Technology for WWTPs.
- Combination green chemistry and clean production.
- Integration of Green Infrastructure and Low power-consumption ecological advanced technologies.
- A nuanced understanding of the nexus‘ multiple facets can help focus and prioritize relevant research and other activities.
- A high-impact strategy would cut across modeling, data, technology, and policy analysis.
- Cross-sector and cross-disciplinary outreach is required at multiple scales to ensure that the broadest possible set of stakeholders is helping to identify the problems and has access to the best solutions