Efficient organic carbon utilization for combined nutrient removal and biogas production in hybrid biofilm activated sludge process

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INTRODUCTION

- Biological wastewater treatment processes
  ➡ developing technologies

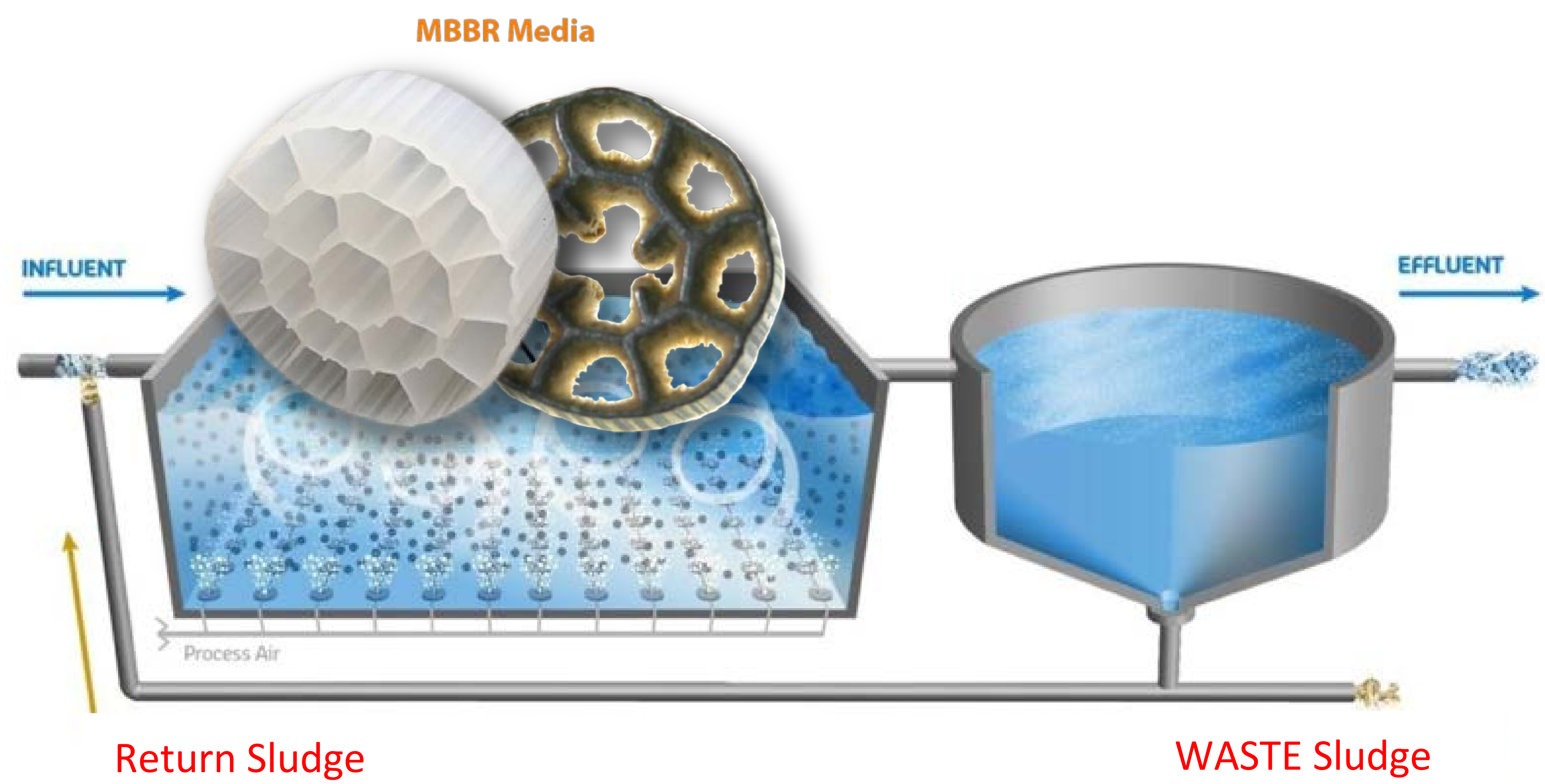
- Organic carbon redirection for biogas production
  - energy recovery from waste ultimate goal for sustainable wastewater management

- Conventional single sludge activated sludge systems (CAS)
  - do not satisfy nutrient removal
  - no effective use of organic carbon
  - extremely energy demanding systems
  - large amount of waste: cost requirement for disposal

INTRODUCTION

- Hybrid systems integrated with biofilm processes
- Hybrid systems (i.e., moving bed bioreactor, MBBR, integrated fixed film activated sludge, IFAS)
  - alternative for cost-effective and reliable process upgrades
  - improved nutrient removal efficiency over conventional suspended activated sludge systems

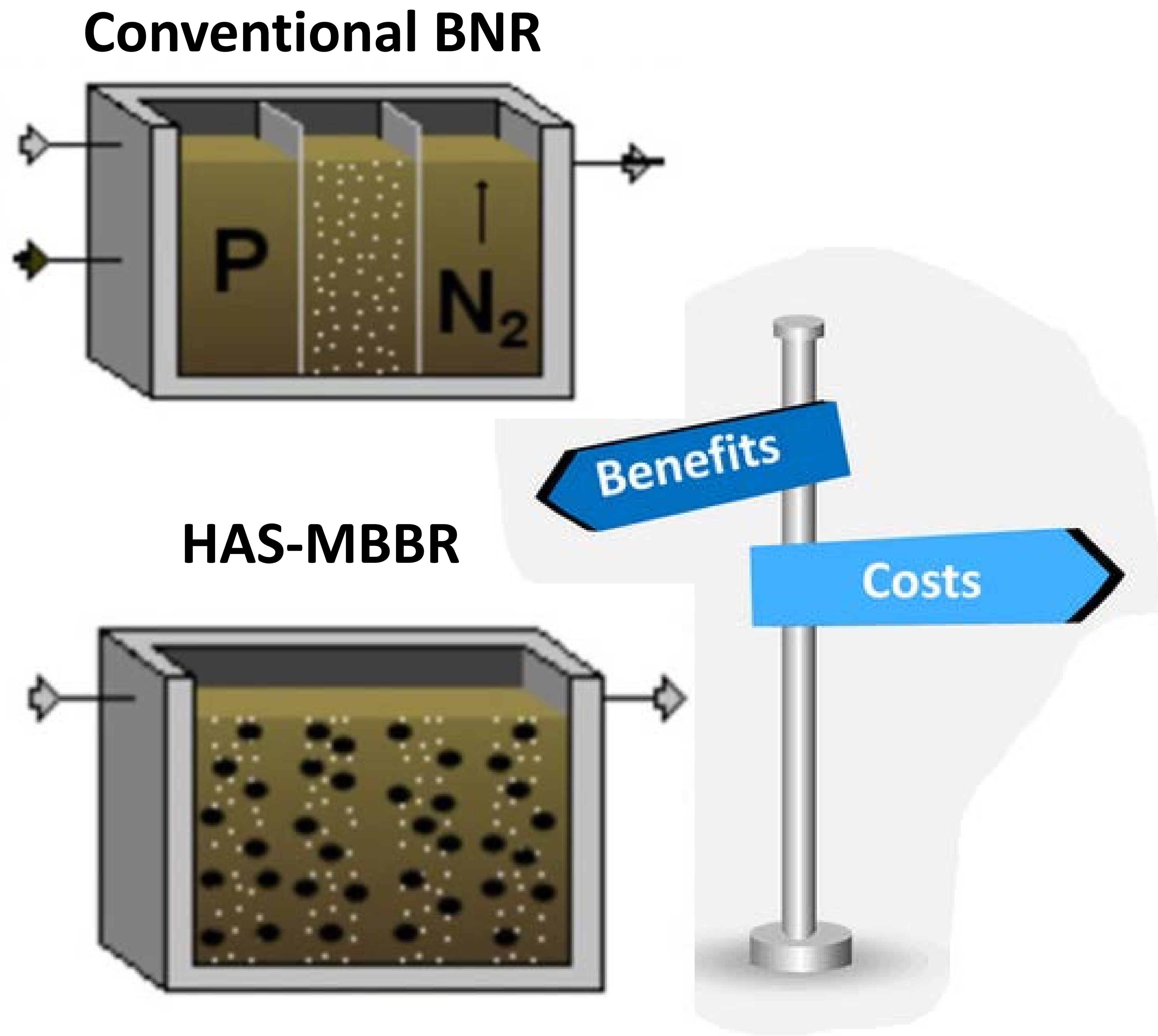
- MBBR
  - successfully used to treat domestic and industrial wastewater with recalcitrant character



INTRODUCTION

- Hybrid systems are advantageous through entrapping and diverting organic matter before oxidizing it in subsequent aerobic phases

- The process efficacy in the hybrid systems allow working at low sludge retention times holding the biomass on the carrier for longer times which could also let to efficient biogas recovery



MATERIAL & METHODS

Pilot Studies

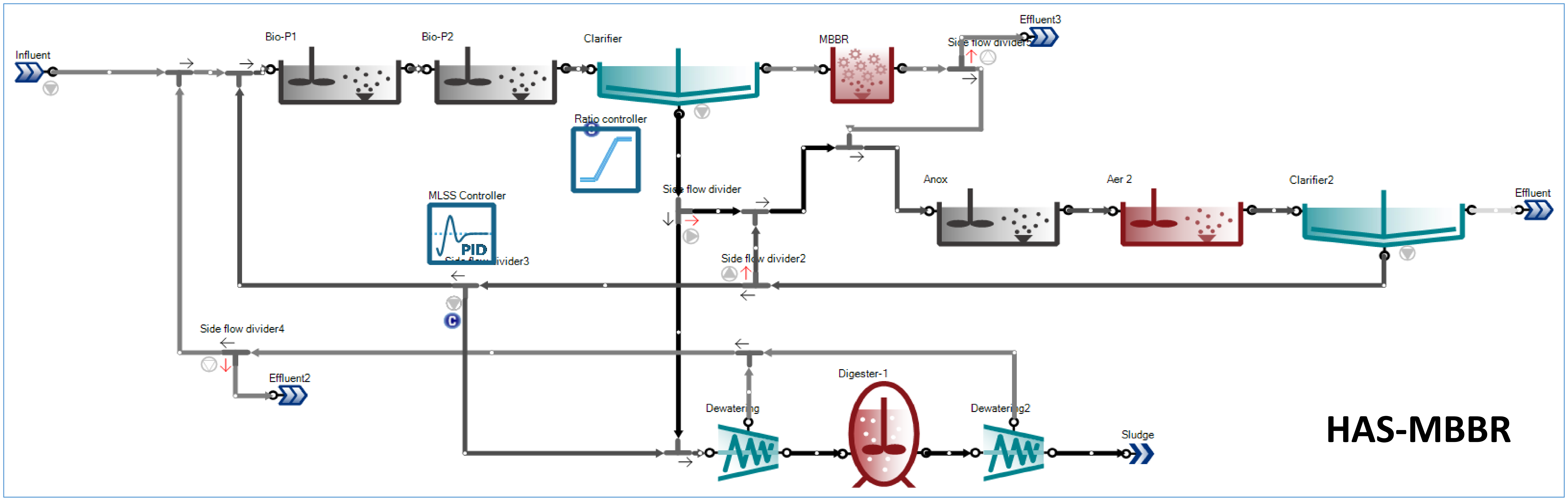
- Located at the headwork of a full-scale municipal wastewater treatment plant in Istanbul
- Inflow: 7 m^3/day
- DO in MBBR 2-3 mg/L
- 2-Sludge System

hybrid biofilm pilot plant

MATERIAL & METHODS

Process Configurations and Simulation

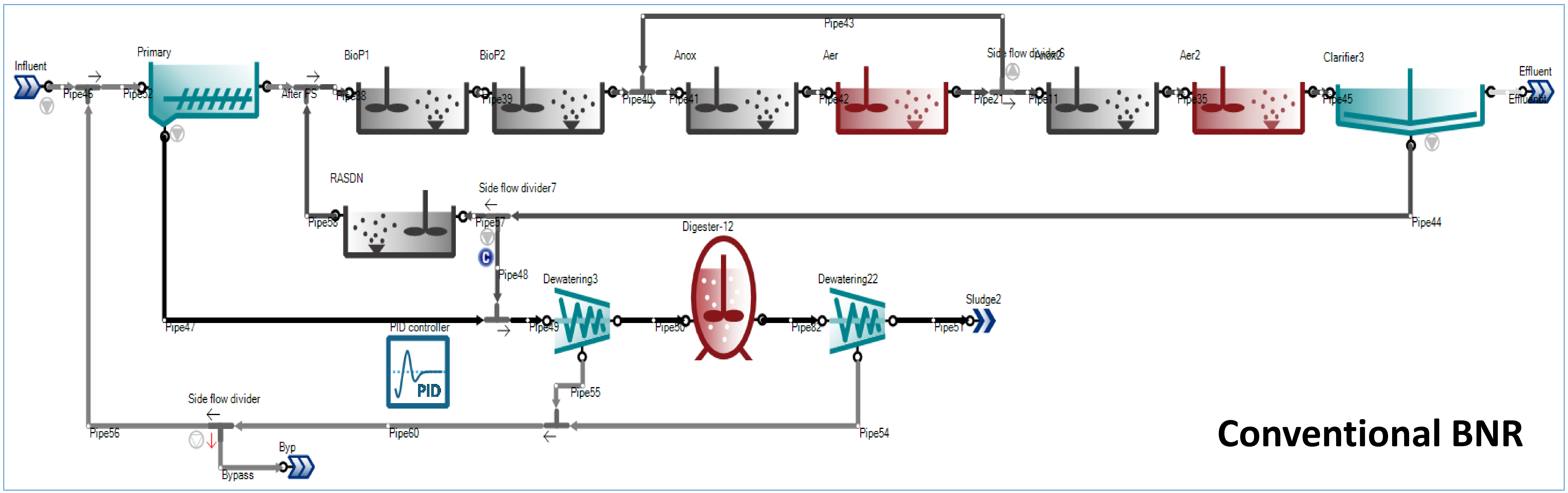
SUMO® software influent flowrate of 100,000 m^3/day (26.4 MGD)



MATERIAL & METHODS

Process Configurations and Simulation

SUMO® software influent flowrate of 100,000 m^3/day (26.4 MGD)



Conventional BNR

MATERIAL & METHODS

COD fractions for referred municipal wastewater

Parameter	Concentration, mg/L	Fraction, % of C_T
Total COD, C_T	610	
Soluble COD, S_T	180	30
Soluble inert COD, S_I	35	5
Readily biodegradable COD*, S_B	125	20
Slowly biodegradable COD, X_B	370	60
Particulate inert COD, X_I	60	15

Dimensions and required installations for treatment plant units (@15 °C)

Process Unit	Unit	Plant Configuration	
		HAS-MBBR	CBNR
Bio-P volume	m3	7,000	7,000
Aerobic reactor volume	m3	11,000	70,000
Biofilm Reactor, MBBR	m3	30,000	-
Anoxic reactor volume	m3	14,000	25,000
Total reactor volume	m3	62,000	102,000
Total biofilm area	m2	8,250,000	-
Internal Recirculation	m3/hour	-	12,500
Anaerobic Digester volume	m3	12,000	12,000
Total clarifier surface area	m2	20,000	17,000

MATERIAL & METHODS

Cost Analysis

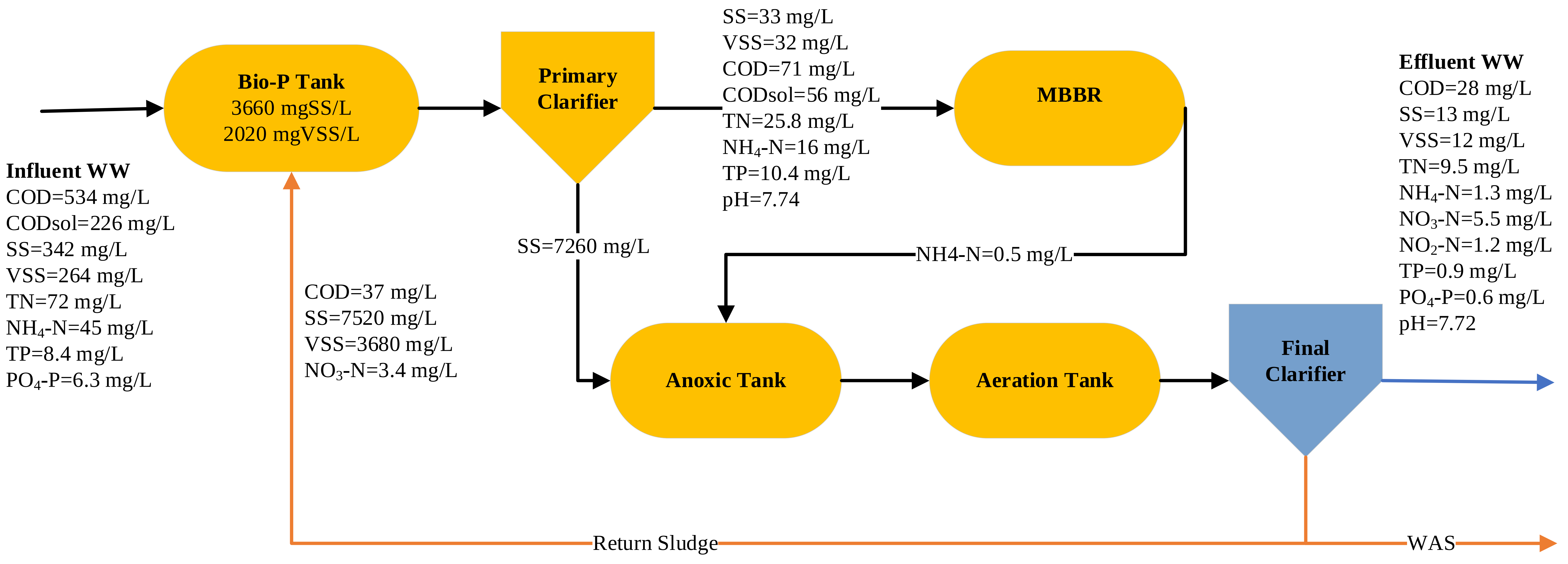
- 15 years of operation covering a reasonable economical life of mechanical equipment

- Biogas from mesophilic anaerobic digestion (MAD) → a revenue

- Construction and installation unit prices Ministry of Environment and Urban Planning of Turkey

RESULTS

Pilot Plant Operation and Mass Balances



Pilot plant layout and the mass balance obtained in the HAS-MBBR configuration

RESULTS

Simulation Studies

Process comparison regarding steady state effluent quality

Parameter	Unit	Influent	Effluent Quality	
			HAS-MBBR	CBNR
Total COD	mgO_2/L	610	40	40
Total nitrogen	mgN/L	55	7.94	9.44
Total ammonia (NH_4)	mgN/L	41	5.64	1.84
Nitrate (NO_3)	mgN/L	-	1.08	6.44
Total phosphorus	mgP/L	8	0.72	0.58
Orthophosphate (PO_4)	mgP/L	5	0.52	0.35

Targeted effluent quality

TN 10 mgN/L

TP 1 mgP/L

RESULTS

Simulation Studies

Operational Parameters for hybrid AS-MBBR and CBNR systems

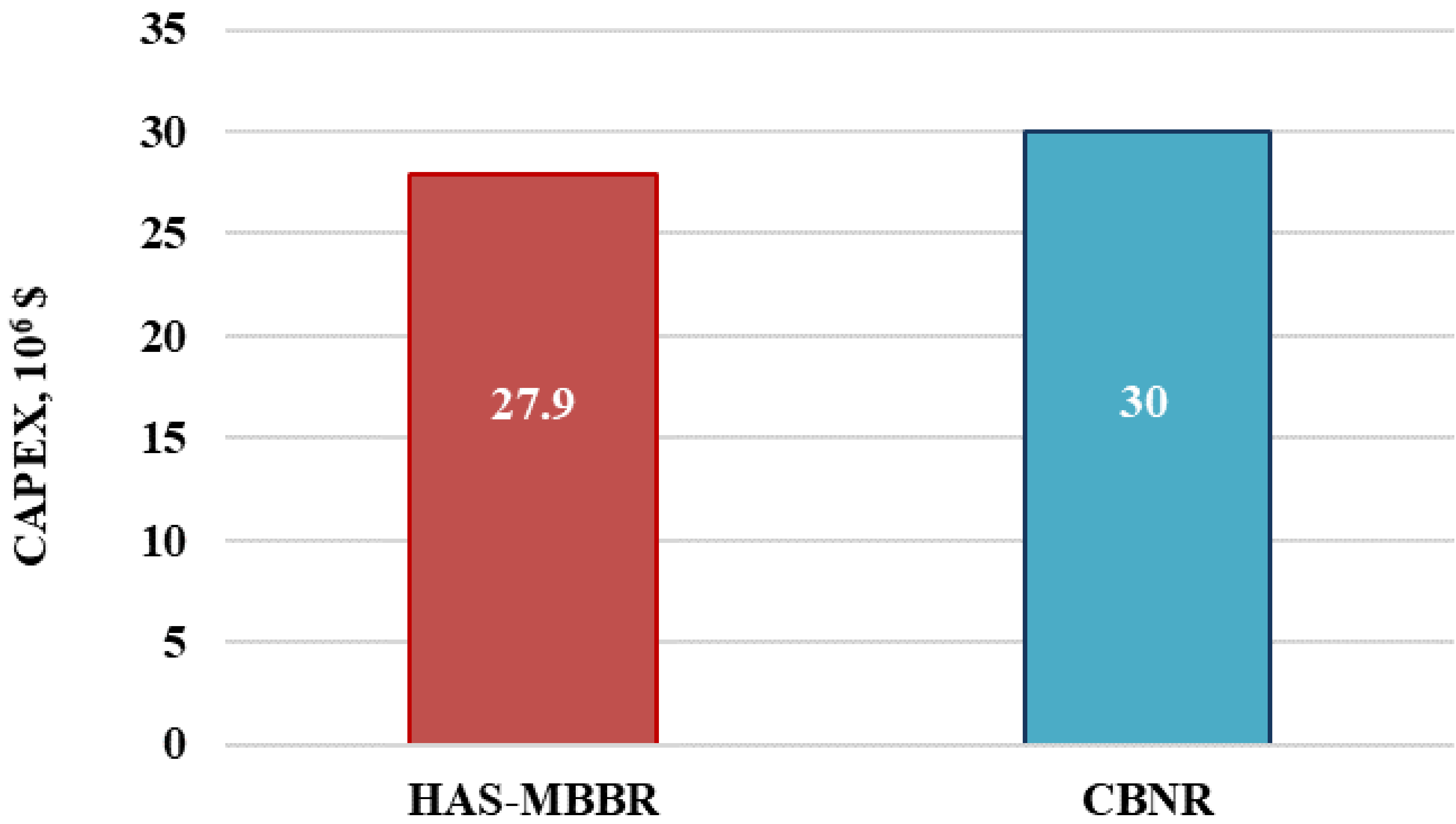
Parameter	Unit	Configuration		
		HAS-MBBR	CBNR	
Average air requirement, Q_{Air}	Nm^3/hour	**33000**	**36000**	9% ↓
Mixing energy requirement	kWh/day	**2500**	3850	
Daily biogas production	m^3/day	**8900**	7000	22% ↑
Solids retention time	days	3.5	18	

Volume requirement of anoxic reactor in HAS-MBBR ~ 44% smaller then CBNR

~ 40% reduction in the Total Volume

RESULTS

Cost Analysis for System Configurations

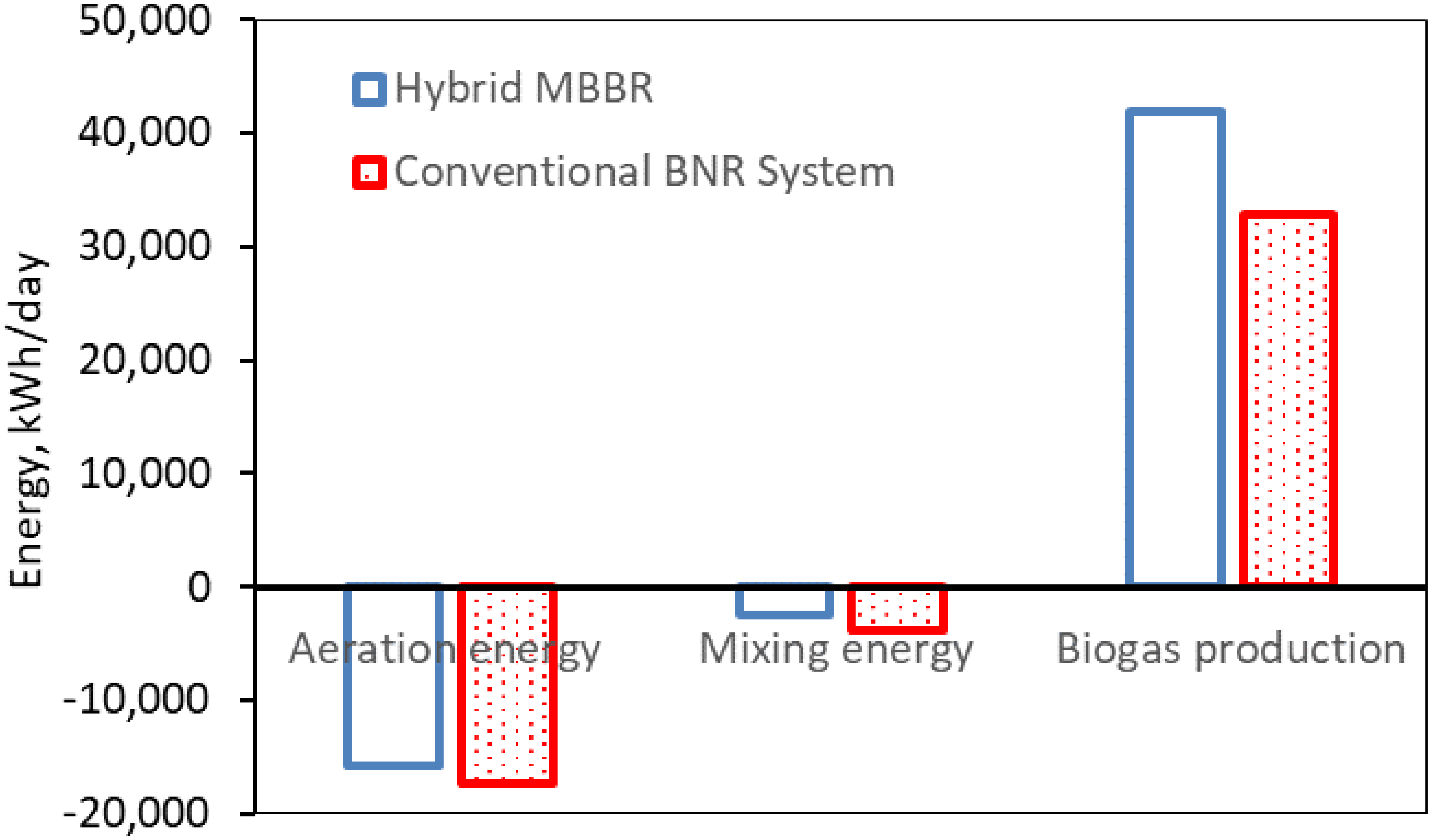


CAPEX advantage of HAS-MBBR over CBNR ($2.1M) can be significant for the developing countries

CAPEX advantage of about 7%.

RESULTS

Cost Analysis for System Configurations



Energy consumption due to aeration, mixing, internal recirculation and other processing units

Energy production from biogas

CONCLUSION

- Nitrification process will not be the decisive factor for sizing the bioreactor compared to conventional BNR system.

- The adsorption capability of return activated sludge provides ultimate organic carbon capture without loosing carbon aerobically.

- The diversion at the head of the HAS-MBBR configuration allows management of organic carbon (i.e., using in denitrification or/and anaerobic digestion) during real time operation.

- Model simulations and techno-economic analysis proved that the proposed HAS-MBBR has great advantages over CBNR systems.

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