SMART ENERGY MANAGEMENT SOLUTION

Smart Energy Management System for Wastewater Treatment Plants

Utility Grid • Solar PV • Energy Storage Integrated Solution

Technical Proposal V1.0 | August 2026

Source • Grid • Load • Storage Coordinated Dispatch

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01 INDUSTRY BACKGROUND

WWTPs Are Typical High-Energy Continuous-Operation Facilities

50~70%

Aeration Power Share
Blowers are the largest power consumers

24/7

Uninterrupted Operation
Shutdown causes effluent violations

30%+

Electricity Share of OPEX
Unit consumption: 0.20~0.35 kWh/m^3

Core Pain Points

High Electricity Costs: Peak tariffs are 2~3x off-peak rates. National max peak-valley spread reaches 1.2291 yuan/kWh (Apr 2026).

Dual Carbon Pressure: Pollution-carbon reduction synergy requirements are clear; plants must lower energy consumption and carbon intensity.

Stable, Optimizable Load: Low daily fluctuation. Daytime peak matches solar output; nighttime off-peak is ideal for storage charging.

High Reliability Needs: Critical processes cannot be interrupted; storage and microgrids provide emergency backup power.

Policy-Driven Pollution-Carbon Reduction Synergy

NDRC et al. [2023] No. 1714

Implementation Opinions on Promoting Synergistic Pollution-Carbon Reduction in Wastewater Treatment. Mandates PV, storage and renewable energy adoption.

Dual Carbon Goals & New Power System

Build source-grid-load-storage integration and multi-energy complementarity. Encourage high-energy users to participate in demand response and VPPs.

Core Policy Requirements

Energy Mix Optimization: By 2025, significantly raise renewable energy utilization in urban WWTPs; encourage distributed PV on rooftops and tank surfaces.

Smart Upgrades: Promote smart water and energy management systems; achieve coordinated process and energy dispatch optimization; improve refined management.

Energy Intensity Reduction: Advance energy-saving retrofits; continuously lower unit water power consumption and carbon intensity; establish online energy monitoring.

Business Model Innovation: Encourage EMC, PPP and other models; introduce social capital to invest in and operate WWTP energy systems.

Source: NDRC et al., Implementation Opinions on Promoting Synergistic Pollution-Carbon Reduction in Wastewater Treatment (NDRC Environment [2023] No. 1714)

03 ARCHITECTURE

Source-Grid-Load-Storage Integrated Architecture

SOURCE
Grid + Solar PV
10kV Utility / 2MWp Distributed PV

→

STORAGE
ESS 1MW / 2MWh
LFP Battery + PCS + BMS + EMS

→

LOAD
WWTP Process Load
Aeration / Pumping / Dewatering / Lighting

→

Grid Connection Point Metering & Protection

EMS SMART ENERGY MANAGEMENT PLATFORM

Data Acquisition & Monitoring • Load & Generation Forecasting • Intelligent Dispatch Optimization • Peak-Valley Arbitrage • Demand Management • Demand Response • Process Synergy • Energy Efficiency Analytics

Communication: Modbus / IEC 61850 → Edge Gateway → Cloud EMS Platform → Web & Mobile Visualization

Distributed Solar PV System Design

2MWp
Installed Capacity (approx. 18,000 m^2 area)

2.2~2.4M
Annual Generation (kWh), 1100~1200 eq. hours

90%
Self-Consumption Rate, surplus to grid

PV Deployment Options Comparison

Type	Location	Capacity / Area	Advantages	Considerations
Tank-Surface PV	Primary, aeration & secondary tanks	80~100 Wp/m^2	Large area, shading reduces evaporation	Anti-corrosion, biogas safety, access lanes
Rooftop PV	Blower, dewatering & admin buildings	120~150 Wp/m^2	Easy installation, close to load	Roof load, waterproofing, orientation
Carport PV	Parking lots & bike shelters	60~80 Wp/m^2	Dual-use land, provides shading	Structural safety, EV charger pre-wiring

Key Equipment: Monocrystalline modules (580~620Wp), string inverters (100~125kW), galvanized steel mounting, smart combiner boxes, anti-islanding protection

04 ENERGY STORAGE

Energy Storage System Design & Operation Strategy

1MW/2MWh
Rated Power / Capacity, 0.5C rate

85.9%
System Round-Trip Efficiency (AC-AC)

2C2D
Daily Cycles, 15-year design life

LFP
Lithium Iron Phosphate, ≥6000 cycles

System Components

Battery System	PCS Inverter	BMS	EMS Controller	Fire & Thermal
LFP cells Battery racks / cabinets	1MW bidirectional PCS Four-quadrant operation	V/temp/SOC monitoring Balancing & protection	Charge/discharge strategy Coordinated dispatch	Novec 1230 / FM-200 Liquid/air cooling

Core Operation Strategies

Peak-Valley Arbitrage: Charge during off-peak (0:00~8:00), discharge during peak (8:00~11:00, 18:00~21:00), 2 cycles daily.

Emergency Backup: Island mode on grid outage; power critical aeration and pumping.

Demand Management: Real-time max demand monitoring; storage discharge for peak shaving to reduce demand charges.

Demand Response: Connect to VPP; respond to grid dispatch signals for subsidies.

Smart EMS Four-Layer Architecture

L4 APPLICATION LAYER

Energy Monitoring Dashboard • Load & Generation Forecasting • Intelligent Dispatch Optimization • Peak-Valley Arbitrage • Demand Management • Demand Response • Energy Efficiency Analysis • Carbon Emission Accounting • Alarm & Reporting

L3 PLATFORM LAYER

Cloud Data Center • Big Data Processing • AI Algorithm Engine • Digital Twin Model • Microgrid Optimization Solver • Open API Interface • Multi-tenant Management

L2 NETWORK LAYER

Industrial Ethernet • RS485 / Modbus RTU • IEC 61850 • LoRa / NB-IoT • 4G/5G Wireless • Edge Gateway • VPN Secure Tunnel

L1 PERCEPTION LAYER

Smart Meters • PV Inverters • ESS PCS & BMS • VFDs & PLCs • Process Sensors (flow/level/DO/pH) • Environmental Sensors • Smart Switches

05 EMS FUNCTIONS

EMS Core Functions & Process Synergy

01 Real-Time Monitoring

Unified dashboard for grid, PV, storage and load. Real-time power, voltage, current, SOC, SOH, energy flow. Multi-dimensional data visualization.

02 Load & Generation Forecasting

AI-based short-term load forecasting (MAPE <3%). PV generation forecasting based on weather data. 24h rolling prediction for dispatch.

03 Intelligent Dispatch Optimization

Multi-objective optimization: minimize cost, maximize PV self-use, reduce peak demand. MPC rolling optimization with 15min dispatch interval.

04 Peak-Valley Arbitrage

Auto charge/discharge based on TOU tariffs. 2 cycles daily. Dynamic strategy adjustment with tariff changes. Expected annual arbitrage revenue.

05 Demand Management & Response

Real-time max demand tracking. Storage peak shaving to reduce demand charges. VPP participation for grid dispatch response subsidies.

06 Process-Energy Synergy

Link aeration DO control with PV output. Shift flexible loads (pumping, dewatering) to high-PV periods. Process quality & energy co-optimization.

Additional: Carbon Emission Accounting • Equipment Health Management • Alarm & Event Logging • Automated Reporting • Mobile APP Access

Typical Daily Operation Strategy & Energy Flow

24-Hour Dispatch Strategy

Time Period	Tariff	PV Output	Storage Action	Strategy Description
00:00~08:00	Off-Peak	None	**Charge (1MWh)**	Charge storage from grid at low tariff; baseline process load from grid
08:00~11:00	Peak	Rising	**Discharge (1MWh)**	PV + storage supply load; reduce grid purchase at peak tariff
11:00~14:00	Flat	Peak	**Standby / Charge**	PV surplus charges storage; shift flexible loads to high-PV period
14:00~18:00	Flat	Declining	**Charge (1MWh)**	Charge storage from grid at flat tariff for evening peak discharge
18:00~21:00	Peak	None	**Discharge (1MWh)**	Storage discharges to cover evening peak; minimize grid peak purchase

Key Performance Metrics

90%+

PV Self-Consumption Rate

2C2D

Storage Daily Cycles

15min

Dispatch Optimization Interval

<3%

Load Forecasting MAPE

Economic Benefit Analysis (50,000 m^3/d WWTP)

¥6.8M
Total Investment (PV + ESS + EMS)

¥1.52M
Annual Net Benefit

4.5 yr
Simple Payback Period

18.2%
20-Year IRR

Investment Breakdown

Item	Cost (¥M)	Share
PV System (2MWp)	3.20	47.1%
ESS (1MW/2MWh)	2.80	41.2%
EMS Platform	0.40	5.9%
Installation & Commissioning	0.40	5.9%
Total	6.80	100%

Annual Benefit Composition

Benefit Source	Amount (¥M)	Share
PV Electricity Savings	0.88	47.8%
Peak-Valley Arbitrage	0.52	28.3%
Demand Charge Reduction	0.24	13.0%
Demand Response Subsidy	0.10	5.4%
Process Energy Saving	0.10	5.4%
Gross Benefit	1.84	100%

Note: Annual O&M cost ¥0.32M (4.7% of investment); net benefit = gross benefit - O&M = ¥1.52M. Assumptions: avg tariff ¥0.75/kWh, peak-valley spread ¥0.65/kWh, PV generation 2.3M kWh/yr, storage throughput 1.46M kWh/yr.

Energy Saving & Emission Reduction Benefits

ANNUAL ELECTRICITY SAVING

2.30 M kWh

PV generation 2.3M kWh + process optimization 0.15M kWh
Equivalent to 8.5% of plant annual electricity consumption

ANNUAL CO_2 REDUCTION

1,610 tonnes

Grid emission factor: 0.5703 tCO_2/MWh (China 2024 avg)
Equivalent to planting 88,000 trees (18 kg CO_2/tree/yr)

Other Environmental Benefits

SO_2 Reduction: 6.9 tonnes/year (0.003 t/MWh grid factor)

NO_x Reduction: 5.98 tonnes/year (0.0026 t/MWh grid factor)

Dust Reduction: 437 tonnes/year (0.19 t/MWh grid factor)

Water Saving: 9,200 m^3/year (thermal power water consumption factor)

Carbon accounting follows IPCC 2006 Guidelines and China grid emission factors. 20-year cumulative CO_2 reduction: ~32,200 tonnes. Supports plant ESG reporting and dual carbon goals.

Implementation Roadmap & Project Milestones

1 Feasibility
Energy audit
Load analysis
Site survey
Investment estimate

2 Design
PV layout design
ESS sizing
EMS architecture
Grid connection plan

3 Procurement
Module & inverter
Battery & PCS
EMS hardware
Cabling & switchgear

4 Construction
PV mounting & wiring
ESS installation
EMS deployment
Grid connection works

5 Commissioning
System testing
Grid acceptance
EMS calibration
Trial operation

6 O&M
Remote monitoring
Predictive maintenance
Performance optimization
Annual audit

Project Timeline & Key Milestones

Phase	Duration	Milestone	Deliverables
Feasibility Study	1 month	Report approved	Energy audit report, feasibility study, investment estimate, ROI analysis
Engineering Design	1.5 months	Drawings issued	PV layout, single-line diagram, ESS design, EMS architecture, BOM
Procurement & Construction	3 months	Mechanical complete	Equipment delivery, installation, wiring, grid connection infrastructure
Commissioning & O&M	Ongoing	Grid acceptance	Test reports, grid acceptance certificate, EMS go-live, O&M manual

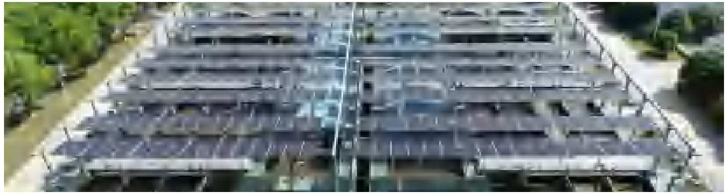
Total project duration: ~5.5 months from feasibility to grid acceptance. EMC model allows zero upfront investment by plant owner.

09 CASE STUDIES

Typical Case Studies & Project Photos

Case 1: Jiangsu 100,000 m^3/d WWTP

Scale: 4MWp PV + 2MW/4MWh ESS + EMS
Annual Savings: ¥3.1M | **CO_2:** 2,620 t/yr
Payback: 4.3 yr (EMC, zero upfront)
Photo: Xiaoshan Linjiang WWTP 30MWp PV (China's largest)



Case 2: Guangdong 50,000 m^3/d WWTP

Scale: 2MWp PV + 1MW/2MWh ESS + EMS
Annual Savings: ¥1.52M | **CO_2:** 1,310 t/yr
Payback: 4.5 yr | VPP adds ¥0.1M/yr
Photo: Kunshan WWTP distributed PV on tank surfaces

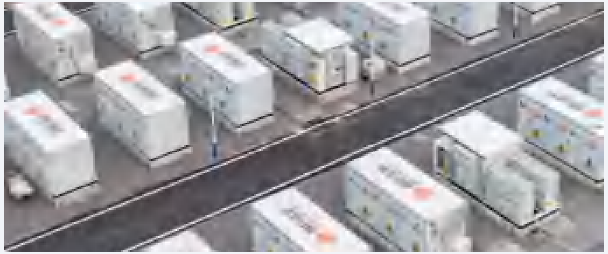
Key Success Factors & Best Practices

Accurate Load Profiling
12-month data analysis for optimal sizing

Process-Energy Co-opt
Link aeration DO control with PV output

Dynamic Tariff Strategy
Real-time TOU tracking, auto-adjust schedule

VPP & Demand Response
Aggregate resources for grid dispatch revenue



Containerized LFP energy storage station (Liuhe, Jiangsu)

Note: Case data based on representative projects; photos show actual WWTP PV and ESS installations.

10 EMC MODEL

Energy Management Contract (EMC) Business Model

EMC Financial Model (50,000 m³/d WWTP)

Item	Value	Description / Assumptions
Total Investment	**¥6.8M**	2MWp PV + 1MW/2MWh ESS + EMS, fully funded by EMCO
Annual Gross Savings	**¥1.84M**	PV savings ¥0.88M + arbitrage ¥0.52M + demand ¥0.24M + DR ¥0.10M + process ¥0.10M
Annual O&M Cost	¥0.32M	4.7% of investment; includes monitoring, maintenance, insurance, EMS platform fee
Annual Net Savings	**¥1.52M**	Gross savings minus O&M; baseline verified by third-party M&V protocol
Sharing Period (Years 1-8)	EMCO 70% / Plant 30%	EMCO recovers investment + ROI; plant gets ¥0.46M/yr without spending
Post-Sharing (Years 9-20)	**Plant 100%**	Equipment ownership transfers to plant; full ¥1.52M/yr savings retained

Plant Owner 20-Year NPV: ~¥14.8M (at 6% discount); EMCO IRR: ~16.5%; Simple payback for EMCO: ~5.9 years after sharing ratio. Win-win structure with zero capital risk for plant owner.

Summary & Key Takeaways

PV + Storage + EMS = Compelling Value for WWTPs

Stable 24/7 load, large available surface area, and high electricity costs make WWTPs ideal candidates for distributed solar + storage + smart energy management.

Quantified Benefits

¥1.52M	4.5 yr	1,610 t	90%+
Annual Net Savings	Simple Payback Period	Annual CO_2 Reduction	PV Self-Consumption Rate

Strategic Recommendations

Start with EMC: Zero upfront investment, technology risk transferred to EMCO, immediate savings from day one.

Scale Gradually: Pilot at one plant, validate M&V protocol, then replicate across the utility's WWTP portfolio.

Prioritize EMS: Smart dispatch unlocks 20-30% additional value beyond hardware; process-energy synergy is the key differentiator.

Future-Proof: Design for VPP participation, EV charging integration, and carbon trading as markets mature.