Deployment Guide: Smart Waste Management DePIN

Pre-Deployment Planning

Site Assessment Checklist

Location Analysis

```
Physical Requirements:

— Bin Accessibility: 2m clearance minimum

— Solar Exposure: 4+ hours direct sunlight

— Network Coverage: WiFi or cellular signal

— Security Level: Vandalism risk assessment

— Maintenance Access: Service vehicle clearance

— Regulatory Compliance: Local permits required

Environmental Factors:

— Temperature Range: -20°C to +60°C operation

— Precipitation: IP65 rating sufficient

— Wind Load: Mounting structure adequacy

— Foot Traffic: High/medium/low classification

— Contamination Risk: Chemical exposure potential

— Wildlife Interference: Animal-proofing needs
```

Stakeholder Engagement

Municipal Partners:
— Waste Management Department
— IT/Technology Department
— Public Works Division
— Environmental Services
— Legal/Procurement Team
Community Relations
Community Outreach:
— Neighborhood Associations
— Environmental Groups
— Schools and Universities
— Local Businesses
— Senior Centers
└── Youth Organizations

Regulatory Requirements

Permits & Approvals

- Installation Permits: Public space modifications
- Electrical Permits: Solar panel installations
- Telecommunications: Radio frequency approvals
- Data Privacy: GDPR/CCPA compliance documentation
- Environmental: Impact assessment if required
- Insurance: Liability coverage for public installations

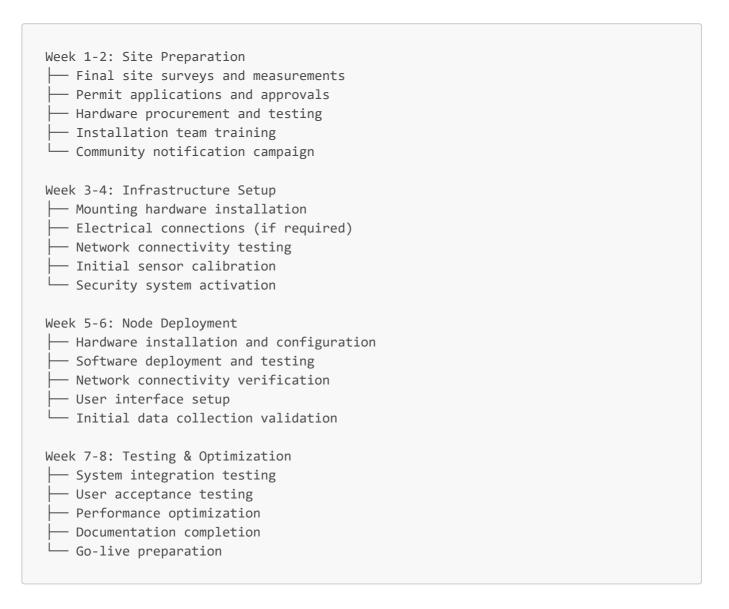
Compliance Standards

- FCC Part 15: Radio emissions certification
- **UL Listed**: Electrical safety standards
- IP65 Rating: Ingress protection verification
- RoHS Compliance: Hazardous substance restrictions
- WEEE Directive: End-of-life recycling plan

Hardware Deployment

Phase 1: Pilot Installation (25 Nodes)

Timeline: 6-8 Weeks



Installation Process (Per Node)

Type A Node (Basic Fill Monitoring)

Step 1: Mounting Preparation (30 minutes)
Step 2: Hardware Installation (20 minutes)
Step 3: Configuration (15 minutes)
Step 4: Testing & Validation (10 minutes) — Fill level measurement test — Data transmission verification — Battery charging confirmation — Tamper detection test — Final system check

Type B Node (Advanced Al-Powered)

```
Step 1: Mounting & Power (45 minutes)

Install reinforced mounting plate

Mount solar panel and controller

Install battery compartment

Run power cables through conduit

Ground system properly

Step 2: Sensor Installation (30 minutes)

Mount camera module with weather shield

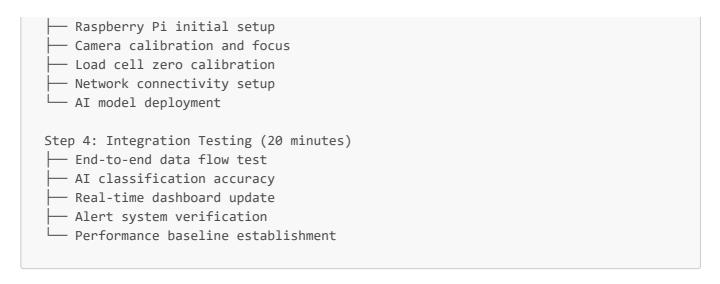
Install load cell platform

Position ultrasonic sensor array

Connect LoRaWAN antenna

Verify all sensor connections

Step 3: System Configuration (25 minutes)
```



Phase 2: Municipal Rollout (200 Nodes)

Deployment Strategy



Installation Teams

```
Team Structure (per 5-node crew):

├── Lead Technician: Installation oversight
├── Hardware Specialist: Sensor configuration
├── Network Engineer: Connectivity setup
├── Safety Officer: Site safety compliance
└── Documentation: Installation records
```

```
Daily Capacity:

Type A Nodes: 8-10 installations per day

Type B Nodes: 4-6 installations per day

Travel Time: 20% of schedule

Testing/Validation: 30% of schedule

Documentation: 10% of schedule

Quality Assurance:

100% functional testing

24-hour burn-in period

Random audit inspections

Customer acceptance sign-off

Warranty registration
```

Software Deployment

Blockchain Infrastructure

Smart Contract Deployment

```
# Deploy to Solana Devnet (Testing)
solana config set --url https://api.devnet.solana.com
solana program deploy target/deploy/waste_management.so

# Verify deployment
solana program show <PROGRAM_ID>

# Initialize program state
solana program invoke <PROGRAM_ID> initialize_program

# Deploy to Mainnet (Production)
solana config set --url https://api.mainnet-beta.solana.com
solana program deploy target/deploy/waste_management.so --upgrade-authority
<AUTHORITY_KEYPAIR>
```

Token Creation & Distribution

```
# Create WASTE token
spl-token create-token --decimals 6

# Create token accounts
spl-token create-account <TOKEN_MINT>

# Initial token minting
spl-token mint <TOKEN_MINT> 10000000000 <DESTINATION_ACCOUNT>

# Set up distribution wallets
spl-token create-account <TOKEN_MINT> --owner <COMMUNITY_WALLET>
```

```
spl-token create-account <TOKEN_MINT> --owner <DEVELOPMENT_WALLET>
spl-token create-account <TOKEN_MINT> --owner <TREASURY_WALLET>
```

Node Software Configuration

Basic Node (Type A) Setup

```
# Flash firmware to ESP32
esptool.py --chip esp32s3 --port COM3 write_flash 0x0 waste_node_basic.bin

# Configure WiFi credentials
waste-config --wifi-ssid "MunicipalNetwork" --wifi-password "SecurePass123"

# Set location and node ID
waste-config --location "40.7128,-74.0060" --node-id "NYC_001_BASIC"

# Configure reporting intervals
waste-config --report-interval 300 --heartbeat-interval 3600

# Start monitoring service
systemctl enable waste-node-basic
systemctl start waste-node-basic
```

Advanced Node (Type B) Setup

```
# Raspberry Pi OS installation and updates
sudo apt update && sudo apt upgrade -y
sudo apt install python3-pip docker.io -y
# Install waste management software
git clone https://github.com/waste-depin/node-software.git
cd node-software
pip3 install -r requirements.txt
# Configure AI models
python3 setup_ai_models.py --download-models --optimize-for-pi4
# Camera calibration
python3 calibrate_camera.py --interactive
# Load cell calibration
python3 calibrate loadcell.py --known-weight 10.0
# Network configuration
sudo nano /etc/waste-node/config.yaml
# Edit: location, node_id, network_settings, ai_settings
# Start services
```

```
sudo systemctl enable waste-node-advanced
sudo systemctl start waste-node-advanced
```

Dashboard & API Deployment

Backend Services (Docker)

```
# docker-compose.yml
version: '3.8'
services:
  api-server:
    image: waste-depin/api-server:latest
    ports:
      - "8080:8080"
    environment:
      - DATABASE_URL=postgresql://user:pass@db:5432/waste_db
      - SOLANA_RPC_URL=https://api.mainnet-beta.solana.com
      - JWT_SECRET=your-jwt-secret
    depends_on:
      - database
      - redis
  database:
    image: postgres:14
    environment:
      - POSTGRES DB=waste db
      - POSTGRES_USER=waste_user
      - POSTGRES_PASSWORD=secure_password
    volumes:
      - postgres_data:/var/lib/postgresql/data
  redis:
    image: redis:7-alpine
    ports:
      - "6379:6379"
  frontend:
    image: waste-depin/dashboard:latest
    ports:
      - "3000:3000"
    environment:
      - REACT_APP_API_URL=http://localhost:8080
      - REACT_APP_SOLANA_NETWORK=mainnet-beta
volumes:
  postgres_data:
```

Deployment Commands

```
# Deploy to production server
docker-compose -f docker-compose.prod.yml up -d

# Initialize database
docker exec waste-api python manage.py migrate
docker exec waste-api python manage.py create_admin_user

# Configure reverse proxy (nginx)
sudo nano /etc/nginx/sites-available/waste-dashboard
sudo ln -s /etc/nginx/sites-available/waste-dashboard /etc/nginx/sites-enabled/
sudo systemctl reload nginx

# SSL certificate setup
sudo certbot --nginx -d dashboard.waste-depin.org
```

Network Configuration

Connectivity Options

WiFi Network Setup

```
Municipal WiFi Requirements:

SSID: WasteManagement_IoT

Security: WPA3-Enterprise preferred

Bandwidth: 1 Mbps minimum per node

Range: 100m coverage radius

Backup: Cellular failover capability

VLAN: Isolated IoT network segment

Configuration Steps:

Configuration Steps:

Configure RADIUS authentication

Set bandwidth limits per device

Enable network monitoring

Configure firewall rules

Test connectivity and failover
```

LoRaWAN Gateway Deployment

```
Deployment Locations:

├── Municipal buildings (city hall, libraries)

├── Water towers and communication towers

├── Schools and community centers

├── Fire stations and police stations

└── Public works facilities
```

Data Flow Architecture

Real-time Data Pipeline

```
Node Sensors → Edge Processing → Gateway → Cloud API → Dashboard

↓ ↓ ↓ ↓ ↓

Raw Data Filtered Data Compressed Processed Visualized

(1Hz) (0.1Hz) (Batch) (Real-time) (Web UI)
```

Blockchain Integration

```
Smart Contract Events:

Node Registration: New hardware deployment

Data Verification: Sensor reading validation

Reward Distribution: Token allocation

Governance Votes: Community decisions

System Updates: Protocol upgrades

Transaction Flow:

Sensor data aggregated locally

Merkle proof generated for batch

Submit proof to smart contract

Validate data integrity on-chain

Trigger reward distribution

Update user balances
```

Testing & Validation

System Integration Testing

Functional Tests

```
Hardware Validation:

├── Sensor accuracy: ±5% tolerance

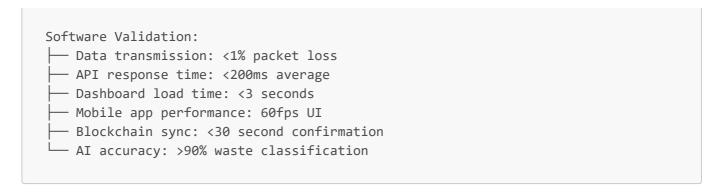
├── Battery life: >6 months Type A, >3 months Type B

├── Solar charging: Full charge in 8 hours sunlight

├── Network connectivity: 99%+ uptime target

├── Tamper detection: 100% alert rate

└── Environmental resistance: IP65 compliance
```



Performance Benchmarks

```
Scalability Testing:

— 1,000 nodes: Baseline performance

— 10,000 nodes: Load testing

— 100,000 nodes: Stress testing

— 1,000,000 nodes: Ultimate capacity

— Failure scenarios: Graceful degradation

Load Testing Results:

— API throughput: 10,000 requests/second

— Database queries: <50ms average

— Blockchain TPS: 2,000 transactions/second

— Dashboard users: 50,000 concurrent

— Mobile app users: 100,000 concurrent
```

User Acceptance Testing

Community Beta Program

```
Beta Participants:

── 100 households across 5 neighborhoods

── 20 municipal staff members

── 10 waste management professionals
 — 15 environmental advocates
└── 5 technology enthusiasts
Testing Duration: 8 weeks
├─ Week 1-2: Onboarding and training
├─ Week 3-4: Basic functionality testing
── Week 5-6: Advanced features testing
├─ Week 7-8: Feedback collection and refinement
Success Criteria:
├── 80%+ user satisfaction rating
├── 90%+ system reliability
├── 95%+ data accuracy
 — <5% support ticket rate</p>

    70%+ daily active usage
```

Maintenance & Support

Preventive Maintenance Schedule

Monthly Tasks

- Visual inspection of all nodes
- Battery voltage and charging verification
- Solar panel cleaning and inspection
- Network connectivity testing
- Software update deployment
- Data backup verification

Quarterly Tasks

- Comprehensive system health check
- Sensor calibration verification
- Hardware component replacement (wear items)
- Security audit and penetration testing
- Performance optimization review
- User feedback analysis and implementation

Annual Tasks

- Complete hardware refresh assessment
- Major software version upgrades
- Regulatory compliance review
- Insurance and warranty renewals
- Expansion planning and budgeting
- Technology roadmap updates

Support Infrastructure

Technical Support Tiers

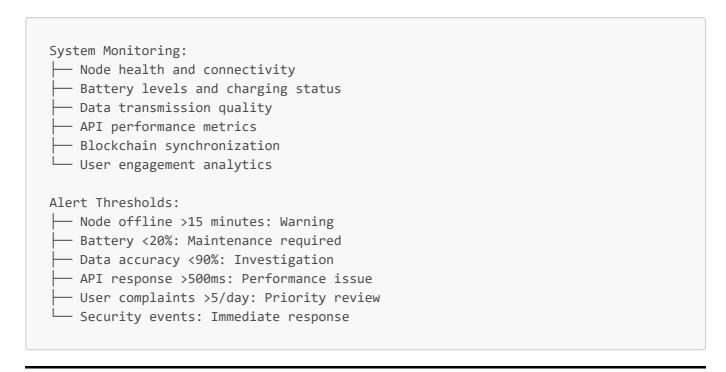
```
Tier 1: Community Support

- Online documentation and FAQs
- Community forum and chat
- Video tutorials and guides
- Mobile app help system
- Automated troubleshooting

Tier 2: Professional Support
- Email support (24-hour response)
- Phone support (business hours)
- Remote diagnostics and repair
- On-site support (if required)
- Training and consultation
```



Monitoring & Alerting



Comprehensive deployment ensuring reliable, scalable, and maintainable waste management infrastructure.