# Zhengzhou Hengling New Energy - Solution

# Smart Tunnel Solution

## Zhengzhou Hengling New Energy Technology Co., Ltd.

---

# 1. REQUIREMENT ANALYSIS & INVESTIGATION

## 1.1 Project Background

Road and railway tunnels present unique lighting challenges: - Critical safety implications for driver visual adaptation - “Black hole effect” at tunnel entrances during daytime - “White hole effect” at tunnel exits - 24/7 operation with high energy consumption - Harsh environment with fumes, moisture, vibration

## 1.2 Stakeholder Requirements

- **Transport Authorities**: Safety compliance, energy efficiency, reliability
- **Tunnel Operators**: Reduced maintenance, remote monitoring, automation
- **Road Users**: Visual comfort, glare reduction, safety enhancement
- **Maintenance Teams**: Predictive maintenance, easy component access
- **Finance Teams**: Low TCO, long service life, energy savings

## 1.3 Tunnel Parameters

- Tunnel types: road, railway, metro, pedestrian
- Length classification: short (<500m), medium (500-3000m), long (>3000m)
- Traffic volume: 5,000 to 100,000+ vehicles per day
- Speed limits: 50km/h to 120km/h
- Environmental conditions: humidity, fumes, temperature, vibration

---

# 2. SOLUTION DESIGN

## 2.1 Zoned Tunnel Lighting Architecture

**Five Critical Lighting Zones:** - **Threshold Zone (Zone 1)**: High brightness for visual adaptation - **Transition Zone (Zone 2)**: Gradual brightness reduction - **Interior Zone (Zone 3)**: Uniform constant illumination - **Exit Zone (Zone 4)**: Gradual brightness increase - **Emergency Zone**: Critical safety lighting for evacuation

## 2.2 Core Technologies

- **Adaptive Luminance Control**: AI-based adjustment to external light conditions

- **Vehicle Detection**: Radar/LiDAR for traffic-responsive lighting
- **Visual Adaptation Algorithm**: CIECAM02 color appearance modeling
- **Fog Penetration Optimization**: Specific spectrum for adverse weather
- **V2X Communication**: Connected vehicle integration

### 2.3 Fixture Specifications

| Zone | Fixture Type | Power Range | Mounting |
|---|---|---|---|
| Threshold | High-Power Tunnel Luminaire | 200W-500W | Ceiling / Side |
| Transition | Medium-Power Linear | 100W-300W | Ceiling |
| Interior | Linear LED Module | 50W-150W | Continuous Row |
| Exit | Medium-Power Tunnel | 100W-300W | Ceiling / Side |
| Emergency | Self-Contained Unit | 10W-50W | Integrated |

### 2.4 Control System Features

- Real-time external luminance monitoring (L20 method)
- Traffic flow and speed responsive dimming
- Weather condition adaptive lighting (fog, rain)
- Individual fixture monitoring and control
- Fault detection and automated alerting
- Energy consumption analytics and reporting
- SCADA integration with tunnel management system
- Emergency lighting automatic activation

---

# 3. PRODUCT CUSTOMIZATION

### 3.1 Environmental Customization

- IP66/IP67 ingress protection rating
- IK09/IK10 impact resistance
- Corrosion-resistant coating (C5-M for coastal tunnels)
- Vibration damping (EN 60068-2-6)
- Extended temperature range (-40°C to +70°C)
- Flame-retardant materials per EN 13501

### 3.2 Optical Customization

- Symmetric / asymmetric light distribution
- Anti-glare optics (UGR <19)
- Custom beam angles for specific tunnel geometry
- Flicker-free operation for camera systems
- High CRI (Ra >70) for color recognition
- Special spectrum for fog penetration

### 3.3 Integration Customization

- SCADA protocol support (IEC 60870-5-104, DNP3)
- Tunnel Management System (TMS) integration
- Traffic control system synchronization
- Fire and gas detection system response
- Ventilation system coordination
- V2X and connected vehicle infrastructure

---

# 4. PROJECT IMPLEMENTATION

## 4.1 Project Timeline

| Phase | Duration | Activities |
|---|---|---|
| Design & Simulation | 2-4 weeks | Photometric simulation, control philosophy |
| Factory Acceptance | 1 week | FAT testing, pre-configuration |
| Manufacturing | 4-8 weeks | Production, QC, environmental testing |
| Installation | 4-12 weeks | Night work, traffic management, phased |
| Commissioning | 2-4 weeks | Calibration, integration, performance testing |
| Total | 13-29 weeks | End-to-end turnkey delivery |

## 4.2 Installation Methodology

- **Traffic Management**: Night work, lane closures, detour planning
- **Safety Protocols**: Confined space entry, fall protection, gas detection
- **Installation Sequence**: Portal areas first, then interior zones
- **Quality Control**: Torque verification, electrical safety testing
- **Documentation**: As-built records, test certificates, photos

## 4.3 Compliance Standards

- CIE 88:2004 Tunnel Lighting Guidelines
- EN 13201 Road Lighting Performance
- IEC 60598-1 Luminaire Safety
- IEC 61508 Functional Safety
- NFPA 502 Standard for Road Tunnels
- EN 12193 Road Tunnel Safety

---

# 5. SYSTEM COMMISSIONING & TESTING

## 5.1 Photometric Commissioning

- Luminance measurement at 24 reference points
- Uniformity verification (U0 >0.4, U1 >0.6)
- Glare assessment (TI <15%)
- Visual adaptation curve verification
- Threshold increment (TI) calculation

## 5.2 Functional Testing

- Adaptive control response time verification
- External luminance sensor calibration
- Traffic detection system integration
- Emergency lighting activation test
- SCADA communication and point mapping
- Failover and redundancy mechanism testing

## 5.3 Performance Validation

- 72-hour continuous operation test
- Energy consumption baseline measurement
- System response to weather condition changes
- Cybersecurity penetration testing
- 30-day trial operation monitoring
- Independent third-party safety audit

---

# 6. PROJECT DELIVERY

## 6.1 Deliverables Package

- Complete tunnel lighting system installation
- Central control system with SCADA integration
- Redundant servers and network infrastructure
- Mobile maintenance access application
- Spare parts inventory and specialized tools
- Comprehensive documentation package

## 6.2 Documentation

- As-built drawings and BIM models
- Photometric calculation reports
- Control sequence of operations
- Operation and maintenance manuals
- Compliance certificates and test reports
- Emergency response procedures
- Training materials and video tutorials

### 6.3 Training Program

- **Control Room Operators**: System monitoring, alarm response, manual override
- **Maintenance Teams**: Component replacement, calibration, troubleshooting
- **IT Administrators**: Network management, cybersecurity, backup procedures
- **Management Team**: Reporting, KPI monitoring, strategic planning
- **Emergency Response**: Crisis procedures, coordination with authorities

---

# 7. OPERATION & MAINTENANCE

## 7.1 Predictive Maintenance System

| Feature | Capability |
|---|---|
| LED Degradation | Lumen depreciation monitoring and prediction |
| Driver Health | Temperature and voltage trend analysis |
| Communication | Network performance and connectivity monitoring |
| Power Quality | Voltage, current, power factor monitoring |
| Work Orders | Automated CMMS ticket generation |

## 7.2 Maintenance Schedule

| Frequency | Activities |
|---|---|
| Real-time | 24/7 system health monitoring |
| Daily | Alarm review and acknowledgment |
| Weekly | Energy consumption analysis |
| Monthly | Visual inspection, fixture cleaning |
| Quarterly | Sensor calibration, connection check |
| Semi-annually | Photometric verification, firmware update |
| Annually | Full system audit, compliance testing |

## 7.3 Lifecycle Management

- **Years 1-5**: Warranty coverage, regular maintenance, software updates
- **Years 6-10**: LED driver replacement planning, efficiency optimization

- **Years 11-15**: Technology upgrade assessment, partial refurbishment
- **Years 16-20**: Full system replacement planning, migration strategy

## 7.4 Performance Metrics

- Energy consumption reduction (target: 50-70%)
- System uptime reliability (target: 99.95%+)
- Mean Time To Repair (target: <8 hours)
- Maintenance cost reduction (target: 60%+)
- Accident rate reduction (target: 30%+)
- ROI achievement (target: 3-4 year payback)

---

**Zhengzhou Hengling New Energy Technology Co., Ltd.** *Safe, Smart, Sustainable Tunnel Lighting*
Website: www.hengling-energy.com | Email: info@hengling-energy.com