MINGFINE

WHITE PAPER · ENGLISH EDITION

Electronic Shelf Labels

The Future of Smart Retail

Electronic Shelf Labels are transforming how retailers manage pricing, product information and store operations. This white paper examines the technology, system architecture, industry applications, business value and implementation path of ESL systems.

Technology · Applications · Business Value · Digital Transformation

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01 Executive Summary

The retail industry is undergoing a significant digital transformation. As retailers face increasing pressure to improve operational efficiency, optimize pricing strategies, reduce labor costs and enhance customer experiences, digital technologies are becoming essential to modern retail operations.

Electronic Shelf Labels (ESLs) are one of the key technologies driving this transformation.

An Electronic Shelf Label is a digital display device installed on retail shelves to present product information, including prices, product names, promotional messages, barcodes, QR codes and other relevant information. Unlike traditional paper price tags, ESLs can be updated remotely and centrally through a software management platform.

By connecting shelf-level displays with retail management systems, ESL technology enables retailers to synchronize product information and pricing across physical stores and digital platforms.

Beyond replacing paper labels, ESL systems provide a foundation for smarter retail operations through automation, connectivity, data management and intelligent pricing.

This white paper explores ESL technology, system architecture, industry applications, business benefits, implementation considerations and future development trends.

It aims to help retailers, system integrators, distributors and technology partners understand the value of ESL solutions and identify opportunities to build more efficient and intelligent retail environments.

02 The Digital Transformation of the Retail Industry

2.1 Changing Retail Environments

Traditional retail operations have long relied on manual processes for shelf labeling, price changes, promotional updates and product information management.

As retail businesses expand, these processes become increasingly complicated.

Retailers must manage:

- Thousands or even millions of product SKUs.
- Frequent price adjustments and promotional campaigns.
- Multiple stores across different regions.
- Consistent pricing across online and offline channels.
- Increasing labor and operational costs.
- Accurate product information and regulatory requirements.

Traditional paper labels are difficult to manage efficiently at scale.

Retailers need more flexible, automated and connected solutions to support modern retail operations.

2.2 The Rise of Smart Retail

Smart retail combines digital technologies, connected devices and intelligent management systems to improve the entire retail value chain.

Key technologies include:

- Internet of Things (IoT).
- Artificial Intelligence (AI).
- Cloud Computing.
- Big Data Analytics.
- Digital Payment Systems.
- Automated Inventory Management.
- Electronic Shelf Labels.

Among these technologies, ESL provides a direct connection between retail information systems and physical shelf displays.

It helps transform static shelf information into dynamic, digitally managed retail content.

03 What Are Electronic Shelf Labels?

Electronic Shelf Labels are electronic display devices designed to replace conventional paper price tags in retail environments.

They are typically installed on shelf edges, product displays, promotional stands or other retail fixtures.

An ESL system generally consists of three main components:

3.1 Information Displayed on ESLs

1. **Electronic Shelf Labels**
   Digital display devices that present product information and pricing.
2. **Communication Infrastructure**
   Gateways or access points that transmit information between the management platform and electronic labels.
3. **ESL Management Software**
   A software platform that allows retailers to create, manage, update and synchronize displayed information.

Depending on the display size and configuration, ESLs can present:

- Product names and descriptions.
- Regular and promotional prices.
- Product barcodes.
- QR codes.
- Product specifications.
- Discount information.
- Stock and inventory indicators.

- Brand logos and images.
- Nutritional or product information.
- Multilingual content.

3.2 From Paper Labels to Digital Labels

Table 1. Traditional paper labels versus electronic shelf labels

Traditional Paper Labels	Electronic Shelf Labels
Manual price changes	Remote digital updates
High printing frequency	Reusable displays
Time-consuming replacement	Centralized management
Difficult multi-store synchronization	Multi-store synchronization
Limited display formats	Flexible digital layouts
Static information	Dynamic content
Manual verification	Digital status monitoring, where supported

ESL technology helps retailers modernize shelf management and reduce dependence on manual operations.

04 How Does ESL Technology Work?

An ESL system connects retail management software with electronic display devices through a wireless communication network.

A typical workflow includes the following steps:

1. **Product Data Management**
   Product information and prices are managed through an ESL software platform or imported from an existing POS, ERP or retail management system.
2. **Content Processing**
   The platform processes product information and generates display templates suitable for different ESL screen sizes.
3. **Wireless Communication**
   The management platform sends updated information to gateways or access points.
4. **Data Transmission**
   Gateways transmit update commands and display data to the corresponding electronic shelf labels.
5. **Display Refresh**
   The ESL receives the new information and refreshes its electronic paper display.
6. **Status Monitoring**
   Depending on system capabilities, retailers can monitor device connectivity, battery status and

update results. This process allows retailers to manage large numbers of electronic shelf labels through a centralized platform.

05 Core Technologies Behind ESL Systems

5.1 Electronic Paper Display (E-Paper)

Electronic paper is one of the most important technologies used in ESL products.

Unlike conventional LCD displays, electronic paper primarily reflects ambient light rather than continuously emitting light.

Key advantages include:

- Low power consumption.
- Excellent readability.
- Wide viewing angles.
- Paper-like visual appearance.
- High contrast.
- Long-lasting image retention without continuous power.

These characteristics make e-paper particularly suitable for retail shelf applications.

5.2 Wireless Communication

ESL devices communicate with management systems through wireless technologies.

Common communication options include:

2.4 GHz RF

Widely used in ESL systems for wireless data transmission between gateways and electronic labels.

- **Bluetooth Low Energy (BLE)** Provides low-power wireless communication and supports flexible deployment scenarios, including certain smartphone-controlled applications.
- **Other Wireless Technologies** Depending on product design and system architecture, other wireless technologies may also be used.

The appropriate communication solution depends on store size, device density, update frequency, infrastructure and deployment requirements.

5.3 NFC Technology

Near Field Communication (NFC) enables short-range wireless communication.

In selected ESL applications, NFC can support:

- Device identification.
- Configuration and maintenance.
- Local information access.
- Mobile interaction.

NFC capabilities depend on the hardware and software configuration.

5.4 Battery and Power Management

Low power consumption is essential for large-scale ESL deployments.

Battery life depends on several factors:

- Display size and type.
- Battery capacity.
- Update frequency.
- Wireless communication conditions.
- Environmental temperature.
- Operating configuration.

An effective power management strategy helps reduce maintenance costs and improve long-term system reliability.

06 ESL System Architecture

A complete ESL solution consists of several interconnected layers.

6.1 Hardware Layer

Includes:

- Electronic Shelf Labels.
- Wireless Gateways.
- Communication Accessories.
- Mounting Rails and Fixtures.
- Optional Networking Equipment.

6.2 Communication Layer

Provides wireless communication between the ESL platform and individual labels.

The network architecture should support reliable transmission, scalable device management and efficient coverage.

6.3 Software Layer

The software platform is responsible for:

- Product information management.
- Price management.
- Template design.
- Label assignment.
- Batch updates.
- Store and user management.
- Device monitoring.
- Data synchronization.

6.4 Integration Layer

The integration layer connects ESL software with existing retail IT infrastructure.

Typical integrations include:

- POS Systems.
- ERP Systems.
- Inventory Management Systems.
- Product Information Management Systems.
- Retail Middleware.
- Third-Party APIs.

A well-designed architecture enables ESL to become part of the retailer's existing digital ecosystem.

07 Electronic Paper Display Technology

Electronic paper technology has evolved significantly, offering more display options for different retail requirements.

7.1 Black and White Displays

Suitable for basic pricing, product names and barcodes.

Advantages include clear readability and simple information presentation.

7.2 Three-Color Displays

Common configurations include:

- Black / White / Red.
- Black / White / Yellow.

These displays provide additional visual emphasis for promotions, discounts and important product information.

7.3 Four-Color Displays

Typical configurations include:

- Black / White / Red / Yellow.

Four-color e-paper provides greater flexibility for product information, promotional content and brand presentation.

7.4 Large-Format ESL Displays

Large-format ESL products are designed for applications where more information needs to be displayed.

Typical applications include:

- Building materials.
- DIY and hardware stores.
- Garden centers.

- Home improvement retailers.
- Large product displays.
- Warehouse retail environments.

Larger displays can present more detailed specifications, product images, QR codes and promotional information.

08 Types and Features of Electronic Shelf Labels

ESL products are available in different sizes and configurations to meet various retail requirements.

Typical product sizes include:

- 1.54-inch.
- 2.13-inch.
- 2.66-inch.
- 2.9-inch.
- 3.5-inch.
- 4.2-inch.
- 5.8-inch.
- 7.5-inch.
- 10.2-inch.
- 13.3-inch.

Product availability and display configurations vary by manufacturer.

8.1 Small-Format ESL

Designed for standard supermarket shelves, convenience stores and small product displays.

8.2 Medium-Format ESL

Suitable for products requiring more detailed information, promotional messages or additional barcodes.

8.3 Large-Format ESL

Designed for large merchandise, building materials, home improvement products and applications requiring extensive product information.

8.4 Specialized ESL

Specialized models can be developed for particular environments and applications, including:

- Low-temperature and refrigerated environments.
- High-visibility promotional displays.
- Multi-color information presentation.
- NFC-enabled applications.
- Customized industrial and commercial displays.

Product selection should consider screen size, operating temperature, wireless technology, battery specifications and installation requirements.

09 Cloud-Based ESL vs. Local ESL Solutions

Different retailers require different software deployment models.

9.1 Cloud-Based ESL

Cloud ESL platforms allow retailers to manage electronic shelf labels through internet-connected software services.

Key advantages:

- Centralized management.
- Remote access.
- Multi-store management.
- Easier system expansion.
- Simplified software maintenance.
- Flexible API integration.

Cloud deployment is particularly suitable for retail chains and distributors managing multiple customers or locations.

9.2 Local / On-Premises ESL

Local ESL solutions are deployed on the retailer's own servers or within its internal network.

Key advantages:

- Greater control over infrastructure.
- Local data management.
- Customizable deployment.
- Support for specific IT and security requirements.
- Reduced dependency on external cloud services.

This model may be preferred by enterprises with strict IT policies or specific data management requirements.

9.3 Private Cloud ESL

Private cloud deployment combines centralized cloud architecture with dedicated infrastructure for individual customers or organizations.

It can provide a balance between centralized management, flexibility and infrastructure control.

9.4 Comparison

Table 2. Comparison of ESL deployment models

Feature	Public Cloud	Private Cloud	Local Deployment
Hosting	Shared cloud infrastructure	Dedicated environment	Customer server
Remote access	Yes	Yes	Depends on configuration
Multi-store management	Yes	Yes	Configurable

Feature	Public Cloud	Private Cloud	Local Deployment
Infrastructure control	Provider-managed	Greater customer control	Customer-managed
Customization	Platform-dependent	More flexible	Highly configurable
Maintenance	Provider-managed	Shared responsibility	Customer/provider

The ideal deployment model depends on the retailer's scale, IT requirements, security policies and long-term business strategy.

10 Applications Across Retail Industries

ESL technology is applicable to a wide range of retail environments.

10.1 Supermarkets and Grocery Stores

Supermarkets are among the most common applications for ESL technology.

Typical use cases:

- Daily price changes.
- Promotional campaigns.
- Product information management.
- Multi-store price synchronization.
- Fresh food pricing.
- Barcode and QR code display.

ESLs help supermarkets reduce manual shelf-label replacement and improve pricing consistency.

10.2 DIY and Hardware Stores

Large-format ESLs are particularly useful in DIY and hardware stores.

These retailers often sell products with complex specifications, different packaging sizes and frequently changing prices.

ESLs can display:

- Product dimensions.
- Technical specifications.
- Material information.
- Product codes.
- Promotional pricing.
- QR codes linking to product details.

10.3 Pharmacies

Pharmacies need accurate product information and efficient shelf management.

ESLs can support:

- Product identification.
- Pricing updates.
- Barcode display.
- Product specifications.
- Multilingual information.

Pharmacy deployments should also consider local regulations and the distinction between retail price information and regulated medical labeling.

10.4 Fashion and Apparel

ESLs can be used in fashion retail to display:

- Product names.
- Sizes.
- Colors.
- Prices.
- Promotional information.
- QR codes.

They can also support more consistent information management across multiple stores.

10.5 Electronics Retail

Electronics stores frequently manage products with complex specifications and promotional pricing.

ESLs can display:

- Product models.
- Technical specifications.
- Product features.
- Discount information.
- QR codes linking to online product pages.

10.6 Convenience Stores

Convenience stores benefit from easy-to-manage shelf pricing and compact digital displays.

ESLs can simplify daily price updates and support centralized management across store networks.

10.7 Food Service and Restaurants

ESL technology can also be used in food service environments, including:

- Digital menu information.
- Product displays.
- Food pricing.
- Promotional displays.
- Kitchen and food retail information.

11 Key Business Benefits of ESL Implementation

11.1 Reduced Labor Costs

Traditional paper price updates require employees to print, sort, replace and verify labels.

ESL systems automate much of this process.

Employees can update prices remotely through a centralized platform, allowing store staff to spend more time on customer service and other operational tasks.

11.2 Improved Pricing Accuracy

Manual price changes can lead to inconsistencies between shelf prices and checkout prices.

ESL systems help synchronize displayed information with the retailer's product and pricing databases.

11.3 Faster Promotional Execution

Retailers can implement promotional campaigns more efficiently by updating large numbers of electronic labels simultaneously.

This is especially useful during:

- Seasonal promotions.
- Holiday campaigns.
- Flash sales.
- Clearance events.
- Daily pricing adjustments.

11.4 Improved Customer Experience

Clear and accurate shelf information helps customers make purchasing decisions.

Color displays, QR codes and larger screens can provide additional product information and improve the shopping experience.

11.5 Reduced Paper Consumption

Reusable electronic displays reduce the need to continuously print and dispose of paper price labels.

This can support retailers' sustainability initiatives.

11.6 Scalable Multi-Store Management

For retail chains, centralized ESL management makes it easier to maintain consistent product information and pricing policies across multiple locations.

12 POS, ERP and Third-Party System Integration

System integration is one of the most important factors in a successful ESL deployment.

An ESL platform should be capable of connecting with existing retail management infrastructure.

12.1 POS Integration

Integration with POS systems enables product prices and information to be synchronized between checkout systems and shelf displays.

12.2 ERP Integration

ERP integration can help manage product information, pricing structures and business data across multiple departments and locations.

12.3 API Integration

Application Programming Interfaces (APIs) allow different software systems to exchange data.

Typical integration scenarios include:

- Product data import.
- Price synchronization.
- Promotional information updates.
- Label assignment.
- Device management.
- Update status reporting.

12.4 MQTT Communication

MQTT is a lightweight messaging protocol commonly used in IoT applications.

Depending on the platform architecture, MQTT can support communication between ESL-related services and external systems.

12.5 Integration Workflow

A typical integration process includes:

- Define the required data fields.
- Establish API or middleware connectivity.
- Map product codes and label identifiers.
- Synchronize product and pricing information.
- Configure display templates.
- Test data accuracy and update performance.
- Deploy and monitor the integrated solution.

The integration architecture should be designed according to the customer's existing infrastructure and technical requirements.

13 How to Calculate ESL Return on Investment

ESL implementation should be evaluated as a long-term operational investment.

The main financial benefits generally come from reduced labor requirements, lower printing expenses, improved operational efficiency and better pricing management.

13.1 Main Cost Components

- ESL hardware.
- Wireless gateways.
- Software platform.
- Installation accessories.
- System integration.
- Installation and deployment.
- Maintenance and support.

13.2 Potential Savings

- Reduced labor for price changes.
- Lower paper and printing expenses.
- Reduced manual checking.
- Fewer pricing inconsistencies.
- Improved promotional execution.
- More efficient multi-store management.

13.3 Basic ROI Formula

> **Annual Net Savings = Annual Operational Savings − Annual Operating Costs**
>
> **ROI (%) = (Annual Net Savings ÷ Initial Investment) × 100**
>
> **Payback Period = Initial Investment ÷ Annual Net Savings**

13.4 Illustrative Example

Consider a retailer operating 10 stores with 10,000 electronic shelf labels in total.

Assume the following illustrative figures:

Table 3. Illustrative return-on-investment calculation

Item	Example
Total ESL devices	10,000
Initial investment	$100,000
Annual labor savings	$45,000
Annual printing savings	$5,000
Other operational savings	$10,000
Annual operating costs	$5,000
Annual net savings	$55,000

Based on these assumptions:

Estimated Payback Period:

$100,000 ÷ $55,000 = Approximately 1.82 years.

These figures are illustrative only. Actual ROI varies depending on retailer size, labor costs, price-change frequency, system pricing, integration expenses and operational conditions.

14 Challenges and Considerations When Adopting ESL

Despite its advantages, ESL implementation requires careful planning.

14.1 Initial Investment

Retailers should evaluate the total cost of hardware, gateways, software, installation and integration.

14.2 Wireless Network Planning

Store layout, shelving materials, device density and wireless interference can affect communication performance.

A proper network survey helps determine gateway placement and coverage requirements.

14.3 Software Compatibility

The ESL platform should support integration with the retailer's existing POS, ERP and product information systems.

14.4 Battery Life and Maintenance

Battery performance should be evaluated based on update frequency, operating temperature and communication conditions.

14.5 Product Quality and Reliability

Retailers should consider display performance, wireless stability, battery specifications, environmental resistance and long-term product availability.

14.6 Technical Support

A reliable supplier should provide technical documentation, integration support, deployment guidance, training and after-sales service.

15 The Future of ESL: AI, IoT and Smart Retail

ESL technology is evolving beyond traditional digital price displays.

Future developments will increasingly connect electronic shelf labels with intelligent retail management systems.

15.1 AI-Driven Dynamic Pricing

AI can analyze market demand, inventory levels, sales performance and other business data to support pricing decisions.

When connected to an ESL platform, approved pricing changes can be distributed to shelf displays automatically.

Retailers must ensure that pricing strategies comply with applicable laws and consumer protection requirements.

15.2 IoT-Connected Retail Environments

ESLs can become part of broader IoT ecosystems.

Potential applications include:

- Smart inventory management.
- Connected shelf monitoring.
- Automated product identification.
- Real-time retail information.
- Intelligent store operations.

15.3 Digital and Physical Retail Integration

As online and offline retail channels become increasingly connected, ESL technology can help retailers maintain consistent product information across physical stores and digital platforms.

15.4 Interactive Retail Experiences

QR codes, NFC and other connectivity technologies can provide additional interaction between customers, products and digital services.

15.5 Large-Format E-Paper Applications

Larger e-paper displays are creating opportunities beyond conventional shelf-edge pricing.

Potential applications include:

- Digital promotional signage.
- Electronic menu boards.
- Store information displays.
- Warehouse and logistics identification.
- Meeting room and office signage.
- Smart home and commercial displays.

ESL technology is therefore part of a broader evolution toward connected, flexible and intelligent display solutions.

16 How to Choose the Right ESL Solution Provider

Selecting the right ESL supplier is essential for a successful long-term deployment.

Retailers, distributors and system integrators should evaluate the following factors:

1. **Product Portfolio**
   Does the supplier offer different display sizes, colors and configurations?
2. **Hardware Quality**
   Are product specifications, battery performance and communication stability suitable for the intended application?
3. **Software Capabilities**
   Does the platform support centralized management, multi-store operations and flexible template design?
4. **Integration Capabilities**
   Does the supplier provide API documentation, technical support and integration flexibility?
5. **Deployment Options**
   Are cloud, private cloud and local deployment options available where required?
6. **Customization**
   Can the supplier provide OEM, ODM and customized product solutions?
7. **Manufacturing Capability**
   Does the manufacturer have sufficient production capacity and quality management processes?
8. **Technical Support**
   Can the supplier provide responsive technical assistance and long-term service?
9. **Partnership Opportunities**
   Does the supplier support distributors, system integrators and regional business partners?

A long-term ESL partnership should combine reliable hardware, flexible software, integration capabilities and sustainable technical support.

17 Conclusion

Electronic Shelf Labels are transforming the way retailers manage pricing, product information and store operations.

By connecting digital management platforms with physical shelf displays, ESL technology helps retailers move from manual processes toward centralized, automated and data-driven retail management.

Its value extends beyond replacing paper labels.

ESL provides a foundation for improving operational efficiency, supporting omnichannel retail, reducing paper consumption and creating more connected shopping environments.

As AI, IoT, cloud computing and electronic paper technologies continue to evolve, ESL solutions will play an increasingly important role in the development of smart retail.

For retailers, distributors and technology partners, investing in the right ESL solution is an opportunity to build a more efficient, flexible and future-ready retail ecosystem.

18 About MINGFINE

MINGFINE – Your Trusted Electronic Shelf Label Solution Partner

Established in 2007, MINGFINE specializes in Electronic Shelf Labels (ESL), e-paper display solutions and intelligent retail technologies.

With extensive experience in electronic display technology, product development and manufacturing, MINGFINE provides solutions for retailers, distributors, system integrators and OEM/ODM partners worldwide.

Our Core Products

- Electronic Shelf Labels.
- Cloud-Based ESL Systems.
- BLE Electronic Shelf Labels.
- Large-Format E-Paper Displays.
- NFC E-Paper Badges.
- E-Paper Signage and Display Solutions.
- AI-Based People Counting Solutions.

Our Core Capabilities

- OEM & ODM Manufacturing.
- Cloud and Local ESL Deployment.
- API & MQTT Integration.
- Customized Hardware and Software.
- Flexible Product Configurations.
- Global Distributor Support.
- Technical and After-Sales Services.

Our Mission

To make retail operations smarter, more efficient and more connected through innovative electronic display technologies.

MINGFINE

Smart Displays. Smarter Retail.

Website: www.mingfine.com

- **Email: sales@mingfine.com** Business Cooperation: OEM / ODM / Distribution / System Integration

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This white paper is intended for general industry education and business reference. Technical specifications, deployment capabilities and commercial results may vary by product model, system configuration and application environment.

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