

# Keeping Coal Plants Online Responsibly

A Practical Path to ELG Compliance through  
Thermal Evaporation

White Paper

# Executive Summary

Compliance isn't a cliff—it's a continuum. America's coal fleet can stay online, stay reliable, and get cleaner if wastewater treatment modernization is approached pragmatically.

Across the U.S., coal-fired power plants generate millions of gallons of toxic wastewater each day — from flue gas desulfurization (FGD) scrubber systems and from ash ponds and landfills that produce combustion residual leachate (CRL). These streams contain selenium, mercury, arsenic, chlorides, and other compounds that can contaminate surface water and groundwater if left untreated.

Meanwhile, rising electricity demand—from data centers, electrification, industrial reshoring, and manufacturing growth—means the coal fleet will continue to play an important role in grid stability for the next decade or longer. Operators face an urgent dual challenge:

- Reduce wastewater volumes and toxic discharges, and
- Deliver reliable, economical baseload power when the system needs it most.

The Environmental Protection Agency's (EPA) Steam-Electric Effluent Limitation Guidelines (ELG) propose extending the Zero Liquid Discharge (ZLD) deadline to December 31, 2034 acknowledges this reality. It recognizes that transformation at scale requires time—and that premature shutdowns could threaten national grid reliability.

The opportunity lies in a staged, data-driven compliance path that reduces wastewater volumes now while methodically advancing toward full ZLD by 2034. This paper outlines that path. Drawing on field experience from Heartland's Concentrator™ systems, it demonstrates how direct-contact thermal evaporation provides a proven, flexible, and cost-effective bridge to near-term compliance.

These systems have demonstrated the ability to:

- Reduce FGD and CRL wastewaters by 90–95% under real operating conditions
- Leverage waste heat or low-cost gas for highly efficient operation
- Preserve reliability through simple, robust, low-maintenance design

EPA's extended timeline creates a window of opportunity for coal units to implement reliable, near-term reduction technologies that fit naturally into a long-term ZLD strategy.

**ELG compliance should be treated not as a regulatory burden, but as an engineering modernization strategy that strengthens environmental protection, operational resilience, and grid reliability.**

# REGULATORY CONTEXT & TIMING

## EPA's 2034 extension reflects a new era of pragmatic compliance.

For nearly a decade, the EPA's Steam-Electric Effluent Limitation Guidelines (ELG) have defined the wastewater treatment expectations for the coal-fired power plant industry. From the original rule in 2015 to the 2024 revision and 2025 proposed extension, the regulatory trajectory has unmistakably moved toward zero discharge of FGD and CRL wastewaters.

However, the proposed extension of the ZLD deadline to December 31, 2034, reflects a new era of pragmatic compliance. This decision creates an essential window (2025–2034) for utilities to sequence investment, learn from field-proven volume reduction technologies, and validate their final ZLD strategies, avoiding a forced compliance shutdown.

What has changed is not EPA's intent, but the context:

- 2015–2020: Foundational rules introduced discharge limits and flexible biological/chemical options.
- 2024: Tighter limits set ZLD as the expected end-state.
- 2025: Proposed extension acknowledges DOE and NERC warnings that aggressive timelines could threaten grid reliability.

EPA's updated schedule gives utilities space for pilot projects, phased capital planning, and adoption of field-proven technologies.

The conversation has shifted from “What must we install?” to “What will actually perform?”

# THE PLANT-LEVEL REALITY

Inside the fence line, compliance is an operations challenge before it's a regulatory one.

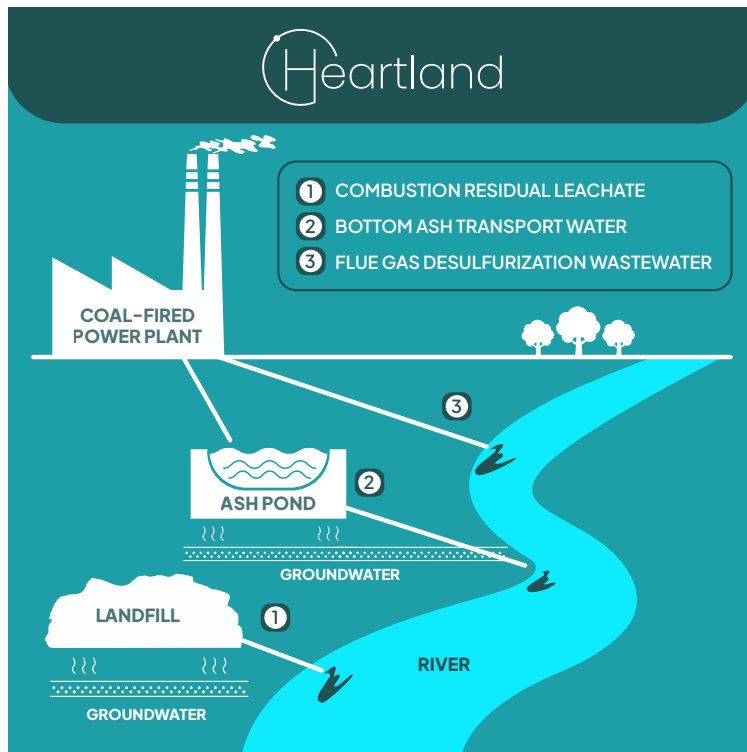
Policy debates happen in Washington. Compliance happens in boiler rooms. Operators manage wastewater chemistries that can shift daily, heat exchangers that scale overnight, and aging ponds and landfills that attract regulatory and community scrutiny.

Common challenges include:

- FGD effluent containing heavy metals, high chlorides, and scaling salts that corrode equipment
- Ash leachate with extremely high total dissolved solids (TDS) and variable pH
- Capital constraints and long permitting cycles that make immediate ZLD unrealistic

Utilities must demonstrate meaningful progress, without compromising operations or reliability. A credible solution must integrate seamlessly with the plant's existing footprint, energy profile, control systems, and staffing levels.

**Figure 1.** Key Wastewater Streams from Coal-Fired Power Plants



Coal-fired power plants generate multiple wastewater streams that require treatment to prevent environmental contamination. These include (1) combustion residual leachate (CRL) from landfills, (2) bottom ash transport water from ash ponds, and (3) flue gas desulfurization (FGD) wastewater from air pollution control systems, all of which can impact groundwater and surface water.

## The Cost of Inaction

Doing nothing carries its own risks.

As discharge limits tighten and public expectations rise, plants that postpone action face:

- Greater exposure to groundwater and surface-water contamination claims
- Mounting operation and maintenance expenses
- Reliability hits from scaling, fouling, or forced outages
- Heightened regulatory and community scrutiny that accelerates closure pressure

# TECHNOLOGY LANDSCAPE & DECISION CRITERIA

## Separate promise from proof: what actually works for high-TDS wastewater?

Utilities evaluating ELG-compliant treatment strategies confront a crowded technology landscape. However, not all options are equally viable for coal wastewater, especially when facing high TDS, variable chemistry, and fluctuating loads. Compliance at scale is as much a function of operational resilience as it is of regulatory adherence.

In the punishing, high-chloride environments typical of FGD effluent and ash leachate, technologies relying on sensitive barriers or complex physical transformations introduce significant operational risks:

- **Membrane / RO Systems:** While effective for water recovery, these systems are vulnerable to the rapid scaling and fouling caused by high concentrations of salts and heavy metals. This operational fragility demands heavy pretreatment, leading to high maintenance costs and increasing the risk of equipment downtime.
- **Crystallizers:** These systems achieve the ZLD end-state but often require substantial upfront Capital Expenditure (CapEx) and specialized operational maintenance (O&M). For immediate, near-term volume reduction, this complexity and cost profile makes full-scale crystallizer deployment unrealistic.

The most effective, near-term bridge to compliance must prioritize reliability through mechanical simplicity. Direct-contact thermal evaporation eliminates the primary sources of system failure by requiring no membranes, no surface heat exchangers, and no complex chemical conditioning. This allows the technology to thrive where other systems fail—handling high chlorides, variable chemistries, and intermittent load cycles.

**Table 1.** Decision Matrix – ELG Wastewater Treatment Options

Technology	Strengths	Operational Limitations (Risk Profile)
<b>Membrane / RO Systems</b>	Effective water reclamation	High operational risk due to rapid scaling and fouling; requires heavy pretreatment and increases downtime risks.
<b>Crystallizers</b>	Achieves ZLD	High capital barrier due to complexity and CapEx; requires specialized O&M.
<b>Direct-Contact Thermal Evaporation</b>	Scalability, tolerance to high TDS, simple mechanics, waste heat compatible, automated operation	Small residual stream remains (requires solidification/dewatering).

Comparative readiness, complexity, and reliability across key wastewater technologies.

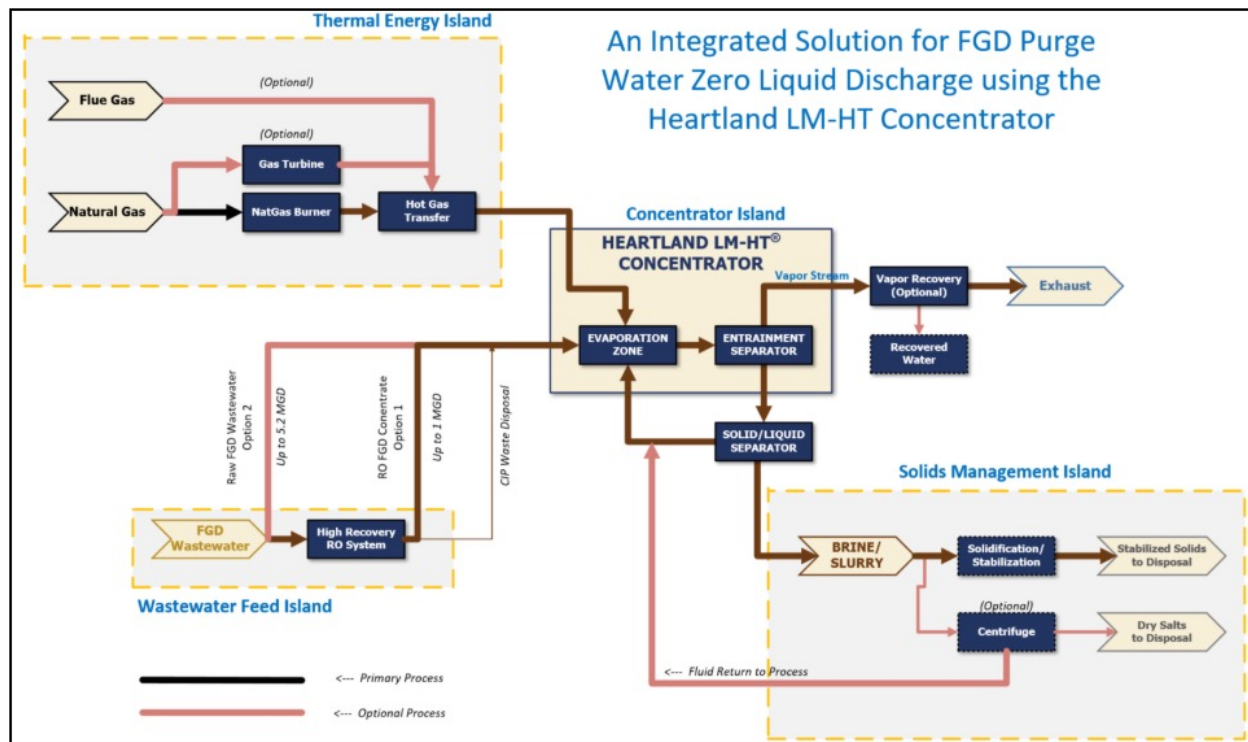
# HOW DIRECT-CONTACT THERMAL EVAPORATION WORKS

## Flexible energy. Reliable performance.

Direct-contact thermal evaporation introduces a hot gas stream—whether from waste heat, natural gas, or electricity—directly into the wastewater stream. The result is a highly adaptive, fouling-resistant evaporative process.

- Low-temperature evaporation (130–160°F) removes water without volatilizing contaminants.
- No surface heat exchange eliminates scaling and fouling.
- Multi-stage mist elimination ensures clean vapor release.

**Figure 2.** Direct-Contact Thermal Evaporation Process Schematic



This system simplifies wastewater treatment by introducing a hot gas stream (from waste heat or natural gas) directly into the liquid. This direct contact eliminates the primary cause of downtime—scaling and fouling—by avoiding surface heat exchangers. Water is evaporated at low temperatures ( $\approx 130\text{--}160^\circ\text{F}$ ), which prevents the volatilization of contaminants. After the vapor passes through multi-stage mist elimination, the system yields a highly concentrated residual and a clean water stream.

Because the energy source is flexible, the system adapts to each site’s operational strategy and economics. The systems have demonstrated wastewater volume reductions of up to 98%, producing a small, manageable residual stream.

Residuals can be stabilized and safely managed using either solidification/stabilization or mechanical dewatering—aligned with site-specific disposal requirements.

# CASE STUDY 1:

## ZLD Demonstration at a Power Plant

### A 14-day evaluation of thermal evaporation for FGD wastewater ZLD

Over a 14-day continuous operation, Heartland partnered with industry to evaluate the Concentrator as a ZLD compliance option.

Key outcomes:

- Treated 10,000+ gallons of FGD wastewater
- Achieved 90–95% volume reduction
- Concentrated wastewater from ~3.5% solids to ~40% solids
- Achieved 98% equipment availability
- Demonstrated reliable operation during daily cycling of EGU load
- Utilized Unit 4 flue gas exclusively as the thermal energy source

Additional solids processing achieved slurry concentrations approaching 80% solids, with TCLP tests demonstrating levels below hazardous waste thresholds.

Integration Observations:

- Successful coordination with plant operations and safety protocols
- Consistent performance across flue gas temperatures (375°F–500°F)
- Fly ash in the flue gas aided solids management rather than impairing operations
- Residuals Management: Samples solidified with fly ash, Portland cement, and additives passed TCLP limits, demonstrating a pathway to ZLD-compliant solid waste disposal.

**Figure 3.** Progression of FGD Wastewater to Solidified Residual



The demonstration shows the progressive concentration of FGD purge water (left) through the Heartland Concentrator. The final sample (far right) illustrates the successful solidification and stabilization of the residual using cementitious materials, resulting in a physically manageable, landfill-ready solid.

# CASE STUDY 2: Commercial Deployment at a Texas Power Plant

## 100,000 GPD Dual-Unit System for FGD Wastewater

**Figure 4.** Dual-Unit Installation at a Texas power plant



Heartland Concentrator system integrated into plant operations.

### **The Challenge:**

Handle high-TDS FGD wastewater, meet tightening discharge limits, and identify a reliable, low-O&M alternative to membrane-based or biological systems

### **The Solution:**

Two 50,000 GPD Concentrators were installed in a redundant configuration, operating on natural gas and fully integrated with plant control systems. The system was recently commissioned to meet strict contractual availability and reduction targets, validating the technology's readiness for baseload utility applications.

### **Contractual Performance Standards:**

Unlike a pilot project, this commercial installation is governed by rigorous performance guarantees. The system is contractually mandated to meet the following design basis, ensuring it delivers ELG compliance without compromising plant economics or environmental permits.

**Table 2.** Contractual Performance Guarantees & Design Basis

Metric	Guaranteed Performance Standard	Operational Impact
<b>Feed Rate (Throughput)</b>	≥ 50,000 GPD (per concentrator)	Ensures capacity to manage maximum purge rates.
<b>Minimum Volume Reduction</b>	≥ 90% (per concentrator)	Drastically reduces disposal volume and associated costs.
<b>Heat Input</b>	≤ 32.0 MMBTU/hr (HHV)	High thermal efficiency keeps fuel costs predictable.
<b>Electrical Usage</b>	≤ 600 kW (combined system)	Low parasitic load minimizes impact on net generation.
<b>Emissions (NOx)</b>	≤ 0.35 lb/hr	Ensures compliance with strict air permitting requirements (Title V).
<b>Emissions (PM)</b>	≤ 4.06 lb/hr	Ensures compliance with strict air permitting requirements (Title V).
<b>Noise Level</b>	≤ 105 dBA	Maintains safe working environment within the equipment envelope.

Note: Performance verification is determined by certified infeed flow meters, 3rd party stack testing, and industry-standard measurement protocols.

### The Path Forward:

The installation provides a model for near-term ELG compliance and future ZLD readiness—demonstrating high availability, small footprint, rapid deployment, and robust integration with plant O&M.

# FGD RESIDUALS MANAGEMENT & ZLD PATHWAYS

## A practical framework for solids handling and ZLD readiness

Heartland's Concentrator typically reduces wet FGD purge water volumes by >90%, producing concentrated liquid residuals suitable for several ZLD strategies:

### 1. Solidification/Stabilization

Mixing concentrated residuals with Class C fly ash or cementitious materials produces solid waste with:

- Reduced thermal energy demand
- Enhanced immobilization of metals and salts
- Physically manageable, landfill-ready solids

### 2. Mechanical Dewatering

Technologies include:

- Filter presses
- Centrifuges
- Vacuum belt filters
- Belt filter presses

Mechanical dewatering yields a cake suitable for landfill disposal, with filtrate returned to the Concentrator.

Note: Final ZLD strategy depends on plant-specific ash characteristics, chemistry, disposal requirements, and landfill design.

# A STAGED ROADMAP TO ZLD COMPLIANCE

## A realistic path from volume reduction to zero discharge

**Figure 5.** A Staged Roadmap to Verified ZLD Compliance (2026–2034)



The extended timeline allows utilities to implement a realistic, three-phase compliance strategy that sequences investment, learning, and validation. By starting now with proven volume-reduction technologies in Phase 1 (Validation), utilities can secure reliable near-term compliance and gather the necessary field data to confidently design and deploy their final ZLD solution in Phase 3 (Deployment). This phased approach transforms compliance obligation into an opportunity for modernization.

<b>Phase 1: Validation</b>	2026–2027: Pilot testing & preliminary design
<b>Phase 2: Demonstration</b>	2028–2029: Multi-year full-scale demonstration
<b>Phase 3: Deployment</b>	2030–2031: Contracting & detailed design 2031–2032: Construction & commissioning 2033–2034: Verified ZLD operation

This roadmap avoids a “compliance cliff” by sequencing investment, learning, and validation.

Phased compliance transforms obligation into opportunity—utilities lead the way to cleaner water while keeping power costs affordable.

# CONCLUSION

## Compliance as a catalyst, not a constraint

The current energy transition demands balance: environmental responsibility without sacrificing reliability and affordability. A technology-neutral, performance-based, phased approach, rooted in real-world field data, is the most effective way to deliver all three.

The EPA's 2034 extension is not a reprieve; it is a strategic window to implement immediate, proven volume reduction technologies, like direct-contact thermal evaporation, that eliminate operational risk and shrink the capital expenditure required for eventual Zero Liquid Discharge (ZLD).

### The Path Forward: Act Now

The strategy for responsible modernization is clear. Utilities should immediately pursue a path that transforms the regulatory obligation into an operational advantage:

- **Secure Near-Term Compliance:** Act now using proven volume-reduction technologies that operate reliably under real-world conditions.
- **Generate Operational Data:** Gather real data via full-scale demonstrations to inform the final ZLD design.
- **Build Trust:** Proactively demonstrate environmental performance to build public trust and minimize regulatory scrutiny.
- **Scale Methodically:** Sequence investment to scale reliably toward ZLD by 2034.

### Leverage Available Funding

Crucially, DOE funding opportunities are now available to accelerate this progress. By leveraging these resources, utilities can de-risk capital investment, modernize responsibly, lower O&M costs, and position their coal units for continued reliability through the foreseeable future.

**Final Thought:** Cleaner water and a stable grid are not competing priorities—they are the twin outcomes of pragmatic innovation.

## ABOUT HEARTLAND

Heartland Water Technology Inc designs and operates advanced thermal evaporation systems for high-TDS industrial wastewaters. With installations across North America and an Evaporation-as-a-Service (EaaS) model that lowers adoption barriers, Heartland offers utilities flexible, reliable pathways to compliance, risk reduction, and long-term operational resilience.

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