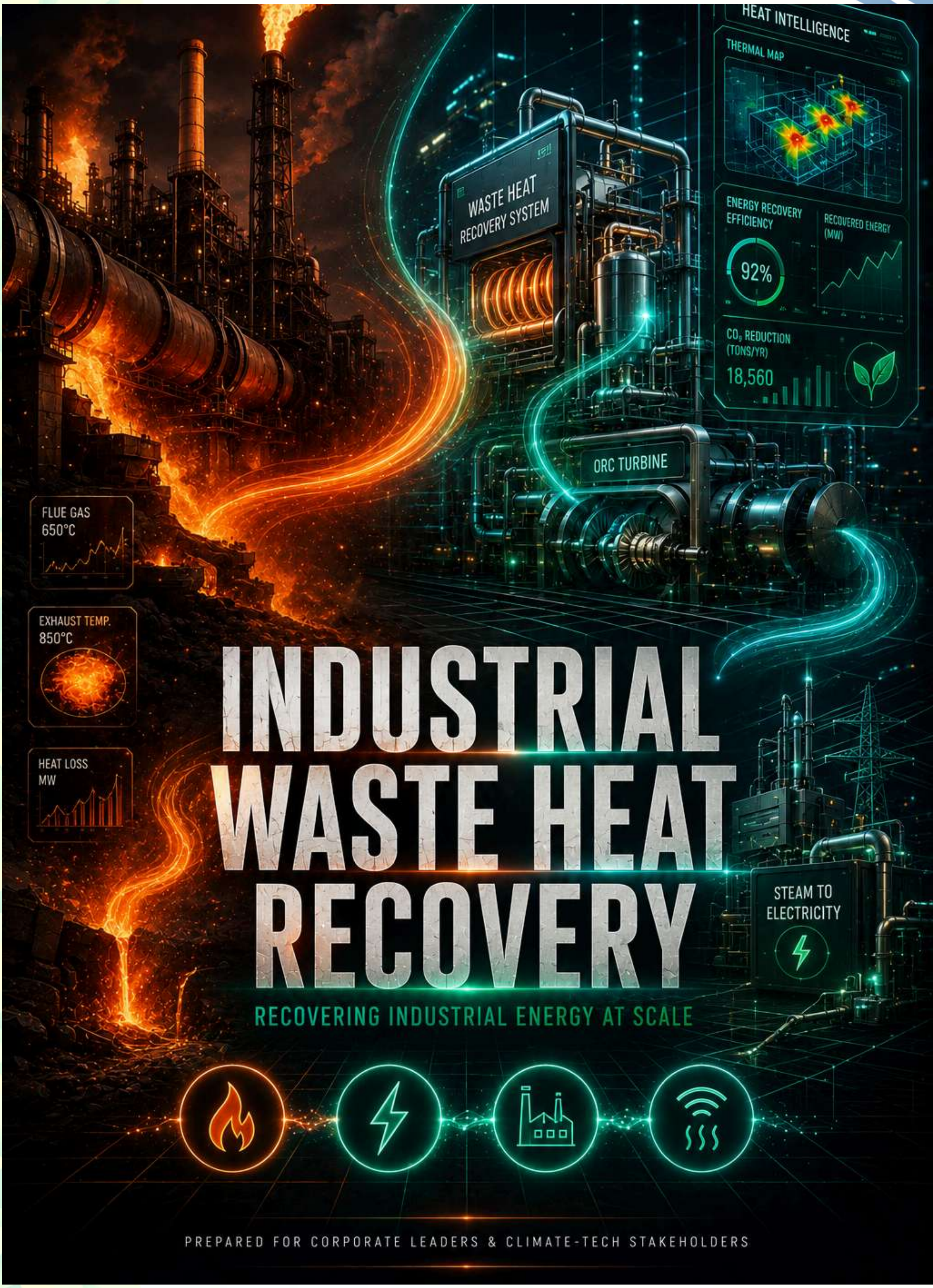
HEAT INTELLIGENCE
THERMAL MAP
WASTE HEAT
RECOVERY SYSTEM
ENERGY RECOVERY
EFFICIENCY
92%
RECOVERED ENERGY
(MW)
CO₂ REDUCTION
(TONS/YR)
18,560
ORC TURBINE
FLUE GAS
650°C
EXHAUST TEMP.
850°C
HEAT LOSS
MW
INDUSTRIAL
WASTE HEAT
RECOVERY
STEAM TO
ELECTRICITY
RECOVERING INDUSTRIAL ENERGY AT SCALE
PREPARED FOR CORPORATE LEADERS & CLIMATE-TECH STAKEHOLDERS

Industrial Waste Heat Recovery

Highlights

- WHR converts lost thermal energy into usable power or heat, delivering immediate fuel and electricity savings with proven technologies
- Cement, steel, glass, chemicals, refineries, paper, and food processing all generate significant recoverable waste heat
- Technologies such as WHRB, ORC, Kalina cycle, and heat pumps are well-proven with long operating lifetimes
- WHR reduces Scope 1 emissions, lowers energy intensity, and improves resilience against fuel and power price volatility

Key recommendations for corporate leaders include:

- Focus on cement kilns, blast furnaces, furnaces, boilers, and high-temperature exhaust streams with stable load profiles
- Match ORC, steam turbines, heat exchangers, or heat pumps to waste-heat grade and end-use (power, steam, hot water)
- Use BOOT, ESCO, or shared-savings structures to overcome customer capex constraints and speed adoption

Opportunity Snapshot: Industrial Waste Heat Recovery

Reduces overall energy consumption through recovering and reusing wasted industrial heat

Market Signals

- High potential in energy-intensive sectors (cement, steel, chemicals)
- Waste heat recovery can improve efficiency by 10–20%
- Annual Market size by 2030: ₹ 12,000 - 15,000 Cr

What Makes or Breaks It?

- Execute retrofits (boilers, turbines) within <15–30 day shutdowns
- Deliver 8–15 MW recovery with <3-year payback (M&V-backed)

Why It Matters NOW?

- Rising energy costs making waste recovery economically attractive
- ESG and net-zero targets pushing efficiency improvements
- Immediate ROI: payback typically 2–4 years

Well Aligned Opportunity for

- Industrial EPC and engineering firms
- Boiler, turbine, and heat exchanger manufacturers
- Energy service companies (ESCOs)

Key Challenges

- High upfront capex for retrofitting existing plants
- Process-specific customization causing complex implementation
- Downtime risks during installation

Business Models

- Waste heat recovery systems for cement, steel, and chemical plants
- Retrofit solutions for existing industrial facilities
- Performance-based ESCO models (shared savings)

Explore this opportunity further with EAI
consult@eai.in / Call Muthukrishnan - +91 9952910083

Introduction and Business Case

Industrial processes — cement kilns, steel furnaces, glass plants, refineries — release enormous amounts of heat that usually dissipates into the air. Waste Heat Recovery (WHR) systems capture this lost energy and convert it into electricity, steam, or process heat, improving efficiency and cutting fuel bills.

For India, WHR represents a low-cost decarbonisation lever that provides multiple benefits: reduces coal/gas use, lowers emissions and enhances competitiveness in energy-intensive industries.

Companies that have the skill sets to provide solutions for waste heat utilization can expect significant business opportunities across a range of industries and application domains.

Market Potential for Industrial Waste Heat Recovery in India

Year	Market Size (₹ Cr)	Capacity Outlook	Drivers
2025	6,000-7,500	~1.5-2 GW WHR capacity	Cement sector adoption, steel pilots.
2030	12,000-15,000	~5 GW capacity	Mandatory PAT/ESG targets; wider adoption in refineries and glass.
2040	35,000-40,000	~12-15 GW capacity	Deep industrial decarbonisation; integration with hybrid RE.

Market Segments and Applications

Segment	Applications	Business Model	Key Drivers
High-Temperature WHR (Steam-Based)	Recovery from kilns, furnaces, reformers	EPC/project delivery + long-term service	Large fuel savings and direct CO_2 reduction
Gas Turbine & Engine WHR	Exhaust heat recovery for power and CHP	Equipment + integration + O&M contracts	Improve overall plant efficiency
Low–Medium Temperature WHR (Organic Rankine Cycle)	Power generation from exhaust/process heat	Modular equipment sales + service	Monetize waste heat previously unusable

Industrial Heat Recovery Boilers (HRSG)	Steam generation from exhaust gases	Project-based EPC	Mature, bankable technology
Heat Exchangers & Process Integration	Pre-heating feedstocks, fluids, air	Equipment sales + engineering services	Fast payback and wide applicability
WHR for District Heating & Heat Reuse	Export waste heat to district networks	Infrastructure partnerships + heat sales	Urban decarbonization policies
Electrified Heat Recovery (Heat Pumps)	Upgrade low-grade heat to useful levels	Equipment + performance-based contracts	Electrification of industrial heat
Modular & Containerized WHR Systems	Brownfield retrofits, remote sites	Productized systems + rapid deployment	Lower capex and installation risk
WHR with Energy Storage Integration	Thermal storage for load shifting	Project + shared savings	Match heat supply with demand
WHR Monitoring & Optimization Systems	Digital optimization of recovery systems	SaaS + lifecycle services	Need to maximize realized performance

Typical Project Capacities & Investments Required in India

Project Type	Typical Capacity	Indicative CapEx (₹ Cr)	Notes
Low-grade heat recovery (50-150°C)	1-5 MWth equivalent	2-10	Economisers, heat exchangers, air preheaters for process heat.
Medium-grade recovery (150-400°C)	5-20 MWth	8-30	Organic Rankine Cycle (ORC), absorption chillers, steam generation.
High-grade recovery (>400°C)	10-50 MWth	20-100	WHR boilers, power turbines for steel, cement, glass sectors.
Cement kiln WHR (Rankine/ORC)	5-15 MW (electric)	40-120	Captive generation from clinker line waste gases.
Steel reheating furnace WHR	3-10 MW (electric/thermal)	25-80	Recuperators, regenerators and waste gas boilers.
Chemical/fertiliser plant WHR	2-10 MWth	15-60	Heat-to-steam or absorption chillers for process integration.

Data centre / HVAC exhaust recovery	0.5-2 MWth	2-8	Liquid-to-air exchangers for pre-cooling or district cooling.

Underlying Technologies & Processes

Element	Options	Key Traits
Heat sources	Kiln exhaust (cement), flue gas (steel, refineries), hot liquids, furnace gases	Sector-specific; medium/high temperature streams are most valuable.
Conversion technologies	WHR boilers + steam turbines; Organic Rankine Cycle (ORC); Kalina cycle	Steam turbines: mature; ORC/Kalina: efficient at lower temperatures.
Applications	Electricity generation, preheating, steam supply, district heating	Improves energy efficiency and cuts fuel bills.
Integration	Retrofit to existing plants; greenfield design integration	Retrofit economics vary by industry and scale.
Digital optimisation	IoT sensors, AI-driven heat flow modelling	Improves recovery efficiency and system uptime.

Key Challenges

Challenge Area	Key Issues	Business Impact	India Specific	Strategic Implications
High Upfront Capital & Financing Constraints	WHR systems require significant capex with long payback periods	Slower adoption despite strong efficiency benefits	Industrial clients prioritize core production investments; limited ESCO financing models	Innovative financing structures and performance contracts needed
Site-Specific Engineering & Technical Complexity	Each plant has unique heat streams, process integration needs	Higher engineering costs and longer project timelines	Aging industrial infrastructure and inconsistent process data	Advanced feasibility studies and modular system designs critical
Demand Awareness & ROI Perception	Limited understanding of energy recovery	Delayed decision-makin g and longer	Energy efficiency often viewed as secondary	Need clear business case communication and

	benefits among SMEs	sales cycles	investment	measurable performance guarantees
Supply Chain & Technology Dependency	Specialized turbines, heat exchangers, and controls often imported	Cost volatility and project delays	Import duties, currency fluctuations, and geopolitical supply risks	Local manufacturing partnerships and diversified sourcing strategies
Operational Integration & Reliability Concerns	Integration must not disrupt core industrial processes	Adoption resistance due to perceived operational risks	Downtime sensitivity in cement, steel, chemicals sectors	Robust design, redundancy, and digital monitoring to ensure reliability

Prominent Players in the Indian Market

Company / Entity	Focus Areas
Thermax	EPC leader in WHR boilers and power plants.
Cethar / ISGEC	Boilers and process equipment for WHR.
Larsen & Toubro (L&T)	EPC for industrial WHR and cogeneration.
Siemens / ABB / GE	Turbines, generators, automation for WHR systems.
Dalmia Cement / UltraTech / Shree Cement	Cement majors with large-scale WHR installations.
Tata Steel / JSW Steel	Coke oven and blast furnace gas WHR.
Indian Oil / BPCL / HPCL	Refinery WHR projects under energy efficiency mandates.
Opel Energy Systems, Atlas Copco	WHR on D.G.Set Exhausts, on Furnace, WHR based ORC

Innovation Perspectives

Innovation	Business Opportunity	For Senior Management
Waste Heat Recovery-as-a-Service (WHRaaS)	Provider finances, owns, and operates WHR	Long-term contracted cash flows; lower adoption friction
Modular, Productized WHR Systems	Standardized modules with known performance	Scalability, faster sales cycles, better margins

Low-Grade Heat Monetization	ORC + heat pumps + storage combinations	Expands addressable market significantly
Sector-Coupled Heat Reuse Platforms	Integrated heat-to-district energy ecosystems	Turns waste heat into a traded energy product
Digital Twins for Heat Integration	Simulation-led design and performance guarantees	De-risks projects and accelerates decisions
Carbon-Backed Commercial Models	Contracts indexed to verified CO_2 reduction	Aligns incentives; improves ROI narrative
WHR + Electrification Hybrids	WHR combined with industrial heat pumps	Future-proofs assets against fuel switching
Plug-and-Play Retrofit Kits	Drop-in systems with minimal downtime	Unlocks massive retrofit market
Thermal Storage-Enabled Flexibility	Stored waste heat for peak demand or grid services	Creates new revenue streams beyond efficiency
Lifecycle Performance & Optimization Platforms	Continuous AI-driven optimization	Protects margins and long-term customer value

Concentric & Satellite Opportunities

- Heat-exchanger & ORC equipment manufacturing: Local OEMs designing modular, dust-resistant WHR units adapted for Indian industrial conditions.
- Thermal audit & simulation firms: Concentric engineering services using AI-driven heat maps and digital twins for retrofit optimisation.
- EPC & O&M specialists: Integrators managing end-to-end WHR deployment, uptime and multi-plant performance contracts.
- Energy-storage hybrid solutions: Satellite applications coupling WHR with molten salt, phase-change, or battery storage for continuous use.
- Carbon finance & MRV platforms: Fintech tools quantifying and monetising verified GHG reductions from heat recovery projects.
- Advanced materials R&D: Development of fouling-resistant coatings and high-temperature alloys to extend exchanger lifespans.

Key Takeaway for Senior Management

Takeaway	Details

Technology-fit to heat grade determines returns	• Matching solution to temperature and duty cycle is critical to IRR
	• Sub-components:
	  ○ High-temp: Steam turbines, WHRB
	  ○ Medium-temp: ORC, Kalina
	  ○ Low-temp: industrial heat pumps, absorption chillers
	• **Recommended innovation focus:** hybrid and cascade recovery architectures
	• **Competitive advantage:** higher recovery rates and shorter payback than one-size-fits-all designs

System-level integration multiplies value	• WHR performs best when integrated with process control, electrification, and energy management • *Examples:* WHR + VFDs, WHR feeding captive loads, steam balancing with process demand • **Competitive advantage:** compounding efficiency gains beyond standalone recovery
Performance-linked financing unlocks scale	• Many industrials prefer outcome-based models over capex-heavy retrofits • *Examples:* BOOT, ESCO, shared-savings, off-balance-sheet SPVs • **Recommended innovation focus:** digital measurement & verification (M&V) tied to contracts • **Competitive advantage:** faster adoption and predictable cash flows
Portfolio replication creates infrastructure economics	• Similar processes across plants enable standardization and rapid rollouts • *Examples:* multi-plant cement groups, steel clusters, chemical parks • **Recommended business focus:** standardized modules and portfolio analytics • **Competitive advantage:** lower unit capex and faster scaling than bespoke projects

Next Steps for Corporate Leaders

Industrial waste heat recovery is gaining traction as corporates pursue energy efficiency, operational cost reduction, and Scope 1 emissions abatement. Heat recovery systems — including WHR boilers, ORC units, economizers, heat exchangers, and heat-to-power solutions — are being deployed across cement, steel, glass, chemicals, refineries, food processing, and other energy-intensive sectors. Digital monitoring, heat mapping tools, and performance contracting models are improving project bankability, while integration with heat pumps and district systems expands use cases for low-grade heat streams.

This could be an attractive climate tech opportunity for industries and firms in specific sectors and industries keen on catering to this market.