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ENERGY EFFICIENCY GUIDELINES

FOR INDUSTRIAL PARKS & SMES ACROSS ASEAN



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MESSAGE FROM ACE EXECUTIVE DIRECTOR

ASEAN's continued economic growth and industrial development are accompanied by rising energy demand, making energy efficiency an increasingly important pillar of the region's energy security, economic competitiveness, and transition towards a low-carbon future. Improving how energy is used is not only essential to reducing energy consumption and emissions, but also to strengthening the resilience and competitiveness of industries across the region.

Industrial parks and micro, small and medium-sized enterprises (MSMEs) are particularly important to ASEAN's economic development and industrial value chains. At the same time, they face persistent barriers to adopting energy-efficiency measures, including limited access to technical expertise, financing, and practical implementation pathways. While significant energy-efficiency potential exists across industrial facilities, translating this potential into implementable and bankable projects remains critical to achieving meaningful impact at scale.

In this context, the ASEAN Energy Efficiency Guidelines for Industrial Parks provide a timely and practical reference to support industrial park authorities, businesses, and other stakeholders in identifying, developing, and scaling energy-efficiency opportunities. The Guidelines complement ASEAN's regional priorities under the ASEAN Plan of Action for Energy Cooperation (APAEC) 2026–2030, particularly Programme Area 4 on Energy Efficiency and Conservation (EE&C), which seeks to accelerate the adoption of energy efficiency and decarbonisation solutions across end-use sectors. They also contribute to the ongoing work of the ASEAN Energy Efficiency and Conservation Sub-Sector Network (EE&C-SSN) in strengthening regional cooperation, knowledge exchange, and implementation.

Through the ASEAN Centre for Energy (ACE), the development of these Guidelines by Sustainable Energy for All (SEforALL) has benefited from consultation with the EE&C-SSN and relevant industry stakeholders, helping to ensure that the recommendations are responsive to the diverse circumstances and needs of ASEAN Member States. ACE is pleased to have collaborated with SEforALL in advancing this important work, with support from the ASEAN–UK Green Transition Fund under the UK Mission to ASEAN. This partnership demonstrates the value of regional cooperation in translating shared energy-efficiency ambitions into practical solutions.

I encourage ASEAN Member States, industrial park authorities, businesses, financial institutions, and other ecosystem actors to consider these Guidelines as a practical reference for developing and scaling energy-efficiency initiatives across the region. By turning energy-efficiency opportunities into concrete investments and actions, ASEAN can strengthen its energy security, enhance industrial competitiveness, and advance a more sustainable and inclusive energy future.

Dato' Ir. Ts. Razib Dawood

Executive Director

ASEAN Centre for Energy

MESSAGE FROM AMBASSADOR, UK MISSION TO ASEAN

The UK is proud to support the development of the Energy Efficiency Guidelines for Industries across ASEAN through the ASEAN-UK Green Transition Fund. ASEAN is a vital partner for the UK, and we recognise that sustainable economic growth and energy security will be central to the region's continued success. At a time when countries around the world are responding to both the climate crisis and growing energy security challenges, energy efficiency remains one of the most practical solutions. As ASEAN looks to the future, improving energy efficiency will play an important role in advancing the region's development ambitions and long-term prosperity.

This publication demonstrates the value of practical cooperation between ASEAN and the UK. The UK has long championed energy efficiency as a cornerstone of sustainable growth, drawing on experience in areas such as energy-efficient buildings, clean heating solutions, and other low-carbon technologies. We are pleased to explore solutions together through our partnership with ASEAN, and I would like to thank all stakeholders whose contributions have made this work possible. As we implement the ASEAN-UK Plan of Action 2027-2031, I look forward to building on this momentum and deepening our partnership in support of ASEAN's sustainable development ambitions. Together, we can continue to advance our shared goals of prosperity, resilience, and sustainable growth across the region.

Helen Fazey

UK Ambassador to the Association of Southeast Asian Nations (ASEAN)

ACKNOWLEDGEMENTS

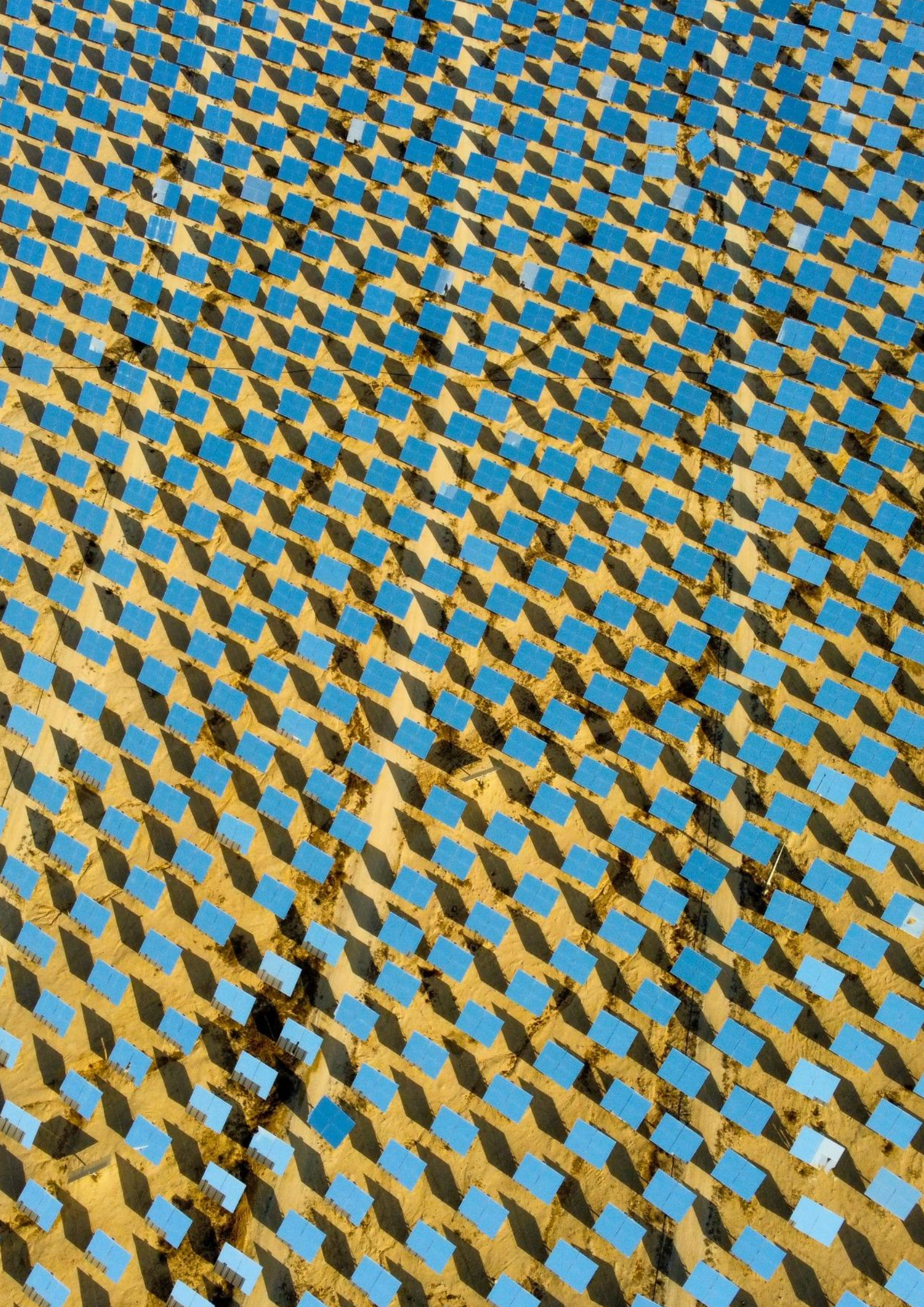
This guideline was funded by the UK Mission to ASEAN through the ASEAN–UK Green Transition Fund (GTF) and implemented by Sustainable Energy for All (SEforALL). We gratefully acknowledge the ASEAN Centre for Energy (ACE) and the Energy Efficiency and Conservation Sub-Sector Network (EE&C-SSN) for their strategic guidance, technical inputs and continued collaboration throughout its development.

The guideline was prepared by a team comprising Mr Alvin Jose, formerly of SEforALL; Ms Jacqueline Lam, formerly of SEforALL; Mr Brian Dean; Mr Ashish Jindal; Mr Sandeep Pahal; Mr Paul Stevenson; Ms Amanda Castolina; Mr Divyam Nagpal; and Ms Anja Wartig Pessoa Barradas. The team undertook the research, analysis, stakeholder engagement, drafting and technical review, drawing on its collective expertise in energy efficiency, industrial development, policy, finance and investment.

We also extend our sincere appreciation to the Energy Efficiency and Conservation team at ACE for its close technical collaboration, review and guidance, which helped ensure that the guideline reflects ASEAN priorities and is relevant to the diverse circumstances of ASEAN Member States.

Our appreciation is further extended to the experts, industrial park representatives, industry partners and small and medium-sized enterprises across the ASEAN region that contributed valuable insights, data and case-study inputs. Their contributions were instrumental in strengthening the practical relevance and applicability of the guideline.

Finally, we thank all project team members and contributors whose dedication and expertise supported this publication and ASEAN's broader efforts to advance energy efficiency, sustainable industrial development and inclusive economic growth.



EXECUTIVE SUMMARY

Small and medium-sized enterprises (SMEs) play an important role in ASEAN's industrial economy, including within industrial parks. However, SMEs often face high energy costs, inefficient equipment, limited technical capacity and difficulty accessing finance for energy-efficiency improvements. Therefore addressing these constraints may reduce operating costs, improve productivity and competitiveness, and contribute to regional energy and climate objectives.

This guideline provides practical guidance for SMEs to identify, assess and implement energy-efficiency measures. It is also intended to support industrial park authorities, policymakers, financial institutions, industry associations, energy service companies (ESCOs) and technology providers in developing coordinated programmes for SMEs.

The guideline covers the foundations of good energy management, including energy data collection, sub-metering, benchmarking, energy audits, and measurement and verification. The document also identifies energy-saving opportunities for common electrical and thermal systems, including motors and drives, pumps, fans and blowers, compressed-air systems, lighting, boilers and steam systems, waste-heat recovery and heating, ventilation and air-conditioning systems. Methods on financial appraisal and practical assessment checklists are also included to support investment decisions and implementation.

Key messages

Energy efficiency should be considered as environmental measures as well as investment in business performance. Improved operating practices, preventive maintenance and better controls often deliver savings, while larger equipment and system upgrades can provide further benefits where supported by reliable energy data, appropriate technical assessment and sound financial analysis. However, SMEs face interconnected technical, financial and institutional barriers. Energy data are often insufficient to identify and verify savings, while limited in-house expertise may make it difficult to evaluate technologies and prepare investment proposals. Individual projects may also be too small to justify the transaction costs associated with technical due diligence and financing.

Industrial parks can help address these barriers by coordinating technical support, aggregating similar projects across multiple SMEs and facilitating engagement with financial institutions, ESCOs and technology providers. Park-level approaches can also support shared infrastructure, pooled procurement, common monitoring arrangements and industrial-symbiosis opportunities that may not be viable for individual enterprises.

Investment in efficient equipment should be accompanied by structured energy management. Energy baselines, sub-metering, performance indicators, regular audits and measurement and verification are necessary to identify priority measures, confirm savings and maintain performance over time. The appropriate level of monitoring should reflect the significance of the energy use, operating conditions and the technical and financial capacity of the enterprise.

Implementation priorities

Implementation should be phased and adapted to the institutional capacity and market readiness of each ASEAN Member State. Initial action should focus on awareness, capacity-building, simplified energy reporting, benchmarking, energy audits and pilot projects. These activities can establish evidence, strengthen technical capacity and build confidence among SMEs and financial institutions.

Successful pilot approaches can be expanded through aggregated project pipelines, dedicated financing instruments and stronger partnerships with ESCOs and technology providers. Over time, Member States may introduce more structured reporting, certification, benchmarking and minimum energy-performance requirements where appropriate.

Priority actions include:



ASEAN institutions: Facilitate knowledge exchange, promote compatible methodologies and disseminate replicable industrial park models.



Member State governments: Establish enabling policies, incentives, proportionate reporting requirements and appropriate minimum energy-performance standards.



Industrial park authorities: Coordinate energy assessments, develop project pipelines, aggregate procurement and facilitate shared energy services.



SMEs: Establish energy baselines, monitor significant energy uses, implement operational improvements and assess investment opportunities.



Financial institutions: Develop simplified and appropriately structured financing products for SMEs and aggregated project portfolios.

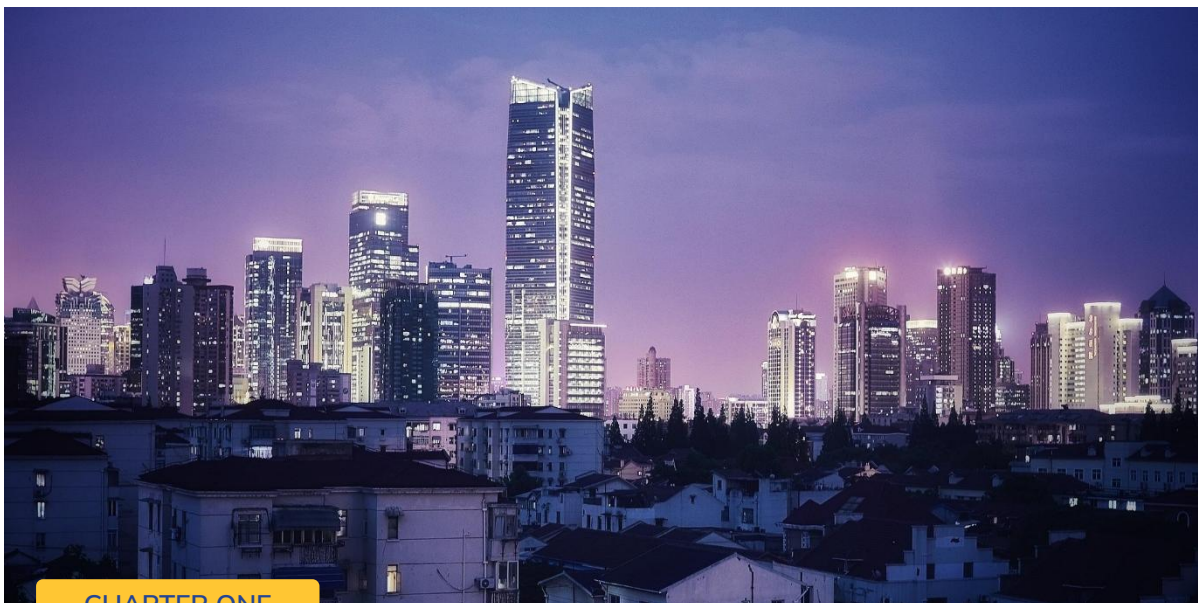


ESCOs and technology providers: Provide integrated technical solutions, transparent performance estimates and credible measurement and verification.



Industry associations and development partners: Support capacity-building, demonstration projects, knowledge exchange and the replication of successful approaches.

The immediate priority is to move from isolated equipment improvements towards coordinated programmes that combine technical assistance, reliable energy data, project aggregation and suitable financing. Demonstrating these approaches in selected industrial parks will provide a basis for wider replication across ASEAN and support a more competitive, resilient and energy-efficient industrial sector



CHAPTER ONE

INTRODUCTION

1.1 Background and Rationale

Southeast Asia (SEA) is one of the fastest-growing regions in the world, with industrial activity driving a significant share of economic growth. The industry sector accounts for approximately 42%¹ of total final energy consumption across ASEAN, and this share is projected to grow further as the region industrialises and urbanises.

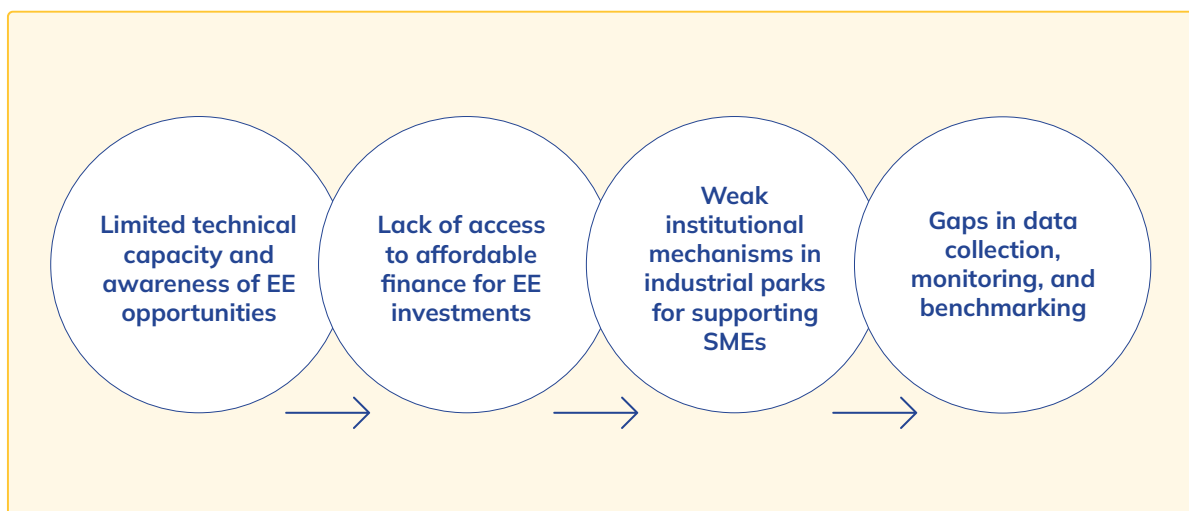
Small and Medium Enterprises (SMEs) play a critical role in ASEAN economies, contributing significantly to employment, economic output, and industrial activity. The contribution is between 35% and 60% of GDP¹ and up to 70-80% of employment¹ across ASEAN member states. ASEAN is among the fastest growing regions globally, sustaining robust economic growth for over three decades.

In recent years, most ASEAN economies have maintained GDP growth rates from ~2%-5%. While the region's export-oriented nature makes it sensitive to global economic cycles, much of the growth has increasingly been driven by domestic consumption. In this evolving landscape, Small and Medium Enterprises (SMEs), which form the backbone of ASEAN's economy, play a critical role in supporting inclusive growth and responding to emerging opportunities.

¹ ASEAN Centre for Energy. (2025). ASEAN Energy Statistics Leaflet 2025. <https://aseanenergy.org/publications/asean-energy-statistics-leaflet-2025>

However, SMEs often face structural challenges in improving energy efficiency (EE):

Figure 1: Challenges faced by ASEAN Region SMEs



As SMEs' contribution to industrial activity and energy demand rises, improving energy efficiency within SMEs becomes essential for sustaining competitiveness and ensuring a low-carbon growth pathway for the region.

Energy efficiency is widely recognised as one of the most cost-effective approaches to reducing energy consumption, lowering operating costs, and supporting decarbonisation objectives as well as national climate commitments under the Paris Agreement. Recognising this, ASEAN member states have integrated EE into their national energy efficiency and conservation (EE&C) roadmaps, but SMEs remain underserved compared to larger industries.

This guideline document addresses the need for practical, sector-specific, and SME-focused EE guidance that can be applied across industrial parks across ASEAN, starting with the more industrialised economies: Indonesia, Thailand, Vietnam, Malaysia, and the Philippines.

1.2 Objectives of the Guidelines

The overall aim of this guideline is to provide action-oriented, practical tools that help SMEs and industrial park managers to improve their energy performance. The specific objectives are to:

- Provide country-focused insights into EE drivers, policies, tariffs, and institutional frameworks.
- Identify priority industrial sectors, particularly those with large numbers of SMEs, where collective EE action can deliver maximum impact.
- Present enabling techniques such as energy management systems, data monitoring, and performance benchmarking to strengthen long-term EE adoption.
- Highlight cross-sectoral EE technologies (motors, boilers, compressed air, lighting, HVAC, and waste heat recovery) with strong “quick-win” potential.

- Offer financial appraisal methods to help SMEs and decision-makers evaluate EE investments beyond simple payback.
- Develop a self-assessment EE checklist for SMEs in industrial parks to identify areas of energy waste and improvement opportunities.
- Provide country-wise summary matrices to allow policymakers, park managers, and associations to design targeted EE interventions.

Why energy efficiency matters for SMEs

1

Reduces operating costs

Energy is a major component of production expenses for SMEs in energy-intensive industries, so improving efficiency can significantly reduce overall operating costs.

2

Improves competitiveness

Lower costs translate into price advantages in domestic and export markets.

3

Enhances resilience

Reduced dependence on imported fuels protects SMEs from price volatility.

4

Supports sustainability goals

Many global buyers (e.g., in textiles, automotive supply chains) demand greener production processes.

1.3 Lead-in to Energy Efficiency (EE) Guidance

Energy efficiency (EE) remains one of the most practical and cost-effective pathways for enhancing industrial competitiveness, especially for small and medium enterprises (SMEs) operating within Industrial Parks (IPs). This Guidance aims to help SME operators, IPs managers, and policymakers understand the tangible benefits of improved energy management and the practical steps required to realise them.

Experience from across ASEAN and globally shows that attention to good Energy Management Systems (EnMS), staff awareness and behaviour, and implementation of no- or low-cost EE interventions such as optimising motors, boilers, lighting, compressors, and other common equipment may deliver energy cost savings in the range of 20–40%, depending on operating conditions and baseline performance. Such savings are most observed in enterprises where energy has not previously been managed as a strategic cost centre.

Furthermore, the EnMS framework provides a robust foundation for sustained improvement. It not only helps establish systematic monitoring and control of energy use but also supports long-term planning by generating credible data and performance baselines. Over time, this approach enables enterprises to justify larger, bankable investments in new technologies and equipment based on proven performance improvements.

This Guidance is therefore structured around four key focus areas to support practical implementation:

1. Strengthen energy data and management practices: Begin with collecting robust energy and production data, introducing energy management controls, and promoting staff awareness and behavioural change.
2. Identify frequent cross-sectoral EE opportunities: Build awareness of the wide range of common EE opportunities found in typical SME operations within IPs, including:
 - Electrical systems: motors, fans, compressors, and lighting.
 - Thermal systems: boilers, steam/hot water distribution, and HVAC.
3. Leverage industrial symbiosis within IPs: Explore shared utility systems, by-product exchanges, and collective efficiency initiatives to achieve park-wide energy and resource savings.
4. Apply rigorous financial appraisal: Evaluate EE projects systematically by considering both cost and lifetime benefits, energy and non-energy to ensure informed and equitable investment decisions.

Together, these elements form the foundation for effective energy efficiency implementation in industrial parks with long-tail SMEs, helping enterprises reduce costs, enhance productivity, and contribute to ASEAN's broader goals of sustainable and inclusive industrial growth.

1.4 Target Audience

This guideline is intended to serve a broad ecosystem of stakeholders who influence, implement, or support industrial energy efficiency (EE) initiatives in the ASEAN region. Each group has a distinct role to play in scaling up energy efficiency within SMEs and industrial parks:

Small and Medium-sized Enterprises (SMEs):

- Primary beneficiaries of the guideline.
- Cover sectors such as manufacturing, food & beverage, textiles, plastics, ceramics, and engineering workshops.
- Often face limited technical and financial resources.
- Guideline provides practical tools, self-assessment checklists, and sector-specific quick-win opportunities to reduce costs and improve competitiveness.

Industrial parks developers and managers:

- Manage clusters of SMEs sharing infrastructure and utilities.
- Can coordinate collective EE actions, e.g., joint audits, shared waste heat recovery, renewable energy systems, training workshops.

Policymakers and regulators:

- Include energy ministries, environment departments, and industry regulators.
- Provide the enabling framework for EE adoption.
- The guidelines support them with insights on policy levers, regulatory tools, and incentive mechanisms.

1.5 Institutional Use and Implementation Pathway

In line with the QPR framework, this guideline is intended to serve not only SMEs but also regional and national institutions responsible for advancing energy efficiency across ASEAN.

The guideline is expected to be anchored institutionally through the ASEAN Centre for Energy (ACE), with engagement through the Energy Efficiency and Conservation Sub-Sector Network (EE&C SSN). In this context, the document can support:

- **ACE** – as a regional reference framework for coordinating SME-focused energy efficiency initiatives, facilitating cross-country knowledge exchange, and monitoring aggregated outcomes across ASEAN.
- **AMS Focal Points and Energy Ministries** – as a practical implementation tool that complements national EE&C policies, supports pilot Programmes in industrial parks, and informs incentive or regulatory design.
- **Industrial parks authorities and developers** – as an operational guide for establishing park-level energy management cells, shared utilities optimisation, monitoring systems, and SME capacity-building programmes.

By clarifying this institutional pathway, the guideline positions itself not only as a technical toolkit for enterprises but also as a structured implementation instrument supporting ASEAN-wide energy efficiency cooperation.

1.6 Scope and Methodology

This guideline provides a comprehensive framework for industrial energy transition across ASEAN. The scope of this guideline is shaped by the need to balance regional comprehensiveness with practical focus:

- **Country focus:** Covering the five larger ASEAN economies – Indonesia, Malaysia, Philippines, Thailand, and Vietnam due to their industrial intensity, energy demand, and policy readiness. Findings and best practices may later be extended to smaller ASEAN nations with similar industrial structures (e.g., Cambodia, Lao PDR, Myanmar).
- **Sectoral focus:** Prioritising sectors with a large SME presence, where generic guidance, case studies, and benchmarks can deliver broad impact. In contrast, larger energy-intensive industries such as cement, steel, and petrochemicals require plant-specific energy efficiency interventions, often involving high capital investments. SMEs, however, represent a sector where well-designed EE guidelines can drive significant impact at scale.
- **Alignment with Scoping Assessment:** The framework builds upon earlier ASEAN Scoping Assessments of industrial energy use and the ASEAN Plan of Action for Energy Cooperation (APAEC) 2021–2025², which emphasises energy efficiency and conservation as a key pillar.
- **Methodology:** The guideline has been developed through:
 - Review of national EE&C policies and regulations in the ASEAN Region
 - Identification of cross-sectoral EE opportunities applicable to SMEs.
 - Compilation of practical tools and checklists for SME-level application.
 - All currency values have been converted to GBP using the United Nations Operational Rates of Exchange applicable at the time of publication, unless otherwise stated.

² ASEAN Centre for Energy. (2025). ASEAN Plan of Action for Energy Cooperation (APAEC) 2026–2030. <https://aseanenergy.org/publications/asean-plan-of-action-for-energy-cooperation-apaec-2026-2030>



RATIONALE FOR ASEAN ENERGY EFFICIENCY GUIDELINE

The industrial sector across ASEAN is at a crossroads. Rising energy demand, coupled with climate change commitments, makes energy efficiency an urgent priority. SMEs, despite their structural challenges, hold the key to unlocking significant savings, competitive gains, and emission reductions. Industrial sectors with large SME populations, especially those clustered within industrial parks, are particularly relevant.

These segments require more generic support on recurring cross-sector technologies such as motors, lighting, boilers, and energy management systems. The most cost-effective way to reach them is through practical EE guidance, local case studies, and simple training materials that can be easily scaled and replicated.

This chapter provides the rationale for developing an EE guideline focused on SMEs in IPs, highlighting the context, barriers, and opportunities that underpin the need for a practical, scalable approach.

By aligning with national targets, building on regional cooperation, and focusing on pragmatic tools, it seeks to enable scalable, measurable, and impactful energy efficiency action.

Table 1: Key Rationale for an SME-Focused EE Guideline

RATIONALE DIMENSION	KEY INSIGHTS	IMPLICATION
High energy share in industry	~42% of ASEAN Total Final Energy Consumption (TFEC) ³	Energy Efficiency is a critical lever for decarbonisation
SME economic importance	SMEs contribute 35–60% of GDP and majority of employment ⁴	Any EE strategy must be SME-inclusive to deliver impactful savings/results
Existing barriers	Finance constraints, capacity gaps, limited data	Tailored interventions needed for SMEs
Policy frameworks	National EE&C plans + APAEC Phase II regional targets	Regional harmonisation and cross-country learning are possible
Global competitiveness	Export markets demanding supply chain decarbonisation	SMEs risk exclusion if not EE-compliant
Energy tariffs & subsidies	Local tariffs (electricity/gas) often lower than EU due to fossil-fuel subsidies	Low tariffs weaken the business case for EE and RE/low-C investment
Legislation effectiveness	Energy/environmental laws exist but enforcement varies by country	Strengthening implementation and compliance mechanisms, where feasible, can enhance long-term impact.

2.1 Industrial Parks and Large SME populations

SMEs across ASEAN often operate within industrial parks, which provide opportunities for shared services, collective training, and coordinated EE action.

- Clustering in IPs allows SMEs to leverage common infrastructure, such as shared energy systems (steam networks, compressed air networks), energy audits, monitoring, and training programmes.
- Sectors with large SME populations e.g., textiles, food processing, plastics, metalworking, ceramics, and pharmaceuticals benefit from EE guidance on recurring technologies.
- The most cost-effective approach is through practical manuals, local case studies, PPT training materials, and replicable tools that can be scaled across multiple SMEs.
- Integration of digital monitoring tools and simple reporting templates can enhance performance tracking and facilitate benchmarking across SMEs.

³ ASEAN Centre for Energy. (2025). ASEAN Energy Statistics Leaflet 2025. <https://aseanenergy.org/publications/asean-energy-statistics-leaflet-2025>

⁴ ASEAN Centre for Energy. (2024). SME Policy Index: ASEAN 2024 – Enabling Sustainable Growth and Digitalisation. https://asean.org/wp-content/uploads/2024/09/Full-Report_ASEAN-SME-Policy-Index-2024_20-Sept-2024.pdf

2.2 Strategic Importance of the Guideline

This EE guideline is designed to:

- Provide practical, SME-tailored guidance for energy efficiency in IPs.
- Complement national EE&C targets while addressing gaps specific to SMEs.
- Facilitate replicable, cross-sectoral interventions in motors, lighting, boilers, HVAC, compressed air, waste heat recovery, and energy management systems.
- Enable scalable, measurable, and cost-effective EE action, even where local policy enforcement or financing support may be limited.
- Support measurable outcomes, including energy savings (%), CO₂ reductions, number of SMEs trained, and payback periods, to track and communicate guideline impact.

Given the combination of energy consumption, SME economic importance, and structural barriers, a dedicated ASEAN EE guideline for SMEs in industrial parks is both timely and necessary. By providing practical, scalable, and measurable guidance, this guideline enables SMEs to:

- Improve energy efficiency and reduce operational costs
- Comply with regional and global standards
- Enhance competitiveness and market access
- Contribute to ASEAN's climate and energy goals

Through practical case studies, replicable tools, capacity building, and continuous monitoring, the guideline provides a clear pathway for SMEs to transition towards energy-efficient and sustainable industrial practices, ensuring long-term regional impact and industrial competitiveness.



CHAPTER THREE

FOUNDATIONS FOR GOOD ENERGY MANAGEMENT

Industrial Parks (IPs) across ASEAN are the beating heart of the region's industrial growth. They host a concentration of small and medium-sized enterprises (SMEs) that drive employment, supply chains, and local economies. These enterprises are typically active in energy-intensive subsectors such as food processing, textiles, plastics, rubber, engineering workshops, and light manufacturing.

Although each SME may be small in scale, together they represent a significant share of industrial energy consumption. This collective footprint makes them a crucial target for energy efficiency (EE) interventions. Moreover, SMEs in IPs often depend on shared utility systems, for example:

- Common steam networks for process heating,
- Centralised compressed air systems for multiple workshops,
- Joint water treatment and pumping facilities.

Such shared infrastructure offers unique opportunities for cost-effective, park-wide EE measures, where coordinated action can deliver benefits far greater than isolated, unit-level initiatives.

This chapter therefore serves two purposes:

1. It establishes the foundations of structured energy management for SMEs covering systems, data, metrics, and audits.
2. It provides practical energy efficiency guidelines tailored to both individual enterprises and industrial park-level interventions, ensuring that the large SME populations can adopt proven, scalable solutions without high technical or financial barriers.

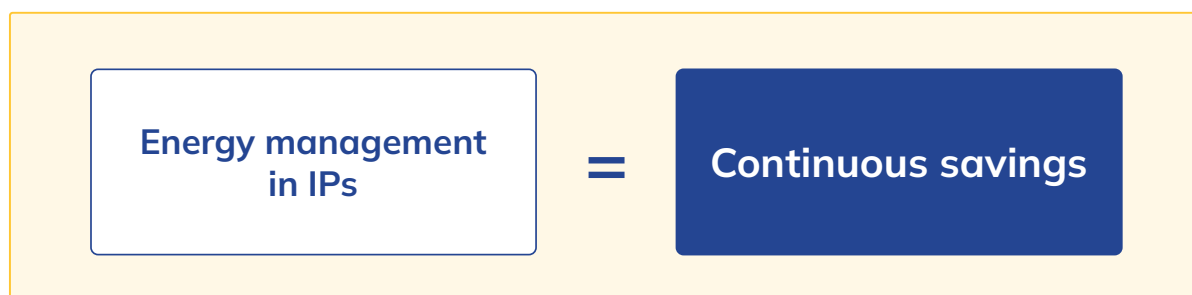
3.1 Basics of Structured Energy Management Systems (EnMS):

3.1.1 Why EnMS Matters in Industrial Parks

Industrial parks offer a unique environment where many SMEs operate in close proximity, often sharing infrastructure and utilities. This creates significant opportunities for collaborative energy efficiency (EE) improvements, which individual SMEs may find difficult or costly to implement on their own.

- **Shared utilities and services:** Many SMEs in IPs rely on common systems, such as steam networks, compressed air networks, or centralised cooling systems. Implementing an EnMS at the park-level ensures that energy efficiency measures are coordinated across the entire system. This avoids inefficiencies where one plant's improvements could be offset by another's high consumption, maximising energy savings across all tenants.
- **Economies of scale:** IPs provide the opportunity to pool resources for training, audits, and equipment upgrades. For example, instead of each SME hiring an external energy consultant individually, the park management can organise a joint energy audit or training session, significantly reducing costs per SME. Similarly, bulk procurement of high-efficiency motors or lighting systems lowers the investment required by individual companies.
- **Visibility, benchmarking, and motivation:** When energy data is collected at the park-level, it enables cross-SME comparison and benchmarking. SMEs can see how they perform relative to peers and identify improvement opportunities. This visibility encourages continuous improvement, creates accountability, and supports adoption of best practices.

EnMS in Industrial Parks leverages shared infrastructure, collective learning, and benchmarking to deliver cost-effective, scalable, and measurable energy efficiency improvements, which individual SMEs alone may struggle to achieve.



3.1.2 Barriers to Establishing EnMS in SMEs

Implementing a structured Energy Management System (EnMS) in SMEs offers measurable benefits, but SMEs particularly those clustered in industrial parks face unique challenges that can slow adoption. Understanding these barriers is crucial to designing practical, targeted EE interventions.

- **Low or subsidised electricity tariffs** – In many ASEAN countries, electricity tariffs are subsidised and often lower than in industrialised nations. This reduces the financial incentive for SMEs to invest in energy efficiency solutions.
- **Limited technical capacity** – Most SMEs do not employ dedicated energy managers, and staff often lack specialised knowledge of energy auditing, sub-metering, or energy-efficient technologies. This reduces the ability to systematically implement and track energy-saving measures.
- **Perceived high costs** – Upfront capital investment for EE improvements (e.g., motors, boilers, lighting upgrades) is often seen as unaffordable, even when payback periods are short. This perception can delay or prevent adoption.
- **Low awareness of benefits** – SME management may underestimate the financial, operational, and environmental gains from EE measures. Without clear evidence or benchmarking, energy savings are not prioritised.
- **Fragmented decision-making** – Energy efficiency is often not treated as a strategic issue. Operational staff make energy decisions without alignment to broader business goals, leading to inconsistent actions and missed opportunities.
- **Weak enforcement and support** – While national energy and environmental laws exist across ASEAN, monitoring and compliance vary. SMEs may lack incentives or feel no obligation to adopt structured EE practices, especially if enforcement is inconsistent.

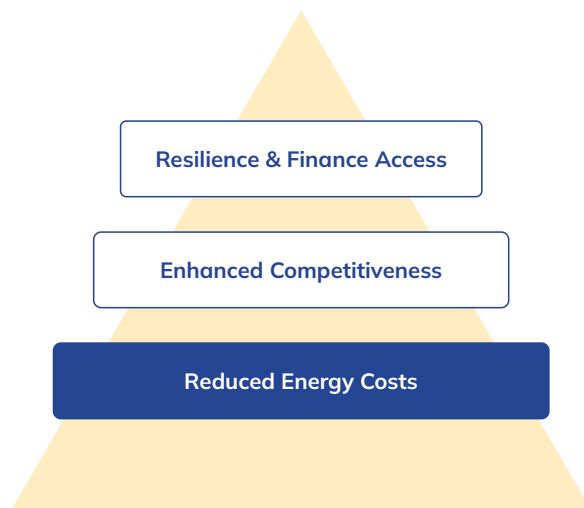
Table 2: Barrier vs. Implication

BARRIER	IMPLICATION FOR SMES IN INDUSTRIAL PARKS
Low/subsidised electricity tariffs	Reduced financial motivation for EE or RE/low-carbon investments
No dedicated energy staff	Limited systematic energy management; ad-hoc approach to EE
High perceived upfront cost	Delays investment in EE upgrades, slow adoption of efficient technologies
Low awareness of EE benefits	Energy-saving potential overlooked; missed cost and emission reductions
Energy not seen as strategic	Fragmented decision-making; no alignment with business goals
Weak enforcement	Limited motivation to comply with energy laws; reduced impact of national EE Programmes

3.1.3 Benefits and Business Case of Implementing an EnMS

Implementing a structured Energy Management System (EnMS) in SMEs, particularly those within Industrial Parks, offers both financial and operational benefits. Beyond energy savings, EnMS provides strategic advantages that strengthen competitiveness, resilience, and sustainability.

- Direct energy cost savings – Systematic monitoring and efficiency measures reduce electricity, gas, and fuel consumption, improving profit margins and freeing resources for other operational investments.
- Enhanced competitiveness – Buyers and global supply chains increasingly require sustainability compliance. SMEs with an EnMS can demonstrate energy-conscious operations, improving market access and business reputation.
- Improved access to financing and incentives – SMEs implementing EnMS are better positioned to access green loans, subsidies, or donor-backed EE Programmes, reducing capital barriers for efficiency investments.
- Resilience against energy price volatility–Structured energy management reduces vulnerability to electricity tariff increases and fossil fuel price fluctuations, ensuring predictable operational costs.
- Support for continuous improvement – The EnMS framework fosters a culture of ongoing energy performance improvement, helping SMEs adapt to evolving regulations and sustainability requirements.

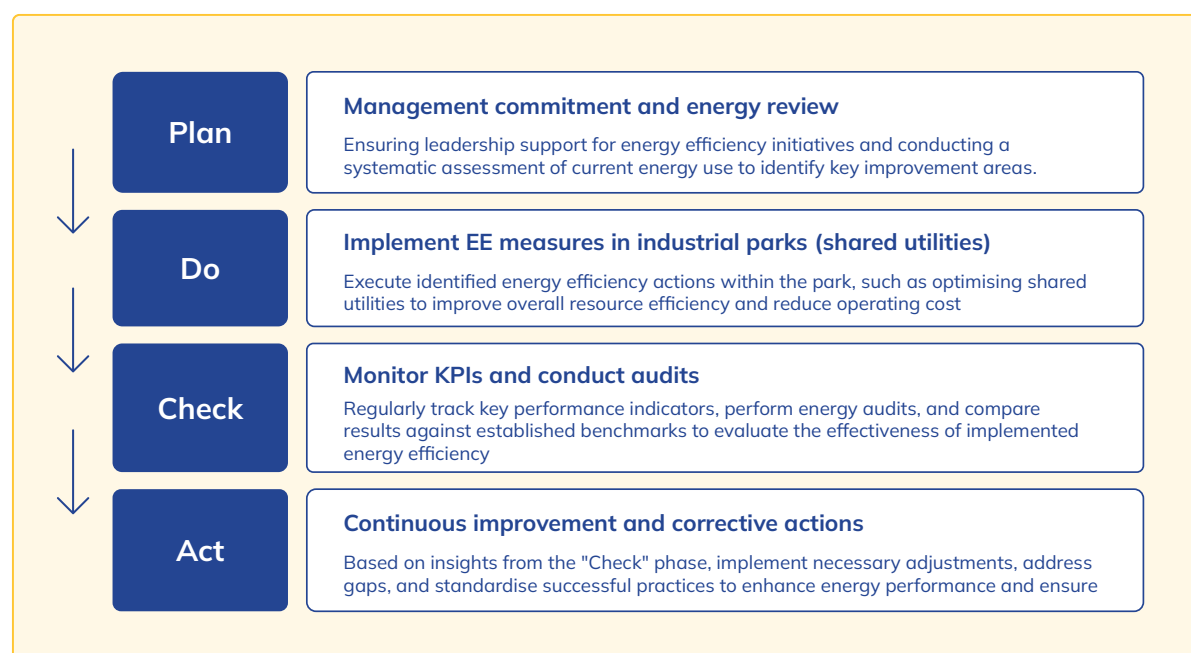


3.1.4 ISO 50001: The International Standard⁵

ISO 50001 provides a globally recognised framework for establishing, implementing, maintaining, and improving an Energy Management System (EnMS). Its structured approach helps organisations of all sizes systematically manage energy use, improve energy performance, and reduce costs and greenhouse gas emissions.

- **Relevance for SMEs in industrial parks** – ISO 50001 is particularly useful in industrial clusters where multiple SMEs operate. Many industrial parks have the option of cluster certification, allowing several SMEs to adopt a common EnMS framework. This reduces the administrative workload and cost per SME while promoting shared learning and benchmarking.
- **Focus on continuous improvement** – Unlike one-time energy-saving projects, ISO 50001 encourages SMEs to establish a cycle of Plan-Do-Check-Act (PDCA). This ensures ongoing improvements in energy performance, operational efficiency, and cost savings over time.

Figure 2: PDCA Cycle for SMEs in industrial parks



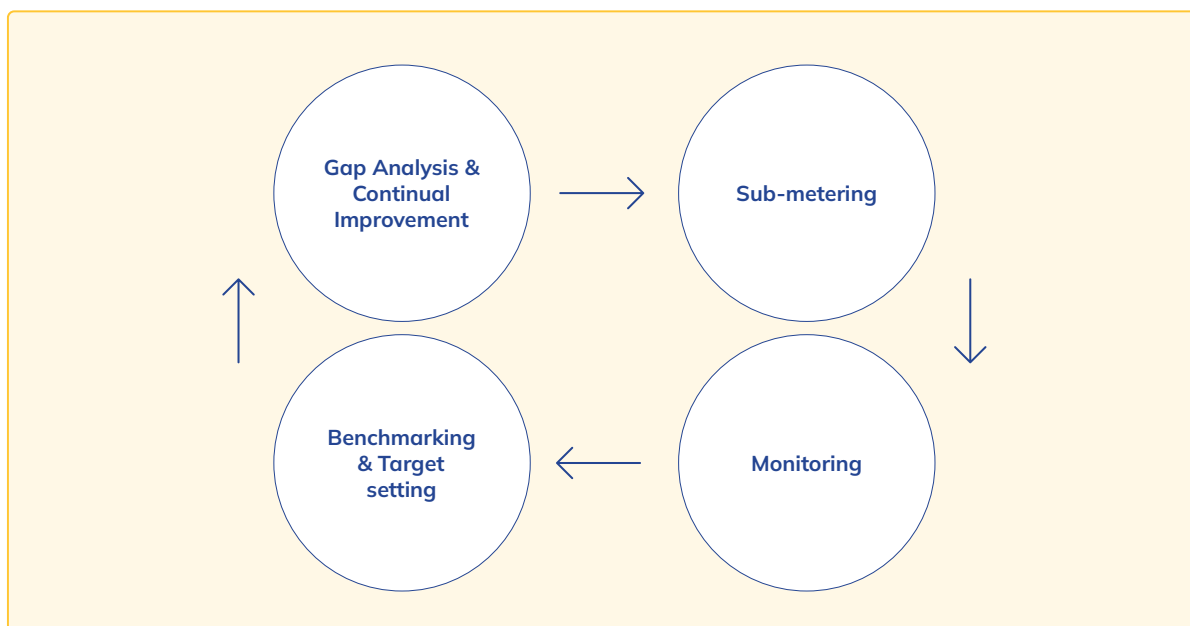
- **Integration with other management systems** – ISO 50001 can be aligned with ISO 9001 (Quality), ISO 14001 (Environmental), or ISO 45001 (Occupational Health & Safety). For SMEs in industrial parks, this integrated approach reduces duplication of efforts and strengthens overall operational management.
- **Benefits for access to finance and incentives** – Certification under ISO 50001 often facilitates access to green financing, subsidies, or tax incentives, as it demonstrates a structured, credible approach to energy efficiency and sustainability.

⁵ International Organization for Standardization (ISO) (2018). ISO 50001:2018 Energy management systems — Requirements with guidance for use. Geneva: <https://www.iso.org/iso-50001-energy-management>

3.2 Energy Data Collection and Management

Energy data is the backbone of any effective Energy Efficiency (EE) initiative. Without accurate data, energy savings remain invisible, and decision-making is often reactive rather than proactive. For SMEs in industrial parks, structured energy data collection, monitoring, and benchmarking are critical to achieving measurable energy and cost reductions.

Figure 3: Energy Data Collection & Management Cycle



3.3 Sub-Metering – Measuring Energy at Source

Sub-metering is the foundation of structured energy management, particularly for industrial parks hosting large SME populations, where many small enterprises share common infrastructure. It allows SMEs to measure energy consumption at the process, system, or utility network level, rather than relying solely on a single facility-wide meter. Accurate sub-metering transforms aggregated energy bills into actionable insights, enabling SMEs to identify high-energy processes, prioritise interventions, and track improvements.

Accurate sub-metering transforms aggregated energy bills into actionable insights, helping SMEs identify high-energy processes, prioritise interventions, and track improvements. Without proper sub-metering, SMEs may assume a flat cost share for shared utilities, which reduces motivation to optimise energy usage.

Sub-Meters should be installed on key equipment and shared utilities:

- **Motors & Drives:** Main motors (>5 kW) that power fans, pumps, and compressors should be metered.
- **Boilers & Steam Networks:** Fuel input and output should be monitored to track efficiency.
- **Compressed Air Systems:** Sub-metering should be applied for critical parameters like CFM (Cubic Flow)
- **HVAC Systems:** Chillers, AHUs, and air distribution units should be metered.
- **Lighting Circuits:** Energy consumption should be monitored to identify inefficient areas and optimise usage.

Table 3: Typical sub-metering parameters and data-collection frequencies⁶

SYSTEM/ EQUIPMENT	RECOMMENDED METERING	FREQUENCY OF DATA COLLECTION	NOTES
Motors & Drives	kWh submeters	Hourly/Daily	Focus on main motors >5 kW
Compressed Air	Flow (CFM), kWh meter, discharge pressure, loading/unloading time or cycle frequency	Hourly	Specific kWh/CFM can be calculated for benchmarking & gap analysis purpose
Boilers/Steam Networks	Steam & kWh meters	Daily	Track fuel vs. output
HVAC	kWh submeters	Daily	Include chillers & AHUs
Lighting	Circuit meters for kwh reading	Weekly	Identify inefficient areas

- Meter selection and installation should be carried out considering SME constraints:
 - Accurate, low-maintenance, and budget-friendly meters should be chosen.
 - Where possible, IoT-enabled or remote-monitoring meters should be used to allow real-time tracking and automated reporting.
 - Installation should be conducted in a simple and minimally disruptive manner, considering limited technical capacity of SMEs.

⁶ SEforALL analysis, informed by the US Department of Energy's Improving Compressed Air System Performance: A Sourcebook for Industry and Improving Steam System Performance: A Sourcebook for Industry, and the Carbon Trust's Motors and Drives Guide. Prepared under the ASEAN-UK Green Transition Fund's Clean and Just Energy Transition Pillar.

3.3.1 Monitoring

Once sub-metering and measurement practices have been established, monitoring serves as the essential process through which collected data is systematically recorded, analysed, and utilised for energy management. Monitoring transforms raw consumption figures into meaningful information, enabling SMEs and industrial parks operators to track progress, identify irregularities, and prepare for deeper efficiency interventions.

In IPs with large SME populations, monitoring is particularly critical, as individual SMEs often lack the resources or capacity to analyse their own energy data in detail.

By adopting structured monitoring frameworks at both enterprise and park levels, the visibility of energy use is significantly enhanced, making opportunities for savings and optimisation more tangible.

Key elements of monitoring in industrial parks:

Data Recording and Logging

- Energy consumption should be logged at regular intervals (shift-wise, daily, or weekly depending on operations).
- Low-cost digital loggers, data acquisition systems, or simple spreadsheets can be deployed by SMEs.
- Automated solutions are encouraged wherever feasible, but manual recording remains valuable if consistently implemented.

Data Visualisation and Dashboards

- Recorded data should be presented in formats that are easy to interpret, such as trend charts or load curves.
- For SMEs, simple excel-based dashboards can be promoted.
- At the IP level, centralised dashboards can be established to present aggregated consumption trends across utilities such as electricity, steam, and compressed air.

Centralised Monitoring Cells at IP Level

- A dedicated monitoring cell at the park level should be tasked with collecting and consolidating SME energy data.
- The aggregated dataset can highlight park-wide patterns such as peak demand periods, common inefficiencies, and utility bottlenecks.
- Shared energy systems (e.g., steam distribution networks or compressed air systems) can be monitored centrally to ensure efficient operation and fair allocation of costs.

Alerts and Exception Reporting

- Automated or semi-automated alerts should be triggered when abnormal consumption spikes occur.
- Exception reports prepared at the IP level should be circulated to SMEs, highlighting specific instances where their consumption diverged from the norm.

Preparation for Benchmarking and Target Setting

- Monitoring is not an end but lays the groundwork for subsequent steps, namely benchmarking, target setting, and gap analysis.
- Without consistent monitoring, such advanced energy management practices cannot be implemented effectively.

By embedding monitoring practices across SMEs and at the park level, a culture of data-driven energy management is fostered. For SMEs, monitoring delivers transparency and actionable insights, while for IP operators, it provides the aggregated intelligence needed to guide common facility management and collective energy efficiency initiatives.

3.3.2 Benchmarking and Target Setting

Benchmarking and target setting serve as the next logical steps once consistent monitoring practices have been established. For SMEs operating within ASEAN industrial parks, these practices provide both a reference point and a pathway towards measurable improvements.

Benchmarking

Benchmarking allows SMEs in industrial parks to compare their energy performance against peers, sectoral averages, or best-practice reference values. Within IPs characterised by large SME populations, anonymised and aggregated park-level data can be used to conduct benchmarking exercises without disclosing sensitive individual company information.

Forms of benchmarking relevant to industrial parks:

- Internal Benchmarking: Comparison of current energy use against the SME's own historical data, establishing baselines.
- Cross-SME Benchmarking: Comparison of similar SMEs within an IP, supported by park-level data aggregation.
- External Benchmarking: Comparison with national, regional, or international standards (e.g., ASEAN EE benchmarks, and Global Benchmarks).

Key Energy Performance Indicators (KPIs):

- Energy intensity (kWh or MJ per unit of product).
- Specific fuel consumption (GJ per tonne of product or service).
- Share of energy cost as a percentage of total operating cost.
- Utility efficiency (e.g., compressed air system efficiency, boiler efficiency).

Target Setting

Based on benchmarking insights, realistic and measurable energy performance targets should be set. In IPs, this can be done at both the enterprise level and the park level, ensuring alignment of SME efforts with collective goals.

- Enterprise-level targets: Progressive reduction of specific energy consumption over a defined timeframe (e.g., indicative improvement of 3–5% over three years), subject to availability of technical support, financing access, and baseline energy performance levels.
- Park-level targets: Improvement in the efficiency of shared utilities (e.g., 10% reduction in distribution losses in steam or compressed air networks).
- Progressive targets: Short-term and readily implementable measures (e.g., lighting retrofits, load management) should be complemented with medium- and long-term targets requiring higher investment (e.g., boiler upgrades, waste heat recovery).

By combining benchmarking with structured target setting, SMEs in IPs are guided towards achievable improvements while also contributing to collective decarbonisation objectives.

It should be noted that the benchmarks and targets outlined above are intended to guide progressive improvement rather than serve as mandatory requirements. Implementation timelines and performance thresholds may be adapted to national contexts, SME capacity levels, financing availability, and institutional readiness across ASEAN Member States.

3.3.3 Gap Analysis and Continuous Improvement

Gap analysis and continuous improvement ensure that monitoring, benchmarking, and target setting are not one-off exercises but part of an ongoing energy management cycle, a step forward in mainstreaming energy efficiency.

Gap Analysis

Gap analysis involves comparing actual performance against set targets and identifying areas of deviation. For SMEs in IPs, this process helps highlight the shortcomings and system inefficiencies.

Application in industrial parks:

- SME-level gaps: Identification of underperforming equipment (e.g., inefficient motors, leaks in compressed air systems).
- Park-level gaps: Recognition of losses in common utility networks such as steam, chilled water, or compressed air.
- Priority actions: Classification of gaps into “no-cost/low-cost” measures and “investment-grade” measures.

Gap analysis also provides valuable input for capacity building, since recurring gaps often point to training or awareness needs among SME operators.

Continuous improvement

Energy efficiency is most effective when pursued as a cycle of continuous improvement, rather than as a one-time intervention. This principle, central to ISO 50001 and global best practices, is particularly relevant to IPs where SMEs evolve and scale over time.

Key elements of continuous improvement:

1. **Periodic review:** Regular review of monitoring data and benchmarking results (e.g., quarterly or annually).
2. **Feedback mechanisms:** Establishment of review meetings at IP level where SMEs are provided with comparative performance feedback.
3. **Updating targets:** Targets should be revised upward once initial goals are achieved, ensuring sustained progress.
4. **Replication of success stories:** SMEs that demonstrate measurable savings should be encouraged to share case studies, enabling knowledge transfer across the park.

By embedding gap analysis and continuous improvement into the operational culture of SMEs and IPs, an iterative framework is created that sustains energy efficiency gains, drives competitiveness, and supports ASEAN's regional energy and climate commitments.

3.4 Energy Audit in SMEs within industrial parks

Energy audits are structured assessments of energy use in facilities. Across ASEAN industrial parks with large SME populations, energy audits are particularly useful to:

- Identify energy-saving opportunities across multiple SMEs with energy intensive equipment & inefficiencies in the system (like low efficiency boilers, inefficient motors, high leakages in compressed air system)
- Provide baseline data for benchmarking and target setting.
- Prioritise cost-effective interventions for small-scale operations where capital and technical capacity may be limited.

Table 4: Types of Energy Audits⁷

AUDIT TYPE	DESCRIPTION	TYPICAL SCOPE FOR SMES IN IPS
Walk-through or Preliminary Audit	Quick site visit to identify obvious inefficiencies	Lighting, motors, boilers, compressed air leaks
Detailed Energy Audit	Quantitative measurement and analysis to identify saving potential and related investments for improvement	Energy balance for processes, HVAC, steam/air networks, sub-metered utilities
Specialised Audit	Focused on specific systems or processes	Heat recovery, process optimisation, complete compressor system of the facilities

⁷ LEAP4SME (2023) Energy Audits: Practical Guide for More Energy Efficient Business. Brussels: LEAP4SME Project. https://leap4sme.eu/wp-content/uploads/2023/03/LEAP4SME_Energy_Audits_Booklet_web_v2.pdf

Audit methodology⁸

Pre-audit preparation

- Collection of facility energy bills (electricity, gas, fuel).
- Identification of major energy-consuming equipment (motors, compressors, boilers, chillers).

On-site assessment

- Inspection of equipment for operational inefficiencies (leaks, improper controls, under/over-sizing).
- Measurement of operating conditions (temperature, pressure, flow rates, power consumption).
- Use of sub-metering for detailed energy flows in SMEs.

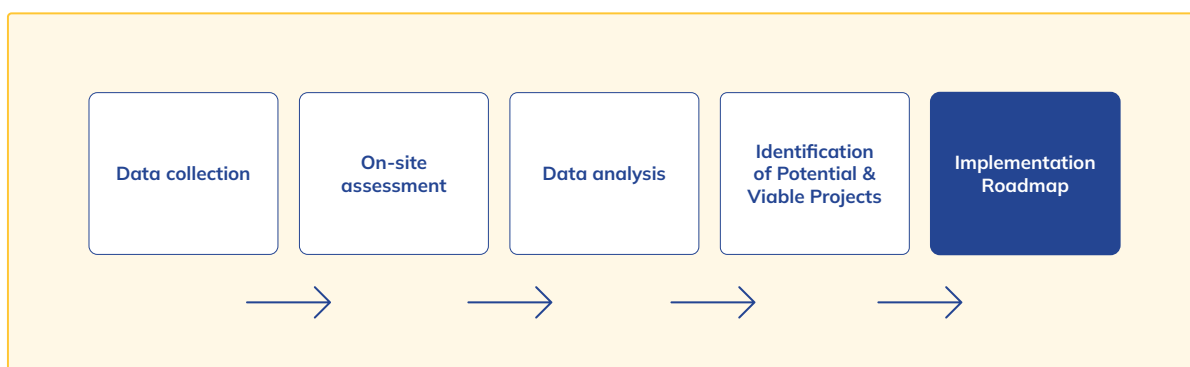
Data analysis

- Perform energy balance: input vs. useful output.
- Identification of readily implementable measures/ low-cost measures and capital-intensive measures.

Report & recommendations

- Highlight potential energy savings, cost savings, payback period
- Providing implementation roadmap, separating measures by cost and complexity (short term or immediate, medium term & long-term projects)

Figure 4: Audit Methodology Flow chart



⁸ LEAP4SME (2023) Energy Audits: Practical Guide for More Energy Efficient Business. Brussels: LEAP4SME Project. https://leap4sme.eu/wp-content/uploads/2023/03/LEAP4SME_Energy_Audits_Booklet_web_v2.pdf

3.5 Measurement, Monitoring & Verification (M&V)⁹

Measurement, Monitoring & Verification ensures that energy efficiency measures implemented in SMEs deliver the intended savings. In industrial parks with large SME populations, M&V helps:

- Track energy consumption in utility systems (steam, compressed air, cooling).
- Evaluate performance of Energy Efficiency interventions.
- Support continuous improvement and decision-making for future projects.

Table 5: Typical M&V Methodology⁹

STEP	DESCRIPTION	RELEVANCE TO ASEAN SMES IN IPS
Measurement Plan	Definition of scope, boundary, frequency	Sub-meter points for electricity, gas, steam, compressed air
Monitoring	Continuous or periodic measurement	Tracking energy use of SMEs and park-level utilities
Verification	Comparison with baseline, adjusted for operational changes	Validation of expected vs. actual energy savings
Reporting	Documentation of energy performance and anomalies	Enables IP-wide dashboards and management decisions

M&V guidelines for SMEs in industrial parks:

1. Sub-Metering: Ensure key utilities are separately metered for each SME or process.
2. Monitoring Frequency:
 - Monthly: billing-level data
 - Weekly: key equipment (motors, compressors, boilers)
 - Real-time: optional for critical systems or common utilities
3. Verification Approaches:
 - Option A: Compare energy use post-intervention against baseline.
 - Option B: Adjust for production or operational changes using energy intensity metrics.

Continuous Improvement

M&V must not be treated as a one-time exercise. Instead, periodic review of energy data should be conducted to identify additional opportunities for savings. Re-baselining every 12–24 months is recommended to account for continuous growth & improvement. Regular engagement with SME operators and industrial parks managers ensures that energy-conscious behaviour becomes an integral part of facility operations.

⁹ Efficiency Valuation Organization (EVO) (n.d.) International Performance Measurement and Verification Protocol (IPMVP). <https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp>

Energy audits and M&V are fundamental tools for identifying, measuring, and sustaining energy efficiency improvements in SMEs within industrial parks. However, their success is dependent on the presence of a structured Energy Management System (EnMS) that integrates these practices into the organisational culture.

An EnMS provides the first pillar of energy efficiency, ensuring that audits are systematically implemented, M&V data is utilised effectively, and continuous improvement is embedded in both SME operations and industrial park-wide management practices.

3.6 Energy Performance Metrics

Energy performance metrics are essential for SMEs to evaluate, monitor, and improve their energy efficiency. By converting raw energy consumption into meaningful indicators, SMEs across ASEAN industrial parks can identify inefficiencies, benchmark against peers, and track progress over time. Such metrics also help in linking energy use with production levels, ensuring that energy efficiency becomes an integral part of overall business performance.

Table 6: Key Energy Performance Metrics¹⁰

METRIC	FORMULA/EXPRESSION	APPLICATION IN SMES	RELEVANCE IN INDUSTRIAL PARKS
Specific Energy Consumption (SEC)	Total Energy Consumption ÷ Production Output	kWh per unit product (e.g., textile, plastics, packaging)	Allows park-level comparison across similar SMEs
Energy Intensity	Energy Consumption ÷ Value of Output (e.g., GBP or local currency)	Useful for diverse SME sectors	Enables economic benchmarking within the park
Energy Use per Floor Area	kWh ÷ m ² of built-up area	Applicable to warehouses, cold storage, commercial SMEs	Common reference metric for service-based SMEs
Load Factor	Average Load ÷ Maximum Demand	Foundries, metal works, high-load SMEs	Helps identify under-utilisation of connected load
System Losses/Leakage Index	(Losses ÷ Input Energy) × 100	Compressed air, steam, chilled water systems	Reduces shared utility costs within the park

CUSUM (Cumulative Sum) analysis is a practical tool to track deviations from expected energy consumption over time. By comparing actual energy use against a baseline, SMEs can quickly detect hidden losses (e.g., compressed air leaks, refrigeration inefficiencies) and take timely corrective actions. At the park level, CUSUM can highlight collective performance drift and prompt capacity-building interventions.

¹⁰ Sustainable Energy for All (SEforALL) under the ASEAN Energy Transition and Green Value Chain for Carbon Neutrality, ASEAN-UK Green Transition Fund – Clean and Just Energy Transition.

3.7 Practical Guidelines for Achieving Energy Efficiency in Industrial Parks with large SME populations

While the previous sub-chapter (3.1 to 3.4) introduced the foundational elements of monitoring, benchmarking, and audits, this chapter provides practical guidelines on how energy efficiency (EE) can be effectively organised and delivered in IPs with large SME populations.

The emphasis is on collective action, park-level facilitation, and simple governance structures that allow SMEs to participate meaningfully without being overburdened by technical or financial complexity.

1. Establishing a Park-Level Energy Cell

- A small Energy Cell should be set up within the industrial parks management or developers' office.
- Responsibilities include consolidating SME energy data, coordinating audits, training SMEs, liaising with financial institutions, and documenting success cases.
- The Energy Cell can act as the “translation layer” between sophisticated EnMS concepts and the practical needs of SMEs.

2. Common Capacity-Building Platform

- Instead of each SME running its own training, the industrial parks can organise joint workshops on basic EE housekeeping, standard operating practices, and safety.
- Use model operating procedures (for boilers, compressed air, HVAC, lighting) that SMEs can adopt without complex redesigns.
- Knowledge transfer can be facilitated by inviting national energy agencies, ESCOs, and equipment suppliers to provide standardised training.

3. Shared Audits and Diagnostic Services

- The industrial parks should arrange cluster audits where one expert team covers multiple SMEs with similar processes.
- Diagnostic tools (portable sub-meters, thermal cameras, leak detectors) should be shared resources at the park level, managed by Energy Cell.
- The audit results should be translated into simple action cards (e.g., “Check insulation on steam lines”, “Replace conventional bulbs/lighting with LED”) that SMEs can implement directly.

4. Installation and optimisation of shared utilities in industrial parks

In many ASEAN industrial parks, particularly those with a long SME tail, shared utilities such as centralised steam networks and compressed air systems provide opportunities for significant collective energy savings. Establishing and managing these shared systems at the park level reduces duplication of energy losses, enables economies of scale, and improves monitoring and efficiency.

Table 7: Example of Shared Utilities and Typical Key EE Measures¹⁰

SHARED UTILITY	KEY ENERGY EFFICIENCY MEASURES
Centralised Steam Network	High-efficiency boilers, insulation of steam lines, condensate recovery, regular maintenance of traps and valves
Compressed Air Network	Leak detection and repair, optimised pressure settings, efficient compressors, centralised controls
Cooling Water Systems	Use of variable speed drives on pumps, proper water treatment, thermal insulation, cooling tower optimisation
Wastewater Treatment	Biogas recovery, energy-efficient aeration, pump optimisation, integration with renewable energy

Well-designed and efficiently operated shared utilities can reduce operating costs, strengthen the business case for green financing, and deliver measurable energy and carbon savings across multiple SMEs in the park.

5. Aggregated Procurement and Financing

- Park management should pool SME requirements for efficient equipment (LEDs, motors, compressors) into bulk procurement Programmes, reducing costs.
- Financing can be unlocked by aggregating projects into one larger proposal for banks or development finance institutions.
- For SMEs, repayment mechanisms can be aligned with utility bills (on-bill repayment) to avoid upfront costs.

6. Park-Level EE Standards and Recognition

- Industrial parks may progressively introduce minimum energy practices, beginning with voluntary guidelines and pilot-based adoption before considering broader requirements (such as mandatory maintenance logs, insulation of all steam lines, or use of power factor correction).
- A recognition Programme (gold/silver/bronze energy-efficient SME) encourages healthy competition among tenant firms.
- Success stories should be showcased within the park and externally to attract further investment.

7. Collective Measurement, Reporting and Verification (MRV)

- The Energy Cell should consolidate results at the park level.
- SMEs only need to provide basic inputs (monthly kWh, production units, operating hours).
- Aggregated MRV helps the park report measurable outcomes to regulators, investors, and green finance schemes without burdening SMEs individually.

Table 8: Example Table-KPIs for SMEs in industrial parks¹⁰

KPI CATEGORY	KPI	UNIT / METRIC	TARGET / BENCHMARK	NOTES / COMMENTS
Energy Consumption	Total electricity consumption	kWh/month	Indicative 5–10% annual improvement vs. baseline, subject to enterprise capacity and support availability.	Measure at main distribution or sub-meter level
	Total fuel consumption	litres / kg / m ³	Indicative 5–10% annual improvement vs. baseline, subject to enterprise capacity and support availability.	Applicable for boilers, furnaces, DG sets
Energy Intensity	Energy per unit of production	kWh/unit or GJ/unit	Compare against sector benchmarks	Helps normalise energy use for varying production scales
Utility Efficiency	Steam system efficiency	%	≥85% (for well-maintained small boilers)	Includes losses from leaks and poor insulation
	Compressed air efficiency	kWh/CFM	Sector benchmark dependent	Include leakages, inappropriate pressure, and idle consumption
Energy Cost	Energy cost share of total production	%	<10–15%	Useful to show financial benefit of EE measures
Process-Specific	Lighting efficiency	W/m ²	Replace <15 W/m ² with LED / ≥50% savings	Applicable for workshop/factory floor
	HVAC / Cooling efficiency	kWh/m ²	Benchmark with local IP averages	Target seasonal efficiency improvements
Monitoring & Reporting	% of SMEs submitting monthly energy data	%	Progressive coverage target towards full participation, subject to capacity	Enables consolidated MRV at park level
Continuous Improvement	Number of implemented EE measures per SME	count	Encourage 1–3 priority EE measures annually, based on enterprise capacity	Readily implementable measures, e.g., timers, insulation, LED replacement

This chapter has outlined the foundational elements of energy efficiency for SMEs across ASEAN industrial parks, starting with the basics of structured Energy Management Systems (EnMS), followed by approaches to data collection, monitoring, benchmarking, target setting, audits, and measurement, reporting, and verification (M&V).

Practical guidelines tailored to the context of industrial parks with large SME populations have also been presented, including the optimisation of shared utilities.

The importance of this lies in setting out the core building blocks for a robust energy efficiency plan. Without these foundations, any technology or equipment-level interventions risk being fragmented or unsustainable. By establishing clear systems for management, measurement, and verification, SMEs and industrial parks can ensure that energy efficiency becomes an ongoing, systematic process rather than a one-time exercise.

With this groundwork in place, the next is equipment- and technology-specific guidelines, translating these principles into practical, sector-relevant applications that directly support energy savings and decarbonisation.



3.8 Industrial Symbiosis and Shared Infrastructure Opportunities in industrial parks

Industrial parks provide a unique opportunity for fostering collaboration among tenant industries to enhance energy efficiency, reduce operational costs, and accelerate the transition towards low-carbon operations. By adopting industrial symbiosis principles where the waste or by-product of one facility becomes a resource for another, IPs can significantly improve their overall energy and resource efficiency.

Key areas where IPs can leverage shared infrastructure and symbiotic relationships include:

- **Common Hot-Water or Steam Networks:** Developing district heating schemes (DHS) through centralised hot-water or steam systems can serve multiple facilities within the park. Traditionally powered by large-scale boilers or combined heat and power (CHP) systems, these networks can be decarbonised through renewable or low-carbon sources such as industrial waste fuels, anaerobic digestion (AD) of food waste, ground-sourced heat pumps, or solar thermal systems.
- **Centralised Compressed Air Systems:** Establishing shared compressed air systems for multiple workshops can reduce duplication of equipment, optimise compressor utilisation, and improve overall system efficiency.
- **Joint Wastewater Treatment and Pumping Facilities:** A collective approach to wastewater treatment minimises redundancy, reduces operational costs, and ensures better environmental compliance across tenant industries.
- **Centralised Renewable Power Generation:** IP Estate Management can capitalise on available rooftop and open space areas to install solar photovoltaic (PV) systems, small-scale wind or hydroelectric power (HEP) units, or even larger-scale CHP plants. Such shared renewable energy systems can lower grid dependency and enhance the park's sustainability profile.
- **Battery Energy Storage Systems (BESS):** Implementing shared battery storage solutions allows the IP to store excess self-generated renewable power for later use. This not only enhances energy reliability and grid stability but also provides an uninterruptible power supply (UPS) during grid failures.
- **Industrial Symbiosis through Resource Exchange:** Encouraging inter-industry collaboration to use one site's waste streams such as heat, water, or by-products as raw materials for others promote circular economy principles and reduces overall waste generation.
- **Knowledge Sharing and Capacity Building:** The IP Estate can act as a central forum for awareness creation, staff training, and dissemination of good energy management practices. Regular knowledge exchange sessions can help tenants replicate successful energy efficiency interventions across the park.

Collectively, these initiatives create a resilient, resource-efficient, and low-carbon ecosystem within industrial parks delivering both environmental and economic benefits to the park management and the SME tenants alike.



CHAPTER FOUR

ENERGY SAVING OPPORTUNITIES FOR EVERYDAY ELECTRICAL EQUIPMENT

This chapter provides Energy Efficiency (EE) and Conservation Guidelines for equipment that are widely used across industries in the ASEAN region, particularly within industrial parks that host a large base of small and medium enterprises (SMEs).

Cross sectoral equipment's such as Motors & Drives, compressed air systems, lighting, Waste Heat recovery system, HVAC System are often the backbone of industrial operations and together contribute significantly to overall energy consumption of industrial parks.

For large SME populations, where individual energy savings may appear modest, a collective focus on efficiency of such equipment within industrial parks can generate significant aggregated energy savings and cost reductions. Moreover, opportunities such as shared utilities and centralised systems (e.g., compressed air networks, steam distribution, or cooling systems) can further enhance performance, reliability, and cost-effectiveness.

The guidelines in this chapter are intended to serve as practical, step-by-step references for SMEs and industrial parks operators to optimise equipment performance, reduce energy intensity, and lay the foundation for a more resource-efficient industrial ecosystem across the ASEAN region.

4.1 Motors & Drives¹¹

Electric motors and drives are the high-impact opportunities of industry, powering a wide range of rotating equipment such as air compressors, pumps, fans, blowers, conveyors, and mixers. Across ASEAN industrial parks, where SMEs form the majority, motors and drives typically account for a large share of electricity consumption (often 60–70% of the manufacturing electricity consumption in different countries¹²). Efficient operation, monitoring, and maintenance of motors can therefore lead to significant energy and cost savings across the industrial ecosystem.

Table 9: Guidelines for Motors & Drives¹⁰

CATEGORY	GUIDELINES
Management and Control	• Motors to be operated close to their optimal loading range (i.e. 75%–80%) for maximum efficiency. Avoid continuous underloading. • Stop motor-driven equipment when not required (idle operation should be avoided). • Maintain balanced three-phase voltage supply for stable motor performance. • Operate motors at a high-power factor (close to unity) using capacitors or automatic power factor correction units. • Ensure proper ventilation and cooling to avoid overheating. • Avoid repeated rewinding. If rewinding has been done more than two times, replace with energy-efficient motors (minimum IE2, preferably IE3 & above). • Motor Starter Selection: Soft Starters and Variable Frequency Drives (VFDs) • Best practice for motors >20 hp (~15 kW), and even smaller sizes if the motor drives variable torque loads such as fans, pumps, blowers, and compressors. • Soft Starters: Enable smooth motor starting and reduce mechanical/electrical stress but have limited energy efficiency benefits. • VFDs: Enable both smooth starting and significant energy savings (up to 30–40% for variable torque loads at part load). • Though initial cost is higher, VFDs usually provide short payback in SMEs where motors often operate below full load.
Measurement & Recording	Record electricity consumption, voltage, current, and power factor daily. Monitor body temperature, vibration, rpm monthly. Maintain proper logs for performance review and benchmarking.
Maintenance & Inspection	• Inspect bolts, shafts, and bearings quarterly. • Check cable tightness to prevent arcing/short circuits. • Maintain proper tension of belts to minimise transmission losses. • Calibrate instruments regularly as per supplier recommendations. • Monitor and maintain lubricant oil level daily.
	• Install energy-saving measures such as VFDs, permanent magnet motors, or fluid couplings for variable loads.

¹¹ Bureau of Energy Efficiency (BEE) (n.d.) Annexure 2. New Delhi: Ministry of Power, Government of India. Available at: <https://beeindia.gov.in/sites/default/files/Annexure%202.pdf>.

¹² Global Efficiency Intelligence (2017) Infographic: Energy Use in Industrial Motor Systems. Available at: <https://www.globalefficiencyintel.com/new-blog/2017/infographic-energy-industrial-motor-systems>

CATEGORY	GUIDELINES
New Installations (Design & Procurement)	- Procure IE3 or above motors for new applications to ensure long-term savings. - Prioritise motors compliance with Minimum Energy Performance Standards (MEPS).
Target Components	- Upgrade existing motors to IE3/IE4 efficiency class. - Explore motor drive integration with automated controls and monitoring. - Adopt condition-based maintenance using IoT sensors in larger industrial parks. - Facilitate shared procurement in industrial parks to lower cost of high-efficiency motors. - Maintain unbalanced voltage within 3%.

4.1.1 Key Performance Parameters and Monitoring Guidelines for Motors & Drives

For sustained energy savings, SMEs in Industrial Parks must regularly monitor key performance parameters of motors and drives. The table below provides common parameters, their relevance, recommended monitoring frequency, and assessment methods, enabling SMEs to identify inefficiencies early and take corrective measures.

Table 10: Common Monitorable Parameters and Performance Assessment for Motors & Drives¹⁰

PARAMETER	DESCRIPTION	FREQUENCY OF MONITORING	PERFORMANCE ASSESSMENT APPROACH
Load Factor (%)	Ratio of actual load to rated load; motors run most efficiently at 75–80% load. Underloading or overloading reduces efficiency.	Weekly/Monthly	Compare with rated efficiency curve; adjust operations to maintain optimal load.
Power Factor (PF)	Indicates how effectively electrical power is converted into useful work. Low PF leads to higher energy losses.	Daily	Maintain PF close to unity with capacitors or automatic power factor controllers (APFC).
Efficiency (%)	Ratio of output power to input power; a key indicator of motor performance.	Quarterly	Benchmark against IE2/IE3 standard efficiency levels.
Voltage & Current Balance	Imbalance in 3-phase systems leads to overheating and premature motor failure.	Daily	Ensure <1% voltage imbalance; take corrective actions if >2%.
Temperature (°C)	Overheating reduces insulation life and motor reliability.	Continuous/Online Monitoring	Compare with manufacturer's permissible limits (usually 80–100°C).

PARAMETER	DESCRIPTION	FREQUENCY OF MONITORING	PERFORMANCE ASSESSMENT APPROACH
Vibration Levels	Excessive vibration indicates misalignment, imbalance, or bearing wear.	Monthly	Follow ISO 10816 ¹³ standards for vibration severity.
Specific Energy Consumption (kWh/Output Unit)	Energy consumed per unit of production (e.g., kWh/tonne of output).	Monthly	Compare with industry benchmarks; identify scope for optimisation.
Starting Frequency	Frequent starts increase stress and losses.	Monthly	Limit starts/hour as per manufacturer's recommendation.

4.1.2 Transmission Systems

- Belts and pulleys: In many SMEs, outdated flat or V-belts are still in use, leading to slippages and approximately more than 5% transmission losses.
 - Recommendation:** Replace with cogged V-belts or synchronous belts, which reduce losses and require less tensioning.
- Direct coupling: Wherever feasible, replace belt-driven systems with direct coupling, eliminating transmission losses altogether.
- Maintenance: Regular alignment, proper tensioning, and lubrication can save up to 2–3% of motor energy use.

4.1.3 Energy Losses in Motor Systems

- Oversized Motors: SMEs often install motors much larger than the load requirement. Motors operating below 50% load have efficiency penalties of 5–15%.
- Recommendation:** Right-size motors based on actual load measurements (through audits or load analysers).
- Low-Efficiency Motors: Standard-efficiency motors waste significant energy over their lifetime.
 - Recommendation:** Replace with IE3/IE4 high-efficiency motors, which typically save 3–7% energy and short payback period.
- Poor Power Quality: Unbalanced voltages, low power factor, or harmonics reduce motor efficiency and lifespan.
 - Recommendation:** Maintain balanced supply voltages, improve power factor (through capacitors or APFC panels), and use filters where harmonic distortion is high.

¹³ International Organization for Standardization (ISO) (2023) ISO 50006:2023 Energy management systems — Evaluating energy performance using energy performance indicators and energy baselines. Geneva: ISO. Available at: <https://www.iso.org/standard/84280.html>

4.1.4 Variable Speed/Frequency Drives (VSDs/VFDs)

- Motors driving variable torque loads (fans, pumps, blowers, compressors) rarely operate at full capacity in SMEs, yet they often run at constant speed with flow controlled by dampers or throttling valves.
- VSDs adjust motor speed to match actual load demand, enabling significant savings:
 - Fans & Pumps: 20–40% energy savings possible.
 - Compressors: Savings of 10–25%, along with reduced maintenance.
- Additional benefits include:
 - Smoother motor starting (lower stress on motor and electrical system).
 - Process flexibility and improved product quality.
 - Reduced mechanical wear and noise levels.

4.1.5 Low-Cost and High-Impact Energy Efficiency Opportunities for SMEs in Motors & Drives

- Replace worn-out V-belts with cogged or synchronous belts; consider direct coupling.
- Right-size motors and replace low-efficiency models with IE3/IE4 motors.
- Use automatic power factor correction (APFC) systems to maintain PF above 0.95.
- Install VFDs for variable torque loads (fans, pumps, compressors) – prioritise motors >10 hp (~>7.5 kw) with high operating hours.
- Implement preventive maintenance practices: proper alignment, lubrication, and timely rewinding to preserve motor efficiency.

4.1.6 Financial benefit & Case study of inefficient motor replacement with IE3 Motor

Electric motors represent the largest share of electricity consumption in SMEs. Globally, motor-driven systems are estimated to consume around 60–70% of total industrial energy use¹⁴. While this figure is based on somewhat older data, it clearly underscores that motors remain the dominant contributors to industrial energy consumption.

Many motors across ASEAN industrial parks are old, inefficient, rewound multiple times, or oversized for their application, resulting in significant energy losses and high operating costs. Replacing such motors with IE3 premium efficiency motors offers a simple, high-impact, and quick-payback opportunity. Beyond direct energy savings, IE3 motors provide improved reliability, reduced maintenance costs, and lower greenhouse gas emissions.

¹⁴ https://iea.blob.core.windows.net/assets/d69b2a76-feb9-4a74-a921-2490a8fefcdf/EE_for_ElectricSystems.pdf

When assessed over their lifetime, the total cost of ownership (purchase + operating cost) of IE3 motors is significantly lower than that of inefficient motors. The following case study illustrates the financial benefits of motor replacement through a simple calculation of energy savings, payback period, and lifetime cost.

Table 11: Sample calculation of energy savings for replacement of IE2 motor with IE3 motor¹⁰

DESCRIPTION	UOM	EXISTING	AFTER REPLACEMENT
Type of Motor		IE2	IE3
Rating		15 kW/ 4P	15 kW/ 4P
Output of motor	Kw	15	15
Motor efficiency ¹⁵	%	90.6%	92.3%
Motor loading %	%	85%	85%
Power tariff ¹⁶	GBP/kwh	0.12	0.12
Operating hrs per annum	hrs	7920	7920
Energy consumption per annum	kWH	111457	109642
Energy Saved per annum over standard motor	kWH	1815	
Savings towards energy bill per annum	GBP/annum	218	
Purchase price of a new motor ¹⁷	GBP	750	
Simple Payback	yrs	3.4	
Considering motor life of 10 years	yrs	10	10
Lifetime cost	GBP	133748	131570
Difference in Lifetime cost of IE2 vs. IE3 Motor	GBP	2,178	

The replacement of inefficient motors with IE3 premium efficiency motors offers SMEs a practical and financially sound energy efficiency measure.

In the 15-kW case study, the IE3 motor delivered annual energy savings of over 1,800 kWh, translating into approximately GBP 162 per year in reduced electricity costs (All currency values have been converted to GBP using the United Nations Operational Rates of Exchange applicable at the time of publication, unless otherwise stated). With a simple payback of just 3.4 years, SMEs recover their investment well within the motor's service life. Over a 10-year period, the total cost of ownership

¹⁵ As per International standard (IEC 60034-30-1:2014)-
<https://havells.com/media/HavellsWebsitePdf/CorporatePdf/dam/havells/brouchers/motors/Prima%20Series%20Motors/Prima%20series%20motor%20Catalogue.pdf>

¹⁶ ASEAN Centre for Energy (ACE) (2024) Energy Highlight on Electricity: January–April 2024. Jakarta: ASEAN Centre for Energy. Available at: <https://aseanenergy.org/wp-content/uploads/2024/07/Energy-Highlight-on-Electricity-Jan-April.pdf>

¹⁷ IndiaMART (n.d.) Siemens IE3 15 kW TEFC Squirrel Cage Motor. Available at:
<https://www.indiamart.com/proddetail/siemens-ie3-15-kw-make-tefc-squirrel-cage-motor-2848981388873.html>

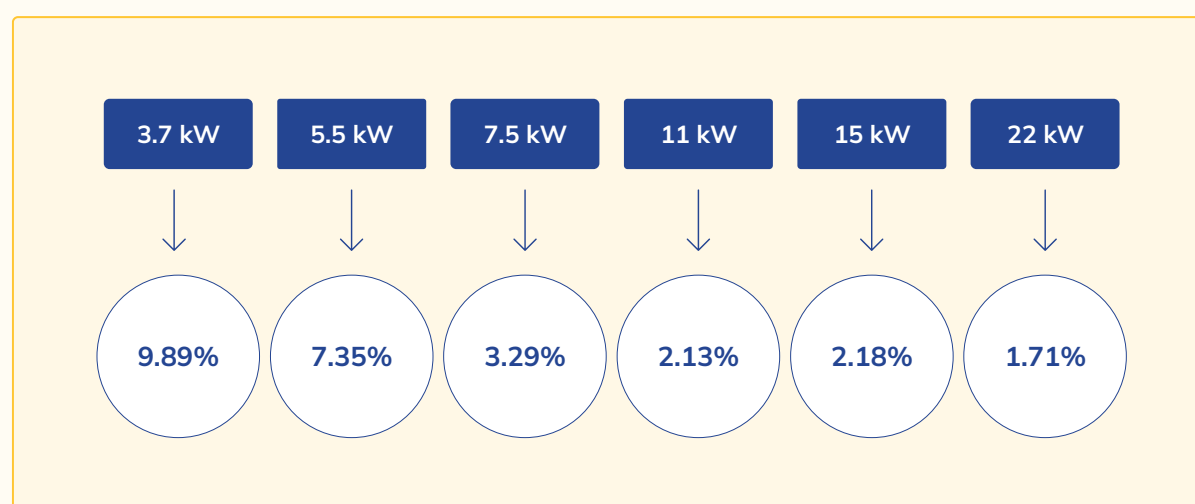
is estimated to be more than GBP 1,040 lower, clearly demonstrating that IE3 motors not only cut operating costs but also provide reliable, long-term financial returns. In this analysis, IE2 motors were considered; replacing IE1 or lower-efficiency motors would result in even higher energy savings and shorter payback periods, making the case for IE3 adoption even stronger. For SMEs with high motor usage, adopting IE3 motors is a quick-win strategy to improve competitiveness while reducing energy demand.

Case Study: Replacement of Old Inefficient motors with Premium Efficiency (IE3) Motors¹⁸

Banswara Syntex Ltd., one of Asia's largest single-mill setups for fibre-dyed yarn, partnered with Energy Efficiency Services Ltd. (EESL) under the National Motor Replacement Programme (NMRP) to modernise its motor fleet. In the first phase, 125 motors ranging from 3.7 kW to 22 kW, 4-pole, were targeted for replacement with IE3 premium efficiency motors. This initiative delivered significant energy savings, lower electricity bills, and reduced maintenance costs, demonstrating a practical, high-impact approach to improving energy efficiency in large-scale industrial operations.

INDUSTRY SUB-SECTOR	TEXTILE
Application	Spinning Mill
Year of Implementation	2018
Type of Investment	Medium
Annual Energy Savings (kwh)	2,44,094
Annual Cost Savings (GBP)	12,250
Payback Period	2 years 5 months

Figure 5: Motor Rating wise Energy Savings (%)



¹⁸ International Copper Association India (2020) Case Study: Banswara Syntex Ltd. New Delhi: International Copper Association India. Available at: https://copperindia.org/oguploads/knowledge_center/CASE-STUDY_Banswara_Syntex.pdf

4.2 Pumps & Pumping system

Pumps are widely used in industries to transport fluids through mechanical action. Based on their operating principle, pumps are classified into dynamic pumps and positive displacement pumps. Dynamic pumps include centrifugal pumps and special-effect pumps, while positive displacement pumps consist of rotary pumps and reciprocating pumps. Among these, centrifugal pumps represent the largest share of electricity consumption in the industrial sector. Common types of centrifugal pumps used in industry include:

1. Monoblock pumps
2. End-suction pumps
3. Split-case pumps
4. Multistage pumps.

This section presents guidelines for pumps and pumping systems in a structured and practical manner.

Table 12: Guidelines for Pumps & Pumping system¹⁰

CATEGORY	GUIDELINES
Management and Control	Operate pumps close to their best efficiency point (BEP) to avoid over- or under-loading or as suggested by OEM (Original Equipment Manufacturer) Stop pumps when not required; avoid continuous idling. Maintain balanced voltage and proper lubrication. Reduce throttling losses by adjusting pump speed with VFDs instead of valves. Right-size pumps to match actual system demand.
Measurement & Recording	Record flow rate, pressure, and energy consumption daily. Monitor vibration and bearing temperature monthly. Maintain logs for performance benchmarking.
Maintenance & Inspection	Inspect impellers, seals, and couplings quarterly. Check for leakage and alignment; repair promptly. Ensure proper belt tension in belt-driven pumps.
New Installations	Procure high-efficiency pumps compliance with MEPS (Minimum Energy Performance Standards) Use VFDs for variable flow applications. Integrate automated control systems for optimised operation.
Target Components	Replace old, inefficient pumps with high-efficiency units. Implement energy monitoring and automated control for multiple pumps. Prioritise shared procurement of high-efficiency pumps in Industrial Parks.

4.2.1 Key Performance Parameters and Monitoring Guidelines for Pumps & Pumping system

Pumps are critical for fluid transport, water circulation, cooling, and process operations in SMEs. Across ASEAN industrial parks with a high concentration of SMEs, pumping systems can account for ~10 to 20% of total electricity consumption. Efficient operation, regular monitoring, and preventive maintenance of pumps can yield significant energy savings and reduce operating costs.

The SMEs can estimate pump efficiency using the following formula:

$$\text{Pump Efficiency (\%)} = \frac{\text{Hydraulic power} \times 100}{\text{Shaft power}}$$

Hydraulic power (Pd) = $[Q \times (h_d - h_s) \times \rho \times g] / 1000$

Pump shaft power (Ps) = Electricity consumption × Motor efficiency

where, g- Acceleration due to gravity (m/s²)

h_d - Discharge head (metre)

h_s - Suction head (metre)

Q- Flow rate (m³/s)

ρ - Density of fluid (kg/m³)

Table 13: Common Monitorable Parameters and Performance Assessment for Pumps & Pumping system¹⁰

PARAMETER	DESCRIPTION	RECOMMENDED FREQUENCY OF MONITORING	PERFORMANCE ASSESSMENT APPROACH
Flow Rate (m³/h)	Actual volume of fluid pumped per hour. Pumps operate most efficiently near their Best Efficiency Point (BEP).	Weekly / Monthly	Compare with design specifications or BEP; adjust operations to maintain optimal flow.
Discharge Pressure (bar/psi)	Pressure at pump outlet; excessive or insufficient pressure increases energy consumption.	Daily	Ensure operating pressure matches process requirement; avoid over-pressurisation.
Power Consumption (kW)	Energy drawn by the pump motor; reflects overall efficiency.	Daily	Compare with expected consumption at given flow and head; identify inefficiencies.
Pump Efficiency (%)	Ratio of hydraulic power delivered to electrical power input.	Quarterly	Benchmark against pump nameplate efficiency or industry standards; investigate low efficiency.

PARAMETER	DESCRIPTION	RECOMMENDED FREQUENCY OF MONITORING	PERFORMANCE ASSESSMENT APPROACH
Motor Load (%)	Indicates how closely the pump motor is operating to rated capacity.	Weekly	Ensure the motor is loaded near 75–80% for optimal efficiency; avoid under- or overloading.
Vibration Levels (mm/s or g)	High vibration indicates misalignment, cavitation, or bearing wear.	Monthly	Follow ISO 10816 standards; address excessive vibration to prevent damage.
Temperature (°C)	Motor, bearing, or fluid temperature; overheating reduces component life.	Continuous / Online	Ensure temperatures remain within manufacturer-specified limits.
Leakage / Suction & Discharge Losses	Leakage in seals or piping reduces hydraulic efficiency.	Monthly	Inspect for visible leaks; quantify losses and repair promptly.
Specific Energy Consumption (kWh/m³)	Energy consumed per unit of fluid pumped.	Monthly	Compare against industry benchmarks; optimise pump sizing, speed, and controls.

4.2.2 Pump Types & Suitability for SMEs

- **Centrifugal Pumps:** Most widely used in SMEs for water supply, cooling, and process fluids. High efficiency when operated near Best Efficiency Point (BEP). Ideal for variable flow applications when paired with VFDs.
- **Screw Pumps:** Suitable for viscous fluids, moderate flow, and low-to-medium pressure applications. Less common in SMEs due to higher capital cost but very efficient for specialised processes.
- **Reciprocating Pumps:** High-pressure, low-flow applications. More suitable for industrial niches than general SME use. Typically, higher maintenance; efficiency can drop significantly with wear.

Recommendation for SMEs in industrial parks:

- Centrifugal pumps with IE3/IE4 motors and VFDs are generally most practical, offering balance between efficiency, ease of maintenance, and low initial cost.
- Use screw or reciprocating pumps only for specific viscous or high-pressure applications where centrifugal pumps are unsuitable.

4.2.3 Transmission Systems & Pump Drive Configurations

- **Belt-Driven Pumps:** Many facilities still use outdated belt-driven pumps with flat or V-belts, causing slippages and energy losses of 5–10%.
 - **Recommendation:** Replace with cogged V-belts or synchronous belts or adopt direct-coupled drives to eliminate transmission losses.
- **Maintenance:** Regular alignment, proper tensioning, and lubrication of pump shafts and couplings can save 2–3% of energy consumed by pumps.

4.2.4 Energy Losses in Pumping Systems

- **Oversized Pumps:** Operating below 50% of design flow leads to 5–15% energy penalty.
 - **Recommendation:** Right-size pumps based on actual flow and head requirements measured through audits or flow meters.
- **Low-Efficiency Motors & Pumps:** Older pump motors or outdated hydraulic designs waste significant energy over their lifetime.
 - **Recommendation:** Replace with premium efficiency pumps or IE3/IE4 motors, which typically save 5–15% energy depending on age and load profile.
- **Poor Power Quality:** Voltage imbalance, harmonics, or low power factor reduces efficiency.
 - **Recommendation:** Maintain balanced supply, improve power factor with capacitors/APFC, and use harmonic filters where required.
- **Cavitation & Friction Losses:** Operating away from BEP, high pipe friction, or throttling leads to efficiency losses.
 - **Recommendation:** Operate near BEP, minimise valve throttling, and clean strainers regularly.

4.2.5 Quick-Win Opportunities for SMEs

- Replace worn-out belts with cogged or synchronous belts or adopt direct-coupled drives.
- Right-size pumps and replace inefficient pumps or motors with premium efficiency models.
- Install VFDs for variable flow applications.
- Repair leaks, clean strainers, and maintain suction/discharge piping.
- Implement preventive maintenance: proper alignment, lubrication, and timely bearing replacement.

4.3 Fans & Blowers

Fans and blowers are primarily used to move air at high velocity and mass flow rates, but typically at relatively low static pressures. They find wide application in transferring air through mechanical action. Based on their operating principle, fans are categorised as:

1. Centrifugal fans
2. Axial flow fans

Similarly, industrial blowers are classified into:

1. Centrifugal blowers
2. Positive displacement blowers

The choice of a fan or blower depends on specific process requirements such as the required air volume, system resistance, output pressure, and the operating environment.

Table 14: Guidelines for Fans & Blowers¹⁰

CATEGORY	GUIDELINES
Management & Control	• Operate fans/blowers close to their best efficiency point (BEP); avoid throttling and flow restrictions. • Stop fans/blowers when not in use or during idle operation. • Ensure balanced voltage supply for fan motors to avoid inefficiency and overheating. • Regularly check system resistance, avoid blocked filters or duct leakages that force fans to work harder • Encourage shared centralised systems in industrial parks to reduce duplication and improve efficiency. • Use logbooks for SMEs to record operating hours, energy use, and abnormalities.
Measurement & Recording	• Record electricity consumption, airflow (CFM), static pressure, and motor current regularly • Track fan speed (rpm), vibration, and noise levels monthly • Benchmark specific energy consumption (kW/CFM) across SMEs within the industrial parks. • Use simple handheld anemometers or clamp meters for SMEs with limited resources.
Maintenance & Inspection	• Clean blades, filters, ducts, and inlets monthly to minimise pressure drops. • Inspect and tighten foundation bolts, shaft couplings, and bearings quarterly. • Check belt tension and alignment (for belt-driven fans) quarterly to avoid slippage and losses. • Lubricate bearings as per OEM recommendation. • Maintain calibration of flow/pressure measurement instruments.
Necessary Measures when Installing New Facilities	• Install high-efficiency fans (aerofoil blades, low-noise designs) in new facilities • Use Variable Frequency Drives (VFDs) or other speed control methods for variable load applications.

CATEGORY	GUIDELINES
	- Design duct systems with minimal bends, proper sizing, and smooth interiors to reduce system resistance. - Replace conventional flat belts with cogged or synchronous belts.
Target Components	- Upgrade to high-efficiency fans (AMCA certified). - Adopt automated monitoring for large systems.

4.3.1 Key Performance Parameters and Monitoring Guidelines for Fans & Blowers

Table 15: Common Monitorable Parameters and Performance Assessment for Fans & Blowers¹⁰

PARAMETER	DESCRIPTION / PURPOSE	TYPICAL FREQUENCY	RELEVANCE FOR ASEAN IPS & SMES
Fan & Blower Efficiency (%)	Ratio of air power delivered to shaft power consumed; the key indicator of overall performance.	Monthly	Helps SMEs and IP operators identify oversized, poorly maintained, or inefficient fans; most important for energy savings.
Air Flow (m³/hr)	Indicates actual delivered air volume vs. design requirement; deviations show inefficiency or blockages.	Monthly /Bi-monthly	Prevents oversizing and ensures shared systems in IPs operate at design efficiency.
Static Pressure (mmWC / Pa)	Measures resistance in ducts and filters; high values indicate blockages, leaks, or poor design.	Monthly	Critical for detecting unnecessary energy losses in common utility networks.
Power Consumption (kW)	Tracks energy use of fan motor; baseline for benchmarking efficiency (kW/CFM).	Daily / Weekly	Allows SMEs to compare performance against IP averages and best practices.
Specific Energy Consumption (kW/m³/hr)	Ratio of energy consumed to air delivered; supports efficiency benchmarking.	Weekly	A simple KPI for SMEs with limited technical capacity.
Motor Current & Power Factor	Identifies motor loading and electrical efficiency.	Weekly	Ensures stable and efficient operation across multiple SMEs.
Fan Speed (RPM)	Confirms operating point; deviations indicate belt slip, wear, or incorrect control settings.	Monthly	Easy, low-cost check for SMEs with minimal tools.
Noise & Vibration Levels	High levels suggest imbalance, bearing wear, or mechanical fault.	Monthly	Helps detect failures early, minimising downtime in SME operations.

PARAMETER	DESCRIPTION / PURPOSE	TYPICAL FREQUENCY	RELEVANCE FOR ASEAN IPS & SMES
Temperature (Motor / Bearing)	Tracks overheating risks and lubrication adequacy.	Monthly	Essential for reliability and avoiding premature equipment failure.

4.3.2 Common Inefficiencies in Fans & Blowers

- Old/inefficient designs: SMEs often use flat-blade or radial-blade fans, which are 15–30% less efficient than modern backward-curved centrifugal or aerofoil axial fans.
- Oversizing: Many fans are selected larger than required, leading to throttling losses and 20–25% higher energy consumption.
- Transmission losses: Belt-driven systems cause 5–10% losses through slippage and poor tensioning.

Recommendation:

- Replace with backward-curved centrifugal or aerofoil axial fans.
- Right-size based on actual flow/pressure demand.
- Use direct coupling or synchronous belts.

4.3.3 Variable Speed/Frequency Drives (VSDs/VFDs)

- Fans and blowers in SMEs often run at constant speed with dampers controlling flow, wasting energy.
- VSDs reduce motor speed to match airflow requirements, avoiding throttling losses.

4.3.4 Quick-Win Opportunities for SMEs

- Outdated radial fans can be replaced with backward-curved centrifugal fans.
- Switch belt drives to direct coupling or high-efficiency synchronous belts.
- Install VFDs on fans >10 hp (~>7.5 kW) with variable load and long operating hours.
- Maintain proper duct design, alignment, and sealing to reduce pressure drops.
- Establish preventive O&M schedules for balancing, lubrication, and cleaning.

4.3.5 Financial Benefit & Case Study of Efficient Fan/Blower Replacement

In SMEs, fans and blowers often operate with outdated radial-blade designs and without speed control, resulting in significant energy losses. Replacing such systems with high-efficiency backward-curved centrifugal fans equipped with VFDs not only improves efficiency but also provides better process control, reduced mechanical wear, and lower maintenance requirements.

The following case study illustrates the potential savings for a 30-kW fan system operating in an SME setting. By replacing an old radial-blade centrifugal fan (60% efficiency) with a backward-curved centrifugal fan and VFD (80% efficiency), significant energy savings are achieved.

- Annual energy savings: 45,900 kWh
- Annual cost savings: GBP 4,100
- Investment cost: GBP 3,000 (approximately cost considered on higher side, might cost equal or less in real scenario, depending upon the Fan air volume & VFD rating requirement)
- Simple payback period: <1 year (0.7 years)

This example highlights how fan retrofits can deliver fast returns and sustained financial benefits over the equipment's lifetime, making them an attractive quick-win measure for SMEs across ASEAN industrial parks.

Table 16: Sample calculation of energy savings for high efficiency impeller blade retrofit¹⁰

DESCRIPTION	UOM	EXISTING	AFTER REPLACEMENT
Type of Fan		Old radial-blade centrifugal fan	Backward-curved centrifugal fan + VFD
Motor Rating		30	30
Fan Efficiency	%	60%	80%
Motor loading %	%	85%	85%
Power tariff	GBP/kwh	0.09	0.09
Operating hrs per annum	hrs	7200	7200
Energy Saved per annum over standard motor	kWH	45900	
Savings towards energy bill per annum	GBP/annum	3050	
Purchase price of a new Fan with VFD	GBP	2232	
Simple Payback	yrs	0.7	

4.4 Compressor & Compressed air network

Air compressors are widely used in industries to support diverse applications such as process requirements, operation of pneumatic tools, and instrumentation needs. These systems work by mechanically compressing and pressurising air, which is then distributed across the facility.

A typical centralised compressed air system consists of:

- Compressor(s)
- Filter and after-cooler
- Air dryer
- Intelligent electronic control system
- Receiver tank(s)
- Distribution piping
- Air cylinders, nozzles, and ejectors

The pressurised air is supplied to various points of use either directly or through receiver tanks, depending on system design.

Table 17: Guidelines for Compressor & Compressed air network¹⁰

CATEGORY	GUIDELINE / RECOMMENDATION
Management & Control	• Operate and control compressors as per Original Equipment Manufacturer (OEM) instructions. • Maintain Specific Power Consumption (SPC) of air compressors within recommended limits for efficiency. • Ensure suction air is clean, cool, and dry to optimise compressor performance. • Pre-set minimum generation pressure based on plant requirements; maintain slightly above maximum demand to compensate for distribution losses. • Install adequately sized receiver/storage tanks to handle process fluctuations without frequent compressor cycling. • Use correctly sized compressors to meet demand; dedicate separate compressors for high- and low-pressure needs. • Install intelligent flow controllers for multi-compressor systems to manage demand effectively. • Use the most energy-efficient compressor for base load in multi-unit operations. • Isolate unused compressed air lines in industrial parks where certain SME units may not require supply continuously. • Install pressure gauges at discharge, air receivers, and end-use points to track distribution pressure losses. • Centralised compressed air network can be designed as per the individual SMEs requirement, reducing the energy wastage and optimising the energy consumption

CATEGORY	GUIDELINE / RECOMMENDATION
Measurement & Recording	• Regularly measure compressor power consumption, SPC (kW/m³/min), and pressure across the system. • Record suction air temperature, humidity, and filter differential pressure. • Monitor storage tank pressure fluctuations and compressor load/unload cycles. • Encourage central monitoring across SME units connected to shared compressed air networks.
Maintenance & Inspection	• Inspect air filters, belts, valves, and lubrication levels at regular intervals. • Check pipelines, joints, and fittings for leaks — a common issue in SME-intensive parks. • Inspect air receivers for corrosion, scaling, or pressure safety valve integrity. • Calibrate pressure gauges and flow meters as per supplier recommendations.
Necessary Measures / Installation	• Right-size compressors to actual load demand in SMEs. Avoid oversizing, which is common in SME-driven IPs. • Optimise compressed air piping layout in industrial parks to reduce pressure drops. • Install air dryers and condensate traps to ensure quality supply. • Use Variable Speed Drive (VSD) compressors for fluctuating demand typical in SME clusters. • Provide centralised compressed air generation and distribution in IPs where multiple SMEs can benefit from shared efficiency.
Target Components	• Install energy-efficient compressors (e.g., screw compressors with VSD). • Adoption of IE3/IE4 high-efficiency motors for compressors. • Deploy leak detection systems and ultrasonic monitoring in IP networks to ensure leakage within 10% • Maintain SPC (kwh/CFM) with the range specified by OEM or benchmark numbers.

4.4.1 Key Performance Parameters and Monitoring Guidelines for Air Compressor & Compressed Air Network

Across ASEAN industrial parks, where SMEs frequently rely on standalone compressed air units, poor maintenance, leakage, and inefficient operation contribute to high energy costs. Regular monitoring and systematic maintenance of compressors and distribution networks can significantly reduce operating expenses and enhance productivity.

Table 18: Common Monitorable Parameters and Performance Assessment for Air Compressors & Networks¹⁰

PARAMETER	DESCRIPTION	FREQUENCY OF MONITORING	PERFORMANCE ASSESSMENT APPROACH
Specific Power Consumption (SPC, kWh/CFM)	Key efficiency metric: energy consumed per unit of air delivered.	Daily	Benchmark against 0.10 kWh/CFM for screw compressors. Higher values indicate inefficiency.
Free Air Delivery (FAD, CFM)	Actual air delivered by compressor at standard conditions.	Monthly	Compare against nameplate/ISO standard FAD values; >5–7% deviation indicates performance deterioration.
Discharge Pressure (kg/cm²)	Excessive pressure increases power consumption by 6–8% per bar.	Daily	Maintain set pressure based on process demand (usually 6–7 bar for SMEs).
Air Leakages (%)	Leakages can account for 20–40% losses in SMEs.	Monthly	Target <10% leakage; take corrective measures above 15%.
Load/Unload Cycle	Frequent load-unload cycling increases energy losses and wear.	Continuous/Online	Optimise with proper receiver sizing and pressure band setting.
Air Quality (Moisture, Oil, Dust)	Poor air quality damages equipment and increases maintenance.	Monthly	Ensure regular filter replacement and dryer maintenance.
Temperature (°C)	High discharge/ambient temperature reduces compressor efficiency and life.	Continuous/Online	Maintain within OEM recommended range ($\leq 100^{\circ}\text{C}$ for screw compressors).
Power Factor (PF)	Low PF increases electricity losses and penalties.	Daily	Maintain $\text{PF} \geq 0.95$ with capacitors or APFC.
Pressure Drop in Piping (kg/cm²)	Excessive drop (>0.5 bar) increases compressor energy use.	Quarterly	Re-size pipelines, remove bottlenecks, and maintain smooth bends.

Key Formulas for Performance Assessment

1. Specific Power Consumption (SPC) =

Energy Consumption (kWh) ÷ FAD (CFM)

2. Free Air Delivery (FAD):

$$\text{FAD} = \frac{V \times P_d \times T_i}{t \times P_s \times T_o}$$

Where:

FAD = Free Air Discharge (ft³ /min)

V = Volume of air receiver including interconnecting pipes (ft³)

t = Time taken to fill receiver (min)

P_d = Cut-off or final air pressure (kg/cm²)

P_s = Atmospheric air pressure (kg/cm²)

T_o = Compressed air exit temperature (°K)

T_i = Inlet air temperature (°K)

*(ISO 1217 standard can be referenced for detailed test conditions.)

3. Leakage Percentage (%):

Onload time (sec) × 100 / [Onload time (sec) + Offload time (sec)]

4. Annual energy wastage (kWh) =

FAD (cfm) × Leakage rate (%) × SPC (kW/cfm) × Annual operating hours (hour)

4.4.2 Energy Losses in Air Compressor Systems

Compressed air systems in SMEs typically suffer losses due to:

- Leakages (usually 20-40% of generated air).
- Excessive pressure settings (every 1 bar extra = 6-8% more energy).
- Oversized or underloaded compressors (15-25% efficiency penalty).
- Poor piping layout & pressure drops (>0.5 bar wastes ~7% energy).
- High intake air temperature and poor filtration (~2% more energy per 10°C rise).

Recommendation: Conduct compressed air audits every 1–2 years, implement leak management Programmes, and optimise system design to limit pressure drops. Typical savings: ~15–30%.

4.4.3 Variable Speed Drives & Controls

Most SMEs operate compressors at constant speed, even when demand fluctuates. This results in long unload cycles and wastes energy.

- VSD Screw Compressors: Adjust motor speed to match compressed air demand, reducing unload losses.

4.4.4 Distribution System & Air Treatment

Compressed air quality and delivery are as important as generation. Losses in distribution often exceed 10–15% in SMEs.

- Network Design:
 - Use ring/loop pipelines instead of radial branches.
 - Size pipes adequately to reduce velocity (<6 m/s for mains).
 - Pressure Drop: Maintain <0.5 bar from compressor to end-use.
- Air Treatment:
 - Use dryers, filters, and moisture separators.
 - Clean filters regularly; clogged filters increase pressure drop by 0.2–0.5 bar.

4.4.5 Quick-Win Opportunities for SMEs

- Detect and repair leaks quarterly.
- Lower compressor set pressure to actual process needs.
- Switch off idling compressors during non-production hours.
- Install auto-drain traps instead of manual drains.
- Optimise piping layout to reduce bends and restrictions.

4.4.6 Financial Benefit & Case Study of Compressed Air Leakage Reduction

Compressed air is often referred to as the “fourth utility” after electricity, water, and steam and one of the most expensive utilities in SMEs. However, it is also one of the most inefficient energy carriers, with only 10–12% of input energy converted into useful work. A major source of inefficiency is air leakage, which is commonly found in old pipelines, joints, valves, and poorly maintained compressed air networks. In many SME installations, leakage levels of 20–40% of total compressor capacity are observed, compared to the best practice benchmark of less than 10%.

Reducing leakage offers one of the most cost-effective opportunities for energy conservation, requiring only modest investment in leak detection and repair while providing significant annual savings.

The following case illustrates the benefit of reducing leakage in a screw compressor system:

Case Study: Leakage Reduction from 30% to 15% in a Screw Compressor System

Assumptions:

- Screw compressor actual demand: 400 CFM
- Operating hours: 7,200 hrs/year
- Specific power consumption (SPC): 0.10 kWh/CFM
- Power tariff: GBP 0.09/kWh
- Investment in leakage reduction (detection, repair, maintenance): GBP 2,750

Table 19: Sample Calculation¹⁰

DESCRIPTION	UOM	EXISTING SCENARIO	AFTER LEAKAGE REDUCTION
Actual demand	CFM	400	400
Leakage %	%	30%	15%
Required compressor generation	CFM	571	471
SPC	kwh/CFM	0.15	
Operating hrs per year	hrs/year	7200	7200
Savings in Compressor generation load	CFM	101	
Energy saved	kWh/year	108,908	
Power Tariff	GBP/kwh	0.09	
Energy cost saved	GBP/year	7,200	
Investment for leakage reduction	GBP	2,750	
Simple Payback	Years	0.38	

By reducing leakage from 30% to 15%, the SME saves more than 100,000 kWh/year, translating to GBP 9,700/year in energy costs. The payback period is less than 5 months, making this one of the quickest and most impactful energy efficiency measures for SMEs across ASEAN industrial parks for compressed air network.

4.5 Lighting System

Lighting plays a vital role in industrial facilities, ensuring safe operations, productivity, and comfort for workers. It is primarily used to illuminate different areas of the plant, but the required illumination levels vary depending on the nature of activity and safety considerations.

For example:

- Shop floors and assembly areas require higher illumination levels to support precision work and reduce errors.
- Office spaces, control rooms, and laboratories demand uniform and glare-free lighting to support concentration and accuracy.
- Outdoor areas such as yards, pathways, and loading bays need robust, reliable lighting for security and safe movement.

Adopting appropriate lighting design not only enhances visibility and worker efficiency but also contributes significantly to energy conservation. Selection of efficient fixtures, optimised placement, and controls (such as occupancy sensors, daylight integration, and timers) further help in reducing energy consumption while meeting functional requirements.

Table 20: Guidelines for Lighting Systems¹⁰

CATEGORY	GUIDELINES
Management & Control	• Use natural daylight where possible. • Turn off lights in idle areas; adopt occupancy sensors. • Maintain appropriate lux levels by application.
Measurement & Recording	• Monitor lighting power density (W/m²). • Record operational hours per zone.
Maintenance & Inspection	• Clean fixtures and diffusers every 6 months. • Replace burned-out lamps promptly to maintain uniformity.
New Installations	• Install LED fixtures with high lumen efficacy (>120 lm/W). • Use electronic ballasts instead of magnetic ones. • Implement smart lighting controls.
Target Components	• Retrofit old systems with LEDs. • Implement centralised lighting controls in industrial parks. • Deploy daylight and occupancy sensors for warehouses and workshops.

4.5.1 Key Performance Parameters and Monitoring Guidelines for Lighting Systems

Efficient lighting is a low-cost measure for energy savings in SMEs across ASEAN industrial parks. Lighting energy consumption accounts for modest total electricity use in small and medium-sized industrial units, with older fluorescent and incandescent systems being particularly inefficient. Optimising lighting design, switching to LED technology, and implementing proper monitoring and control strategies can provide significant energy and cost savings

Table 21: Key Performance Parameters¹⁰

PARAMETER	DESCRIPTION	FREQUENCY OF MONITORING	ASSESSMENT APPROACH
Installed Load	Total lighting load (kW) installed in the facility	Annual	Compare against production floor area; ensure no excess wattage is installed
Operating Hours	Total hours lights are in use per day or per shift	Daily/Monthly	Track usage patterns; identify areas with excessive or unnecessary lighting
Energy Consumption	Electricity consumed by lighting (kWh)	Monthly	Compare against baseline; identify increases due to additional lighting or failures
Luminous Efficacy / Lumens/Watt	Efficiency of lamps and fixtures in converting electrical energy to visible light	Quarterly	Evaluate whether existing lamps meet modern efficiency standards (LED, CFL)
Illuminance Level (lux)	Light intensity at the working plane	Quarterly/Annually	Measure with a lux meter; ensure compliance with recommended standards (100–500 lux for workshops)
Maintenance Schedule Compliance	Frequency and timeliness of lamp, ballast, and fixture maintenance	Quarterly	Ensure proper cleaning, timely replacement, and functional check of all lighting fixtures
Control Systems	Presence and functionality of lighting controls such as timers, occupancy sensors, and dimmers	Monthly/Quarterly	Verify controls are operational and optimise switching schedules
Power Factor	Power factor of the lighting circuits	Quarterly	Maintain near unity PF for reduced losses; use capacitors if necessary

Some formula's that can used by facilities for monitoring:

1. $LPD (W/ m^2) = Lux/ Efficacy$

2. $Lux = Lumen/m^2$

3. $Efficacy = Lumen / Watt$

ISO 8995-1:2002 – Lighting Standards for Industrial Areas

Table 22: Standard illumination for lighting¹⁰

LIGHTING AREA	AVERAGE ILLUMINATION (LUX)	LIMITING GLARE INDEX (LGI)
General industrial areas	150–200	25
Assembly areas	200–300	25
Inspection and testing areas	300–500	22
Fine assembly or inspection (e.g., electronics)	700–1000	19
Very fine work (e.g., microelectronics)	1500–3000	10
Warehouses and storage areas	100–150	28
Outdoor areas (e.g., yards, loading docks)	50–100	28

4.5.2 Quick-Win Opportunities for SMEs in Lighting Systems

Lighting retrofits and simple operational changes often provide high-impact, low-cost energy savings for SMEs. The following measures are practical and can be implemented quickly:

- Replace inefficient lamps with LEDs:
- Swap incandescent, halogen, or old fluorescent lamps with LED alternatives.
- Longer lamp life reduces maintenance frequency and costs.
- Implement occupancy-based controls:
- Install motion sensors or presence detectors in rarely used areas (storerooms, corridors, toilets).
- Lights automatically switch off when spaces are unoccupied, reducing energy wastage.
- Use daylight harvesting and dimming controls:
- Utilise natural daylight in areas with windows or skylights.
- Dim or switch off artificial lighting when sufficient daylight is available.
- Optimise lighting layout and reduce over-illumination:
- Remove or relocate redundant fixtures.

- Adjust height or orientation to focus light only where needed.
- Schedule operational hours effectively:
- Turn off lighting during non-production hours or breaks.
- Combine with timers or Programmable logic controllers (PLC) for consistent enforcement.
- Regular maintenance of fixtures and reflectors:
- Clean lamps, fixtures, and diffusers periodically to maintain luminance efficiency.
- Replace failed lamps promptly to prevent areas from being over-illuminated elsewhere.
- Benchmark and monitor lighting energy:
- Track monthly consumption per unit area (kWh/m²) or per production unit.
- Identify excessive energy use or anomalies for corrective action.

Adopting these quick-win measures can reduce lighting energy consumption by 30–40%, with simple payback periods often under 1–2 years, depending on the scale of retrofit and local electricity tariffs.

4.5.3 Financial Benefit & Case Study of Lighting Retrofit

Lighting retrofits are one of the most cost-effective energy efficiency measures for SMEs, especially in industrial parks with older installations. Replacing inefficient fluorescent or incandescent lamps with LED technology, combined with simple operational controls, can deliver significant energy savings and reduce maintenance costs.

Case Study: Retrofit of Old Fluorescent Fixtures to LED in SME Facility

Retrofit of Old Fluorescent Fixtures to LED in SME Facility

Assumptions:

- Existing lighting: 200 fluorescent tubes, 40 W each
- New LED lighting: 200 LED tubes, 18 W each
- Operating hours: 3,600 hours/year
- Power tariff: GBP 0.09/kWh
- Investment for LED retrofit: GBP 3,000

Table 23: Calculation Table¹⁰

DESCRIPTION	UOM	EXISTING (CONVENTIONAL LIGHTS)	AFTER RETROFIT (LED INSTALLATION)
Number of fixtures	Nos	200	200
Lamp wattage	W	40	18
Operating hours per annum	hrs	3,600	3,600
Energy consumption per annum	kWh/year	28,800	12,960
Energy saved per annum	kWh/year	15,840	
Power Tariff	GBP/kwh	0.09	
Energy cost saved per annum	GBP/year	1,400	
Investment for LED retrofit	GBP	3,000	
Simple payback	Years	2.1	
Maintenance savings	GBP/year	150	
Total annual financial benefit	GBP/year	1,600	

The LED retrofit reduces energy consumption by 55%, saving 15,840 kWh/year, with annual electricity cost savings of about GBP 1,400. Including reduced maintenance costs, the total financial benefit is GBP 1,600/year, resulting in a simple payback period of just 2.1 years.

For SMEs across ASEAN industrial parks, where lighting systems are often old and inefficient, this represents a quick-win energy efficiency opportunity that reduces costs, enhances workplace lighting quality, and contributes to sustainable operations.



CHAPTER FIVE

ENERGY SAVING OPPORTUNITIES FOR EVERYDAY THERMAL EQUIPMENT

5.1 Boilers & Steam System

Boilers and steam systems are integral to many SME sectors across ASEAN industrial parks, especially in textiles, food processing, pulp & paper, rubber, and chemicals, where thermal energy is required for heating, drying, steaming, or sterilisation.

Wherever possible, waste steam or heat generated in one process can be utilised in another process within the same facility or across neighbouring SMEs, exemplifying industrial symbiosis and reducing overall energy consumption. For example, within an ASEAN industrial parks, excess steam from a textile dyeing SME can be supplied to a nearby finishing SME through the park's centralised utility corridor, reducing total fuel consumption and showcasing industrial symbiosis.

Steam generation and distribution often account for 15-40% of total energy use in these industries. A report on US Industries claimed that Thirty-seven percent of the fossil fuel burned in U.S. industry is burned to produce steam¹⁹.

¹⁹ de Almeida, A.T., Fonseca, P. and Falkner, H. (2001) Improving industrial motor systems in the EU: efficiency and savings opportunities. In: Proceedings of the ACEEE Summer Study on Energy Efficiency in Industry, Washington, DC:

However, SMEs typically operate old, oversized, or poorly maintained boilers, leading to high fuel consumption and energy losses.

Energy-efficient operation, proper maintenance, and adoption of modern technologies can deliver 10-30% fuel savings²⁰, reduce operating costs, and enhance process reliability. Additionally, integrating boilers with waste heat recovery units and sharing excess steam or hot water with adjacent processes or facilities can further amplify energy savings.

Table 24: Guidelines for Boilers and Steam Systems¹⁰

CATEGORY	GUIDELINES
Management and Control	• Operate boilers close to design pressure and load conditions for best efficiency. • Avoid continuous operation at very low loads (<40% of rated capacity). • Monitor boiler efficiency weekly using flue gas analysis and steam/fuel ratio. • Maintain steam distribution pressure as low as process requirements allow.
Measurement & Recording	• Record daily: fuel consumption, steam generation, steam-to-fuel ratio. • Measure flue gas oxygen (O₂) and temperature weekly. • Record feedwater temperature and stack losses monthly.
Maintenance & Inspection	• Inspect and clean boiler tubes monthly to reduce soot/scale formation (1 mm soot increases fuel use by ~5%). • Check steam traps quarterly to prevent live steam leakage. • Calibrate pressure and temperature gauges as per OEM recommendations. • Inspect refractory lining and insulation annually.
New Installations (Design & Procurement)	• Procure boilers with efficiency ≥80% (for solid fuel) and ≥85% (for oil/gas). • Install economisers and air pre-heaters where feasible. • Opt for fluidised bed combustion (FBC) boilers for biomass/solid fuel applications. • Integrate boilers with waste heat recovery units in energy-intensive SMEs.
Industrial Symbiosis / Integration	• Explore opportunities to share excess steam or hot water with other processes or nearby industries. • Implement heat cascade systems where high-temperature steam from one process is utilised for low-temperature heating needs in another. • Track potential energy recovery from inter-process sharing
Target Components	• Upgrade old boilers (>15 years) with modern high-efficiency models. • Replace single-stage burners with multi-stage/modulating burners. • Adopt automatic blowdown controls to reduce water and energy wastage. • Install steam flow meters and condensate recovery systems (≥60% recovery target).

American Council for an Energy-Efficient Economy (ACEEE). Available at: https://www.aceee.org/files/proceedings/2001/data/papers/SS01_Panel1_Paper46.pdf

²⁰ Carbon Trust (n.d.) Energy Efficiency Opportunities in the Food and Beverage Sector. London: Carbon Trust.

5.1.1 Key Performance Parameters and Monitoring Guidelines for Boilers

Optimising boiler performance is critical for reducing energy costs, improving reliability, and lowering emissions in SMEs in industrial parks. Continuous monitoring of operating parameters helps in identifying inefficiencies, maintaining safe operation, and ensuring sustained energy savings.

Table 25: Key Performance Parameters and Monitoring Guidelines for Boilers¹⁰

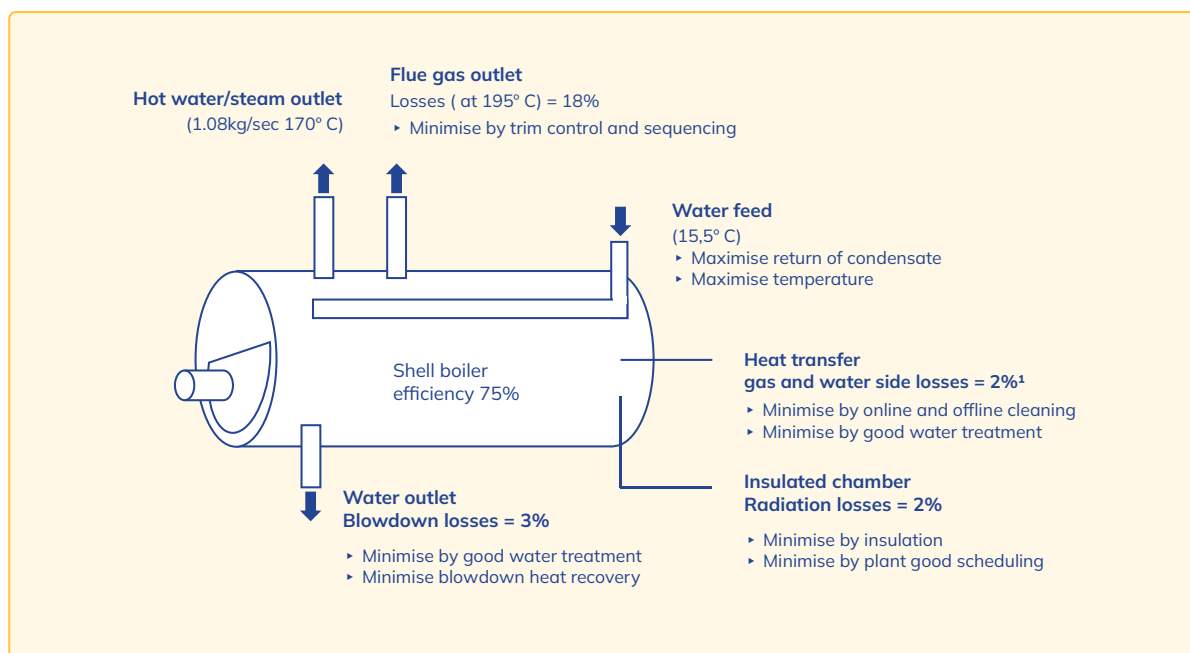
PARAMETER	DESCRIPTION	TYPICAL RANGE	MONITORING FREQUENCY	PERFORMANCE ASSESSMENT APPROACH
Boiler Efficiency (%)	Ratio of heat output (steam) to heat input (fuel).	70–85% (SMEs); >85% (best practice)	Weekly	Use an indirect method (flue gas analysis). Benchmark against design efficiency.
Steam-to-Fuel Ratio	kg steam generated per kg of fuel.		Daily	Compare with benchmark (10–12 kg/kg for coal; 13–14 for oil/gas).
Flue Gas O₂ (%)	Indicates combustion quality.	3–6% (oil/gas); 5–8% (solid fuel)	Weekly	Maintain 4–6% for oil/gas, 6–9% for solid fuels.
Stack Temperature (°C)	High values indicate poor heat recovery.	180–250 °C (coal/oil); 140–200 °C (gas)	Weekly	Should be ~150–250°C depending on fuel. Higher values suggest fouling.
Blowdown Ratio (%)	Water drained to control TDS.	2–5% of feedwater	Monthly	Maintain 2–5%; excessive blowdown wastes energy.
Condensate Recovery (%)	% of condensate returned to boiler.	>70% (good practice)	Monthly	Target ≥70% recovery to save energy and water.
Steam Leaks	Leaks in pipelines, valves, joints.		Monthly	Conduct ultrasonic/visual surveys; repair promptly.
Radiation Losses	Thermal imaging, periodic inspection	≤2% (insulated)	Monthly	Minimise with insulation and preventive maintenance.

5.1.2 Energy Losses in the Boilers & Steam System

The operational efficiency of a boiler is measured in terms of the proportion of the fuel input energy that is delivered as useful heat output.

The diagram illustrates typical losses that occur when generating steam. Flue gas losses are the most significant, accounting in some cases up to 20% of the total losses, while other heat losses are due to moisture in the fuel and in the air, as well as radiation and blow-down losses.

In total this example shows that about 75% of heat energy created goes to steam.



Typical energy losses in boiler systems include:

- Flue gas (stack) losses (~18%) – due to incomplete combustion or high excess air; minimised by proper O₂ trim control, sequencing of burners, and efficient combustion practices.
- Heat transfer losses (~2%) – from scaling or fouling on gas and water sides; reduced by regular online/offline cleaning and effective water treatment.
- Radiation & convection losses (~2%) – from poorly insulated boiler surfaces; minimised by proper insulation and optimal plant scheduling.
- Blowdown losses (~3%) – hot water and heat lost with boiler blowdown; minimised by good water treatment and recovery systems.
- Condensate losses – failure to recover condensate raises fresh water, fuel, and chemical needs; best practice is to achieve >70% condensate return.

By systematically monitoring these parameters, industries can benchmark performance, reduce operating costs, and extend equipment life.

5.1.3 Quick-Win Opportunities for SMEs in Boilers & Steam Systems

Many SMEs across ASEAN industrial parks operate small and medium-sized boilers with limited automation and maintenance, which makes them prone to efficiency losses.

The following readily implementable measures can deliver immediate savings with short payback periods:

Table 26: Typical readily implementable measures in Boiler & steam systems¹⁰

OPPORTUNITY	DESCRIPTION	INDICATIVE SAVING POTENTIAL*
Optimise Excess Air	- Excess air beyond optimal levels ($O_2 > 6\%$ for oil/gas; $>9\%$ for coal/biomass) leads to significant flue gas losses. - Installing an O_2/CO_2 analyser and maintaining optimum levels (oil/gas: 4-6% O_2; coal/biomass: 6-9% O_2) reduces heat loss and fuel wastage.	2–3% fuel savings
Recover Condensate & Flash Steam	Condensate and flash steam often go unutilised in SMEs. By recovering hot condensate ($>90^\circ C$) and returning it to the boiler feed tank, both fuel and water treatment costs are reduced.	5–10% fuel + water savings
Repair Steam Leaks	Leaks in steam lines, valves, traps, and fittings are common in SMEs and can waste 2–5% of total steam generated. A systematic leak detection and repair Programme is low-cost but highly effective.	2–5% steam savings
Insulate Hot Surfaces	Uninsulated steam pipes, valves, tanks, and boiler shells radiate significant heat. Proper insulation (50–80 mm glass/mineral wool with cladding) can cut radiation losses by half.	2–5% energy savings
Automatic Combustion Control	Manual control often leads to unstable combustion, high excess air, and fluctuating efficiency. Installing automatic combustion control (ACC) systems with O_2 trim ensures steady, optimised operation.	3–5% fuel savings

*Savings are just indicative and depend on baseline condition, boiler type, and operating hours.

5.1.4 Financial Benefit & Case Study of Boiler Efficiency Improvement

Assumptions- A textile dyeing SME operated a 2 TPH coal-fired boiler that was over 20 years old, with average efficiency of ~65%. High fuel costs and frequent downtime affected profitability.

Intervention:

- Replaced old boiler with 2 TPH fluidised bed combustion (FBC) boiler (efficiency ~78%).
- Installed an economiser to recover heat from flue gases.
- Implemented steam trap management Programme (audited 120 traps, replaced 20 faulty ones).
- Introduced condensate recovery system (65% recovery achieved).

Table 27: Sample Payback calculation¹⁰

DESCRIPTION	UOM	BEFORE	AFTER	REMARKS
Boiler Efficiency	%	65%	80%	
Fuel Consumption	kg coal/kg steam	1.55	1.26	
Annual Steam Generation	tonnes	9,600	9,600	Equivalent to ~800 tonnes/month or ~26–30 tonnes/day of steam. This aligns with a medium-sized textile dyeing unit in an SME cluster, where boilers operate ~300 days/year at ~32 tonnes/day output.
Annual Fuel Savings	tonnes/year	2,790		
Coal Tariff	GBP/tonne	40		GBP40/tonne coal price was assumed (typical for industrial steam coal across ASEAN around that period).
Cost Savings	GBP/Year	115,000		
Capex cost	GBP	260,000		The cost includes new economiser, insulation improvements, combustion control system, condensate recovery system, and auxiliary retrofits.
Payback Period	years	2.3		

By implementing targeted boiler efficiency measures, SMEs can achieve significant energy and cost savings, along with significant CO₂ reductions. This case demonstrates that relatively moderate capital investments can deliver short payback periods (<2.5 years), making boiler optimisation a high-impact, practical energy efficiency measure for large SME populations across ASEAN industrial parks.

Case Study: Boiler Efficiency Improvement in Textile Dyeing SME by 6.3%²¹**Sector: Textile (Dyeing & Finishing)****Location: India**

A textile manufacturer in Rajasthan, India was experiencing deviation in Boiler efficiency which affected productivity. The boiler efficiency was 79% against the target of 84%. The Total dissolved solids level was high, posing risks of scaling and corrosion. Additionally, the boiler ON/OFF Cycle was at 1.3 cycles per hour, resulting in significant efficiency loss.

An IoT-enabled system designed to enhance boiler efficiency was used to improve the boiler efficiency from 79% to 84%.

Case Study: Boiler Efficiency Improvement in a Food Processing Plant²²**Sector: Food Processing****Location: Malaysia**

In a food processing facility located in Penang, Malaysia, energy efficiency measures were implemented on their coal-fired boiler system as part of a broader sustainability Programme. The plant operated a 4 TPH water-tube boiler used for steam generation in various processing steps.

According to an energy audit:

- The boiler efficiency prior to intervention was about 75%, with excessive fuel consumption and heat losses due to poor insulation, inefficient burners, and lack of condensate recovery.
- The plant replaced the existing burners with high-efficiency low-NOx burners and installed economisers to recover heat from flue gases.
- Steam traps were audited and repaired to minimise leaks and condensate losses.
- Improved operational controls automated combustion and blowdown processes.

Results:

- Boiler efficiency improved to around 85%, an increase of 10 percentage points.
- Annual fuel savings of approximately 500 tonnes of coal equivalent, representing about 18% reduction in fuel use.
- Reduction in CO2 emissions by around 1,200 tonnes per year.
- Payback period of less than 2 years due to fuel cost savings and reduced maintenance requirements.

²¹ Forbes Marshall (2025) EverSense for Boiler Efficiency: Case Study. Pune: Forbes Marshall. Available at: <https://www.forbesmarshall.com/wp-content/uploads/2025/09/D0007-IND-FM-Digital-Textile-EverSense-for-boiler-efficiency-case-study.pdf>

²² Shankar Ganesh Pariasamy et al., "Study on Steam Energy Efficiency Enhancement, Cost Management and CO2 Emissions in the Food Industry," Energy 313 (2024): 133757, <https://doi.org/https://doi.org/10.1016/j.energy.2024.133757>.

5.2 Waste Heat Recovery Systems (WHRS)

Waste heat recovery systems (WHRS) capture energy from flue gases, exhaust streams, or process vents that would otherwise be lost to the environment and convert it into useful thermal or electrical energy. In SMEs across ASEAN industrial parks, sectors such as textiles, food processing, rubber, and chemicals often generate significant low- to medium-temperature waste heat. Implementing WHRS can provide significant energy savings, reduce fuel costs, and lower greenhouse gas emissions.

Table 28: Guidelines for Waste Heat Recovery Systems¹⁰

CATEGORY	GUIDELINES
Management and Control	- Identify high-potential waste heat streams (flue gas, exhaust, hot water). - Operate WHRS in tandem with existing boilers, steam networks, or hot water loops. - Implement control and sequencing strategies to maximise recovery without affecting process operations.
Measurement & Recording	- Measure temperature, flow, and pressure of waste streams continuously. - Record energy recovered (kWh or equivalent fuel saved) daily. - Monitor equipment efficiency monthly (e.g., economiser efficiency, heat exchanger effectiveness).
Maintenance & Inspection	- Clean heat exchangers, economisers, and ducts regularly to prevent fouling and scaling. - Inspect insulation on ducts and pipes quarterly. - Check pumps, fans, and valves for proper operation.
New Installations (Design & Procurement)	- Procure WHRS units sized for actual waste heat potential. - Integrate WHRS with boilers, air preheaters, or process heating systems. - Select corrosion-resistant materials for high-temperature or high-moisture streams.
Target Components	- Upgrade existing flue gas economisers or install plate-fin or shell-and-tube heat exchangers. - Adopt combined heat and power (CHP) where feasible. - Explore low-grade heat applications (preheating boiler feedwater, drying, space heating).

5.2.1 Potential Areas of Waste Heat Recovery in SMEs of industrial parks

In most SMEs across ASEAN industrial parks, significant opportunities exist for recovering waste heat from process operations. These streams, often vented to the atmosphere without utilisation, can be tapped to improve overall energy efficiency, reduce fuel consumption, and lower GHG emissions. The following areas are typically found to have waste heat recovery potential:

Table 29: Potential areas of waste heat recovery in SMEs of industrial parks (ASEAN region)¹⁰

SME PROCESS / EQUIPMENT	SOURCE OF WASTE HEAT	POSSIBLE USE OF RECOVERED HEAT
Boilers (small & medium capacity)	Flue gases, blowdown water	Feedwater preheating using economisers, blowdown recovery
Dryers (textiles, food, paper, agro processing)	Hot exhaust air	Pre-drying feedstock, hot water generation, space heating
Air Compressors	Hot cooling air / cooling water	Space heating, boiler feedwater preheating
Small Foundries / Heat Treatment Furnaces	Flue gases and hot surfaces	Preheating combustion air, raw material preheating
Diesel Generator (DG) Sets	Exhaust gases, engine cooling water	Hot water generation, absorption cooling (small scale)
Refrigeration & HVAC Systems	Condenser heat	Hot water for cleaning, washing, or low-temp process use
Community Kitchens / Food Units	Flue gases from stoves and ovens	Hot water/steam generation, space heating

5.2.2 Key Performance Parameters and Monitoring Guidelines for WHRS

Waste Heat Recovery Systems (WHRS) capture unused thermal energy from hot exhausts, or process streams and return it back into useful applications such as steam generation and hot water. For SMEs, installation & systematic monitoring of WHRS performance ensures sustained energy savings, improved boiler efficiency, and shorter payback periods.

Table 30: Key Performance Parameters and Monitoring Guidelines for WHRS¹⁰

PARAMETER	DESCRIPTION	TYPICAL RANGE	MONITORING FREQUENCY	PERFORMANCE ASSESSMENT APPROACH
Temperature Drop (ΔT)	Difference between waste stream inlet & outlet	40–120°C (depending on application)	Daily	Indicates heat recovery effectiveness; compare with design ΔT
Heat Recovered (kWh/day)	Energy captured by WHRS	Varies by stream	Daily	Calculate from mass flow $\times$ $C_p \times \Delta T$; benchmark against potential heat available
Pressure Drop (Pa)	Across heat exchangers	<200–500 Pa typical	Weekly	Excessive ΔP reduces efficiency; clean/repair if exceeded
Fouling / Scaling	Surface deposits reducing heat transfer	None/minimal	Monthly	Regular cleaning to maintain efficiency
System Availability (%)	Operating hours / total hours	>95%	Monthly	Ensures WHRS contributes reliably to energy savings

5.2.3 Quick-Win Opportunities for EE in WHRS in SMEs

For SMEs across ASEAN industrial parks, readily implementable measures in waste heat recovery come from simple, low-cost measures that require minimal modifications:

- Boilers: Install economisers to recover flue gas heat; implement blowdown heat recovery to preheat boiler feedwater.
- Dryers (textile, food, paper, agro processing): Reuse hot exhaust air through heat exchangers or air recirculation systems.
- Air Compressors: Channel hot cooling air into adjacent spaces for heating; recover jacket water heat for boiler feedwater preheating.
- Furnaces and Ovens: Use recuperators to preheat combustion air with flue gases; insulate surfaces to minimise radiant heat loss.
- Diesel Generator Sets: Recover heat from exhaust gases and jacket cooling water for hot water applications.
- Refrigeration & HVAC: Capture condenser heat for washing, cleaning, or low-temperature process hot water.
- Community Kitchens/Food Units: Recover stove/oven flue gases for hot water or steam generation.

5.2.4 Financial Benefit & Case study for Waste Heat Recovery System

Assumptions: A food processing SME with a 2 MW boiler and high-temperature flue gas (~250°C) installed a flue gas economiser and recovered 1.2 MW of thermal energy for preheating boiler feedwater.

- Flue gas stream temperature: 250°C
- Waste heat available for recovery: 1.2 MW (thermal)
- Operating hours: 8,000 hours/year (~22 h/day × 365 days)
- Boiler efficiency before WHRS: 75%
- Fuel type: Coal (industrial steam coal)
- Calorific value of coal: 5,000 kcal/kg (~5.82 kWh/kg)
- Coal tariff: GBP 40/tonne

Table 31: Sample Calculation¹⁰

PARAMETER	ASSUMPTION / VALUE	REMARKS
Flue gas waste heat recovered	1.2 MW (thermal)	–
Operating hours	8,000 h/year	Annual energy recovered = 1,200 × 8,000 = 9,600,000 kWh/year
Steam production basis	9,600 tonnes steam/year (≈1.2 MW recovered)	Equivalent to 1.2 MW continuous recovery
Boiler efficiency (before WHRS)	75%	
Fuel Input (MW steam)	13.33	Fuel input = 13.33 MW for 10 MW steam
Fuel type	Coal	
Coal calorific value	5,000 kcal/kg (≈5.82 kWh/kg)	
Coal tariff	GBP 40/tonne	
Coal saved	1,649	$9,600 \div 5.82 = 1,649$ tonnes/year
Annual fuel cost savings	68,000	$1,649 \text{ t} \times 40 \text{ GBP/t} = \text{GBP}68,000/\text{year}$
CAPEX (economiser, ducting, controls)	45,000	GBP
Simple payback	2.2	With downtime & efficiency losses → ~2.2 years (realistic case)
Effective boiler efficiency after WHRS	84%	$(10 \text{ MW steam} + 1.2 \text{ MW recovered}) \div 13.33 \text{ MW input} = 85\%$

By implementing WHRS, SMEs can achieve fuel savings of ~1,650 tonnes per year, improve process efficiency, and reduce emissions. The moderate capital investment offers a short payback (<3 years), making WHRS an effective energy efficiency measure.

5.2.5 Case study: Financial Benefit of Waste Heat Recovery System²³

Stenter frames are widely used in the textile-finishing sector for drying and heat treatment of woven and knitted fabrics, with typical operating temperatures around 180-200°C. Exhaust air from stenter frames contains oil, fibre, wax particles, and valuable thermal energy. In addition to high electricity demand for motors and fans, stenter frames require significant thermal input, usually from gas or thermal oil, making energy costs a large portion of production expenses. Recovering this waste heat while meeting emission regulations can significantly reduce operating costs, improve energy efficiency, and lower CO₂ emissions.

Table 32: Case Study Results¹⁰

PARAMETER	DETAILS
Name of Industry Sub-Sector	Textile finishing (stenter machines)
Location	Bursa, Turkey
Year of Implementation	Reported 2017–2019
Energy Savings	720 kw per hr (Reduced energy consumption of the stenter frame, Heating of process water (e.g. for dye works))
CO₂ Reduction	680 tonnes /yr
Annual Energy cost savings	72.000 Euros

²³ KMA Environment A/S (n.d.) Example: Stenter Frame. Brønderslev: KMA Environment A/S. Available at: <https://www.kma-filter.com/industries/case-studies-overview/example-stenter-frame>

Case Study: Waste Heat Recovery Technology Implementation in a Fishmeal Production Plant²⁴**Sector: Fishmeal Production****Location: Vietnam**

In a fishmeal production facility in Sóc Trăng, Vietnam, energy efficiency improvements were carried out by implementing waste heat recovery (WHR) technology. This process aimed to enhance the energy performance of the facility's coal-fired boiler system, which was critical for the steam generation required during fishmeal production.

The plant operated with a boiler that was energy-intensive, consuming significant amounts of fuel and contributing to high CO₂ emissions. To address these issues, an energy audit was conducted, revealing the following inefficiencies:

- **Boiler Efficiency:** Prior to the intervention, the boiler operated with an efficiency rate of around 70%, with significant heat loss through flue gases, poor insulation, and high fuel consumption.
- **Energy Consumption:** The factory was consuming significant amounts of biomass fuel (rice husk pellets), contributing to high operational costs and significant CO₂ emissions.

Table 33: Case Study Results¹⁰

RESULT CATEGORY	BEFORE INTERVENTION	AFTER INTERVENTION	IMPROVEMENT
Boiler Efficiency	70%	85%	15% increase
Specific Energy Consumption (SEC)	263 GJ/tonne	117 GJ/tonne	55.5% reduction
Annual Energy Savings	-	4537.57 GJ/year	-
Annual Cost Savings	-	GBP 19,700	-
CO₂ Emission Reduction	2.05 tonnes of CO ₂ per tonne of fishmeal	0.85 tonnes of CO ₂ per tonne of fishmeal	58.37% reduction in CO ₂ emissions
Annual CO₂ Emission Reduction	-	866.70 tonnes/year	-

²⁴ Tra Van Tung et al., "Energy Efficiency and Environmental Benefits of Waste Heat Recovery Technologies in Fishmeal Production Plants: A Case Study in Vietnam," Sustainability (Switzerland) 15, no. 17 (September 2023), <https://doi.org/10.3390/su151712712>.

Case Study: Power Generation System Using Waste Heat Recovery from Oil Well²⁵**Location: Kamphaeng Phet Province, Thailand**

This case study presents the design and implementation of a power generation system that utilises waste heat recovery from an oil well in Kamphaeng Phet Province, Thailand. The system uses heat exchangers to transfer heat from crude oil to clean water, which then feeds into a 10-kW Organic Rankine Cycle (ORC) system to generate power. The study reports an average net power generation of 2.97 kWe and a net system efficiency of 2.24%. Economic analysis of the system shows a levelised electricity cost of 0.11 GBP/kWh and annual energy production of 24,936 kWh, offering a sustainable and cost-effective solution for utilising waste heat in oil extraction processes.

Table 34: Case Study Results¹⁰

RESULT CATEGORY	BEFORE INTERVENTION	AFTER INTERVENTION	IMPROVEMENT
Heat Recovery	No heat recovery system	Crude oil waste heat used for generating power	Crude oil used as heat source
Power Generation	No power generation	2.97 kWe net power output	2.97 kWe generated
Efficiency	-	Thermal Efficiency ($\eta_{\text{ORC,th}}$) = 5.42%	-
Net Power	-	Net System Power ($W_{\text{Sys, net}}$) = 2.97 kWe	-
System Efficiency	-	Net System Efficiency ($\eta_{\text{Sys, net}}$) = 2.24%	-
Levelised Electricity Cost	-	0.11 GBP/kWh	-
Annual Electricity Generation	-	24,936 kWh/year	-
Annual Production Energy Cost	-	GBP 957/year	-
Total Investment Cost	-	GBP 33,500	-

²⁵ Puchit Pengsiri, A Power Generation System Using Waste Heat Recovery of Oil Well (2024), <https://www.researchgate.net/publication/382917295>.

5.3 HVAC System

Heating, Ventilation, and Air Conditioning (HVAC) systems are widely used in SMEs for maintaining indoor air quality, temperature, and humidity in offices, production floors, and storage areas. HVAC often accounts for 10–25% of total electricity consumption in SMEs, particularly in food processing, pharmaceuticals, electronics, and textile sectors. Efficient HVAC design, operation, and maintenance can reduce energy consumption significantly, improve occupant comfort, and extend equipment life.

Table 35: Guidelines for HVAC Systems¹⁰

CATEGORY	GUIDELINES
Management and Control	• Operate HVAC based on actual load and occupancy; avoid continuous 24/7 operation. • Set temperature and humidity within recommended comfort/process range (24–26°C, RH 50–60%). • Use Programmable thermostats, occupancy sensors, and timer controls.
Measurement & Recording	• Record electricity consumption, indoor temperature, humidity, and setpoints daily. • Monitor chiller water supply/return temperatures, air flow, and fan energy weekly.
Maintenance & Inspection	• Clean filters, coils, and ducts monthly. • Inspect compressors, condensers, fans, and pumps quarterly. • Check refrigerant levels and leaks annually.
New Installations (Design & Procurement)	• Install energy-efficient chillers (EER/COP ≥ industry standard) and AHUs with VFDs on fans. • Use high-efficiency motors, variable air volume (VAV) systems, and economisers. • Optimise ducting and insulation to minimise losses.
Target Components	• Upgrade old chillers, AHUs, or packaged AC units. • Adopt IoT-enabled monitoring and BMS integration for HVAC. • Implement heat recovery from condensers for water heating where feasible.

5.3.1 Key Performance Parameters and Monitoring Guidelines for HVAC

Table 36: Parameters and monitoring guidelines for HVAC Systems¹⁰

PARAMETER	DESCRIPTION	TYPICAL RANGE	MONITORING FREQUENCY	PERFORMANCE ASSESSMENT APPROACH
Coefficient of Performance (COP) / EER	Ratio of cooling/heating delivered to energy consumed	COP 3–6 (chillers), EER 8–12 (AC units)	Monthly	Compare with design and rated values; identify inefficiencies
Air Flow Rate	m ³ /h delivered to space	Design specified	Weekly	Check for blockages, fan performance, VAV operation
Chilled/Hot Water Supply Temp	°C	6–12°C chilled, 50–60°C hot	Daily	Ensure setpoints maintained for process comfort
Setpoint Deviations	°C / RH	±2°C / ±5% RH	Daily	Maintain comfort and process requirements
Energy Consumption	kWh/unit	–	Daily	Benchmark against similar-sized facilities

5.3.2 Quick-Win Opportunities for HVAC Systems in SMEs

- **Optimise Set Points:** Maintain temperature and humidity levels as per process/occupancy requirements; avoid overcooling or overheating.
- **Regular Maintenance of Filters & Coils:** Clean or replace air filters, evaporator, and condenser coils to ensure efficient airflow and heat transfer.
- **Install Variable Speed Drives (VSDs) on Fans and Pumps:** Adjust motor speed based on actual demand rather than running at full speed continuously.
- **Seal Ducts and Insulate Piping:** Prevent air leakage and reduce thermal losses in supply and return ducts.
- **Implement Zoned Control:** Use thermostats and dampers to condition only occupied areas, reducing unnecessary energy use.
- **Recover Heat from Exhaust Air:** Use energy recovery ventilators (ERVs) or heat exchangers to pre-condition incoming fresh air.
- **Upgrade to High-Efficiency HVAC Equipment:** Replace old chillers, AC units, and pumps with energy-efficient models (preferably complying with regional MEPS).
- **Monitor and Control Operation Timing:** Schedule HVAC operation based on occupancy and production hours to avoid unnecessary running during idle periods.
- **Regular System Audits:** Periodically check refrigerant levels, airflow rates, and fan/pump performance to detect inefficiencies early.

5.3.3 Financial Benefit & Case Study of HVAC Efficiency Improvement

In many SMEs, HVAC systems operate continuously without demand-based control, leading to high energy consumption. By implementing energy efficiency measures such as optimised set points, VSDs on fans/pumps, duct insulation, and heat recovery, energy use can be significantly reduced. The table below illustrates a typical before-after scenario:

Table 37: Sample Calculation Table¹⁰

PARAMETER	UOM	BEFORE EE MEASURES	AFTER EE MEASURES	REMARKS
HVAC System Size	TR	50 TR	50 TR	Cooling capacity unchanged
Operating Hours per Year	hrs	4,000 hrs	4,000 hrs	Same production/occupancy hours
Energy Consumption	kwh/year	5,40,000	3,78,000	~30% reduction due to VSDs, optimised set points, and heat recovery
Electricity Tariff	GBP/kwh	0.09	0.09	Typical industrial rate across ASEAN region
Annual Electricity Cost	GBP/year	48,200	33,800	Saving of GBP14,500/year
Savings in Electricity Cost	GBP/year	14,500		
CAPEX	GBP	44,700		Includes VSDs, duct insulation, controls, minor retrofits
Payback Period	years	3.1		Based on energy savings

The energy savings of 162,000 kWh/year come from:

- Reducing fan and pump energy via VSDs (~15–20% of total system load)
- Optimising temperature/humidity set points (~5–10%)
- Recovering heat from exhaust air (~5%)
- Reducing losses through insulated ducts and leak sealing (~2–5%)

Implementing simple HVAC energy efficiency measures in SMEs can reduce energy consumption by ~30%, lower annual electricity costs by nearly GBP 15,000, and achieve a payback of about 3 years, making this a practical and high-impact EE measure for ASEAN industrial parks.

5.3.4 Case study: Financial Benefit of HVAC Efficiency Improvement²⁶

A commercial building in Riyadh, Saudi Arabia, underwent a significant HVAC system revamping to enhance energy efficiency. The existing system was outdated and inefficient, leading to high energy consumption and operational costs. Following solutions were implemented to reduce the overall energy consumption.

Solutions:

- Replacement of old chillers with new right sized high efficiency VSD chillers (504 kW x 3 No).
- Adiabatic cooling system on condensers for air cooled chillers.
- Replacement by right sized pumps and VFD on Primary Pumps.
- Chiller Plant Manager system

Table 38: Case study table¹⁰

PARAMETER	DETAILS
Industry Sub-Sector	Commercial Building
Location	Riyadh, Saudi Arabia
Year of Implementation	Not specified in the source
Energy Savings	1. Chiller SPC improved - 0.9-1.3 kW/TR 2. 46% reduction in HVAC energy consumption
CO ₂ Reduction	Not specified in the source
Cost savings	0.26 mil GBP/year
Payback Period	Less than 1 year

²⁶ Green Flame (n.d.) HVAC System Revamping in Commercial Building Gave 30% Energy Savings. Available at: <https://www.greenflameindia.com/casestudy-details/1/hvac-system-revamping-in-commercial-building-gave-30-energy-savings>

Case Study: Energy Efficiency Improvement Using Building Energy Management System (BEMS) in Convenience Stores²⁷

Location: Thailand

Sector: Energy Management

This case study focuses on improving the energy efficiency of air conditioning and refrigeration systems in a convenience store in Thailand through the implementation of a Building Energy Management System (BEMS). The system uses new logic controls to manage the air conditioning units and refrigeration cabinets, reducing energy consumption while maintaining desired temperatures for the store. The experiment demonstrated a significant reduction in energy usage, with a payback period of 4.4 years. The study offers insights into optimising energy use in convenience stores, promoting sustainability in retail energy consumption.

Table 39: Case Study Results¹⁰

RESULT CATEGORY	BEFORE INTERVENTION	AFTER INTERVENTION	IMPROVEMENT
AC System Energy Consumption	79.2 kWh/day	72.1 kWh/day	8.9% reduction
Annual Energy Savings (AC System)	-	2591.5 kWh/year	-
Refrigeration System Energy Consumption	59.5 kWh/day	56.7 kWh/day	4.8% reduction
Annual Energy Savings (Refrigeration)	-	1022.0 kWh/year	-
Total Energy Savings	-	3613.5 kWh/year	Total 9.9 kWh/day savings
Payback Period	-	4.4 years	-

²⁷ Thitiporn Thomyapitak et al., "A Study on the Energy Efficiency of an Energy Management System for Convenience Stores," *Energies* 17, no. 19 (October 2024), <https://doi.org/10.3390/en17194941>.

Case Study: Air Conditioning Energy Efficiency and Thermal Comfort in Hotel Buildings in Hot and Humid Tropical Climates²⁸

Location: Indonesia
Sector: Building Energy Management

This study examines the energy efficiency of air conditioning systems and the thermal comfort levels in hotel buildings located in hot and humid tropical climates. The research aims to identify strategies for improving energy consumption while maintaining the comfort of hotel guests. The study involved analysing the performance of various air conditioning systems under different operational conditions and optimising energy usage without compromising thermal comfort. The findings offer practical solutions for hotels to improve energy efficiency and sustainability.

Table 40: Case Study Results¹⁰

RESULT CATEGORY	BEFORE INTERVENTION	AFTER INTERVENTION	IMPROVEMENT
AC Energy Consumption	High energy consumption	Reduced energy consumption	Improved operational efficiency
Thermal Comfort (Indoor Temperature)	Not within optimal comfort range	Maintained within comfort range	Thermal comfort improved
Annual Energy Savings	-	Significant reduction in energy use	Energy consumption reduced by 15-30%
Energy Efficiency	Low efficiency	Improved efficiency with optimised AC systems	Enhanced energy performance
Guest Comfort (Thermal Comfort)	Variability in guest comfort	Consistent comfort for guests	Higher guest satisfaction

²⁸ Nasrullah and Muhammad Hamdy, "Air Conditioning Energy Efficiency and Thermal Comfort in Hotel Buildings in Hot and Humid Tropical Climates _ Engineering, Technology & Applied Science Research," Engineering Technology and Applied Research, 2024.



CHAPTER SIX

FINANCIAL APPRAISAL OF ENERGY EFFICIENCY (EE) PROJECTS

Financial appraisal is a critical step in planning, implementing, and prioritising energy efficiency (EE) projects. For SMEs across ASEAN industrial parks, where capital budgets are often constrained, robust financial analysis helps demonstrate both short-term and long-term benefits, builds confidence among decision-makers, and ensures that investments in EE are economically viable. Understanding the financial implications also allows SMEs to strategically allocate resources, compare alternatives, and justify the adoption of energy-saving technologies.

6.1 Static Methods

Static methods are simple, straightforward approaches to evaluate project viability. These methods do not account for the time value of money, but they are very useful for SMEs for quick assessments of payback and cost-effectiveness.

Simple Payback (SPB):

- Measures the time required to recover the initial investment from annual energy cost savings.
- Formula: $\text{SPB (years)} = \text{Capital Cost} / \text{Annual Energy Savings}$
- Particularly useful for small, low-risk EE projects where quick returns are desirable.

Marginal Payback:

- Evaluates the additional investment required for a higher-efficiency option versus standard equipment, compared to incremental savings.
- Useful when comparing alternative EE solutions, for example, replacing an IE2 motor with IE3 premium efficiency motor.

Return on Investment (ROI):

- $\text{ROI (\%)} = (\text{Annual Savings} / \text{Investment Cost}) \times 100$
- Offers a simple measure of cost-effectiveness and helps SMEs prioritise projects without delving into detailed cash flows.

6.2 Dynamic Methods

Dynamic methods account for the time value of money, providing a more accurate long-term assessment. These are essential when projects involve higher capital investment, longer lifetimes, or multiple-year operational savings.

Net Present Value (NPV):

- Calculates the present value of all future energy savings minus the initial investment.
- Formula: $\text{NPV} = \sum \text{Savings}_t / (1+r)^t - \text{Investment}$, where r = discount rate, t = year
- A positive NPV indicates a financially viable project.

Internal Rate of Return (IRR):

- The discount rate at which NPV equals zero.
- Projects with IRR above the cost of capital are considered attractive.

Life Cycle Costing (LCC):

- Considers all costs over the equipment's life, including purchase, operation, maintenance, and disposal.
- Helps SMEs compare low-cost, short-term solutions with higher-efficiency options to make informed decisions based on total lifetime cost.

Benefit to Cost Ratio (BCR):

- Ratio of total discounted benefits to total discounted costs.
- A BCR greater than 1 indicates benefits outweigh costs and the project is economically justified.

6.3 Choosing the Appropriate Financial Method for EE Projects

Low-Cost, Quick-Win Projects:

- Examples: Motor replacement, LED lighting, compressed air leak repairs.
- Recommended Method: Static methods (SPB, ROI) are sufficient due to small CAPEX and short payback periods.

High-CAPEX Projects with Long Lifetimes:

- Examples: Boiler upgrades, WHRS, HVAC retrofits.
- Recommended Method: Dynamic methods (NPV, IRR, LCC, BCR) are necessary to assess long-term financial viability and justify investment.

Medium Projects or Projects with Uncertain Savings:

- Examples: Energy-efficient chillers, process heat recovery.
- Recommended Method: Use both static and dynamic methods; SPB provides a quick screening, while NPV/IRR confirms the long-term benefits.

Importance:

- Static methods allow SMEs to quickly screen projects and identify short-payback opportunities, helping to prioritise immediate actions.
- Dynamic methods provide a realistic view of lifetime benefits, factoring in energy price escalation, discount rates, and operational risks, which is crucial for larger or long-term investments.
- Using both approaches together ensures SMEs across ASEAN industrial parks can make informed, financially sound decisions while maximising energy savings and reducing operational costs.

6.4 Worked Example: Financial Appraisal of 15 kW Motor Replacement (IE2 → IE3)

Scenario:

An SME in an ASEAN industrial parks operates a 15-kW standard-efficiency motor (IE2) driving a fan for ~8,000 hours/year. The motor is often underloaded (~85% of rated capacity), resulting in higher energy consumption. The SME is considering replacing it with an IE3 premium-efficiency motor to reduce electricity costs.

Table 41: Assumptions for calculation¹⁰

PARAMETER	UNIT	EXISTING MOTOR (IE2)	PROPOSED MOTOR (IE3)
Rated Power	kW	15	15
Operating Hours	hrs/year	8,000	8,000
Motor Efficiency	%	90.6	92.3
Electricity Tariff	GBP/kWh	0.09	0.09
Capital Cost	GBP	-	560

Step 1: Annual Energy Consumption

Formula: Energy Consumption (kWh/year) = Rated Power × Operating Hours / Efficiency

- IE2 Motor: $15 \times 8,000 / 0.906 \approx 132,450$ kWh/year
- IE3 Motor: $15 \times 8,000 / 0.923 \approx 130,011$ kWh/year

Annual Energy Savings: $132,450 - 130,011 \approx 2,440$ kWh/year

Annual Cost Savings: $2,440 \times 0.09 \approx$ GBP 219/year

Step 2: Static Methods

Simple Payback (SPB):

SPB (years) = Capital Cost / Annual Savings = $560 / 219 \approx 2.56$ years

ROI:

ROI (%) = (Annual Savings / Capital Cost) × 100 = $(219 / 560) \times 100 \approx 39.1\%$ per year

Step 3: Dynamic Methods

Net Present Value (NPV):

Assuming project lifetime = 10 years, discount rate = 10%

$NPV = \sum (\text{Annual Savings} / (1 + r)^t) - \text{Capital Cost}$

NPV ≈ GBP 782

Interpretation: Positive NPV confirms the project is financially viable over 10 years life.

Internal Rate of Return (IRR):

IRR is the discount rate at which NPV = 0. For this project, IRR $\approx$ 37%, well above typical SME cost of capital ($\sim$ 10%).

Life Cycle Costing (LCC):

LCC = Initial Investment + Operating Cost (over 10 years)

- IE2 Motor: LCC = 0 + (132,450 kWh $\times$ 0.09 $\times$ 10) $\approx$ GBP 119,200
- IE3 Motor: LCC = 560 + (130,011 kWh $\times$ 0.09 $\times$ 10) $\approx$ GBP 116,000

Lifetime Cost Savings: 119,200 – 116,000 $\approx$ GBP 3,000

Benefit-to-Cost Ratio (BCR):

BCR = Present Value of Savings / Capital Cost $\approx$ 1,051 / 750 $\approx$ 1.41

Interpretation: BCR > 1 indicates benefits outweigh investment costs.

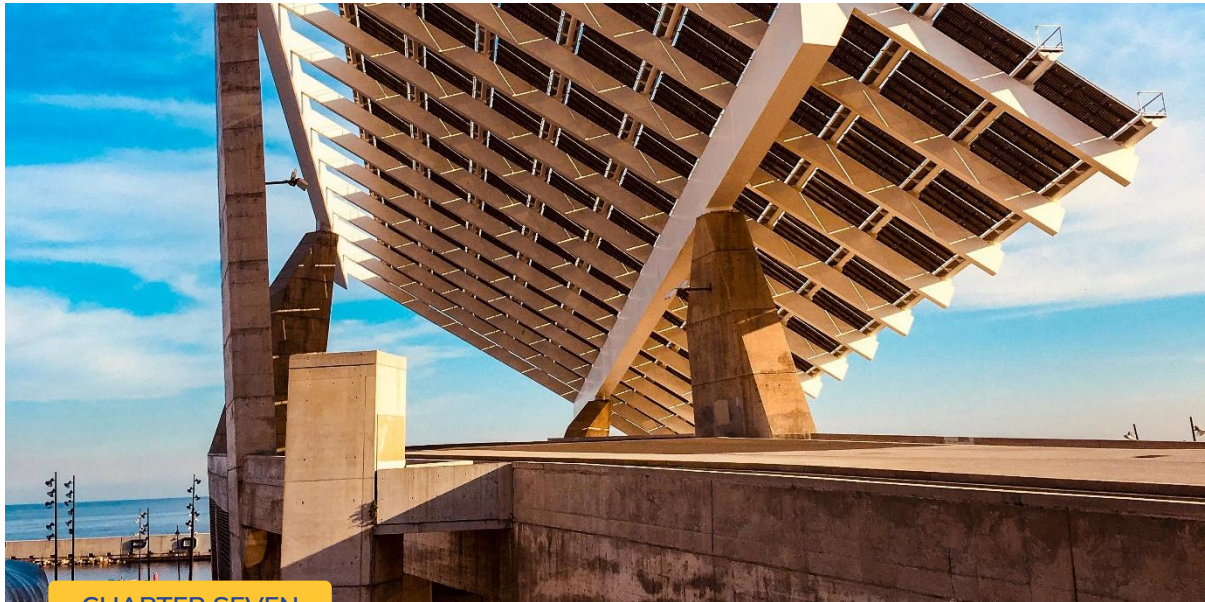
Table 42: Summary Table of Financial Indicators¹⁰

INDICATOR	VALUE	INTERPRETATION
Simple Payback (years)	2.56	Quick recovery of investment
ROI (%)	39.1	High annual return relative to cost
NPV (GBP)	782	Positive long-term financial benefit
IRR (%)	37	Exceeds SME cost of capital
Lifetime Cost Savings (GBP)	3,000	Reduces total operating costs over motor life
BCR	1.41	Economic justification: benefits > costs

Key Takeaways for SMEs across ASEAN industrial parks

1. **Quick-Win Potential:** Small EE projects like motor replacements offer rapid payback and tangible savings even for low-capex SMEs.
2. **Decision Support:** Using both static and dynamic methods ensures SMEs evaluate projects from both short-term cash recovery and long-term profitability perspectives.
3. **Scalability:** Replacing multiple inefficient motors across an industrial parks cluster can significantly reduce electricity consumption and operating costs.
4. **Financing & Incentives:** Clear financial metrics help SMEs access loans, grants, or incentives for EE projects.
5. **Operational Monitoring:** Continuous monitoring of motor load, energy consumption, and efficiency helps maintain projected savings.

This worked example demonstrates the relevance and applicability of all financial appraisal methods for SMEs, helping them prioritise EE projects, manage capital efficiently, and achieve energy savings with tangible financial returns.



CHAPTER SEVEN

ENERGY EFFICIENCY ACTION CHECKLIST FOR SMEs

7.1 Purpose of the Checklist

The Energy Efficiency (EE) Action Checklist is designed to help Small and Medium Enterprises (SMEs) across ASEAN industrial parks identify, assess, and implement cost-effective energy-saving measures.

The checklist provides a practical, step-by-step framework for SMEs to:

- Conduct self-assessments of energy consumption.
- Quickly identify areas of energy wastage.
- Prioritise EE interventions with high cost-benefit potential.
- Facilitate systematic planning and reporting for energy management.

By using this checklist, SMEs can progress to reduce energy costs, improve competitiveness, and support sustainability goals within industrial parks ecosystems.

7.2 Self-Assessment Questions for SMEs

SMEs should regularly ask themselves the following questions to evaluate energy performance:

1. Are energy bills monitored regularly (monthly/quarterly) and compared with production levels?
2. Are motors, pumps, compressors, boilers, and HVAC systems operating efficiently and maintained as per guidelines?
3. Are energy-intensive processes optimised for minimum fuel/electricity consumption?
4. Are lighting systems, including emergency lighting, energy-efficient and properly controlled?
5. Are there unnecessary idle operations, leaks, or standby losses in equipment?
6. Is there a Programme to recover waste heat, condensate, or other process energy?
7. Are energy recovery options evaluated for process or facility use?
8. Are employees trained and aware of energy-saving practices?

7.3 Quick Identification of Energy Wastage

The following areas should be checked frequently for energy wastage in SMEs:

- Motors & Drives: Underloaded or oversized motors, unoptimised speed drives, worn-out belts, low power factor.
- Boilers & Steam Systems: Low efficiency, excessive blowdown, uninsulated pipes, steam leaks, poor combustion control.
- Waste Heat: Unutilised flue gases, hot exhaust streams, lack of heat recovery devices.
- Compressed Air Systems: Leaks, inappropriate pressure settings, idle compressors.
- HVAC & Refrigeration: Overcooling/heating, blocked ducts, dirty filters, unmaintained chillers.
- Lighting Systems: Always-on lighting, high-wattage bulbs, poor layout, lack of motion/occupancy controls.
- Process Inefficiencies: Excessive raw material usage, prolonged heating/cooling cycles, low yield operations.

7.4 Priority Actions for Cost-Effective EE

SMEs should focus first on measures that are easy to implement, low-cost, and deliver immediate savings. Priority actions include:

1. **Operational Control:** Switch off idle equipment, optimise production schedules, avoid peak loads.
2. **Maintenance:** Regular cleaning, lubrication, alignment, and calibration of motors, boilers, and HVAC systems.
3. **Lighting:** Replace incandescent/fluorescent lamps with LEDs, install timers or motion sensors, optimise layout.
4. **Compressed Air:** Fix leaks, reduce system pressure, install automatic drain traps.
5. **Boilers & Steam:** Recover condensate, repair leaks, insulate pipes, optimise combustion.
6. **Motors & Drives:** Replace old motors with IE3/IE4 efficiency class, install VFDs for variable load applications.
7. **Waste Heat Recovery:** Capture flue gas or exhaust heat for preheating, drying, or water heating.
8. **Monitoring & Measurement:** Install meters, log consumption, benchmark against best practices.

7.5 Template checklist for industrial parks

The following template checklist can be adapted for SMEs across ASEAN industrial parks. It enables easy recording of present status, identification of opportunities, and tracking of implemented actions.

Table 43: Sample template for checklist¹⁰

AREA	ACTION	CURRENT STATUS	ACTION REQUIRED	RESPONSIBLE PERSON	TARGET COMPLETION
Motors & Drives	Replace old motors with IE3/IE4	[Yes/No]	[Replace/Monitor]	[Name]	[Date]
Boilers & Steam	Condensate recovery & insulation	[Yes/No]	[Install/Repair]	[Name]	[Date]
Compressed Air	Detect & repair leaks	[Yes/No]	[Repair/Upgrade]	[Name]	[Date]
Lighting	Replace lamps with LED & install sensors	[Yes/No]	[Upgrade]	[Name]	[Date]
HVAC	Clean filters, optimise setpoints	[Yes/No]	[Maintain/optimise]	[Name]	[Date]
Waste Heat	Install WHRS / heat exchangers	[Yes/No]	[Install/Assess]	[Name]	[Date]
Process Efficiency	Reduce idle heating/cooling	[Yes/No]	[Optimise]	[Name]	[Date]
Energy Monitoring	Install meters & record consumption	[Yes/No]	[Install/Track]	[Name]	[Date]

* Note: SMEs can modify the checklist based on the specific processes and energy systems present in their unit. The goal is to create a simple, actionable record that supports energy efficiency improvements, cost reduction, and sustainability compliance across ASEAN industrial parks.

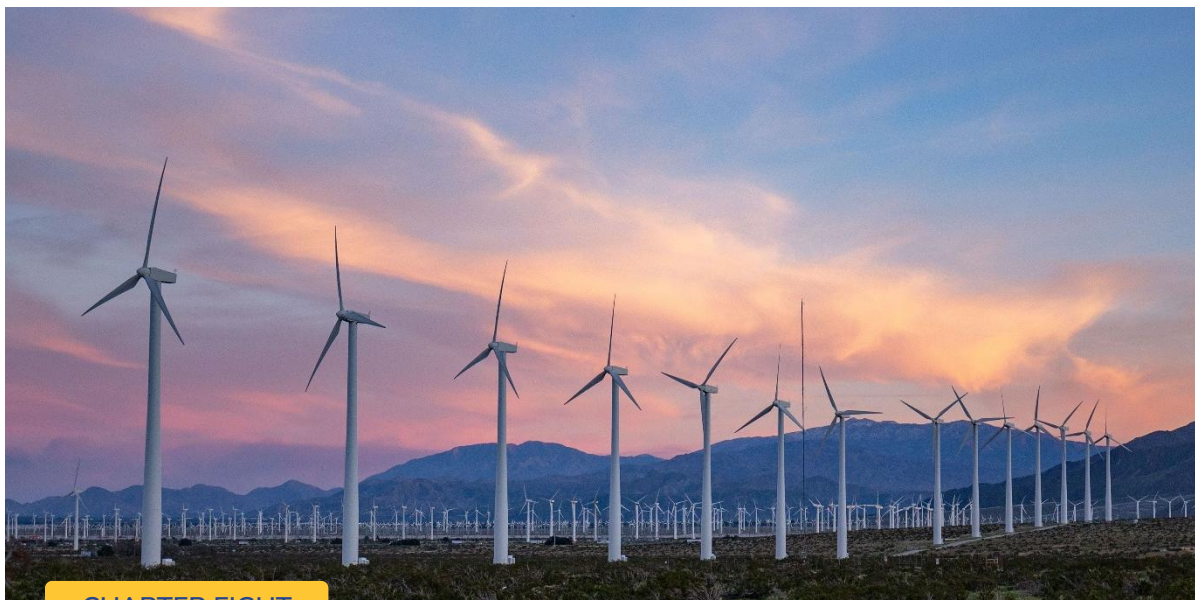
7.5.1 Consolidated checklist of key parameters equipment wise:

Table 44: Sample template for checklist¹⁰

EQUIPMENT	KEY PERFORMANCE / AUDIT PARAMETERS	REMARKS / ACTION PLAN
Boilers	- Operating pressure & temperature - Feedwater temperature - Fuel type, flow rate & calorific value - Flue gas temperature & O₂/CO₂/CO levels - Blowdown rate & flash steam recovery - Condensate return % - Boiler efficiency (direct/indirect method) - Heat loss survey	e.g., Optimise excess air; Recover heat from flue gas; Improve condensate return
Waste Heat Recovery System	- Waste heat source temperature & flow (°C / kg/s / m³/h) - Heat recovery (kW or kcal/hr) - Energy recovered (kWh or kcal/hr) - Overall system efficiency (%) - Pressure drops & flow losses - Integration with process (preheating, steam generation, hot water) - Operating hours & availability	e.g., Monitor energy recovered vs potential; Extend operating hours; Recover heat for preheating feedwater or air
Air Compressors	- Type (reciprocating/screw/centrifugal) - Free Air Delivery (FAD) - Power input (kW) - Specific Power Consumption (kW/CFM) - Operating vs required pressure - Leakage % - Pressure drops across filters/dryers/piping - Cooling water ΔT - Efficiency	e.g., Reduce system pressure; Fix leaks; Install VFD; Optimise piping layout
Fans & Blowers	- Type (centrifugal/axial) - Power input (kW) - Flow rate (m³/hr or CFM) - Pressure developed (mmWC) - Fan efficiency - Operating point vs system curve - Damper position - Motor loading % - VFD usage	e.g., Replace with backward-curved fan; Use VFD; Balance impellers; Optimise ducting
Pumps	- Type (centrifugal/positive displacement) - Flow rate (m³/hr) - Head developed (m) - Power input (kW) - Pump efficiency - Operating point vs pump curve (BE point) - Motor loading % - Throttling losses - VFD usage - Specific energy consumption (kWh/m³)	e.g., Replace oversized pumps; Trim impellers; Install VFD; Shift to high-efficiency pumps

EQUIPMENT	KEY PERFORMANCE / AUDIT PARAMETERS	REMARKS / ACTION PLAN
Cooling Towers	- Type (induced/natural) - Water flow (m³/hr) - Inlet & outlet temperature - Ambient wet bulb temperature - Range (ΔT of water) - Approach (outlet – WBT) - Effectiveness - Fan power (kW) - Cycles of concentration (CoC) - Blowdown & make-up water	e.g., Optimise CoC; Use VFD fans; Maintain fills & drift eliminators; Improve water treatment
HVAC Systems	- Chiller type (air-cooled/water-cooled) - Cooling load (TR) - Power input (kW) - kW/TR (COP) - Condenser water inlet & outlet temperature - Chilled water flow & ΔT - AHU power & efficiency - Pump & fan power per TR - Specific power consumption	e.g., Retrofit with high-COP chillers; Optimise chilled water pumps; Improve maintenance
Lighting Systems	- Installed load (W/m²) - Lamp type (incandescent, CFL, LED, fluorescent) - Lamp efficacy (lm/W) - Lux levels at work plane - Operating hours & controls (manual, sensors, timers) - Daylight integration - Specific energy consumption (kWh/m²/yr) - Maintenance practices	e.g., Replace with LEDs; Install occupancy/daylight sensors; Redesign layout for uniform lux

*Note - These are suggested key parameters for measurement and analysis. SMEs are encouraged to monitor additional parameters as per their specific operational requirements and process characteristics.



CHAPTER EIGHT

CONCLUSION & RECOMMENDATIONS

8.1 Key Enablers for Scaling SME Energy Efficiency

Energy efficiency represents a practical opportunity in ASEAN industrial parks to reduce operating costs, improve productivity and strengthen competitiveness, while contributing to national and regional energy and climate objectives. The technical measures presented in this guideline demonstrate that savings can be achieved through a combination of improved operational practices, better maintenance, systematic energy management and investment in efficient equipment and systems.

However, SMEs often face interconnected barriers that prevent technically viable measures from being implemented. These include limited access to reliable energy data, insufficient in-house technical expertise, competing investment priorities, restricted access to suitable financing and uncertainty regarding the financial and operational performance of energy-efficiency technologies. Addressing these barriers therefore requires an integrated approach that combines technical assistance, financing, institutional coordination and sustained capacity-building.

Many SME energy-efficiency projects are individually small and dispersed, resulting in high transaction and financing costs. Industrial parks can help overcome this fragmentation by aggregating similar projects across multiple enterprises, coordinating energy audits and procurement, establishing common monitoring arrangements and facilitating access to technology providers, energy service companies and financial institutions. Park-level coordination can also enable shared infrastructure and services that may not be technically or financially viable for individual SMEs.

Investment in efficient equipment should be accompanied by structured energy management. Sub-metering, energy baselines, performance indicators, regular energy audits, preventive maintenance and measurement and verification are essential for identifying priority interventions, confirming achieved savings and sustaining improvements over time. Technology replacement alone will have limited impact if equipment continues to be incorrectly sized, poorly controlled or inadequately maintained.

The diversity of industrial structures, institutional capacities and market conditions across ASEAN means that implementation should be phased and adapted to the circumstances of each Member State. Early action should focus on awareness, capacity-building, simplified energy reporting, benchmarking and demonstration projects. These measures can establish evidence and build market confidence before programmes are expanded through project aggregation, dedicated financing instruments and stronger regulatory requirements where appropriate.

Overall, the guideline establishes the following key messages:

- Energy efficiency should be treated as a strategic investment in SME productivity and competitiveness, rather than solely as an environmental compliance measure.
- Technical, financial and institutional barriers must be addressed together to achieve implementation at scale.
- Industrial parks provide an effective platform for aggregating SME demand, building shared technical capacity and developing investable project pipelines.
- Energy-management practices, reliable data and measurement and verification are necessary to ensure that energy savings are achieved and sustained.
- Governments, industrial park authorities, SMEs, financial institutions, technology providers and ESCOs have complementary implementation responsibilities.
- ASEAN-wide scaling should follow a phased, context-sensitive approach that reflects differences in Member State readiness and market maturity.

The widespread adoption of Energy Efficiency (EE) in SMEs across ASEAN industrial parks requires a combination of technical, financial, and institutional enablers. Key enablers include:

- Access to Finance: Simplified credit lines, concessional loans, and ESCO-based models for SMEs.
- Capacity Building: Regular training Programmes for plant engineers, operators, and energy managers.
- Technology Access: Availability of proven, affordable EE technologies adapted to SME needs.
- Awareness & Knowledge Sharing: Dissemination of success stories, benchmarks, and case studies.
- Digitalisation: Use of smart meters, IoT-enabled monitoring, and energy dashboards to enable quick decision-making.

8.2 Policy and Regulatory Recommendations

Given the diversity of institutional capacity, enforcement mechanisms, and industrial development levels across ASEAN Member States (AMS), the policy options outlined in this section should be interpreted as phased and context-sensitive approaches rather than uniform mandates

A progressive sequencing approach is recommended:

- Phase 1 – Incentive-based measures and awareness Programmes
- Phase 2 – Simplified reporting and voluntary benchmarking frameworks
- Phase 3 – Pilot Programmes within selected industrial parks
- Phase 4 – Gradual introduction of regulatory or mandatory requirements, where institutional capacity and market readiness allow

This phased structure enables AMS to align implementation with local capacity, financing availability, and enforcement mechanisms, ensuring practicality and sustained adoption.

To mainstream EE in SMEs, ASEAN member states should adopt coherent and supportive policies:

- Mandatory Energy Reporting for medium and large SMEs, with simplified formats.
- Minimum Energy Performance Standards (MEPS) for motors, compressors, boilers, and lighting equipment.
- Fiscal Incentives & Tax Rebates for SMEs investing in energy-efficient technologies.
- Cluster-Level EE Programmes in industrial parks, focusing on shared utilities (e.g., compressed air, steam).
- Integration with Climate Policies such as Nationally Determined Contributions (NDCs) to position SME EE as a contributor to decarbonisation.

8.2.1 Separation of Policy Guidance and Technical Toolkit

To ensure clarity of purpose and audience, this guideline distinguishes between high-level policy direction and practical technical implementation tools.

In line with the QPR, short policy briefs are planned to complement this guideline. These briefs will distill key strategic messages for:

- ASEAN Centre for Energy (ACE)
- ASEAN Member State (AMS) focal points
- Energy ministries and regulators

The present guideline, by contrast, serves primarily as a practical reference for SMEs and industrial parks authorities, providing operational tools, equipment-level guidance, checklists, and financial appraisal methodologies.

This separation allows policy messages to remain concise and strategic, while enabling the technical toolkit to remain detailed, actionable, and implementation-focused. Together, these outputs create a coherent framework supporting both institutional decision-making and enterprise-level adoption.

8.3 Industry Association & Stakeholder Roles

Industry associations and stakeholders play a critical facilitation role in implementing SME EE Programmes:

- **Industry Associations:** Create awareness, facilitate training, and develop voluntary EE codes of practice.
- **Industrial Park Authorities:** Enable shared services (WHRS, central utilities), coordinate cluster-level EE projects.
- **Financial Institutions:** Design SME-focused credit instruments with simplified appraisal processes.
- **Technology Providers & ESCOs:** Offer end-to-end solutions, performance-based contracts, and technology demonstration.
- **Development Agencies & NGOs:** Support pilot projects, capacity building, and knowledge exchange platforms.

8.4 Roadmap for ASEAN-wide Rollout

A phased roadmap is recommended to ensure practical adoption and scalability of Energy Efficiency in SMEs across ASEAN industrial parks to contribute to ASEAN's overall goal of reducing energy intensity by 32% by 2025 (2005 baseline)²⁹.

Phase 1 (0–2 Years): Foundation Building

- Develop regional SME EE guidelines (this document as a reference), emphasising energy-efficient practices that reduce industrial energy intensity.
- Launch pilot demonstration projects in priority sectors (textiles, food processing, rubber, chemicals) to showcase energy savings and CO₂ reduction potential.
- Establish financing mechanisms with local banks to support SMEs in adopting EE measures, facilitating early investment and readily implementable measures.

Phase 2 (3–5 Years): Scaling Up

- Expand successful pilot models to additional industrial parks across ASEAN, scaling EE adoption in SMEs.
- Institutionalise capacity-building Programmes across ASEAN to ensure SMEs have technical know-how for sustained energy efficiency improvements.
- Implement Minimum Energy Performance Standards (MEPS) and cluster-level energy reporting in SME hubs.

²⁹ ASEAN Centre for Energy. (2025). ASEAN Plan of Action for Energy Cooperation APAEC 2016-2025 Phase II: 2021-2025. <https://asean.org/wp-content/uploads/2023/04/ASEAN-Plan-of-Action-for-Energy-Cooperation-APAEC-2016-2025-Phase-II-2021-2025.pdf>

Phase 3 (6–10 Years): ASEAN-wide Integration

- Create a regional SME EE certification and benchmarking system to recognise high-performance SMEs.
- Mainstream digital energy management systems in SMEs to enable continuous monitoring, benchmarking, and optimisation of energy consumption.
- Integrate EE targets into ASEAN climate and industrial development strategies, ensuring SMEs' energy savings contribute to national and regional goals.

The reference to the 32% energy intensity reduction target by 2025 reflects the commitment under APAEC Phase II (2021–2025). The subsequent 2026–2030 framework is intended to build upon these achievements, with updated regional targets to be confirmed in line with official ASEAN agreements and evolving national energy strategies.

8.5 Priority Technology Intervention and Call to Action

Table 45: Policy intervention areas¹⁰

INTERVENTION AREA	TECHNOLOGY READINESS	FINANCIAL SUPPORT NEED	POLICY PUSH	PRIORITY LEVEL
Motors & Drives	High	Medium	Medium	Very High
Boilers & Steam Systems	Medium	High	High	Very High
Lighting Systems	High	Low	Low	Medium
Compressed Air Systems	Medium	Medium	Medium	High
Waste Heat Recovery (WHR)	Medium	High	High	Very High
HVAC Systems	High	Medium	Medium	High
Monitoring & Digital Tools	Medium	Medium	Low	Medium

Note: Priority levels reflect the indicative combination of technology maturity, typical energy-saving potential, financing needs, applicability across SME subsectors and the level of policy support required. Priorities should be validated against local energy prices, operating conditions and sector characteristics.

CONCLUSION

This guideline document has been developed to serve as a practical roadmap for SMEs across ASEAN industrial parks to mainstream energy efficiency (EE) into their day-to-day operations. SMEs form the backbone of industrial activity in the region, yet face unique challenges such as limited access to capital, lack of technical know-how, and minimal exposure to global best practices. Through structured chapters, this document provides sector-relevant EE guidelines covering major energy-using systems/equipment like boilers, compressed air, motors, WHRS, HVAC, and lighting, along with tools for financial appraisal and a practical action checklist.

The guidelines not only address technical interventions but also highlight the importance of management practices, monitoring, and maintenance ensuring SMEs can achieve both immediate and readily implementable measures and long-term efficiency improvements. By including static and dynamic financial appraisal methods, SMEs are guided on how to evaluate EE investments, strengthening the business case for implementation. The action checklists, self-assessment questions, and case studies provide a hands-on toolkit for SME managers and operators to identify, plan, and execute energy-saving measures.

Beyond the technical scope, this document emphasises awareness creation, capacity building, and knowledge sharing among SMEs, industrial park authorities, industry associations, and financial institutions. It provides insights on policy and regulatory framework to support SMEs, while encouraging shared utilities, cluster-level approaches, and digital monitoring to maximise impact.

In conclusion, the document is designed to function as both a practical manual and a strategic enabler, helping SMEs across ASEAN IPs reduce costs, improve competitiveness, and contribute meaningfully to the region's decarbonisation agenda.

ASEAN can accelerate SME energy efficiency by moving from isolated equipment upgrades towards coordinated industrial-park programmes that combine energy data, technical assistance, project aggregation and fit-for-purpose financing. The immediate priority is to establish a pipeline of demonstrable projects in selected industrial parks, document their performance and use the results to refine financing instruments, technical standards and enabling policies. This approach will allow Member States to scale implementation progressively while accommodating different levels of institutional and market readiness.

ANNEX: TECHNICAL GUIDANCE

9.1 Governance, Structuring, and Sustainability of Park-Level Energy Cells

While the previous sub-chapter (3.7) introduced the park-level energy cell solution to resolve the transition of conventional industrial zones into Eco-Industrial Parks (EIPs), for the energy cell to operate effectively, it should hold a mandate from either the national energy ministry or the park's master developer. This mandate should authorise the cell to:

1. Co-manage the energy usage data throughout the park under a standardised and anonymised framework
2. Establish minimum environmental performance required for new and existing tenants of the industrial park
3. Coordinate shared utility infrastructure

For example, in Vietnam, this mandate is enabled by Decree 82/2018/ND-CP, which defines EIPs and binds industrial park's tenants to cleaner production audits and a shared industrial symbiosis³⁰. Park operators must transition their staff to energy system coordinators to build their capacity, by establishing specialised technical training centers. This effort was reflected in the Global Eco-Industrial Parks Programme (GEIPP) implemented by UNIDO and other international support programs.

Sustaining the energy cell also requires a transition to market-driven, self-financing models for it to achieve the initial lifespan of international development programs. There are three feasible funding pathways defined below:

³⁰ Stucki, J., Flammini, A., van Beers, D., Phuong, T.T., Tram Anh, N., Dong, T.D., Huy, V.Q. and Hieu, V.T.M. (2019) 'Eco-Industrial Park (EIP) Development in Viet Nam: Results and Key Insights from UNIDO's EIP Project (2014–2019)', Sustainability, 11(17), Article 4667. Available at: <https://doi.org/10.3390/su11174667> (Accessed: 2 July 2026).

Table 46: Funding pathways¹⁰

FUNDING MODEL	OPERATIONAL MECHANISM	FINANCIAL RECOVERY ROUTE	RISK MITIGATION
On-Bill Recovery (OBR)	A standardised administrative surtax is integrated into the centralised bills shared to industrial parks' tenants (e.g., electricity, water, or steam).	Amortised across the industrial park's existing utility cycle of billing to ensure zero additional invoicing overhead.	Requires legal utility-billing mandates; tenant defaults must be managed through standard protocols.
Shared savings retainers	Coordinated cluster audits identify low-cost/no-cost measures. The Energy Cell retains a contractually defined percentage of savings.	A retainer is charged to the industrial park's tenant for a specified duration (e.g., 5% to 10% of monthly monetised savings for 24 months).	Relies on robust sub-metering and standardised measurement and verification (M&V) protocols to prevent saving calculations disputes.
Blended finance and ESCO retainers	The Energy Cell aggregates projects and bundles multiple small SME retrofits into a single, bankable commercial tender.	The cell receives a management fee from the chosen ESCO (typically 2% to 5% of project CAPEX)	Mitigated by partnering with national credit guarantee facilities to reduce lender risk (e.g., Vietnam's VSUEE project).

Industrial parks in priority of Southeast Asia economies typically host heterogeneous tenant mixes consisting of textiles, rubber, food processing, plastics and chemicals. These different sectors possess different energy intensity profiles, operational hours, and process temperatures fundamentally. Energy Cell must deploy a tier-based monitoring and benchmarking framework to maintain accountability and to prevent free-rider issues.

Table 47: Tier-based monitoring and benchmarking framework for different energy intensity profiles¹⁰

INDUSTRIAL SUB-SECTOR	PRIMARY ENERGY CARRIER	BASELINE KPI (METRIC)	STANDARD DIAGNOSTIC TOOL	COORDINATED ENERGY CELL INTERVENTION
Textiles & Garments	Steam & Thermal Oil (Process Heating); Electricity (Spinning motors).	Fuel consumption (GJ/tonne of fabric)	Flue gas analysers; thermal imaging cameras.	Insulation of distribution networks; condensate and flash steam recovery.
Food & Beverage	Electricity (Refrigeration & Cooling); Steam (Sterilisation).	Energy consumption (Wh/tonne of product).	Ultrasonic leak detectors; sub-metering on chillers.	Variable speed drives on ammonia compressors; boiler combustion optimisation.
Rubber & Plastics	Electricity (Extrusion & Injection Molding Motors).	Motor loading and power factor (PF).	Portable power quality analysers; clamp meters.	Upgrading to IE3/IE4 motors; installation of automatic power factor correction (APFC).
Chemicals	High-Grade Process Heat; Medium-Pressure Steam.	Thermal transfer efficiency (%).	Flow meters; temperature transmitters.	Waste heat recovery networks (economisers/recuperators); Thermal PPAs.

Case Study: Vietnam's Provincial Industrial Zone Management Board Model

In Vietnam, the park-level "Energy Cell" function has been institutionalised through the provincial Industrial Zone Management Boards. The board is coordinated by the Ministry of Planning and Investment (MPI) in partnership with UNIDO and funded by the Swiss State Secretariat for Economic Affairs (SECO). During the pilot eco-industrial park programs, the management boards acted as the centralised technical coordination hubs for transitioning traditional zones, such as Hoa Khanh (Da Nang) and Tra Noc (Can Tho), into eco-industrial parks.³¹

- The provincial Management Boards are empowered to coordinate environmental and energy data, to oversee environmental safety protocols, and to provide technical training on Resource Efficient and Cleaner Production (RECP). This structure shifts the administrative and technical burden away from individual, resource-constrained SMEs.
- Under this centralised technical oversight, 88 tenant enterprises (a heterogeneous mix of food, chemical, paper, and textile SMEs) identified and implemented over 603 RECP solutions. These collective actions generated annual operational savings of VND 69.2 billion (approx. GBP 2 million) through reduced electricity, fuel, and water consumption, proving that a centralised administrative board can successfully coordinate diverse SME sectors.
- To ensure these coordination mechanisms survive beyond initial program support, Vietnam formally codified this model into national legislation through Decree 82/2018/ND-CP and modernised it via Decree 35/2022/ND-CP. Under Decree 35, eco-industrial parks and eco-enterprises with certifications may receive access to green loans from the Vietnam Environment Protection Fund (VEPF), the Vietnam Development Bank (VDB), and international bilateral packages, providing a permanent, self-sustaining financial framework.

Case Study: Thailand's Industrial Estate Authority (IEAT) Eco-Industrial Town Model

In Thailand, IEAT acts as the centralised governing body and technical coordinator for over 68 industrial estates across 16 provinces, where the authority directly manages 15 provinces.

- Under IEAT's certified "Eco-Industrial Town" framework (such as the Eco-Champion and Eco-Excellence tiers), each estate's management office operates a dedicated environmental and energy committee. This committee acts as the park's Energy Cell, which functions to establish estate-wide energy benchmarking, coordinate collective energy-saving targets, and monitor compliance.
- IEAT organises group energy audits and shares specialised diagnostic tools (e.g., thermal imaging, ultrasonic leak detectors) among tenant SMEs, which lowers the transaction and advisory costs for individual, financially constrained firms. This structure supported energy conservation targets, which led to savings of about ~881 GJ per industrial facility on average and facilitated a 20% national savings goal over a 15–20 year horizon.
- The program is supported by the national Energy Conservation Promotion Fund (ENCON Fund) and aligned with the energy-intensity reduction targets under the Energy Efficiency Plan (EEP 2015–2036). Financing is integrated with utility load management and regional utility incentives to ensure that the park-level Energy Cell has access to continuous funding and specialised technical services.

³¹ EU4Environment (2024) Eco-Industrial Parks Advancement Guide. Paris: EU4Environment Programme. Available at: <https://www.eu4environment.org/app/uploads/2024/12/Eco-Industrial-Park-Guide.pdf>

Case Study: Indonesia's GEIPP Pilot (MM2100, Batamindo, and Karawang)³²

In Indonesia, the park-level coordination and Energy Cell approach has been actively demonstrated since 2019 under the Global Eco-Industrial Parks Programme (GEIPP), implemented by UNIDO in partnership with the Ministry of Industry. The pilot initiative initially targeted three major industrial estates: MM2100 Bekasi, Batamindo (Batam), and Karawang, which host a concentration of heterogeneous manufacturing and processing tenants.

- To establish effective coordination, the park operators deployed standardised Environmental and Energy Management Systems (EMS and EnMS) aligned with ISO 14001 and ISO 50001 standards, supported by metering and monitoring systems. This created a centralised data repository at the park operator level, effectively serving as the park's Energy Cell to identify and evaluate energy efficiency opportunities.
- From 2020-2023, this centralised technical facilitation has enabled 35 tenant enterprises during Phase I of the project to achieve an annual reduction of 12,000 tCO₂. The pilot mobilised GBP 1.4 million in private sector investment and generated verified financial savings of GBP 1.1 million per year.
- Specific industrial interventions:
 - In the Batamindo Industrial Park, the coordination cell assisted a tenant in replacing an outdated chiller featuring a reciprocating compressor with a highly efficient screw compressor, combining this with chiller temperature setpoint optimisation.
 - In the MM2100 Bekasi Industrial Park, the automation of blower operations at the centralised wastewater treatment plant (WWTP) led to electricity savings of 119 MWh/year and an annual GHG reduction of 87 tonnes of CO₂. Additionally, an online monitoring system for WWTP effluent further reduced laboratory energy requirements by 28 MWh/year.
 - Batamindo Industrial Park installed a pilot 472-kWp solar PV system on its powerhouse rooftop, producing 621 MWh/year of renewable energy and saving 391 tonnes of CO₂ emissions per year.

³² Global Eco-Industrial Parks Programme (GEIPP) Indonesia (n.d.) Eco-Industrial Park (EIP) Resource Pool. Available at: <https://www.geippindonesia.org/eco-industrial-park-eip-resource-pool/> and <https://geipp.org/projects/geipp-indonesia/>

9.2 Operational Design and Implementation of Pooled Procurement Schemes

SMEs are sensitive to the initial capital expenditure of upgrading equipment to comply with energy efficiency, even when the return on investment is favorable. While standard high-efficiency components, such as Premium Efficiency (IE3) induction motors and variable frequency drives (VFDs) reduce lifetime operating costs, SMEs rarely procure the items in volumes that are sufficient to bypass standard retail markups. A coordinated park-level pooled procurement could solve this barrier, however, aggregating procurement system across independent and heterogeneous SMEs could present several challenges:

- **Aligning Replacement Cycles:** Independent companies and SMEs operate with different equipment lifespans and depreciation schedules. Therefore a single and park-wide procurement deadline is seen to be impractical. To resolve this, the Energy Cell must establish a "rolling procurement program" that could aggregate demand over a 12 to 24-month period and maintain a standardised backup inventory for emergency replacements at a park-level.
- **Managing Diverse Specifications:** Different manufacturing lines require varied motor capacities with different torque limits and mounting orientations. The Energy Cell must compile a "Standardised Technology Catalog," prioritising highly bought technologies, such as three-phase, line-operated induction motors in the range of 1.1 kW to 22 kW, 4-pole, which could cover the majority of industrial pump, fan, and compressor applications used in SMEs.
- **Supplier Relationship and Contract Dispute Management:** Suppliers are often reluctant to contract with numerous small SMEs due to payment and default risk. The park operator must act as the primary contract facilitator that can route transactions through a centralised escrow account managed by a partner or a commercial bank. All supply contracts must feature manufacturer warranties with clear performance-arbitration clauses overseen by the Energy Cell to manage any disputes regarding the performance from the equipment.

Case Study: ESL National Motor Replacement Programme (NMRP)³³**Location: India**

The success story to validate this model is illustrated by the National Motor Replacement Programme (NMRP) implemented by Energy Efficiency Services Limited (EESL). EESL utilised demand aggregation and bulk procurement to bypass the standard retail distribution network, negotiating directly with premium manufacturers to secure a 20% to 30% discount below standard retail prices for end-users (i.e., Crompton Greaves, Siemens, and ABB). Furthermore, EESL addressed risks from technical and financial sides by implementing 36-month warranties into the tender agreements, compared to the commercial retail market warranty standard of 12 to 18-month. To accelerate adoption, particularly among financially constrained SMEs, EESL deployed two distinct business models:

Table 48: Case studies and business models¹⁰

OPERATIONAL PARAMETER	UPFRONT PAYMENT (PROJECT MANAGEMENT COST / PMC MODEL)	SHARED SAVING (ESCO MODEL)
Financial Structuring	The end-user bears the direct, discounted product cost discovered through competitive bidding.	EESL/ESCO finances 100% of the upfront equipment and installation costs.
Project Management Fee	The end-user pays a 10% Project Management Cost (PMC) fee to EESL for administrative support.	The PMC fee, commercial interest, and return on equity are amortised into the contract.
Repayment Terms	None; immediate ownership transfer upon delivery.	Structured as Equated Quarterly Installments (EQI) over a maximum 3-year period.
Repayment Sizing	N/A	EQI payments are sized to approximately 50% to 70% of the verified quarterly energy savings.
Target Audience	Larger industrial clients with strong reserve funds.	SMEs with restricted capital but high operating hours.

³³ United for Efficiency (U4E) (2020) National Motor Replacement Programme: India Case Study. Paris: United for Efficiency. Available at: https://united4efficiency.org/wp-content/uploads/2020/11/U4E_Case-Study_India-Motor_2020-11-26.pdf

9.3 Structural Pathways for Shared ESCO and Industrial Symbiosis Systems

Mainstreaming energy efficiency across industrial parks in the Southeast Asia region would require a transition from individual component upgrades to systemic, multi-tenant utility networks. By sharing centralised infrastructure, such as steam or compressed air networks, companies can leverage economies of scale, reduce overall energy losses, and lower their capital cost through "servitisation". Under the servitisation model, also known as Energy Efficiency-as-a-Service (EEaaS), SMEs would not purchase physical boilers or chillers individually but a specialised ESCO installs, owns, and maintains the equipment. The SMEs would purchase the delivered utility (steam, chilled water, or light) under guaranteed performance terms, therefore it allows them to transfer all operational and technical risks away from their balance sheets.

Case Study: Hoa Khanh Heineken Biogas-to-Steam Project³⁴

Location: Vietnam

In the Hoa Khanh Industrial Zone (Da Nang, Vietnam), a major industrial symbiosis project was identified and implemented under the UNIDO eco-industrial park framework. Heineken, a major anchor tenant in the zone, operated a large wastewater treatment facility that generated approximately 4,800 m³ of raw biogas per day which was composed of 60% to 70% methane and 20% to 30% carbon dioxide. Previously, this biogas was discharged directly into the atmosphere. However, a technical audit revealed that a third-party ESCO operated a steam-generation boiler a mere 350 meters away, which supplied steam to Heineken's production processes.

To monetise this waste stream, a collaborative agreement was established. Heineken transferred the generated biogas to the ESCO at zero cost. The ESCO invested GBP 84,000 in capital to construct a 350-meter gas pipeline connecting Heineken's wastewater plant directly to a new 1.5 tons/hour biogas-fired boiler installed on the ESCO's premises. To prevent boiler equipment corrosion, a de-aerator was installed to extract hydrogen sulfide (H₂S) from the biogas. The ESCO operates and maintains the system, selling the generated steam back to Heineken at the same standard price, thereby displacing 33% of the ESCO's conventional biomass fuel consumption and fulfilling one-third of Heineken's steam demand at zero additional operational cost to the manufacturer.

Table 49: Case studies¹⁰

PARAMETER / METRIC	PROJECT VALUE	TECHNICAL CONTEXT & ANALYSIS
Initial capital investment (CAPEX)	GBP 84,000	Covers pipeline construction, 1.5 TPH boiler, and H ₂ S de-aerator.
Annual Operating Costs (OPEX)	GBP 20,000/year	Borne entirely by the ESCO for system maintenance.
Annual Generated Revenue	GBP 174,000/year	Revenue from steam sales back to the anchor tenant.
Simple Payback Period	~3 months	Extremely rapid capital recovery due to zero fuel raw-material cost.
Biogas Volume Transferred	4,800 m ³ /day	Sourced from centralised anaerobic digestion.
Pipeline Length	350 meters	Connects the wastewater treatment plant directly to the ESCO.
Carbon Abatement Potential	10,000 to 17,000 tons CO ₂ eq/ year	Prevents direct methane venting and displaces solid biomass.

³⁴ United Nations Industrial Development Organization (UNIDO) (2023) Recovery and Reuse of Waste Heat in Eco-Industrial Parks. Best Practice Series, Issue 2. Vienna: UNIDO. Available at: https://hub.unido.org/sites/default/files/publications/Rev.2%20BPS%20Issue%202_Recovery%20and%20Reuse%20of%20Waste%20Heat%20in%20EIPs.pdf

Case Study: Tra Noc Common Boiler Utility Synergy Project³⁰

Location: Vietnam

In the Tra Noc Industrial Park (Can Tho, Vietnam), a technical scoping assessment of tenant firms identified a high concentration of small, inefficient, fossil fuel-fired boilers (capacities ranging from 2.5 to 6 tons of steam per hour). These boilers were running at extremely low efficiency due to poor technical operation and irregular maintenance. To establish a utility synergy, UNIDO experts selected three neighboring factories located within 300 meters of one another: a paper and packaging company, an animal feed mill, and a chemical fertiliser factory. Under this collaborative model, the paper company leased a section of its land to a third-party ESCO to construct and operate a centralised, high-efficiency biomass boiler with a steam capacity of 21 tons per hour.

The ESCO invested GBP 747,000 in CAPEX, constructing the centralised boiler and a 600-meter insulated steam pipeline to link the three facilities. This allowed the three factories to entirely decommission and liquidate their inefficient individual boilers. Instead of operating their own steam systems, the companies now purchase high-pressure steam from the ESCO at a discounted rate, saving significant operational and fuel expenses while completely displacing the use of coal.

Table 50: Case studies¹⁰

PARAMETER / METRIC	PROJECT VALUE	TECHNICAL CONTEXT & ANALYSIS
Initial capital investment (CAPEX)	GBP 747,000	Covers the 21 TPH boiler and 600m distribution pipeline.
Annual Operating Costs (OPEX)	GBP 570,000/year	Sourced and managed by the ESCO, covering biomass fuel.
Annual Steam Sales Revenue	GBP 810,000/year	Combined steam sales to the three participating plants.
Simple Payback Period	~3 years	Highly viable investment for the developer.
Centralised Boiler Capacity	21 tons of steam / hour	Replaces three separate, sub-scale individual boilers.
Displaced Fossil Fuel Volume	10,000 tons of coal / year	Complete transition from coal to renewable biomass fuel.
Carbon Abatement Potential	26,000 tons CO ₂ eq/ year	Significant contribution to the park's net-zero targets.
SME Participant Annual Savings	Paper: GBP 61,400 Feed: GBP 11,500 Fertiliser: GBP 140,000	Substantial operational cash savings with zero upfront CAPEX.



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