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وزارة الصناعة والثروة المعدنية
Ministry of Industry and Mineral Resources
الأكاديمية الوطنية للصناعة
National Academy For Industry

Certificate in Energy Management and Efficiency Practices for Industry Professionals

Welcome & Opening

Welcome to the course: “Certificate in Energy Management and Efficiency”

Thank you for investing your time – “energy is not just a bill, it is a strategic factor for the success of our facilities”

Quick interaction:

Who has previously participated in an energy reduction project?

Who believes there are still major saving opportunities not yet utilized?

Training program objectives

Provide practical knowledge and tools to manage energy efficiently in industrial facilities

Understand the fundamentals of energy consumption in industrial systems and how to identify waste and inefficiencies

Get familiar with key energy systems (lighting, motors, HVAC) and how to improve their efficiency

Learn the key steps of an energy audit according to ISO 50002, from data collection to analysis

Use digital tools and real-time monitoring systems to measure and improve energy performance

Develop an integrated energy management plan, including KPIs, ROI calculation, and practical energy efficiency strategies for your facilities

Training agenda: day 1

Module 1: Introduction of Energy Management

Module 2: Understanding energy demand and industrial systems

Module 3: Identifying Inefficiencies and Waste

Module 4: Overview of Energy Consumption Systems

Module 5: Practical Case Study

Training agenda: day 2

Module 6: Introduction of Energy Audit

Module 7: ISO 50002 Standards & Tools

Module 8:Data Collection & Real-Time Monitoring Systems

Module 9: Data Analysis & Performance Comparison

Workshop : Audit Simulation Workshop

Training agenda: day 3

Module 10: Efficiency Measures Implementation

Module 11: Role of Building Management Systems and Automation

Module 12: Energy Management Plan

Module 13: KPIs, ROI & Action Plans

Workshop

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Introduction of Energy Management

Module 1

What Do We Mean by Energy Management?

- **Measurement & Monitoring:** Knowing where and how energy is used in the facility
- **Continuous Improvement:** Continuously identifying and implementing saving opportunities
- **Linked to Strategic Objectives:** Cost, reliability, sustainability, and competitiveness

Benefits of Implementing Energy Management Programs

1. Reduce energy costs and improve profitability
2. Improve operational efficiency and reliability
3. Strengthen regulatory compliance and reduce risk
4. Support sustainability goals and enhance corporate reputation
5. Strengthen internal organization and build an energy-conscious culture

Financial Impact: Lower Costs, Higher Profitability

- Reduce consumption of electricity, fuel, gas, etc.
- Lower production and operating costs
- Improve return on investment (ROI) for energy efficiency projects
- Early savings are often reported in the **10–20%** range (varies by baseline and discipline)

Note: Studies by the International Energy Agency (IEA) indicate average savings of around 11% in the first years of implementing energy management programs.

Operational Impact: Higher Efficiency and Reliability

- Better day-to-day control of equipment and processes
- Prevent overload on transformers/cables and reduce stress on assets
- Lower unplanned downtime and maintenance events
- Extend equipment lifetime and stabilize performance

Compliance and Risk Reduction

- Meet energy efficiency regulations and legal requirements
- Be better prepared for inspections and audits by authorities
- Reduce the risk of penalties or loss of incentives
- Facilitate certification to standards such as ISO 50001

Sustainability and Reputation

- Reduce environmental footprint through verified energy performance
- Support sustainability commitments and reporting narratives
- Enhance brand trust with customers and the community
- Strengthen long-term organizational credibility

Building an Internal Energy Management Culture

- Clarify roles and responsibilities (energy policy, energy team, clear ownership)
- Raise employee awareness and capture saving opportunities from the shop floor
- Standardize procedures and practices across the organization
- Improve decision-making based on reliable, data-driven insights

Examples of Energy Management Program Results

- Average savings of ≈11% of energy consumption in the first years in many industrial facilities (IEA – https://www.iea.org)
- Many manufacturers report 5–30% reduction in energy costs after implementing ISO 50001-based energy management systems (bprhub – https://bprhub.com)
- Improved regulatory compliance and reduced emissions reported by organizations implementing ISO 50001 regionally and globally (DNV – https://www.dnv.com)

Competitive Industries Enabled by Energy Efficiency – Real Examples

- Energy-intensive industries (steel, cement, chemicals)
- Automotive and advanced manufacturing
- Data centers and the digital economy
- Food retail (supermarkets and hypermarkets)

Iron & Cement – Lowering Energy Intensity to Stay Competitive

- Energy (heat + electricity) is a major component of the cost per ton of product
- IEA studies show significant energy efficiency improvements in iron, steel, and cement sectors in G20 countries, with further potential using best available technologies (see https://www.iea.org)
- Investing in energy efficiency reduces production cost per ton and strengthens competitiveness in global markets

Data Centers – Energy Efficiency as a Survival Factor in a Cost-Sensitive Market

- Data centers consume around 1% of global electricity; energy is a major share of operating costs (IEA – https://www.iea.org)
- Google data centers achieve an average PUE ≈ 1.09 vs. an industry average ≈ 1.56, using about 84% less “overhead” energy per IT watt (Google – https://sustainability.google/projects/efficiency/)
- By 2023, Google reports its data centers are ~1.5× more energy-efficient than typical facilities and deliver about 3× more computing power per unit of electrical energy compared with five years ago (Google – https://sustainability.google/reports/)

What Do We Learn from These Examples?

- Energy efficiency = **lower cost per unit of product or service**
- Energy efficiency = **better reliability and operational performance**
- Energy efficiency = **a measurable competitive advantage** in profitability and market share
- Energy management principles can be applied in any sector (industrial, commercial, digital)

Activity (1): Brainstorming Your Current Energy Challenges

- Think about your facility: where is the biggest energy challenge today?
- Write down 3–5 key energy challenges you are currently facing
- Focus on the **current situation**, not the solutions

To help your thinking, ask yourself:

- **Technology & Equipment**: Old equipment, low efficiency, frequent failures
- **Operations & Production**: Uncontrolled operation, high peak loads, running equipment outside actual needs
- **Data & Measurement**: Lack of meters, unclear consumption, difficulty analyzing data
- **People:** Wasteful behaviors, low awareness, resistance to change
- **Management & Decisions**: No clear energy policy, difficulty convincing management to invest in projects
- **Regulations & Tariffs**: High tariffs, changing pricing structures, new regulatory requirements

Suggested Template – Energy Challenges Table

Challenge Description	Cause / Impact	Available Data	Notes
	Cost – Failures – Quality – Compliance, etc	Bills only, meters, no data, etc	

Understanding energy demand and industrial systems

Module 2

Understanding Energy Demand

- **Energy demand = instantaneous power draw (kW)** at any moment (what your facility is "pulling" right now).
- **Energy (kWh) ≠ Demand (kW):**
  - kW = rate of use (like **speed**)
  - kWh = total used over time (like **distance**)
- Utilities often bill demand using the **highest 15–30 min average kW** in the month (**peak demand**).
- A short peak (e.g., many motors/chillers starting together) can **raise the whole month's bill**, even if kWh is normal.

What Is a “Load”?

Definition (short and clear):

A **load** is any equipment or system that draws energy from a supply source (electrical, thermal, mechanical) to perform a task.

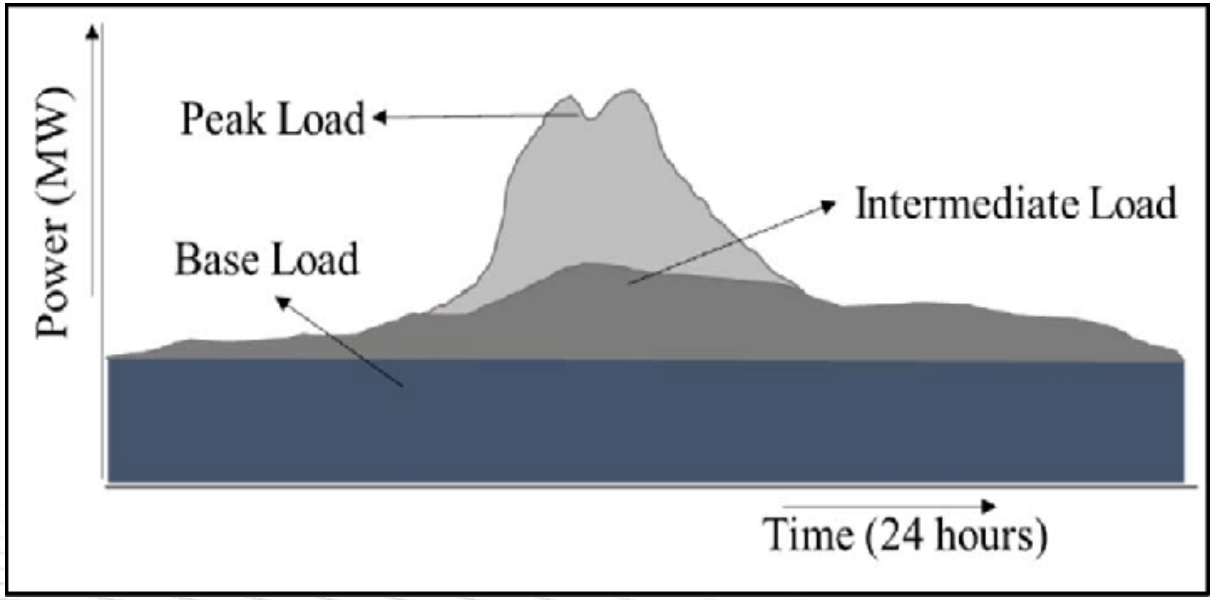
Quick breakdown:

Electrical load: draws electrical power **(kW)**

Mechanical/thermal load: the required work (e.g., pumping, lifting, heating)

Load Profile: The Picture of Demand Over Time

- A **Load Profile** is a chart of **power (kW)** versus **time**
- It helps you see:
  - What is always running
  - When peaks occur
  - How operations affect energy demand patterns



Types of Load by Energy Form

1. Electrical Load:

Motors, lighting, compressors, HVAC systems, control systems

2. Mechanical Load:

Torque or force required from the motor: pumping, rotating, conveying materials, compressing air

3. Thermal Load:

Heating/cooling of materials, furnaces, heat exchangers, boilers

Practical Example – Reading a Load Profile

- What are the peak hours?

- Where is the base load?

- Which loads can be shifted or delayed?

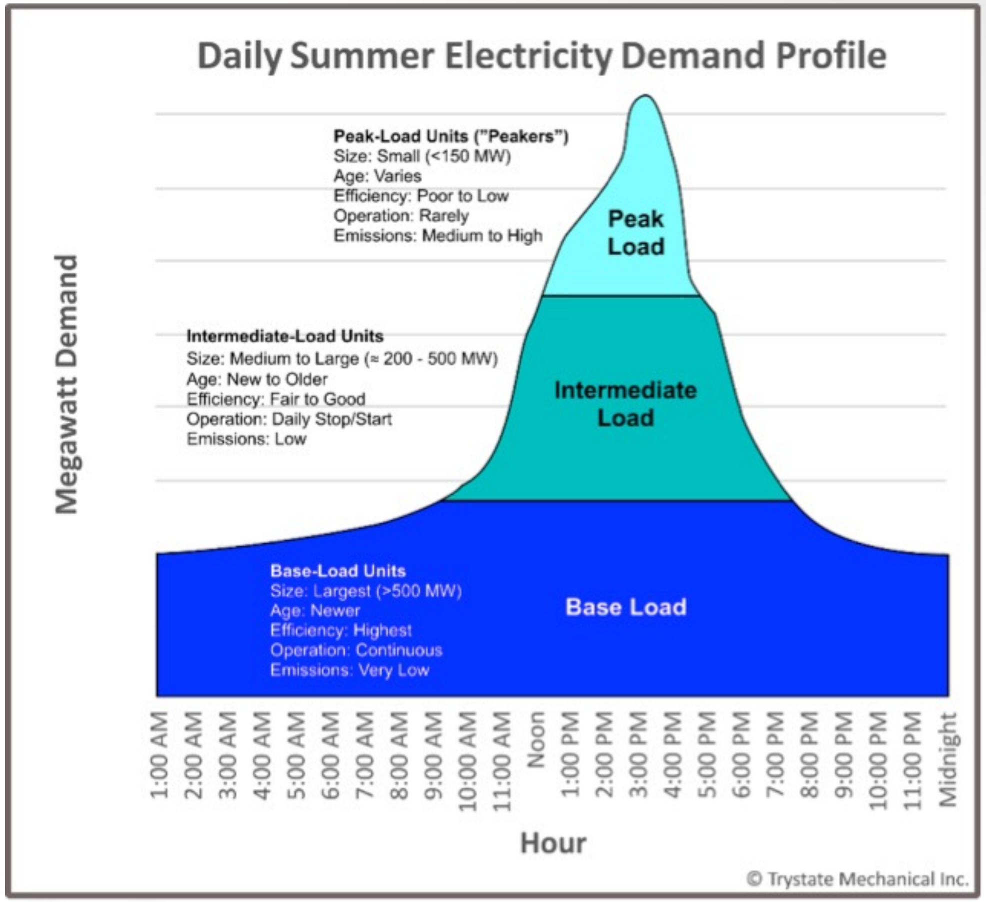


Figure 2 - Summer Electric Demand Profile Example

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Base Load: Loads That Don’t Stop Easily

- **Base Load** = loads that operate **almost continuously**
- They remain present even when production is reduced or temporarily stopped
- Usually linked to:
  - safety / essential services
  - continuity requirements (e.g., continuous cooling)
  - fixed operational constraints

Variable Load: Production- or Time-Dependent Loads

- **Variable Load** = loads that do **not** run continuously
- They increase/decrease depending on:
  - production level
  - operating schedules
  - occupancy or activity intensity
- They typically reduce significantly during shutdowns, idle times, or holidays

Group Activity: Build an “Energy Map”

1. List the main energy-consuming systems in your facility (e.g., motors, compressors, conveyors, HVAC, boilers/ovens if any, lighting)
2. Identify your **top 3 energy consumers**
3. For each one, classify it: **Base Load** or **Variable Load**
4. Share your map with the group and compare classifications

Example of Loads in Industrial & Commercial Facilities

1. **Base Loads** – Control systems, servers, safety lighting, continuously running pumps
2. **Process Loads** – Motors, compressors, furnaces, production / packaging lines
3. **HVAC & Comfort Loads** – Chillers, AHUs, split units, ventilation fans
4. **Lighting Loads** – Indoor and outdoor lighting, office lighting, warehouse lighting
5. **Shiftable Loads** – Laundry processes, auxiliary compressors, battery charging, non-critical support equipment
6. **Critical Loads** – Safety systems, fire pumps, medical equipment, critical process lines

Relationship Between Operations, Production and Energy Use

- Every operating decision has an energy impact
- Energy consumption does not always increase in the same proportion as production
- Key metric: energy consumption per unit of production

How Does Energy Consumption Build Up in a Facility?

Total energy consumption = Base load + Production-related load

Base Load:

Continuous lighting, control systems, servers, and other loads that do not change much over time

Production-Related Load:

Production line motors, furnaces, compressors, etc. that increase or decrease with production volume

What Happens to Energy Use When Production Changes?

Case	Production Change	Energy Change	Interpretation
1	+20%	≈ +20%	Specific energy use roughly constant
2	+20%	≈ +10%	Better efficiency, better use of base load
3	+20%	≈ +40%	Worse efficiency, ineffective operation

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Identifying Inefficiencies and Waste

Module 3

Identifying Energy Waste and Performance Gaps

- Where do we waste energy?
- How do we distinguish between **technical**, **operational**, and **behavioral** waste?
- Real examples from industrial and commercial facilities

Sources of Energy Waste: A Big-Picture View

1. Operational Waste
2. Technical / Equipment Waste
3. Behavioral Waste (People & habits)
4. Organizational / Management Waste
5. Engineering Design Waste
6. Measurement & Data Waste

Operational Waste

- Running equipment when not needed (HVAC, lighting, compressors, etc.)
- Operating lines or machines at **very low load** for long periods
- Poor scheduling (timers / operating schedules not optimized)
- High peak demand due to poor production planning
- Simultaneous starts of heavy loads (lack of **staggered start**)

Technical Waste in Equipment and Systems

- Old, low-efficiency equipment (motors, chillers, outdated lighting)
- Not using available technologies (VFDs, high-efficiency motors, LED)
- Poor thermal insulation (tanks, pipes, boilers, hot surfaces)
- Leakage losses (compressed air, steam, chilled water)
- Operating outside optimal range (pressure/temperature higher than needed)

Behavioral Waste

- Lighting or HVAC left on in unoccupied areas
- Equipment left running during breaks or between shifts
- Manual override of control settings (thermostats / BMS)
- Ignoring leaks, abnormal noise, or early warning signs
- Poor adherence to efficient operating practices

Organizational and Management Waste

- No clear energy policy, targets, or direction
- No defined ownership (Energy Manager / Energy Team)
- No budget for efficiency improvements
- Procurement based on lowest price only (ignoring lifecycle cost – **LCC**)
- No energy performance KPIs (or KPIs not used)

Engineering Design Waste

- Poor building envelope design (excessive glazing, weak solar/thermal control)
- Oversizing equipment (HVAC, pumps, fans) “just in case”
- Complex/long ducting and piping → higher pressure losses
- Inefficient lighting design (layout, spacing, mounting height)
- Poor zoning and control segmentation

Waste Caused by Weak Measurement and Data

- One main meter only (no breakdown by major loads)
- Lack of sub-metering for big systems (HVAC, compressed air, production lines)
- Unreliable or non-recorded energy data (no history, no analysis)
- Energy data not linked to production data

From Waste Awareness to an Action Plan

- Identifying waste is the first step before proposing solutions
- Each waste category requires different tools and treatments
- Next, we will:
  - link waste to the energy audit findings
  - prioritize improvement actions based on impact and feasibility

Quick Indicators of Energy Waste

- Simple numeric indicators that reveal **waste** or **performance gaps**
- Link energy consumption to **production** and **operations**
- Help prioritize actions and track improvement over time

Specific Energy Consumption (SEC)

- **Definition**: SEC = Energy Consumption ÷ Output
  - Examples: **kWh/ton**, **kWh/m³**, **kWh/unit**
- **SEC increases** → likely waste, poor operation, or equipment degradation
- **SEC decreases** → efficiency improvement
- Choose the right SEC unit for each facility/process

Load-Related Indicators: Load Factor & Utilization

- **Load Factor** = Average Demand ÷ Maximum Demand
  - Near **1.0** → stable load profile, fewer peaks
  - Low value → high peaks, unbalanced operation
- **Utilization Factor (equipment)** = Actual Operating Hours ÷ Available Hours
  - Reveals overuse, underuse, or oversizing

Energy Use With No Real Production

- **Downtime / Low-load Energy Ratio**

= (kWh during downtime or low load ÷ total kWh) × 100%

- Examples to analyze:
  - Weekends and holidays
  - Between shifts
  - Idle time in production lines

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Overview of Energy Consumption Systems

Module 4

Main Energy-Consuming Systems in Industrial & Commercial Facilities

- HVAC systems (heating, ventilation, and air-conditioning)
- Electric motors and drive systems (pumps, fans, compressors, conveyors)
- Lighting systems (indoor, outdoor, production areas, warehouses, offices)

Lighting Systems

- A major energy consumer in industrial buildings, commercial buildings, and warehouses
- In some commercial buildings, lighting can account for more than 30% of total electricity use
- In industry, lighting is a smaller share (e.g. around 6% of electricity use in some factories) but still a clear and relatively easy area for savings

Lighting Systems: Types and Efficiency

- Lighting supports **comfort, safety, and productivity**
- A significant share of energy use in many industrial and commercial buildings
- Upgrading from older lighting to **high-efficiency LED** often delivers fast, visible savings

Lighting Basics: What Do We Measure?

- **Illuminance (Lux):** light level on the work surface
- **Luminous Flux (Lumen):** total light output from the source
- **Luminous Efficacy (lm/W):** lumens delivered per watt of electricity
- Higher **lm/W** = more light for the same power = better efficiency

Simple KPIs for Lighting Performance

- Annual lighting energy intensity: **kWh/m²/year**
- Lighting energy per actual operating hour
- % of lighting converted to **LED**
- % of areas covered by controls (occupancy/daylight/timers)

Lighting Controls: Efficiency Without Changing Lamps

- **Zoning**: control lighting by area, not “all on/all off”
- **Occupancy sensors**: warehouses, restrooms, meeting rooms, corridors
- **Daylight sensors:** reduce artificial lighting near windows
- **Timers / schedules:** aligned with operating hours (and BMS when available)
- **Dimming:** provide the right light level only when needed

Electric Motors – The Beating Heart of Industrial Operations

- Drive pumps, fans, compressors, conveyors, mixers, and many other process machines
- Typically, the largest single consumer of electricity in industry
- Global estimates:
- Motors and motor-driven systems (pumps/fans/compressors) account for ~50–53% of global electricity use
- In industry, motor systems can reach ~70% of total electricity consumption (see IEA – https://www.iea.org)

What Is Motor Efficiency?

- **Motor Efficiency (η)** = Mechanical Output Power ÷ Electrical Input Power
- Input: electrical power from the grid **(kW)**
- Output: useful mechanical power on the shaft **(Torque × Speed)**
- The difference is **losses** (heat, friction, electrical/magnetic losses)

Where Do Motor Losses Come From?

- Copper losses (windings heating)
- Iron/core losses (magnetic losses)
- Mechanical losses (bearings, internal fan)
- Ventilation/cooling losses

Why Real-World Efficiency Drops

- Running at very low load for long periods **(underloading)**
- Selecting a motor larger than needed **(oversizing)**
- Voltage issues (low voltage or phase imbalance)
- Poor maintenance (bearings, cooling fan, dust buildup)
- High ambient temperature / weak ventilation

When Is a VFD the Right Choice?

Best fit when:

- Load is pump/fan/compressor with variable demand throughout the day
- Current control uses throttling valves, dampers, or bypass

Not a top priority when:

- Speed must be constant most of the time
- Very small motors (savings may not justify cost)
- Constant-torque/special applications (needs deeper engineering review)

HVAC (Heating, Ventilation & Air-Conditioning) : Why It Matters

- HVAC is often one of the **largest electricity consumers** in offices, control rooms, and enclosed buildings
- In industrial sites, HVAC may also serve **production halls, clean rooms, labs, and cold stores**
- HVAC is a **system**, not a single device: cooling + air movement + controls

Where Does HVAC Consume Energy in Your Facility?

- Administration buildings and offices
- Control rooms and server rooms (often 24/7)
- Air-conditioned production areas
- Clean rooms, laboratories, refrigerated storage
- Corridors and service areas

What Drives HVAC Energy Consumption?

- **Cooling/Heating demand (Load):** indoor–outdoor temperature difference
- **Humidity (Latent load):** dehumidification can be a hidden driver
- **Ventilation requirements**: outdoor air must be conditioned
- **Operating hours:** schedules often cause the biggest waste
- **System performance:** controls, maintenance, and part-load behavior

Common Waste Patterns in HVAC

- Setpoints too low (e.g., cooling offices to extreme temperatures)
- Cooling unoccupied or low-use areas
- Running outside actual need (before/after shifts)
- Air leakage / poor insulation (open doors, weak duct insulation)
- Poor maintenance: dirty filters/coils, faulty sensors

Thermal Comfort and “Hidden Waste”

Thermal comfort depends on:

Temperature + humidity + air movement

Common misconception:

People reduce setpoint to solve “stuffy air” (often a **humidity/ventilation** issue)

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Practical Case Study

Module 5

Exercise Overview: Hypothetical Industrial Facility Data Analysis

- A facility producing one main product
- Available data: **energy consumption, production**, and basic indicators
- Objective: apply what we learned about **KPIs** and **waste detection** in a practical way

Facility Profile (Scenario)

- A plant producing a **single volume-based product** (choose a relevant example: plastics / food / building materials)
- Operates **3 shifts/day**, **6 days/week**
- Main systems:
  - Production lines (motors, pumps)
  - Compressed air system
  - HVAC for offices/control rooms and some production areas
  - Lighting for plant and warehouses

Monthly Data Snapshot: Electricity and Production

Month	Electricity (kWh)	Production (ton)
Jan	1,000,000	6,000
Feb	950,000	5,800
Mar	1,050,000	6,200
Apr	1,200,000	6,100
May	1,350,000	6,300
Jun	1,450,000	6,250

Calculating Specific Energy Consumption (SEC)

Month	kWh	ton	SEC (kWh/ton)
Jan	1,000,000	6,000	167
Feb	950,000	5,800	164
Mar	1,050,000	6,200	169
Apr	1,200,000	6,100	197
May	1,350,000	6,300	214
Jun	1,450,000	6,250	232

Initial Diagnosis: Working Hypotheses

Possible reasons for increasing kWh/ton:

- Higher HVAC load as summer starts (plus poor setpoints or weak performance)
- Compressed air degradation (leaks, excessive pressure, inefficient operation)
- More stops/rework (production waste = energy waste)
- Extra standby equipment running “just in case”
- Deferred maintenance (chillers, motors, compressors)

Breakdown by System (Example: April vs June)

System	April (kWh)	June (kWh)
Production lines (motors)	700,000	720,000
Compressed air	150,000	230,000
HVAC	180,000	300,000
Lighting	100,000	110,000
Other/support	70,000	90,000
Total	**1,200,000**	**1,450,000**

Guided Questions for Group Analysis

1. Which months show the **best SEC** and which show the **worst SEC**?
2. Which systems are most responsible for the SEC decline?
3. What type of waste is likely in each system (operational / technical / behavioral / management)?
4. What are your **top 3 quick improvement actions**?

Example Summary (For Debrief) (1/2)

- Best months: **Jan–Feb** (SEC ≈ 160–170 kWh/ton)
- Worst months: **May–Jun** (SEC > 210–230 kWh/ton)
- Main suspects:
  - **HVAC** (seasonal increase + control/maintenance effectiveness)
  - **Compressed air** (increase too large to ignore)

Example Summary (For Debrief) (2/2)

- Likely waste:
  - HVAC: excessive setpoints, schedule issues, dirty filters/coils, faulty sensors
  - Compressed air: leaks, pressure too high, unnecessary compressor operation
- Quick actions:
  - Leak detection campaign + optimize pressure setpoints
  - Review HVAC schedules and temperature setpoints
  - Review off-hours lighting and office loads

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Day 2
Energy Monitoring and Auditing

Introduction of Energy Audit

Module 6

What Is an Audit?

- An **audit** is a **systematic, documented, and evidence-based** evaluation.
- Purpose: confirm **what is happening**, **how well it performs**, and **where gaps exist**.
- Audits rely on **data, observations, and records**—not assumptions.
- Output: clear findings and **actionable recommendations**.

What Is an Energy Audit?

- An **energy audit** is a structured assessment of:
  - **Energy use and consumption patterns**
  - Major consumers (systems/processes) and operating conditions
- Objectives:
  - Identify **energy-saving opportunities**
  - Estimate **savings, costs, and priorities**
  - Improve performance without compromising **safety, quality, or production**

Why Do We Conduct an Energy Audit?

- Reduce **energy cost** and improve **operating margins**
- Establish a baseline and track performance using **KPIs/EnPIs**
- Improve **reliability** (less stress, fewer failures, better maintenance planning)
- Support **compliance** and sustainability reporting
- Build a strong **business case** for upgrades and investments

Scope and Boundaries

- Define **boundaries**: site, building, process line, or utility system
- Define **scope**:
- Which energy sources (electricity, fuel, steam, compressed air, etc.)
- Time period and operating modes (normal, peak, seasonal)
- Confirm **data availability** and required measurements
- Agree on what “success” looks like (savings targets, reliability, compliance)

Typical Audit Outputs

Energy profile / energy balance (where energy goes)

List of opportunities:

- **No-cost**, **low-cost**, and **capex** measures

Savings estimates (kWh, fuel, cost), risks, and assumptions

Priority roadmap with **payback** and implementation plan

Monitoring plan to sustain results

Preliminary vs. Detailed Energy Audit (PA vs. DA)

- Energy audits typically come in **two practical depth levels**:
- **Preliminary Audit (PA):** fast, high-level, opportunity screening
- **Detailed Audit (DA):** deep analysis, measurement, investment-grade decisions
- Both aim to reduce energy waste while protecting **safety, quality, and production**.

What Is a Preliminary Audit (PA)?

•A **rapid, structured assessment** to understand where energy goes and where savings may exist.

•Focus: **identify and prioritize** the biggest opportunities.

•Best used when you need a quick roadmap and “where to start” clarity.

PA Typical Inputs and Outputs

Typical inputs

Utility bills (12–24 months) and basic operating information

Site walk-through + short interviews (operations/maintenance)

Typical outputs

High-level energy breakdown (major consumers / systems)

List of opportunities (often **no-cost / low-cost** first)

Rough savings and payback ranges

Recommended scope for a **Detailed Audit (DA)**

What Is a Detailed Audit (DA)?

- A **comprehensive, data-driven** audit to quantify savings with higher confidence.
- Focus: build a **business case** and implementation plan for major actions.
- Often includes short-term measurements and deeper engineering analysis.

DA Typical Activities and Deliverables

Typical activities

- Sub-metering or temporary measurements (as needed)
- Load profiling, baseline development, and performance modeling
- Root-cause analysis of inefficiencies (controls, setpoints, maintenance, sizing)

Typical deliverables

- Savings estimates with assumptions and accuracy bands
- CAPEX/OPEX estimates, ROI, payback, and risk notes
- Prioritized project pipeline + implementation plan
- Measurement & Verification approach (how to prove savings)

Key Differences (PA vs. DA)

Aspect	Preliminary Audit (PA)	Detailed Audit (DA)
Purpose	Screening and prioritization	Decision-grade evaluation and implementation planning
Depth	High-level review	Engineering-level analysis
Data required	Utility bills + walk-through + interviews	Bills + measurements/logging + detailed operating data
Methods	Quick calculations, benchmarks, visual checks	Load profiling, modeling, root-cause analysis, metering
Output detail	Opportunity list with indicative savings ranges	Detailed project list with quantified savings and assumptions
Accuracy	Directional / indicative	Higher confidence (investment-grade)
Time & effort	Shorter, lower cost	Longer, higher cost

When to Use PA vs. DA

Choose PA when

You need a quick start, limited data, or many sites to screen

You want fast wins and a prioritized list

Choose DA when

You're preparing a major upgrade (HVAC, motors, compressed air, process heat, etc.)

You need reliable numbers for budget approval, procurement, or performance contracts

Recommended Workflow

- PA → shortlist opportunities → DA on top priorities → implement → verify savings
- This avoids spending detailed-audit effort everywhere and focuses resources where ROI is best.

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ISO 50002 Standards & Tools

Module 7

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What is ISO 50002

- **ISO 50002** is an international standard that sets **requirements and guidance for conducting energy audits**.
- It defines a structured audit approach: **plan → collect data → site assessment → analysis → report → closing**.
- It helps ensure audits are **consistent, evidence-based, and repeatable**, with clear assumptions and documentation.
- It supports identifying **energy-saving opportunities**, estimating savings, and prioritizing actions.
- It can be applied across sectors, with dedicated parts for **buildings** and **industrial processes**.

Why ISO 50002?

- Creates a consistent, transparent framework for energy audits
- Improves credibility and comparability of audit results
- Emphasizes evidence-based analysis and measurement
- Helps prioritize energy performance improvement actions (EPIAs)
- Aligns with ISO 50001 and can support the energy review

Use cases

- Standalone audits for cost and emissions reduction
- Audit programs across multiple sites
- Inputs to ISO 50001 energy review
- Pre-investment screening and detailed studies

The ISO 50002 series (2025)

ISO 50002-1

General requirements + guidance for use

Applies across buildings, processes, systems, and transport.

ISO 50002-2

Buildings guidance using ISO 50002-1

Envelope, HVAC, lighting, controls, and occupant behavior.

ISO 50002-3

Processes guidance using ISO 50002-1

Manufacturing, utilities, labs, data centres, and more.

What ISO 50002 covers (and what it doesn't)

Covers

• Audit principles and process requirements
• Roles and responsibilities (auditor vs organization)
• Deliverables and reporting expectations
• Guidance on determining/evaluating auditor competence

Does not cover

• Selecting/evaluating competence of bodies that provide audit services
• Auditing an organization's energy management system (EnMS)

For EnMS audit & certification bodies, see ISO 50003.

Core audit principles (practical interpretation)

- Systematic: a planned method—not an ad-hoc walkaround
- Evidence-based: conclusions trace back to data, observations, and records
- Transparent: assumptions, methods, and limitations are explicit
- Fit-for-purpose: depth and effort match the decision being supported
- Action-focused: deliverables lead to implementable EPIAs

Quality check questions

- Can another auditor reproduce the logic?
- Are data gaps and assumptions stated?
- Are savings tied to a baseline/driver?
- Is the recommendation implementable with owners and timing?

Define scope, boundaries, and objectives

- Boundary: site / building / process line / utility system
- Energy types: electricity, fuels, steam, compressed air, chilled water, etc.
- Operating modes: normal, peak, seasonal, shutdown, product mix
- Objective: compliance, cost reduction, reliability, decarbonization, or investment planning

Audit boundary

Inside scope
- Systems
- Processes
- Metering points
- Operating rules

Outside scope
- Uncontrolled third-party loads
- Non-representative events
- Excluded buildings/lines

Who does what? (organization vs auditor)

Organization

- Define objectives and constraints
- Provide data and site access
- Assign counterparts (ops/maintenance/finance)
- Validate operating assumptions
- Own implementation and tracking

Energy auditor

- Plan the audit approach and methods
- Collect evidence and measurements
- Analyze energy drivers and opportunities
- Quantify savings with assumptions
- Deliver a clear report and prioritized actions

A simple end-to-end audit workflow

Keep it predictable: plan → evidence → analysis → decisions → actions.

Plan → Collect data → Site work → Analyze → Report → Follow-up

Deliverable mindset

Each stage should produce a concrete output (e.g., audit plan, data pack, measurement log, analysis workbook, report draft, action register).

Pre-audit data package (recommended checklist)

Aim for "minimum viable data" first—then measure where uncertainty matters.

Energy + cost

- Utility bills (12–24 months)
- Tariffs, demand charges, contracts
- Fuel purchase records (if applicable)
- Submeter data (if available)

Operations + assets

- Production volumes & drivers
- Operating schedules / shifts
- Asset list (major equipment)
- Drawings: single-line, P&ID, layout
- O&M logs and known constraints

Site visit: how to work fast without missing essentials

- Start with safety + access rules; confirm what is “normal operation” today
- Walk the energy map: utilities → distribution → major users → end-use
- Interview operators and maintenance (what works, what hurts, what is bypassed)
- Capture setpoints, control modes, and operating hours (not just nameplates)
- Document evidence: photos, readings, logs, and assumptions

Capture list (quick)

- Loads that run when they shouldn’t
- Oversized equipment operating at low load
- Leaks, bypasses, and manual overrides
- Heat losses and poor insulation
- Scheduling opportunities (load shifting)

Data validation: a lightweight checklist

- Completeness: do we have coverage for all major energy sources?
- Consistency: units, timestamps, timezones, and scaling factors
- Outliers: explain spikes/drops with operations, weather, or events
- Reconciliation: bills vs submeters vs equipment estimates
- Traceability: keep a clear chain from raw data to results

Common failure modes

- Wrong CT/PT ratios
- Missing production driver
- Non-representative sampling window
- Mixed units (kW/kWh/kVA)
- Unstated assumptions

Measurement plan: target uncertainty, not perfection

- Decide what must be measured vs what can be estimated
- Choose representative windows (load cycles, shifts, seasons)
- Log key variables: power, flow, pressure, temperature, runtime, setpoints
- Document instrument accuracy and measurement conditions
- Store datasets in a structured format (time series + metadata)

Typical instruments

- Power analyzer (kW/kWh/kVA/PF)
- Data logger (time series)
- IR camera / spot readings
- Flow/pressure (utilities)

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ISO 50002-2: buildings — what to focus on

Use ISO 50002-1 as the process framework; apply building-specific guidance.

Envelope

Insulation, glazing, air leakage, shading, thermal bridges

Operation

Occupancy patterns, comfort complaints, overrides, seasonal modes

Systems

HVAC, lighting, controls, schedules, setpoints, maintenance condition

Outputs

EPIAs that reduce cost while improving comfort and sustainability

ISO 50002-3: processes — what to focus on

Designed for industrial, commercial, and institutional processes using ISO 50002-1.

Process energy balance

Model where energy enters, transforms, and leaves (losses and useful output)

Benchmarking & EnPIs

Compare performance using indicators tied to drivers (production, hours, load)

Utilities & support systems

Steam, compressed air, pumps, fans, cooling, heat recovery

Multi-site sampling

Approach for organizations with many sites (where applicable)

Analysis toolbox (use what fits the decision)

ISO 50002-3 encourages energy-balance modeling, benchmarking, and indicator tracking.

- Load profile (15-min / hourly)
- Energy balance (Sankey thinking)
- Benchmarking (internal/external)
- SEU ranking (Pareto)
- EnPIs (normalized)
- Scenario & sensitivity

EPIAs: structure the opportunity list

Capture opportunities across technical, operational, and organizational layers.

Technical

Equipment upgrades
VFDs and controls
Heat recovery
Insulation
Efficient lighting/HVAC

Operational

Scheduling / load shifting
Setpoints and modes
Start/stop discipline
Leak management
Preventive maintenance

Organizational

Ownership and routines
Training and awareness
KPIs/EnPIs dashboards
Procurement specs
Continuous improvement cadence

Quantify savings: make assumptions explicit

- Define baseline and drivers (production, hours, weather) before "savings"
- Use measured data where uncertainty changes the decision
- State assumptions: runtime, load, efficiency, controls, degradation
- Provide ranges (best/expected/worst) for high-uncertainty items
- Document interactions: one project can change another project's savings

Output format (recommended)

For each EPIA:
- Baseline condition
- Change description
- Calculation method
- Estimated savings (energy + cost)
- CAPEX/OPEX + payback
- Risks + prerequisites

Prioritize actions: value, feasibility, and risk

Impact vs Effort

	Low effort	High effort
High impact	**Quick wins**	**Strategic**
Low impact	**Fill-ins**	**Defer**

Business case essentials

- Annual savings (energy + cost)
- CAPEX/OPEX and payback
- Reliability & production impact
- Safety/quality constraints
- Implementation window & commissioning
- Risks and sensitivity

Audit report: make it decision-ready

- Executive summary: top findings and top actions
- Scope, boundary, baseline, and key assumptions
- Energy profile and significant energy users (SEUs)
- EPIA register with quantified savings, costs, and priority
- Implementation roadmap + measurement plan for tracking

Good reports are…

- Traceable (data → logic → result)
- Practical (owners, dates, dependencies)
- Honest about uncertainty
- Aligned to the organization's goals

Energy auditor competence: what “good” looks like

ISO 50002-1 includes guidance on determining/evaluating auditor competence.

Competence checklist

- Energy systems knowledge (electrical, thermal, utilities)
- Process/building domain expertise (fit to the site)
- Measurement and data analysis skills
- Ability to quantify savings with clear assumptions
- Communication: findings that management can act on
- Professional judgement and ethics (evidence-based, impartial)

References (public pages)

ISO 50002-1:2025 overview	**https://www.iso.org/standard/83645.html**
ISO 50002-2:2025 overview	https://www.iso.org/standard/83662.html
ISO 50002-3:2025 overview	https://www.iso.org/standard/83663.html
ISO 50003:2021 overview	https://www.iso.org/standard/77575.html

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Data Collection & Real-Time Monitoring Systems

Module 8

Data Collection & Real-Time Monitoring Systems

Use-case driven design for industrial energy performance

Design

From objectives to data architecture (tags, granularity, integration).

Detect

Move beyond thresholds to baselines, drift, and anomaly patterns.

Deliver

Close the loop: alerts → actions → verification → sustained results.

Module outcomes

What participants should be able to do after this module

- Define high-value real-time monitoring use cases and translate them into data requirements and actions.
- Build a practical energy data model (asset hierarchy + tagging) that scales across sites.
- Select sampling frequency and metering granularity based on decision value—not preference.
- Specify a robust monitoring architecture: edge, storage, analytics, dashboards, and alerts.
- Implement a closed-loop operating model: detect → triage → act → verify.

Use-case first approach

Start with operational value, then design the data

How to define a monitoring use case

- Business objective (cost, reliability, compliance, sustainability).
- Target system / SEU and decision owner.
- Trigger condition (what should be detected).
- Action playbook (what happens next, by whom, and how fast).
- Success metric (how you know it worked).

Example use cases (industrial)

Use case	Minimum data	Action
Peak demand control	15-min kW, schedule, demand limit	Shift loads / stage equipment
Idle energy detection	Run/stop + kW baseline	Shut down / fix interlocks
Compressed air leaks	Pressure + compressor power	Leak hunt + verify drop
HVAC drift	Zone temp/RH + setpoints	Tune setpoints / controls

Energy data model & tagging standard

Make data searchable, scalable, and analysis-ready

Asset hierarchy (example)

Site
↓
Area
↓
System
↓
Equipment
↓
Meter/Point

Minimum tagging metadata

- Unique tag name + description (human-readable).
- Unit of measure (kW, kWh, A, °C, bar, etc.).
- Location and asset link (system/equipment ID).
- Scaling factors (CT/PT ratios, multipliers).
- Timestamp/timezone policy + time sync source.
- Ownership (operations/maintenance) and data steward.
- Calibration/verification date and method.

Sampling strategy & data granularity

Choose frequency based on decision value and dynamics

Design rules

- Use the slowest interval that still supports the use case.
- Align sampling with process dynamics (seconds vs minutes vs hours).
- Standardize default intervals (e.g., 1-min, 5-min, 15-min, hourly).
- Separate raw data retention from aggregated reporting needs.
- Always log quality flags (missing, substituted, out-of-range).

Recommended granularity (rule-of-thumb)

Decision type	Typical interval	Notes
Real-time protection / fast control	1–10 sec	Only where needed (high data volume)
Operational alerts & anomaly detection	1–5 min	Most useful “real-time” layer
Demand management / peak tracking	15 min	Matches typical demand windows
Daily reporting and management review	Hourly / daily	Use aggregates, not raw

Connectivity & protocols (OT/IIoT basics)

Make integration predictable and supportable

Common protocols (practical view)

- Modbus: widely used for meters and industrial devices.
- BACnet: typical in building systems (BMS/HVAC).
- OPC UA: industrial interoperability with strong data modeling.
- MQTT: lightweight publish/subscribe for IIoT telemetry.
- Rule: standardize a small set; avoid "one-off" integrations.

Design choices

- Wired vs wireless: reliability, interference, and maintenance access.
- Gateway buffering: don't lose data during network outages.
- Time synchronization: consistent timestamps across all sources.

Integration map (simplified)

Meters & sensors

↓

Gateways / edge

↓

Historian / DB

↓

Analytics

↓

Dashboards & alerts

Aim: reliable data flow with minimal custom work.

End-to-end monitoring architecture

From data capture to operational action

Reference architecture

Capture	→	Edge	→	Store	→	Analyze	→	Act
Meters, sensors, BMS/SCADA		Gateways, buffering, time sync		Historian / time-series DB		Rules, baselines, ML, KPIs		Dashboards, alerts, work orders

Design for maintainability: standard tags, documented mappings, and clear ownership.

Keep an audit trail: configuration changes, thresholds, and KPI formulas should be traceable.

Cybersecurity & access control

Protect operations while enabling visibility

Core controls (practical)

- Network segmentation: separate OT from IT; control the interfaces.
- Least privilege: role-based access (view, configure, admin).
- Prefer read-only data collection; tightly control write paths.
- Secure remote access: MFA, jump hosts, and logging.
- Change management: track who changed tags, thresholds, and dashboards.

Operational guardrails

- Define “golden” configurations for critical assets.
- Back up gateway configurations and KPI definitions.
- Implement alert tuning governance (avoid alarm fatigue).
- Document emergency procedures (monitoring outage / data loss).

Data engineering workflow

Ingestion → quality → transformations → published KPIs

A simple, scalable pipeline

Ingest
Connectors, gateways, APIs

→

Validate
Ranges, missing, units, time sync

→

Transform
Scaling, aggregation, derived signals

→

Calculate
KPIs / EnPIs, baselines, models

→

Publish
Dashboards, alerts, reports

Governance: KPI formulas and models must be versioned (change history + effective dates).

Quality flags should travel with the data (so dashboards never hide missing or substituted points).

Event-based analytics

Convert time-series into operational facts

Why events matter

- Raw time-series are hard to interpret without context (shift, batch, run/stop).
- Events enable “energy per batch / per shift / per start-up”.
- They help isolate root causes and compare like-for-like operation.
- They reduce false alarms by respecting operating states.

Common event extraction examples

- Run/stop events from motor current or kW threshold + debounce.
- Batch boundaries from recipe ID, valve state, or production counters.
- Maintenance windows from CMMS work orders or operator inputs.
- Shift schedules and planned shutdowns from calendar sources.

From signal → event → KPI

kW time-series

↓

Run/stop events

↓

Energy per run (kWh/run)

Comparable across shifts and months

Closed-loop operations

Alerts must lead to verified actions

Operating model

Detect → Triage → Investigate → Correct → Verify → Learn

Make it executable:

- Each alert has an owner, severity, and response time (SLA).
- Investigation checklist: what to check first; what data to pull.
- Corrective actions link to work orders (CMMS) when needed.
- Verification step confirms savings and closes the case.
- Lessons learned update thresholds, models, and operating practices.

Commissioning & ongoing QA

Ensure the system works before you depend on it

Go-live acceptance tests

- Meter list validation: tag names, units, scaling, and locations.
- Signal checks: compare readings with handheld measurements.
- Time sync test: timestamps align across all sources.
- Data loss test: confirm gateway buffering and recovery.
- Dashboard sanity checks: totals match trusted references.
- Alert tests: trigger, route, and close the alert lifecycle.

Ongoing QA routines

- Periodic scaling checks (CT/PT ratios, multipliers).
- Sensor drift monitoring and calibration schedule.
- Duplicate/flatline detection (stuck sensors).
- Threshold and model review (quarterly tuning).
- Change-log reviews (who changed what, and why).

Scaling across multiple sites

Standardize to compare and improve faster

Standard libraries to build

- Tag library: naming rules and metadata templates.
- Dashboard library: reusable layouts for key systems (HVAC, compressors, process lines).
- Alert library: standardized rules + recommended actions.
- Metering playbook: where to meter by site type.
- Documentation pack: data dictionary, mappings, and change logs.

Benchmarking guardrails

- Compare like-for-like: normalize for production and operating hours.
- Use consistent boundaries (site vs line vs utility system).
- Define a governance cadence: monthly review + quarterly deep dives.
- Separate performance from measurement artifacts (data quality flags).

Common pitfalls (and how to avoid them)

Fast lessons learned

Pitfalls

Pitfall	Avoid by…
Collecting everything	Start from use cases; choose minimal data that supports decisions.
No data ownership	Assign owners and response SLAs for each alert and dashboard.
Tag chaos	Use a strict naming convention + metadata template from day one.
Alarm fatigue	Tune thresholds, use context (run/stop), and prioritize by cost impact.
No commissioning	Test scaling, time sync, buffering, and dashboard totals before go-live.
No verification	Require “verify” before closing actions; keep a savings log.

Summary

- Start with use cases and actions—then design data and technology around them.
- Standardize the data model: hierarchy, tags, metadata, and governance.
- Choose sampling and metering by decision value and process dynamics.
- Use event-based analytics and baseline models to reduce noise and detect real issues.
- Close the loop: alerts must drive work, and work must be verified.
- Scale through libraries (tags/dashboards/alerts) and consistent benchmarking rules.

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Data Analysis & Performance Comparison

Module 9

Module outcomes

- Compare sites/lines/months fairly using like-for-like rules and operating-state segmentation
- Normalize performance using multiple drivers (not only kWh per unit)
- Build and explain a simple baseline model, then track improvement over time
- Distinguish normal variation from true performance change and identify root causes
- Translate data findings into quantified opportunities and a management decision pack

Rules of fair comparison (Like-for-like)

Compare apples to apples

- Same boundary: meters, processes, and energy sources included
- Same operating mode: product grade, recipe, and shift pattern
- Same constraint set: safety, quality, and uptime requirements
- Same data rules: time window, units, missing-data handling

Quick test: If the comparison result changes when you adjust for product mix or operating hours, your “improvement” is likely a comparison artifact—not a real efficiency gain.

Operating-state segmentation

Segment before you compare

- Split data into states: Run / Idle / Shutdown (and Warm-up if needed)
- Then segment further: shift, batch, product family, ambient band
- Compare within the same state first—then aggregate with clear weights
- Use state-level KPIs: Energy per run-hour, per batch, per shift

Why it matters: A “monthly average” hides operational waste (idle energy) and creates false trends when schedules change.

Normalization methods (beyond kWh per unit)

Normalize to the right drivers

- Choose drivers that explain energy use: production rate, operating hours, flow, pressure, temperature, occupancy
- Use multi-driver normalization when one indicator is not enough
- Report both: (a) normalized KPI and (b) raw totals for cost/utility context
- Document assumptions so results remain defensible

Rule of thumb: If two months have different operating hours or different product mix, a single “kWh/ton” number is rarely sufficient.

Weather & season adjustment

Adjust for climate when relevant

- HVAC and cooling loads often track outdoor temperature and humidity
- Use weather bands or simple degree-day style grouping (where suitable)
- Compare “same-season” periods or normalize with weather as a driver
- Present results clearly: “This change is seasonal” vs “This change is operational”

Baseline modeling (simple → practical)

Build an explainable baseline

- Select a stable reference period (known “normal” operation)
- Start simple: one key driver (e.g., production rate) → then add drivers only if needed
- Validate: does the baseline follow reality in the reference period?
- Use the baseline to compute expected energy and isolate deviation

Communication tip: Use plain language: “Expected energy for this production level” instead of statistical jargon.

Control charts for stability

Separate noise from signal

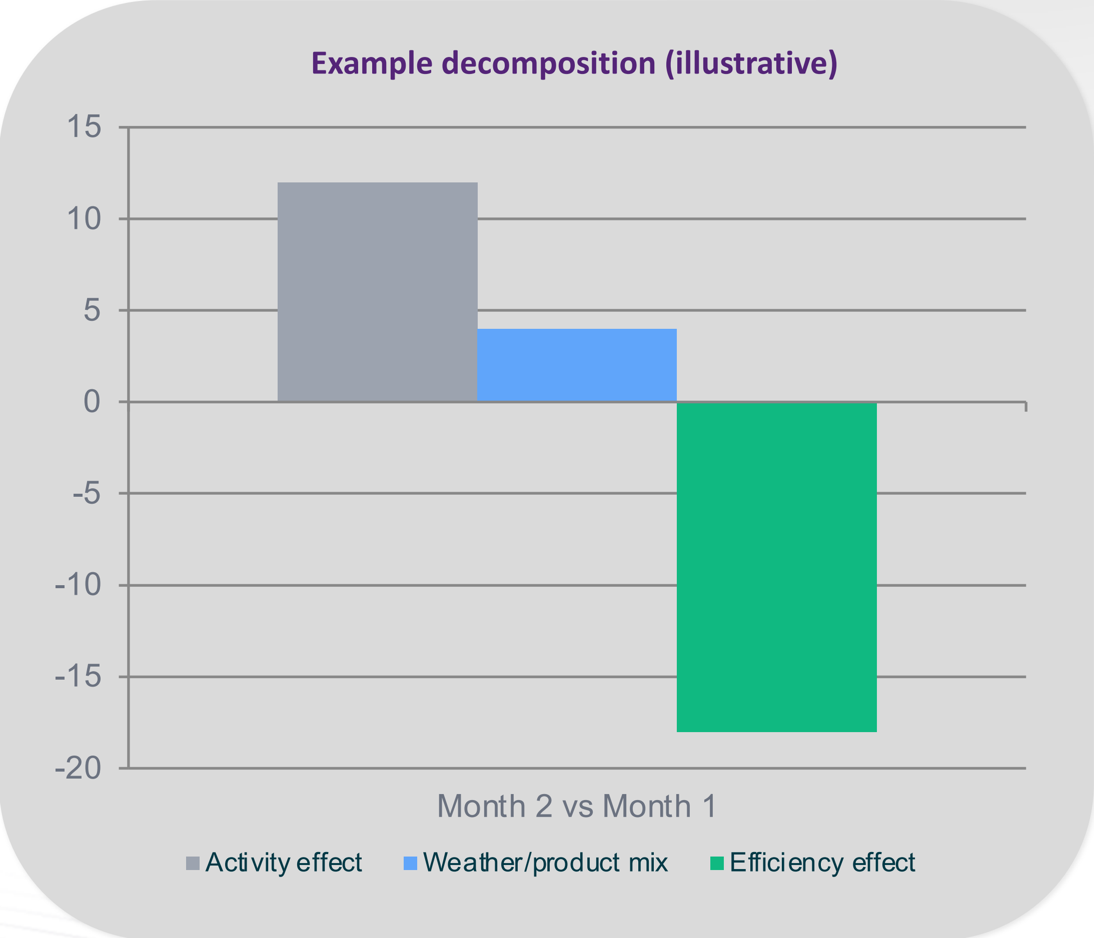
- Define expected operating range (control limits) from a stable period
- Investigate only when data crosses limits or shows abnormal patterns
- Reduces “alarm fatigue” at the analytics level (not only at sensors)
- Supports consistent decision-making across teams and sites

Practical rule: If a KPI is within stable limits, focus on sustained improvement projects—not daily firefighting.

Change attribution (what caused the change?)

Decompose the change

- Activity effect: production, hours, throughput (how much we operated)
- Efficiency effect: true performance change (how well we operated)
- Other factors: weather, product mix, quality constraints
- Use the baseline model to quantify each component



Top-down → drill-down root-cause workflow

Diagnose deviations systematically

Recommended workflow

1) Detect: deviation from baseline

2) Localize: which site/line/system?

3) Timebox: when did it start?

4) Segment: run/idle/shift/product

5) Correlate: what else changed (setpoints, pressure, temp, schedule)?

6) Confirm: field check or targeted measurement

7) Fix + verify + document

Best-period benchmarking (internal best practice)

Benchmark against “best achieved”

- Identify your best week/shift/batch under comparable conditions
- Treat it as an achievable reference, not a theoretical target
- Estimate potential: current performance – best-period performance
- Use it to motivate teams and define realistic improvement goals

Opportunity sizing from data (Data → Projects)

Turn insights into savings

- Quantify “idle energy” and estimate savings if reduced to best-practice levels
- Size leaks and drift: translate deviations into kWh and cost
- Express results with ranges (low / expected / high) and assumptions
- Prioritize by impact, feasibility, and operational risk

Performance comparison pack for management

Make it easy to decide

Recommended monthly pack

Slide 1: Executive summary (what changed, why it matters)

Slide 2: KPI/EnPI trends (normalized + raw totals)

Slide 3: Top deviations and drivers (segmented)

Slide 4: Opportunity pipeline (savings, owners, payback bands)

Slide 5: Decisions needed (approvals, resources, deadlines)

Common pitfalls (and how to avoid them)

- Comparing different product mixes or operating hours without adjustment
- Using too many drivers → models that cannot be explained or maintained
- Ignoring data quality (time sync, units, missing data) and trusting results anyway
- Chasing every fluctuation instead of using stability rules and thresholds
- Reporting insights without owners, actions, and verification steps

Summary

- Start with like-for-like rules and operating-state segmentation
- Normalize with the right drivers; keep models explainable
- Track improvement over time (deviation + accumulation) and use stability rules
- Attribute change, drill down efficiently, and quantify opportunities
- Package results for decisions: owners, actions, and verification

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Day 2
Audit Simulation Workshop

Workshop

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Day 3
Implementing Measures and Developing the Energy Management Plan

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Efficiency Measures Implementation

Module 10

Module outcomes

By the end, you can…

- Convert audit opportunities into scoped projects (deliverables + owners).
- Select measures for lighting, motors, and HVAC with a "no/low/capex" lens.
- Write clear specifications: performance, controls, and safety constraints.
- Plan commissioning and handover so savings persist.

Implementing Efficiency Measures on:

Lighting • Motors • HVAC

Turning audit findings into executable projects (scope, design, procurement, installation, commissioning, verification).

Lighting

Quality + safety first; then reduce watts and hours.

Motors

System efficiency beats motor-only thinking.

HVAC

Controls, schedules, and commissioning deliver fast wins.

Implementation Playbook

1) Define scope	2) Engineer solution	3) Procure	4) Install	5) Commission	6) Verify
Boundary • constraints • success metric	Design • controls • safety • specs	Vendor checks • submittals • QA	Method statement • LOTO • permits	Functional tests • tuning • training	Baseline • KPIs • evidence • closeout

What "good implementation" looks like

- Clear scope and success metric (energy + operational outcome).
- Controls and sequences documented — not left to "default settings".
- Commissioning checklist completed, signed, and archived.
- M&V evidence prepared (baseline, post data, assumptions).
- Handover includes roles, schedules, and maintenance updates.

Build a Portfolio (No/Low/CAPEX)

Quick wins (No/Low cost)

- Operating schedules, setpoints, and shutdown discipline.
- Controls tuning and sensor calibration.
- Maintenance fixes that recover performance (filters, leaks, alignment).
- Simple safeguards: lockable setpoints, standard operating procedures.

Investments (CAPEX)

- Retrofits/upgrades with documented specs and acceptance tests.
- Integration with BMS/SCADA where needed for persistence.
- Plan downtime and commissioning windows early.
- Use staged rollouts (pilot → scale) to reduce risk.

Rule of thumb: never approve a CAPEX measure without a commissioning + verification plan.

Lighting Measures

Where savings come from

- Lower installed power (efficient luminaires and drivers).
- Lower operating hours (controls + zoning + schedules).
- Better distribution (right light in the right place).
- Reduced over-lighting (target illuminance by task).

Typical scope (industrial)

- High-bay / low-bay luminaires in production & warehouse.
- Office lighting + corridors + meeting rooms.
- Outdoor lighting (yards, parking, perimeters).
- Emergency lighting (do not compromise compliance).

Lighting — Quick Wins (No/Low Cost)

No-cost / operational

- Switch-off discipline during breaks and non-production hours.
- Zoning: light only occupied areas (aisles vs racks, lines vs staging).
- Clean luminaires and diffusers; remove obstructions that block light.
- Fix “always-on” overrides and update the responsibility matrix.

Low-cost / controls

- Occupancy sensors for intermittent areas (stores, corridors, toilets).
- Daylight harvesting near windows/skylights.
- Time schedules for outdoor and office lighting.
- Delamping only where illuminance is above required levels (verify).

Lighting — Retrofit Planning

Retrofit steps

- Define target illuminance by task (not “one level everywhere”).
- Survey: fixture types, mounting heights, wiring, hazardous areas.
- Mock-up a pilot area and validate: lux, uniformity, glare, flicker.
- Finalize the bill of materials and installation method statement.
- Acceptance test: measurements + functional checks + documentation.

Specification checklist

- Efficacy and driver quality; compatible with local power quality.
- Ingress protection and temperature rating for the environment.
- Photometrics: beam angle, distribution, glare control.
- Color quality: CRI and CCT aligned with the workplace needs.
- Warranty, spares strategy, and maintainability.

Lighting — Controls & Commissioning

Control design

- Define zones to match operations (lines, aisles, safety routes).
- Choose sensor logic: occupancy, vacancy, or manual-on for offices.
- Set time delays thoughtfully (avoid nuisance switching).
- Define override policy and who can change settings.

Commissioning checklist

- Verify sensor coverage and setpoints (daylight thresholds).
- Test schedules, overrides, and emergency lighting operation.
- Record “as-built” zones, device IDs, and settings.
- Train supervisors and maintenance; define PM tasks.

Lighting — Verification (M&V)

Before / After evidence

- Document baseline: installed power, operating hours, control state.
- Collect “before” photos and a representative lux survey.
- After installation: repeat lux survey and functional tests.
- Confirm schedules and sensor settings are live (not bypassed).

Measurement options

- Simple: fixture count × rated watts × verified hours.
- Better: submeter the lighting panel(s) for 1–2 weeks pre/post.
- Ongoing: track hours-of-use and override events.
- Report: kWh, cost, and any operational impacts (comfort/safety).

Motor System Measures

System view

- The motor is rarely the whole story — controls and throttling matter.
- Highest value: optimize the load (pumps, fans, compressors, conveyors).
- Avoid running big motors lightly loaded for long periods.
- Measure run state and operating point before choosing upgrades.

Common motor-driven systems

- Pumps (process, chilled water, condenser water).
- Fans (AHUs, exhaust, cooling towers).
- Conveyors and material handling.
- Compressors and blowers.

Motors — Quick Wins (No/Low Cost)

No-cost / operational

- Stop idle motors and remove “always-run” habits where safe.
- Eliminate unnecessary throttling (valves/dampers) where possible.
- Reduce mechanical losses: alignment, belt tension, lubrication.
- Standardize start/stop logic to match production schedules.

Low-cost / reliability-linked

- Fix air leaks and pressure setpoints in pneumatic systems.
- Maintain filters and strainers to reduce pressure drop.
- Improve cooling/ventilation around motors and drives.
- Introduce simple condition checks (vibration/temperature).

Motors — When a VFD Makes Sense

Good candidates

- Variable-torque loads: fans, pumps, cooling towers.
- Systems currently controlled by throttling (valves/dampers).
- Frequent start/stop that causes mechanical stress.
- Need for tighter process control (flow/pressure/temperature).

Watch-outs

- Constant-torque loads may have limited savings.
- Harmonics and EMC: check power quality and filtering needs.
- Minimum speed constraints (cooling, lubrication, stall risk).
- Commissioning is essential: wrong tuning can waste energy.

Motors — Efficiency Upgrades (CAPEX)

Replacement strategy

- Prioritize high-run-hour motors and critical systems.
- Standardize frame sizes and spares to simplify inventory.
- Decide rewinding vs replacing (policy with quality controls).
- Capture nameplate and operating data before procurement.

Specification checklist

- Efficiency class and test standard as required by policy.
- Correct sizing for the operating point (avoid chronic underload).
- Compatibility with VFDs (insulation, bearings, cooling).
- Environmental requirements (IP rating, temperature, dust).

Motors — Monitoring & Verification

What to track

- Run hours and start/stop counts (operational discipline).
- kW profile and load factor for major motor groups.
- Flow/pressure/throughput drivers (so comparisons are fair).
- Condition indicators: vibration and temperature trends.

Verification approach

- Define baseline operating state (speed, valve position, schedule).
- Use like-for-like periods and normalize by the right driver.
- Document control setpoints and VFD parameters post-commissioning.
- Create an exception list: when the measure is bypassed and why.

HVAC Measures

Key energy drivers

- Schedules and occupancy (hours matter as much as capacity).
- Temperature and humidity setpoints; deadbands.
- Ventilation rates and outside air strategy.
- Heat rejection and plant efficiency (chillers/condensers).

Typical HVAC scope

- Air handling units and fans (supply/return/exhaust).
- Chilled water systems (chillers, pumps, cooling towers).
- Packaged units / split systems (as applicable).
- Controls, sensors, and sequences (BMS/standalone).

HVAC — Quick Wins (No/Low Cost)

No-cost / operational

- Align schedules with real occupancy; eliminate after-hours drift.
- Setpoints and deadbands: avoid “heating and cooling fight”.
- Lock critical setpoints and document change control.
- Improve housekeeping: doors, leaks, and infiltration control.

Low-cost / control tweaks

- Economizer and free cooling (where conditions allow).
- Demand-controlled ventilation for variable occupancy spaces.
- Static pressure reset and supply-air temperature reset.
- Sensor calibration and replacing failed actuators.

HVAC — Upgrade Measures (CAPEX)

Fans, pumps, and distribution

- VSDs on variable loads (air and water).
- Duct and pipe insulation; reduce leaks and pressure drop.
- High-efficiency filters with optimized replacement strategy.
- Heat recovery where exhaust energy is significant.

Plant-level measures

- High-efficiency chillers or staged capacity where appropriate.
- Cooling tower performance improvements (water management).
- Chilled water temperature optimization (within constraints).
- Controls integration for sequencing and optimal staging.

HVAC — Commissioning & Handover

Commissioning checklist

- Verify sensors (temperature, humidity, pressure) and calibration dates.
- Test sequences: start/stop, resets, economizer, staging, alarms.
- Confirm airflow and water balancing (TAB) where applicable.
- Record setpoints, schedules, and trend logs as the "as-built".
- Train operators: what to change, what not to touch, and why.

Verification & persistence

- Define baseline periods and normalize for weather and occupancy.
- Track KPIs (kW, kWh, temperature compliance, run hours).
- Use exception tracking: overrides, maintenance mode, failures.
- Schedule a 30–60–90 day re-tuning after handover.

Project Implementation Template

Scope

- Boundary & assets
- Constraints
- Success metric

Plan

- Timeline & downtime
- Safety/permits (LOTO)
- Roles & owners

Execute

- Install method
- QA checks
- Commissioning tests

Verify

- Baseline
- Post data
- Closeout report

Tip: Use the same template for lighting, motors, and HVAC so decisions are comparable.

Measurement & Verification (M&V) Plan

Define baseline

- What period represents “normal”? (production, weather, schedules)
- What data sources are trusted? (meters, logs, BMS trends)
- What drivers must be tracked for fairness? (tons, hours, temp)
- Document assumptions and exclusions clearly.

Verify & report

- Collect post-implementation data for an agreed duration.
- Compare like-for-like states (RUN/IDLE, shift, occupancy).
- Record exceptions and bypasses; update the opportunity register.
- Publish a short closeout note with evidence attachments.

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Role of Building Management Systems and Automation

Module 11

Role of BMS, EMS & SCADA

- Three systems, three purposes: **control, visibility, and governance**
- Best results come from **integration**, not isolated tools
- Goal: **stable operations + lower energy + measurable performance**

Why These Systems Exist

- **Operations need control** (real-time actions)
- **Management needs accountability** (KPIs, targets, reporting)
- **Engineering needs traceability** (events, trends, root cause)

What is BMS (Building Management System)

- Monitors and controls **building services**
- Typical scope: **HVAC, lighting, ventilation, pumps, alarms**
- Strength: **setpoints, schedules, sequences, comfort control**
- Output: trends, alarms, basic reporting

What is SCADA

- Supervisory control for **industrial processes**
- Typical scope: **process equipment, utilities, PLCs, interlocks**
- Strength: **real-time process supervision + operational safety**
- Output: alarms, historian trends, operator screens (HMI)

What is EMS (Energy Management System)

- Energy-focused layer: **metering + analytics + KPIs + reporting**
- Turns raw data into **EnPIs, baselines, deviations, savings**
- Supports **audit, verification, and continuous improvement**
- Bridges operations and management with **decision-ready insights**

Quick Comparison (BMS vs EMS vs SCADA)

Item	BMS	SCADA	EMS
Primary role	Building services control	Process supervision/control	Energy performance management
Typical users	Facilities / HVAC techs	Operators / process engineers	Energy team / management
Time scale	seconds–minutes	milliseconds–seconds	minutes–monthly
Best at	schedules, setpoints	process alarms/interlocks	KPIs, baselines, savings
Outputs	comfort & runtime control	safe stable operation	decisions, reports, M&V

Data Types and Granularity

- **BMS**: temps, setpoints, valve positions, fan speeds (often 1–5 min)
- **SCADA**: flows, pressures, motor states, batch events (sec or faster)
- **EMS**: meters (kWh/kW), cost, production drivers (15-min to daily)

Control vs Management: Where Decisions Live

- Control decisions: **BMS/SCADA** (setpoint, sequence, interlocks)
- Management decisions: **EMS** (targets, deviations, project prioritization)
- Integration makes a loop: **Detect (EMS)** → **Act (BMS/SCADA)** → **Verify (EMS)**

Alarm Management Across Systems

- **BMS/SCADA alarms:** operational and safety events
- **EMS alerts:** performance deviations and abnormal consumption
- Reduce noise: state-based alarms + clear owners + SLAs
- Close the loop: alert → action → verification

Governance: Setpoints, Changes, Accountability

- Setpoint authority: who can change what
- Change log: thresholds, schedules, KPI formulas
- Standard operating procedures (SOPs) for overrides
- Monthly performance review cadence

Cyber & Reliability (Simple Rules)

- OT/IT segmentation + least privilege
- Prefer **read-only** data links to EMS
- Backups, redundancy, and time synchronization
- Documented recovery plan

Practical Roadmap (From Zero to Mature)

- Phase 1: stabilize BMS/SCADA basics (schedules, sequences, historian)
- Phase 2: EMS KPIs + baselines + deviation reporting
- Phase 3: closed-loop workflow (alerts→work orders→verification)
- Phase 4: optimization and continuous commissioning

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Energy Management Plan

Module 12

Energy Management Plan: What and Why

- A practical roadmap to improve energy performance
- Links **audit findings → measures → responsibilities → tracking**
- Turns “ideas” into **owned actions with timelines**

Plan Structure (One-Page View)

- Policy / commitment (leadership)
- Baseline + EnPIs
- Targets and objectives
- Action plan (projects + operational controls)
- Monitoring, review, and continual improvement

Step 1: Define Scope and Boundaries

- Define boundary: site / building / process line
- Identify energy types (electricity, fuel, steam…)
- Clarify constraints: safety, quality, production, compliance
- Assign the plan owner and governance

Step 2: Build the Energy Baseline

- Select baseline period (e.g., last 12 months)
- Ensure data quality and consistency
- Normalize when needed (production, hours, weather)
- Baseline = reference for proving improvement

Step 3: Define EnPIs (Energy Performance Indicators)

- Choose indicators aligned with the business:
  - kWh/ton, kWh/unit, kWh/m³, kWh/m²
- Include demand-related indicators when relevant:
  - Peak kW, load factor
- Keep EnPIs simple, measurable, and owned

Step 4: Identify SEUs and Key Drivers

- Identify Significant Energy Users (SEUs)
- Determine drivers: production, schedules, setpoints, maintenance condition
- Prioritize SEUs by impact + controllability

Step 5: Set Objectives and Targets

- Objectives: direction (e.g., improve SEC, reduce peaks)
- Targets: measurable and time-bound
- Example: reduce SEC by 4% by Q4
- Align targets with constraints and budget

Step 6: Build the Action Plan (Core Slide)

For each Action plan:

•Description + system (lighting/motors/HVAC/process)

•Owner + due date

•Expected savings (kWh, SAR)

•Resources (CAPEX/OPEX, shutdown)

•M&V method (how we will verify)

Monitoring and Reporting Cadence

- Daily/weekly operational checks for SEUs
- Monthly KPI review (EnPIs vs baseline)
- Exception reporting: deviations, top drivers, actions
- Management review: decisions and resource approvals

Risk, Dependencies, and Change Management

- Production constraints and shutdown windows
- Supplier lead times and commissioning needs
- Safety and compliance requirements
- Risk register for high-impact actions

Roles and Governance (RACI)

- Sponsor (leadership): approve resources
- Energy manager/team: planning, tracking, reporting
- Operations: implement and sustain controls
- Maintenance: reliability + verification support
- Finance: validate savings and investment logic

Plan Template (What to Produce)

- 1-page summary (scope, targets, KPIs)
- Action plan register (projects list)
- Metering / monitoring map for SEUs
- Monthly performance report format

KPIs, ROI & Action Plans

Module 13

KPIs, ROI & Action Plans: Turning Ideas into Decisions

- Define the right **KPIs/EnPIs**
- Quantify value with **ROI and payback**
- Build an **action plan** that gets implemented and verified

KPI Selection Rules (Keep it Useful)

- Relevant to business goals
- Measurable with available data
- Sensitive to improvement actions
- Simple to explain and repeat monthly
- Owned (someone is accountable)

Core Energy KPIs/EnPIs (Recommended Set)

- Total energy (kWh) and **energy cost (SAR)**
- **SEC**: kWh/ton (or kWh/unit)
- **Peak demand (kW)** and **load factor**
- SEU KPIs: HVAC kWh, Compressed Air kWh, Process kWh
- Idle / no-production energy %

Baseline and Normalization (Fair Measurement)

- Baseline period (e.g., last 12 months)
- Normalize by key drivers: production, hours, weather
- Define comparison rules: like-for-like
- Document assumptions

KPI Governance (So Numbers Don’t Change Every Month)

- KPI definition sheet: formula, units, data source, frequency
- Data owner and approver
- Change control for formulas and thresholds
- Versioning + audit trail

ROI Basics for Energy Projects

- Annual savings = (kWh saved × tariff) + demand savings (if applicable)
- **Simple payback** = CAPEX / annual savings
- ROI is not only money: reliability, downtime reduction, compliance

Cost Elements You Must Not Forget

- CAPEX: equipment, installation, commissioning
- OPEX: maintenance, consumables, calibration
- Production impact: shutdown time, productivity risk
- Lifetime and degradation (persistence)

Payback Bands (Decision-Friendly)

- No/Low cost actions: target payback **< 6 months**
- Medium projects: **6–24 months**
- Strategic CAPEX: **> 24 months** (needs stronger business case)
- Use prioritization: savings + ease + risk

Example (Simple ROI Calculation)

•Current: Motor runs 6,000 h/year at 30 kW average

•Improvement: save 10% energy

•Savings = 30 × 6,000 × 10% = 18,000 kWh/year

•Cost savings = 18,000 × tariff

•Payback = CAPEX / annual savings

Action Plan Structure (What Makes it Executable)

Each action must include:

- Scope/system + description
- Owner + due date
- Expected savings (kWh/SAR) + CAPEX/OPEX
- Dependencies + risks
- Verification method (M&V)
- Status tracking

Prioritization Matrix (Fast and Clear)

- Impact (SAR/year) vs effort/complexity
- Add risk filter: safety, quality, downtime
- Build a 3-tier roadmap:
  - Quick wins
  - Mid-term improvements
  - Strategic investments

Verification (How to Prove Savings)

- Define boundary for each action
- Before/after with normalization (if needed)
- Evidence: meter trends, logs, work orders
- Persistence check after 30–60 days

Monthly Reporting Pack (5 Slides)

1. Executive summary (wins + issues)
2. KPIs vs baseline/target
3. Top deviations and drivers
4. Project progress + ROI tracking
5. Decisions required (resources, approvals)

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