ECO PHARMA

Energy & Resource Efficiency • Process & Utility Optimization
• Waste Valorization

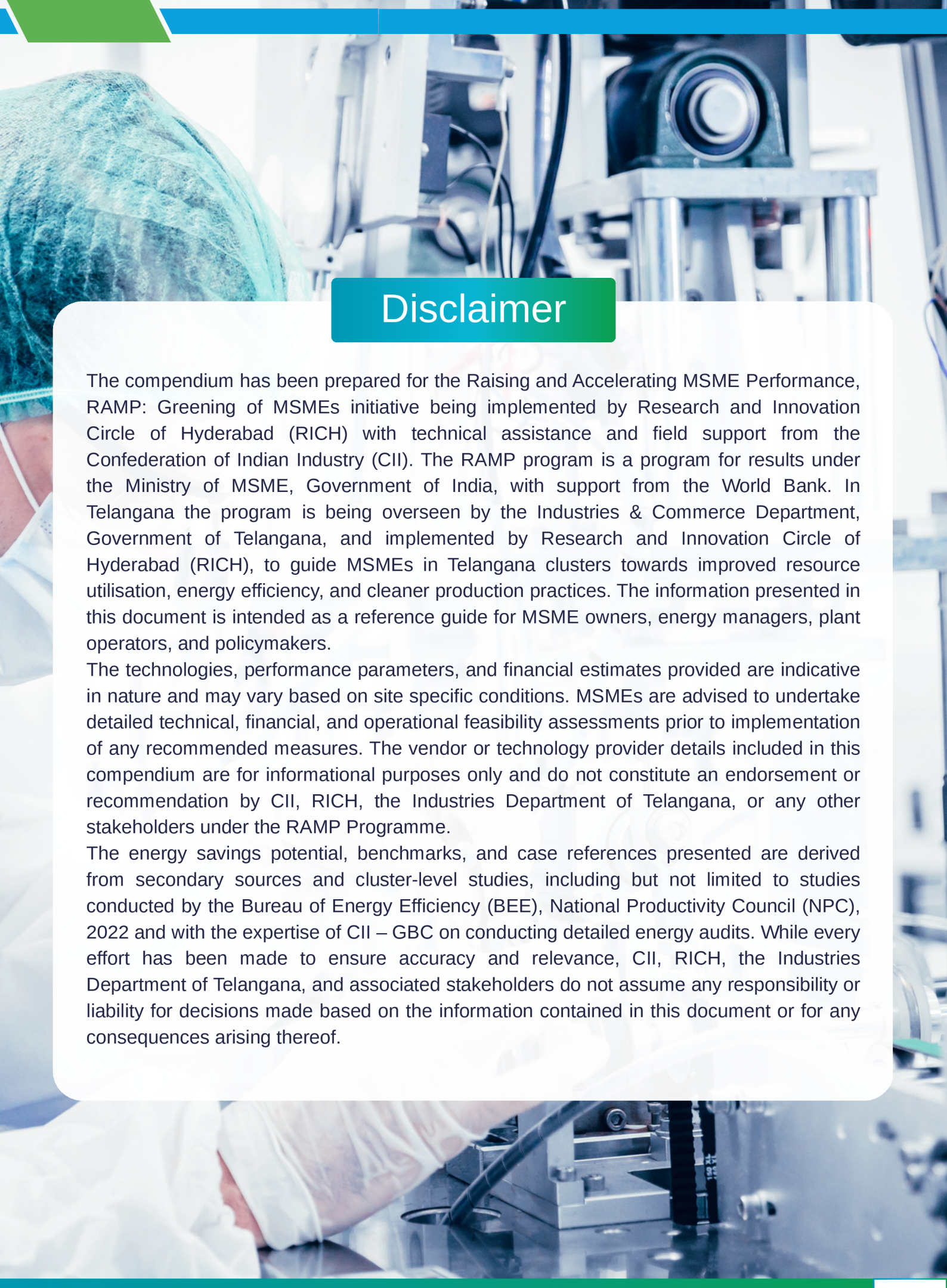
Compendium of Clean Technologies and Use Cases for Resource Efficiency & Cleaner production



Prepared by CII for Research and Innovation Circle of Hyderabad (RICH) as part of the RAMP Telangana Greening of MSME Initiative

May 2026

Confederation of Indian Industry



Disclaimer

The compendium has been prepared for the Raising and Accelerating MSME Performance, RAMP: Greening of MSMEs initiative being implemented by Research and Innovation Circle of Hyderabad (RICH) with technical assistance and field support from the Confederation of Indian Industry (CII). The RAMP program is a program for results under the Ministry of MSME, Government of India, with support from the World Bank. In Telangana the program is being overseen by the Industries & Commerce Department, Government of Telangana, and implemented by Research and Innovation Circle of Hyderabad (RICH), to guide MSMEs in Telangana clusters towards improved resource utilisation, energy efficiency, and cleaner production practices. The information presented in this document is intended as a reference guide for MSME owners, energy managers, plant operators, and policymakers.

The technologies, performance parameters, and financial estimates provided are indicative in nature and may vary based on site specific conditions. MSMEs are advised to undertake detailed technical, financial, and operational feasibility assessments prior to implementation of any recommended measures. The vendor or technology provider details included in this compendium are for informational purposes only and do not constitute an endorsement or recommendation by CII, RICH, the Industries Department of Telangana, or any other stakeholders under the RAMP Programme.

The energy savings potential, benchmarks, and case references presented are derived from secondary sources and cluster-level studies, including but not limited to studies conducted by the Bureau of Energy Efficiency (BEE), National Productivity Council (NPC), 2022 and with the expertise of CII – GBC on conducting detailed energy audits. While every effort has been made to ensure accuracy and relevance, CII, RICH, the Industries Department of Telangana, and associated stakeholders do not assume any responsibility or liability for decisions made based on the information contained in this document or for any consequences arising thereof.



Acknowledgement

This compendium has been developed as part of the Greening of MSMEs in Telangana under RAMP Programme to conduct Resource Efficiency and Cleaner Production (RECP) Assessments and implement measures in MSMEs from Telangana state.

The Confederation of Indian Industry (CII) gratefully acknowledges the guidance, support, and contributions of the following stakeholders:

- Ministry of MSME, Government of India, for extending strategic direction and support under the RAMP Programme
- Industries & Commerce Department, Government of Telangana, for facilitating implementation and enabling ecosystem support within the State
- Research and Innovation Circle of Hyderabad (RICH), for driving innovation-led approaches to MSME ecosystem in Telangana
- World Bank, for financial and technical support to the RAMP Programme
- Industry associations and sector bodies for domain knowledge and sectoral inputs
- Local technology providers, service providers, and MSME units across Telangana, for their active participation, data sharing, and practical insights during assessments

Table of Contents

Executive Summary....7
Key Findings....7
Technology Attractiveness Summary....7
1. Indian Pharmaceutical Sector....9
1.1 Background....9
1.2 Pharma Sector Growth and Revenue....11
1.3 Telangana Pharma Cluster....11
1.4 About the RAMP Project....12
2. Pharma Manufacturing Processes and Energy Consumption....13
2.1 Overview of Pharmaceutical Manufacturing Processes....13
2.2 Energy Consumption in MSME Pharma Units....15
3. RECP Opportunities in Pharmaceutical Manufacturing....16
3.1 Introduction to RECP in Pharmaceutical Manufacturing....16
3.2 Major Resource Consumption Areas in Pharmaceutical Sector....16
4. RECP – Technology Case Studies and Opportunities....18
Energy Efficiency Case Studies:....19
Case Study 1: Conversion of HSD/LDO-fired Boiler to Biomass/Briquette-fired Boiler....19
Case Study 2: Steam Operated Pumping Traps (SOPT)....21
Case Study 3: Steam Driven Heat Pump (VAM)....23
Case Study 4: Variable Frequency Drive (VFD) for Screw Chiller Compressor....25
Case Study 5: De-Superheater for Chiller Compressors....27
Case Study 6: kVAr Energy Compensator for Chiller Compressor....29
Case Study 7: VFD for Chilled Water Pumps....31
Case Study 8: Evaporative Condenser....33
Case Study 9: Electronically Commutated (EC) Motors for AHUs....35
Case Study 10: Online Condenser Cleaning System....37
Case Study 11: Replace 3-Port with 2-Port Valves in AHUs + VFD for Chilled Water Pump....39
Case Study 12: Active Refrigerant Agent Addition in Lube Oil for Chillers....41
Case Study 13: Optimize Chilled Water Pumping System....43
Case Study 14: Usage of high energy efficient Magnetic Bearing chillers (Oil-free Centrifugal chillers)....45
Case Study 15: VFD for Air Compressor....46
Case Study 16: Energy Efficient Pumps....48
Case Study 17: Replacement of HP Compressor with LP Compressor....50
Case Study 18: Usage of Heat Pumps to generate hot water....52
Case Study 19: IoT-based Energy Management System....53
Material Efficiency & Yield Improvement Opportunities:....55
Case Study 20: Organic Solvent Nanofiltration (OSN) for Solvent Recovery....55
Case Study 21: Automated Dry Granulator (Roll Compactor) replacing Manual Compactor....57
Case Study 22: Rotary Vacuum Paddle Dryer (RVPD) replacing Vacuum Tray Dryer + Blender....58

Table of Contents

Case Study 23: Automated Reactor Auto-sampler System....59
Case Study 24: Agitated Nutsche Filter Dryer (ANFD) replacing centrifuge + dryer....60
Water Conservation & Circularity Opportunities/Case studies:....61
Case Study 25: Condensate Recovery System....61
Case Study 26: IoT-based Water Management System....63
Renewable Energy Opportunities/Case studies:....65
Case Study 27: Grid-Connected Solar Rooftop PV System....67
Case Study 28: Solar-Wind Hybrid System....69
5. Water and Waste Management....69
5.1 Water Management....69
5.2 Effluent Treatment and ZLD....69
5.3 Solvent Recovery....70
5.4 Waste Management – Usage in Cement plants as Alternate Fuel Resource (AFR) – A case study....71
6. Financial Mechanisms and Support Schemes....74
7. Energy Benchmarks and Key Performance Indicators....74
7.1 National Benchmarks for MSME Pharma Units....75
8. Conclusion and Roadmap....75
8.1 Summary....75
8.2 Recommended Priority Actions....75
8.3 Implementation Roadmap....75
Bibliography and References....76

List of Abbreviations

AHU	Air Handling Unit
API	Active Pharmaceutical Ingredient
APFC	Automatic Power Factor Controller
BEE	Bureau of Energy Efficiency
BEP	Best Efficiency Point
BLDC	Brushless Direct Current
CAGR	Compound Annual Growth Rate
CII	Confederation of Indian Industry
COP	Coefficient of Performance
EE	Energy Efficiency
ETP	Effluent Treatment Plant
FBC	Fluidized Bed Combustion
GEF	Global Environment Facility
GHG	Greenhouse Gas
HVAC	Heating, Ventilation and Air Conditioning
IPLV	Integrated Part Load Value
IoT	Internet of Things
IRR	Internal Rate of Return
LED	Light Emitting Diode
MSME	Micro, Small and Medium Enterprises
NPC	National Productivity Council
NPV	Net Present Value
O&M	Operation and Maintenance
PISS	Pashamylaram Industrial Services Society
PV	Photovoltaic
RAMP	Raising and Accelerating MSME Performance
RE	Renewable Energy
RECP	Resource Efficient and Cleaner Production
SEC	Specific Energy Consumption
TOE	Tons of Oil Equivalent
TR	Tons of Refrigeration
UNIDO	United Nations Industrial Development Organization
VFD	Variable Frequency Drive
VVR	Variable Volume Ratio
WHR	Waste Heat Recovery

Executive Summary

The Telangana pharmaceutical cluster is one of the largest MSME pharma hubs in India, with over 523 registered units concentrated primarily in the Hyderabad-Medak belt, covering industrial areas such as Pashamylaram, Bollaram, Jeedimetla, IDA Nacharam, Genome valley, and Patancheru. Under the RAMP Project (Raising and Accelerating MSME Performance), CII – GBC is conducting 2,000 Resource Efficient and Cleaner Production (RECP) assessments across Telangana MSMEs, of which the pharma sector is a key focus area.

This Technology Compendium has been prepared to serve as an actionable guide for energy managers, plant heads, and policymakers in the Indian pharma sector. It consolidates proven resource-efficient and cleaner production technologies applicable to MSME pharmaceutical manufacturing units, structured around four critical systems: Energy Efficiency Opportunities, Material Efficiency & Yield Improvement, Water Management and Renewable Energy.

Based on the BEE-NPC national energy mapping study (2022), the Telangana pharma cluster consumes approximately 1,402 GWh of electrical energy and 7.9 T kcal of thermal energy annually. Chillers constitute about 50% of total electrical consumption, followed by pumping systems (26%), compressed air (11%), and AHUs (4%). Thermal energy is predominantly met through boilers (solid and liquid fuel fired).

Key Findings

Energy costs in MSME pharma units typically constitute 10-20% of total manufacturing costs. Analysis of the cluster reveals significant gaps between current energy performance and benchmark levels:

System	Current SEC	Benchmark SEC	EE Potential
Chiller (+5°C)	1.27 kW/TR	0.60 kW/TR	**~53%**
AHU	1.02 W/CFM	0.25 W/CFM	**~75%**
Air Compressor	0.18 kW/CFM	0.15 kW/CFM	**~25%**
Pumps (efficiency)	~50%	>70%	**~40%**
Vacuum Pumps	44.14 kWh/1000m³	30 kWh/1000m³	**~32%**
Boiler (thermal eff.)	~62%	>80%	**~18%**

Note: *Source: BEE-NPC Energy and Resource Mapping of MSME Clusters - Pharma Sector, February 2022.*

Overall, the national MSME pharma sector has demonstrated potential for around 24% reduction in electrical energy consumption and 16% reduction in thermal energy consumption through technology upgrades. For the Telangana cluster with 523 units, this translates into substantial monetary savings and GHG emission reductions.

The compendium includes 28 detailed technology case studies across steam, refrigeration, utilities, renewable energy, and cleaner production categories. Each case study covers the baseline scenario, proposed technology, technical and financial feasibility, energy and GHG savings, and vendor details.

Technology Attractiveness Summary

S.No	Technology	IRR (%)	Payback (Months)	Investment (INR Lakh/TOE)
1	Biomass/Briquette-fired Boiler	>150%	9-12	Low
2	Condensate Recovery System	>250%	4-6	0.3
3	Steam Trap Monitoring & Replacement	>200%	6-12	0.2
4	VFD for Chiller Compressor	73-90%	18-24	1.2
5	Evaporative Condenser	60-70%	24-30	1.7
6	EC Motors for AHUs	85-90%	18-22	1.1
7	Online Condenser Tube Cleaning	48-55%	30-36	2.2
8	VFD for Air Compressor	>120%	11-14	0.6
9	IE3 Energy Efficient Pumps with VFD	65-70%	17-20	0.6
10	Solar Rooftop PV System	18-22%	54-60	3.5
11	IoT-based Energy Management System	>150%	8-12	Low
12	LED Lighting with Smart Controls	>100%	12-18	Low

Note: *Financial parameters are indicative and based on Cluster Compendium (UNIDO-BEE-CII – GBC, 2020) and NPC Benchmarking Report (2022). Actual values depend on plant-specific parameters, equipment sizing, and prevailing market rates*

Technology Attractiveness Matrix

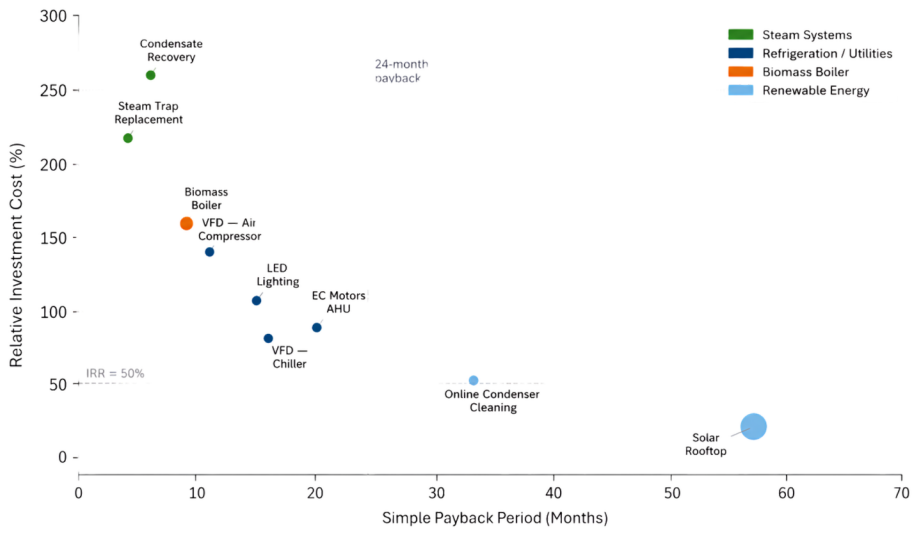


Figure 1: Technology Attractiveness Matrix for RECP measures

1. Indian Pharmaceutical Sector

1.1 Background

India is the world's largest supplier of generic medicines, accounting for approximately 20% of global generic drug exports by volume. The Indian pharmaceutical industry, valued at over USD 50 billion (as on 2023-24), is the third – largest in volume and fourteenth – largest in value globally. India supplies more than 50% of global vaccine requirements and fulfils about 40% of the United States' generic drug demand. The industry contributes approximately 1.72% of India's GDP and employs over 2.7 million people directly.

Table 1: Pharmaceutical Units by State - India (Top States)

State	*No. of Registered Pharma Units*	*Key Clusters*
Gujarat	3332	Ahmedabad, Vapi, Ankleshwar, Baroda
Maharashtra	929	Pune, Mumbai, Aurangabad, Thane
Tamil Nadu	514	Chennai, Mical, Tiruvallur
Telangana	**523**	**Hyderabad, Medak, Pashamylaram**
Himachal Pradesh	555	Baddi
Uttar Pradesh	408	Kanpur
Karnataka	376	Bengaluru, Bidar
West Bengal	180	Kolkata
Uttarakhand	220	Haridwar
Andhra Pradesh	261	Visakhapatnam, Parwada

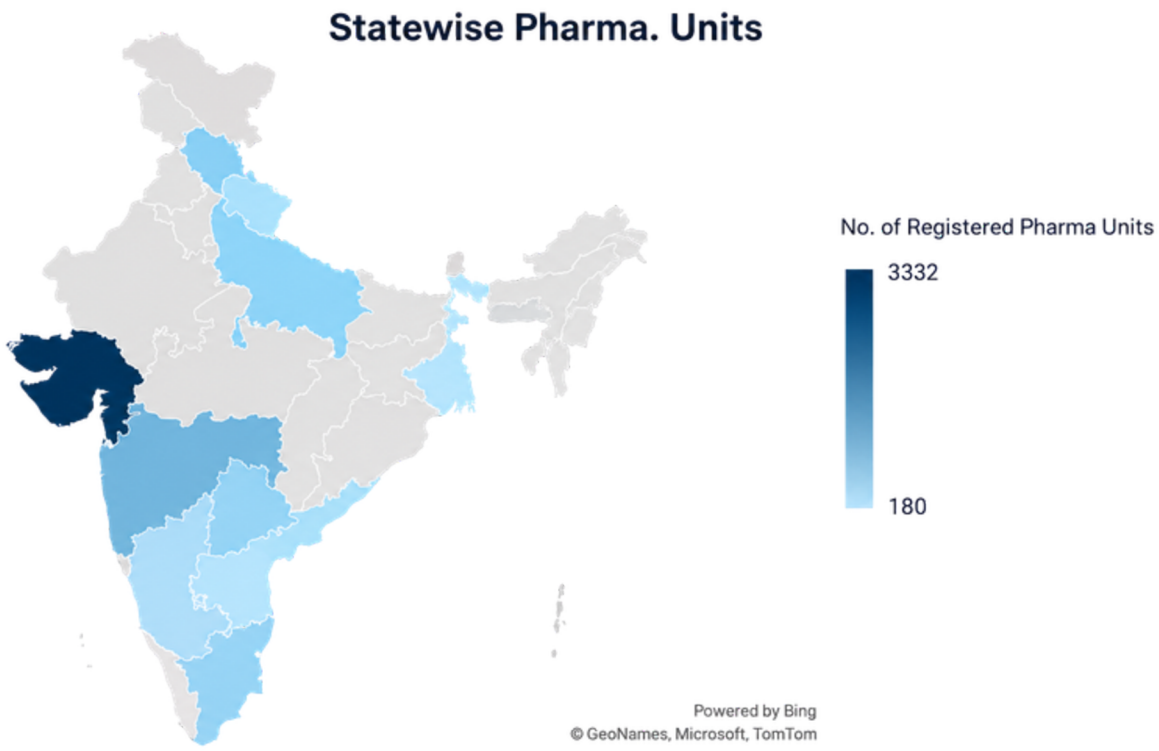


Figure 2: State-wise Pharma. units in India (Top 5)

Note: *Source: BEE-NPC Energy and Resource Mapping of MSME Clusters - Pharma Sector, February 2022*

The pharmaceutical sector in India is broadly divided into bulk drug (Active Pharmaceutical Ingredient / API) manufacturing and formulation. Formulation units, which dominate the MSME space, produce tablets, capsules, syrups, injectables, ointments, and other dosage forms. The sector is governed by the Ministry of Chemicals and Fertilizers (Department of Pharmaceuticals) and is regulated by the Central Drugs Standard Control Organisation (CDSCO) and respective State Drugs Control Authorities.

Note: *Source: Indian Brand Equity Foundation (IBEF) Pharmaceuticals Sector Report, 2024; Department of Pharmaceuticals, GoI, Annual Report 2023-24.*

1.2 Pharma Sector Growth and Revenue

India's domestic pharmaceutical market has grown consistently at a Compound Annual Growth Rate (CAGR) of approximately 10-12% over the past decade. The market size has grown from USD 33 billion in 2017 to over USD 50 billion in 2023-24, with exports contributing significantly. The Indian pharma sector aims to reach USD 130 billion by 2030, as per the pharmaceuticals sector vision document of the Department of Pharmaceuticals.

Table 2: Indian Pharma sector metrics

Pharmaceutical Sector	
Global rank (volume)	3rd
Global rank (value)	11th
Generic export share	20% of global
Vaccine supply share	>50% of global
Export markets	191 countries
Manufacturing units	10,500+
2030 target (PIB)	$130B

1.3 Telangana Pharma Cluster

Telangana is home to one of India's most significant pharmaceutical manufacturing clusters, particularly in the Hyderabad-Medak industrial corridor. With over 523 registered pharma units (as per BEE-NPC data (2022)), the cluster ranks among the top five states in the country by number of pharma units, alongside Gujarat, Maharashtra, Tamil Nadu, and Himachal Pradesh.

The major industrial areas housing pharma units in Telangana include:

- Pashamylaram Industrial Area (Medak District) - one of the largest dedicated pharma zones in South India
- Bollaram and Jeedimetla Industrial Area (Hyderabad)
- IDA Nacharam (Hyderabad)
- Patancheru Industrial Area (Sangareddy District)
- Bonthapally and Gaddapotharam (Yadadri Bhongir and Medak Districts)
- Genome Valley (Medchal - Malkajgiri district)

The cluster produces a wide range of formulations including tablets, capsules, liquid orals, injectables, ointments, and APIs. Major industry associations active in the cluster include the Pashamylaram Industrial Services Society (PISS), Bulk Drugs Manufacturers Association (BDMA), and the Indian Drug Manufacturers Association (IDMA).

The Telangana State Government, through the Telangana Industrial Health Clinic (TIHCL) and TS-iPASS (Telangana State Industrial Project Approval and Self Certification System), has been facilitating MSME growth and compliance in the pharma sector. The Telangana Pharma City at Mucherla, envisaged as a world-class pharma manufacturing hub, is expected to further strengthen the cluster's position nationally and globally.

1.4 About the RAMP Project

The RAMP (Raising and Accelerating MSME Performance) project is a Government of India initiative supported by a World Bank loan, aimed at improving the performance and competitiveness of MSME enterprises across India. Under the RAMP project, CII – GBC – GBC (Confederation of Indian Industry – Green Business Centre) has been engaged to conduct 2,000 RECP (Resource Efficient and Cleaner Production) assessments across MSME units in Telangana, spanning multiple sectors including pharmaceuticals, textiles, food processing, engineering, chemicals etc.

The RECP assessments involve detailed on-site evaluation of energy consumption, water usage, material efficiency, and waste generation, followed by identification and recommendation of technically and financially feasible improvement measures. This technology compendium is prepared as a cluster-level reference tool to support the RECP assessments in the pharma sector, enabling assessors, energy auditors, and plant teams to identify, evaluate, and implement suitable technologies with greater speed and accuracy.

2. Pharma Manufacturing Processes and Energy Consumption

2.1 Overview of Pharmaceutical Manufacturing Processes

MSME pharma units in India are engaged in formulation plant, with some units also engaged in API synthesis and intermediate production. The manufacturing processes vary by product type (solid, liquid, semi-solid, and sterile dosage forms) but share common unit operations and utility requirements. Key manufacturing processes for API manufacturing and formulations include:



Formulation Plant — Process Flow (Solid dosage Tablet)

Incoming
- Receipt of API & Excipients
- Incoming QC Testing

Dispensing
- Weighing & Dispensing
- Sifting & De-lumping

Granulation



Lubrication and Blending
- Drying, Granule Milling & Sizing
- Lubrication & Final Blending

Coating
- Tablet Compression
- De-dusting & Metal Detection

Packing
- Bulk Finished Product QC Testing
- Primary Packing
- Secondary Packing and Labeling

QA Release
- Finished Product QC & Stability Sample
- QA Batch Review & Release
- Finished Goods Warehouse & Dispatch

Utilities System
Boilers (Steam), Chillers, Compressed Air system, AHUs, ETP

2.2 Energy Consumption in MSME Pharma Units

Energy in pharma units is consumed in two primary forms: electrical energy and thermal energy (steam/hot water via boilers). The BEE-NPC energy mapping study (2022) reveals the following distribution of electrical energy consumption in MSME pharma units at the national level:

S.No	Energy System / Utility	Annual Consumption (GWh)	Share (%)
1	Chillers	11,322	**50%**
2	Air Handling Units (AHUs)	833	**4%**
3	Air Compressors	2,537	**11%**
4	Pumps	5,896	**25%**
5	Vacuum Pumps	417	**2%**
6	Others (lighting, drives, miscellaneous)	1,868	**8%**
Total		**22,873 GWh/year**	**100%**

Note: *Source: BEE-NPC, Energy and Resource Mapping of MSME Clusters - Pharma Sector, February 2022. National-level data; representative of Telangana cluster profile.*

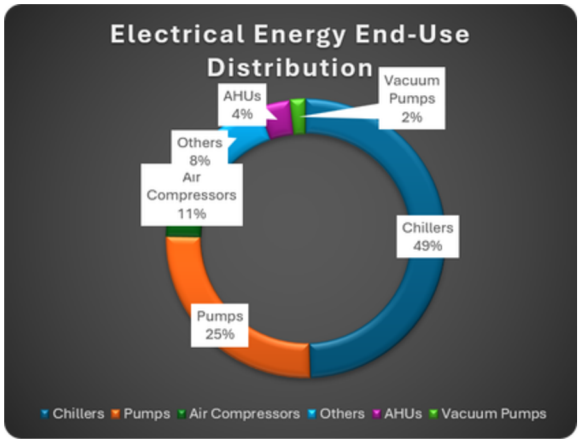


Figure 3: Electrical Energy share across Utilities in Pharma. sector

For Telangana specifically, the cluster of 523 units consumes approximately 1,402 GWh of electrical energy per year (equivalent to 1,20,582 TOE) and approximately 7.9 T kcal of thermal energy annually (790,669 TOE). Energy costs typically constitute 10-20% of total manufacturing costs in MSME pharma units, making energy efficiency a critical lever for competitiveness.

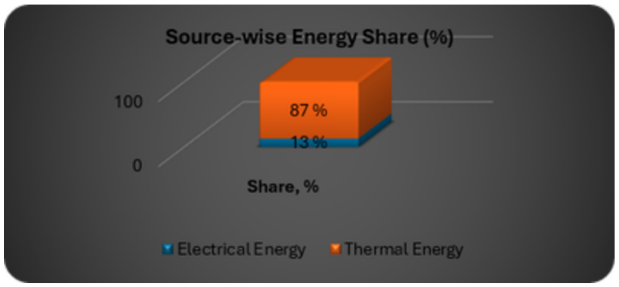


Figure 4: Energy share of Telangana Pharma. sector

3. RECP Opportunities in Pharmaceutical Manufacturing

3.1 Introduction to RECP in Pharmaceutical Manufacturing

Resource Efficient and Cleaner Production (RECP) is an integrated preventive environmental strategy aimed at improving resource productivity, minimizing waste generation, and reducing environmental impacts while enhancing operational efficiency and competitiveness. Unlike conventional pollution control approaches that focus mainly on end-of-pipe treatment, RECP emphasizes optimization at the source through efficient utilization of energy, water, raw materials, chemicals, and utilities across the manufacturing process.

For MSME pharmaceutical industries, RECP offers significant opportunities to improve productivity, reduce operating costs, strengthen environmental performance, and enhance long-term sustainability and competitiveness.



3.2 Major Resource Consumption Areas in Pharmaceutical Sector

Resource consumption in pharmaceutical manufacturing is largely driven by process utilities, thermal operations, solvent handling, cleanroom requirements, and wastewater treatment systems. Thermal energy represents a major share of total energy consumption in pharmaceutical manufacturing, particularly in Active Pharmaceutical Ingredient (API) production facilities. Steam and hot water are extensively used for reactor heating, distillation, evaporation, drying, sterilization, clean-in-place (CIP) systems, and solvent recovery operations. These thermal systems are commonly supported by boilers, thermic fluid heaters, and evaporators, which contribute significantly to fuel consumption and greenhouse gas emissions.

Energy Efficiency in Steam Systems:

Steam systems represent the primary thermal energy consumer in pharma units. The following table summarizes key energy efficiency measures applicable to steam generation and distribution:

Table 3: Energy Efficiency in Steam Systems

S. No	Measure	Potential Savings	Implementation Effort
1	Convert HSD/LDO-fired boiler to biomass/briquette-fired boiler	60-70% reduction in fuel cost	Moderate
2	Install condensate recovery system	5-8% fuel savings; water savings	Moderate
3	Steam trap survey, monitoring and replacement	3-5% of total steam cost	Low to moderate
4	Install economizer / APH on boiler	3-5% boiler efficiency improvement	Moderate
5	Insulate steam distribution pipelines	2-4% thermal savings	Low
6	Optimize boiler blow-down with automatic controls	1-3% savings	Low
7	Install heat pump for process heating (replacing steam)	30-40% primary energy savings	High

Electrical energy consumption is dominated by utility systems such as HVAC systems, chillers, cooling towers, pumps, compressed air systems, and air handling units (AHUs). HVAC systems alone account for a substantial portion of electricity consumption due to continuous operation of cleanrooms, temperature and humidity control systems, and air filtration systems required for maintaining pharmaceutical manufacturing standards.

Energy Efficiency in Refrigeration Systems and Utility:

Refrigeration systems and Utilities are the largest electrical energy consumer in pharma units. The following measures are applicable to MSME pharma units:

Table 4: Energy Efficiency in Refrigeration systems

S.No	Measure	Potential Savings	Technology
1	Install VFD on chiller compressor	15-25% energy savings	VFD
2	Replace evaporative condenser (vs. cooling tower)	10-20% refrigeration energy savings	Evaporative Condenser
3	Install online condenser tube cleaning system	8-15% chiller efficiency improvement	Auto-cleaning system
4	Install EC motors for AHU fans	25-30% AHU fan energy savings	EC Motor
5	Install VFD for chilled water pumps	20-40% pumping energy savings	VFD
6	Waste heat recovery from chiller compressor (de-superheater)	Reduce boiler load by 15-25%	Desuperheater / WHR
7	Replace 3-port valves with 2-port valves in AHUs	10-15% AHU system savings	Valve & VFD upgrade
8	Install VVR (Variable Volume Ratio) technology chiller	SEC as low as 0.36 kW/TR vs 1.27 kW/TR	New chiller (VVR)
9	Install Magnetic bearing chillers	SEC as low as 0.30 kW/TR vs 1.27 kW/TR	New chiller (Available from 100 TR minimum)

Table 5: Energy Efficiency in Utilities

S.No	Measure	Potential Savings	Technology
1	Install VFD on air compressors	20-35% compressor energy savings	VFD / Screw compressor
2	Replace reciprocating with screw compressors	10-20% SEC improvement	Screw compressor
3	Waste heat recovery from compressors	20-30% equivalent of compressor energy is reutilized	WHR by Air-source heat pump
4	Replace old pumps with IE3 motor pumps with inbuilt VFD	Pump efficiency from ~50% to >70%	IE3 pump with VFD
5	Install screw-type vacuum pumps with VFD	~50% energy savings vs. conventional	Screw vacuum pump
6	Replace conventional lighting with LED	50-70% lighting energy savings	LED fixtures
7	Install IoT-based EnMS system	5-15% overall energy savings	IoT / SCADA
8	Install APFC for PF correction	Avoid PF penalty charges (4-8% of bill)	APFC panel

Water is another critical resource in pharmaceutical industries and is used for process operations, cooling, cleaning, utility systems, and production of purified water and water for injection (WFI). Large quantities of wastewater are generated during process operations, equipment cleaning, and solvent handling activities, resulting in high treatment and disposal requirements.

Solvent consumption is particularly significant in API manufacturing for chemical synthesis, extraction, purification, and crystallization processes. Inefficient solvent handling and recovery practices can result in material losses, increased emissions, and higher operational costs.
Therefore, identification and implementation of RECP opportunities in pharmaceutical industries must focus on improving resource efficiency across utilities, process operations, water systems, material utilization, and waste management practices.

4. RECP – Technology Case Studies and Opportunities

This chapter presents 28 detailed technology case studies and opportunities, that are categorized under different RECP themes for easier understanding, prioritization, and implementation.

S.No	Technologies/Opportunities
Energy Efficiency Opportunities	
1	Conversion of HSD-fired Boiler to Biomass-fired Boiler
2	Steam Operated Pumping Traps
3	Steam Driven Heat Pump
4	VFD for Screw Chiller Compressor
5	De-Superheater for Chiller Compressors
6	kVAr Energy Compensator for Chiller Compressor
7	VFD for Chilled Water Pumps
8	Evaporative Condenser
9	Electronically Commutated Motors for AHUs
10	Online Condenser Cleaning System
11	Replace 3-Port with 2-Port Valves for AHUs + VFD
12	Active Refrigerant Agent Addition in Lube Oil
13	Optimize Chilled Water Pumping System
14	Usage of high energy efficient Magnetic Bearing chillers
15	VFD for Air Compressor
16	Energy Efficient Pumps
17	Replacement of HP Compressor with LP Compressor
18	Usage of Heat Pumps to generate hot water
19	IoT-based Energy Management System
Material Efficiency & Yield Improvement	
20	Organic Solvent Nanofiltration (OSN) for Solvent Recovery
21	Automated Dry Granulator (Roll Compactor) replacing Manual Compactor
22	Rotary Vacuum Paddle Dryer (RVPD) replacing Vacuum Tray Dryer + Blender
23	Automated Reactor Auto-sampler System
Water Conservation	
25	Condensate Recovery System
26	IoT-based Water Management System
Renewable Energy	
27	Solar Rooftop System
28	Solar-Wind Hybrid System

Energy Efficiency Case Studies:

Case Study 1: Conversion of HSD/LDO-fired Boiler to Biomass/Briquette-fired Boiler

a. Unit Profile

Boiler Type	Fire Tube, HSD Fired, Shell Type (2 units × 2 TPH)
Boiler Capacity	2 TPH each
Boiler Design Pressure	10.5 kg/cm² g
Operating Pressure	7.5 – 9.5 kg/cm² g
Average Operating Hours	15 hours per day (2 shifts/day)
Fuel Type	High Speed Diesel (HSD)
Fuel GCV	45,187 kJ/kg
Cost of Fuel	INR 67/- per litre
Average Fuel Consumption	36 litres per hour
Number of Working Days	365 days per year
Average Steam Demand	450–600 kg/hr at 7.5–10 kg/cm² g
Peak Steam Requirement	1,200 kg/hr (all processes running)

b. Baseline Scenario

The unit has installed two numbers of 2-TPH HSD-fired three-pass boilers for steam generation, which are used for process applications. The HSD consumption of one boiler was identified to be at 36 litres/hr. The average steam demand is 450–600 kg/hr at 7.5–10 kg/cm² g. Normally, temperature levels of process steam of the plant are below 130°C.

The average steam generation is 0.7 tons per hour with an average consumption of 420 to 600 kg/hr. The peak steam requirement in plant is 1,200 kg/hr, when all processes are in operation.

c. Implemented Technology

An efficient replacement for the current HSD-fired boiler assists in cutting down the increasing production cost. It is recommended to install a new boiler in the plant with an alternative sustainable fuel such as wood or briquette, with the same specifications as the HSD-fired boiler (Capacity: 2 TPH and Design pressure: 10.5kg/cm² g). HSD used in the boiler can be totally substituted by Wood or Briquette with an equivalent ratio of 2.7:1 kg/litre on the basis of calorific value. This usually results in saving of more than 60% in operating cost.

Pre-requisites

❖ Availability of good quality and continuous supply of fuel within a 30 km radius circle.
❖ Availability of sufficient space for new boiler installation and fuel storage (dry, moisture-free).
❖ Install new generation biomass-fired boiler with automation -continuous monitoring and controlling.

Merits

❖ Automation results in feeding optimum amount of fuel to boiler, reducing unburnt losses.
❖ Ensures maximum possible feed water inlet temperature for maximum steam generation.
❖ Better water quality.
❖ Ensures periodic maintenance of boiler tubes, reducing radiation loss.
❖ Zero emissions.

Limitations

❖ Fuel supply distance should be less than a 30 km radius circle.
❖ Estimation of proper back pressure required.
❖ Storage area for fuel must be dry and protected from moisture.

d. Investment & Payback

Annual Fuel Savings	1,47,849 litres of HSD
Annual Monetary Savings	INR 84.20 lakh
Total Investment	INR 60 lakh
Payback Period	9 months
IRR	>169%
NPV (70% Debt @ 12%)	INR 399.17 lakh

e. Energy and Cost Savings

Annual Fuel Savings	Annual Energy Savings	Aunnual GHG Savings
1,47,849 Litres of HSD	148.79 TOE	461.62 T CO_2

f. Environmental Benefits

By switching from HSD to biomass/briquette fuel, the unit eliminates fossil fuel combustion for boiler operation. The estimated annual GHG saving is 461.62 T CO,. Biomass is considered carbon neutral as the CO, released during combustion is offset by the CO_2 absorbed during the growth of biomass feedstock. This also reduces dependence on petroleum-based fuels, improving the unit's environmental footprint significantly.

Case study 2: Steam operated Pumping Traps(SOPT)

a. Unit Profile

Boilers Installed	1 × 2-TPH + 1 × 1-TPH HSD-fired boilers
Operation	One boiler at a time (2-TPH normally; 1-TPH on standby/maintenance)
Steam Trap Type (Reactors)	25 NB Ball Float Steam Trap with PID temperature control valve
Steam Traps (Ghee Kettle)	Inverted Bucket Traps
Operating Pressure	3.5 kg/cm² (can be reduced to <2 kg/cm²)
Bypassed Traps	4 Nos. (due to failure)
Steam Loss per Bypassed Trap	30 kg/hr (5 mm orifice at 3.5 kg/cm²)
Temperature Requirement	90–110°C

b. Baseline Scenario

The unit has installed a 2-TPH and a 1-TPH HSD-fired boiler in the plant. At any given time, only one boiler is working. Steam traps are used to separate condensate from steam. It is observed that some steam traps on reactors have been bypassed due to failure. In Block 1, steam traps have not been installed for many reactors, leading to passage of steam to atmosphere.

Since PID temperature control valves are installed with a temperature requirement of 90–110°C, there are chances of stalling of condensate. When stalling occurs, the bypass of the trap is opened, resulting in live steam loss. The orifice size of the 15 NB bypass valve at 3.5 kg/cm² operating pressure results in a steam loss of 30 kg/hr.

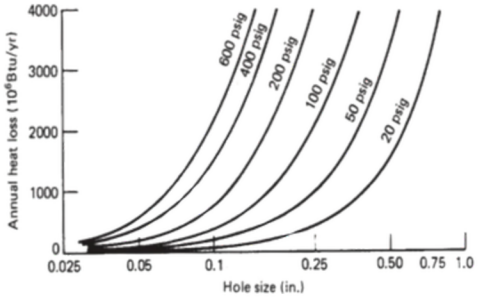


Figure 5: Steam Loss Chart

c. Implemented Technology

It is recommended to replace the ball float steam trap with Steam Operated Pumping Trap (SOPT). With SOPT in place, whenever the condensate pressure is low, motive steam/air provides additional thrust to make the condensate flow and avoid any stalling. This eliminates the need for bypassing and the consequent live steam loss.

Merits

- Improved condensate recovery.
- Reduced steam leakages through the system.

Limitations

- Proper maintenance is required.



Figure 6: steam operating pumping trap

d. Investment & Payback

Annual Fuel Savings	19,302 litres of HSD
Annual Monetary Savings	INR 12.93 lakh
Total Investment	INR 5.11 lakh
Payback Period	5 months
IRR	284.87%
NPV (70% Debt @ 12%)	INR 63.18 lakh

e. Energy & Cost Savings

Annual Fuel Savings	Annual Energy Savings	Aunnual GHG Savings
19,302 Litres of HSD	17.51 TOE	51.73 T CO_2

f. Environmental Benefits

Eliminating live steam loss through failed/bypassed steam traps directly reduces fuel consumption. The annual GHG saving is 51.73 T CO_2. Additionally, reduced steam venting lowers the heat rejected to the atmosphere, contributing to improved local thermal environment around the plant.

Case Study 3: Steam Driven Heat Pump (VAM)

a. Unit Profile

Boilers Installed	2 × HSD-fired; 1 × 1.0-TPH operating at 9 kg/cm²
Hot Water Generators	2 × 191 kW for AHUs (hot water at 55°C)
Current Steam Consumption (Hot Water)	280 kg/hr
Return Water Temperature from AHUs	45°C
Technology Proposed	191 kW Steam Driven Vapour Absorption Machine (VAM)
Steam Required with VAM	115 kg/hr (vs. 286 kg/hr existing)

b. Baseline Scenario

The unit has installed two HSD-fired boilers for process application. One 1.0-TPH HSD-fired boiler operating at 9 kg/cm² is running and the other is on standby. The heating process is done by indirect heating. Two hot water generators of 191 kW heating load each generate hot water at 55°C for AHUs to maintain proper room conditions along with humidity control. Current steam consumption for this application is 280 kg/hr.

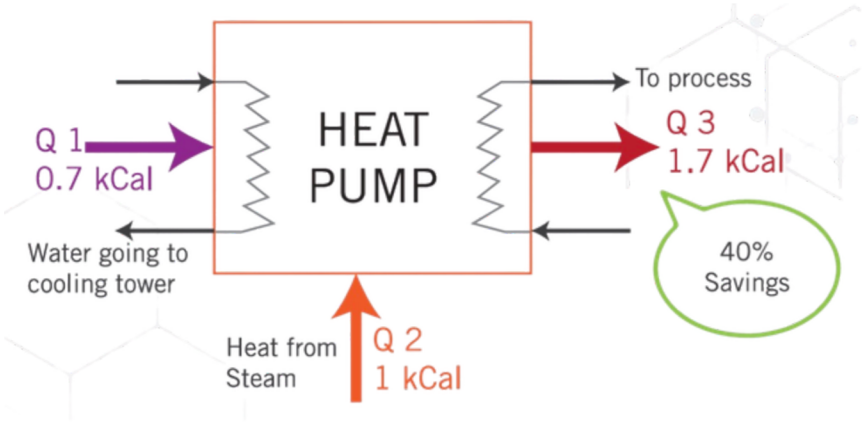


Figure 7: Schematic of Heat pump

c. Implemented Technology

It is recommended to install a 191 kW steam driven heat pump (Vapour Absorption Machine - VAM) for generating hot water at 55°C for the AHUs. Heat naturally flows from higher to lower temperature. The absorption heat pump is thermally driven, using heat rather than mechanical energy to drive the cycle.

Absorption heat pumps utilise steam to pump low grade heat. Heat is extracted from the heat source in the evaporator. Useful heat is given off at medium temperature through the absorber and condenser. VAM uses water as refrigerant and LiBr solution as absorbent. The steam required for running the VAM is 115 kg/hr compared to 286 kg/hr for the existing hot water generator - a saving of 171 kg/hr of steam.

Merits

- Highly compatible with existing system.
- Improves the efficiency of the boiler.
- Simultaneous delivery of heating and cooling.
- Easy installation and occupies less space near the utilisation point.

Demerits

- High upfront cost.
- Requires system modification.

d. Investment & Payback

Annual Fuel Savings	1,07,179 litres of HSD
Annual Monetary Savings	INR 71.81 lakh
Total Investment	INR 30.00 lakh
Payback Period	5 months
IRR	271.00%
NPV (70% Debt @ 12%)	INR 350.12 lakh

e. Energy & Cost Savings

Annual Fuel Savings 1,07,179 Litres of HSD	Annual Energy Savings 97.23 TOE	Annual GHG Savings 287 T CO_2

f. Environmental Benefits

The steam driven heat pump significantly reduces HSD consumption for AHU hot water generation by 60% (from 286 to 115 kg/hr steam equivalent). The annual GHG saving is 287 T CO_2. The VAM technology has a COP greater than 1, meaning it delivers more useful heat energy than the steam energy input, representing a thermodynamically efficient use of high-grade steam energy.

Case Study 4: Variable Frequency Drive (VFD) for Screw Chiller Compressor

a. Unit Profile

Chiller Capacity	100 TR (Screw Chiller)
Evaporator Pressure	32 psi
Condenser Pressure	135 psi
Condenser Leaving Water Temp	33.2°C
Evaporator Leaving Water Temp	5°C
Total Operating Power	80.50 kW
Operating TR	88.20 TR
SEC	0.90 kW/TR
Current Operation	Continuous full load - no speed control

b. Baseline Scenario

The unit has installed a 100 TR screw chiller for the chilled water requirement inside the plant. The chiller compressor is running continuously at full load irrespective of load variations in the plant.
Total compressor power is a function of suction pressure, discharge pressure, total system load, and part load controls. Once the evaporator attains temperature, if there is no speed control, the compressor continues to do the same work, resulting in lower suction pressure and same power consumption. VFD can reduce power consumption with speed control via proper feedback mechanism.

c. Implemented Technology

It is recommended to install a VFD for the high-speed chiller compressor with suction pressure as the feedback signal. The VFD enables smooth control of operation and allows the compressor to handle additional load when suction pressure of the low-speed compressor exceeds the set value. It is recommended not to run the chiller at very less load.

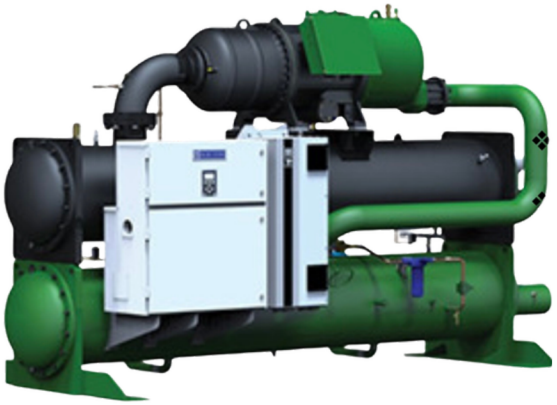


Figure 8: Schrew chiller

Merits

- Better operating efficiencies.
- Reduced power consumption.
- Smooth control of compressor.
- VFD can act as a soft starter.

Limitations

- Speed reduction is possible only up to 25 Hz.

d. Investment & Payback

Annual Electricity Savings	25,200 kWh
Annual Monetary Savings	INR 1.38 lakh
Total Investment	INR 2.66 lakh
Payback Period	23 months
IRR	73.04%
NPV (70% Debt @ 12%)	INR 5.78 lakh

e. Energy & Cost Savings

Annual Electrical Savings	Annual Energy Savings	Annual GHG Savings
25,200 kWh	2.17 TOE	20.66 T CO_2

f. Environmental Benefits

VFD installation on the chiller compressor reduces electrical energy consumption by matching compressor speed to actual cooling demand. The annual GHG saving is 20.66 T CO_2. Reduced power draw also lowers thermal losses in electrical distribution, contributing to overall plant energy efficiency improvement.

Case Study 5: De-Superheater for Chiller Compressors

a. Unit Profile

Chiller Compressors	2 × 50 TR capacity (ammonia refrigerant cycle)
Operation	One compressor continuous; second on demand
NH_3 Gas Temperature (Compressor Discharge)	~100°C
Target Hot Water Temperature	70°C (heated from ambient 30°C)
Heat Recovery per Compressor (50 TR)	6 kW of heat per 15 kW refrigeration load
Amount of Water Heated	294 litre/hr
Total Heat Recovered	16.4 kW

b. Baseline Scenario

The unit has installed two 50-TR capacity compressors. Refrigeration plants with air-cooled and water-cooled condensers produce significant waste energy by dumping condensation energy to the ambient air. This waste heat from the superheated refrigerant gas discharged from the compressor is currently not recovered. There is an existing need for hot water for boiler feedwater heating, process heating, and cleaning applications.

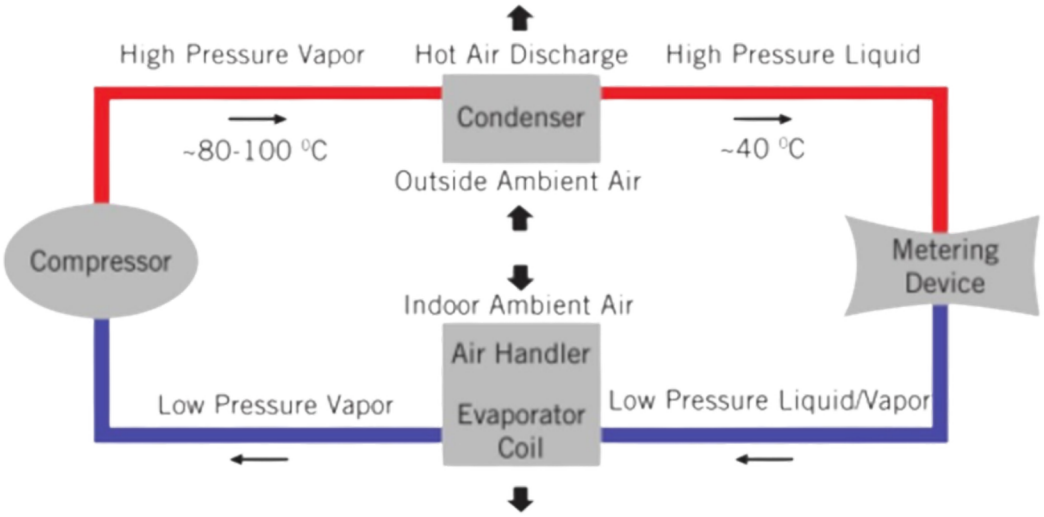


Figure 9: vapor compression cycle

c. Implemented Technology

It is recommended to install a de-superheater on the discharge side of the chiller compressors to recover the waste heat of ammonia gas. The NH_3 gas temperature of ~100°C is cooled to ~60°C, and the recovered heat heats water from ambient (30°C) to 70°C.

De-superheater units are located between the compressor and condenser to utilise the high-temperature energy of superheated refrigerant gas. The heat load on the condenser reduces after the de-superheater, which can also marginally reduce condensing pressures, leading to additional reduction in compressor power consumption.

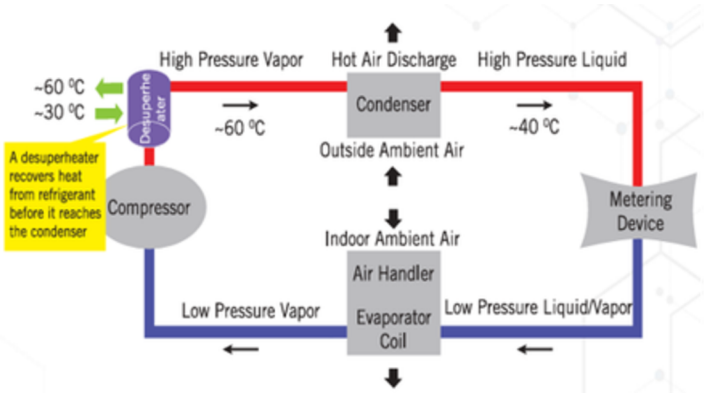


Figure 11: Proposed - WHR from chiller compressor



Figure 10: Desuperheater

d. Investment & Payback

Annual Fuel Savings	9,655 litres of HSD
Annual Monetary Savings	INR 6.47 lakh
Total Investment	INR 7.15 lakh
Payback Period	13 months
IRR	116.52%
NPV (70% Debt @ 12%)	INR 29.52 lakh
Reference Unit	Ernakulam Dairy (MILMA), Thrippunithura, Kerala

e. Energy and Cost Savings

Annual Fuel Savings	Annual Energy Savings	Annual GHG Savings
9,655 Litres of HSD	8.76 TOE	25.88 T CO_2

f. Environmental Benefits

The de-superheater converts waste heat from refrigerant discharge gas into useful hot water, eliminating the need for boiler fuel for that heating purpose. Annual GHG saving is 25.88 T CO_2. Additionally, reduced condenser heat rejection improves chiller efficiency, providing a secondary energy and emissions benefit.

Case Study 6: kVAr Energy Compensator for Chiller Compressor

a. Unit Profile

Chiller Compressors	3 × 60 TR reciprocating (2 continuous + 1 on demand)
Compressor 1 (Power/PF)	73.1 kW / PF 0.87
Compressor 2 (Power/PF)	74 kW / PF 0.85
Overall PF	0.86 (both compressors)
Existing PF Correction	Central capacitor bank at source level
Technology Proposed	kVAr Energy Compensator (local, near load end)

b. Baseline Scenario

The unit has installed three reciprocating chiller compressors of 60-TR capacity each. During normal operation, two compressors run continuously and the third runs on demand. Both compressors are running without VFD and operating at a PF of 0.86. A central capacitor bank is installed at source for PF correction at plant level, but reactive current is still being drawn from the supply over long distribution distances.

c. Implemented Technology

It is recommended to install a reactive current injector locally near the load end to reduce the reactive current drawn from the supply. The kVAr compensator works by reclaiming, storing, and then supplying locally the reactive power element of electricity to inductive motors and loads. As the equipment operates, this reactive power is 'pulled and pushed' to and from the kVAr compensator by the motor, recycling reactive power on the spot without drawing it from the grid.

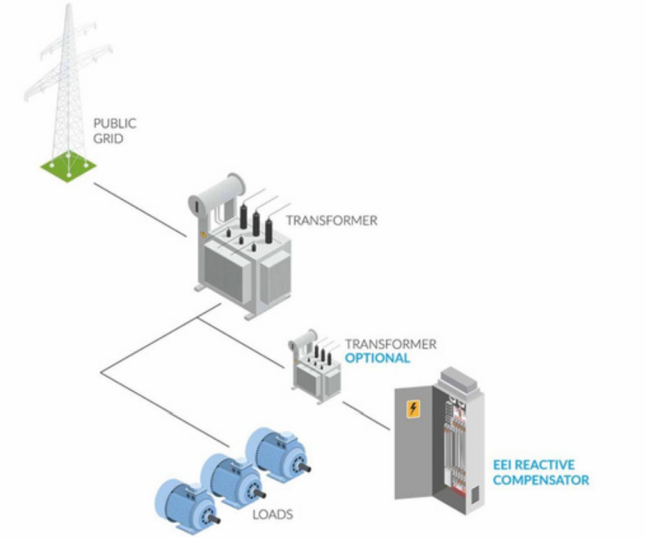


figure 12: Reactive Compensator

Merits

- Reduced distribution losses (I^2R) across the infrastructure -translates to cost savings.
- Reduced kW demand charge - frees up extra capacity in the supply panel.
- Improved voltage regulation and phase imbalance due to reduced voltage drop.
- Reduced operating cost of machinery.
- Improved Power Factor of induction motors.
- Works on all line-start and soft-start inductive loads - motors, compressors, pumps, chillers, fans.
- Customised unit built for each load after real-time monitoring and testing.

Demerits

- Not suitable for chillers with VFD.

d. Investment & Payback

Annual Electricity Savings	**46,570 kWh**
Annual Monetary Savings	**INR 2.56 lakh**
Total Investment	**INR 4.20 lakh**
Payback Period	**20 months**
IRR	**83.57%**
NPV (70% Debt @ 12%)	**INR 11.06 lakh**

e. Energy and Cost Savings

Annual Electricity Savings	Annual Energy Savings	Annual GHG Savings
46,570 kWh	4.00 TOE	38.19 T CO_2

f. Environmental Benefits

By improving the power factor locally at the load end, distribution losses are reduced and overall electrical energy drawn from the grid decreases. The annual GHG saving is 38.19 T CO_2. Improved power factor also reduces the kVA demand charge, which has an indirect financial benefit beyond the direct energy savings.

Case Study 7: VFD for Chilled Water Pumps

a. Unit Profile

Chilled Water Pumps	4 × 10 HP (3 operating + 1 standby)
Flow Requirement	1,000–2,500 LPM
Discharge Line	180 mm dia, up to 500 m length
Current Discharge Pressure	2 kg/cm²
Current Power Consumption	22 kW (3 pumps)

b. Baseline Scenario

The unit has installed four chilled water pumps of 10 HP each for pumping chilled water to process. During normal operation, three pumps are in operation. The flow requirement to different processes varies in the range of 1,000 to 2,500 LPM. The current operating practice is to operate the pumps such that a discharge pressure of 2 kg/cm² is available with maximum flow of 2,500 LPM. One pump operates at full load and the other two are manually controlled for required pressure and flow conditions.

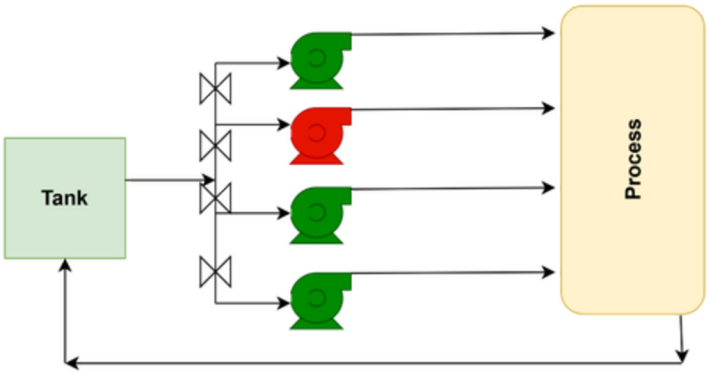


Figure 13: Existing layout

c. Implemented Technology

The best possible solution is to install a VFD in one of the pumps and operate the other two pumps in fully open conditions. The required system pressure is given as feedback to the VFD, based on which the required flow can be obtained. Overall savings are in terms of higher operating efficiency of one pump and lower RPM for the third pump. The pump with VFD also ensures minimum recirculation under no-load conditions.

Merits

- ❖ Higher operating efficiencies.
- ❖ Reduced power consumption.
- ❖ Optimum flow and head.

Limitations

- ❖ Higher installation costs.
- ❖ May require system stoppage during installation.

d. Investment & Payback

Annual Electricity Savings	24,000 kWh
Annual Monetary Savings	INR 0.96 lakh
Total Investment	INR 0.50 lakh
Payback Period	6 months
IRR	4.64%
NPV (70% Debt @ 12%)	INR 222.60 lakh

e. Energy and Cost Savings

Annual Electricity Savings	Annual Energy Savings	Annual GHG Savings
24,000 units	2.06 TOE	19.68 T CO_2

f. Environmental Benefits

VFD control of chilled water pumps eliminates wasted pump energy during low-demand periods. Annual GHG saving is 19.68 T CO_2. The elimination of manual throttling also reduces mechanical wear on pump and valve components, extending equipment life and reducing maintenance-related material consumption.

Case Study 8: Evaporative Condenser

a. Unit Profile

Chiller Compressors	2 units (180 HP + 150 HP, 100 TR each)
Existing Condenser Type	PHE condenser (180 HP) + Shell & tube (150 HP)
Cooling System	Open cooling tower arrangement
Current Condensing Temperature	40°C
Evaporation Temperature	-2°C
Condenser Heat Load	158.5 TR
Chiller Compressor Power	103 kW
Condenser Pump Power	17.71 kW
Cooling Tower Fan Power	5.4 kW
Proposed Evaporative Condenser	200 TR capacity

b. Baseline Scenario

The plant has a normal PHE condenser with cooling tower arrangement for the 180 HP chiller. The compressor is running at 40°C condensing temperature and -2°C evaporation temperature. The current system has separate PHE condenser and cooling tower, resulting in higher auxiliary loads. Water quality can affect condenser performance due to scaling and fouling, increasing compressor power. The condensing temperature was found to be on the higher side.

c. Implemented Technology

It is recommended to replace the existing PHE condenser with an evaporative condenser. Evaporative condensers combine the features of a cooling tower and water-cooled condenser in a single unit. Water is sprayed from the top onto a bank of tubes carrying the refrigerant, and air is induced upwards. The evaporative cooling maintains a thin water film around the condenser tubes.
With installation of the evaporative condenser, a condensing temperature of 36°C can be achieved for the same cooling capacity (4°C reduction from existing 40°C). As a result, compressor power comes down due to lower condensing temperature. The required airflow rate is 350–500 m^3/h per TR of refrigeration capacity.

Merits

- Reduces fouling tendency.
- Air and water flow in parallel path.
- Increased water flow over the arant coil and evaporative cooling water in the fill.
- Colder spray water; lower condensing temperature.

Demerits

- High upfront cost.
- Requires system modification.

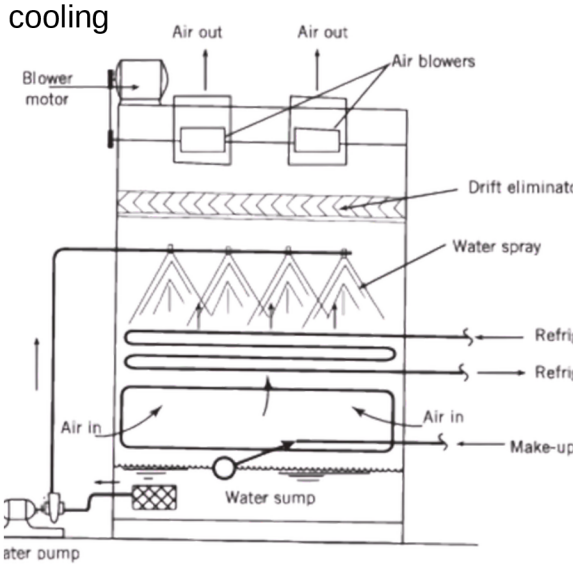


Figure 14: Evaporative condensers

d. Investment & Payback

Annual Electricity Savings	1,98,129 kWh (1.98 lakh units)
Annual Monetary Savings	INR 13.07 lakh
Total Investment	INR 29.52 lakh
Payback Period	27 months
IRR	63.79%
NPV (70% Debt @ 12%)	INR 52.75 lakh

e. Energy and Cost Savings

Annual Electricity Savings	Annual Energy Savings	Annual GHG Savings
1.98 lakh kWh	17.04 TOE	162.47 T CO_2

f. Environmental Benefits

The evaporative condenser reduces condensing temperature and eliminates a separate cooling tower pump, significantly reducing total electrical consumption. Annual GHG saving is 162.47 T CO_2. The system also uses less water per unit of heat rejection compared to conventional cooling towers at the same load, contributing to water conservation.

Case Study 9: Electronically Commutated (EC) Motors For AHUs

a. Unit Profile

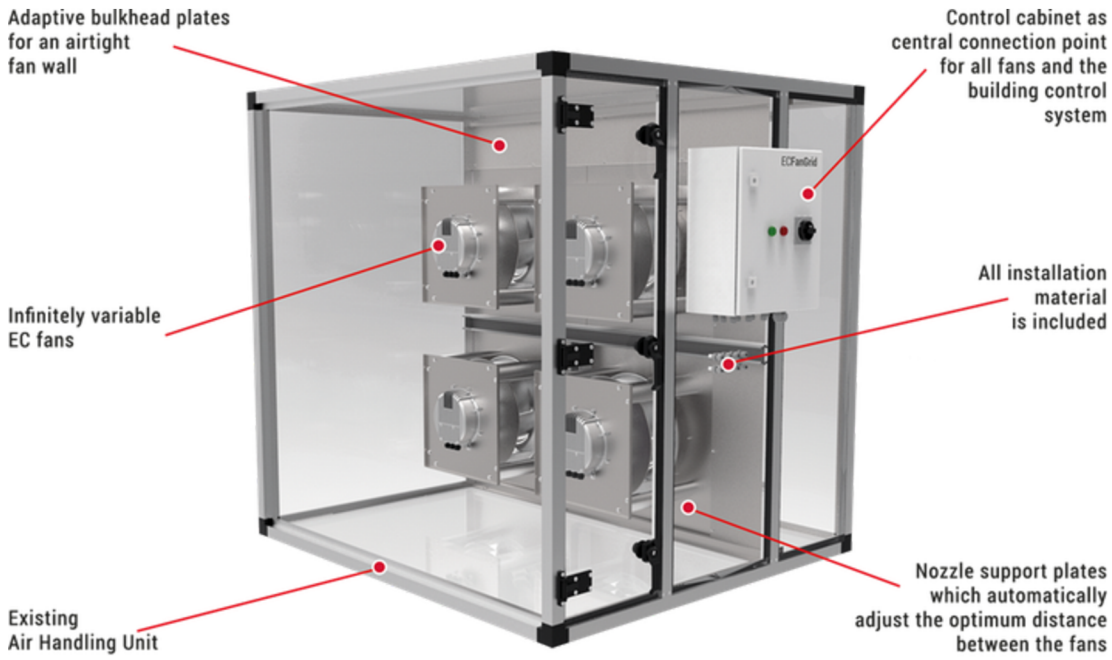
AHUs Installed	Multiple units in plant (pharma manufacturing areas)
Motor Loading	40–60% of rated load (below rated value)
Current Motor Type	Conventional AC induction motor
AHU Fans to be Replaced	3 Nos.
Total AHU Power Consumption	19 kW
Technology Proposed	EC (Electronically Commutated) Fan Motors with Servo Motor System

b. Baseline Scenario

Air handling units are installed in the plant, and the efficiency of these low-capacity fans is at a reasonable range. The motors are operated at a loading of around 40–60%. As motors are operated below rated value, they are likely to give low efficiency and operate at a lower power factor. There is a potential of increasing motor efficiency in the range of 4–6% by replacing existing ones with new energy efficient motors.

c. Implemented Technology

Using energy efficient fans with servo motor-based systems with speed control. The savings achievable by using servo motors with EC fans is 25–30%. Energy efficient fans come as a complete package with servo motors. Major energy savings come from motor replacement - even under part load operation, energy savings of 20% can be expected.



Advantages of servo motors include smooth rotation at low speeds, low-cost drive, no power used at standstill, high peak torque, flat speed-torque curve, and wide variety of types available. EC fans have no belt/pulley losses and come with inherent speed control capability.

Merits

- Low power consumption.
- No pulley losses.
- Smooth control of operation.

Demerits

- High upfront cost.
- Requires system modification.

d. Investment & Payback

Annual Electricity Savings	41,040 kWh (1.98 lakh units)
Annual Monetary Savings	INR 2.58 lakh
Total Investment	INR 4.00 lakh
Payback Period	18 months
IRR	87.59%
NPV (70% Debt @ 12%)	INR 11.24 lakh

e. Energy and Cost Savings

Annual Electricity Savings	Annual Energy Savings	Annual GHG Savings
41, 040 kWh	3.53 TOE	33.65 T CO_2

f. Environmental Benefits

EC motor replacement in AHUs reduces electrical energy consumption by 25–30% per fan unit. Annual GHG saving is 33.65 T CO_2. Additionally, noise levels are maintained at less than 65 dB (23% less than existing belt-driven system), improving the occupational environment. Reduced cooling requirements in clean rooms also help improve overall HVAC efficiency.

Case Study 10: Online Condenser Cleaning System

a. Unit Profile

Condenser Water TDS	2,000 ppm
Current Cleaning Practice	Manual cleaning once every 3 months
Cooling Tower Water Temperature	30°C
Existing Condensing Temperature	>40°C (standard should be <38°C)
Chiller Power Consumption	61 kW
Temperature Reduction Possible	3°C (with online cleaning)

b. Baseline Scenario

The condenser water at the chiller has a TDS of 2,000 ppm. The plant team follows a cleaning procedure on condensers once every three months. During this period the compressor power consumption increases to a higher level and fluctuates between minimum and maximum values.

The cooling water temperature from the cooling tower is 30°C, which is 7°C more than the wet bulb temperature. The condenser temperature of the chiller was observed above 40°C - standard operating temperature should maintain condensing temperature less than 38°C. There is potential to reduce condensing temperature and superheat of refrigerant by installing an online condenser cleaning system.

c. Implemented Technology

It is recommended to install an online condenser cleaning system to improve condenser performance. The system consists of sponge balls which are continuously circulated through the heat exchanger tubes. The dirt is removed by injection of these balls. A ball trap removes and refreshes (cleans) the balls, making them ready for reuse.

As the operating temperature of refrigerant is lowered, condenser pressure reduces, in turn reducing power consumed by the compressor. About 4% of energy consumption of the chiller is reduced for every 1°C reduction in condenser cooling temperature.

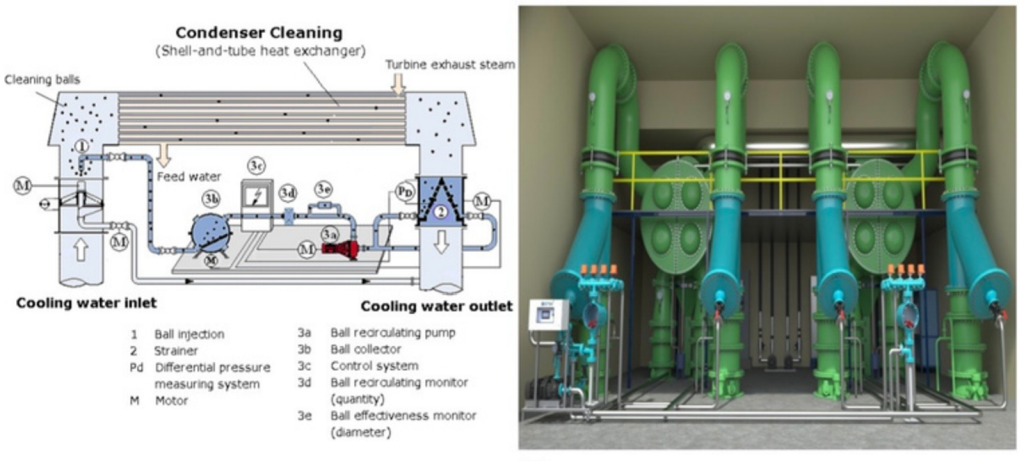


Figure 16: Online condenser cleaning system

Merits

- Reduced power consumption of compressor.
- No fouling - continuous tube cleanliness maintained.
- High reliability.

Limitations

- High upfront cost.
- Maintenance issues.
- Space constraints.

d. Investment & Payback

Annual Electricity Savings	24,156 kWh
Annual Monetary Savings	INR 1.52 lakh
Total Investment	INR 4.50 lakh
Payback Period	35 months
IRR	50.46%
NPV (70% Debt @ 12%)	INR 5.65 lakh

e. Energy and Cost Savings

Annual Electricity Savings	Annual Energy Savings	Annual GHG Savings
24,156 units	2.08 TOE	19.82 T CO_2

f. Environmental Benefits

Maintaining clean condenser tubes continuously prevents the efficiency degradation that occurs between manual cleaning cycles. Annual GHG saving is 19.82 T CO_2. The system eliminates the chemical cleaning agents and water used for periodic manual descaling, reducing chemical waste and water consumption from cleaning operations.

Case Study 11: Replace 3-port With 2-port Valves In AHUs + VFD for Chilled Water Pump

a. Unit Profile

Secondary Chilled Water Pump Power	10 kW
Current Valve Type	3-element (3-port) control valves for AHUs
Current Control Method	Bypass when desired temperature achieved (constant pump power)
Proposed System	2-port valves + VFD on secondary CHW pump
Feedback Signal for VFD	Discharge pressure of AHU
Annual Operating Hours	3,300 hrs

b. Baseline Scenario

The 3-element valve controls the amount of chilled water entering the respective AHU. Once the desirable temperature is achieved in the conditioned space, the 3-element valve bypasses the chilled water entering the AHU, avoiding overcooling. However, pumping power in a 3-element control system does not change irrespective of temperature - the pump continues to run at the same power even during bypass operation.

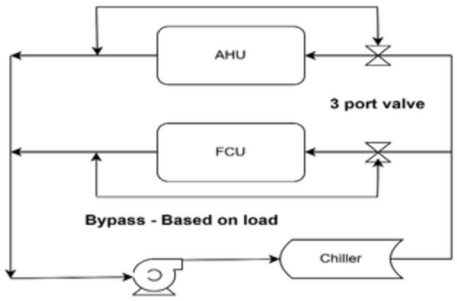


Figure 17: Three element control for AHUs

c. Implemented Technology

The 3-port bypass control is replaced with 2-port control valves. In the 2-port system, bypass operation is avoided and quantity of chilled water required through the AHU is optimised - chilled water is either let in or rejected based on temperature setting. An additional recirculation line is provided bypassing the AHU users to avoid icing in the pipeline. The VFD on the secondary pump is controlled by AHU discharge pressure as feedback signal.

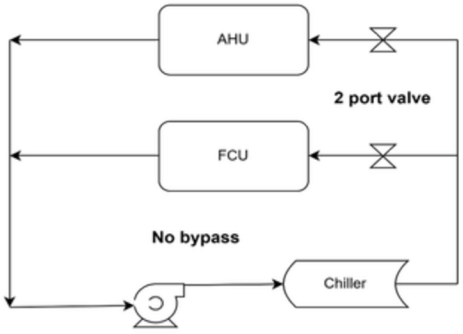


Figure 18: Two port control for AHUs

Merits

❖ Ease of operation.
❖ Better cooling and precise control of pumps.

Limitations

❖ Upfront cost.
❖ System modification required.

d. Investment & Payback

Annual Electricity Savings	6,600 kWh
Annual Monetary Savings	INR 0.42 lakh
Total Investment	INR 0.70 lakh
Payback Period	20 months
IRR	81.74%
NPV (70% Debt @ 12%)	INR 1.79 lakh

e. Energy and Cost Savings

Annual Electricity Savings	Annual Energy Savings	Annual GHG Savings
6,600 units	0.57 TOE	5.41 T CO_2

f. Environmental Benefits

Converting from 3-port to 2-port AHU control with VFD eliminates constant-speed pumping during bypass periods, saving electrical energy. Annual GHG saving is 5.41 T CO_2. While individual savings per unit are modest, this measure is highly replicable across all pharma units with AHU systems, giving significant cluster-level impact.

Case Study 12: Active Refrigerant Agent Addition in Lube Oil for Chillers

a. Unit Profile

Chiller	310 TR, R134a refrigerant-based Trane water-cooled chiller
Current SEC	0.501 kW/TR (average)
Observed Issue	Frequent fouling of heat exchanger tubes due to compressor oil
Oil Circulation	0.5–8% of compressor lube oil circulates with refrigerant
Power Consumption	143 kW
Technology	Active Refrigerant Agent - Intermetallic compound

b. Baseline Scenario

The plant has a 310 TR, R134a refrigerant-based Trane water-cooled chiller. Average energy consumption per ton of refrigeration was found around 0.501 kW/TR. Frequent fouling of heat exchanger tubes due to compressor oil was observed. During piston stroke in the cylinder, refrigerant carries a small amount of oil from the compressor, which over time adheres to the inner pipe of the evaporator. This oil acts as an insulator reducing heat transfer capacity. Typically, an AC system's efficiency deteriorates more than 30% over 20 years.

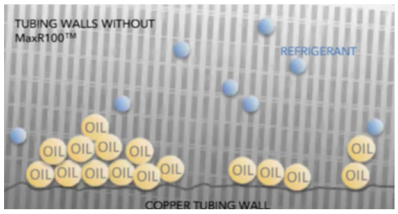


Figure 19: Oil coagulation inside copper tubes

c. Implemented Technology

It is recommended to use an active refrigerant agent - an intermetallic compound technology which, when introduced into the refrigerant oil, forms a permanent bond to metal surfaces. This removes oil fouling, changes the thermal nature of the metal, and lowers the boiling point of the refrigerant gas, resulting in a more efficient operating system.

The additive defeats the Van der Waals surface tension forces that cause compressor oil globules to adhere to refrigerant tubing walls. It bonds to metal surfaces in a layer that is one molecule thick, preventing recurrence of oil contamination. The release of oil contamination restores 20–30% of lost thermal transfer efficiency. Capillary tubes and expansion valves are also cleaned and protected from future fouling.

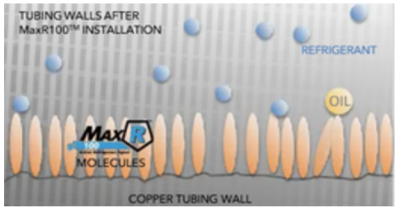


Figure 20: Protective layer formation by active refrigerant agents

Merits

- Does not affect equipment warranty.
- ROI of less than 12 months.
- Copper corrosion resistance.

Limitations

- System modification required for first application.

d. Investment & Payback

Annual Electricity Savings	1,71,600 kWh
Annual Monetary Savings	INR 10.81 lakh
Total Investment	INR 8.00 lakh
Payback Period	9 months
IRR	163.78%
NPV (70% Debt @ 12%)	INR 51.12 lakh

e. Energy and Cost Savings

Annual Electricity Savings	Annual Energy Savings	Annual GHG Savings
1,71,600 units	14.76 TOE	140.71 T CO_2

f. Environmental Benefits

The active refrigerant agent restores chiller efficiency to near-new condition, reducing electrical energy consumption by up to 20%. Annual GHG saving is 140.71 T CO_2. Since the treatment is non-invasive (added to existing lube oil) with no equipment modification, the environmental footprint of the intervention itself is minimal.

Case Study 13: Optimize Chilled Water Pumping System

a. Unit Profile

Current System	Primary + secondary pumping system
Total Pump Power	16 kW (primary + secondary)
Proposed System	Single pump system (head: 25 m; flow: 60 m³/hr)
New Pump Power	9 kW
Chilled Water TDS	1,500 ppm (recommended: <300 ppm for CHW; <1,500 ppm for condenser)
Annual Operating Hours	11 hrs/day × 300 days = 3,300 hrs

b. Baseline Scenario

The current system consists of a primary and secondary pump. The primary pump transfers hot-well water from process to the chiller. The secondary pump transfers cold-well water from chiller to the process. Chilled water consumers include AHUs and reactors. The TDS of the water was found to be more than 1,500 ppm -recommended level for chilled water pumping systems is less than 300 ppm.

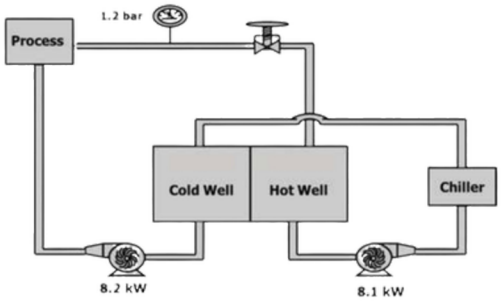


Figure 21: Present pumping system

c. Implemented Technology

Latest technology of chilled water pumping consists of a single pump to pump through the chiller and the process. The pressure drop across the chiller was found to be 0.4 kg/cm². The single pump system is designed based on pressure drop across the total system. A recirculation line is provided after this modification to maintain minimum flow through the chiller before switching it off - this recirculation line avoids icing of chilled water.

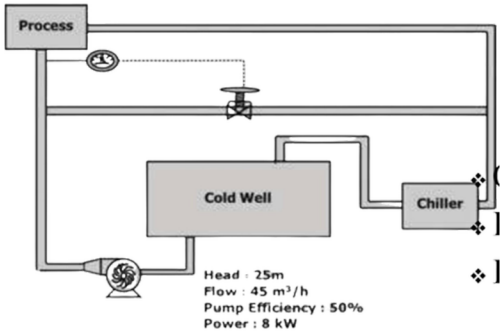


Figure 22: Proposed pumping system

Merits

- Optimised operation.
- Better efficiency.
- High reliability.

Limitations

- Requires system modification.
- Suitable only for short networks.

d. Investment & Payback

Annual Electricity Savings	23,100 kWh
Annual Monetary Savings	INR 1.46 lakh
Total Investment	INR 4.50 lakh
Payback Period	36 months
IRR	48.49%
NPV (70% Debt @ 12%)	INR 5.31 lakh

e. Energy & Cost Savings

Annual Electricity Savings	Annual Energy Savings	Annual GHG Savings
23,100 kWh	1.99 TOE	18.94 T CO_2

f. Environmental Benefits

Consolidating primary and secondary pumps into a single optimised pump reduces total pumping energy by ~44% (from 16 kW to 9 kW). Annual GHG saving is 18.94 T CO_2. Maintaining proper CHW TDS (<300 ppm) through appropriate blowdown also reduces corrosion and fouling of heat exchange surfaces, extending equipment life.

Case Study 14: Usage of high energy efficient Magnetic Bearing chillers (Oil-free Centrifugal chillers)

a. Unit profile and Baseline Scenario

The unit has installed a conventional screw chiller for the chilled water requirement inside the plant. The chiller is running continuously at full load and has a design SEC of 1.2 kW/TR.

b. Implemented Technology

Replacing the current Energy Intensive Screw Chiller with New Energy Efficient Chillers with magnetic bearing technology and IE5 motor installed for compressor.

Magnetic Bearing Chillers, also known as Oil-Free Centrifugal Chillers, use magnetic bearings to suspend and rotate the compressor shaft without physical contact, eliminating the need for lubricating oil. The compressor in a magnetic bearing chiller is driven by a high-speed permanent magnet motor, and the shaft is levitated using electromagnetic forces controlled by an electronic control system. Since there is no mechanical contact between rotating components, friction losses are significantly reduced.

Another key advantage of oil-free chillers is the absence of lubricating oil in the refrigerator circuit. In conventional chillers, oil contamination can accumulate on heat exchanger surfaces and reduce heat transfer efficiency. By eliminating oil from the system, magnetic bearing chillers maintain higher heat exchanger performance and improve overall system efficiency.



These chillers are particularly suitable for applications that require high efficiency at part-load conditions, which are common in most industrial cooling operations.

Figure 23: Installation photo of Magnetic bearing chiller

d. Investment & payback

Installed chiller SEC	**0.65 kW/TR**
Energy reduction achieved	**17%**
Annual Monetary Savings	**INR 35 lakhs**
Total Investment	**INR 100 lakhs**
Payback Period	**36 months**

Case Study 15: VFD for Air Compressor

a. Unit Profile

Compressor Type	*15 kW Screw Compressor*
Maximum Working Pressure	6–7 kg/cm²
Loading Pattern	36% load / 64% unload
Load Power	17.5 kW
Unload Power	6.6 kW
Usage	Process and instrumentation section
Annual Operating Hours	4,320 hrs

b. Baseline Scenario

The unit has installed a 15 kW screw compressor for the process and instrumentation section. The maximum working pressure in the system is 6–7 kg/cm². The compressor loading percentage is only 36%, indicating significant potential for VFD installation.

During the time the compressor goes into unload mode, there is no useful work done. Since the compressor is of screw type, losses during unloading are higher compared to a reciprocating system. The installed compressor is of much higher capacity than the system requirement, which is evident from the 64% unload the compressor is operating at.

c. Implemented Technology

It is recommended to install a VFD and operate it with closed loop for the compressor to avoid unloading. The feedback for VFD is given as the required receiver pressure. By installing VFD, the compressor can be operated in a pressure bandwidth of ±0.1 bar. Saving potential of 4.2 kW is available through VFD installation.

Merits

- ❖ Reduced fluctuations in pressure.
- ❖ Ease of operation.
- ❖ High reliability.

Limitations

- ❖ Viable only up to 40% unload situations.
- ❖ Maintenance issues.
- ❖ Space constraints.

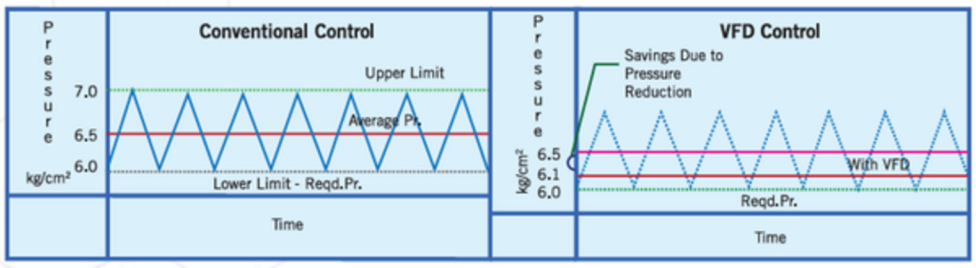


Figure 24: Capacity control of compressor by VFD

d. Investment & Payback

Annual Electricity Savings	18,247 kWh
Annual Monetary Savings	INR 1.03 lakh
Total Investment	INR 0.90 lakh
Payback Period	11 months
IRR	142.02%
NPV (70% Debt @ 12%)	INR 4.81 lakh

e. Energy & Cost Savings

Annual Electricity Savings 18,247 units	**Annual Energy Savings 1.57 TOE**	**Annual GHG Savings 14.96 T CO_2**

f. Environmental Benefits

VFD installation eliminates the energy wasted during compressor unloading cycles by matching compressor output to actual demand. Annual GHG saving is 14.96 T CO_2. Pressure stabilisation within ±0.1 bar also reduces mechanical stress on compressed air system components, extending equipment life and reducing maintenance material use.

Case Study 16: Energy Efficient Pumps

a. Unit Profile

Pumps Installed	2 × 5.5 kW chilled water pumps (1 running + 1 standby)
Current Power Consumption	6 kW (at 15.5 m³/hr, 40 m head)
Design Efficiency	39% (very low)
Measured Efficiency	31% (lower than design)
Flow	15.5 m³/hr (existing) → 16 m³/hr (proposed)
Head	40 m (existing) → 45 m (proposed)
Proposed Pump Efficiency	53%

b. Baseline Scenario

The unit has installed two chilled water pumps for pumping chilled water to process. Design efficiency of the pump is 39% (very low), and measured efficiency is 31%, which is lower than design efficiency. Reasons for low efficiency include poor operational practices, the pump being very old with frequent maintenance, and poor selection of pump for the application.

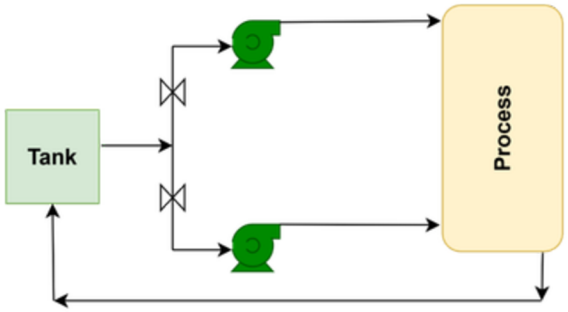


Figure 25: Current pumping system

c. Implemented Technology

It is recommended to replace the old chilled water pump with an energy efficient pump. Energy efficient pumps offer higher efficiency than conventional pumps and consume less power, leading to significant energy savings. The new pumps have an overall efficiency of 53%. The pump operates at its Best Efficiency Point (BEP) where operating efficiency is highest and radial bearing loads are lowest. Selecting a pump with a BEP close to the system's normal operating range results in significant operating cost savings

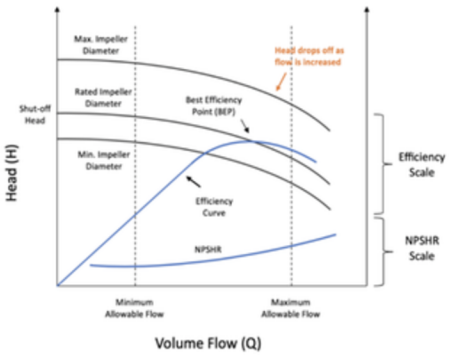


Figure 26: Pump Characteristic curve

Merits

- Higher operating efficiencies.
- Reduced power consumption.
- Optimum flow and head.

Limitations

- High installation cost.
- May require system stoppage during installation.

d. Investment & Payback

Annual Electricity Savings	17,520 kWh
Annual Monetary Savings	INR 0.70 lakh
Total Investment	INR 0.98 lakh
Payback Period	17 months
IRR	66.74%
NPV (70% Debt @ 12%)	INR 2.34 lakh

e. Energy & Cost Savings

Annual Electricity Savings 17,520 kWh	Annual Energy Savings 1.51 TOE	Annual GHG Savings 14.37 T CO_2

f. Environmental Benefits

Replacing inefficient pumps (31% efficiency) with energy efficient pumps (53% efficiency) reduces electrical consumption by 25% per pump unit. Annual GHG saving is 14.37 T CO_2. Well-selected pumps operating near BEP also last longer with lower maintenance requirements, reducing the lifecycle material consumption and waste associated with frequent pump replacements.

Case Study 17: Replacement of HP Compressor with LP Compressor

a. Unit Profile

Application	Pushing material from reactor
Current Compressor Type	HP Compressor
Current Pressure Set Point	2.5–6.5 bar
User End Requirement	Maximum 2 bar only
Current Power Consumption	7 kW
Current FAD	23 CFM
Current SEC	0.30 kW/CFM (very high)
Proposed SEC (LP Compressor)	0.10 kW/CFM

b. Baseline Scenario

The plant is operating with an HP compressor for pushing material from the reactor. The set point pressure is 2.5–6.5 bar, but the plant user-end requirement is a maximum of 2 bar only. Power consumption is 7 kW. A capacity test on the compressor revealed a specific energy consumption of 0.30 kW/CFM, which is very high for HP compressors. Reduced efficiency is due to ageing of compressor, maintenance requirements, or inherent design limitation.

c. Implemented Technology

It is recommended to replace the HP compressor with a highly efficient LP compressor operating at 2 kg/cm² pressure with an SEC of 0.10 kW/CFM. Since the user-end pressure requirement is only 2 bar, the HP compressor is significantly over-specified. The LP compressor exactly matches the application requirement, operating at optimum efficiency.

Merits

- ❖ Higher operating efficiencies.
- ❖ Reduced power consumption.

Limitations

- ❖ High installation cost.
- ❖ May require system stoppage during installation.

d. Investment & Payback

Annual Electricity Savings	5,397 kWh
Annual Monetary Savings	INR 0.34 lakh
Total Investment	INR 1.00 lakh
Payback Period	35 months
IRR	50.70%
NPV (70% Debt @ 12%)	INR 1.27 lakh

e. Energy and Cost Savings

Annual Electricity Savings 5,397 kWh	Annual Energy Savings 0.46 TOE	Annual GHG Savings 4.43 T CO_2

f. Environmental Benefits

Right sizing the compressor to match actual process pressure requirements eliminates wasteful over-compression. Annual GHG saving is 4.43 T CO_2. This case study also highlights a broader lesson - proper compressor selection based on actual end-user pressure requirements can prevent long-term energy waste throughout the equipment's operational life (typically 10–15 years).

Case Study 18: Usage of Heat Pumps to generate hot water

a. Unit profile and Baseline Scenario

The unit has hot water generation of 200 kL per day for melting of Jelatin and nearly 10 kL of hot water per day for maintaining the viscosity of this Jelatin.

The unit uses series of Electrical heaters for generating this hot water and the hourly energy consumption of all these heaters at peak load is 690 kWh.

b. Implemented Technology and Payback analysis

An efficient Heat Pump technology is proposed for this requirement with a design capacity of 840 kW and a COP of 2.25.

Description	Unit	Value
Hourly Energy Consumption of the Electrical Heaters at peak load	kWh	690
Hourly Energy Consumption Cost	Rs.	4,727
Daily Energy Operational Cost of the Heaters	Rs.	113,436
Annual Energy Operational Cost of the Heater	Rs.	41,404,140
HP Capacity Designed, to be positioned	kW	840
Rated Input Power of the 840 kW Heat Pump	kW	375
COP	No unit	2.24
Electrical input needed to generate 690 kW Energy	kW	308.04
Hourly Operational Cost for 690 kW Energy	Rs.	2,110.04
Daily Operational Cost of the Heat Pump to deliver the 690 kW Thermal Energy	Rs.	50,641
Annual Operational Cost of the Heat Pump	Rs.	18,483,991
The Annual Operational Cost on Electrical Energy	Rs.	41,404,140
Annual Operational Cost of the Heat Pump proposed	Rs.	18,483,991
The Comparative Annual Operational Savings	Rs.	22,920,149
Total Project Value of the Direct Integration set up of the 840 kW Heat Pump System	Rs.	19,300,000
Return on Investment	Months	10



c. Environmental Benefits

Switching from electric heaters to heat pump system significantly reduces electricity consumption - from 690 kWh per hour to just ~308 kW input – with the current COP of 2.24. This leads to substantial reduction in greenhouse gas emissions associated with power generation.

Case Study 19: IoT-based Energy Management System

a. Unit Profile

Annual Energy Consumption	90,89,850 kWh
Current Measurement	Digital meter readings at certain points; Not monitored
Technology to be implemented	IoT-based Energy Management System (cloud + mobile app)

b. Baseline Scenario

A medium-scale pharma unit with a connected contract demand of 3000 kVA, with chillers, boilers, compressors, and auxiliaries, was assessed for IoT energy monitoring deployment. Prior to implementation, the plant had no sub-metering beyond the main utility incomer, and the average recorded total annual consumption of more than 90,00,000 kWh.

Energy monitoring in most MSME forging units is limited to monthly electricity billing data from the utility meter, with no granular visibility into consumption at equipment level, making it impossible to identify which assets are consuming excessively, when peak loads occur, or whether equipment is running inefficiently during idle periods. Decisions on energy management are largely reactive rather than data driven.

c. Implemented Technology

IoT-based energy management systems deploy wireless smart sensors and sub-meters at individual equipment level, transmitting real-time data to a cloud-based platform that provides dashboards, automated alerts, and consumption analytics. This enables plant managers to identify and act upon inefficiencies as they occur rather than discovering them weeks later through utility bills.

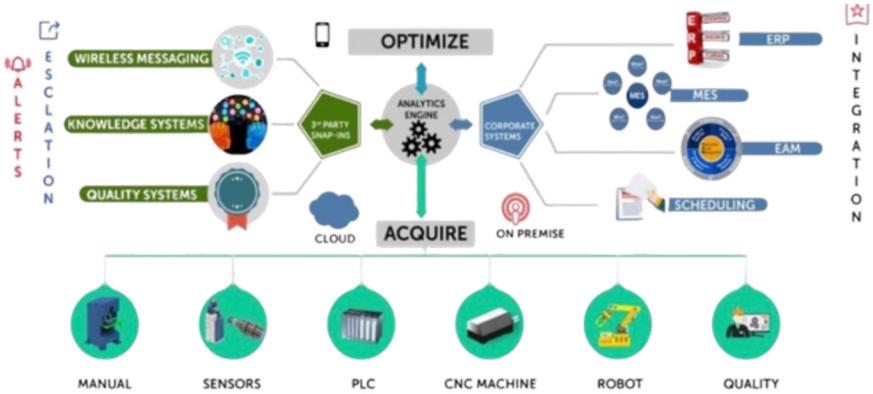


Figure 27: IoT elements in an EnMS system

IoT energy management systems function through four integrated layers. Sensors and smart meters capture real-time data on electricity consumption, fuel flow, temperature, pressure, and compressed air flow at each major asset. Data is transmitted via wired or wireless networks to a central cloud platform. Analytics software processes data using algorithms to detect anomalies, benchmark performance, and generate actionable reports. The control layer enables automated responses such as load shedding during peak tariff periods or alerts when equipment deviates from set energy parameters.

Merits

- Real-time visibility enables immediate identification and correction of energy losses
- Automated peak load alerts facilitate active electricity tariff management
- Predictive maintenance alerts reduce unplanned downtime and associated energy waste
- Consumption benchmarking across shifts and production batches drives operational accountability
- Provides verified data foundation to support investment decisions for further efficiency measures

d. Investment & Payback

Annual Fuel Savings	INR 8.2 lakh
Annual Monetary Savings	INR 2.5 lakh
Total Investment	4 months

e. Energy and Cost Savings

Units that actively engage with IoT data, implement shift-level energy targets, and act on predictive maintenance alerts consistently report reductions of 5–10% on pre-monitoring baselines. For the current unit, a saving of 1% on the annual energy consumption is possible, which results in a capital savings of Rs. 8.20 Lakhs.

Beyond direct energy savings, the IoT system also provides the verified consumption data required to apply for BEE star ratings, access green financing, and demonstrate progress against sustainability commitments to automotive OEM customers increasingly requiring supplier environmental disclosures.

Material Efficiency & Yield Improvement Opportunities:

Case Study 20: Organic Solvent Nanofiltration (OSN) for Solvent Recovery

Problem Statement:

In Active Pharmaceutical Ingredient (API) manufacturing, several reactions, crystallization, and purification steps generate mother liquor streams containing dissolved product residues, solvents, impurities, and intermediate processes. Traditionally, after product crystallization and separation, the remaining mother liquor is either partially recycled or sent to effluent treatment systems. However, these streams often contain valuable dissolved products or intermediates that remain unrecovered, leading to product losses and additional energy consumption in upstream production processes

Technology Overview:

Nanofiltration (NF) is an advanced membrane separation technology that enables selective separation of molecules based on molecular size and charge. It operates at relatively low pressures compared to reverse osmosis and can separate small organic molecules, dissolved solutes, and impurities from solvent streams. The installation of a nanofiltration system for processing mother liquor streams enables the recovery and concentration of valuable API products or intermediates that would otherwise be lost. By recovering these materials, the system reduces the need for additional production batches and lowers the overall energy consumption associated with raw material processing, solvent evaporation, and crystallization.

Nanofiltration systems typically consist of high-performance membranes, feed pumps, pressure vessels, and control systems designed to handle pharmaceutical-grade processing requirements. The recovered product stream can be recycled back to the crystallization or purification stage, while the permeate stream containing solvents or smaller impurities can be reused or treated further.

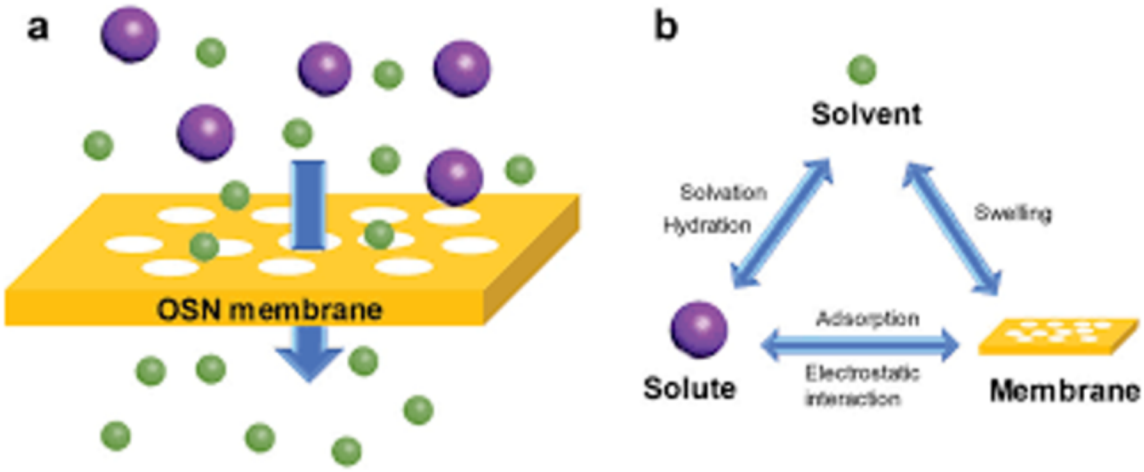
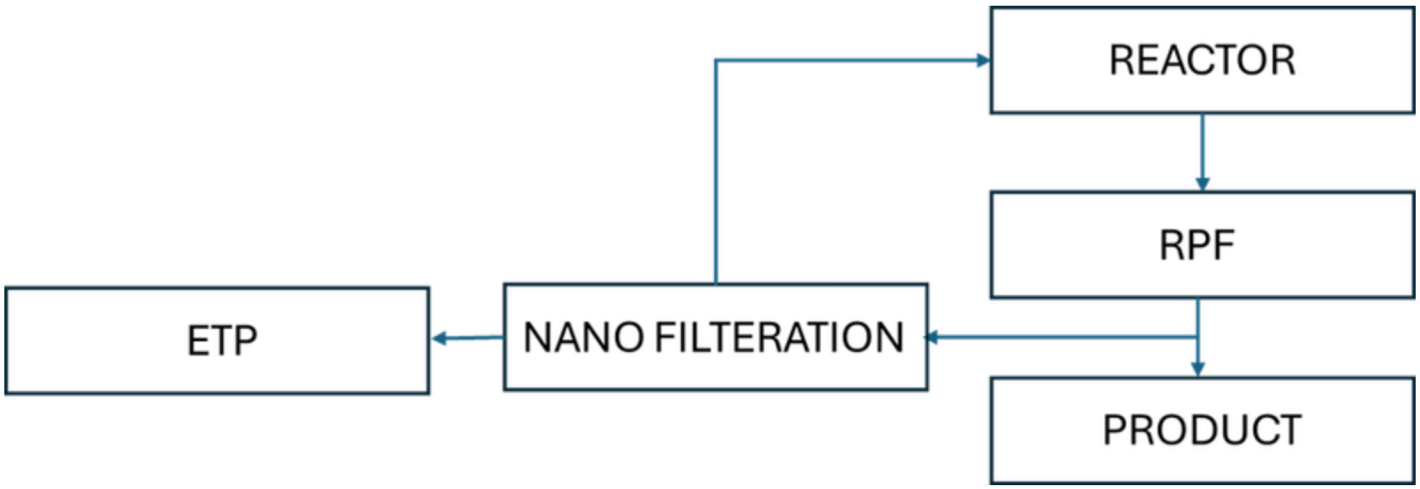


Figure 28: Schematic of a OSN membrane working

Nanofiltration membranes allow selective permeation of solvents and small molecules, while retaining larger organic molecules such as APIs or intermediates.

1. The process operates as follows:
2. Mother liquor is pumped into the nanofiltration module.
3. Pressure is applied using a high-pressure pump.
4. The membrane selectively separates the components:
    a. Retentate stream: concentrated product molecules
    b. Permeate stream: solvent and smaller impurities
5. The retentate containing recovered product is recycled back to the process.
6. Because separation occurs at ambient or moderate temperatures, technology requires significantly less energy compared to evaporation or distillation.



Objective	***Installation of nano filtration system for extracting products from mother liquor***
Investment	15 Lakhs
Payback	6 Months
Outcome	Yield improvement by 3.5% and 5% reduction in SEC

Case Study 21: Automated Dry Granulator (Roll Compactor) replacing Manual Compactor

Problem Statement:

Granulation is an important unit operation in pharmaceutical and Active Pharmaceutical Ingredient (API) manufacturing, particularly for improving powder flow properties, uniformity, and downstream processing efficiency. Traditionally, in several pharmaceutical manufacturing facilities, manual compaction or semi-manual granulation techniques are used to compact powder materials before further processing. These conventional practices often involve manual pressing, milling, and repeated handling of materials, which can result in inconsistent product quality, higher energy consumption, and longer processing times.

Technology Overview:

The Automated Dry Granulator (Roll Compactor) is an advanced pharmaceutical processing equipment designed to convert powders into uniform granules through mechanical compaction.

Working Principle:

In a roll compactor system, powder material is continuously fed between two counter-rotating compaction rolls. The applied pressure compresses the powder into a dense ribbon or sheet.

The process includes the following steps:

1. Powder material is fed into the compaction zone through a screw feeder.
2. Two rotating rolls compress the powder into a compact ribbon.
3. The compacted ribbon is passed through a granulator or milling system.
4. The ribbon is broken into uniform granules of desired size.
5. Oversized particles are recycled back to the compaction process.

The entire process is automated and controlled through programmable logic controllers (PLC) that regulate parameters such as roll pressure, roll speed, and feed rate.

Key Features

1. Continuous operation
2. Uniform compaction pressure
3. Controlled granule size distribution
4. Automated process control
5. Reduced material handling

Conclusion:

The installation of Automated Dry Granulators (Roll Compactors) in place of manual compaction systems represents a significant advancement in pharmaceutical granulation processes. By automating the compaction and granulation operations, the technology improves process consistency, reduces labor requirements, and enhances product quality.

Objective	***Installation of Automated Dry Granulator (Roll Compactor) replacing Manual Compactor***
Investment	18 Lakhs
Payback	27 Months
Outcome	Operation time reduced by 3 Hrs and >40% Energy Saving

Case Study 22: Rotary Vacuum Paddle Dryer (RVPD) replacing Vacuum Tray Dryer + Blender

Problem Statement:





Drying is a critical unit operation in pharmaceutical manufacturing, particularly in the production of active pharmaceutical ingredients (APIs) and intermediates. Conventionally, drying is carried out using Vacuum Tray Dryers (VTD) where the wet cake from filtration is manually loaded into trays and subjected to heating under vacuum conditions.

After drying, the material is transferred to a blender or mixer to achieve uniformity. Although widely used, this conventional approach has several limitations such as Multiple equipment operations (dryer + blender), High manual handling and labor, longer batch cycles, higher energy consumption due to prolonged heating, Product loss during material transfer and Increased contamination risks

Technology Overview:



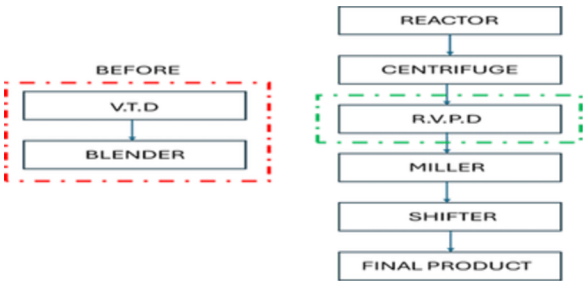


RVPD is a closed, agitated vacuum drying system that integrates drying and mixing in a single piece of equipment. The system uses heated paddles rotating inside a jacketed vessel under vacuum, enabling efficient heat transfer and uniform drying of wet solids.

Continuous agitation improves heat distribution, enhances solvent evaporation, and eliminates the need for separate blending operations. The RVPD operates under vacuum conditions, which significantly reduces the boiling point of solvents, allowing drying at lower temperatures and protecting heat-sensitive products.

Solution Implemented:

Replacing the vacuum tray dryer and blender with suitably sized RVPD, this significantly reduces drying time, lowers steam consumption and improves product quality.With energy savings of 20–40% RVPD represents a high-impact energy efficiency measure for API's.



Objective	*Rotary Vacuum Paddle Dryer (RVPD) replacing Vacuum Tray Dryer + Blender*
Investment	50 Lakhs
Payback	15 Months
Outcome	Reduction of cycle time from 72 hrs to 18 hrs

Case Study 23: Automated Reactor Auto-sampler System

Problem Statement:

In manual reactor sampling, operators must periodically extract liquids— a process that is labor-intensive, error-prone, interrupts production, and risks exposure to hazardous materials. The present sampling process involves stopping the reactor and removing the vacuum and utilities, Manual sampling also leads to inconsistent sample timing, higher rework rates, and reduced data quality.



Traditional sample collection adds indirect energy usage through repeated process stoppages (typically for 30 min) and quality checks.

Solution Implemented

Install closed-loop automated sampling systems for reactors with purge and sample collection to HPLC vials or inline analyzers.

1. **Productivity Gains**
   a. Automated vial mixing ensures ready-to-analyze samples with fewer re-runs.
   b. High throughput: up to 96 samples per automatic run.
   c. No interruption of reactor operation during sampling — enables true continuous monitoring.
2. **Accuracy & Reproducibility**
   a. Automated timing and precise liquid handling ensure highly reproducible samples.
   b. Variable sample volume: from 5 to 500 µL selectable for process needs.
   c. Controlled dilution and quenching preserve sample state at time of collection.

Energy Saving Potential: 10%

Installation Photos	***Automated Reactor Auto-sampler System***
Installation Photos	
Investment	3.5 Lakhs
Payback	16 Months
Outcome	Reduction of cycle time with reduction in steam and power

Case Study 24: Agitated Nutsche Filter Dryer (ANFD) replacing centrifuge + dryer

Problem Statement:

Filtration and drying are critical unit operations in pharmaceutical and chemical manufacturing, particularly in the production of Active Pharmaceutical Ingredients (APIs), intermediates, and specialty chemicals. Traditionally, these operations are carried out using two separate pieces of equipment: a centrifuge for solid-liquid separation followed by a dryer such as a vacuum tray dryer, rotary dryer, or paddle dryer. In the conventional process, slurry from a reactor is first transferred to a centrifuge, where solid-liquid separation occurs. The resulting wet cake is then manually transferred or conveyed to a separate dryer for moisture removal. After drying, the product is discharged for further processing or packaging.

This conventional approach has several operational limitations including:

1. Higher energy consumption due to repeated heating cycles
2. Increased material handling
3. Longer batch processing times

Technology Overview:

The Agitated Nutsche Filter Dryer (ANFD) is a closed vessel that combines filtration, washing, and drying within the same equipment. It consists of a cylindrical vessel with a filter plate at the bottom, an agitator assembly, and a heating jacket. The vessel operates under vacuum or pressure conditions.

Process sequence in ANFD , Slurry from the reactor is charged directly into the ANFD -> Filtration occurs through the filter plate under vacuum or pressure -> The wet cake is washed if required -> The agitator breaks and mixes the cake to improve drying efficiency -> Heat is supplied through the jacket using steam or hot water -> Moisture evaporates under vacuum and is condensed in a condenser system-> Dried products are discharged through the bottom valve.

The agitation mechanism continuously breaks and mixes the cake, ensuring better heat transfer and uniform drying. ANFD performs filtration, washing and drying in a closed system — reducing solvent losses and energy.

Solution Implemented:

Adopt ANFD sized for batch volumes with appropriate jackets, vacuum and inerting systems.

Objective	***Agitated Nutsche Filter Dryer (ANFD) replacing centrifuge + dryer***
Investment	160 Lakhs
Payback	48 Months
Outcome	Reduction of cycle time from 18 hrs to 3 hrs and 46% power reduction

Water Conservation & Circularity Opportunities/Case studies:

Case Study 25: Condensate Recovery System

a. Unit Profile

Boiler Capacity	*2 TPH, HSD-fired*
Operating Pressure	9 kg/cm²
Steam Temperature	150°C
Steam Used In	Reactors, MEE plant, hot water generator (ANFD), steam ejectors
Current Condensate Recovery	15–20%
Condensate Available	900 kg/hr (considering losses)
Unit Capacity	1,198 kl (API manufacturing)

b. Baseline Scenario

The unit has installed one 2-TPH HSD-fired boiler for process applications across three blocks and an MEE plant. The steam is used in reactors, MEE plant, hot water generator of ANFD, steam ejectors, and other users.

At present, the condensate recovery is low (around 15–20%), unlike the recommended range of >90%. There is a good potential to recover the condensate which will give appreciable savings in fuel apart from the savings in water. Condensate can be recovered from reactors heating and tray driers.

c. Implemented Technology

Condensate recovery is a process to reuse the water and sensible heat contained in the discharged condensate. A flash vessel and condensate transfer/pumping unit is installed to recover all the condensate from various processes. The condensate pumping/transfer system uses motive steam (no electric motor required). Condensate is one of the purest forms of water with TDS of only 3.5 ppm.

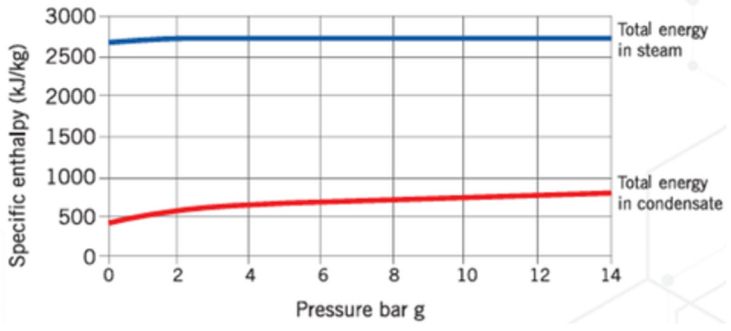


Figure 29: Heat content in condensate

A flash steam generator can also be installed just before the condensate recovery system to recover flash steam for heating boiler feed water or low-pressure steam applications

Merits

- ❖ High availability due to zero moving parts - high reliability and equipment availability.
- ❖ Low wear & tear, low maintenance, low downtime.
- ❖ High motive inlet pressure - no pressure reducing valve/station required up to 10 kg/cm².
- ❖ High discharge of condensate: 50 litres per stroke.
- ❖ High condensate temperature return - no cavitation issues over electrical pumps.
- ❖ Conductivity-based level controller with large LED display and flow totaliser.
- ❖ Suitable for outdoor installations; energy efficient - steam trap drains and pump vent returned to receiver tank.

Limitations

- ❖ Requires regular maintenance.
- ❖ Estimation of proper back pressure required.
- ❖Inventory of electronic spare parts to be maintained.

d. Investment & Payback

Annual Fuel Savings	30,000 litres of HSD
Annual Monetary Savings	INR 20.10 lakh
Total Investment	INR 7.00 lakh
Payback Period	4 months
IRR	319.49%
NPV (70% Debt @ 12%)	INR 98.64 lakh

e. Energy & Cost Savings

Annual Fuel Savings	Annual Energy Savings	Annual GHG Savings
30,000 Litres of HSD	27.22 TOE	80.40 T CO_2

f. Environmental Benefits

Condensate recovery reduces the need for fresh make-up water (conserving a water resource) and reduces the fuel required to raise cold water to boiling point. The annual GHG reduction is 80.40 T CO_2. Additionally, reduced chemical treatment requirements lower the chemical load on the effluent treatment system.

Case Study 26: IoT-based Water Management System

a. Unit Profile

Daily Water Consumption	~4,00,000 litres (400 kl/day); Reference unit: 12,000 kl/day
Water Sources	Borewells / external vendor purchases
Water Types Used	RO water, soft water, raw water
Current Measurement	Manual meter readings - once a day; prone to errors
Number of Measurement Points	17 consumption points + 4 level measurement points
Technology	IoT-based Water Management System (cloud + mobile app)

b. Baseline Scenario

Water is consumed at various points in the facility as RO water, soft water, or raw water. The source of water is from nearby borewells or external vendor purchases. Several issues were identified:

- Facility's mechanical engineering team had personnel to note values - manual errors made while noting down readings.
- Location of meters at far off places - hard to reach, occupational hazards.
- No real-time data of water being consumed since values were noted only once a day.
- Plausible inaccurate and inefficient meter reading led to inaccurate product costing.
- Inaccurate production efficiency calculations.

c. Implemented Technology

The IoT system measures water consumption at various points within the infrastructure and calculates total water usage and health of the infrastructure. This consumption pattern is compared with previous days, weeks, and months' data to ensure a healthy water infrastructure is maintained. The architecture is based on IIoT (Industrial Internet of Things). The system monitors the level of water in OHTs and sumps, ensuring availability of enough water. The plant manager or ground staff can interact with the dashboard using a mobile application or remote desktop application.

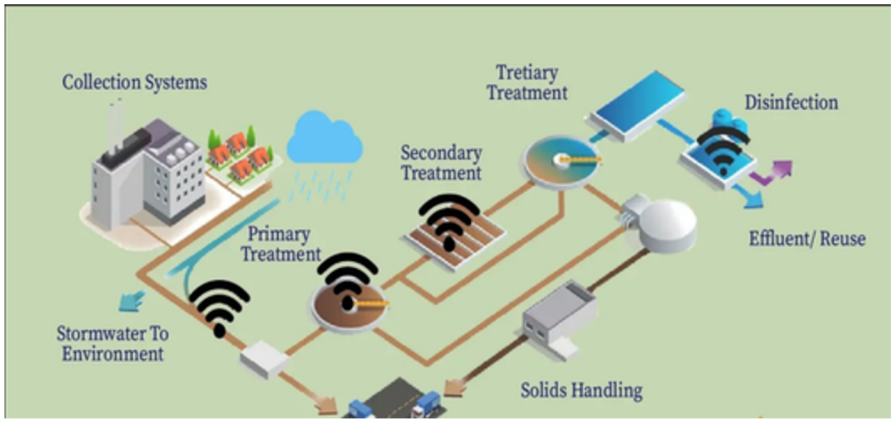


Figure 30: Schematic of an IoT based water management system for a wastewater treatment facility

Merits

- Real-time productivity and water consumption monitoring.
- Identifies potential inefficiencies in water consumption.
- Monitors section-wise consumption - identifies production and cleaning phases.
- Tracks and monitors borewell and water pump operations.
- Monitors every shift-wise consumption to track plant operation effectively.
- Provides vigilance over water infrastructure (RO plant, softener, ETP).
- Excess consumption detection and notifications.
- Alerts to help ground staff become aware about leakage, wastage, and overconsumption.
- Helps identify health of RO and softener plants.
- Quarterly consultant visits with water experts and monthly reports for water auditing.

Limitations

- Replacement of mechanical flow meters in infrastructure with digital meters.

d. Investment & Payback

Annual Monetary Savings	INR 1.70 lakh
Total Investment	INR 1.12 lakh
Payback Period	8 months
IRR	181.12%
NPV (70% Debt @ 12%)	INR 8.10 lakh

e. Energy & Cost Savings

The IoT-based water management system generates savings primarily through water conservation (reduced consumption, reduced vendor purchase costs) and energy savings from water infrastructure operations (pumps, RO plant). Annual monetary savings: INR 1.70 lakh from water conservation and maintenance savings. Additionally, energy savings from reduced pump operations contribute to indirect energy and GHG reduction.

f. Environmental Benefits

Real-time monitoring and leak detection reduce unnecessary water consumption, directly conserving a precious natural resource. Reduced water extraction from borewells lowers the environmental stress on local groundwater resources. Accurate monitoring also reduces excess wastewater generation, lowering the load on the Effluent Treatment Plant (ETP) and reducing chemicals consumed in treatment. The system has a replication potential across all pharma units.

Renewable Energy Opportunities/Case studies:

Case Study 27: Grid-Connected Solar Rooftop PV System

a. Unit Profile

Contract Demand	260 kVA
Electricity Price	INR 7.0/kWh
Average Load	150–200 kW
Effective Rooftop Area Available	200 sq. m. (true south facing)
Location (Lat/Long)	27.15°N / 88.15°E (Sikkim)
Altitude Above Sea Level	1,315 m
Direct Normal Irradiance	4.22 kWh/m²/day (annual average)
Wind Speed	2.77 m/sec
Proposed Solar PV Capacity	25 kWp
System Type	Grid-connected rooftop PV (GCRT), no battery

b. Baseline Scenario

The unit is purchasing electricity from the grid for the power requirement in its plant. The unit has sufficient rooftop area which can be utilised to install solar PV for self-generation of electricity rather than purchasing from the grid. Monthly solar irradiance data shows strong generation potential particularly from October to January and lower generation during monsoon months (June–August).

Solar Irradiance graph (For the unit) à Latitude: 27.15o, Longitude: 88.15o
Annual average solar irradiance: 4.22 kWh/m2/day

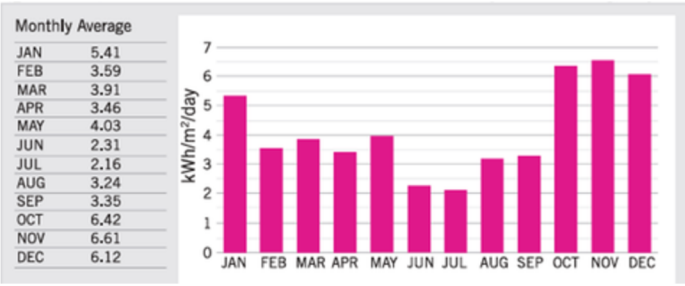


Figure 31: Solar Irradiance

c. Implemented Technology

As per the site specifications, the unit has potential to install 25 kWp solar rooftop which can generate around 0.40 lakh units of electricity annually. The proposed system is a grid-tied Solar PV power plant consisting of: PV array, Module Mounting Structure, Power Conditioning Unit (PCU) with Maximum Power Point Tracker (MPPT), Inverter, Controls & Protections, interconnect cables, junction boxes, and distribution boxes.

As per the site specifications, the unit has potential to install 25 kWp solar rooftop which can generate around 0.40 lakh units of electricity annually. The proposed system is a grid-tied Solar PV power plant consisting of: PV array, Module Mounting Structure, Power Conditioning Unit (PCU) with Maximum Power Point Tracker (MPPT), Inverter, Controls & Protections, interconnect cables, junction boxes, and distribution boxes



Figure 32: Rooftop PV installation (Depictive image)

Merits

- PV panels provide clean and green energy - no harmful greenhouse gas emissions during generation.
- Technology development in solar power industry is constantly advancing, resulting in lower costs.
- PV panels have no mechanically moving parts - far less breakage and lower maintenance than other RE systems.

Limitations

- High initial cost of purchasing a solar PV system (panels, inverter, batteries, wiring, installation).
- Efficiency drops during cloudy and rainy days, resulting in lower generation.
- Installing a large PV system requires significant roof area.

d. Investment & Payback

Proposed Solar Capacity	*25 kWp*
Annual Energy Generation	40,000 kWh (1,600 kWh/kWp/year)
Annual Monetary Savings	INR 2.60 lakh
Total Investment	INR 12.50 lakh (INR 50,000/kWp)
Payback Period	57 months (4.75 years)
IRR	19.81%
NPV (70% Debt @ 12%)	INR 4.45 lakh
Useful Life	25 years

e. Energy & Cost Savings

Annual Electricity Savings	Annual Energy Savings	Annual GHG Savings
40,000 kWh	3.44 TOE	32.80 T CO_2

f. Environmental Benefits

Solar PV generation directly displaces grid electricity (which is fossil fuel-based), resulting in annual GHG savings of 32.80 T CO_2 per 25 kWp system. Over the 25-year project life, total CO_2 savings amount to approximately 820 T CO_2 per unit. PV panels have no emissions during operation and require minimal water for cleaning only. The technology supports India's commitment to increasing its renewable energy capacity under the National Solar Mission and Paris Agreement targets.

Case Study 28: Solar-Wind Hybrid System

a. Unit Profile

Contract Demand	450 kVA
Electricity Price	INR 6.5/kWh
Average Operating Load	260–300 kW
Proposed Hybrid Capacity	50 kWp (Solar-Wind combined)
System Name	Solar Mill (Savonious type vertical axis wind turbine + Solar PV)
Area Required	60 m²
Wind Power Generation Starts At	5 kmph
Mechanical Braking Activates At	18 m/s
Design Life	25 years

b. Baseline Scenario

The unit is purchasing electricity from the grid for the electrical energy requirement. Renewable energy implementation posts challenges such as capital cost and consistency of power output. The latter challenge can be solved by the installation of a Solar-Wind hybrid system. The plant has sufficient rooftop area which can be utilised to install a solar-wind hybrid system that harnesses both solar and wind energy.

c. Implemented Technology

The Solar-Wind Hybrid System (also known as Solar Mill) generates: daytime energy from both sun and wind; day and night energy from wind; energy even on cloudy days; and more energy on hot sunny days due to the cooling effect of wind on solar panels. It consists of three vertical axis wind turbines (Savonious type) coupled to three permanent magnet generators. Automatic mechanical braking is provided once wind speed exceeds the cut-off speed. On-board smart electronics include dynamic MPPT.

For a rooftop installation, combining solar and wind power is complementary - many locations are less windy in the middle of the day when the sun is at its peak, and wind picks up after dusk. Solar modules also provide protection for wind turbine portions from direct rain and hail. Power from both wind and solar generation is routed into a common 48V DC bus with built-in charge control for a lead-acid battery bank.



Figure 33: Solar Wind Hybrid system

Merits

- Power generation during daytime and nighttime.
- Reliable power generation even on cloudy days.
- A compact hybrid solar mill to meet a portion of plant load.
- Power generation starts at 2–5 m/s; mechanical braking beyond 18 m/s.
- Power generation can be monitored online.

Limitations

- Higher investment compared to solar-only systems.

d. Investment & Payback

Installed Capacity	50 kWp (Solar-Wind combined)
Average Generation/Day/kWp	6.0 kWh
Annual Energy Savings	1,09,500 kWh (conservative basis)
Annual Monetary Savings	INR 7.11 lakh
Total Investment	INR 50 lakh
Payback Period	63 months
IRR	20.88%
NPV (70% Debt @ 12%)	INR 13.15 lakh

e. Energy & Cost Savings

Annual Electricity Savings	Annual Energy Savings	Annual GHG Savings
1,09,500 units	9.42 TOE	89.79 T CO_2

f. Environmental Benefits

The solar-wind hybrid system provides more continuous renewable electricity generation than solar-only systems, resulting in higher annual GHG savings of 89.79 T CO_2 per 50 kWp unit. Over 25 years, total CO_2 savings are approximately 2,245 T CO_2 per unit. The dual-generation system maximises utilisation of available renewable resources (both solar irradiance and wind), improving the Capacity Utilisation Factor to 25–30% compared to 19–22% for solar-only. The vertical-axis wind turbine design is low-noise and suitable for urban/industrial rooftop environments.

5. Water and Waste Management

5.1 Water Management

Pharmaceutical manufacturing is water-intensive, particularly for cleaning-in-place (CIP), equipment washing, WFI generation, and cooling water. Benchmarking data suggests that MSME pharma units consume 10-30 litres of water per kg of finished product. Key water conservation measures include:

- Counter current rinsing systems for equipment washing (reduces water use by 50-70%)
- Closed-loop cooling water systems with water treatment and reuse
- Rainwater harvesting and grey water recycling for non-potable uses
- Monitoring water consumption at process level with IoT-based meters
- Leak detection and repair (typically 5-15% of water is lost through leaks in MSME units)

5.2 Effluent Treatment and ZLD

All the MSME pharmaceutical units are mandated for Zero Liquid Discharge (ZLD), that are generating effluent above prescribed limits. ZLD systems, typically using Multiple Effect Evaporators (MEE) or Mechanical Vapor Recompression (MVR) followed by Agitated Thin Film Dryers (ATFD), which consumes significant energy due to its High-Pressure steam requirements and pumping systems (thermal and electrical).

Energy efficiency opportunities in ETP/ZLD systems include:

- MVR (Mechanical Vapor Recompression) technology for MEE - reduces thermal energy consumption by 70-80% compared to conventional MEE using live steam
- Heat integration between ETP streams and process streams
- Biogas recovery from biological treatment stages (for units with high organic load)
- Proper ETP load monitoring and segregation of low-TDS and high-TDS streams to reduce MEE load

5.3 Solvent Recovery

API and chemical intermediate MSME manufacturing units use significant quantities of organic solvents (IPA, acetone, ethanol, methanol, toluene, MDC, etc.). Solvent recovery through distillation columns reduces both raw material cost and solvent waste disposal cost. Modern solvent recovery systems with automated controls can achieve recovery rates of 90-95%, with payback periods of 6-18 months in units consuming more than 500 litres/day of recoverable solvents.



Figure 34: Solvent recovery plant (Depiction)

5.4 Waste Management – Usage in Cement plants as Alternate Fuel Resource (AFR) – A case study

Background:

The API (Active Pharmaceutical Ingredients) manufacturing process generates high calorific value organic residue, mostly from the solvent distillation process. These wastes are generally disposed either through site incineration or sent to TSDF for incineration. The opportunity of consumption of this high calorific value wastes as alternate fuel in cement industry was explored.

Although there are some restrictions and uncertainties in types and quantities of wastes that could be used as fuels in cement plants, this form of disposal was found to be cost effective, with less environmental impact as compared to conventional disposal methods such as land fill and incineration

Implementation Details:

All high calorific value residue and its physical states were quantified and four streams of waste in liquid state were identified, which could be used as alternate fuel. A total of 2395 MT (10.3% of total waste) of waste was sent to a nearby cement plant for co-processing as an AFR in the cement kiln. The trials were successful with the waste streams being utilized fully in the cement kilns, although there were very minimal operational challenges faced by the cement plants.

Savings and Results:

- Reduction of GHG emission = 1185 MT/Annum of CO_2
- 527 MT/Annum of coal savings at cement plant
- Reduced Organic waste disposal cost by 50%



Figure 35: Waste disposal from pharma units

With rising AFR consumption in cement plants for various aspects, this method of waste disposal for pharma plants are proving to be an efficient and cost-effective method for their waste processing.

6. Financial Mechanisms and Support Schemes

Pharma MSME industries are eligible for a range of financial incentives designed to promote technology upgradation, green transformation, and manufacturing excellence.

1. Technology Upgradation and Green Financing (MSE-GIFT):

The MSE Green Investment Financial Technology (MSE-GIFT) scheme is highly relevant for the pharmaceutical sector, which is specifically recognized in the scheme's approved 890-technology list.

- **Interest Subvention:** Eligible units can receive a 2% interest subvention per annum for up to 5 years on term loans up to ₹2 crores.
- **Risk Sharing Facility (RSF):** Provides credit guarantee coverage for loans up to ₹2 crores to mitigate risk for financial institutions.
- **Eligible Pharma Equipment:** The sources list specific machinery for "Pharmaceutical & Bulk Drugs" that qualifies for these benefits, including:
    - Flash Dryers or Rotary Vacuum Dryers.
    - Nauta Mixers (Blenders) and Blister Packing Machines.
    - Semi-Automatic Capsule Filling Machines and Fluidized Bed Boiler Blowers.
    - CNC Precision Forming Machines and Submerged Mechanical Aerators/Agitators.

2. Capital Subsidy for Circular Economy (MSE-SPICE):

Existing brownfield pharma units that invest in Circular Economy practices (such as waste management or recycling systems) can avail of the MSE-SPICE scheme.

- **Subsidy Amount:** A direct 25% Credit Linked Capital Subsidy on the cost of plant and machinery.
- **Maximum Limit:** The subsidy is capped at ₹12.5 lakhs for projects costing more than ₹50 lakhs.

3. MSME Sustainable (ZED) Certification Incentives:

Pharmaceutical companies can improve their quality standards and environmental footprint through Zero Defect Zero Effect (ZED) certification.

- Technology Upgradation: Certified MSMEs can receive a subsidy of up to ₹3 lakhs for "Zero Effect" solutions.
- Certification Support: Financial assistance for testing, quality, or product certification covers up to 75% of costs (max ₹50,000).
- Handholding Support: Consultancy for ZED-certified units is available up to ₹2 lakhs.
- Case Insight: Century Pharmaceuticals Ltd. reported saving ₹1.39 lakhs in annual electricity costs by implementing ZED-related improvements in their Effluent Treatment Plant (ETP).

4. Telangana State Specific Incentives:

If the unit is located in Telangana, it can access state-level capital subsidies under the 2024 MSME Policy:

- **T-IDEA:** General category units receive a capital investment subsidy of 15% to 25% (capped at ₹30 lakhs).
- **T-PRIDE:** For SC/ST-owned units, the subsidy is currently 35% and is proposed to increase to 50% of the cost (up to ₹1.00 crore).
- **Common Facility Centers (CFCs):** The state government aims to establish Cluster Based Testing Facilities (CBTFs) through PPP models specifically for bulk drug manufacture clusters to provide affordable quality testing.

5. Innovation and Intellectual Property (MSME-Innovative):

Pharma MSMEs investing in new product design or patent protection can access:

- **Design Component:** GoI contributes **75% (Micro)** or **60% (Small & Medium)** of project costs, up to **₹40 lakhs for** design-led manufacturing.
- **IPR Support:** Reimbursement of up to **₹1 lakh for domestic patents** and **₹5 lakhs for foreign patents.**

6. Subsidies for SC/ST Entrepreneurs:

- Under the **National SC-ST Hub**, entrepreneurs from these categories are eligible for a **25% subsidy on the purchase of plant and machinery** (up to ₹25 lakhs) through the Special Credit Linked Capital Subsidy Scheme

Eligible equipment under MSME GIFT Scheme: Pharmaceuticals and Bulk drugs

Eligible Equipment / Technology	***Energy Saving Min (%)***	***Energy Saving Max (%)***	***Other Advantages***
Flash Dryers or Rotary Vacuum Dryers (Product Drying)	28	50	Low-cost instant drying with no pulverizing, low initial investment as compared to spray dryer, control batch drying process, control of material
Use of Biomass Gasifier with Slurry Economizer (Incinerator) Utilize agricultural & industrial waste	50	60	Heat recovery system, eco- friendly, carbon credits can be earned
Nauta Mixers (Blenders) Grains do not break	15	20	No manual charging / discharging, shorter mixing time, easy addition of liquid & cleaning
Blister Packing Machine (using Variable Frequency Drive)	30	35	Reduce edge cutting wastage, improve blister quality

Semi-Automatic Capsule Filling Machine (with	20	30	AC Frequency Drive) PLC controlled, loader disengaged automatically, different speed to fill different type of powder / pellet, drug hopper design reduce time to dismantle / unload powder, auto-drug hopper feed-in mechanism reduce weight variation & improve productivity
Variable Frequency Drive for Fluidized Bed Boiler Blower	30	40	Extend equipment life, reduce maintenance, reduce peak demand, safety against power fluctuation
Regenerative Furnace & Refractory Recuperator	25	35	High flame temperature, lower emissions
Co2 Flue Gas Recovery Plant Based on Flue Gas System Less corrosive effect on inner surface	25	30	Carbon credits can be earned
Flaker with Silo and Screw Conveyer (Ice Flaker) Automatic operation	5	10	No spillage, no water, no latent heat loss
CNC Precision Forming machine High-Speed positioning	45	55	Sleek Design, High Accuracy, Precision welded frame construction for maximum strength and rigidity, adjustable bending speed, High resolution.
Programmable Dosing and misting Systems Speed-controlled gear motor with speed display and adjustment through the display	30	35	Monitoring of the component pressure using the digital display
Submerged Mechanical Aerator/Agitator (Aquarator) Easy maintenance	30	40	Accommodates various processing methods, achieves homolytic aeration mixing, no settling sludge and no clogging
Oxygen Plant (Manufacture of Oxygen and Nitrogen by Air Separation Method) Capable of simultaneously producing oxygen and nitrogen	20	25	Easy access for maintenance, better life

7. Energy Benchmarks and Key Performance Indicators

7.1 National Benchmarks for MSME Pharma Units

The following table presents the recommended energy performance benchmarks for key utilities in MSME pharma units, based on the BEE-NPC Energy Mapping Study (2022) and OEM specifications. These benchmarks should serve as targets for units during RECP assessments:

S.No	*System*	*UOM*	*Present (Avg.)*	*Benchmark (Long-term)*	*Best Tech.*	*EE Potential*
1	+5°C Chiller	kW/TR	1.27	0.6	0.36	~53%
2	-5°C Brine Chiller	kW/TR	1.34	1	N.A.	~25%
3	-10°C Brine Chiller	kW/TR	1.81	1.75	N.A.	~3%
4	-20°C Brine Chiller	kW/TR	2.37	2	N.A.	~16%
5	AHU	W/CFM	1.02	0.25	0.22	~75%
6	Air Compressor	kW/CFM	0.18	0.15	0.14	~25%
7	Pumps	% efficiency	50%	>70%	>82%	~40%
8	Vacuum Pumps	kWh/1000m³	44.14	30	26	~32%
9	Boiler (Solid fuel)	% thermal eff.	61.70%	>80%	85%	~18%
10	Boiler (Liquid fuel)	% thermal eff.	61.10%	>90%	94-95%	~32%

Note: *Source: BEE-NPC, Energy and Resource Mapping of MSME Clusters - Pharma Sector, National Productivity Council, February 2022; OEM specifications from Daikin, Carrier, Bluestar, Atlas Copco, Grundfos, Thermax.*

8. Conclusion and Roadmap

8.1 Summary

The Indian Pharma Sector is a significant contributor to India's manufacturing ecosystem. At the same time, it represents a major opportunity for resource efficiency improvement and cleaner production.

The 28 technology case studies and opportunities presented in this compendium span four key areas: energy efficiency, material circularity, water & waste management and renewable energy adoption. The technologies (specially for energy efficiency) range from low-cost operational improvements (steam trap maintenance, power factor correction, LED lighting) to moderate-investment upgrades (VFDs, EC motors, condensate recovery) and capital investments (biomass boilers, solar rooftop, chiller replacement).

8.2 Recommended Priority Actions

For MSME pharma units, the following priority technology interventions are recommended based on ease of implementation, financial attractiveness, and capital saving potential:

Priority	***Technology***	***Energy Savings***	***Energy Savings***	***Investment***
1	Steam trap audit and replacement	3-8% thermal	2-6 months	Low
2	Condensate recovery system	5-8% fuel cost	4-8 months	Low-Moderate
3	VFD on air compressors	20-30% compressed air energy	8-15 months	Moderate
4	LED lighting replacement	50-70% lighting energy	12-18 months	Low-Moderate
5	VFD on chiller compressor and CHW pumps	15-25% refrigeration energy	12-20 months	Moderate
6	EC motors for AHU fans	70-78% AHU fan energy	15-24 months	Moderate
7	Biomass boiler conversion (where feasible)	60-70% boiler fuel cost	6-12 months	Moderate-High
8	Solar rooftop PV system	15-30% grid energy offset	4.5-6 years	High

8.3 Implementation Roadmap

A phased implementation approach is recommended for MSME pharma units:

- Phase 1 (0-6 months): No-cost and low-cost measures - operational optimization, energy monitoring, steam trap maintenance, compressed air leak fixing, LED lighting, power factor correction
- Phase 2 (6-18 months): Moderate investment measures - VFDs for compressors and chillers, condensate recovery, EC motors for AHUs, pump replacement with IE3+VFD units
- Phase 3 (18-36 months): Capital investment measures - biomass boiler conversion, solar rooftop installation, chiller upgradation, IoT-based energy and water management
- Ongoing: Continuous monitoring, benchmarking, and progressive improvement toward national best-practice performance levels

Bibliography and References

1. National Productivity Council (NPC). (2022). Benchmarking & Policy Recommendation Report for Energy Efficiency in MSME - Pharma Sector (Energy and Resource Mapping of MSME Clusters). Submitted to Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India. February 2022.

2. CII – GBC Sohrabji Godrej Green Business Centre, UNIDO & BEE. (2020). Technology Compendium: Energy Efficiency and Renewable Energy Opportunities in Pharma Sector - Sikkim Pharma Cluster. September 2020.

3. Bureau of Energy Efficiency (BEE). (2024). Energy Conservation Building Code for Industry. Ministry of Power, Government of India.

4. Indian Brand Equity Foundation (IBEF). (2024). Pharmaceuticals Sector Report. www.ibef.org.

5. Ministry of New and Renewable Energy (MNRE). (2024-25). Benchmark Costs for Rooftop Solar Projects. Government of India.

6. Telangana State Electricity Regulatory Commission (TSERC). (2022). Net Metering Regulations. Hyderabad.

7. Thermax Ltd. Product Specifications: COMBLOC Biomass-fired Boilers; SHELLMAX GLOBAL Liquid/Gas Fired Boilers. 2024.

8. Daikin Industries Ltd. Product Specifications: Navigator-WWV (VVR Water-cooled Screw Chiller). 2024.

9. ebm-papst. EC Motor Technology for HVAC Applications. 2023.

10. Grundfos India. IE3 Motor Pumps with Integrated VFD - Technical Specifications. 2024.

11. Atlas Copco India. VFD Screw Compressor Product Range. 2024.

12. Department of Pharmaceuticals, Government of India. Annual Report 2023-24.

13. Telangana State Pollution Control Board (TSPCB). Environmental Standards for Pharmaceutical Units. 2023.

14. Taprogge GmbH. Online Condenser Tube Cleaning Systems - Technical Literature. 2023.

Greening of MSMEs in Telangana

The Government of Telangana has taken up the “Greening of MSMEs” initiative, under the Raising and Accelerating MSME Performance (RAMP) Programme, with an intent to support MSMEs in adopting sustainable and resource-efficient industrial practices. Research and Innovation Circle of Hyderabad (RICH) is implementing the Greening of MSMEs program in Telangana with technical support and program delivery comprising awareness creation, energy audits, and handholding support being provided by CII. The initiative promotes cleaner technologies, energy and water conservation, waste reduction, and improved operational efficiency through Resource Efficient and Cleaner Production (RECP) assessments, awareness programs, and cluster-level interventions. By facilitating technical guidance and implementation support, the programme helps MSMEs reduce environmental impact, improve productivity, and enhance their competitiveness in both domestic and global markets.

Research and Innovation Circle of Hyderabad (RICH)

RICH was launched in 2017 as a first-of-its-kind initiative by the Government of Telangana. RICH was established to bridge the gap between research and real-world applications by enabling collaboration among research institutions, industry, startups, and government bodies. RICH also serves as Hyderabad’s Science and Technology City Cluster, under a national initiative led by the Office of the Principal Scientific Adviser to the Government of India. In this capacity, RICH drives multidisciplinary projects to address complex local and national challenges. Working at the intersection of science, technology, and entrepreneurship, RICH focuses on three critical sectors “Life Sciences”, “Food & Agriculture”, and “Sustainability”. In the Sustainability area, RICH focuses on Clean Energy Transition, Industrial Decarbonization and Circularity through strategic partnerships, pilot initiatives, and policy engagement. RICH fosters a culture of innovation that delivers scalable and transformative solutions for long-term impact.

Mr. Srinivas Cherla
Director of Sustainability
E: dir-sa-rich@telangana.gov.in

Mr. Kishore Kumar Gadam
Senior Project Manager, Sustainability,
E: srpm-citsa-rich@telangana.gov.in

Mr. U Guru Sri Charan
Project Manager, Sustainability
E: pm-citsa-rich@telangana.gov.in



RICH
Research and Innovation Circle of Hyderabad

RICH, T-Hub Foundation, Plot No 1/C, Sy No 83/1, Raidurgam Panmaktha,
Hyderabad Knowledge City, Hyderabad, Telangana – 500081
cmanager-rich@telangana.gov.in