



**REGENT EDUCATION & RESEARCH
FOUNDATION GROUP OF INSTITUTIONS**

**DEPARTMENT OF MECHANICAL
ENGINEERING**

MECHANICA

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"Innovate • Design • Analyze • Inspire"

Message from the Head of the Department

The Department of Mechanical Engineering proudly launches MECHANICA, a platform dedicated to technical learning, innovation, creativity, and student engagement. This E-magazine aims to showcase emerging technologies, industrial developments, coding skills, project innovations, and engineering achievements of our students and faculty members.

Dr. Pritish Banerjee
Head, Department of Mechanical Engineering

Editorial Note

MECHANICA serves as a bridge between classroom learning and real-world engineering applications. Through technical articles, industry updates, coding tips, project showcases, and creative content, students are

encouraged to develop professional and research-oriented thinking.

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Department Vision

To nurture competent mechanical engineers through quality education, innovation, research, entrepreneurship, and sustainable engineering practices for the benefit of society.

*‘Engineering the Future Through
Knowledge and Innovation’*

JALNOVA

SOLAR-POWERED ADAPTIVE WATER PURIFICATION & REAL-TIME QUALITY MONITORING SYSTEM

A student innovation for rural and mining-affected communities

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Figure 1. Proposed JalNova prototype and treatment architecture (concept illustration from the project report).

Introduction

Access to safe water remains a major challenge in rural and mining-affected areas, where source water may contain suspended particles, dissolved minerals, microbial impurities and site-specific contaminants. Purification alone is not enough: a system also needs to monitor water quality and respond when readings fall outside configured limits.

JalNova is a proposed low-cost, portable and solar-assisted water-treatment platform that combines multi-stage purification with real-time sensing and automatic quality-based routing. Designed for a 10–15 litre batch demonstration, it aims to make water treatment more adaptive and easier to monitor in locations with limited infrastructure.

The JalNova Blueprint

The project follows a closed-loop engineering approach: Sense → Decide → Treat → Verify → Accept/Reject. An ESP32 controller receives measurements from pH, total dissolved solids (TDS), turbidity and temperature sensors. Based on configured rules, it selects the required treatment mode and checks the treated batch before routing it to a clean-water tank or a reject/holding tank.

How the Treatment Train Works

- 1. Electrocoagulation:** Aluminium electrodes promote the formation of flocs that can capture suspended and colloidal matter. Operating current, electrode spacing, pH and treatment time must be optimized during trials.
- 2. Settling and 5 μ m Filtration:** The water rests so flocs settle by gravity, then passes through a fine sediment cartridge to remove residual particles.
- 3. Activated Carbon:** The carbon stage can reduce colour, odour and selected organic impurities. It is not a dependable method for reducing dissolved salts.
- 4. pH Control:** A controlled dosing pump adjusts pH toward a configured process range, followed by a new sensor reading.
- 5. Reverse Osmosis:** The RO membrane reduces dissolved salts and produces lower-TDS permeate. The concentrate/reject stream is collected separately for assessment and responsible handling.
- 6. UV-C and Final Verification:** The permeate passes through an enclosed UV-C module intended to inactivate microorganisms. Final sensors check the batch before the controller selects the clean or reject route.

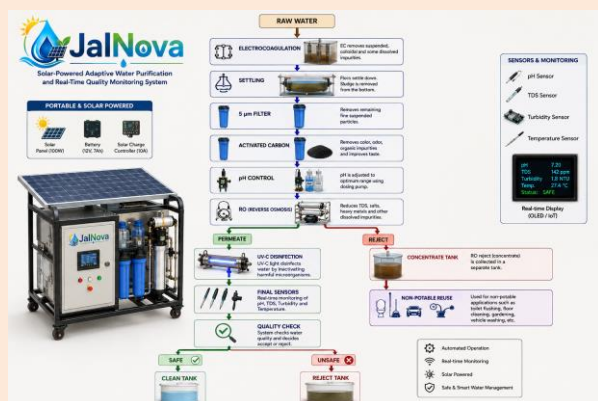


Figure 2. Proposed treatment stages and sensor-based control concept.

What Makes It Innovative?

- Solar-assisted operation: a proposed 100 W panel, 12 V battery and charge controller support demonstration use.
- Four-parameter monitoring: pH, TDS, turbidity and temperature are monitored as part of the treatment workflow.
- Adaptive control: treatment stages can be selected according to measured source-water conditions.
- Automatic quality routing: a batch is directed to the clean tank only when configured prototype criteria are met.
- Responsible reject management: RO concentrate is stored separately for source-specific assessment before non-potable reuse or safe disposal.
- Portable construction: the proposed trolley-mounted unit targets 10–15 L batch treatment.

Prototype at a Glance

SIH Problem Statement	26040
Controller	ESP32
Sensors	pH, TDS, turbidity and temperature
Proposed capacity	10–15 L batch
Power	100 W solar panel + 12 V, 7 Ah battery
Estimated budget	Approx. ₹14,700

Challenges and the Road Ahead

The next stage is to build and test the physical prototype, calibrate the sensors, optimize electrocoagulation, measure RO recovery and energy use, and validate UV performance through appropriate testing. The system's suitability will depend on the chemistry and microbiological quality of each water source.

The four online sensors do not establish complete drinking-water safety. Mining-related contaminants such as arsenic, lead, manganese, iron or fluoride require source-specific laboratory analysis. UV-C hardware must remain enclosed, electrocoagulation sludge must be managed responsibly, and RO concentrate should be treated as potentially contaminated until assessed.

Conclusion

JalNova's central contribution is the integration of established treatment technologies with real-time monitoring, adaptive control and final quality-based routing in a portable, solar-assisted concept. It remains a proposed proof-of-concept, and laboratory validation is essential before any claim of drinking-water compliance or field deployment.

DAIRY SETU

A DUAL-STAGE PASSIVE MILK-CHILLING CAN FOR SMALL-SCALE DAIRY FARMERS

A lightweight, modular cold-chain concept combining phase-change material, ice cartridges and multilayer insulation

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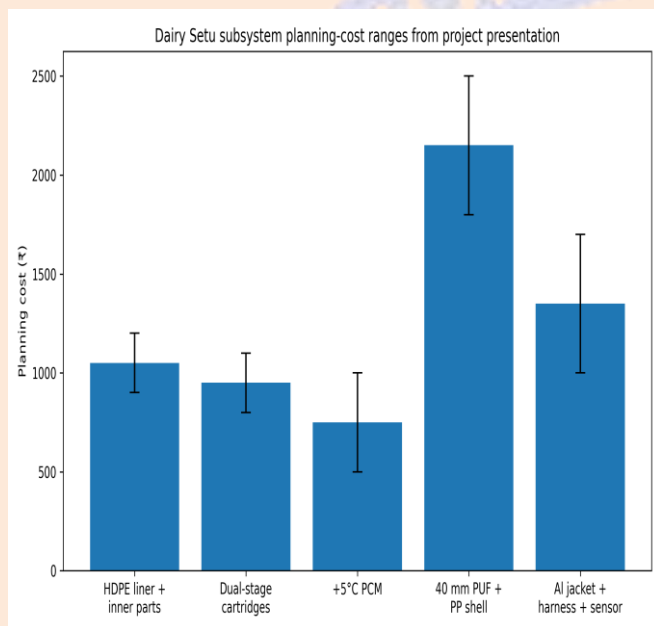


Figure 1. Dairy Setu proposed 25 L milk-chilling can and layered thermal-management concept. Illustration from the project report; prototype performance requires experimental validation.

THE IDEA IN BRIEF Dairy Setu is a proposed 25 L passive milk-cooling can intended to help small-scale dairy farmers slow temperature rise during collection and short-distance transport. It combines a +5°C phase-change material (PCM) buffer, six removable water-ice cartridges, 40 mm polyurethane foam (PUF) insulation, a protective polypropylene shell and a reflective outer jacket. It requires no continuous electrical power while in transit.



Figure 2. Integrated Dairy Setu infographic: prototype model, component architecture, assembly details and working principle.



Figure 3. Exploded and assembled views of the proposed Dairy Setu milk-chilling can.



Figure 4. Technical assembly drawing and component specifications of the proposed 25 L system.



Figure 5. Conceptual working sequence: PCM thermal buffer, ice-based cooling, PUF insulation and reflective outer jacket.

The Rural Cold-Chain Challenge

Milk is highly temperature-sensitive after collection. In rural areas, the journey from the farm to a collection or chilling centre may take several hours, sometimes without access to continuous refrigeration. As the milk warms, the risk of quality deterioration and spoilage increases, potentially affecting farmer income. A conventional milk can provides storage and transport, but generally has no integrated cooling system. Powered chilling equipment can cool actively, yet it brings added cost, power requirements and maintenance.

Dairy Setu addresses this gap with a milk-can-specific thermal-management system. Instead of carrying a compressor, refrigerant circuit or large battery, it stores cooling energy in preconditioned thermal media and slows environmental heat gain through insulation.

How the Design Works

Freshly collected milk is placed in a food-grade high-density polyethylene (HDPE) inner chamber. Heat passes through the chamber wall to a +5°C PCM buffer, which absorbs heat during its phase change and is intended to moderate the local temperature near the milk liner. Six removable water-ice

cartridges arranged around the chamber provide the main stored cooling capacity.

A 40 mm closed-cell PUF layer reduces heat transfer from the surroundings. A ribbed polypropylene (PP) shell protects the insulation and cartridges, while a reflective outer jacket is intended to reduce radiant heat gain. An insulated lid and silicone gasket help limit heat entering through the top. An optional temperature probe and display can record temperature during prototype trials.

The operating sequence is: condition the PCM and ice modules → install the cartridges → fill and seal the milk chamber → transport without continuous power → monitor temperature → exchange or recondition cartridges at the collection centre.

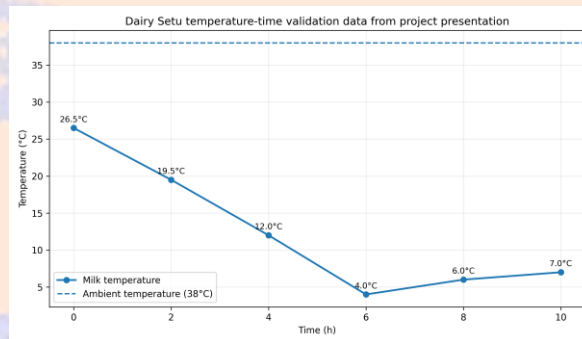


Figure 2. Layered thermal architecture and dual-stage cooling principle from the project report.

What Makes Dairy Setu Different?

- Dual-stage passive cooling: a +5°C PCM buffer works alongside low-cost water-ice cartridges.
- Six removable modules: distributed cooling and individual replacement without rebuilding the entire can.
- Milk-can-specific geometry: a dedicated cylindrical liner and cartridge layout rather than a generic ice box.
- Multilayer heat protection: 40 mm PUF insulation combined with a reflective outer jacket.
- Rural service model: cartridges can be conditioned or exchanged at a cooperative or village collection centre.
- Optional temperature monitoring: supports data collection and validation without making electronics essential to the basic concept.

Design Snapshot

Problem Statement ID	26110
Nominal milk capacity	25 L
Inner chamber	Food-grade HDPE; approx. 280 mm internal diameter
Thermal buffer	+5°C PCM layer
Cooling modules	6 removable water-ice cartridges
Insulation	40 mm PUF
Protective layers	Ribbed PP shell + reflective outer jacket
Dry-body target	Approx. 6.8–7 kg
Estimated prototype cost	Approx. ₹6,000–₹7,500; design-stage estimate

Thermal Feasibility: What Must Be Tested?

The project report uses a 25 L design case and estimates approximately 2.41 MJ of heat removal to cool milk from 30°C toward 6°C. It also gives a design heat leak of about 20

W. For an eight-hour worst-case sizing basis, the report estimates around 10.2 kg of water ice plus 1.7 kg of PCM. These are design-stage estimates and must be checked against the selected PCM supplier data and actual prototype measurements.

The report includes a temperature-time curve beginning at 26.5°C in an ambient temperature of 38°C, with plotted values of about 19.5°C at 2 h, 12°C at 4 h, 4°C at 6 h, 6°C at 8 h and 7°C at 10 h. The report explicitly states that performance must be validated experimentally. These values should therefore be treated as reported project data, not as a guaranteed product specification.

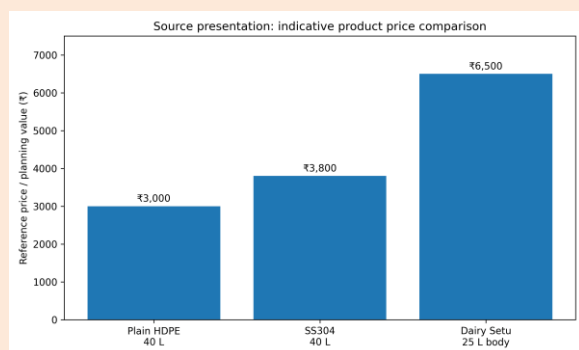


Figure 3. Temperature-time validation plot included in the source report.

Cost, Portability and Market Fit

The source report estimates a prototype target of approximately ₹6,000–₹7,500, with an illustrative value of about ₹6,500 for the 25 L Dairy Setu body. These are planning estimates, not final vendor quotations. The proposed dry-body target is about 7 kg, while the fully loaded can may weigh approximately 44–45 kg because milk and cooling media dominate the mass. This distinction is important: straps, handles, base and attachment points must be checked under realistic loaded conditions, and trolley or two-person assistance may be required.

The intended users include small dairy farmers, village milk collectors, dairy cooperatives and short-distance rural transport operators. Compared with a plain milk can, Dairy Setu adds passive cooling and insulation. Compared with powered chilling, it avoids continuous electrical power during transport. Its value lies in thermal protection and serviceability, not in being cheaper than every storage-only container.

Prototype Development and Future Scope

The next steps are to finalize CAD geometry, fabricate and leak-test the milk liner and cartridges, verify insulation continuity, load-test the handle and base, calibrate the temperature probe, and run repeatable thermal trials. Tests should record liquid volume, initial temperature, ambient temperature, PCM and ice mass, conditioning state, lid openings and temperature at defined intervals. Control trials—plain can, ice only, PCM plus ice, and complete insulated assembly—would help isolate the contribution of each feature.

Hygiene must remain central to development. The milk-contact surface should be food-compatible, smooth and easy to clean; cooling media must remain sealed and separate from

milk. The prototype should not claim formal food-safety compliance or guaranteed cooling duration until relevant tests, material declarations and applicable requirements have been verified.

Conclusion

Dairy Setu proposes a practical bridge between milk collection and the next chilling point. Its core idea is the integration of a +5°C PCM buffer, removable water-ice cartridges, multilayer insulation and a lightweight protective body in a purpose-built 25 L milk can. By storing cooling energy before transport, it aims to slow milk warming without requiring continuous power on the route. Prototype testing will determine the actual cooling duration, handling performance, durability and final cost.

CODING TIPS & TRICKS

CODE • SIMULATE • ANALYSE • OPTIMISE

Practical digital tools for core Mechanical Engineering

ENGINEERING HACK: If a calculation, graph or data-processing task is repeated, turn it into a reusable script. Always verify units, assumptions and results before using code for design decisions.

1 | MATLAB QUICK START

Start clean to avoid old variables or figures affecting a new calculation:

```
clc; clear; close all;
```

Tip: Save related commands as a script (.m file) so the analysis can be repeated and checked.

2 | MACHINE DESIGN: CALCULATE NORMAL STRESS

For a member under direct axial load, average normal stress is $\sigma = F/A$. Use consistent SI units.

```
F = 5000;           % force in N
A = 0.002;          % area in m^2
sigma = F/A;         % stress in Pa
fprintf('Stress = %.2f MPa\n', sigma/1e6);
```

Result for these example values: 2.50 MPa. This simple calculation does not replace a full strength or safety assessment.

3 | THERMAL ENGINEERING: PLOT TEMPERATURE DATA

Turn measured temperature readings into a quick trend graph:

```
time_min = [0 5 10 15 20];
T_C = [25 34 43 49 53];
plot(time_min, T_C, '-o', 'LineWidth', 1.5);
xlabel('Time (min)'); ylabel('Temperature (°C)');
title('Heating Curve'); grid on;
```

Trick: Label axes with units and include the test conditions when you export the figure.

4 | MANUFACTURING: COMPARE TOOL-WEAR DATA

Use a table or vector to compare tool wear across machining trials:

```
cutting_speed = [60 90 120 150]; % m/min
wear_mm = [0.08 0.11 0.17 0.25];
plot(cutting_speed, wear_mm, '-s');
xlabel('Cutting speed (m/min)');
ylabel('Tool wear (mm)'); grid on;
```

Tip: Change one parameter at a time when comparing trials, and record feed, depth of cut, material and tool grade.

5 | FLUID MECHANICS: ESTIMATE REYNOLDS NUMBER

For flow in a circular pipe, $Re = \rho V D / \mu$, where ρ is density, V is mean velocity, D is pipe diameter and μ is dynamic viscosity.

```
rho = 998;           % kg/m^3
V = 0.5;             % m/s
D = 0.02;            % m
mu = 1.0e-3;         % Pa.s
Re = rho * V * D / mu;
fprintf('Reynolds number = %.0f\n', Re);
```

Always use fluid properties at the relevant temperature. Flow-regime thresholds depend on the geometry and flow conditions.

6 | MACHINE LEARNING: A SIMPLE PREDICTIVE- MAINTENANCE WORKFLOW

Use vibration, temperature or current data to classify machine condition. A basic workflow is:

**SENSORS → CLEAN/LABEL DATA →
TRAIN/TEST SPLIT → TRAIN MODEL →
EVALUATE → MONITOR**

Trick: Keep test data separate from training data. Do not report accuracy alone—also inspect precision, recall, confusion matrix and performance on unseen operating conditions.

MATLAB option: Classification Learner can help explore classification models with a graphical workflow. Validate any model with real, representative data before relying on its predictions.

7 | SIMULINK: TEST THE IDEA BEFORE BUILDING

Build a block diagram for a simple thermal, mechanical or control system before assembling hardware. Start with the input, system model, output and feedback path; then compare simulation with measured data.

**INPUT → SYSTEM MODEL → OUTPUT →
COMPARE WITH EXPERIMENT**

8 | QUICK TRICKS THAT SAVE TIME

TRICK	WHY IT HELPS
Use vectors	Process a complete set of test readings together instead of calculating each value separately.
Preallocate arrays	For large MATLAB loops, create the output array first to reduce repeated memory allocation.
Check dimensions	Confirm that force, area, pressure, length and temperature use compatible units before calculating.
Annotate plots	Add a descriptive title, axis labels, units, legend and grid where useful.
Keep raw data	Save an untouched copy of experimental data before filtering or removing outliers.
Check model validity	A neat plot or high machine-learning score does not prove the model is physically correct.

ENGINEER'S CORNER

“Code the calculation. Validate the result. Improve the design.”

Learning Resources

- MathWorks — MATLAB documentation: <https://www.mathworks.com/help/matlab/>
- MathWorks — Simulink documentation: <https://www.mathworks.com/help/simulink/>
- MathWorks — Machine Learning and Predictive Maintenance resources: <https://www.mathworks.com/solutions/predictive-maintenance.html>
- NPTEL — Engineering courses and computational methods: <https://nptel.ac.in/>

NATURE-INSPIRED CARBON CAPTURABLE ARTIFICIAL ENERGY TREE

*Mimicking Nature to Capture Carbon,
Generate Clean Energy and Build
Sustainable Cities*

By Dr. Sabyasachi Mukherjee

Associate Professor, Department of Mechanical
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Concept illustration of the proposed artificial energy tree; this is an illustrative visualization, not a photograph of a completed prototype.

Introduction: When Engineering Learns from Nature

Trees absorb carbon dioxide, release oxygen through photosynthesis and support life. Inspired by these functions, the Nature-Inspired Carbon Capturable Artificial Energy Tree (NICCAET) explores how carbon capture, renewable energy generation and air

treatment could be combined in one tree-inspired structure for urban environments.

1. The Carbon Capture System

NICCAET proposes chambers that use adsorption and chemical absorption to separate CO₂ from incoming air. Potential materials include activated carbon, metal-organic frameworks (MOFs) and amine-based sorbents. Airflow channels are designed to improve contact with the capture media. Captured CO₂ would require a suitable regeneration process before storage or utilization.

2. Nature's Chemistry: Spirulina Cultivation

The proposed system directs captured CO₂ to Spirulina cultivation chambers. This photosynthetic microalga uses carbon dioxide and light for growth and releases oxygen during photosynthesis. Light, nutrients, temperature and pH would need to be monitored. Harvested biomass may have potential uses after suitable processing.

3. A Hybrid Energy Canopy: Solar Meets Wind

Solar panels convert sunlight into electricity, while proposed vertical-axis wind turbines harvest wind from different directions. Battery storage would help supply power when generation fluctuates. Electricity is intended to support air circulation, sensors, CO₂ capture, algae cultivation and LED lighting. Actual output depends on local conditions and system efficiency.

4. Smart Integration: One Tree, Multiple Functions

Sensors and a control unit could monitor CO₂ concentration, temperature, light intensity and energy output, coordinating the capture chambers, cultivation units and energy storage. The concept brings mechanical design, environmental engineering, renewable energy and biotechnology into one modular installation.

What Makes NICCAET Innovative?

Its proposed integration of carbon capture, solar and wind energy, Spirulina-based CO₂ utilization, energy storage and environmental monitoring within a tree-inspired structure is its key innovation. Potential locations include campuses, parks, public plazas and selected urban spaces, where it could also serve as an educational installation.

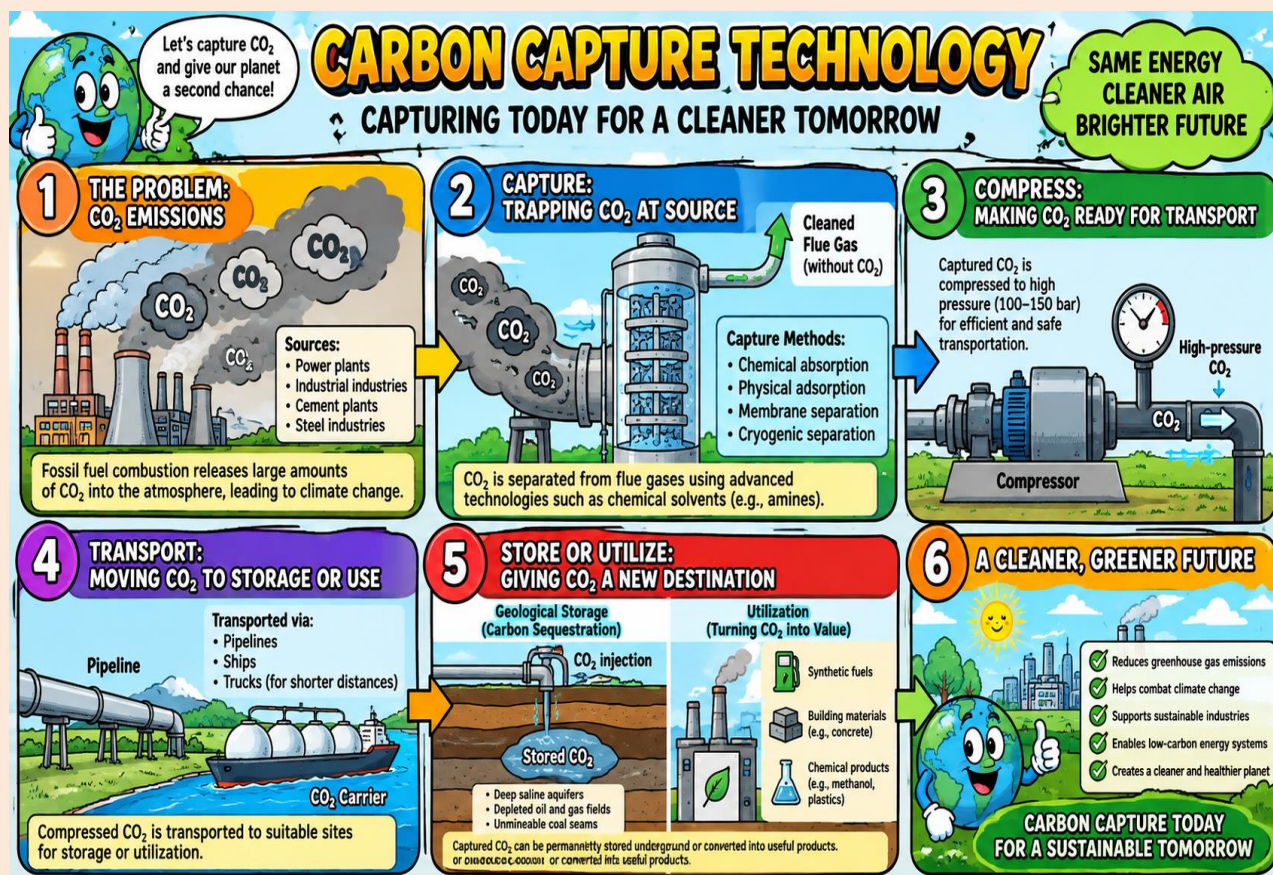
Expected Benefits and Future Scope

If developed and experimentally validated, NICCAET could support carbon management, provide supplementary renewable electricity, enable biological CO₂ utilization and incorporate suitable air filtration. Future work includes building a prototype, measuring capture rates, testing solar and wind output, evaluating algal growth, and assessing energy use, maintenance and cost.

Conclusion

The Nature-Inspired Carbon Capturable Artificial Energy Tree demonstrates how biomimicry can inspire multifunctional green infrastructure. By combining carbon capture, renewable energy and photosynthetic technology, NICCAET presents a promising concept for sustainable cities. Its real-world value will depend on prototype testing, verified performance and practical economic assessment.





Carbon Capture Technology: Capturing Today for a Cleaner Tomorrow

Carbon capture technology is an innovative approach to reducing carbon dioxide (CO₂) emissions and combating climate change. It involves capturing CO₂ from major industrial sources, such as power plants, cement factories, steel industries, and other emission-intensive facilities, before it enters the atmosphere. The captured CO₂ is then compressed and transported through pipelines, ships, or specialised vehicles to suitable locations for permanent underground storage or utilisation in useful products, including synthetic fuels, chemicals, and building materials. Various techniques, such as chemical absorption, physical adsorption, membrane separation, and cryogenic separation, can be employed to capture CO₂. By integrating carbon capture with sustainable energy systems and

industrial processes, this technology can help reduce greenhouse gas emissions, support cleaner industrial development, and contribute to a greener, more sustainable future.