

Industry-Oriented Problem-Solving Challenge

Real industrial problems • Engineering design • Techno-economic solutions

Call for Solutions from PhD and M.Tech Students

1. About the Challenge

PyroAsia 2026 invites PhD and M.Tech students to participate in an **Industry-Oriented Problem-Solving Challenge** focused on real engineering problems encountered in commercial and emerging pyrolysis systems. The objective is to move from conventional research questions to practical problems where process design, equipment engineering, troubleshooting, process integration and economics must be considered together. The challenges cover the complete pyrolysis value chain—from collection and preparation of feedstock to reactor operation, vapour handling, product recovery, upgrading, energy integration and utilization of pyrolysis products. Particular emphasis is placed on problems where a technically attractive solution must also be practical at industrial scale. **Kindly submit your response using: <https://forms.gle/nSbc4fgdJoxmPxb26>**

IMPORTANT: The statements below describe the nature of the industrial challenge. Detailed plant data, design basis and constraints will be supplied in the final problem brief, if not supplied assume a reasonable value from the literature. Any illustrative number stated here is contextual and should not override the final design basis.

2. Who Can Participate?

The challenge is open to all levels of students/scholars (PhD, PG,UG) of Chemical, Mechanical, Energy Engineering, Environmental Engineering, Materials Science, Mechanical Engineering and related disciplines). Interdisciplinary teams are encouraged. Participants may work individually or in teams (Max size 3). Each team should select one problem and develop a complete engineering solution.

PA26-IP01 – Feedstock Collection, Quality & Logistics

Industrial context. Large-scale pyrolysis based on agricultural residues is a logistics problem as much as a thermal-conversion problem. Crop residues such as rice straw are generated over large, dispersed agricultural areas immediately after harvesting. Loose rice straw has been reported at only about 13-18 kg/m³ on a dry-matter basis, whereas representative round bales can be around 60-90 kg/m³. Thus, a truck carrying loose straw can become volume-limited long before reaching its payload limit. Baling reduces transport volume, but requires field machinery, labour, fuel, handling and storage. Indian crop-residue management systems already use combinations of straw-management equipment, rakes, balers, custom-hiring arrangements and transport. The current methods mostly fail because of high processing speed requirement as the collection window is only open for 10-15 days (time between harvesting to

planting a new crop) Other non-conventional densification solutions can also be proposed with viability study.

The challenge. Design a practical biomass aggregation and logistics system capable of collecting and supplying a specified feedstock during the open window (Max. 15 days for straws). Address where and how residues are collected from the field, whether they should be raked, baled, chopped or densified before loading, how many machines and trucks are required, how intermediate storage is organized, and how moisture and contamination are controlled. The problem can be analyzed as a resource/logistic management problem considering the available technologies. Examine the trade-off between transporting very low-density material and spending energy/capital to densify it before transportation.

What the student should address. Map field collection → preprocessing/densification → temporary storage → loading → transport → unloading → plant receiving. Quantify collection radius, truck payload, trips/day, field capacity, fuel use, losses, storage requirement and delivered biomass cost (₹/Ton/km). Identify the preferred logistics configuration under the stated plant capacity and seasonal availability.

PA26-IP02 – Feed Preparation & Reliable Feeding

Industrial context. Pyrolysis plants often receive feedstock in a form very different from that required by the reactor. Biomass may arrive as bales with variable moisture and foreign material; tyres may arrive whole, shredded or partially de-beaded; plastics may be mixed and contaminated. Size reduction, drying, separation, screening and densification can improve feeding and reactor performance, but each operation adds energy use, capital and maintenance. Even in many stances feedstocks are stored for long time which leads to moisture pickup and aging. Consider that also in your solution.

The challenge. Develop a feed-preparation and feeding train that converts the incoming material into a stable reactor feed. Define the required particle size, moisture range, bulk density and feed rate and identify the minimum preprocessing necessary for reliable operation. Consider bridging, rat-holing, screw wear, hopper blockage, dust generation, tyre-wire handling and feed-composition fluctuations.

What the student should address. Provide a process flow diagram, equipment selection, throughput and sizing basis, power requirement, material losses, and capital and operating cost. By choosing a feedstock (agro residues, MSW, tyre) demonstrate how the system maintains stable mass flow into the reactor.

PA26-IP03 – From Batch to Efficient Pyrolysis Reactor

Industrial context. Many commercial waste-tyre pyrolysis systems use externally heated, horizontally oriented rotary vessels operated in batch mode. Heat is provided directly at the bottom from the combustion of verities of feedstock including char, tyre itself, etc. you can visualize the process as a rotating boiler. Heat must pass through the vessel wall and then through a changing bed of tyres and partially reacted material. As the feed softens and decomposes, heat-transfer resistance, mixing and vapour removal change during the batch (some material can also deposit on the internal surface reducing the heat transfer area). This can result in temperature non-uniformity, long cycle time and high external energy demand. Waste-tyre pyrolysis is commonly reported in approximately the 400-600°C range, while reactor type, heating rate and vapour residence time strongly influence product distribution.

The challenge. Develop a reactor or reactor-operation strategy that improves heat transfer and productivity while remaining industrially realistic. You may modify the existing rotary reactor, propose an alternative configuration, change the heating arrangement, introduce heat-transfer enhancement or propose semi-continuous/continuous operation.

What the student should address. Develop the reactor design basis, heat-transfer calculation, residence/batch time, heating duty, dimensions or scale-up method, energy consumption and expected product yield. Quantify expected reductions in cycle time and/or external energy consumption, cost saving/kg of feed.

PA26-IP04 – Vapour Quenching, Condensation & Energy Recovery

Industrial context. Pyrolysis vapours contain compounds with a wide boiling range. Unsuitable cooling can promote secondary reactions, polymerization and fouling, while poorly designed rapid condensation can cause product losses and heavy deposits. In waste-tyre pyrolysis, published studies report substantial light, medium and heavy fractions; one rotary-kiln study reported about 39-42 wt% light naphtha, 32-33 wt% medium fraction and 26-29 wt% heavy fraction after distillation. Actual distribution depends strongly on feed and process conditions. Moreover, the high temperature vapor leaving the reactor are cooled using a cooling water without any energy recovery mechanism, instead the water need to be sent to a cooling water (consume power) before it is circulated back to the cooler. Devise an energy-integration strategy to recover heat from the vapor stream and reuse it within the plant, thereby minimizing external energy consumption.

The challenge. Design a staged vapour-handling, quenching, condensation and fractionation system that produces a controllable liquid product slate while minimizing heat loss, fouling and pressure drop. Consider direct quenching, indirect condensation, staged cooling, gas-liquid separation and fractional condensation. Also consider the viscosity and adhesive properties of the oil in the calculation.

What the student should address. Develop material and energy balances. Estimate condensation duty, heat-transfer area, coolant requirement, operating temperatures, pressure drop and equipment arrangement. Define how the energy will be recovered and used, with techno-economic validation.

PA26-IP05 – The Product Utilization Challenge

Industrial context. Pyrolysis can generate a heavy liquid fraction with high viscosity, poor pumpability and limited direct marketability. In waste-tyre pyrolysis, published data show heavy fractions can represent roughly one-quarter of distilled liquid in some rotary-kiln cases. Tyre pyrolysis oil can also contain sulfur, nitrogen, aromatics and unsaturated compounds, so increasing liquid yield does not necessarily increase product value. Additionally, waste tires contain sulfur introduced largely through vulcanization. During pyrolysis, sulfur is distributed among char, oil and gas; sulfur-bearing gases can include H_2S (~7200 mg/m³) and other sulfur compounds. Reviews report combustible tire-pyrolysis gas but also identify sulfur management as a constraint for direct fuel use because of SO_x emissions, corrosion and material compatibility.

The challenge. (1) Develop a practical route for converting the heavy fraction into a higher-value or more readily usable product. Possible routes include blending, fractionation, thermal/catalytic cracking, solvent-assisted processing, emulsification, fuel formulation or conversion into another product. No route is prescribed. (2) Design an integrated gas-cleaning and utilization system that allows pyrolysis gas to be safely used as process fuel. The system may include cooling, condensate removal, particulate removal, H_2S capture, adsorption, absorption or another justified sulfur-control route before combustion. Balance sulfur removal against pressure drops, sorbent/chemical use, energy demand, waste generation and management, and capital cost. The industry wants to use it as a fuel for heating the pyrolysis reactor. Assume the composition of product gas stream as, CO_2 12%, N_2 10%, H_2 27%, CH_4 26%, C_2H_6 15%, C_4H_{10} 10%.

What the student should address. Define feed and product specifications, treatment sequence, equipment, operating conditions, yield, energy use and economics. Compare at least two utilization routes

where possible and justify the selected route using technical feasibility, CAPEX, OPEX and payback. Follow the following literature for property data.(1) [https://doi.org/10.1016/S0165-2370\(97\)00085-5](https://doi.org/10.1016/S0165-2370(97)00085-5). Use the supplied gas composition and flow rate to size the treatment and burner/fuel-utilization system. Quantify sulfur removal, SO_x reduction, energy recovery, operating cost and waste/sorbent requirement, and determine what fraction of process heat demand can be met.

4. Plant Scale & Design Basis

Every problem will specify an existing or target plant capacity. Depending on the challenge, the design basis may include feedstock availability, composition, moisture, ash, particle size, bulk density, collection radius, transport distance, reactor dimensions, heating system, temperature, pressure, residence/batch time, product yields and properties, gas composition, utility consumption and economic constraints.

Participants should design for the stated industrial scale and should not extrapolate directly from laboratory experiments without an appropriate scale-up argument.

Example: For agricultural residues, bulk density must be treated as a design variable. Loose rice straw has been reported at approximately 13-18 kg/m³ dry matter, while representative round bales may be about 60-90 kg/m³. Thus, collection, baling, truck loading, storage volume and transport economics can dominate the delivered biomass cost.

5. Student Response: Required Engineering Content

The proposed solution must be an engineering solution rather than a literature review. Every response should address five questions:

1. **Diagnose:** What is the industrial problem and what are the likely root causes?
2. **Design:** What should be designed or modified? Include process flow diagram, balances, equipment sizing and operating conditions as applicable.
3. **Demonstrate:** How will the proposed system work in practice? Address heat/mass transfer, residence time, controls, safety, maintenance and integration.
4. **Techno-economic analysis:** What will it cost and what economic benefit will it provide? At minimum report CAPEX, OPEX, annual benefit/revenue and simple payback.
5. **Quantify impact:** What measurable improvement will the industry obtain in throughput, energy, yield, product quality, emissions, operating cost or product value?

6. Minimum Deliverables

- Process flow diagram or engineering schematic.
- Design basis and assumptions.
- Material and energy balances, wherever applicable.
- Major equipment selection and sizing calculations.
- Operating and control strategy.
- Safety and environmental considerations.

- Techno-economic assessment including CAPEX, OPEX and payback.
- Quantified comparison of existing and proposed performance.
- References for property data, correlations, design methods and cost assumptions.

7. Submission & Presentation

Interested participants are required to express their interest by filling in the online form. The participants must register on the portal to participate in the presentation. The presentation will be for 10 minutes including the Q&A sessions. The problem code (e.g., PA26-IP03) should be clearly indicated. Assumptions must be transparent, and industry-provided data should be distinguished from estimated values.

8. Evaluation Criteria

Criterion	Weight
Problem understanding & diagnosis	15%
Technical design & engineering soundness	25%
Practical feasibility & operability	20%
Innovation/originality	10%
Techno-economic analysis	15%
Quantified technical/environmental impact	10%
Clarity of presentation	5%

9. What We Are Looking For

The strongest solutions will demonstrate engineering judgement, realistic scale-up, clear design logic, quantitative analysis and a credible path to implementation. The objective is not to identify the most complicated solution, but the solution that best balances technical performance, practicality, economics, safety and environmental impact.

Participation: Submission deadline, registration/submission portal, detailed problem briefs and contact information will be announced on the PyroAsia 2026 conference website.