

Challenge — Development of Indigenous, Scalable, and Economically Viable Plasma-Based Nitrogen Fertiliser Technologies for Indian Agriculture

In Collaboration with the Bill & Melinda Gates Foundation · Anchored by ANRF · May 2026

The Challenge

India's dependence on imported nitrogen fertiliser was structurally exposed by the 2026 Strait of Hormuz disruption: domestic N output fell 27%, FY27 urea imports are projected 78% above budget at emergency prices of \$935–\$959/MT CFR, against a subsidy line of \$14.3 billion. Plasma-based nitrogen fixation — producing plant-available N from air, water, and electricity — is a credible medium-term route to decentralised, import-independent production. India's BARC has demonstrated an atmospheric-pressure thermal plasma system at 20 kW (~12.8 MJ/mol N). The global frontier is approaching 1 MJ/mol N; leading GF portfolio companies (Nitricity, PlasmaLeap, VitalFluid) are all targeting sub-1 MJ/mol N and a Levelized Cost of Nitrogen (LCON) ≤\$450/MT urea-equivalent. In import-dependent and landlocked markets (including parts of Sub-Saharan Africa), high freight costs can make local plasma nitrogen competitive even above the global energy benchmark; the LCON framework is designed to capture these country-specific economics. This challenge is an explicit Government of India request, co-designed with the Gates Foundation to build indigenous capacity with an explicit view to scaling across South Asia and Sub-Saharan Africa.

Dimension	AS-IS — Problem Today	TO-BE — Challenge Target (indicative milestone: Tracks 1–2 outputs by Year 2; Track 3 field pilots by Year 3; regulatory pathway defined by Year 4)
Import Dependence	~60% of urea imported or on imported gas; domestic output ~27% (Mar 2026)	Air + water + any electricity as sole inputs; zero fossil-feedstock dependence
Energy Efficiency	BARC baseline: ~12.8 MJ/mol N; H-B optimised world-scale: ~0.48 MJ/mol N	Pathway toward ≤1 MJ/mol N (H-B high-end benchmark); stretch target <0.7 MJ/mol N
Cost (LCON)	Urea \$935–\$959/MT CFR (May 2026 emergency); structurally elevated	LCON pathway to ≤\$450/MT urea-equivalent; standardised formula across all applicants
Decentralisation	Centralised Haber-Bosch; fragile supply chains vulnerable to geopolitical shocks	FPO/cluster/agro-service systems at defined scale; any electricity source eligible
Indigenous IP	Largely foreign technology and IP; no indigenised commercial pathway	ANRF-registered Indian IP; commercially licensable; India-sourced BoM

What We Are Looking For

The challenge invites proposals to develop, validate, and pilot indigenous plasma-based systems converting air and water, using electricity, into plant-available nitrogenous fertiliser streams. All proposals must address the eight requirements below.

Requirement	Summary
1. Energy Efficiency (SEC)	Report Specific Energy Consumption (MJ/mol N) with full methodology (plasma type, gas flow, pressure, electrode, input power, fixation yield). No minimum gate for Tracks 1–2 but a credible pathway toward ≤1 MJ/mol N (H-B high-end benchmark) is required. Track 3: SEC ≤5 MJ/mol N + roadmap to ≤1 MJ/mol N.
2. LCON (\$450/MT urea eq.)	Mandatory from Track 2: LCON analysis using standardised secretariat template. Benchmark: \$450/MT urea-equivalent (conversion basis: 46% N content of urea). The secretariat will publish conversion factors for all accepted output types (nitrate, nitrite, ammonia solutions) at launch. The \$450/MT benchmark reflects Indian import-replacement economics as of 2025–26 and may be adjusted for different target markets (e.g. SSA) in co-investment applications. Standardised assumptions: 10% discount rate; electricity sensitivity across grid (~₹7–8/kWh) and solar (~₹2.5–3/kWh); full BoM; capacity utilisation stated. Any electricity source eligible.
3. Feedstock, Product & Market Fit	Air + water + electricity; no imported N-bearing reactants in the primary fixation step. Accepted outputs: plasma-activated water, dilute nitric acid, ammonium solutions, or solid nitrate formulations. Applicants must address: (a) whether output needs post-processing (granulation, blending) before application; (b) target farmer segment and equipment implications (e.g. retrofitting irrigation); (c) storage/supply-chain requirements for agro-service operators. Plasma-enhanced organic fertilisers (e.g. plasma-activated slurry) are in scope; applicants must justify differences in LCON/SEC vs. aqueous plasma-N fixation. Product characterisation (TDN, RONS profile, pH, stability) required across at least 3 agro-climatic zones.
4. Deployment Model	Define: max rated output (kg N/day), footprint, weight, minimum infrastructure. Modular design positive but not mandatory. State whether continuous or intermittent power is supported — grid connection is fully acceptable. Priority to FPO/agro-service models. Note: any electricity source is eligible; however, proposals integrating renewable energy sources (solar, wind) will be positively weighted in the environmental sustainability sub-criterion of the evaluation.
5. Indigenous IP & Localisation	Core IP must be Indian-origin or registered with ANRF; commercial licensing to Indian entities required. BoM must identify India-sourced vs. imported components with localisation plan.
6. Agronomic Safety & RONS	RONS profile characterised. Evidence of plant-available N delivery in ≥1 Indian crop system (e.g. rice, wheat, maize, pulses, or sugarcane) under Indian field or controlled conditions. Soil microbiology impact plan required. Track 2+ proposals align with ICAR Applied Research Programme protocols.
7. Safety, Stability & QC	Farmer/operator handling safeguards specified. Product stability demonstrated across at least 3 Indian agro-climatic zones (e.g. humid tropical, semi-arid, arid/hot-dry). Batch QC metrics and shelf-life data.
8. Regulatory Pathway (Pass/Fail)	FCO compliance pathway required — pass/fail threshold; ineligible without this. Where no FCO category applies, applicant proposes draft classification with ICAR.

Three-Track Structure

Proposals are invited under three tracks matching Technology Readiness Level. **Track 3 applicants must have completed Track 2-equivalent work (prototype + independently validated TEA) before deployment funding is released.** Very few organisations globally are likely to meet Track 3 conditions without prior Track 2 work.

	Track 1 — Core Science & Lab	Track 2 — Pilot-Ready Prototype	Track 3 — Field-Deployable Demo
TRL at entry	TRL 2–4	TRL 4–6	TRL 6–8
Target applicant	Universities, research institutes, early-stage startups with lab results	Teams with working prototype; repeatable output; pilot partner confirmed	Advanced teams with prototype + completed TEA. Track 2-equivalent mandatory for direct applicants.
Key deliverables	SEC + methodology; product characterisation; LCON trajectory; plant-safety data	Prototype validated; pilot results; full LCON analysis (standard template); BoM; RONS plan	Field pilots ≥ 2 agro-climatic zones; comparative efficacy vs. urea; farmer safety; commercialisation plan
Funding (indicative)	Up to ₹50 lakh (~\$60k)	Up to ₹3 crore (~\$360k). 50% on award; 50% on prototype + LCON validation	Up to ₹10 crore (~\$1.2M). Staged; deployment funds withheld until TEA independently validated.
Gate condition	Fixation demonstrated; SEC methodology; improvement pathway	Prototype validated; LCON submitted & reviewed	TEA independently validated before deployment funds released. Track 3 applicants without prior Track 2 participation must submit TEA for secretariat validation as condition of review.

What Will NOT Be Considered

- Proposals not converting air and water, using electricity, into plant-available nitrogenous fertiliser streams.
- Technologies depending on imported N-bearing reactants (pure N₂, externally sourced NH₃ or NO) in the primary fixation step.
- Proposals without a credible LCON pathway to $\leq \$450/\text{MT}$ urea-equivalent (LCON analysis mandatory Track 2+).
- Track 3 applications without Track 2-equivalent completion (prototype + full TEA + secretariat validation). **Deployment funding not released without validated TEA.**
- Proposals without RONS characterisation or a safety plan for farmer handling and soil application.
- Proposals without an FCO-compliant regulatory pathway (pass/fail threshold).
- Proposals primarily replicating the BARC baseline without a credible SEC or cost improvement pathway.

Evaluation Criteria

Criterion	Weight	Key Assessment Questions
Energy Efficiency & SEC Pathway	25%	SEC methodology rigour; credibility of pathway to ≤ 1 MJ/mol N; engineering milestones
Cost Competitiveness (LCON)	20%	LCON analysis completeness; electricity price sensitivity; pathway to $\leq \$450/\text{MT}$ urea-equivalent
Agronomic Evidence & RONS Safety	20%	RONS characterisation; crop performance evidence; soil health plan; ICAR-aligned trial design
Indigenous IP & Localisation	15%	ANRF IP registration plan; India-sourced BoM; localisation roadmap for imported components
Deployment Model & Scalability	10%	Scale definition (kg N/day, footprint, infrastructure); FPO/agro-service fit; scale-up pathway. Environmental sustainability sub-criterion: proposals integrating renewable electricity sources are positively weighted.
Team & Institutional Credentials	10%	Track record; institutional support; field-testing partnerships
Regulatory Pathway	Pass/Fail	Credible FCO-compliant pathway required; ineligible without this regardless of other scores

Linkage with the ICAR Applied Research Programme

This challenge operates in parallel with a GF-co-funded ICAR Applied Research Programme (\$1.5M) on agronomic validation of plasma-derived fertiliser products, creating a closed-loop innovation-to-validation pipeline.

- ICAR conducts multi-location agronomic trials across ≥ 5 Agro-Climatic Zones (rice, wheat, maize, pulses, sugarcane), establishing dose-response, N-equivalence, and yield benchmarks versus urea.
- ICAR's RONS safety framework and FCO regulatory classification process is made available to applicants; Track 2+ proposals align with ICAR protocols rather than developing independent regulatory pathways.
- Track 2/3 technologies may be nominated for independent ICAR field evaluation; ICAR cost-of-application models will inform LCON template assumptions.

Global Technology Context

The global plasma nitrogen field is small (fewer than two dozen serious developers). The GF’s standard approach is a targeted scan rather than an open challenge. This challenge is adopted specifically to build indigenous Indian capacity; standards must therefore be equivalently rigorous to a scan.

Technology / Actor	Plasma Type	Reported SEC	Status & Notes
Haber-Bosch (conventional)	Thermal catalytic	~0.48 MJ/mol N (world-scale)	Commercial benchmark; large centralised plants
BARC (India)	Thermal plasma (catalytic air)	~12.8 MJ/mol N	20 kW atmospheric-pressure prototype; Indian domestic baseline
Nitricity (USA, ARPA-E)	Non-thermal microwave	Targeting <1 MJ/mol N	Pre-commercial; on-farm pilot scale; GF portfolio
PlasmaLeap / Talus	Non-thermal plasma	Targeting <1 MJ/mol N	Prototype stage; GF portfolio
ACS 2026 (pulsed in-water)	Pulsed discharge, in-water	1.14 MJ/mol N	Published result approaching H-B benchmark (ACS Sust. Chem. Eng. 2026)
Gliding-arc (elevated pressure)	Gliding arc, pressurised	1.8 MJ/mol N; 94% NO ₂	Pilot scale; published record low for production-competitive system
NTP theoretical minimum	Non-thermal plasma	~0.2 MJ/mol N	Not yet achieved; ~2.5x lower than H-B thermodynamic floor
Challenge benchmark	—	≤1 MJ/mol N pathway required	H-B high-end benchmark; all leading global players targeting this or better

Governance, Proposal Requirements, Budget & Timeline

Governance: ANRF anchors: prize administration, IP registration, award agreements. Gates Foundation India Country Office: co-design, technical secretariat, LCON template, independent TEA validation (no new GF funding above existing ANRF commitments). ICAR: trial protocols, RONS safety standards, FCO regulatory pathway, cost-of-application models; co-runs parallel \$1.5M programme. BARC: technical reference; review panel input (recused on conflicts).

Proposals must include: Executive summary (max 2 pp); technology description (plasma type, reactor, power management); indigenous IP and BoM (India-sourced vs. imported; localisation plan); SEC measurements + methodology + improvement pathway; electricity strategy (power source; continuous vs. intermittent); LCON analysis (mandatory Track 2+, standard template); RONS profile and agronomic safety plan (ICAR-aligned trial design); FCO regulatory compliance pathway; deployment model (scale definition, FPO/agro-service context); commercialisation pathway (IP licensing under ANRF); budget with milestones.

Budget Summary

Track	Max Award	Release Condition
Track 1	Up to ₹50L (~\$60k)	On award; 12-month milestone review
Track 2	Up to ₹3Cr (~\$360k)	50% on award; 50% on prototype + LCON validation
Track 3	Up to ₹10Cr (~\$1.2M)	Staged; TEA validated before deployment funds released
ICAR Programme	\$1.5M (GF co-funded)	Parallel; separate from prize purse

Indicative Timeline

Phase	Timing
EoI Open (2-pg concept, TRL, SEC data)	Months 1–2
EoI Screening & Shortlisting	Month 3
Full Proposals (LCON mandatory T2+)	Months 4–5
Evaluation & Awards; ANRF IP agreements	Months 6–7
Track 1 Milestone Review	Month 19
Track 2 Prototype + LCON Validation	Months 19–24
Track 3 TEA Validation Gate	Months 20–24
Track 3 Field Pilots (≥2 agro-climatic zones)	Months 24–36
Final Evaluation + SSA/South Asia Lessons	Month 42

Contact & Submission: Challenge secretariat contact, standardised LCON template, EoI portal, and full evaluation rubric published at launch on ANRF and Gates Foundation India websites.

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