



IDENTIFYING SOLUTIONS

Monetizing Waste Streams

Five technically feasible routes to eliminate, convert or sell a nitrogen-rich process stream — assessed against economics, scale and who can actually deliver them.

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EXECUTIVE SUMMARY

Project Background

A manufacturer sought to address and mitigate the costs associated with a nitrogen-rich waste stream through effective and sustainable strategies.

An organic process producing NH_3 and CO_2 gases is treated and washed with an ammonia solution, producing a scrubber solution containing ammonium carbamate, carbonate, bicarbonate and other N-containing compounds. These components are critical, and their disposal is costly.

The goal is comprehensive solutions addressing one or more of these pathways, reducing or eliminating the costs associated with waste disposal while ensuring environmental compliance and sustainability.

Addressing the source

- Develop methods to remove or capture NH_3 and CO_2 gases before they react to form the scrubber solution

Elimination of the solution

- Explore possibilities to sell the solution as a product
- Investigate ways to convert the solution into more valuable or easily disposable products
- Research methods to safely neutralize or eliminate the solution

Removal of critical components

- Identify and remove critical N-containing components (carbamate, carbonate) from the solution
- Develop processes to convert these components into valuable products, or substances that can be disposed of at little cost
- Aim to leave only a water solution that is safe and inexpensive to dispose of

EXECUTIVE SUMMARY

Ezassi Methodology

Qualitative analysis

- Ezassi followed a qualitative approach — directly interviewing industry subject matter experts
- Interviews were conducted anonymously

Quantitative analysis

- Investigation of publicly available information only
- **Data sources explored:** news feeds, web-monitoring, patents, publications, supplier and vendor databases, startup databases, grants, trademarks, clinical trials and public financial statements
- **Geographic regions covered:** global, with Europe the priority

EXECUTIVE SUMMARY

Potential Value Proposition

THE CHALLENGE

- **High disposal costs:** a substantial recurring annual expense
- **Environmental burden:** hazardous N-compounds
- **Lost value:** discarded chemical components

SOLUTION APPROACH

- Convert the waste stream into marketable products
- Implement on-site treatment system
- Capture NH_3 and CO_2 before the scrubber solution forms

VALUE DELIVERED

- **Cost reduction:** 70–90% decrease in waste costs
- **New revenue:** potential annual revenue from recovered chemicals
- **Sustainability:** reduced environmental footprint
- **Operations:** simplified handling, less liability

BOTTOM LINE

- ROI within 1–3 years, with the potential to convert a recurring disposal expense into a profit centre

EXECUTIVE SUMMARY

Target Options

Startups & companies, geographically located

VIABLE

Looking to commercialize their products, open to small-scale development to validate and build use cases that can be marketed to large-scale opportunities.

Research institutions

VIABLE

Business model is small scale to fund future research. Provide the most viable option, as size and scale are not usually an issue if they can generate revenue for future research.

Commercial solutions / end customer of gas

NOT VIABLE

Volume of waste is not viable for an ROI. This includes gas separation technology outside a startup or research institution, reuse of gas except internally only, or selling off gas that may be able to be created and sold in the market.

Technically Feasible Pathways

Sell the scrubber solution as-is

Major learning: Amounts not large enough for industrial use (pharma, agro). Opportunity in smaller farming communities closer to the source.

Sources: Yara, and others

Open leads: None

Solution conversion to chemicals

Major learning: The solution can be converted to ammonium sulfate — a more stable product with a larger agricultural market than the raw liquor. Speculative and volatile market. CapEx required for conversion.

Sources: Fraunhofer

Open leads: Fraunhofer, SINTEF, Casale

Technically Feasible Pathways

Gas separation and recycling (NH₃, CO₂, N₂)

Major learning: Increased development of technologies for gas separation, purification and recycling over the past decade. Market for the gases exists. Logistics and infrastructure required to enter it. Economy of scale insufficient. Significant CapEx.

Sources: Evonik, Air Liquide, SINTEF, VTT, Univastum, REICAT

Open leads: SINTEF, VTT, Univastum, Casale

Gas conversion to chemicals

Major learning: Conversion of NH₃ and CO₂ to urea is technically feasible; economy of scale insufficient.

Sources: Casale, thyssenkrupp, Stamicarbon, DECHEMA

Open leads: SINTEF, VTT, Casale

Gas conversion to energy

Major learning: Increased attempts at using NH₃ as an energy source; economy of scale insufficient and significant CapEx.

Sources: Amogy, REICAT, industry expert interview

Open leads: None

EXECUTIVE SUMMARY

Areas of Opportunity

Organisation	Category	What is applicable	Location
AmmoRe (Fraunhofer IGB)	Gas separation, conversion to new gas	TMCA technology is viable where feedstock is pre-concentrated above 1,000 mg/L NH_4^+ , modular skids are deployed with REPowerEU grants, and pretreatment shifts from ultrafiltration to lower-energy methods such as sand filtration. Pilot-scale nutrient recovery expertise.	Germany
Casale	Gas separation, conversion to new gas	Reducing the carbon footprint of chemical synthesis, to create sustainable products that minimize environmental impact throughout their lifecycle.	Netherlands
SINTEF	Gas separation, conversion to new gas	Capture of NH_3 and CO_2 , and the handling and eventual upgrading of the solution, fall within SINTEF's stated competence.	Northern / Central Europe
VTT	Gas separation	Thermochemical conversion infrastructure supporting companies in developing and piloting carbonisation, liquefaction, gasification and synthesis gas processes.	Finland
Univastum	Gas separation, conversion to new gas	WARP [®] gasification technology, delivering renewable energy while reducing the operator's carbon footprint.	Ireland

EXECUTIVE SUMMARY

Recommended Action

Engage in further discussion with the following organisations. Each has been given the project scope and considers that it could provide a viable solution.

Fraunhofer

Germany

Specializing in membrane stripping technology

Casale

Switzerland

Decarbonised ammonia technologies, with full engineering services

SINTEF

Northern / Central Europe

Expertise in CO₂ capture and handling**VTT**

Finland

Offering thermochemical conversion infrastructure

Univastum

Ireland

Developers of gasification technology



APPENDIX

Technology Partner Findings

- One page per organisation contacted
- What they do, and what the assessment established
- Subject matter expert panel

TECHNOLOGY PARTNER • GERMANY • MEMBRANE STRIPPING

Fraunhofer

What they do

A research organisation working on nitrogen recovery and circularity. Its approach recovers gaseous ammonia upstream of the process using hydrophobic membrane stripping: gases permeate the membrane while liquids are repelled. The system runs at pilot scale, with industrial partners able to build it at production scale; capacity is extended by adding modules. As a research organisation it works through partners, and also works with BASF, Bayer and others.

Assessment

The stream runs at approximately 30% solids, so the current configuration does not transfer directly. Establishing whether the concept can be adapted would require a research project on the composition of the stream. The route also introduces additional equipment and produces a material that needs its own customers.

What the assessment found

- The current system is a crossflow filtration membrane fed with ammonia water. Adjusting pH and temperature extracts NH_3 through a semipermeable membrane into the inner channels, where H_2SO_4 is fed; the combination yields ammonium sulfate, which is sold to local farmers.
- The membranes are niche but a standard offering. The setup is engineered and built by Fraunhofer, which rents units for research rather than building them for sale — though the design concept may be available.
- The setup is built from PVC and is not designed for high pressures.
- The current solution is specified for feeds containing less than 5% solids.

TECHNOLOGY PARTNER • NORTHERN / CENTRAL EUROPE • CO₂ CAPTURE

SINTEF

What they do

A research institute developing technologies and processes for CO₂ capture, utilisation and storage, aimed at reducing the footprint, cost and energy consumption of capture installations. Its CO₂Hybrid work integrates membrane separation with chemical absorption for both post- and pre-combustion capture, targeting 90% capture at 95% purity, with high-performance CO₂-selective membrane materials and modules developed toward demonstration readiness.

Assessment

Worth keeping on the list of ideas. Installation and the open question on recovered ammonia would require research before the concept is ready, so it is not a lead option.

What the assessment found

- SINTEF has research facilities comparable to Fraunhofer's. It develops technical concepts for a posed problem; the deliverable is a conceptual plan rather than engineering.
- One route emerged that had not already been considered: selective removal of ammonia using carbon or other adsorbers, with regenerative adsorbers allowing the ammonia to be recovered.
- Open questions: what to do with the recovered ammonia, logistics for storing the gas, and installation of the equipment.

TECHNOLOGY PARTNER • SWITZERLAND • AMMONIA & UREA TECHNOLOGY

Casale

What they do

A Swiss-headquartered engineering group providing technology for processes around ammonia — urea, nitrates and related products. It offers a complete range of services and technologies for revamping existing plants and building new ones, and extends its commitment to the energy transition into technologies for producing decarbonised ammonia.

Assessment

The economics depend on whether the full output can be sold, and at a higher price than the current disposal route.

What the assessment found

- Proposed neutralisation with nitric acid at the producer's own facilities, to produce a 50–70% ammonium nitrate solution.
- Has experience regulating heat and exhaust gases for this kind of process.
- Offered to run tests on the material and prepare a proposal for the technology component.
- Open topics: gas handling, logistics and available vessel capacity.

TECHNOLOGY PARTNER • FINLAND • THERMOCHEMICAL CONVERSION

VTT

What they do

Thermochemical conversion infrastructure at the VTT Bioruukki Pilot Centre, supporting the development and piloting of carbonisation, liquefaction, gasification and synthesis gas processes. The facilities are built for researching the use of waste feedstocks and industrial side products — forestry and agricultural biomass, plastic waste, municipal solid waste and carbon dioxide — and for developing sustainable fuels, chemicals and chemical plastic recycling before committing to large investments.

Assessment

Development timelines do not fit the near-term decision this assessment was scoped against.

What the assessment found

- Advanced technologies and ideas across thermochemical conversion.
- The routes discussed are not economically viable at the scale of this waste stream in the near term.

TECHNOLOGY PARTNER • IRELAND • GASIFICATION

Univastum

What they do

Developers of WARP[®] gasification technology. The reactor is a lined shaft furnace 14 metres in height. Material is loaded from above through a hopper and descends slowly through an oxygen-free zone, passing low-temperature pyrolysis, high-temperature pyrolysis and coking zones.

Status

Assessment not completed within the study period.

What the assessment found

- In the combustion zone, under a lack of oxygen, coke, steam and semi-coke react with O₂. Temperature is held below 1200 °C by supplying water vapour, which increases CO and H₂ formation and accelerates processing time.
- Ash and catalyst pass the combustion zone and discharge slowly from the base.
- Heat is recovered by counter-current flow: gasification products leave the reactor at 200–250 °C, ash and catalyst discharge at 150 °C, and catalyst is recycled to the reactor at 100 °C.
- The process is regulated by a vacuum exhaust fan located outside the reactor.

APPENDIX

Subject Matter Expert Panel

Four subject matter experts were interviewed. Interviews were conducted anonymously, so individuals and their employers are described by domain and depth of experience rather than by name.

Waste-to-energy & air pollution control

Over 17 years as co-founder, technical director and chief executive of an environmental systems business. Developed technologies now used internationally in the environmental control market. Mechanical engineering background; an expert in abatement and renewable technologies, waste-to-energy solutions, air pollution control, and turning waste streams into revenue-producing assets.

Ammonia recovery, anaerobic digestion & biochar

A group supplying environmental protection solutions for more than thirty years. Developer, supplier and operator of turnkey solutions for anaerobic digestion, biomethane, ammonia recovery, pyrolysis and biochar production, with offices and representatives across Europe, Asia, the Americas and Oceania.

Ammonia, urea & nitrate process technology

A global chemical-industry partner offering integrated technologies, engineering, contracting and construction for over a century. A private group of more than 400 professionals headquartered in Switzerland, with presence in the Czech Republic, China, Brazil, India and the United States.

Fertilizer trading

Fifteen years in the fertilizer trading space across product management and trading roles at a major industrial group, latterly directing fertilizer trading.