IEA Bioenergy
Technology Collaboration Programme

Implementation Examples for Organic Waste Valorization Technologies

IEA Bioenergy: Task 36

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Photo from Tønder Biogas

Implementation Examples for Organic Waste Valorization Technologies

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Preface

This report is a compilation of use cases showing different technological pathways (anaerobic digestion with carbon capture and utilization/sequestration, hydrothermal carbonization, hydrothermal liquefaction, etc.) for organic waste valorization for local solutions. The selected projects pair a reliable wet waste feedstock with a clear, local outlet for products and straightforward site integration.

IEA Bioenergy Task 36, working on the topic “Material and Energy Vaporization of Waste in a Circular Economy”, seeks to raise public awareness of sustainable energy generation from biomass residual and waste fractions including municipal solid waste (MSW), as well as to increase technical information dissemination. As outlined in the 3-year work programme, Task 36 seeks to understand what role energy from waste and material recycling can have in a circular economy and identify technical and non-technical barriers and opportunities needed to achieve this vision.

The technologies and solutions presented in this compilation were selected due to their relevance in the field of waste sorting technologies. However, IEA Bioenergy Task 36 does not endorse any commercial products that may be mentioned on this report.

See: http://task36.ieabioenergy.com/ for links to the work performed by IEA Bioenergy Task 36.

Introduction

Organic wastes—such as wastewater sludge, animal manure, and food waste—present both a management challenge and an opportunity to recover energy and valuable materials. Established approaches like anaerobic digestion (AD) and composting are widely deployed, but they typically produce a limited set of products and may only be viable where supportive local markets or policy incentives exist. Exploring additional technologies and conversion pathways can expand the range of potential products and end markets while enabling solutions better matched to the characteristics of specific waste streams. Rather than relying on a one-size-fits-all approach, communities can consider a broader set of options that may open new commercialization pathways and increase overall resource recovery.

In that context, this brochure profiles a set of commercial or near-commercial pathways that illustrate how these recovery technologies can work in practice, presented as concise use cases. AD with carbon capture and utilization/storage (CCU/CCS) captures biogenic carbon dioxide (CO_2) from biogas upgraders (historically vented as a waste stream) for local use or potential geological storage. Hydrothermal carbonization (HTC) and hydrothermal liquefaction (HTL) are hydrothermal processes that treat high-moisture feedstocks in hot pressurized water: HTC typically yields a dewaterable hydrochar solid, while HTL converts organics into an energy-dense biocrude for upgrading. Pyrolysis thermochemically transforms dewatered biosolids in an oxygen-limited environment to make biochar, reducing mass and enabling beneficial-use pathways. Finally, hydrogen production from wastewater via proton exchange membrane (PEM) electrolysis uses polished wastewater effluent and renewable electricity to produce hydrogen as a product, with the option to feed an oxygen byproduct back into aeration systems to support wastewater treatment. Each use case highlights basic technical specifications, years of operation, business arrangements, and practical factors that support project delivery.

Anaerobic Digestion with Carbon Capture and Utilization

CROFTHEAD FARM—DUMFRIES, SCOTLAND

Photo from Kanadevia Inova

Crofthead is a farm-based AD/biomethane plant commissioned in December 2019 that produces biogas from the digestion of 60,000 to 100,000 tons[1] per year of agricultural waste, made up mostly of manure from two adjacent farms (one dairy, one beef). The plant upgrades the biogas to produce roughly 40 gigawatt hours (GWh) of biomethane annually for injection into the natural gas grid (SGN, n.d.). In 2022, a separately operated, adjacent CO_2 recovery and dry-ice unit was added to capture the biogenic CO_2 separated in the biogas upgrader, polish and liquefy it, and produce food-grade dry ice for regional customers (SEPA 2022). Co-location of the dry ice production allows the project to avoid liquid CO_2 transport, helping to strengthen project economics. The AD/biomethane plant was financed by Iona Capital and is operated by Biogas Power Ltd, a specialist in on-farm AD facilities. The CO_2 and dry ice facility is owned and operated by Carbon Capture Scotland. The separate but adjacent facilities allowed for streamlined permitting – Carbon Capture Scotland applied for an additional permit, and the original AD/biomethane permit remained unchanged – and enabled specialist operation for each process (SEPA 2022). By capturing and processing the CO_2, Carbon Capture Scotland capitalizes on a product stream that was previously vented as a waste.

Co-located carbon capture and utilization (CCU) turns formerly vented CO_2 produced from upgrading of 158,000 gigajoules (GJ)/year of biogas into a marketable food-grade dry ice. More information can be found here.

[1] All tons listed in the report are metric.

TERRES D'AQUITAINE AD—SAINT-SELVE, FRANCE

Photo from SUEZ

In May 2025, SUEZ brought online a biogenic CO_2 recovery unit at its Terres d'Aquitaine AD facility near Bordeaux. The unit captures the CO_2 stream separated during biogas upgrading and purifies and liquifies it on-site. The CO_2 is supplied under contract to Rougeline – an association of six agricultural cooperatives in southern France – for greenhouse enrichment; it is already used by two greenhouses in the Landes region to enrich tomatoes, replacing fossil CO_2. The nameplate CCU capacity is up to 3,500 tons per year of biogenic CO_2 (SUEZ 2025). The AD operation, commissioned in 2006, runs on a mixed organic waste stream, including food waste from retail, municipalities, and industry, as well as agricultural residues from the surrounding region. The site produces more than 45 GWh of biomethane annually, which is injected into the gas distribution network (SUEZ 2025). In January 2025, the solid digestate was certified under the European Union (EU) Fertilizing Products Regulation as an organic soil amendment; over 9,000 tons will be sold annually to regional farmers, further enhancing the facility economics (EBA 2025). The CO_2 recovery unit was co-funded between SUEZ and a €560,000 grant from the Nouvelle-Aquitaine Region, representing 40% of the total investment (SUEZ 2025).

At Terres d'Aquitaine nearly 3,500 tons per year of biogenic CO_2 is captured on-site and supplied to local greenhouses. More information can be found here.

TØNDER BIOGAS—TØNDER, DENMARK

Photo from Tønder Biogas

At Tønder Biogas, one of Europe's largest AD facilities, approximately 930,000 tons per year of organic wastes are converted into roughly 410 GWh of upgraded biomethane which is injected into the local gas grid (Tønder Biogas, n.d.). AD feedstocks consist primarily of manure, along with some other agricultural biomass from local farms as well as industrial food wastes. The facility can capture up to 48,000 tons of biogenic CO_2, which is purified and liquified before being trucked to European Energy's Power-to-X (PtX) plant in Kassø, Denmark (Tønder Biogas, n.d.). There, the CO_2 is combined with hydrogen to synthesize up to 42,000 tons per year of e-methanol, which is used by Maersk as an alternative fuel for ships. Digestate produced from the AD is returned to area farms as fertilizer.

The plant was initially commissioned in November 2022, and after a major expansion, reached full operational capacity in 2025. The first delivery of biogenic CO_2 from Tønder was received at the PtX facility in March 2025 (CIP, n.d.). The project was undertaken by Anaergia Inc. (a private waste-to-energy developer) and in February 2023 was acquired by Copenhagen Infrastructure Partners (CIP) through a private equity fund. To support construction and operations of the project expansion, the Nordic Investment Bank approved a DKK 250 million, 16-year loan to Tønder Biogas. The project is further supported by a 20-year state-backed subsidy for supplying biogas to the grid (CIP, n.d.).

At one of Europe's largest AD facilities, 48,000 tons of captured biogenic CO_2 enables the synthesis of up to 42,000 tons of e-methanol annually. More information can be found here.

Notable Development: Anaerobic Digestion with Carbon Capture and Storage

Image generated by Claude AI, May 29, 2026, from the prompt "large scale anaerobic digestion facility with carbon capture and sequestration"

Several developers are working on AD with CO_2 capture for permanent storage instead of utilization, aiming to capture biogenic CO_2 and send it to geological storage to generate carbon-removal credits. While there are no existing AD plus CCS operations, there are many developing plans. One of the most advanced public programs is Future Biogas (United Kingdom), which plans to build a new fleet of AD facilities (up to 25), with each plant designed to capture up to 21,000 tons of CO_2 for permanent storage (Future Biogas, n.d.). In the U.S. NLC Energy (California) signed a CO_2 management agreement with Carbon TerraVault to store CO_2 from a new renewable natural gas (RNG) complex that will convert biomass and agricultural wastes; project documents indicate the storage agreement is for 430,000 tons CO_2 per year and the RNG facility is scoped at roughly 2 GWh/day (California Resources 2024). While there are not currently any fully operating AD plus CCS sites, these projects and others show a developing pathway for waste valorization through creditable CO_2 removals.

Hydrothermal Carbonization of Wastewater Sludge

JINING WASTEWATER TREATMENT PLANT—SHANDONG, CHINA

Photo from TerraNova Energy

The Jining municipal wastewater treatment plant (WWTP) installed a hydrothermal carbonization (HTC) line in 2016 to process dewatered sewage sludge on site. HTC heats liquid sludge under pressure then mechanically dewaters the carbonized slurry to approximately 70% total solids, producing a coal-like hydrochar – significantly reducing mass and volume without thermal drying. At Jining, the HTC line processes roughly 14,000 tons of dewatered sludge annually (a feed rate of about 2 tons per hour) and produces roughly 3,000 tons of hydrochar that is co-fired at a nearby power plant. Reported first-year data indicate a roughly 75% reduction in mass from dewatered sludge to the final hydrochar product and approximately 7.5 GWh of annual energy savings as compared to a thermal drying alternative (Buttmann 2018). HTC is seen as an attractive technology for managing China's rapidly increasing wastewater sludge quantities (more than doubling nationwide between 2013 and 2022 [Liu 2025]), as it significantly reduces sludge volume and mass, creates a valuable energy product, and allows for relatively straightforward nutrient recovery (phosphorus, nitrogen).

Full-scale HTC, treating 14,000 tons per year of dewatered sludge since 2016. Hydrochar is co-combusted locally for energy production. More information can be found here.

PAU-LESCAR "BIOFACTORY"—PAU BÉARN PYRENEES, FRANCE

Image generated by Claude AI, May 5, 2026, from the prompt "Pau-Lescar wastewater treatment plant photo"

The Pau-Lescar WWTP pairs AD (biogas upgraded to biomethane) with HTC of digested sludge. Similar to the WWTP in Jining, the HTC line at Pau-Lescar produces a solid hydrochar "biocoal," while the HTC process water is returned to the anaerobic digester. The line was commissioned in late 2023, and by early 2025, the facility had roughly 1.5 years of continuous operation, with results showing an approximately 20% increase in biomethane yield with the addition of the HTC process water (TerraNova Energy 2025). Sludge volumes are reduced to approximately a quarter of the starting volume while requiring about 3 to 4 times less energy than thermal drying (SUEZ, n.d.). The hydrochar is incinerated locally for energy generation. Planned additions to the plant (e.g. e-methane synthesis from CO_2 captured in biogas upgrading; nitrogen recovery from liquid residues) aim to further valorize current waste streams, with the ultimate goal of capturing 10 resource streams and producing 13 GWh of bio- and e-methane (SUEZ, n.d.).

The public authority awarded a 17-year contract valued at €79 million to a consortium led by SUEZ to operate the WWTP and design and build the new units (AD, biogas upgrading, HTC, etc.) (SUEZ 2021). A €15 million loan from La Banque Postale was used to cover project financing and construction (La Poste Groupe 2022).

In Pau-Lescar, HTC paired with AD results in a 75% reduction in sludge volume and a 20% increase in biomethane yields. More information can be found here.

Pyrolysis of Wastewater Sludge to Biochar

SILICON VALLEY CLEAN WATER—REDWOOD CITY, CALIFORNIA, USA

Photo from Bioforcetech Corporation

The Silicon Valley Clean Water (SVCW) installed an on-site biodrying and pyrolysis line that is applied to biosolids after they have undergone AD. The combined line can reduce biosolids by up to 90% by weight as reported by the utility, and results in a marketable U.S. Class A biochar product, eliminating over 500 truck trips for sludge disposal annually (Bioforcetech 2020). The installation has been in continuous service since 2018, and operations were analyzed in 2020 to provide greater information on the technology. The analysis determined that the SVCW system processed approximately 3,500 tons per year of dewatered biosolids and produced roughly 400 tons per year of biochar, along with 55 kilowatt hours (kWh) per ton of added energy. Analysis on the produced biochar showed near total per- and polyfluoroalkyl substance (PFAS) removal (≥98%), supporting land application pathways (Thoma 2022). The project's business model began as a 10-year service contract in which Bioforcetech built, operated, and maintained the facility for a guaranteed annual tonnage – giving SVCW predictable service pricing and performance.

On-site biodrying and pyrolysis reduce biosolids 90% by weight and yield saleable biochar product. More information can be found here.

Notable Development: Hydrothermal Liquefaction of Wet Waste

Hydrothermal liquefaction (HTL) converts wet organic wastes into an energy-dense biocrude under elevated temperature and pressure. As of fall 2025, no commercial-scale wet waste HTL plants were confirmed in operation, and the IEA Bioenergy Task 34 June 2023 review (IEA Bioenergy 2023) remains the most in-depth and up-to-date source on HTL facility status. Activity is currently concentrated in demonstration/near-to-market projects, with several planning steps towards commercial scale. For wastewater sludge, notable demonstrations include Metro Vancouver (Annacis Island, Canada) – a system sized to process approximately 2 dry tons of sludge per day – and Sludge2Fuel (Fredericia, Denmark) that is designed to process roughly 15 dry tons of sludge per day with downstream upgrading of the produced biocrude at Crossbridge Refinery. Other long-running demonstrations processing wet wastes include Reliance (Jamnagar, India), which tested sludge, food waste, and algae, and Altaca (Gebze, Turkey), which has run digestate, sludge, and other organics. For a more detailed look at technical specifications and site notes, readers can consult the IEA Task 34 "Commercial Status of Direct Thermochemical Liquefaction Technologies" report (IEA Bioenergy 2023).

Notable Development: Hydrogen Production from Wastewater via Proton Exchange Membrane Electrolysis

Early projects demonstrate how hydrogen can be produced at WWTPs by taking the cleaned effluent water, polishing it to an ultrapure state, and feeding it into a proton exchange membrane (PEM) electrolyser to split the water into hydrogen and oxygen. Electricity produced from AD at the plant (or other renewable sources) powers the electrolyser. The hydrogen is then usable as a fuel or energy source, while the oxygen is piped back into the treatment process, often reducing energy required for aeration and operating costs. In the U.S., the City of St. Cloud (Minnesota) is installing a PEM electrolyser at their Nutrient, Energy, and Water Recovery Facility that will produce hydrogen for facility heating and can be used as a transportation fuel in the community. The project is anticipated to be complete in 2027 (City of St. Cloud, n.d.). In the United Kingdom, Anglian Water is piloting an electrolyser at a WWTP to use treated water as a feedstock for hydrogen production and loop the resulting oxygen into an aerated membrane reactor to reduce emissions in the treatment process. The initial pilot project is underway, with testing being carried out to determine optimal running conditions (Ford 2023).

Summary and Conclusions

Variation exists across cases in project scale, ownership structure, and financing mechanisms, reflecting the range of contexts in which these technologies have been deployed. Table 1 summarizes key characteristics of the profiled cases.

Table 1. Summary of Profiled Organic Waste Valorization Projects

Project	Technology	Feedstock	Scale / Capacity	Primary Products	Business / Ownership Model	Financing	Operational Since
Crofthead Farm (United Kingdom)	AD + CCU (dry ice)	Agricultural waste (manure); 60,000–100,000 t/yr	~40 GWh/yr biomethane; CO_2 capture unit added 2022	Biomethane (grid injection); food-grade dry ice	Two separate operators: Biogas Power Ltd (AD); Carbon Capture Scotland (CCU)	Private equity (Iona Capital); separate CCU permit avoided major refinancing	AD: 2019 CCU: 2022
Terres d'Aquitaine (France)	AD + CCU (greenhouse CO_2)	Food waste (retail, municipal, industrial); agricultural residues	~45 GWh/yr biomethane; up to 3,500 t/yr CO_2 captured; 9,000+ t/yr digestate	Biomethane (grid injection); biogenic CO_2 for greenhouse enrichment; fertilizer	SUEZ-operated; CO_2 supply under contract to Rougeline agricultural cooperative	Owner equity + €560,000 regional grant (40% of CO_2 unit cost)	AD: 2006 CCU: 2025
Tønder Biogas (Denmark)	AD + CCU (e-methanol synthesis)	Manure + agricultural biomass + industrial food waste; ~930,000 t/yr	~410 GWh/yr biomethane; up to 48,000 t/yr CO_2 captured; up to 42,000 t/yr e-methanol synthesis	Biomethane (grid injection); biogenic CO_2 for e-methanol synthesis; fertilizer	Private equity ownership (CIP); CO_2 sold under offtake to European Energy PtX plant	Private equity fund; DKK 250 million, 16-yr Nordic Investment Bank loan; 20-yr state-backed grid subsidy	2022 (expanded to full capacity 2025)
Jining WWTP (China)	HTC of wastewater sludge	Dewatered wastewater sludge; ~14,000 t/yr	~2 t/hr feed; ~3,000 t/yr hydrochar; ~7.5 GWh/yr energy savings vs. thermal drying	Hydrochar (co-fired at nearby power plant); ~75% mass reduction	Municipal utility-owned; hydrochar co-fired under local arrangement	Not publicly reported	2016
Pau-Lescar "Biofactory" (France)	AD + HTC of digested sludge	Municipal wastewater sludge (post-AD); combined with biogas upgrading	~75% sludge volume reduction; ~20% increase in biomethane yield;	Biomethane (grid injection); hydrochar (incinerated locally); future: e-	17-yr public contract to SUEZ-led consortium for design, build, and operation;	€79M public contract; €15M loan (La Banque Postale)	2023

			planned 13 GWh bio/e-methane	methane, recovered nitrogen	public authority retains ownership		
Silicon Valley Clean Water (United States)	AD + biodrying + pyrolysis of biosolids	Dewatered biosolids (post-AD); ~3,500 t/yr	~400 t/yr biochar; up to 90% mass reduction; ~55 kWh/t net energy output; ≥98% PFAS removal	Class A biochar (land application / sale)	10-yr service contract: Bioforcetech built, operated, and maintained facility; SVCW pays per guaranteed annual tonnage (ownership/ operations separated from utility)	Private service contract; capital provided by Bioforcetech	2018

Across these examples, successful projects tend to pair a reliable wet waste feedstock with a clear, local outlet for products and straightforward site integration. Many of these projects pursue co-location of conversion or CCU units next to the waste stream or CO_2 source, which may lower logistics costs and risk (e.g., Crofthead's on-site dry ice unit). Additional patterns observed across cases include: (1) separate but coordinated operators – specialists running CCU or thermal units can simplify operations for the host; (2) sequential delivery – commissioning the base asset (e.g., AD to grid) before adding additional lines/processing like CCU, HTC, or pyrolysis may ease start-up and financing; (3) attention to stream purity and/or product quality to ensure market value; and (4) practical site integration and community interface – odor controls, compact footprints, and reduced truck-miles may aid in acceptance and permitting.

Policy context plays an important role in the viability of many projects. Several AD-to-grid projects have benefited from biomethane support schemes (historic or current), while other projects leverage additional policy support. For example, UK AD plants accredited under the Non-Domestic Renewable Heat Incentive and legacy Feed-in Tariff era could claim support for biomethane and combined heat and power, and Denmark allows a 20-year price premium for biomethane injected into the grid.

Financing models differ by pathway and sponsor. Several assets are privately financed (e.g. owner equity or private-equity funds) alongside long-term loans from commercial or multilateral lenders; some projects also leverage public grant funding for a portion of project costs. For example, Tønder Biogas combined private equity ownership with a loan from the Nordic Investment Bank; Terres d'Aquitaine's CO_2 unit leveraged regional grant funding along with owner equity; and Pau-Lescar supported project financing and construction with a loan from La Banque Postale. Service-contract models also appear (e.g., SVCW's pyrolysis line, Pau-Lescar's contract with SUEZ for design and operation), illustrating that ownership and/or operations can be separated from the host utility.

Ultimately, there is no single "best" pathway. Where supportive policy is available and funding is aligned, projects may be better positioned to proceed. Communities, utilities, and project developers can use these use cases to understand options, constraints, and transferable practices to help evaluate which combination of technology, market, and business model fits local goals, infrastructure, and financing.

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