IEA Bioenergy
Technology Collaboration Programme

Status report on thermal gasification of biomass and waste 2021

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Annex 3

Gasification facilities for fuel synthesis – planned, under construction, under commissioning, operational

In this annex, the thermal gasification facities for fuel synthesis with TRL 6-9 are included. Only few, important facilities with lower TRL could be found here as reference.

	Operational
	Planned/ Under construction / under commissioning

	Owner	Name	Country	Page
	Advanced Biofuels Solutions Ltd.	Swindon Advanced Biofuels Plant	UK	2
	Advanced Biofuels Solutions Ltd.	ABSL bio-SNG demonstrator	UK	3
	Aemetis/Lanzatech	Project Aemetis Riverbank	USA	4
	BioMCN	BioMCN commercial	NL	5
	Total	BioTfuel demo	FR	6
	Cutec	Synthesis Cutec Clausthal-Zellerfeld	DE	7
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	Enerkem Alberta Biofuels LP	Edmonton Waste-to-Biofuels Project	CA	11
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	Fulcrum BioEnergy Sierra Biofuels plant	Synthesis Fulcrum BioEnergy City of McCarran		13
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	NREL	Thermochemical Users Facility (TCUF)	USA	17
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	Tembec Chemical Group	Synthesis Tembec Chemical Quebec	CA	19
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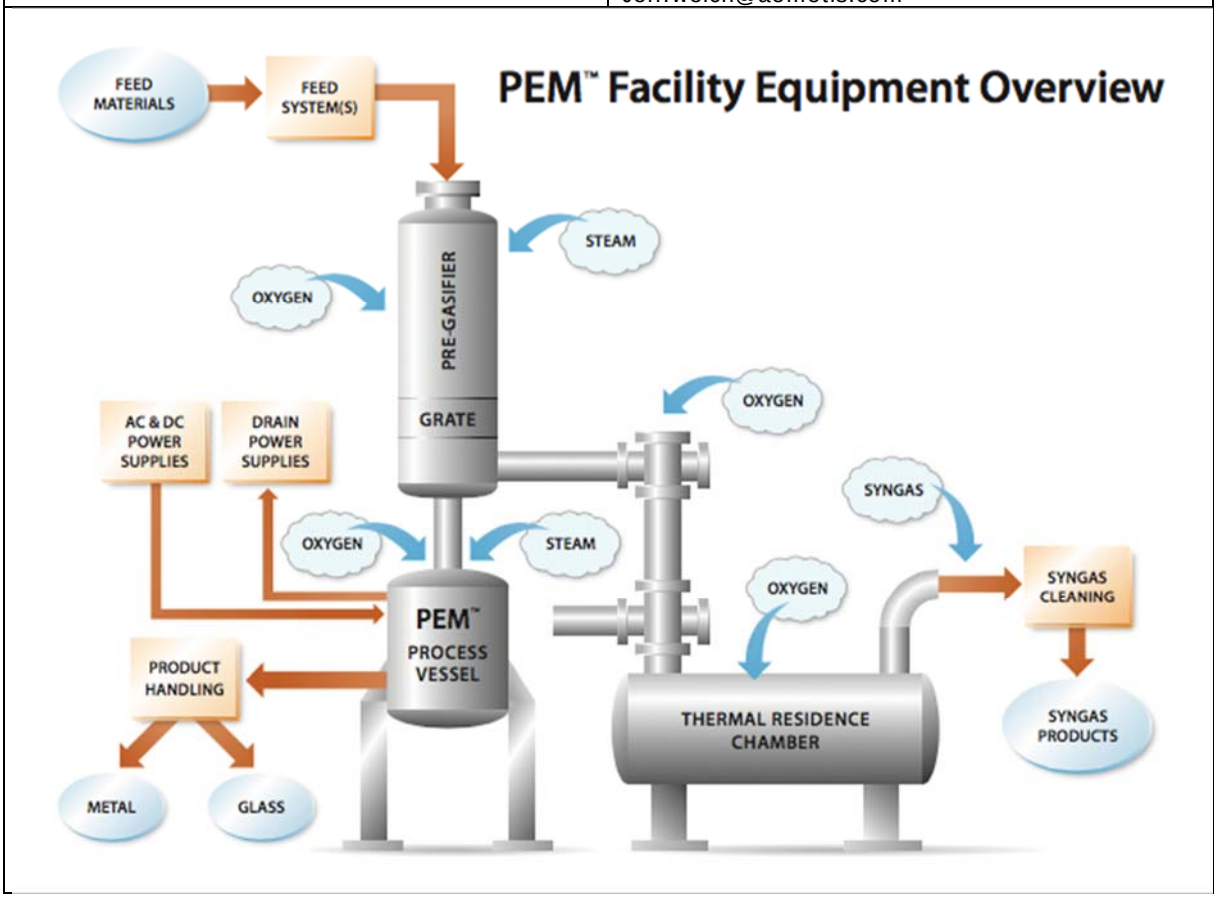
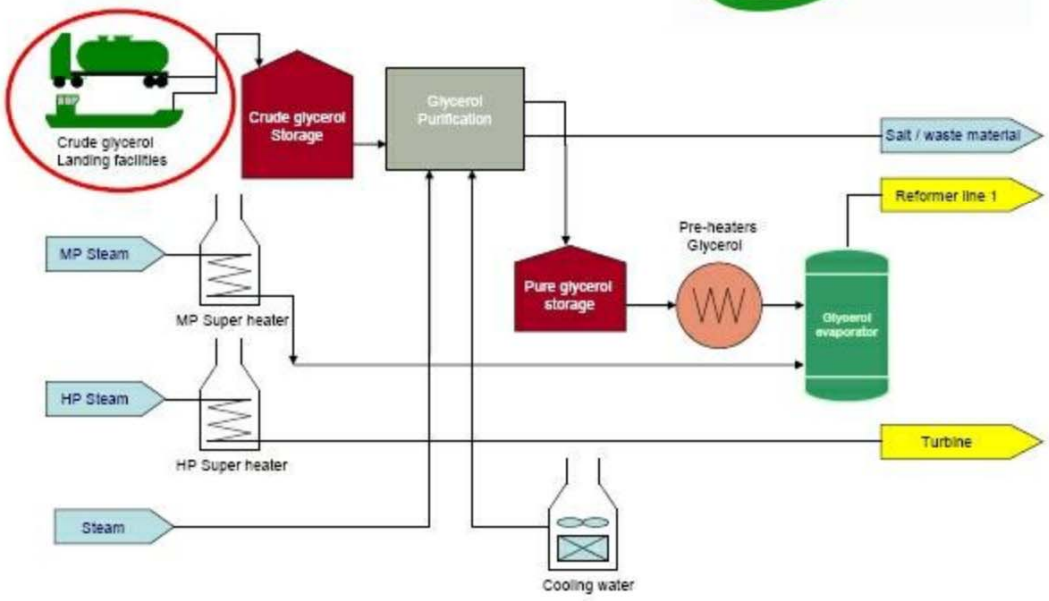
Project name	Swindon Advanced Biofuels Plant
Project owner	Advanced Biofuels Solutions Ltd
Status	commissioning
Start up	2022
Country	UK
City	Swindon
Type	TRL 8 First-of-a-kind commercial
Technology	Fuel Synthesis
Technology additional information	ABSL RadGas and Wood VESTA technology
Raw Material	organic residues and waste streams Refuse derived fuel and waste wood (8,000 t/y)
Output 1	SNG (1,500 t/y)
Output 2	Hydrogen (500 t/y)
Total investment	GBP 30,000,000
Technology Brief	The facility will accept 8,000 tonnes per year of waste from the local area and convert it into 22GWh, or 2.2 million cubic metres, of natural gas, enough to heat 1,800 homes or fuel 75 HGVs. The plant will also produce 6,000 tonnes of carbon dioxide to be liquified for use in industry and 400 tonnes of vitrified ash for use as an aggregate. The process is made up of the following steps: 1. Prepared waste is brought to the site in a moving floor trailer and then stored 2. The waste is conveyed to an oxy-steam fluidised bed gasifier to produce a dirty syngas 3. The dirty syngas is heated and exposed to oxygen free radicals to catalyse the reformation of tar 4. The tar free syngas is cooled with steam raised used elsewhere in the process 5. The gas is filtered to remove particulates and then scrubbed to remove acid and alkali contaminants 6. The clean syngas is compressed and then passed over catalysts to convert it into natural gas and carbon dioxide 7. The carbon dioxide is separated and liquified 8. The remaining natural gas is metered into the grid The process equipment has been installed and integrated on site and commissioning is underway. Commissioning is due to complete in 2021. Once it is operational the plant will act as a template for large scale commercial facilities.
Contact	Tel: 01793 832 860 Unit A4, Marston Gate South Marston Industrial Estate Stirling Road Swindon SN3 4DE UK

Project name	ABSL bio-SNG demonstrator
Project owner	Advanced Biofuels Solutions Ltd
Status	commissioning
Start up	2022
Country	UK
City	Swindon
Type	TRL 6-7 Demonstration
Technology	Fuel Synthesis
Technology additional information	RadGas. Follow on from GoGreenGas project – two stage (Plasma?) process.
Raw Material	RDF (8,000 t/y)
Output 1	SNG (2,200,000 m3/y)
Technology Brief	Follow on from GoGreenGas project.
Contact	Andy Cornell info@absl.tech +44 1793 832860

Project name	Project Aemetis Riverbank
Project owner	Aemetis/Lanzatech
Status	Planned (securing financing)
Start up	TBD (construction planned to beginn 2020)
Country	USA
City	Riverbank, CA
Type	TRL 8
Technology	Fuel synthesis
Raw Material	Agricultural waste
Output 1 Name	Cellulosic ethanol
Output 1 Capacity	12 mill.
Output 1Unit	US gallons per year
Funding	USDA loan guarantee ($125M), California Energy Commission ($5M)
Technology Brief	Gasification with syngas fementation (InEnTec gasifier, Lanzatech syngas fermentation)
Contact	Jeff Welch Jeff.welch@aemetis.com

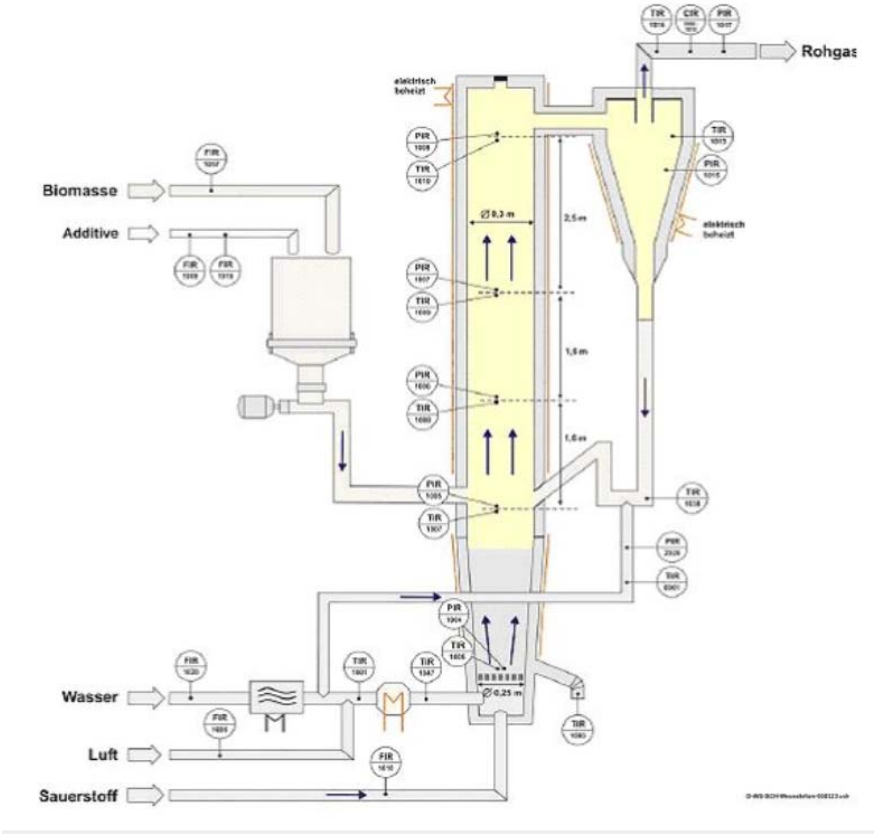


Project name	BioMCN commercial
Project owner	BioMCN
Status	operational
Start up	2009
Country	NL
City	Farmsum
Type	TRL 8 First-of-a-kind commercial
Technology	Fuel synthesis
Technology additional information	
Raw Material	biomethane
Output 1	methanol (65,000 t/y)
Partners	Waterland, Teijin, NOM
Technology Brief	Constructed for converting glycerine (a by-product from biodiesel production) into bio-methanol, but currently feeding on biomethane. The facility currently simply turns biomethane into biomethanol, using only a fraction of their capacity
Contact	info@biomcn.eu



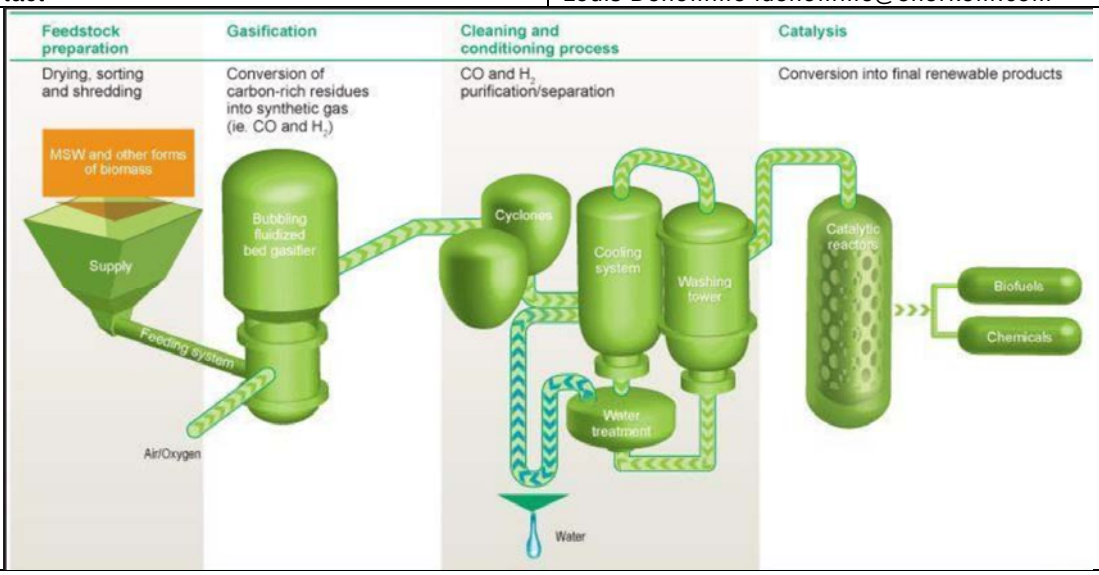
Project name	BioTfuel demo
Project owner	Total
Status	operatinal
Start up	2021
Country	France
City	Dunkirk
Type	TRL 6-7 demo
Technology	Fuel synthesis
Raw Material	Forest waste, straw, green waste, dedicated crops
Output 1 Name	FT liquids (jet fuel component)
Output 1 Capacity	8000
Output 1Unit	t/y
Partners	Axens, CEA, IFP Energies Nouvelles, Avril, ThyssenKrupp Industrial
Technology Brief	The BioTfueL project is focused on developing an innovative process for converting biomass into high-quality biodiesel and bio-jet fuel. Gasification makes it possible to produce biofuels from lignocellulosic material, such as agricultural by-products, forest waste and energy crops. The process can also convert fossil feedstock mixed with biomass to account for seasonal variations in resource availability. The biomass feedstock is torrefied and then converted into syngas in a gasifier. Once the syngas has been cleaned and conditioned, it is converted into a hydrocarbon mixture that can be used to produce fuel.
Contact	http://www.total.com/en/energy-expertise/projects/bioenergies/biotfuel-converting-plant-wastes-into-fuel

Project name	Synthesis Cutec Clausthal-Zellerfeld
Project owner	Cutec
Status	operational
Start up	1990
Country	Germany
City	Clausthal-Zellerfeld
Type	TRL 4-5 Pilot
Technology	Fuel Synthesis
Raw Material	lignocellulosics
Input 1	Straw, wood, dried silage, organic residues
Output 1	FT liquids (0.02 t/y)
Technology Brief	BtL production; atmospheric gasifier; artfuel project
Contact	Stefan Vodegel stefan.vodegel@cutec.de

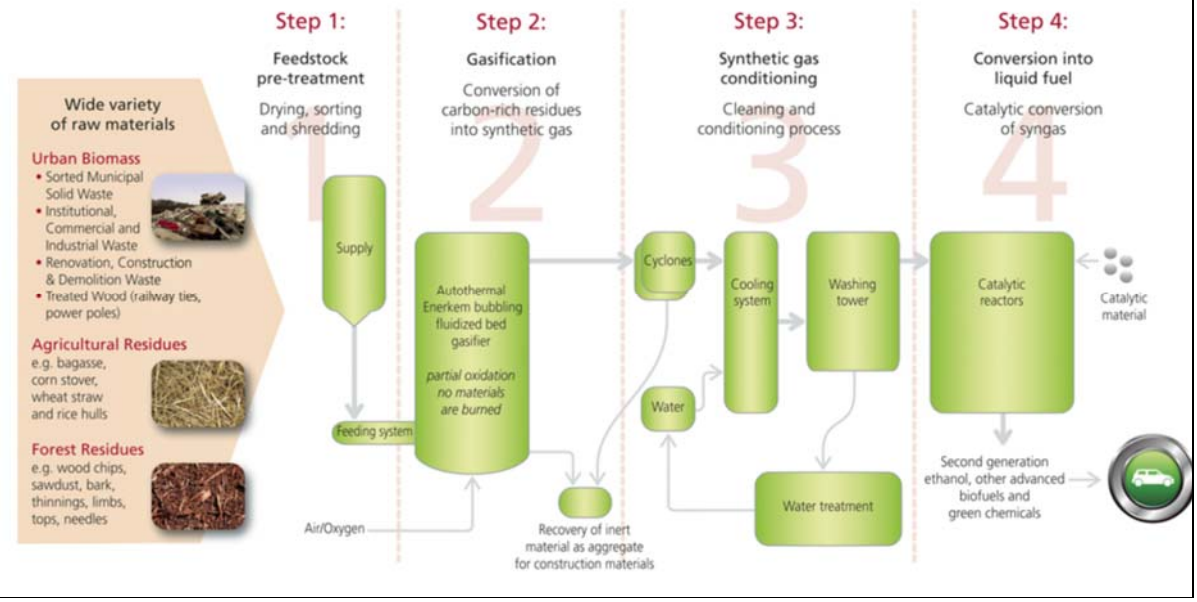


Project name	Varennes Carbon Recycling
Project owner	Enerkem
Status	Under construction
Start up	2023
Country	Canada
City	Varennes
ype	TRL 6-7 Demonstration
Technology	Fuel Synthesis
Raw Material	organic residues and waste streams
Input 1	Forest residues and non-recyclable waste from the commercial and institutional sector (200,000 t/y)
Output 1	other (125,000 m3/y)
Output additional information	Biofuels and renewable chemicals
Total Investment	CAD 875,000,000
Partners	n December 2020, Enerkem announced the construction of a C$875 million biofuels plant in Varennes with a group of strategic partners including Shell, as lead investor, as well as Suncor and Proman, and Hydro-Québec, which will supply renewable hydrogen and oxygen, and with the support of the governments of Quebec and Canada.
Technology Brief	The plant will leverage green hydrogen and oxygen produced through electrolysis, transforming Quebec's excess hydroelectricity capacity into value-added biofuels and renewable chemicals. Enerkem's proprietary thermochemical process will enable the recycling of the carbon and hydrogen contained in non-recyclable waste and wood waste currently landfilled or burned. In addition to providing a second life to waste material, VRC will expand the overall supply of alternative fuels and increase biofuel production in Québec increasing its leadership in renewable energy and innovation. Commissioning of the first phase is scheduled for 2023.
Additional Information	https://enerkem.com/company/facilities-projects/
Contact	Marie-Helene Labrie mlabrie@enerkem.com

Project name	Westbury commercial demonstration facility
Project owner	Enerkem
Status	Operational
Start up	2009
Country	Canada
City	Westbury, Quebec
Type	TRL 6-7 Demonstration
Technology	Fuel Synthesis
Input 1 Name	Treated wood (i.e. decommissioned electricity poles, and railway ties), wood waste and MSW (48 t/d)
Output 1	cellulosic ethanol (4,000 t/y)
Output 2	methanol (1,000)
Output 3	various chemicals
Technology Brief	Enerkem develops biofuels and chemicals from waste. With its proprietary thermochemical technology, Enerkem converts abundantly available municipal solid waste (mixed textiles, plastics, fibers, wood and other non-recyclable waste materials) into chemical-grade syngas, and then methanol, ethanol and other chemical intermediates that form everyday products.
Contact	Louis Dénommé ldenomme@enerkem.com



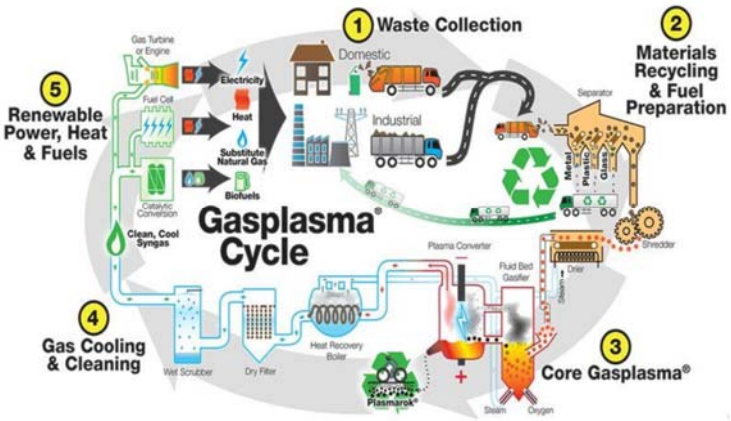
Project name	Synthesis Enerkem Sherbrooke
Project owner	Enerkem
Status	Operational
Start up	2003
Country	Canada
City	Sherbrooke
Type	TRL 4-5 Pilot
Technology	Fuel Synthesis
Raw Material	lignocellulosics
Input 1	municipal solid waste, wood chips, treated wood, sludge, petroleum coke, spent plastics and wheat straw
Output 1	cellulosic ethanol (375 t/y)
Output 2	methanol (475 m3/y)
Output 3	SNG
Partners	University of Sherbrooke
Technology Brief	Enerkem has developed a gasificationâ€ based process technology that transforms sorted municipal solid waste (MSW) and residues from the forest and agricultural industries into transportation fuels, highvalue chemicals and electricity. Enerkem refers to
Additional Information	Pilot Plant Facility, Sherbrooke, Quebec, Canada: Enerkem has been operating the pilot plant in Sherbrooke, Quebec since 2003, accumulating over 4,000 hours of operation. Through processing of solid materials, slurries, and liquids, the facility generates
Contact	Vincent Chornet vchornet@enerkem.com



Project name	Edmonton Waste-to-Biofuels Project
Project owner	Enerkem Alberta Biofuels LP
Status	Operational
Start up	2014
Country	Canada
City	Edmonton, Alberta
Type	TRL 8 First-of-a-kind commercial demo
Technology	Fuel Synthesis
Input 1 Name	Post-sorted municipal solid waste (MSW) (100,000 t/y)
Output 1	Ethanol (30,000 t/y)
Output 2	Methanol
Output 3	Various chemicals
Partners	
Technology Brief	Enerkem develops biofuels and chemicals from waste. With its proprietary thermochemical technology, Enerkem converts abundantly available municipal solid waste (mixed textiles, plastics, fibers, wood and other non-recyclable waste materials) into chemical-grade syngas, and then methanol, ethanol and other chemical intermediates that form everyday products.
Contact	Marie-Helene Labrie mlabrie@enerkem.com

Project name	Gaya
Project owner	GDF Suez + consortium
Status	Comissioning, commercial operation 2023
Start up	2017
Country	France
City	Lyon
Type	TRL 1-3 Research
Technology	Fuel synthesis
Input 1 Name	Wood pellets, wood chips
Output 1	SNG 0,1 t/y
Partners	Engie, Repotec, UCFF, LGC, LRGP, UCCS, Rapsodee, CEA, CIRAD, CTP, FCBA
Technology Brief	http://www.projetgaya.com/en/

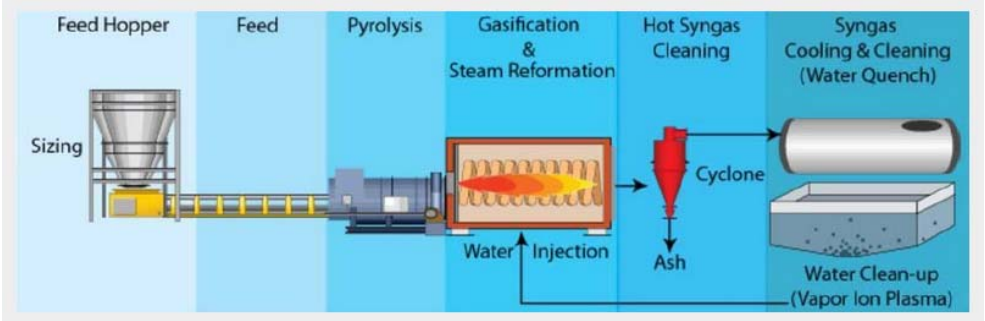
Project name	Synthesis Fulcrum BioEnergy City of McCarran
Project owner	Fulcrum BioEnergy Sierra Biofuels Plant
Status	planned
Start up	
Country	USA
City	City of McCarran, Storey County, Nevada,
Type	TRL 9 Commercial
Technology	Fuel Synthesis
Raw Material	organic residues and waste streams
Input 1	Waste (20,000 t/y)
Output 1	FT liquids (314,913 t/y)
Output 2	power (electricity)
Technology Brief	IPlasma Enhanced Melter (PEM) system provides a means of producing renewable energy from waste. The PEM process utilizes heat from plasma (electrically charged vapor) to convert waste feedstocks to valuable products including power generation.
Additional Information	In the City of McCarran, Storey County, Nevada, the plant will convert 90,000 tons of MSW into 10.5 million gallons of ethanol per year. Fulcrum has obtained the necessary local and state regulatory permits.
Contact	Fulcrum BioEnergy Sierra Biofuels Plant info@inentec.com

Project name	GoGreenGas
Project owner	Go Green Fuels Ltd
Status	Under construction
Start up	2019
Country	United Kingdom
City	Swindon
Type	TRL 8 First-of-a-kind commercial demo
Technology	Fuel Synthesis
Input 1 Name	Refuse derived fuel and waste wood (7,500 t/y)
Output 1	SNG (1,500 t/y) Product: 4 MW, 22 GWh
Total investment	GBP 25 000 000 11 million pound sterling public funding, 6 million pound sterling private funding
Partners	
Technology Brief	The Gogreengas pilot plant is a development facility for proving and optimizing the process for manufacturing Bio-SNG from Refuse Derived Fuel (RDF) and biomass feedstocks. The project is a partnership between Cadent (aka National Grid Gas Distribution), Advanced Plasma Power (APP), Progressive Energy and Carbotech (a subsidiary of Viessmann). The funding and strategic backing for the project comes from the UK energy regulator Ofgem's Network Innovation Competition, the European BioEnergy Securing the Future ERANET programme and the project partners. Dried RDF and other feedstocks are converted to syngas in a two-stage gasification process using APP's Gasplasma® technology (fluidized bed gasifier at atmospheric pressure designed by Outokompou Energy, close-coupled with a plasma converter). The plasma stage removes tars leaving a syngas which is predominantly CO and H2 and is also used to vitrify the ash. After further conventional gas processing, the syngas undergoes a water gas shift to adjust the proportions of the CO and H2, followed by catalytic methanation. The arising CO2 is removed from the methane using a pressure swing absorption unit to produce pipeline / vehicle quality Bio-SNG. The design incorporates provisions to evaluate a number of reactor configurations and a variety of catalyst bed geometries during the testing period. The plant has been commissioned and initial experimental work undertaken using test gases. End-to-end operation is about to commence, initially at low dilutions, and the plant will be progressively brought on stream and optimized during the remainder of 2016. The process challenges include the removal of heat in the highly exothermic methanation reactions given the smaller scale than conventional fossil plants, and the production of a substitute natural gas that meets the stringent regulations for gas grid injection.
	

Project name	GTI gasifier Des Plaines
Project owner	GTI Gas Technology Institute
Status	operational
Start up	
Country	USA
City	Des Plaines
Type	TRL 4-5 Pilot
Technology	Fuel Synthesis
Raw Material	lignocellulosics
Input 1	Pellets, wood chips (24 t/d)
Output 1	heat (5 MWth)
Output 2	gasoline-type fuels (38 m3/y)
Funding	USD 2,000,000
Partners	Carbona (Finland and USA) biomass gasification process (based on cooperation with VTT of Finland), Velocys (USA) Fischer Tropsch Technology, UPM (funding); Andritzâ€ Carbona;
Technology Brief	"Carbona (Finland and USA) biomass gasification process is originally based on licenses from the Gas Technology Institute and has subsequently been developed further by Carbona. Its first commercial application is under the Skive BGGE Small Modular Biopower
Additional Information	Gasification, sulfur removal, and tar reforming will be conducted at 1000 kg/h. The WGS, compression, CO2 removal, and heat exchange will be conducted at about 1400 scd/h (1/50th of the gasifier stream). The FT reactor will produce about 25 gal/d.
Contact	GTI gasifier Des Plaines P. Vann Bush

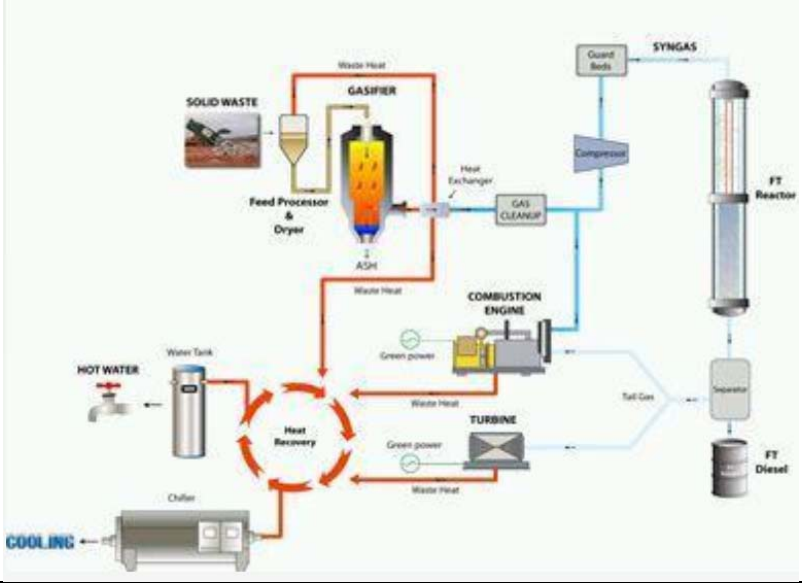
Project name	Synthesis bioliq - process Karlsruhe
Project owner	Karlsruhe Institute of Technology (KIT)
Status	operational
Start up	2012
Country	Germany
City	Karlsruhe
Type	TRL 4-5 Pilot
Technology	Fuel synthesis
Raw Material	Lignocellulosic crops
Input 1 Name	Straw
Input 1 Capacity	1
Input 1Unit	t/h
Output 1 Name	Gasoline type fuels
Output 1 Capacity	608
Output 1Unit	t/y
Partners	KIT, Lurgi, MUT, MLR
Total Investment	64 mio.
Total Investment Currency	Euro
Technology Brief	The bioliq process, developed at the Karlsruhe Institut für Technologie (KIT) aims at the production of synthetic fuels and chemicals from biomass. The bioliq technology is based on a two step process with decentral pyrolysis for the production of transportable slurry from biomass (e.g. straw) and central slurry gasification and BtL production. At KIT Karlsruhe a pilot plant with 2 MW fast pyrolysis and biosyn-crude production and 5 MWth high pressure entrained flow gasifier operated up to 8 MPa (both in cooperation with Lurgi GmbH, Frankfurt), as well as the hot gas clean-ing (MUT Advanced Heating GmbH, Jena), dimethylether and final gasoline synthesis (Chemieanlagenbau Chemnitz GmbH) are in operation.
Additional Information	
Contact	Mark Eberhard mark.eberhard@kit.edu

Project name	Thermochemical Users Facility (TCUF)
Project owner	NREL
Status	operational
Start up	1985
Country	USA
City	Golden
Type	TRL 4-5 Pilot
Technology	Fuel Synthesis
Technology additional information	Different Technologies, Gasification, Fast Pyrolysis,...
Raw Material	lignocellulosics
Output 1	various chemicals (50 t/y)
Total Investment	USD 30,000,000
Funding Explanation	government and industry
Additional Information	expansion in progress
Contact	Robert Baldwin Robert.Baldwin@nrel.gov

Project name	Commercial plant
Project owner	Red Rock Biofuels
Status	Under construction
Start up	2022
Country	USA
City	Lakeview, Oregon
Type	TRL 8 First-of-a-kind commercial
Technology	Fuel Synthesis
Technology additional information	FT-route
Raw Material	forest residues
Input 1	dry wood (127,000 t/y)
Output 1	FT liquids (44,000 t/y)
Output 2	jet fuel component
Output additional information	FT liquids include 40% diesel, 40% kerosene, 20% naphta
Funding	USD 70,000,000
Technology Brief	Red Rock has partnered with TCG Global on the gasification process. The FT technology selected comes from Velocys based on its Fischer Tropsch microchannel reactor technology for small-scale distributed production of biofuels, and this will be one of the first full-scale versions of this technology. The TCG Global gasification technology has been tested by others in a plant that was constructed in Denver, Colorado for Red Lion Bio-Energy in 2004 at a scale of 9-25 dry tonnes/day. The gasification plant was in 2008 moved to Toledo, OH, USA, for the purpose of a DOE Integrated Biorefinery (IBR) project started in 2010 the primary objective was to upgrade the 23 tonnes/day Red Lion thermochemical conversion (TCC) system and build a new liquid fuel production (LFP) system supplied by Greyrock Energy that directly converts biomass into diesel fuel. Construction of the plant in Toledo, started in April 2012. Plant performance and validation tests were initiated in Q2 2012 and seventeen test campaigns were carried out until Q3 2013. The integrated IBR plant was operated on wood, rice hull and other materials for a total of 992 hours and the gasifier for some 200 hours in addition, excluding start-up and shut-down periods.
Additional Information	FedEx and Southwest Airlines have off-take agreements for the total available volume of jet fuel from the Red Rock plant.
Contact	Terry Kulesa
	

Project name	Synthesis Tembec Chemical Quebec
Project owner	Tembec Chemical Group
Status	Operational
Country	Canada, Quebec
City	Temiscaming
Type	TRL 6-7 Pilot
Technology	Fuel synthesis
Raw Material	Lignocellulosic crops
Input 1 Name	spent sulphite liquor feedstock
Output 1 Name	Cellulosic ethanol
Output 1 Capacity	13 000
Output 1Unit	t/y
Contact	Lyle Biglow lyle.biglow@tembec.com

Project name	Technology development laboratory and pilot plant - thermochemical
Project owner	Thermochem Recovery International
Status	Operational
Start up	2007
Country	USA
City	Durham
Type	TRL 4-5 Pilot
Technology	Fuel Synthesis
Raw Material	lignocellulosics
Input 1	Cellullulosics, Municipal wastes, syngas (4 t/d)
Output 1	FT liquids (0.002 t/y)
Output 2	mixed alcohols
Output 3	power (electricity)
Total Investment	USD 30,000,000
Funding	USD 20,000,000
Partners	Commercial and US government clients
Technology Brief	thermochemical conversion, catalytic liquids synthesis, hot and cold syngas cleaning
Contact	Tim Hansen hansen@southernresearch.org



Project name	Ambigo
Project owner	TNO
Status	Planned
Country	NL
City	Alkmaar
Type	TRL 6-7 Demonstration
Technology	Fuel Synthesis
Technology additional information	Synova power technology
Raw Material	lignocellulosics
Input 1	biomass (1 t/h)
Output 1	SNG (2.8 MW)
Output 2	heat (4 MWth)
Partners	Gasunie, Royal Dahlman
Contact	Mark Overwijk Overwijk@ecn.nl

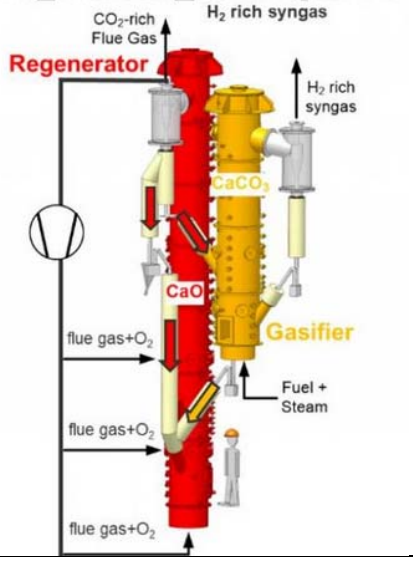
Project name	Booster
Project owner	TU Munich
Status	Operational
Country	Germany
City	Munich
Type	TRL 4-5 Pilot
Technology	Fuel Synthesis
Technology additional information	Entrained flow gasifier, Refractory lining; full water quench for gas cooling; oxygen and ai ras gasifying agents – additionally steam and carbon dioxide
Raw Material	other
Input 1	pre-treated (torrefaction and hydrothermal carbonization) and raw biomass and organic residues
Output 1	SNG (0.15 MW)
Contact	philipp.johne@tum.de

Project name	Magnus
Project owner	Uni Stuttgart
Status	Operational
Country	Germany
Type	TRL 4-5 Pilot
Technology	Fuel Synthesis
Raw Material	other
Input 1	solid fuels (e.g. wood, coal) Auxiliary materials (e.g. lime, sand)
Input 2	waste
Output 1	clean syngas (0.33 MWth)
Technology Brief	Gasifier – Bubbling bed reactor Regenerator – Circulating fluidized bed combustion, gasification, solid looping processes and other high temperature fluid bed process Three coupled fluidized bed reactors; refractory concrete; bayonet coole / bed cooler
Contact	max.schmid@ifk.uni-stuttgart.de

MAGNUS – 200 kW pilot plant for Sorption Enhanced Reforming at IFK

- Gasifier
  - bubbling bed reactor
  - diameter: 330 mm
  - height: 6 m
- Regenerator
  - circulating fluidized bed
  - diameter: 210 mm
  - height: 10 m
- Gas analyses
  - Gasifier
  - H_2, O_2, CO, CO_2, CH_4, C2-C4, tar
  - Regenerator
  - CO, O_2, CO_2, SO_2, NO_x
- no electrical heating
- gravimetric fuel dosing
- fuels: wood pellets, waste, residues

→ **TRL 6 SEG pilot plant**



Project name	LLC Thermal Reformer Synthesis West BiofuelsWoodland , CA
Project owner	West Biofuels
Status	Operational
Start up	2007
Country	USA, CA
City	Woodland
Type	TRL 6-7 demo
Technology	Fuel synthesis
Raw Material	Forest residues
Input 1 Name	clean wood, waste wood
Input 1 Capacity	5
Input 1Unit	t/d
Output 1 Name	FT liquids
Output 1 Capacity	-
Output 1Unit	t/y
Partners	University of California
Technology Brief	West Biofuels uses dual fluidized bed thermal reforming system that breaks down biomass into its molecular components through chemical reactions brought on by high heat, oxygen and steam at low pressure.
Additional Information	Woodland Biomass Research Center, Woodland, CA, USA: The Woodland Research Center is located approximately 20 miles northwest of Sacramento in Woodland, California. The facility was built in cooperation with the University of California
Contact	Matt Summers matt.summers@westbiofuels.com