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Environment – Waste to Diesel

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Turning Unwanted Weed Grass / Waste into Power by Ultra Clean Gasification Process (UCGP)

7 July 2022

For more information refer to GSCE website to get the latest updates
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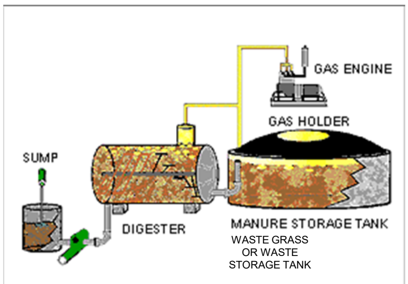
Process Overview of UCGP a small Scale for Waste Grass Processing



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Waste Grass Processing

Dewater

- Originally sewage is – 80% water
  Dewater to 40%

Gasify & clean

- Scrub away Sulphur (H_2S), Nitrogen (N_2) & Oxygen (O_2)
- Produce clean Synthesis gas (Syngas) with CO & H_2

Burn to generate electricity or condense into dies

- Generates – 1.2MWhr/Ton of dewatered sludge or
- Produces – 230L /Ton of dewatered sludge

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- The partner Companies has installed over 1000 low NOx burners
  - It has set the emissions standards 4 times lower, currently < 9ppm NOx, < 50ppm CO
- First experience in gasification in Daoling, China in 1993
  - Makes 24,000 gals/day of fuel from tyre
  - Pyrolize tyers at 400-450°C to make black oil suitable as coal substitute for power production, but not good for autos, more like light bunker fuel with ~0.4% sulfur
- Built a similar 12,000 g/d tyre plan in Nankang, Taiwan in 2000
  - Produces a cleaner fuel
- Italy glass recycling plant
  - Since 4yrs, 100 kg/hr, remove plastic & metals from auto glass
  - Heat used for power generation to run the plant, though still in pilot
  - Larger plant being designed at 500 kg/hr
- 220 kg/hr plant in Oregon generates 265 kW net Power
- Human sludge plant in Los Angeles (Carson), demo plant @ 50 kg/hr
  - Has led to orders for 4 plants at 1-10 ton/hour for Brazil, China, Malaysia, India

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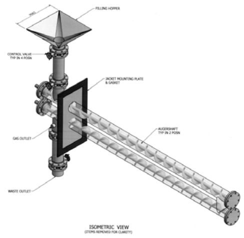
- Processes carbonaceous material, such as coal, wood chips or sewage sludge into carbon monoxide and hydrogen ($CO + H_2$)
  - Partial vacuum – reduces oxygen content in the chamber
    - Reducing oxygen content reduces $CO_2 + SO_X$ formation
  - Patented burner system leads to lowest NO_X emissions in the world

$$C + H_2O \rightarrow H_2 + CO$$

- Rotating feed column circulates coal in reactor over a period of time (30mins -55mins)
- Inert ash is collected at the base of the reactor
- Ideal feedstock
  - Water content ~25%
    - Increases hydrogen production
  - Low ash / high calorific condition
  - Low Sulphur
    - Reduce cost of clean up stage



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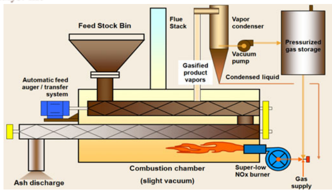
- Technology
  - Gasifies organic matter, coal or pet-coke at 750-1000 F to produce syngas (H2, CO and CO2)
  - Syngas used to create synthetic diesel and other petroleum products
  - Remainder used to generate electricity for plant
- Operates too cool to for CO or NOx
  - 400-650°C (750-1200°F) vs 980-1650°C (1800-3000°F)
- 12 proven units in the field operating various feedstock
  - Coal, pet-coke, municipal solid waste (MSW), tires, plastics
- Automatic augur system removes slag
  - Less maintenance, longer catalyst life



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- The process requires a ~2:1 hydrogen to carbon monoxide ratio
- Most coal types do not produce enough hydrogen
  - Additional hydrogen is created in the reforming step
- Pyrolysis step also produces a large amount of methane, perfect for reforming with steam
  - $CH_4 + H_2O \rightarrow 3H_2 + CO$
  - $CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$
- Depending on operating conditions either reaction 1 or 2 will be favoured. Reaction 2 generates more hydrogen but as a consequence generates more CO2

% gas composition after pyrolysis

Hydrogen	**23.4112**
CO	**16.7571**
Methane	31.7013
Ethane	**0**
Propane	**1.7765**
i-Butane	0.9432
n-Butane	0.2282
i-Pentane	1.3242
n-Pentane	1.0329
C6+	1.7787
Oxygen	1.0731
Nitrogen	9.0869
CO2	6.2899
Ethylene	4.5968
Total	**100**

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- As previously stated the and H_2 CO must be fed into the reactor as 2:1 ratio to maximise conversion efficiency
- All Sulphur and other contaminants must be removed to prevent poisoning the catalyst
- The process uses a floating bed reactor with a high B.P fluid to transport the catalyst
  - Encourages mixing and reduce chance of carbon deposits on catalyst
- There are 2 types of catalyst WET – EIG asia provides
  - Iron Oxide

    Cheaper but more susceptible to pressure changes. Produces lighter hydrocarbon chains
  - Cobalt

    Produces a constant stream of product not depending on pressure. Also catalyst tends to produce heavier compounds, ideal for refinery specification
- Reaction formula:

$$(2n+1)\ H_2 + nCO \rightarrow CnH_{2n+2} + nH_2O$$

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In addition to grass, the research has gassified over 75 types of coal, a dozen different plastics, rubber, rail road ties, municipal solid waste, medical waste and biomass (rice straw, grass, wood chips, soy bean shells, switch grass etc.)

Separation Unit

Test burn of synthesis gas

Burner / Gasifier

Synthetic Diesel

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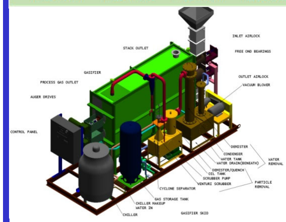

Waste plant in Los Angeles (Carson), demo plant @ 100Kg/hr has run 24 hr /day almost continuously since Jan 2009. Avoids $70/Ton transport charge to San Diego. Reduces volume by 92%, lose 1.8% remaining residue (carbon / Phosphorous) makes good fertilizer Give back surplus water. Currently planning for 60 Ton/hr plant for 3.5 M people of long beach and surrounding area.

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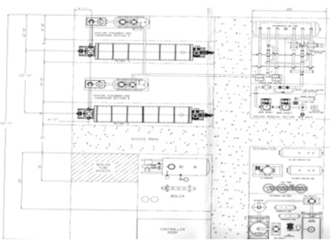
- 2 pyrolysis units @ ½ ton/ hr capacity
- 2 venturi scrubbers
  - Remove particulates
  - Cool syngas
- 1 gas compression unit
- 1 desulphurization unit
  - 3 towers if sulphur content is over 1%
- 1 reforming step - hydrogen production
  - Steam injection
- 2 PSA (Pressure swing adsorption) units
  - Captures and separates H2 and CO
  - Enables plant operator to control gas ratio in F-T process
- 1 F-T reactor for liquid fuel production
  - Final liquid upgrade and distillation



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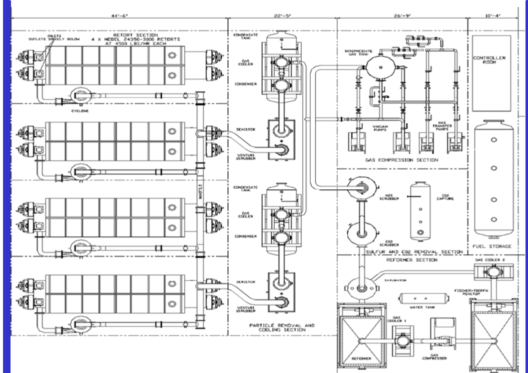
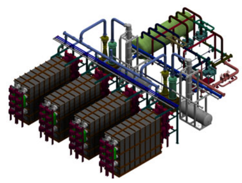


Once started the plant is Auto-Reforming.
Output depends upon feedstock.
For 150,000 L/day:
- 370 tons of Plastic
- 540 tons of Coal (8,000 btu/lb Lignite)
- 700 tons of human sludge (@ 40% water)
- 750 tons of Biomass

Note: plant can be configured for 75,000 L/day or 35,000 L/day



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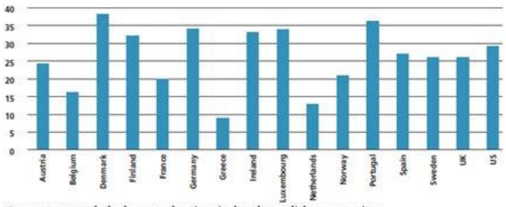
- Plant size depends upon size of legacy deposit and on-going population needs



Current annual sludge production in kg dry solids per capita

Note: on a wet basis the figures above will be 5x larger

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- No water for sewage sludge
  - Other feed stocks require little water (1.5 L water / L diesel)
    - Competing systems use up to 24 L water / L diesel
- High yield (~65% efficiency, best in class)
  - Actual conversion depends energy content of the feedstock
  - Testing with many dozen types of coal, waste, biomass and sewage sludge
  - Sulphur content easily removed
    - Coal illustrates that yield depends upon heat value of feedstock
      - Sewage sludge varies by diet, but is roughly 10,000 BTU/lb or 5,600 kcal/kg

Coal/Day, Short & Metric Tons	6,000	5,500	5,000	4,500	4,000	3,600
Coal/Yr, Mln Short & Metric Tons	2.1	1.9	1.8	1.6	1.4	1.3
Heat Content, BTU/Lb & Kcal/Kg	8,000	4,400	10,000	5,600	12,000	6,700
Yield, Gallons/Ton & Litres/Tonne	67	280	86	360	103	430
Diesel/Year, million gallons & litres	140.7	532.5	150.5	569.6	144.2	545.8

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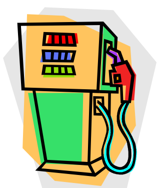
- Plant can be configured to produce only electricity, or just fuel or a combination

- Factors to consider
  - Generating electricity is less expensive, but power is very difficult to store
    - Better overall conversion efficiency, though it also depends upon turbine efficiency
  - A range of fuels can be produced
    - In addition to diesel, the plant can produce gasoline, jet fuel and, if there is demand for it, then certain waxes

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Wet Sludge (% moisture)	80%	375	750	1,125	1,500	1,875	2,250
Dewatered metric tons / day	**25%**	**100**	**200**	**300**	**400**	**500**	**600**
Capex							
Dewatering		$0.3m	$0.5m	$0.8m	$1.0m	$1.3m	$1.5m
Gassification		$6.0m	$10.0m	$14.0m	$16.8m	$20.5m	$24.2m
Power Generator	$1.0m	$6.0m	$9.9m	$14.9m	$17.9m	$21.8m	$25.7m
Start-up & Training		$0.1m	$0.1m	$0.1m	$0.2m	$0.2m	$0.2m
Contingency	10%	$1.2m	$2.1m	$3.0m	$3.6m	$4.4m	$5.2m
Total Power Capex		**$13.5m**	**$22.6m**	**$32.8m**	**$39.4m**	**$48.1m**	**$56.8m**
$/capacity ton		$135,000	$113,000	$109,000	$99,000	$96,000	$95,000
Operating Data							
Output kWhr/d		119,000	238,100	357,400	476,400	595,400	714,500
Sales $/day @ $/kWhr	$0.07	$8,300	$16,700	$25,000	$33,300	$41,700	$50,000
Operating costs/day		-$1,900	-$3,700	-$5,600	-$7,400	-$9,300	-$11,100
Operating income/day		$6,400	$13,000	$19,400	$25,900	$32,400	$38,900
Annual pre-tax income (350 days)		**$2.2m**	**$4.6m**	**$6.8m**	**$9.1m**	**$11.3m**	**$13.6m**
Returns							
Payback Yrs		6.0	5.0	4.8	4.3	4.2	4.2
IRR		16%	20%	20.2%	22.6%	23.2%	23.6%
NPV 10%		$6m	$16m	$25m	$38m	$48m	$59m