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Application of Biogas in Chemical Energy and Liquid Fuel Production

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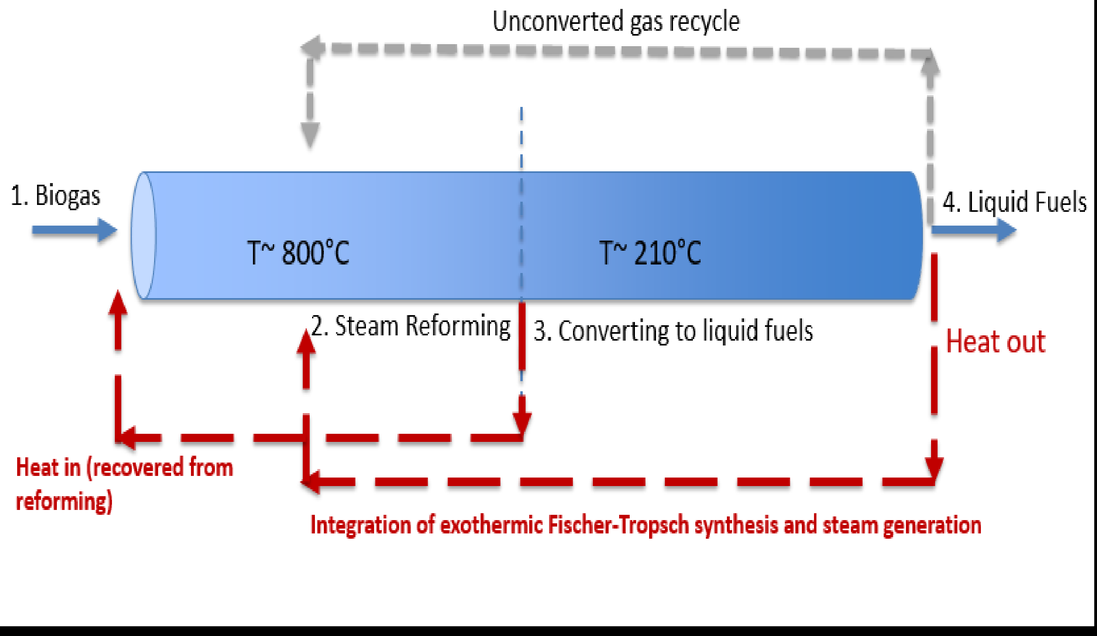


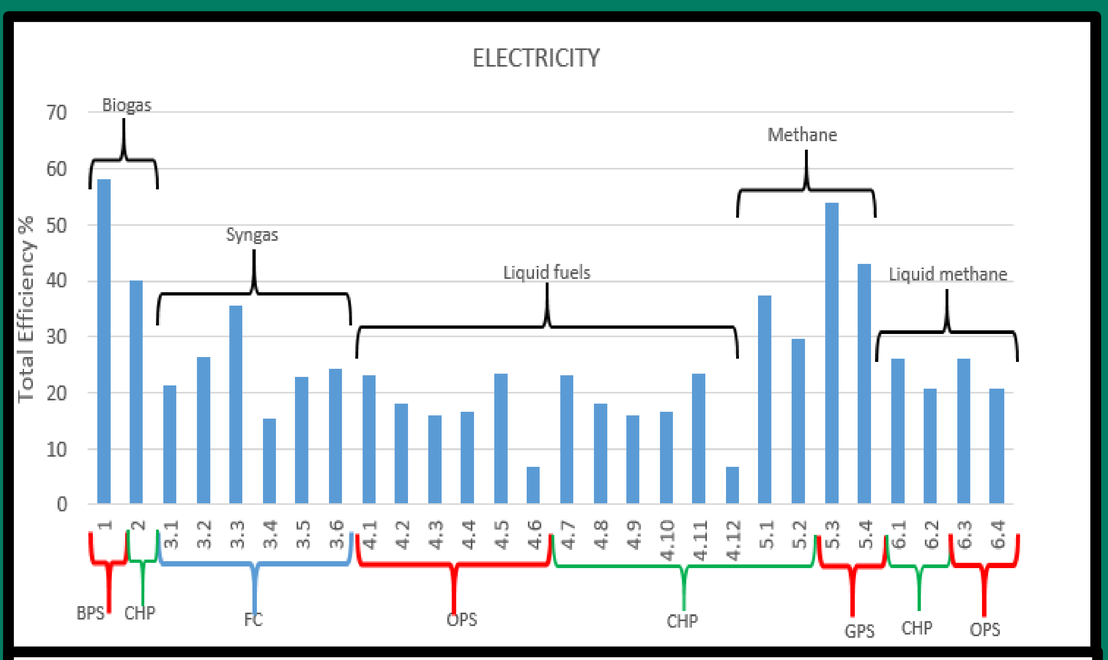
Figure 1: Schematic for a coupled system producing liquid fuels from biogas at 1 bar

I. Aim

Study the feasibility of the applicability of Fischer Tropsch (FT) in a coupled system at 1 bar for generation of liquid fuels from biogas. Following experimental analysis, an economic and energy efficiency investigation various exploitation options (e.g. CHP, upgrading, ICE, injection into gas grid) for electrical generation was conducted. The economic investigations were based on current technologies and associated costs based on a 250kWe plant size.

Table 1: Economic analysis result summary

Scenario	Details	Capital Annual expenditure (£/yr)	Total Capital Expenditure (£)	Profit (£/yr)	Profit(with Tariff) (£/yr)	Profit per m3 of Biogas (£/m³)	Profit per m3 of Biogas (with tariff) (£/m³)	Profit per kWhe Equivalent (£/kWhe)	Profit per kWhe Equivalent (with Tariff) (£/kWhe)	Return On Capital employed (%)	Return On Capital employed with tariff (%)
1	AD → (Biogas) Powerstation	458,405	468,750	-362,812	5,542	-0.37	0.01	-0.18	0.00	-79.15	1.21
2	AD → (Biogas) CHP	458,405	468,750	-268,945	99,409	-0.27	0.10	-0.14	0.05	-58.67	21.69
3	AD → Upgrading (Biomethane)→ Grid Injection (Fuel Sold) → Powerstation/CHP	508,811	571,550	-455,577	-39,689	-0.46	-0.04	-0.23	-0.02	-89.54	-7.80
4	AD → Upgrading (Biomethane)→Liquefaction (LNG) → (Fuel Sold) Powerstation/CHP	600,668	558,550	-547,434	-131,545	-0.56	-0.13	-0.28	-0.07	-91.14	-21.90
5	AD → Sabatier (Biomethane)→ Powerstation	987,473	2,894,637	-803,862	-189,048	-0.82	-0.19	-0.41	-0.10	-81.41	-19.14
6	AD → Sabatier (Biomethane)→ CHP	987,473	2,894,637	-623,568	-8,754	-0.64	-0.01	-0.32	0.00	-63.15	-0.89
7	AD →Sabatier (Biomethane)→ Grid Injection (Fuel Sold) → Powerstation/CHP	825,157	2,170,137	-721,351	89,633	-0.74	0.09	-0.37	0.05	-87.42	10.86
8	AD → Sabatier (Biomethane)→Liquefaction (LNG) → (Fuel Sold) Powerstation/CHP	916,877	2,357,137	-813,071	-2,088	-0.83	0.00	-0.41	0.00	-88.68	-0.23
9	AD →Reforming → Fuel cell (Powerstation)	812,388	1,818,520	-693,572	-295,723	-0.71	-0.30	-0.35	-0.15	-85.37	-36.40
10	AD →Reforming → Fuel cell (CHP)	812,388	1,818,520	-623,770	-225,920	-0.64	-0.23	-0.32	-0.11	-76.78	-27.81
11	AD →Reforming → Fischer Tropsch →Transportation → (Fuel Sold) Powerstation/CHP	773,202	1,488,945	-644,385	n/a	-0.66	n/a	-0.33	n/a	-83.34	n/a



1.	AD → Power station (PS)
2.	AD → CHP
3.1-3.6	AD → Reforming technologies to syngas → Fuel Cell (FC)
4.1-4.6	AD → Reforming technologies to syngas → Fischer Tropsch to liquid fuel → PS
4.7-4.12	AD → Reforming technologies to syngas → Fischer Tropsch to liquid fuel → CHP
5.1	AD → Biogas upgrading to bio-methane → CHP
5.2	AD → Sabatier + electrolysis to methane→ CHP
5.3	AD → Biogas upgrading to bio-methane → PS
5.4	AD → Sabatier + electrolysis to methane→ PS
6.1	AD → Biogas upgrading to bio-methane → Liquefaction → CHP
6.2	AD → Sabatier + electrolysis to methane→ Liquefaction → CHP
6.3	AD → Biogas upgrading to bio-methane → Liquefaction → PS
6.4	AD → Sabatier + electrolysis to methane→ Liquefaction → PS

Figure 2: Routes' overall energy efficiency for electricity generation BPS: Biogas power station, OPS: Oil power station, GPS: Gas power station

II. Results

- Electricity generation routes are significantly unprofitable without tariff support. The return on capital employed (ROCE) with no tariff support ranges from -58.7% to -91.14%.
- With the current Northern Ireland tariff system, only options 1, 2 and 7 are profitable. CHP plants can only achieve a maximum return if all of the process-generated heat energy created is used to offset production costs.
- Overall efficiencies showed the lowest values for liquid fuels via FT (~11%). However, in Northern Ireland there is a high demand on liquid fuel as most households do not rely on gas grids and use oil as their main heating fuel.
- Experimental results showed liquid fuel production at P=1 bar and T=210° C with considerable selectivity to liquid fuels within 1 week, proving potential small scale applicability.