Modelling of Synthetic Natural Gas Production via Biomass Gasification for Renewable Gas Grid Injection

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Introduction
Ireland relies heavily on imported natural gas, which is used for electricity generation, heating and cooking. Therefore, grid injection of renewable gas is very attractive. Replacing heat from fossil fuels with heat from renewable sources is a significant challenge. Due to Ireland’s favourable growth climate, bioenergy is expected to play a major role in supplying renewable heat (and transport) targets; however, to date its uptake has been very low. Barriers include: low efficiency of conversion technologies; high capital and biomass fuel costs; absence of large heat loads (no district heating networks and very little heavy industry). Synthetic natural gas production via biomass gasification (BiSGNG) with subsequent grid injection can overcome these barriers. With reference to Fig. 1, a BiSG-SNG plant comprises a gasifier followed by gas cleaning (removal/conversion of impurities) and upgrading (methanation and inert gas removal) steps.

Gasification
Gasification is a process in which a carbonaceous fuel is converted to a combustible gas. It occurs when a controlled amount of oxygen is reacted at high temperatures with available carbon in a fuel within a gasifier. It offers the possibility of conversion to heat and power (CHP), liquid fuels, chemicals or SNG. Thus, it enables biomasses to contribute to all three types of renewable energy targets, i.e. heat, electricity and transport. The main chemical reactions that occur during the process are listed in Table 1.

Table 1 Main gasification reactions [5, 6]

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Equation</th>
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<tbody>
<tr>
<td>Formation of CO and H2</td>
<td>CO + H2O → CO2 + H2</td>
</tr>
<tr>
<td>Methanation</td>
<td>CH4 + H2O ⇌ CO + 3H2</td>
</tr>
<tr>
<td>Methanation of CO</td>
<td>CO + 3H2 ⇌ CH4 + H2</td>
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A major disadvantage of the O2 blown BiSGNG technology is that O2 production is expensive (cryogenic air separation) and therefore large scale plants are required typically a few hundred MW). The sustainability of such large scale bioenergy plants is questionable.

The main suppliers for the steam blown technology include: Repetec/TU Wien FICFB technology (fast internally circulating fluidised bed implemented at GoBiGas plant), Silvagas technology, ECN MILENA technology (4 MW BiSG-SNG demonstration plant in planning [8], Agnion Heatpipe Reforming technology.

The main suppliers for the O2 blown technology include: Foster Wheeler pressurised CFB (circulating fluidised bed) [9] and Carbona/GTI pressurised BFB (bubbling fluidised bed).

Methanation
The main chemical reaction is the reverse of Eq. 3.10 in Table 1 (CO + H2O → CO2 + H2O). A catalyst is required, typically nickel based, at the reactor conditions. The two main reactor types are: a series (typically 2-3) of adiabatic fixed beds and the isothermal FB reactor. The Paul Scherrer Institute supplies the FB technology. Different variations of the fixed bed technology are available from Lurgi, Haldor Topsoe (TREMP) and Foster Wheeler (VESTA).

Research in Ireland to date
To date, research in Ireland has focussed on anaerobic digestion (AD) systems for biogas production, upgrading and grid injection. Numerous articles have been published by a research group at UCC. In 2010, a Bord Gáis report titled “The Future of Renewable Gas in Ireland” based on the results of research carried out at UCC was published [10]. It highlighted the potential production of renewable gas from grass and waste via anaerobic digestion in Ireland. Under the baseline scenario (i.e. realistic potential), there is the potential to meet 7.5% of Ireland’s natural gas demand with renewable gas by 2020 (shown in Fig. 4).

Biomass gasification has many advantages over anaerobic digestion with respect to renewable gas production:

- BG is a more efficient process (70-80% versus 20-40%) AD is limited by seasonal and spatial availability of (economics of collection and transportation of wet biomass)
- BG exhibits greater potential for improvement in biomass to SNG performance (e.g. pressurised steam blown BG would enhance methanation process efficiency)
- BG is a much faster process and allows greater control over process operation

Considering gas injection quantities (in Ireland), it will be necessary to connect BG-SNG plants to the high pressure transmission natural gas grid; whereas, small scale AD plants would be connected to the low pressure distribution grid. It would not be financially viable to connect small scale AD plants to the transmission grid (gas compression costs). As a result, AD plants will be limited by residential/commercial hot demand meaning they would have to shutdown during summer. BG-SNG plants connected to the transmission grid would not be affected by this drop in demand because natural gas power plants operate year round. A combined effort of anaerobic digestion and gasification will be required to deliver sufficient renewable gas to replace a significant level of fossil natural gas.

References
[7] Rauch et al., Biomass gasification for synthesis gas production and applications of the syngas, WIREs Energy
[13] Not available for synthesis gas production and applications of the syngas, WIREs Energy

Fig. 1 BG-SNG plant and applications block diagram

Development of these plants is at an early stage; 1 MW_SNG (SNG output) pilot plant tested in Austria and 20 20 MW_SNG demonstration plant operating in Sweden (refer to Fig. 2 and Fig. 3).

Fig. 2 Simplified schematic of GoBiGas 20 MW_SNG demo plant Gothenburg Sweden [1]


Fig. 3 Photo of GoBiGas demo plant [2]

Fig. 4 Fossil fuel based natural gas displacement by biogas in Ireland [10]

Fig. 5 FICFB gasifier model Aspen Plus Flowsheet

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