



Gasification of Biomass, Gas Cleaning and Purification, and Production of a Second Generation Bio-Liquid



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1. Executive Summary

Biomass has a critical role in meeting the UK's renewable energy targets and can be used to provide power, heat, gas, bioliquids and biofuels. The UK's need for biofuels, in particular, is currently being met using 'first generation' ethanol and biodiesel. Whilst these go a long way to meeting the UK's objectives there are benefits in producing biofuels from a wider feedstock base including ligno-cellulosic and waste-derived biomass via thermochemical processes (gasification + synthesis). These are perceived to deliver greater GHG reductions and to have lower sustainability concerns. Among a number of potential candidates in the second generation sector (Fischer Tropsch BTL, bio-methanol and/or DME synthesis) bio-methanol seems to be the simplest bioliquid to produce and can be used for transportation.

The focus of this study was to determine an overall technical approach for the production of a second generation bio-methanol liquid based on existing, but redundant, process assets and using CHOREN's existing Carbo-V[®]-biomass gasification technology. In order to provide a realistic reference point, the assumption made was that the gasification stage would feed an existing Methanol facility at Billingham in the Tees Valley, Teesside, UK. The Billingham methanol plant was in operation for nearly 30 years up until 2001, and producing up to 1500 t/d of methanol using natural gas and CO₂ feedstocks. The plant appears to be in sufficiently good condition to require only limited refurbishment.

It has been determined that up to three 160 MW CHOREN gasifiers would be sufficient to fully operate the existing methanol synthesis process, whilst one gasifier is sufficient to operate the existing facility. The existing methanol synthesis unit, distillation and storage, gas system and a number of utilities from the existing plant could be used. One gasifier would result in a viable technical solution with the lowest overall investment cost and producing 400 tonnes per day, or 120 -130 K tonnes per year, of bio-methanol. Besides the gasifier, gas cleaning and conditioning process stages would be required comprising gas scrubbers, a compressor, a CO-shift, a CO₂-separation unit and an ultra purification. The overall CAPEX for these elements (based on one gasifier) has been estimated to be of the order of £100-150M. The total CAPEX including biomass pretreatment, storage facilities, utilities interconnection to the existing plant, and site refurbishment would take CAPEX to approximately £150-250M. This results in a specific investment of approximately £350-600k for every tonne/day capacity of bio-methanol at worst comparable with equivalent biomass-to-biomethanol plants currently being planned in the EU.

Beside a biomass consumption of 40.3 t of waste wood (20% water) per hour (250 odt/a), oxygen would be the major consumable. The steam demand, and a significant amount of the power demand, could be satisfied internally.

Increasing production of bio-methanol to plant capacity (three biomass gasifiers) and using a larger gas cleaning/gas conditioning train would lower the specific investment to around 70%, leading to a higher project internal rate of return (IRR) while increasing the overall investment to around £300-500M. Any potential initial development based on one 160 MW



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gasifier should consider the benefit of larger scale operation when determining site layout and scaling the gas cleaning train and the steam boiler.

Assuming a project preparation phase including Front-End-Engineering Design (FEED) of 30 months, were such a project to commence in 2011, commissioning of such a plant could start in 2015.

Based on this assessment it can be concluded that the transformation of the existing Billingham Methanol facility to bio-methanol production appears technically feasible at both small and larger scale and at acceptable specific investment, and is worth further evaluation.



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2. Introduction

The key considerations for all biofuel products are the availability of feedstock, the cost of conversion and the market price for the resulting product. The feasibility of an implementation is dependent on securing sufficient feedstock to achieve economies of scale and on the capital cost of the conversion process.

The focus of this study was to define an overall technical solution for the simplest liquid synthetic biofuel that can be produced, namely bio-methanol; and to establish an indicative CAPEX. The study assumed:

- (i) an implementation on Teesside using advanced thermochemical conversion and
- (ii) scales compatible with specific numbers of gasifiers corresponding to 250K to 750K tonnes oven dry tones (ODT) biomass per annum.

There are merits in determining the smallest technically viable implementation as this minimizes investment, feedstock sourcing and logistics, and securing bio-methanol offtakes in a nascent market. A specific objective was therefore to identify the smallest technically viable technical solution.

This study provides an assessment of the technical requirements and approximate capital cost for gasification into an advanced bio-fuels process.



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3. The Billingham Methanol facility (history and state of the art)

The Methanol 2 plant at Billingham was built in 1972 with a design capacity of 1150 MTPD. The plant used natural gas as feedstock via two Foster Wheeler reformers and an ICI low pressure methanol synthesis loop. The plant's capacity was increased by the addition of carbon dioxide (CO₂) from an adjacent ammonia plant to the synthesis loop.

The plant was linked to the Billingham Site Hydrogen System, importing hydrogen for desulphurisation and plant start-up, and exporting excess gases from the synthesis loop for hydrogen recovery (the gas after removal of hydrogen was returned for use as fuel in the reformers). The plant was used in two distinct modes: to maximising methanol production or hydrogen production.

The last major overhaul was carried out in 1996, during which the methanol synthesis converter was changed to the more effective Methanol Casale ARC type internals.

Since 2001 work has been undertaken on the plant to both maintain and refurbish key components (e.g. pumps and valves) with a view to a plant restart.

4. Review of the Existing Plant

In order to develop an overall picture of how the existing plant could be used in association with a biomass gasifier the following overall assessment was undertaken. This assessment was based on existing plant documentation. The task:

- identified the process units of the existing plant that are relevant for use in a Bio-methanol facility
- determined the minimal operating conditions and
- derived the requirements for additional process units to complete a bio-methanol plant.

The review was based on a set of flowsheets representing the current technical status of the plant provided by the project owners.

4.1. Existing process units

The Billingham methanol plant consists of the following process units (see **Appendix 1**)

1. Natural gas preheating in the preheating oven and desulphurization (two-stage)
2. Steam methane reforming in the reformer (SMR)
3. Compression of the synthesis gas by steam turbines
4. Methanol synthesis in the AR-reactor type with raw methanol storage
5. Two-stage raw methanol distillation with pure methanol storage
6. Separate steam generator (70 barÜ)
7. Steam range system (64 bar, 28 bar and 3.5 bar)
8. Complex gas system with
 - offgas use
 - flash gas use
9. Complex, integrated steam generating and overheating system with steam user, affecting plant units 1 to 8 and 10



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10. Several auxiliary equipment such as:

- boiler feed water treatment,
- flare

and external supply and disposal facilities including:

- instrument air,
- inert gas (N₂),
- electricity supply,
- natural gas supply
- process water disposal
- oxygen supply
- compressed air

4.2. Applicable plant systems

The following plant units could be employed where the existing syngas production unit (SMR) is replaced by a Carbo-V[®]-gasification unit:

- The methanol synthesis system including the raw methanol storage
- Two-stage raw methanol distillation with raw methanol storage
- Steam network (64 bar, 28 bar and 3.5 bar) without the steam generating and superheating system integrated in the reformer
- The compressor and necessary pumping system powered by steam (to be confirmed)
- Boiler feed water treatment with feed water degassing and conditioning system
- Flare

Furthermore existing supplies would be required:

- natural gas (capacity needs to be identified),
- demineralized water for the boiler feed water
- instrument air/air
- electricity
- nitrogen

As well as the disposal of:

- process waste water and
- disposal/application of fusel oils

4.3. Additional process units

The following systems would need to be installed to support the production of syngas from biomass:

- complete Carbo-V[®]-gasification system with
 - biomass feeding and storage system
 - biomass preconditioning system, if necessary



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- oxygen supply
- gas cleaning system (dedusting and detoxing)
- gas compression to > 19 bar
- CO-converting with CO₂-scrubbing (to adjust to the necessary H₂/CO-relation)
- ultra-purification

Furthermore the following plant units would be needed:

- separate steam generator for about 70 bar, fired with natural gas (for commissioning and securing) and offgas and flashgas during normal operation to feed the existing steam range system and using the higher alcohols (>C1) for the steam generation or in the gasification. To improve the GHG footprint, biomass as feedstock for this boiler could be considered depending on real operating conditions (load change requirements, operating hours).
- disposal of the inorganic process waste water or alternatively a treatment to re-use most of the water and dispose highly concentrated inorganically polluted waste water.

The boiler feed water pumps are also steam driven. If the existing pumps were to be used the respective steam pipes would need to be integrated with the new steam boiler

4.4. Tie in point of the syngas

The most appropriate tie in point for syngas from the Carbo-V[®]-gasification system to the existing plant would be in front of the air cooler. The existing CO₂-integration points into the syngas would be disconnected as the biogenic syngas is inherently CO₂ rich and additional CO₂ is not required to enhance methanol synthesis.

4.5. Process Unit Overview

Table 1 gives a summary of the process units:

No.	Description	Existing			New
		Could be used as is	Needs modification	Not required	
1	Natural gas preheating in the preheating oven and desulphurization (two-stage)			x	
2	Steam methane reforming in the reformer (SMR)			x	
3	Compression of the synthesis gas by steam turbines	x			
4	Methanol synthesis in the AR-reactor type with raw methanol storage	x			
5	Two-stage raw methanol distillation with pure methanol storage	x			
6	Separate steam generator (70 bar)				x
7	Steam range system (64 bar, 28 bar and 3.5 bar)	x			
8	Complex gas system with (a) offgas use (b) flash gas use		x		
			x		
9	Complex, integrated steam generating and overheating system with steam user, affecting plant units 1 to 8 and 10		x		
10	Utilities and auxiliary units (OSBL bio-methanol facility):				
	(a) boiler feed water treatment,	x			
	(b) flare	x			
	(c) instrument air,				x
	(d) inert gas (N ₂),	x			
	(e) electricity supply,	x			
	(f) natural gas supply	x			
	(g) process water treatment	x			
	(h) oxygen supply				x
	(j) compressed air				x
11	Carbo-V [®] -gasification				x
12	Biomass preconditioning and storage				x



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13	gas cleaning system (dedusting and detoxing)				x
14	syngas compressor to (3 to 30 bar, 40 kNm ³ /h)				x
15	CO-shift (20 kNm ³ /h feed)				x
16	CO ₂ -wash (Selexol, 40 kNm ³ /h feed)				x
17	ultra-purification				x



5. Description of a Bio-methanol Plant Using Gasification

Appendix 2 provides a block flow diagram for a Bio-methanol plant based on the proposed configuration covering main process units and the related streams. The plant comprises:

- biomass gasification unit
- CO-shift
- Selexol unit for CO₂ separation
- syngas compressor
- existing methanol synthesis unit
- water-steam system

The proposed water-steam system includes an extension to the existing steam piping and steam driven compressors.

The following chapters describe these units in more detail.

5.1. CHOREN's Carbo-V[®] biomass gasification process

The Carbo-V[®] gasification process developed by CHOREN provides an innovative and efficient way of converting biomass feedstock into clean and tar-free synthesis gas.

The Carbo-V[®] gasification process enables the use of entrained flow gasification which has conversion and process advantages and was originally developed for the efficient utilization of coal. Entrained flow is achieved by using a pre-conditioning stage for solid biomass in a thermal process (pyrolysis) referred to as "Low Temperature Gasification" (LTG).

The process is shown below.

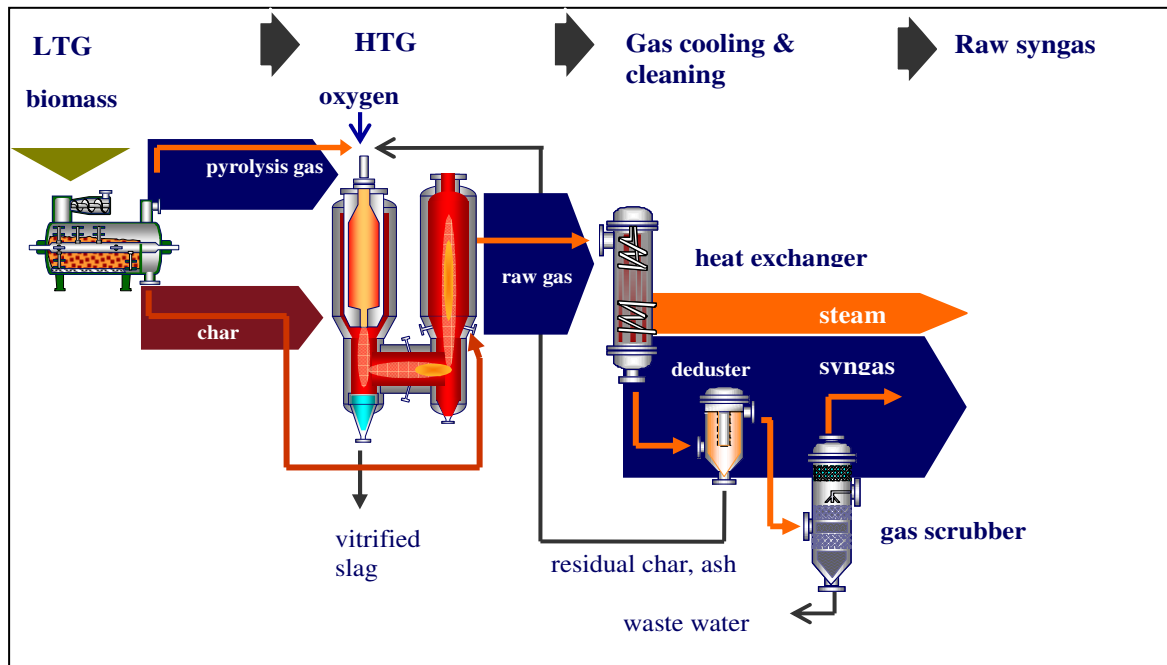


Figure 1: The Carbo-V[®] gasification process

A raw gas rich in CO and H₂ is produced from the feedstock using Carbo-V[®] gasification. This process involves the following stages:

Low Temperature Gasification (LTG)

During this stage feedstock is converted into a pyrolysis gas (Low Temperature Gasification gas or 'LTG gas') containing tar, and tar-free pyrolysis coke at temperatures of 400 °C – 500 °C

High Temperature Gasification and Endothermic Gasification

During this stage the LTG gas is partially oxidized together with the residual coke dust and oxygen at temperatures above the melting point of the ash (approx. 1,400 °C - 1,450 °C). The molten ash is removed from the lower part of the High Temperature Gasifier (HTG) via a discharge system.

The hot high temperature gasification gas (HTG gas comprising CO, CO₂, H₂, H₂O, N₂) is used in the second process stage as the gasification agent for the endothermic entrained flow gasification process with pyrolysis coke. During the following endothermic reactions, the HTG gas is cooled and gas components CO and H₂ formed for further use.



The Carbo-V[®] gasifier is currently available in 45 MW and 160 MW scales. The spec. CAPEX for the 160 MW is considerably lower and produces ~ 40,000 Nm³/h clean syngas (CO+H₂) per hour.

5.2. Capacity of the Plant Operating with Biomass Gasifiers

A base unit of the Carbo-V[®]-gasification would supply syngas for the production of about 35 Ma.-% of raw methanol (about 1/3 of the existing methanol synthesis and methanol distillation). The methanol synthesis loop as well as the distillation stages could be operated with this feed stream.

The steam turbines for the compressors could also be operated with a smaller load. However whether the compressor side could also be used requires investigation in more detail. In the current mass+energy balance it's assumed that the methanol loop compressor would be the existing steam driven one while the main syngas compressor would be electrically driven.

5.3. Description and Specifications of the New Process Units

The syngas from the biomass gasification, which has to be fed into the methanol plant according to its tie in point, has the following characteristics:

T	<130 °C
p	>19 bar

This needs to be made consistent with the quality necessary for methanol synthesis, namely:

- free of catalyst poisons
- low inert gas percentage (about < 5%)
- ratio (H₂-CO₂)/(CO₂+CO)>2.1

To achieve this, the following process units would be required:

- 1 x 160 MW Carbo-V[®] biomass gasification system (description see 5.1)
- gas cooling and dry gas cleaning
- steam boiler
- gas conditioning consisting of
 - wet gas scrubbing

- gas compression to 33 bar
- CO-shift
- CO₂-scrubbing
- ultra-purification

5.3.1. Gas Cooling and Dry Gas Purification

The dust-containing gas from the endothermic gasification process is cooled down during several cooling stages to $\leq 180^{\circ}\text{C}$. The heat released by the gas is used to produce saturated HP steam.

The dust present in the raw gas is separated using a cyclone and a bag filter and is then fed back into the high temperature gasification process. A small part of the dust separated in the bag filter is removed from the process as filter dust to control the level of components that tend to enrich in the coke cycle (e.g. Ka). The main part is recycled into the Carbo-V[®] process via the main burners in the HTG.

5.3.2. Gas conditioning

The gas coming from the gasification unit will go through the following steps in the gas conditioning unit:

The **wet gas cleaning** includes 4 steps:

- In the venturi the gas is scrubbed via own-condensate and cooled down to saturation temperature
- In the 2nd scrubber mainly dust, halogens, NH₃ and other water soluble impurities are removed
- In the 3rd scrubber, sulphur containing particles and any remaining fine dust are separated. To bind the sulphur, H₂O₂ is added.
- In the final stage, the gas is cooled to 40 °C leading to the condensation of the gas water including a separation of very fine dust.

Caustic Soda (NaOH) is used to control the pH-level.

Gas compression: The raw synthesis gas pressure must be elevated by a multi-stage compressor to a pressure level suitable for further gas conditioning. As CO₂ separation is best operated around 30 bar, the gas would be compressed to 33 bar.

CO conversion: This process is required in order to adjust the H₂:CO ratio in the synthesis gas prior to Methanol-Synthesis. One part of the gas stream is converted to H₂, the other



part bypasses the CO-conversion. After both streams are mixed, the appropriate ratio is achieved. Before entering the CO-shift reactor, the syngas will be enriched by water steam. This is done through a water saturation column. In front of the shift reactor, high-pressure steam is injected.

The CO shift reaction:



is exothermic which causes a significant increase of the gas temperature.

H₂S/CO₂ absorption/hot regeneration: As an example, an acid gas washing process using physical absorption for CO₂ removal (e.g. Selexol) is described below. However other processes and configurations are possible.

The gas stream from the CO conversion is now treated in wash columns with organic solvents. In the CO₂ absorption column the CO₂ in the syngas is removed to a large extent. The CO₂ loaded solvent is flash regenerated and recycled back to the middle section of the CO₂ absorption column as semi lean solvent.

During the CO₂ absorption processes CO₂ off-gas is produced. The part of the off-gas which is not needed for the gasification process requires further catalytic processing (traces of CO) before being vented to the atmosphere or sequestered. Part of the CO₂ is used as inert gas in upstream process steps to reduce the N₂ demand and content in syngas in steady state operation.

Any loss of solvent is compensated via the Selexol make-up.

After this process step, the residual CO₂ content in the gas is reduced to less than 2% by volume.

Trace impurity removal: Traces of sulphur compounds as well as traces of other catalyst poisons are removed by several different packed safe guard adsorption beds. All remaining impurities in the gas will now be adsorbed from these materials. The catalysts of the Methanol-synthesis process are highly sensitive to catalyst poisons and therefore require an ultra-clean syngas.

The syngas is now ready to be fed into the existing methanol plant.

5.3.3. Steam boiler

Off-gases from the methanol production as well as lower alcohols were formerly used for preheating the natural gas before entering the SMR. As this process unit would not be operated in the considered option, the best use of these streams is to superheat the saturated steam flows of the various pressure levels. From an energy balance perspective,

the existing main compressors may still be steam driven while any new compressor will be equipped with an electrical drive.

This boiler might also be used for start-up purposes, in which case it would be fired using natural gas. Its parameters are:

p 70 bar

T 460 °C

Bearing in mind a potential extension to 3 biomass gasifiers, one single bigger unit might best be selected from the outset.

5.3.4. Input and Output streams

Figure. 1 shows the major input and output streams of the bio-methanol facility.

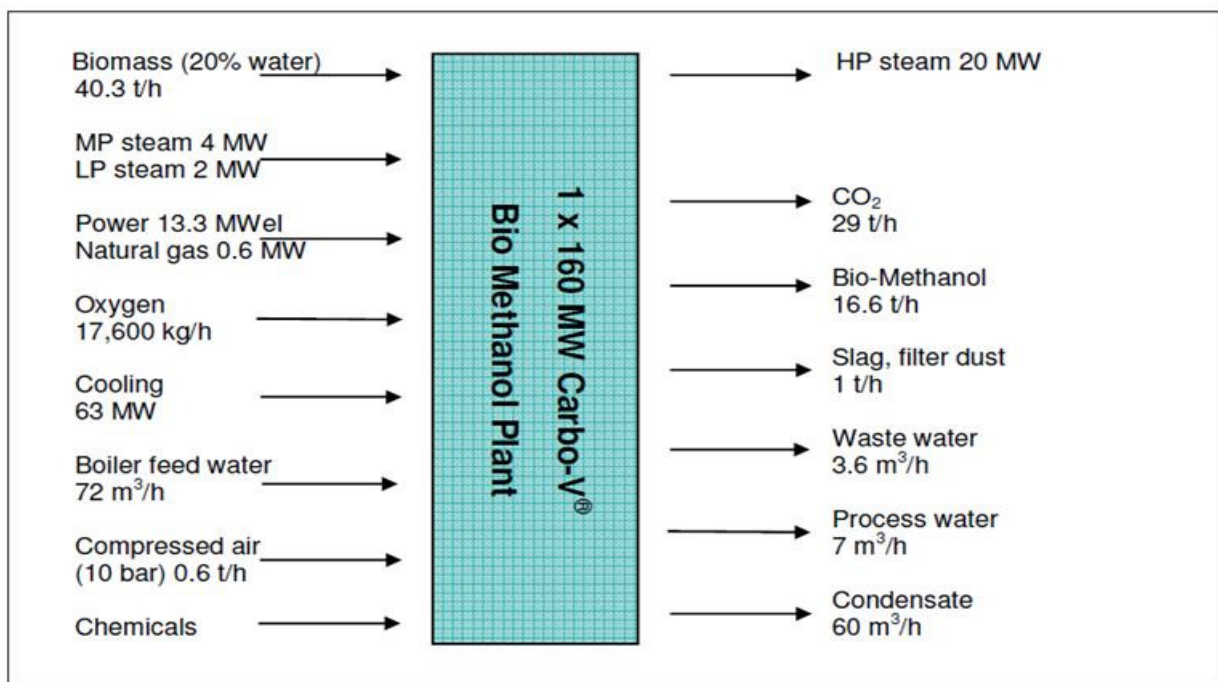


Figure. 1:

The whole mass and energy balance is based on waste wood as **biomass** feed with a water content of 20% using CHOREN's database. That means that the slag and filter dust have been derived from these flow parameters. Therefore, for specific properties of the local waste wood, the amount and composition of slag, filter dust and waste water may vary.



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Most of the **power** demand results from the different compressors. Power and **steam** balance are not yet optimised. Currently, 20 MW of HP steam are exported. This steam is suitable:-

- a) to produce up to 7 MW of the required 13.3 MW of power or
- b) to drive compressors directly and reduce the power demand or
- c) to be partially used for power via decompression to the MP/LP level and to fulfil MP/LP demand.

Chemicals are required for the gas scrubbers esp. to get most of the sulphur out. Depending on the contaminants in the feedstock, around 200 kg/h of NaOH (25 % solvent) and 160 kg/h of H₂O₂ (50 % solvent) will be consumed.

As with the existing plant, the **bio-methanol** facility will produce Grade AAA methanol. The following parameters can be expected:

H₂O < 300 ppm

light ends (methylether) < 20 ppm,

higher alcohol < 10 ppm,

ethanol < 100 ppm

After some minor treatment the **CO₂** should be in a suitable condition for sequestration.

The main part (> 90%) of the **slag/filter dust** stream consists of vitrified slag ready for disposal in standard landfills or might be used for road construction. The smaller part consists of filter dust that needs special treatment.

Waste water mainly consists of an inorganic fraction, while just 0.5 m³/h contain organics from the methanol unit.

Process water and **condensate** might be used for boiler feed water production.



6. Estimation of Capital Cost (CAPEX)

The cost estimate was performed using parametric models by comparing capacities of identified process units in the plant with those estimated for previous projects. Cost point: Q4 2010, no escalation has been included.

The CAPEX estimate for the new facilities without refurbishment of the existing plant is £100-150M.

As shown in the block diagram in **Appendix 2**, it is assumed that the oxygen requirement is provided from an external plant. This might be either an existing ASU or an onsite approach where the ASU is built and operated by a third party.

Biomass handling and storage, refurbishment of the existing plant, interconnecting pipes, utilities and planning require an estimated £50–100M resulting in total CAPEX of £150-250M and a specific CAPEX, per daily capacity, of £350-600K per tonne of biomethanol per day at worst which is comparable with equivalent biomass-to-biomethanol plants currently being planned in the EU

Increasing bio-methanol production to the capacity of the plant, using a total of three biomass gasifiers and a larger gas cleaning/gas conditioning train, would lower the spec. investment to around 70% leading to a higher project internal rate of return (IRR), while increasing the overall investment to around £300-500M.

The potential for future development beyond an initial phase based on one 160 MW gasifier should be kept in mind when determining site layout and scaling the gas cleaning train and the steam boiler.



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Table 2 shows what is included/excluded in the cost estimate:

Table 2: Cost Estimate

Item	Included	Excluded
<u>Engineering</u>		
- Feasibility Study		X
- Basic Engineering		X
- Detail Engineering and Procurement services	X	
<u>Construction</u>		
- Construction contracts management & Field supervision	X	
- Pre-Commissioning	X	
- Commissioning	X	
- Start-up assistance	X	
- Temporary construction facilities	X	
- Vendors Representatives		X
<u>Contract</u>		
- Lump sum contracts obligations, guarantees (risks) and fee		X
- BAR (Builder All Risk) Insurance & Third Party Liability,		X
<u>License and Catalysts</u>		
- License	X	
- 1 st charge of catalyst and chemicals	X	
<u>Spare Parts</u>		
- Capital spares		X
- 1 year operation		X
- Commissioning		X



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<u>Exclusions</u>		
- Owner Costs (management ...)		X
- Provision for change orders		X
- Financial charges, bank charges, etc.		X
- Taxes & Duties, Local taxes, customs duties, VAT etc		X
- Force Majeure		X
- Exchange Rates variations,		X
- Major scope variation,		X
- Crash planning,		X
- Unforeseen Market variations.		X
- Authority approvals		X
- Training		X
- Laboratory equipment		X
- Unforeseen voids, obstructions or other sub-soil conditions		X
- Removal of contaminated soil		X
- Common site preparation		X
- Buildings incl. fire extinguishing system for administration, central control room, substations		X
- Permanent plant fencing, entrance gates		X
- Landscaping		X
- Off-site pipelines/ utilities		X
- HV cabling outside of specified boundary limits		X
- Waste water and drains disposal off-site		X
- Raw materials and utilities required for pre-commissioning, commissioning, test runs and start-up operation of the plants		X



7. Layout

Appendix 3 shows the outside appearance of the Carbo-V[®]-gasifier

The additional process units will require approximately following areas:

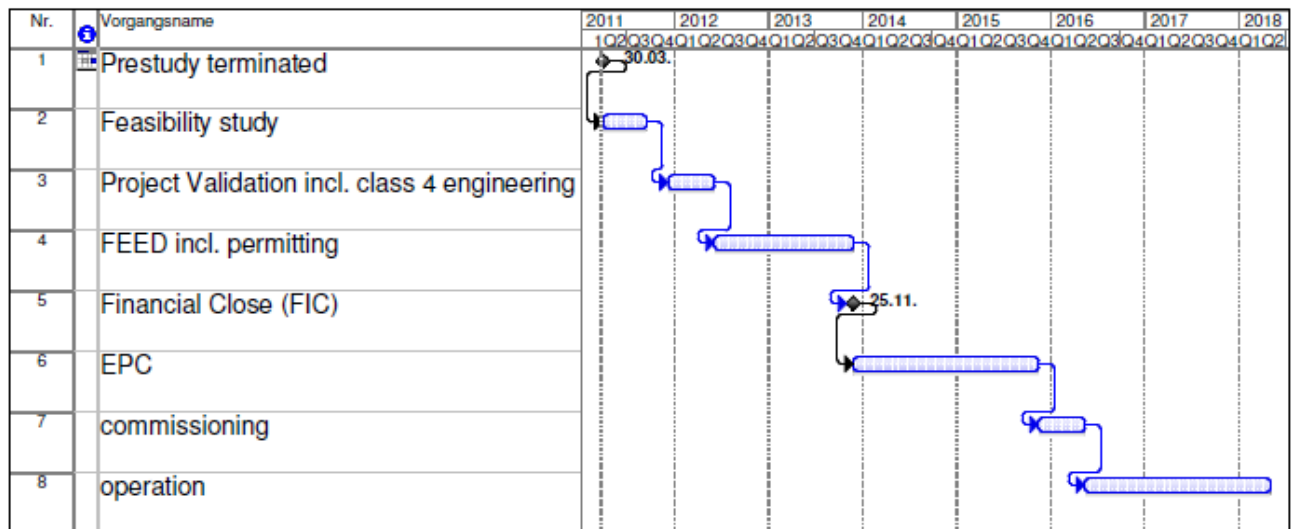
Gas cleaning (scrubber):	30 x 60 m ²
Syngas compressor:	20 x 20 m ²
CO-shift:	30 x 30 m ²
CO ₂ -wash incl. ultra purification	40 x 80 m ²

For a future project development, this space demands would have to be incorporated to the specific site at Billingham.

8. Preliminary Time Schedule (EPC)

A Preliminary Time Schedule indicating the main steps of the further project development up to start of operation of the plant including the main project phases is provided in Table 3.

Table 3: EPC Time Schedule





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9. Conclusions & Recommendations

Implementation of a project to produce 2nd Generation bioliquids in the Tees Valley can be effected using biomass gasification and the existing Billingham Methanol plant. This could be achieved at scales of operation from 125k tonnes per annum to 375k tonnes per annum. Using 1 to 3 CHOREN Carbo-V[®] gasifiers, gas cleaning and purification prior to feed into the existing methanol plant.

Based on preliminary CAPEX estimates the cost would be, at worst, comparable with equivalent biomass-to-biomethanol plants currently being planned in the EU. Whilst technically feasible at the lower scale, full scale operation will reduce the specific CAPEX increasing the commercial viability of the plant.

Exploration of the viability of this will require a detailed assessment of the state of the current plant, feedstock availability and market demand for methanol at volume and price it can be produced. Ideally development would aim for the largest possible scale of operation, even if achieved in phases.

Should such a project be initially implemented at the lower scale, consideration of scaling gas processing (etc) for full scale operation should be made at the outset.

More detailed analysis is required of energy and mass balance flows in order to establish optimal operation of such a project.

10. Acknowledgements

This work was commissioned by the North East Process Industry Cluster (NEPIC) as part of the Regional Strategy for Transport Biofuels. This work is funded by One North East.



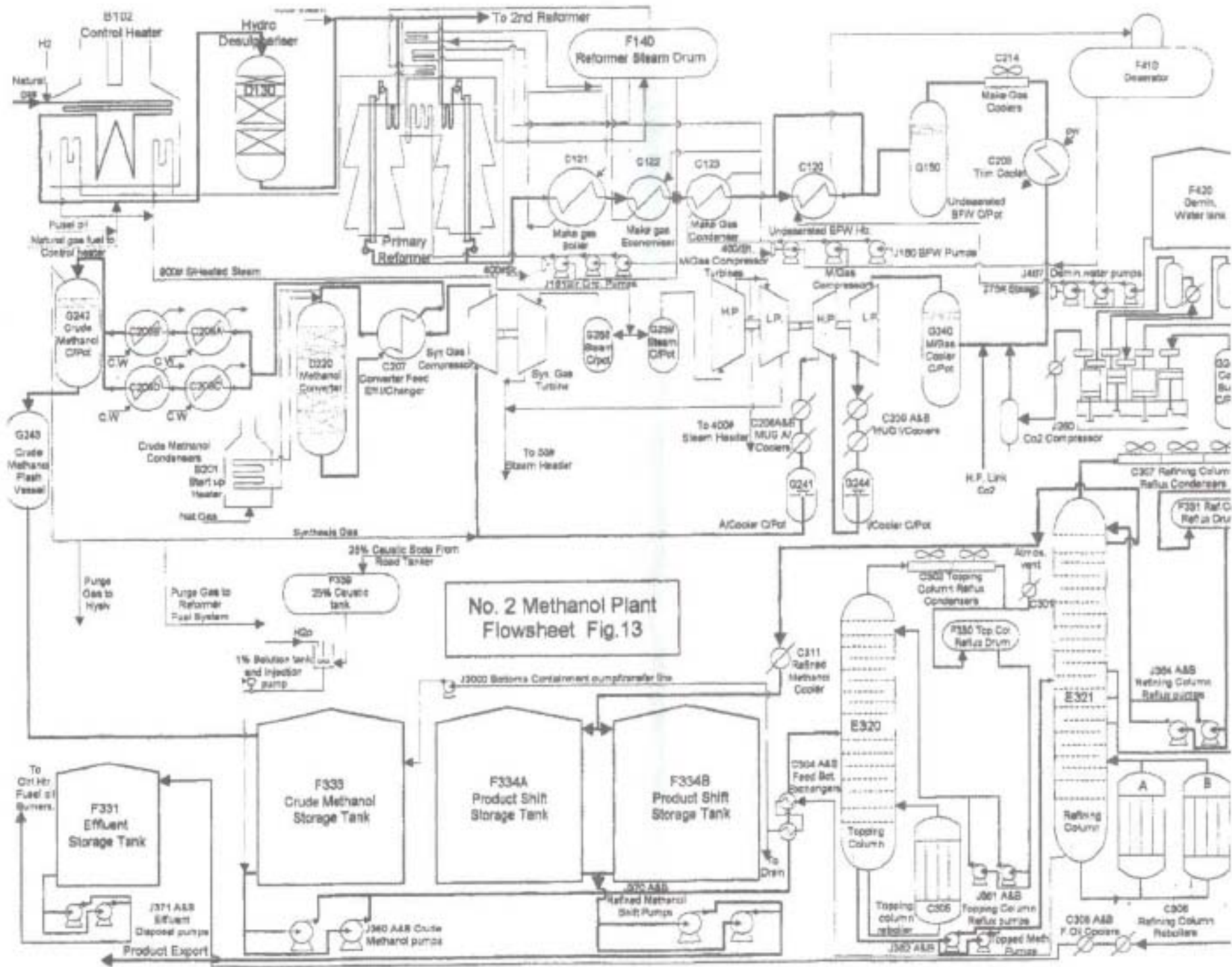


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Appendix 1

Process flow diagram existing plant



No. 2 Methanol Plant
Flowsheet Fig.13



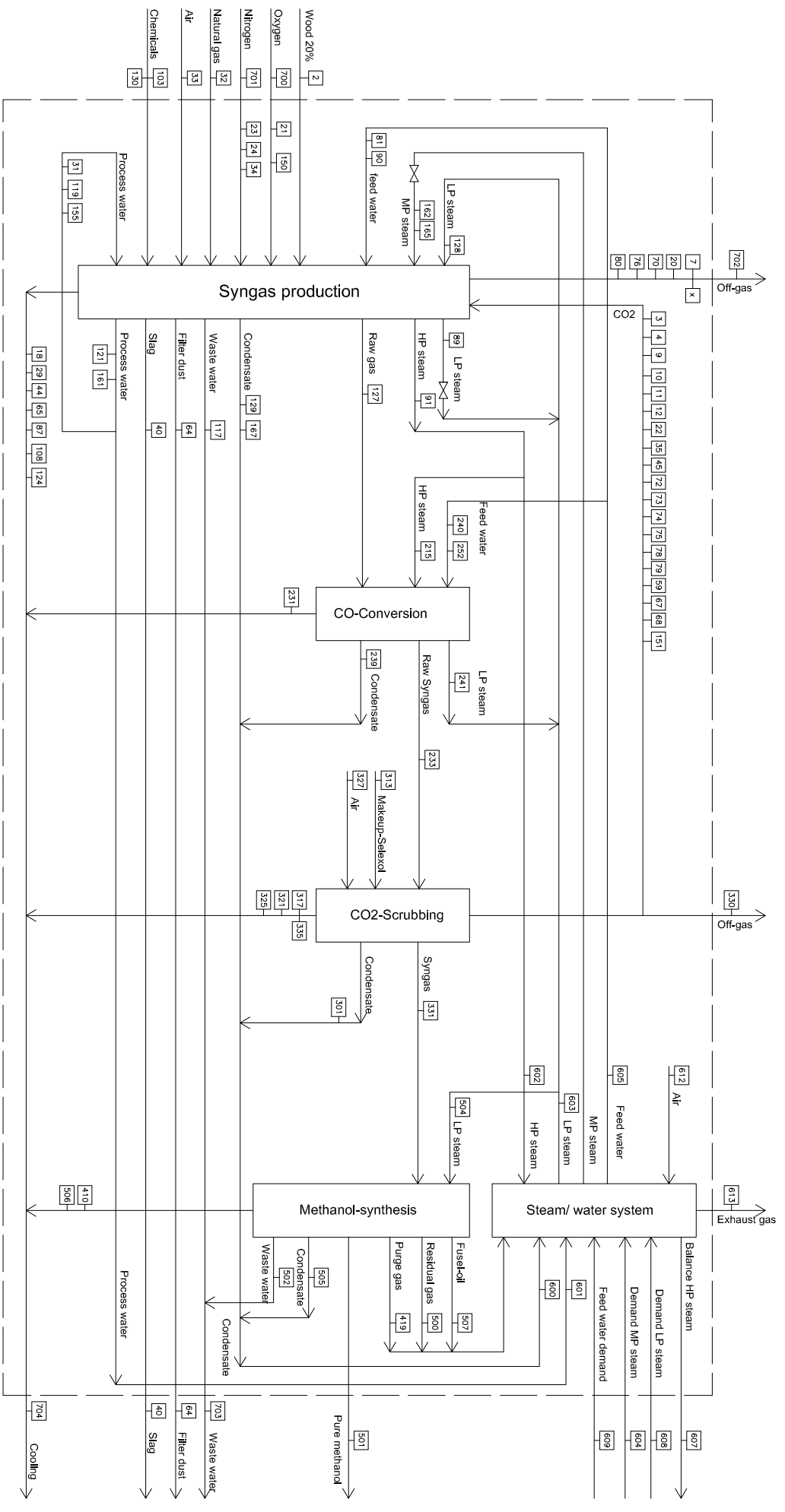
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Appendix 2

**Block Flow Diagram
incl. Mass & energy balance
Bio-Methanol plant**

No.	Unit	2	32	33	40	64	103	130	313	327	330	501	604	607	608	609	612	613	700	701	702	703	704
Mass flow	kg/h	40273.0	42.2	540.6	965.6	88.2	208.3	159.2	0.0	291.4	29205.7	16598.6	4979.3	21987.0	2446.8	13004.3	10975.8	13051.5	17594.9	50.0	5051.3	3500.8	0.0
Volume flow	Bm ³ /h	0.0	5.2	45.5	0.0	0.2	0.2	0.2	0.0	237.8	16283.3	22.1	624.0	1082.6	1331.0	8364.8	17538.1	1989.7	4.3	2769.5	3.6	0.0	0.0
Pressure	MPa	0.000	1.000	1.000	0.000	0.770	0.350	0.050	0.050	0.101	0.101	0.100	1.500	6.430	0.400	0.101	0.110	0.650	1.000	0.100	0.000	0.000	0.000
Temperature	°C	15.0	0.0	20.0	40.0	30.0	40.0	105.6	20.0	15.0	25.8	45.0	198.3	460.0	143.6	105.0	20.0	180.0	15.0	20.0	20.0	0.0	0.0
Enth.-flow	kW	180332.9	565.8	3.0	8.3	829.7	9.7	19.5	0.0	1.2	176.0	90411.6	3858.8	20286.5	1860.7	1585.4	61.3	735.7	47.8	0.1	23.4	170.0	62778.7



Werkstuf	Projekt	Methanol Billingham
Masse zül. Adv.	Projek-Nr.	Auftrags-Nr.
Übersicht	Auftragsgeber	
geprüft	Datum	Name
gelesen	23.03.11	Rüger
Benennung		Methanol
Zeichn.-Nr.		
Ersatz für		ersetzt durch
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Benennung	Mass	Volume	Pressure	Temperature	Enth.-flow
Wood 20%	2				
Oxygen	720	21	150		
Nitrogen	701	23	24	34	
Natural gas	12				
Air	33				
Chemicals	103				
Process water	31	119	135		

Appendix 3: Layout biomass gasifier

