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(56) Documents Cited:
GB 2448685 A **GB 2100282 A**
WO 2008/041921 A1 **WO 2006/113293 A1**
WO 2000/025380 A3 **WO 1995/031423 A1**
CN 101225319 A **US 20040180971 A1**

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(54) Title of the Invention: **Manufacture of methanol from agricultural by-product cellulosic/lignitic material**
Abstract Title: **Manufacture of methanol from agricultural by-product cellulosic/lignitic material**

(57) The Cellulosic/Lignitic byproduct that remains after the cropping of agricultural produce is converted to carbon dioxide by calorific oxidation. In another section of a synthesis factory hydrogen gas is produced by electrolysis; the hydrogen gas is then reacted with the carbon dioxide to make methanol. In a related process carbon dioxide exhausted by the process of fermentation of agricultural produce to form ethanol is captured and reacted with hydrogen to form methanol. The quantity of alcohol fuel produced by an agricultural region is thereby increased without increase in the area under cultivation.

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BACKGROUND TO THE INVENTION

The invention relates to the manufacture of alcohol fuel.

5 More specifically, the invention relates to the manufacture of methanol using as a raw material the cellulosic and lignitic waste material that arises after cropping of corn (maize), wheat and other cereal products, and sugar cane.

Sugar Cane Production

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Typically sugar cane is crushed to release the sugar sap, and the bagasse, which is the waste material after crushing, is burned.

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The burning of the bagasse is typically usefully employed to raise steam which is used in the sugar refinery process to facilitate evaporation.

The major component of the bagasse, cellulose, is converted to carbon dioxide and water, and released to the atmosphere.

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During the growing cycle of the sugar cane plant, carbon obtained from carbon dioxide in the atmosphere is organically fixed into the structure of the sugar cane plant mainly in the forms of lignin, cellulose and sucrose.

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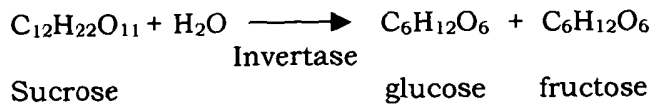
Of this organically renewable fixed carbon, only the portion present in the sucrose is recovered for consumption. When the sucrose is processed to manufacture ethyl alcohol (ethanol) by fermentation, one third of the carbon content is lost to atmosphere by the fermentation process.

30

In the fermentation of cane sugar the following processes occur.

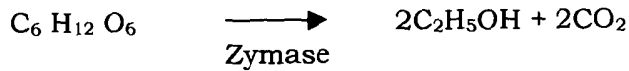
Sucrose, the most important and abundant sugar in cane sugar molasses, is first converted to hexose sugars.

This is accomplished through the action of the enzyme invertase



5

The mixture is converted into ethyl alcohol and carbon dioxide by Zymase



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It can thus be seen that in the fermentation process one third of the fixed carbon is lost.

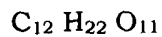
Sugar cane comprises the following constituents:

15

	% by mass
Sucrose	13
Other solubles	2
Fibre	14
Water	<u>71</u>
Total	<u>100</u>

20

Sucrose and the other solubles have the basic formula



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and thus contains 42.1% carbon by mass.

The cellulosic fibre with the formula $(\text{C}_6\text{H}_{10}\text{O}_5)_n$ contains approximately 44.4% carbon by mass.

30

Thus of the total carbon that is organically fixed, the following proportions are retained and released back to atmosphere.

Retained Carbon

$$\begin{array}{l} 0.67 \times 0.42 \times 0.15 = \underline{0.0424} \\ \text{or } 33.75\% \end{array}$$

35

Carbon released back to atmosphere

$$\begin{array}{rcl}
 0.33 \times 0.42 \times 0.15 & = & 0.021 \\
 + & & \\
 5 \quad 0.444 \times 0.14 & = & \underline{0.0622} \\
 & & \underline{0.0832} \\
 & \text{or} & 66.24\%
 \end{array}$$

To a very close approximation two parts of the carbon fixed by photosynthesis
 10 are returned to the atmosphere for each part that is converted to alcohol fuel.

If the carbon contained in the waste bagasse may be converted to alcohol,
 together with the carbon dioxide by-product from the fermentation process for
 every unit of carbon presently converted to alcohol fuel, three units of carbon
 15 will be converted to alcohol fuel.

Thus, without the necessity for increased land area the quantity of alcohol fuel
 produced from carbon dioxide in the atmosphere is increased by 200%.

20 Maize Production

In the case of maize production, the ratio of the carbohydrate material contained
 in the maize seeds attached to the maize cob; to the mass of the shelled cob,
 stalk, leaves and upper root is more variable.

25

Typically, for each tonne of dry maize produced, there remains 1.4 tonnes of dry
 carbohydrate (woody and pithy) waste.

As for sugar cane two thirds ($\frac{2}{3}$) of the carbon in the carbohydrate material, in
 30 this case starch, is converted to alcohol in the fermentation process, and one
 third is exhausted to atmosphere as a waste product of fermentation.

Thus, for every tonne of maize produced 0.67 tonne of carbohydrate is converted
 to alcohol fuel.

1.4 tonne of carbohydrate, or approximately double the quantity currently consumed, is available for alcohol manufacture.

- 5 If this carbohydrate may be converted to alcohol fuel, for every tonne of alcohol fuel that is currently produced from renewable resources, 3 tonnes of alcohol fuel may be produced, without any increase in land area.

10 **The Economic Conversion of the Waste Carbohydrate Material (Typically Cellulosic and Lignitic Material) Contained in Sugar Cane Waste Material (Bagasse) and the Stems and Cobs of Maize Following Harvesting of the Starch, to Methanol Fuel**

Various schemes have been proposed, evaluated and tested to convert cellulosic agricultural by-product to ethanol, by hydrolysis to hexose sugars, followed by fermentation.

The major difficulty encountered in the conversion of cellulosic material to ethyl alcohol is the capital cost involved in the conversion of the cellulose, by hydrolysis. This is accomplished in the presence of dilute mineral acid, subjected to heat and in some schemes under pressure.

As for the conversion via the fermentation process of starch and sugar to ethanol, the conversion of cellulosic waste material to ethanol is accompanied by carbon dioxide emission to atmosphere, amounting to one third (1/3rd) of the carbon fixed by the process of photosynthesis.

In the invention it is proposed to convert the cellulosic waste material to methanol, with the formula CH_3OH , instead of ethanol with the formula $\text{C}_2\text{H}_5\text{OH}$.

The outline method of conversion of the cellulosic material to methanol is as follows:

- The cellulosic material is gathered and transported to a central processing plant;

- The material is oxidized (burnt) to produce heat and raise steam.
- The steam raised is passed through a turbo alternator set to produce electricity.
- In another section of the facility imported electricity together with electricity generated on site is used to produce hydrogen gas and oxygen by electrolysis of water.
- The hydrogen gas is compressed.
- The carbon dioxide gas produced by the burning of the waste cellulosic material is captured, purified and compressed.
- The carbon dioxide (CO₂) and hydrogen (H₂) is passed over a copper catalyst at a pressure of approximately 70 – 80 bar to produce methanol

$$\text{CO}_2 + 3\text{H}_2 \longrightarrow \text{CH}_3\text{OH} + \text{H}_2\text{O}.$$
- The water is removed by distillation and purified for recycling or other disposal.

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Whereas crude oil, and the derived products petroleum and diesel, are proven in their use in automotive engines, and in particular in the four stroke piston engine whether of the spark ignition type or the adiabatic compression auto-ignition type (diesel), this fuel suffers from a number of disadvantages.

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The primary disadvantages of the use of the distillation products of crude oil, petrol and diesel as automotive liquid fuels are as follows.

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The global reserve of crude oil is finite and is being depleted at an ever increasing rate.

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- At some time in the future a severe shortage of crude oil will prohibit the usage of petroleum and diesel unless these products are synthetically manufactured.
- The shortage of crude oil will be exacerbated by the requirements of the petro-chemical industry which depends on crude oil to produce ethylene glycol, polyethylene, polypropylene, acrylonitrile, butadiene elastomers and caprolactam as major products.

- Resulting from the shortage of petroleum products a rise in the price of fuel will lead to a general increase in the price of transportation, and a concomitant price increase in most goods and services.

5

- Crude oil reserves are not uniformly distributed around the world, but are concentrated in certain areas. This leads to a number of difficulties including:
 - High transportation costs to certain areas;
 - Political and social problems caused by legitimate or illegitimate concerns relating to the financial or other control of crude oil production and distribution.
- Petroleum and Dieseline are often the cause of vehicular exhaust pollution, and in particular photo-chemical pollution in major conurbations.

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In the light of these problems relating to the exploitation of crude oil and its refinery products, and in particular supply constraints, it is clear that at some stage in the future, a replacement for crude oil derived petroleum and dieseline must be evolved to enable the continuation of economic vehicular transportation.

20

The basic requirements of such a fuel are that it remains as is, or exhibits characteristics as follows:

- a. The fuel must be cheap to manufacture;
- b. The fuel should ideally be suitable for use in existing four stroke piston engines of the spark ignition type (petrol) or the compression heat ignition type (diesel). There are a number of cogent reasons why the fuel should be compatible with existing automobile engines, mainly relating to the minimization of a dislocation in the economic working of the worldwide automotive industry, and automobile servicing and repair industry;
- c. The fuel must be dispensed in the normal way using existing equipment and primary and secondary fuel distribution infrastructures. As a counter example the distribution of cryogenic liquid hydrogen and oxygen would require major changes in distribution infrastructure;

30

- d. The fuel must be as safe as or safer than petroleum and dieseline, both as concerns primary and secondary (retail) distribution and in traffic accidents;
- e. The fuel must exhibit drivability characteristics that are equal to or superior to the existing fuels, petroleum and dieseline. These drivability characteristics include:
- acceleration
 - top speed
 - torque
 - idling
 - cold start
 - hot start
- f. The fuel must be as efficient or more efficient in terms of distance traveled per unit cost;
- g. The fuel must exhibit pollution characteristics that are equal to or better than those evinced by petroleum and dieseline;
- h. The fuel must be able to be introduced gradually into the existing worldwide transportation network and infrastructure, incorporating such diverse elements as technical college training, motor vehicle design, legal statutes, vending, road safety, bulk transportation capability and many others.

A replacement fuel that fulfils all of the requirements listed in A-G above is ALCOHOL. This is in fact presently the only motor fuel that is used in significant quantities in competition with petroleum and dieseline.

The alcohol fuel that is currently distributed is the chemical compound ETHANOL, with the chemical formula C_2H_5OH .

ETHANOL is produced in world scale quantities in two regions in the world.

- In Brazil where ethanol is the fermentation product of sugar cane. Approximately 5 million cars operate using ethanol blends, or pure ethanol which is marketed as E96 or Ethanol with 4% water.

- In the United States where maize (corn) is the raw material for the ethanol. It is marketed throughout the United States as a dilute blend in petroleum, and in the Mid West States, as E85, which is 85% Ethanol with 15% petroleum.

5

However, the capability of the international agricultural economy will be to produce only approximately 3–5% of the total fuel requirement.

ETHANOL may be synthesized from a carbonaceous feedstock via a process route that first entails the production of METHANOL.

10

METHANOL with the chemical formula CH_3OH has the same basic properties as ETHANOL and satisfies all of the requirements A–G listed above. The economics of synthetic METHANOL manufacture are considerably superior to synthetic ETHANOL manufacture.

15

It is probable therefore that METHANOL will take precedence over ETHANOL as the primary replacement for petroleum and dieseline in the market place.

It is not likely that any other chemical substance will supplant ALCOHOL in general, and METHANOL and ETHANOL specifically, as the major replacement compounds for PETROLEUM and DIESELINE.

20

The reasons for this are mainly their superior fuel efficiency, cost and pollution characteristics, coupled with essential compatibility with the existing engines, and distribution infrastructure.

25

The invention relates specifically to the use of carbon dioxide generated by burning agricultural cellulose/lignite, with the chemical formula CO_2 as the carbonaceous feedstock for the production of the automotive fuel.

30

Thus, whilst the carbon dioxide has no value in its normal role as a chemical reductant, economically it may be used simply as the CARBON skeleton upon which other elements and in particular HYDROGEN may be added through the

introduction of ENERGY, to overcome heat of formation limitations and create relatively complex chemical compounds, and in particular METHANOL.

THE IMPORTANCE OF METHANOL

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Whilst it has not yet been brought into popular focus, methanol is very likely to become extremely important as a motor fuel.

There are a number of reasons for this, as follows:

10

1. Methanol is the only fuel that may be synthesized from coal and/or natural gas that can economically sustain a crude oil price collapse.

15

A major difficulty in the substitution of naturally occurring crude oil with synthetically produced petrol and diesel, is the capital intensity of the projects.

20

In the case of smaller developed nations, such as (say) South African, New Zealand and Argentina, the size requirement of a synthetic fuel facility to provide sufficient economy of scale to compete with crude oil, results in capital investment on a scale that impinges noticeably on the nationally economy.

25

In the case of South Africa, the SASOL 2,3 initiative, which continues to produce approximately 25% of the nation's fuel needs, was underwritten by government. This was done in order to allow financing of the project, and also for strategic reasons. During the crude oil price collapse of the 1990s, it is possible that closure of the facility would have been forced, if the project was not state protected, since for a period of 5-6 years fixed and variable production costs were higher than crude oil importation and refining costs.

30

In the case of New Zealand a parliamentary decision was reached not to underwrite the SYNFUEL project.

Whilst technically most successful, closure of the SYNFUEL facility was forced after a few years of operation by the crude oil price collapse of the late 1980s and persisting until the late 1990s.

5 Due cognizance of the failure or the partial failure of these, the only two
worldscale synthetic fuel initiatives, to survive a crude oil price collapse has
been made in the marketplace.

10 Free market capital investment in synthetic fuel projects producing the
traditional fuels, petrol and dieseline, is not likely to be forthcoming in the
absence of a guarantee against massive downward price dislocation, such as
that which caused the failure of the New Zealand SYNFUEL project.

15 In the future, when alcohol fuel is available generally for vehicular
transportation, projects to synthetically produce methanol from coal and/or
natural gas will encounter significantly less resistance from potential
investors.

20 The reason for this is that the capital requirement to produce methanol is
about 60-65% that required to produce traditional synthetic fuel (on a
calorific equivalence basis).

25 Fixed costs of production (personnel and maintenance) are lowered in
approximate proportion to the capital investment.

Variable cost of production, (the usage of coal or natural gas) is lowered by
about 20%.

30 When these savings are compounded, the net result is that methanol may
economically be produced synthetically at a price level of about half that of
synthetic petrol and diesel, on a calorific value basis.

2. Alcohol fuel has already gained wide acceptance in the marketplace in the
form of ethanol. This has arisen from extensive commercial production in

two areas from an agricultural base. These areas are Brazil, where ethanol is produced from sugar cane, and the mid-Western States of the United States of America (corn belt) where ethanol is produced from fermentation of the sugars that arise from the hydrolisation of maize.

5

Methanol operates as a motor fuel in a very similar way to ethanol, and most of the groundwork required to introduce methanol into the marketplace has already been conducted.

10

For example, such innovations as:

- Vehicle lubricants more suited to hydrophilic liquids
- Higher compression ration spark ignition (petrol replacement) vehicles
- Variable petrol/alcohol percentage dial-in vending at filling stations, commensurate with relevant level of vehicular modification
- “Hybrid” motor vehicles which may accept alcohol fuel or petrol or alcohol/petrol mixtures
- Larger fuel tanks
- Cold start enhancement

15

20

have already been carried out.

3. The EU has recently legislated to include alcohol fuel into all fuel used by spark ignition vehicles.

25

This has probably been undertaken for environmental reasons, although it is possible that the logic of the requirement may be flawed on this basis.

Nevertheless, the widespread introduction of ethanol fuel into Europe has commenced.

30

This ethanol fuel may equally well be replaced by methanol, with essentially the same physical effect.

If this methanol fuel is produced using the exhaust from fossil fuel fired thermal power stations, a lowering of carbon dioxide emissions to atmosphere exhibiting a small collateral environmental impact is demonstrable.

5

This is not necessarily the case for partial replacement with ethanol since vast acreages of monoculture are required.

10

Importation costs and the exhaust to atmosphere of carbon dioxide from farm machinery and exhaust resulting from transportation to the market from distant lands, has led a significant lobby to argue that the introduction of ethanol into Europe is counterproductive from an environmental viewpoint.

15

There is also a lobby which objects to the introduction of ethanol into Europe on the basis that conversion of agricultural produce to automotive fuel leads to a rise in food prices unsustainable by the world's poor, at least in the short to medium term.

20

These arguments do not apply to alcohol fuel produced using as a carbon skeleton waste carbon dioxide from existing power stations.

There will be collateral environmental damage in the erection of electricity generating facilities which do not themselves produce carbon dioxide.

25

Wind power is suitable, as is nuclear power, as power sources required to split water by electrolysis.

30

The introduction of ethanol fuel will have had two strongly positive effects, in the event that it is later supplanted by methanol fuel. First is the phenomenon of "methane back out". Introduction of a small quantity of alcohol, as the result of the interaction of the hydrophilic -OH radical with the hydrocarbon fuel results in the desorption of the light paraffinic gases methane, ethane, propane, butane and propane from the fuel.

5 Instead of incorporating these light hydrocarbons into the fuel by the standard refinery techniques of reforming and oligomerisation, it is more economic to employ physical absorption of the gases by bubbling into the liquid petrol.

Addition of alcohol in low quantities results in the desorption of these high value gases, which must be alternatively disposed of.

10 Light hydrocarbon gas desorption will have been encountered and solved in the event that methanol is later introduced into the fuel pool as a replacement for ethanol.

15 The second effect that ethanol has on petrol when introduced as a small percentage, is to raise the Anti-knock Index (AKI) or Octane Rating of the fuel. Most fuel in Western Europe incorporates MTBE (Methyl Ter-Butyl Ether) as an Octane Number enhancer. This prevents pre-ignition (or pinking) problems.

20 The introduction of alcohol in small quantities into petrol lowers or relieves the necessity for further AKI enhancement.

25 Since MTBE is a profitable sideline for petroleum refineries, the lowering of the quantity of MTBE introduced into fuel in Europe must have had some economic consequences, which will have been encountered and solved if an when methanol is introduced in addition or as a replacement to ethanol.

30 4. Pollution resulting from vehicle exhaust is not particularly problematic in Western Europe as a result of prevailing wind and precipitation patterns, coupled with strict control of visible emissions, especially from diesel vehicles.

In many parts of the world, however, and particularly those areas with massive conurbations situated in arid, still areas, and which are prone to

atmospheric inversion layering, vehicle pollution leads to chronic health problems.

5 Alcohol fuel has a very significantly lower pollution profile than the traditional fuels petrol and diesel.

10 When used as a replacement for petrol, alcohol fuel, because it burns at a much lower temperature than petrol, does not react with nitrogen in the air to any significant degree. Photochemical pollution is essentially eliminated, and the requirement for catalytic conversion of toxic exhaust compounds to less toxic compounds or inert compounds is reduced.

15 When used as a replacement for diesel, emission of microscopic particulates is reduced to an extent such as to make this form of pollution insignificant.

20 The practical observation of the beneficial effects of the use of alcohol fuel on an urban environment has been made in the case of São Paulo. In the past (late 1980s), when the relative prevalence of ethanol fuel was at its height, a complete turnaround in the atmosphere of that city was noted for a number of years.

25 During the subsequent oil price collapse when it became difficult to produce ethanol fuel economically, in spite of state subsidisation, the physical atmospheric conditions in São Paulo worsened.

People in Brazil are reported to refer to the ethanol fuelled vehicles as “vacuum cleaners”, since in many cities the air that enters the vehicle is less clean than the exhaust from the vehicle.

30 In many cities in the world the level of atmospheric pollution that results from motor vehicle exhaust is such that periodically the public is advised to wear protective equipment.

In such cities it is likely that, if alcohol fuel could be synthesized on a

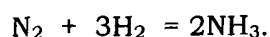
competitive economic basis to traditional fuels, its use would become mandatory.

5 Even in such cities as London and Paris where vehicle exhaust is not a primary health issue, the improvement that would be realised by wide scale use of alcohol fuel might well lead to subsidisation of the use of alcohol fuel within a prescribed geographical area and/or a disincentive to use traditional motor fuel within this demarcation.

10 **Co-Production of Ammonium Nitrate Fertilizer**

The method of electrolysis of water to produce hydrogen gas for use in the manufacture of anhydrous ammonia (NH₃) using as a nitrogen source atmospheric air is well established. The essential stoichiometry is:

15



In Norway seasonal hydroelectric power has been used to produce ammonia in this way.

20

The method is well suited to variable electricity supply from a renewable source such as variable electricity supply from wind turbines or hydro-electric power, since the production of ammonia represents a method of electricity storage.

25 The co-production of anhydrous ammonia with methanol manufactured from organic waste, using as an electricity source wind turbine generation represents a most attractive synergy from multiple viewpoints as follows:

- 30 • Ammonium nitrate fertilizer in large quantities is required for the production of the agricultural produce, maize and sugar cane.
- The ammonium nitrate fertilizer will be produced in the heart of the growing area. Production of anhydrous ammonia by electrolysis of water is less economic than production via the normal route, which involves steam

reforming of natural gas to produce hydrogen. However, transport costs of either the anhydrous ammonia or the bulk ammonium nitrate fertilizer make up a large proportion of the total costs in some instances, and in particular areas away from natural gas feedstock.

5

- The front end of the methanol manufacturing facility and of the ammonia manufacturing facility, namely the electrolytic cells producing hydrogen gas is identical.

10

This will lower the capital cost of the installation through economy of scale. Fixed costs of operation, labour and maintenance will also be reduced, on a unit basis.

15

- The quantity of methanol manufactured and the quantity of anhydrous ammonia manufactured, may be continuously balanced in the most economic manner to utilize all of the incoming electrical energy.

20

As an example co-production of anhydrous ammonia and of methanol is considered in the corn belt of the United States of America, utilizing gas as a power source electrical energy from wind turbines.

During exceptionally windy periods the rate of burning of the waste cellulose material must be increased to provide sufficient carbon dioxide raw material.

This will result in:

25

- Firstly, more electricity generated internally in the manufacturing facility, and more carbon dioxide generation,
- Secondly more electrolytic cells will become available for the manufacture of ammonia.

30

The ammonia plant will operate at a higher rate when the methanol plant also operates at a high rate, in order to utilize all of the incoming wind turbine generated electricity.

During periods in which less wind is available to drive the wind turbines, the ammonia plant production rate may be lowered and less waste cellulosic material is burned. This will produce less carbon dioxide to be absorbed as methanol production, together with a lower internally generated electrical supply.

In this way no cellulosic material is burned without conversion to methanol, and no electricity is wasted during windy periods.

- 10 • The cellulosic raw material will be deposited at the methanol/ammonia station and using the same transport the ammonium nitrate fertilizer may be on-loaded for dispatch back to the farm.
- 15 • The ash from the burning of the cellulosic waste material may be conveniently collected and added to the ammonium nitrate fertilizer. In this way, compounds of sodium, potassium and phosphorous may be returned (on average) to the fields from which they originated.
- 20 • Co-location of the methanol plant, the anhydrous ammonia plant, and the nitric acid/ammonium nitrate facilities, together with the methanol plant will lower environmental impact of the industrial facility.
- 25 • It is envisaged that the farmer will operate, at least in the medium term when the project is well under way, alcohol powered vehicles. The alcohol fuel could be collected from the station as a credit, simultaneously with off loading of the cellulosic raw material.
- 30 • Oxygen from the electrolytic cells (both electrolytic cells used for ammonia manufacture and for methanol manufacture) can be used to lower the excess air required for combustion of the cellulosic waste material.

DISCUSSION

- **Operation of the Combined Methanol/Ammonium Nitrate Facility**

5 The combined methanol/ammonium nitrate facility would receive power primarily from two sources, namely electrical power from wind turbines and a semi-conventional power station operated using waste cellulosic material.

10 The exhaust carbon dioxide from this power station represents the organic raw material from which the methanol is made.

For convenience of operation, however, and as a guaranteed of continuous operation, the station will be linked to an electrical grid system

15 It is also envisaged that the power plant which normally operates using waste bagasse, would have the capability for operation using coal as a feedstock. The exhaust carbon dioxide from this power station would also be converted to methanol fuel.

- 20 • **Cropping from Fallow Land**

Any plant material in the agricultural region would be suitable for the production of methanol, by conversion of the carbon dioxide following combustion.

25 All of the ash remaining after combustion should be incorporated into the ammonium nitrate fertilizer.

- **Zea Mays Hybrid Selection and Development**

30 The quantity of the woody cellulosic portion of the maize plant is not currently a dominant factor in the selection of seed hybrids suitable for economic maize production.

In the medium to long term, however, it is likely that photosynthesis will play a major role in the fixing of carbon from the atmosphere independently of the role of photosynthesis in capturing solar energy and transforming this into chemical energy (food).

5

In other words, at some time in the not too distant future the carbon cycle will be brought into equilibrium, whilst it is currently in dis-equilibrium – more carbon dioxide is currently being exhausted to atmosphere than is being fixed by plant life.

10

The carbon cycle will not be brought into equilibrium solely through human utilization of carbohydrates as food, so long as carbon based compounds are used as automotive fuel.

15

Photosynthesis must be employed as the only known method of fixing atmospheric carbon dioxide independently of the food value of the fixed carbohydrate material.

20

It is most probable that in the medium term, and possibly also in the short term, that the woody portion of the maize plant will achieve an economic importance such that the Zea Mays varieties selected for planting will evince a similar, albeit slightly decreased, corn production potential but a very much higher cellulose content.

25

This will greatly increase the overall quantity of carbon extracted from the atmosphere by photosynthesis, and converted to alcohol automotive fuel.

- **Independence of Ammonium Nitrate Fertilizer from the Carbon Cycle**

30

The ammonium nitrate fertilizer that is co-produced with the methanol fuel is independent of the carbon cycle.

The anhydrous ammonia (NH_3) is produced from air and water using wind power.

The process is as follows:

5 Water is electrolyzed to produce hydrogen and oxygen using electrical power generated from wind stations.

Air is cooled and liquefied using standard oxygenic (air separation) technology. The nitrogen thus obtained is compressed, together with the hydrogen from the electrolytic cells.

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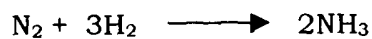
The hydrogen and nitrogen is mixed together in a stoichiometric proportion as follows:

15

N_2	$3H_2$
1 mole	3 moles

and then compressed using a centrifugal compressor to a pressure of approximately 200–300 Bar.

20 The stoichiometric mixture is passed over an iron catalyst, and anhydrous ammonia is produced.

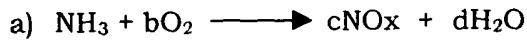


25 The anhydrous ammonia produced is then converted to ammonium nitrate fertilizer.

This is achieved first by manufacture of nitric acid by oxidizing the anhydrous ammonia with atmospheric air over a platinum catalyst to provide
30 a mixture of nitrous oxides.

The nitrous oxides are then absorbed in water to form nitric acid.

These reactions may be represented as follows:

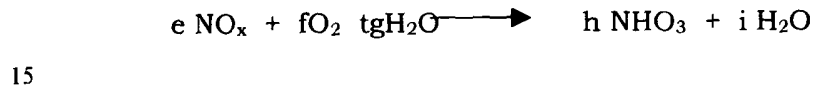


5 Where NO_x is a mixture of a number of species resulting from the variable valency of nitrogen

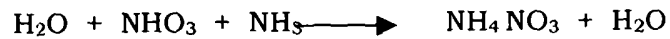
NO , NO_2 , N_2O , N_2O_{21} , NO_{31} , N_2O_3 etc, in various proportions.

10 b) Variable oxides of nitrogen (commonly termed NO_x) are then absorbed into water to form nitric acid.

This may be represented as:



The nitric acid so produced is then reacted against the anhydrous ammonia in order to produce ammonium nitrate as follows -



20 The ammonium nitrate so produced is typically de-sensitized by admixture with magnesium carbonate and prilled in a prilling tower.

The entire process is well known.

25 Manufacture of anhydrous ammonia by electrolysis of water was first commercially exploited in Norway. It is also carried out in Zimbabwe.

The manufacture of ammonia by means of the electrolytic decomposition of water is most attractive economically under the following circumstances.

30

- In regions where variable generation of electricity may not be exploited by reticulation to cities. In Norway hydro-electricity is to a considerable extent seasonal. Melting snow provides a source of hydro-electricity.

This electricity is effectively STORED by electrolysis of water, followed by conversion to ammonium nitrate.

- The process is also ideally suited to wind turbine electricity generation. As variable production of electrical power occurs both divinally and seasonally, all of the power may be utilized by electrolysis of water.

In the invention the electrolysis of water is the starting point for BOTH METHANOL SYNTHESIS and AMMONIUM NITRATE SYNTHESIS.

Because the production of methanol through the absorption of burning cellulose waste is seasonal, and application of ammonium nitrate fertilizer is also seasonal, but occurring at a different time, storage volumes of both cellulose raw material for methanol manufacture, and of ammonium nitrate fertilizer, may be reduced.

The manufacture of anhydrous ammonia by the electrolysis method is secondly suited to those regions where ammonium nitrate has, in the normal course of events, to be imported. This is because the economics of fertilizer application at any location is combinatorial – manufacturing costs of the ammonium nitrate make up (normally) the major portion of the overall cost structure, but transportation costs are significant.

In many regions transportation cost of the fertilizer makes up 30 – 40% of the total cost.

- **The Manufacture of Ammonium Nitrate Fertilizer Independently of the Carbon Cycle (continued)**

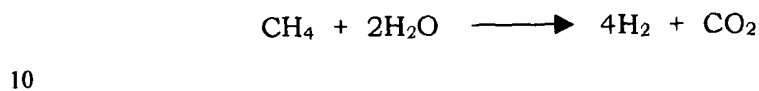
- Conventional Method of Manufacture of Anhydrous Ammonia.

Almost all of the ammonium nitrate fertilizer in the world is made using natural gas as a feedstock.

The hydrogen required for the reaction with nitrogen is supplied by a process known as STEAM REFORMATION.

5 In the process, methane gas is passed together with steam through a tubular reactor in the presence of a nickel catalyst

The reaction may be presented as follows:



Additional CO₂ is produced by endothermic burning of methane to power the endothermic reaction. The carbon dioxide produced is exhausted to atmosphere. The hydrogen is recovered and mixture with a stoichiometric proportion of nitrogen, compressed and passed over an iron catalyst to form anhydrous ammonia as described above.

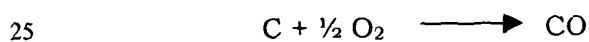
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Of the small proportion of ammonium nitrate that is not manufactured by this method, nearly all of the remainder is manufactured using coal as a reductant, to draw hydrogen gas from the water molecule.

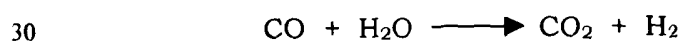
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The processes used to achieve this are as follows:

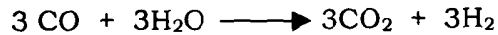
Firstly, the coal is gasified by partial oxidation with atmospheric oxygen.



This carbon monoxide is then SHIFTED with steam in an exothermic reaction to produce carbon dioxide and hydrogen gas.



Since 3 moles of hydrogen gas are required, this reaction may be alternatively styled.



5 It can thus be seen that considerably more carbon dioxide gas is exhausted to atmosphere when carbon (as typically coal, lignite or anthracite) is used to produce hydrogen gas by the reduction of water, than is produced by the natural gas reformation process.

Whichever process is used, the net result is that carbon dioxide is exhausted to atmosphere.

10

For the case of ammonium nitrate manufactured from natural gas, the following applies:-

15 1 mole of methane gas produces 2 ²/₃rds mole of anhydrous ammonia. However, some methane gas is used to drive the endothermic STEAM REFORMATION reaction.

As an approximation, therefore, 1 mole of methane gas produces 2 moles of anhydrous ammonia and 1 mole of carbon dioxide is produced.

20

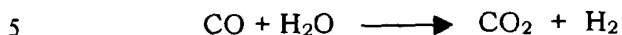
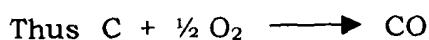
When ammonium nitrate fertilizer is produced, 2 moles of anhydrous ammonia are used, together with 1 mole of carbon dioxide waste product exhausted to atmosphere.

25 The molecular weight of ammonium nitrate is 80, and the molecular weight of carbon dioxide is 44.

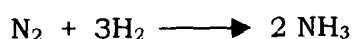
30 Thus, for each tonne of ammonium nitrate is produced, about 0.55 tonnes of carbon dioxide is exhausted to atmosphere, when natural gas is used as a feedstock.

When coal is used as a feedstock the quantity of carbon dioxide gas exhausted to atmosphere increases dramatically. In this case the

stoichiometric quantity of carbon dioxide produced is 1 mole for each mole of hydrogen produced.



Now three moles of hydrogen gas are required to produce 2 moles of anhydrous ammonia.



The quantity of carbon dioxide produced is 3 moles, according to the stoichiometry.

15 However, in industrial practice the chemical plant power requirements are also supplied by oxidation of coal, and, as an approximation 4 moles of CO_2 are employed to produce 2 moles of anhydrous ammonia.

Approximately 2.2 tonnes of carbon dioxide is exhausted to atmosphere, therefore, for each tonne of ammonium nitrate fertilizer produced.

20

TRANSPORTATION CONSIDERATIONS

Waste Cellulosic Material

25 For the waste cellulosic material to be economically converted to alcohol fuel by the method according to the invention, a number of synergetic economies must be made.

It must be, in the first instant, economically attractive for the maize farmer to 30 co-produce cellulosic material, with the grain including delivery costs.

For this to be a reality, the transportation costs of the cellulosic material to the methanol production facility must be lower than the price offered to the farmer for the collection and transport of the cellulosic material, per tonne produced.

A major economy will be realised if the cellulosic waste material is transported to the same storage depot as for the maize product.

5 For this to be achieved economically, compressed bales of cellulosic material would need to be produced by the farmer. These would be delivered simultaneously to the same depot as that utilized for grain conversion to ethanol fuel.

Ammonium Nitrate Fertilizer

10

The ammonium nitrate fertilizer will be produced at the same facility as that employed for manufacture of the methanol fuel, by the method according to the invention, and the ethanol fuel by the standard fermentation process.

15 Typically the cost of transportation of ammonium nitrate fertilizer makes up a significant proportion of its cost to the farmer.

As an example, the case of anhydrous ammonia produced at a coastal refinery, using a low opportunity value gas feedstock is taken.

20

This low opportunity value gas feedstock is used to produce anhydrous ammonia employing the normal gas REFORMATION technology described above, in world scale facilities employing economy of scale.

25 A low unit price of manufacture of the anhydrous ammonia is achieved, and F.O.B. factory gate the cost of the raw material is (say) approximately 20 - 0% lower than that using the method of electrolysis of water and atmospheric nitrogen.

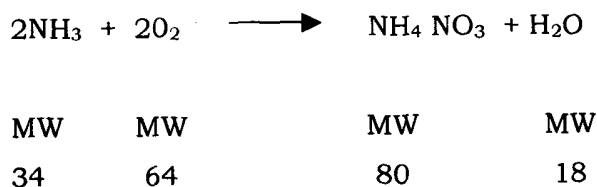
30 At this point the anhydrous ammonia must be converted to ammonium nitrate fertilizer and transported to the farmer.

Typically at this point a choice must be made whether to transport the raw material anhydrous ammonia to a fertilizer manufacturing plant in its

unconverted state, which involves transportation of a low tonnage, or to convert the anhydrous ammonia to ammonium nitrate fertilizer at (or close to) the site of the coastal refinery.

- 5 If the anhydrous ammonia is exported in its raw form, the tonnage to be transported is much lower. This is because the finished ammonium nitrate essentially comprises anhydrous ammonia with the addition of oxygen from the air.

10 Thus, stoichiometrically:



15

Since the ammonium nitrate also contains some water as a result of the manufacturing process, the weight to be transported is approximately three times that of the anhydrous ammonia raw material.

- 20 For transportation of the ammonium nitrate fertilizer use may be made of unspecialized transportation, whether it be by rail or road.

25 Anhydrous ammonia however, must be transported in specialized tankers purpose designated for the material. This increases the cost, to a level which dependant on particular circumstances, including the unit fixed and variable costs of conversion to the fertilizer at the transport terminus, will determine which of the two transportation options is employed.

30 According to the invention the ammonium nitrate fertilizer is co-produced with the methanol utilizing the same production front end, namely electrolytic cells producing hydrogen gas.

The anhydrous ammonia is thus produced at the same site as the methanol fuel is produced, and which is in the heartland of the farming area.

The anhydrous ammonia will be converted to ammonium nitrate fertilizer at the terminal, and transportation costs to the terminal will be zero.

- 5 The farmer will be able to collect ammonium nitrate fertilizer from the same terminus to which the cellulosic raw material and the grain is delivered.

Transportation costs will be minimized in general, and in specific instances will make the ammonium nitrate fertilizer competitive with fertilizer imports.

10

It is predicted in particular; that for the "corn belt" of the United States approximate cost parity will be achieved between electrolytically produced ammonium nitrate fertilizer and that produced by steam reformation of natural gas or refinery of gas, when transportation considerations are factored into the total cost.

15

Co-production of Methanol (Methyl Alcohol - CH₃OH), and Ethanol (Ethyl or Grain Alcohol - C₂H₅OH)

- 20 A number of synergies are evident if the METHANOL manufacturing facility is co-located with the ETHANOL manufacturing facility.

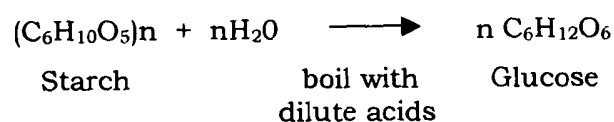
1. The major synergy insofar as the atmospheric carbon balance is concerned is in the conversion of the carbon dioxide exhausted by the fermentation process, to methyl alcohol.

25

In the conversion of starch to ethyl alcohol the following two essential processes occur.

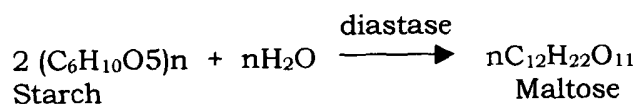
30 ONE

- The starch in the corn is converted to glucose. This may be achieved directly by boiling with dilute acid.



35

Alternatively, the starch may be first converted to maltose. This is typically achieved by adding crushed malt and maintaining the mixture at a temperature of 50 - 60° C. The starch is converted to maltose, or malt sugar by enzymic action. The enzyme involved is diastase.



10

The MALTASE in yeast converts the maltose to glucose.

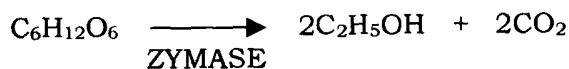


15

TWO

- Whichever method is employed to convert the starch to glucose, the glucose is now converted to ethyl alcohol, by the process known as fermentation.

20



25

As indicated by the stoichiometry of the reaction, the formation of ethyl alcohol is always accompanied by the release of carbon dioxide.

Stoichiometrically one third of the carbon fixed by photosynthesis is released back to the atmosphere as carbon dioxide.

30

It is this carbon dioxide, released by the fermentation process which may be captured and converted to METHANOL by the process of conjoining with electrolytic hydrogen.

35

To recap, the formation of methanol is achieved by production of hydrogen through the process of electrolysis of water.

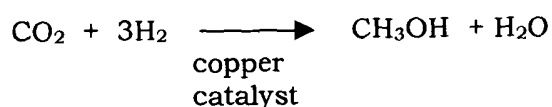
This hydrogen is mixed with the captured carbon dioxide and compressed to a pressure of 60 - 80 Bar.

3 moles of hydrogen are required for each mole of carbon dioxide.

The mixture is passed over a copper catalyst, supported on alumina, and a
 5 mixture of methanol and water is obtained. The catalyst selectivity is high, and
 essentially pure methanol is obtained (98%).

The major by products of the reaction are ethanol and propanol which make up
 most of the balance.

10



15 The water is distilled off by simple distillation, to obtain fuel grade methanol.

The carbon dioxide which is released by the fermentation process is captured by
 undertaking the fermentation in a closed vessel.

20 2. A second synergy that may be obtained is the drying and combustion of any
 carbon containing waste matter that results from the fermentation and
 associated processes, to produce carbon dioxide, by combustion. This
 material may then be converted to methanol fuel.

25 3. Blending facilities for both ethyl alcohol and methyl alcohol are located at a
 single site, as are primary storage tanks and road/rail tanker filling and
 weighbridge facilities.

PROVISION OF ELECTRICITY

30

The raw material with which the carbon dioxide, generated both by the
 fermentation process and by burning of waste cellulosic material, is combined is
 HYDROGEN.

35 The HYDROGEN is generated by electrolysis of water, which produces as a by-
 product, oxygen.

This is achieved in an electrolytic cell, in which purified de-ionized water, treated with a conductivity modifier, has a direct current passed through it between the ANODE and the CATHODE. The conductivity modifier is typically Potassium Hydroxide – the hydroxide is the same species as that which migrates to the ANODE. Hydrogen gas is produced at the cathode, which is then collected and compressed.

For the fixing of atmospheric carbon dioxide by the process of photosynthesis and the producing of alcohol fuel by both the fermentation process, and the process described by the invention to produce METHANOL, to represent a lowering of the total atmospheric carbon dioxide content, it is obvious that ELECTRICITY MUST BE GENERATED WITHOUT ITSELF PRODUCING CARBON DIOXIDE.

There are a number of methods in which this may be carried out, the chief of which are:-

- Thermo-nuclear electricity
- Hydro-electric power
- Wind turbine generated electricity
- Solar electricity, by heat production or photo-electric cells or both
- Oceanic/estuary tidal power.

The most effective power sources, from the point of view of the invention are those sources, which provide a steady power output, and which are dedicated to the alcohol production facility. This allows forward planning and also minimizes storage volumes of raw materials.

Suitability for Wind Turbine generation of Electricity in the Mid-West (Corn Belt) Region of the United States

The corn belt of the United States is in general a suitable region for the utilization of wind turbine generated electricity.

The so-called Mid-Western portion of the contiguous United States is climatically suitable for both the production of corn (maize) and “farming” of wind.

5 The major difficulty encountered with the exploitation of wind generated electricity is the continuously variable diurnal production rate, coupled with seasonal variation.

10 The combined alcohol production facility including ammonium nitrate fertilizer production capability will only be able to accommodate the variable electricity production rate through a combination of methods.

SUMMARY TO THE BACKGROUND OF THE INVENTION

In summary the following points are relevant:

- 5 • The quantity of carbon dioxide entering the atmosphere mainly from coal based power plants is of considerable concern.

This gas may be significant contributory factor in average global surface temperature increase, commonly known as "global warming",

10

- Methanol is the cheapest of the major liquid automotive fuels to synthetically manufacture from a carbonaceous feedstock. This is mainly as a result of the simplicity of the chemical facility required, resulting from the very high catalyst selectivity. Thus very nearly all of the synthesis gas is converted to methanol (approximately 98%), and the remaining reaction products are mainly ethanol and propanol which are simply added to the fuel-grade methanol.
- 15

Water is the reaction by-product.

20

- When methanol is manufactured from coal a significant quantity of carbon dioxide is exhausted into the atmosphere. However, this quantity of carbon dioxide is lower than that for the manufacture from coal of traditional automotive fuels, or of ethanol.

25

- Methanol and ethanol are entirely compatible with the four-stroke piston engines currently in use worldwide as petrol (spark ignition) and diesel (compression ignition) engines.

- 30 • The alcohol may be added as a blend to petrol or it may be used in its neat form.

In most respects, and particularly in terms of the efficiency and pollution characteristics, ethanol and methanol are superior to the traditional automotive

fuels petroleum and diesel, within the boundaries outlined in the Background above.

SUMMARY OF THE INVENTION

5

According to the invention carbon dioxide gas exhausted produced by burning agricultural cellulose/lignite waste is used as the raw material, to manufacture liquid fuel for use in automobiles, or for other uses.

10 Thus the carbon dioxide gas is, according to the invention, one of the raw materials for the production of liquid automotive fuel.

The other raw material for the production of the liquid automotive fuel is hydrogen gas.

15

The hydrogen gas is obtained from a breakdown of liquid water by means of electrolysis.

A fundamental premise of the invention is that the electrical power used to
20 electrolyse the liquid waste to produce hydrogen is generated by an energy source, which itself does not produce a carbon dioxide by-product. For most applications this energy source will arise from nuclear power stations, wind turbines, or hydroelectric power stations..

25

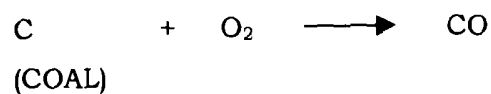
METHANOL MANUFACTURE: OUTLINE OF CHEMISTRY - BASIC STOICHIOMETRY

METHANOL MANUFACTURE - CARBON SOURCE COAL

5

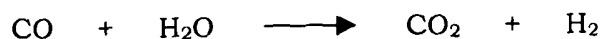
Manufacture Using Coal as a Feedstock

The basic reactions in a simplified form are as follows:

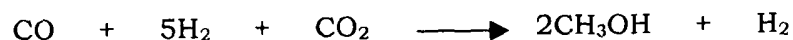


GASIFICATION

10



SHIFT REACTION

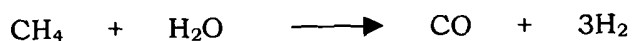


SYNTHESIS REACTION

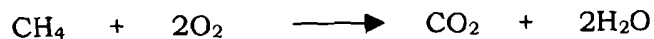
METHANOL MANUFACTURE - CARBON SOURCE NATURAL GAS

15

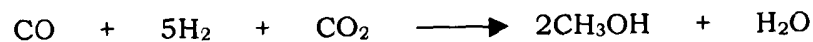
Manufacture Using Natural Gas (Methane) as a Feedstock



STEAM REFORMING REACTION



COMBUSTION OF METHANE



SYNTHESIS REACTION

20

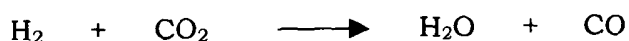
METHANOL MANUFACTURE - CARBON SOURCE AGRICULTURAL WASTE CARBON DIOXIDE

Manufacture Using Fossil Fuel Burning Power Station Exhaust CO₂ Gas as a Feedstock

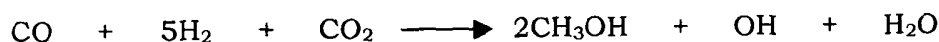
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ELECTROLYSIS OF WATER



REVERSE SHIFT REACTION



SYNTHESIS REACTION

10 **DISCUSSION OF BASIC CHEMISTRY**

Coal Process

When coal is used as a feedstock, carbon monoxide CO is formed by partial
15 oxidation, in the gasifier.

The hydrogen, H₂, is formed by reacting the carbon monoxide with water. This has the effect of reducing the water.

20 Part of the by-product of this reaction produces the carbon dioxide (CO₂) required for the synthesis reaction.

According to the basic stoichiometry of the process:

25 3 KG.MOLE of C is used for each KG.MOLE OF CH₃OH (METHANOL). Of this:

- 2KG.MOLE of C is used to make 2KG.MOLE of H₂
- 1KG.MOLE of C is used to make 1KG.MOLE of CO
- 1 KG.MOLE of CH₃OH is produced
- 30 • + 2 KG.MOLE of CO₂ is exhausted to atmosphere

Natural Gas Process

When natural gas is used as the feedstock to produce methanol the methane (CH₄) is reacted with steam (H₂O). This produces both the CO and the H₂ required for the reaction.

- 1 KG.MOLE of CH₄ and 1 KG.MOLE of H₂O produces 1 KG.MOLE of CO and 3 KG.MOLE of H₂
- 1 KG.MOLE of CH₃OH is produced from 1 KG.MOLE of CH₄
- 1 KG.MOLE of excess H₂ is produced
- (zero) 0 KG.MOLE OF CO₂ is exhausted to atmosphere

A portion of the natural gas is combusted to power the steam reforming reaction. This provides the carbon dioxide (CO₂) required.

15

Agricultural Waste Carbon Dioxide Process

When carbon dioxide is used as the carbon source for the process, hydrogen (H₂) is first produced by electrolysis of water (H₂O).

20

A portion of the hydrogen (H₂) is reacted against a portion of the carbon dioxide (CO₂) to form the carbon monoxide (CO) required for the reaction.

According to the basic stoichiometry of the process:

25

3 KG.MOLE of H₂O is electrolytically decomposed to form 3 KG.MOLE of H₂ and 1.5 KG.MOLE of O₂.

Of this:

- 1 KG.MOLE of H₂ is reacted with 1 KG.MOLE of CO₂ to produce, 1 KG.MOLE of CO
- 2 KG.MOLE of H₂ reacts with the CO so formed
- 1 KG.MOLE of CH₃OH is produced from 3 KG.MOLE of H₂
- + 1.5 KG.MOLE of oxygen is exhausted to atmosphere

30

- - 1 KG.MOLE of CO₂ is exhausted to atmosphere

In the waste carbon dioxide process, carbon dioxide that would be exhausted to atmosphere is consumed. Minus one KG.MOLE of CO₂ is produced per
5 KG.MOLE of methanol produced.

At present the only known visible method of fixing atmospheric carbon dioxide economically on a large scale remains the natural process of photosynthesis.

10 Alcohol fuel in the form of ethanol is manufactured from the products of photosynthesis, namely sugars and starches (carbohydrates).

A number of proposals have been mooted for conversion of the bagasse in sugar cane to fermentable sugars by the process of hydrolysis.

15

The hydrolysis of the cellulosic and lignitic material contained in the waste bagasse would be conducted in a weakly acidic environment at an elevated temperature (approximately 50-60°C).

20 Such proposals have until recently foundered on the issue of capital cost, since the best acid to use for the hydrolysis appears to be hydrochloric acid.

The cost of the reaction vessels required to undertake the hydrolysis is then prohibitive.

25

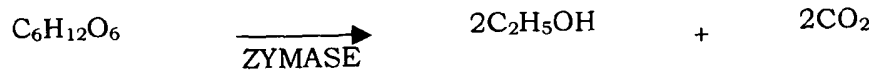
No doubt the re-evaluation of this technology will be undertaken as the financial pressure to locally produce automotive fuel in certain regions of the world, and the combination of environmental concern and economic affordability in other areas will promote deeper exploration into renewable resource fuel initiatives.

30

Be that as it may, a number of restrictions will still pertain to the production of ethanol by the hydrolysis/fermentation process:

- In the first place, fermentation, which is an organic process is always accompanied by the release of carbon dioxide as a by-product of the fermentation. Stoichiometrically the quantity of carbon dioxide released back to the atmosphere is fixed at one third

5



Thus, independent of process inefficiencies, one third of the carbon fixed by photosynthesis is released back into the atmosphere.

10

- In the second place, weak acid hydrolysis may be relatively easily constrained to break down soft cellulosic material, but less easily to break down harder lignitic (woody) material. There will thus always be a significant portion of the organic material that is not amenable to conversion to alcohol in this way.

15

- Thirdly, the process is relatively complex and is variable dependent on the nature of the raw material, be it (say) sugar cane bagasse, maize plant stems and cobs, or hay.

20

The technology that is under review, that is the conversion of carbon dioxide to methanol by reaction with electrolytically produced hydrogen, may be applied to the waste material after cropping of various agricultural produce.

25

For example, the waste material bagasse from sugar cane production, or the water material from maize production, namely the stalk, roots and cob, may be converted to methanol fuel economically in certain regions of the world by this method.

30

In combination with the carbon dioxide produced by burning the waste material, the waste carbon dioxide from the manufacture of ethanol could be captured and converted by the process into methanol.

As a result of the combination of the existing fermentation technology to

produce ethanol, with the “carbon skeleton” carbon dioxide reaction with electrolytically produced hydrogen to produce methanol, the quantity of alcohol fuel produced renewably by the photosynthetic fixing of atmospheric carbon dioxide will be increased manifold.

5

As an example of the increase in the quantity of organically produced alcohol that would result, were this technology to prove economically viable, ethyl alcohol production from the mid-Western States of the United States of America is semi-quantitatively explored.

10

INCREASE IN ORGANICALLY PRODUCED ALCOHOL FROM THE MID-WESTERN STATES OF THE UNITED STATES OF AMERICA

15

Use of Technology to Combine Carbon Dioxide Gas with Electrolytically Produced Hydrogen to Manufacture Methanol

Basis

20

- Ethanol is produced by conversion of the starch in maize to fermentable sugars, followed by fermentation.
- 42% of the maize plant by dry mass comprises the grain, 58% by dry mass cellulosic and lignitic material with the general formula $(C_6H_{10}O_5)_n$.

25

Assumptions

30

- 30% of the current crop is converted to ethanol.
- 40% of the waste cellulosic/lignitic material is converted to silage for cattle at present, and is not available for conversion to alcohol fuel.
- Methanol synthesis stations will be co-located with ethanol synthesis stations in order to capture carbon dioxide exhausted by the fermentation process.

35

- A cash credit is given to the farmer for disposal of waste cellulosic material, to cover transportation costs and provide economic incentive to supply the alcohol fuel stations with the carbonaceous material.

5 **Current Conversion of the Atmospheric Carbon Dioxide Fixed by Photosynthesis to Alcohol Fuel (Ethanol Only)**

$$\begin{aligned}
 &= 0.3 \quad (\text{proportion of crop currently converted to ethanol}) \\
 &\quad \times \\
 &\quad 0.42 \quad (\text{proportion of maize plant that comprises the grain}) \\
 &\quad \times \\
 &\quad 0.66 \quad (\text{proportion of carbon retained - one third is lost in the fermentation process}) \\
 &= 0.084 \quad (8.4\%)
 \end{aligned}$$

10 **Projected Conversion of the Atmospheric Carbon Dioxide Fixed by Photosynthesis to Alcohol Fuel (both Methanol and Ethanol)**

Part A: Waste carbon dioxide from the fermentation process to produce ethanol. This carbon dioxide is converted to methanol

15 $0.3 \times 0.42 \times 0.33 = 0.042$

Part B: Cellulosic material converted to methanol

20 $0.6 \times 0.58 = 0.348$

Part C: Ethanol produced by fermentation of sugars produced from breakdown of starch

25 $0.3 \times 0.42 \times 0.66 = 0.084$

Total A + B + C = 0.474

5 These figures indicate that the increase in carbon dioxide capture from a renewable resource is increased by a factor of 5.65 (approximately a sixfold increase), with no increase in the area of land under monoculture, and without specifically impinging on the current balance between agricultural produce earmarked for food and that for fuel.

10 The increase in fuel produced is, however, greater than this on a volumetric basis, since the specific gravity of the ethanol and methanol is the same (0.79 at 25°C), but only 1 mole of CO₂ is required for each mole of methanol and 2 moles for each mole of ethanol.

Thus in terms of litres of alcohol fuel produced, the increase is approximately by a factor of 7.5.

15 On a calorific value basis, which is probably the best way to approach the multiplication factor, the increase in fuel production is by a factor of about 6.2 or 620%.

METHANOL MANUFACTURE - EXISTING PROCESS - COAL FEEDSTOCK

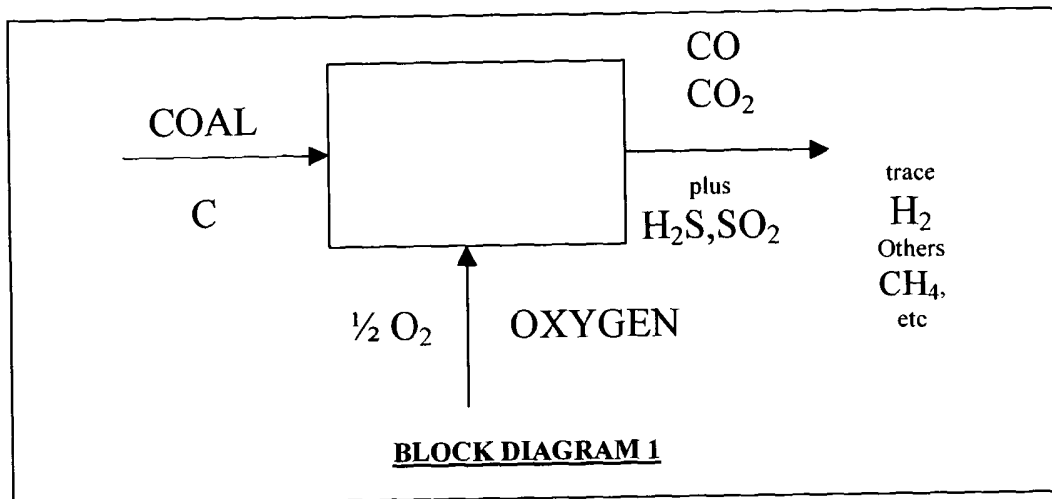
TECHNICAL DESCRIPTION

5

In the normal production of methanol using a coal feedstock, the coal is first GASIFIED to produce mainly carbon monoxide (CO). Unwanted by-products are, typically, hydrogen sulphide (H₂S) or sulphur dioxide (SO₂), (dependent on gasification temperature), and carbon dioxide (CO₂).

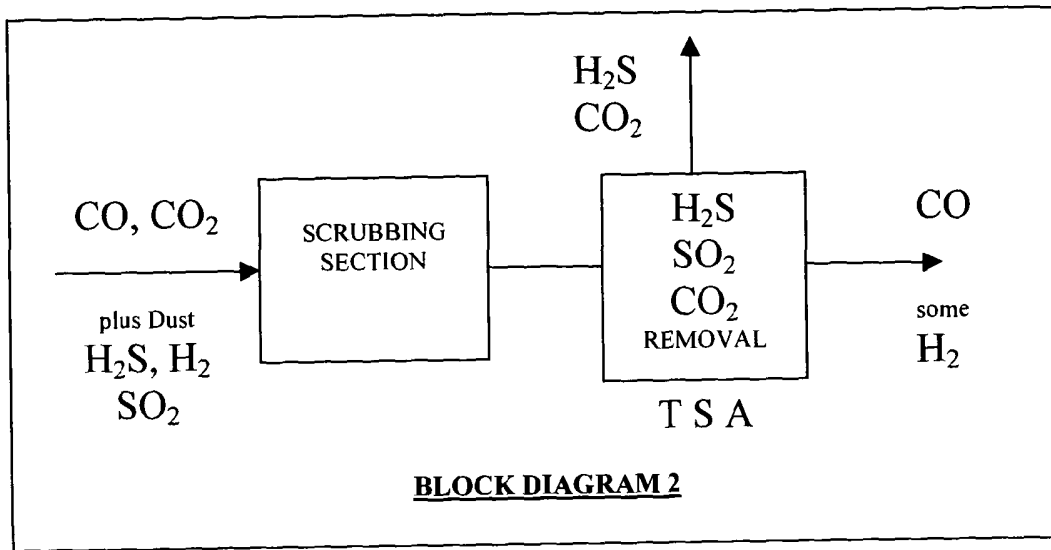
10

Step One

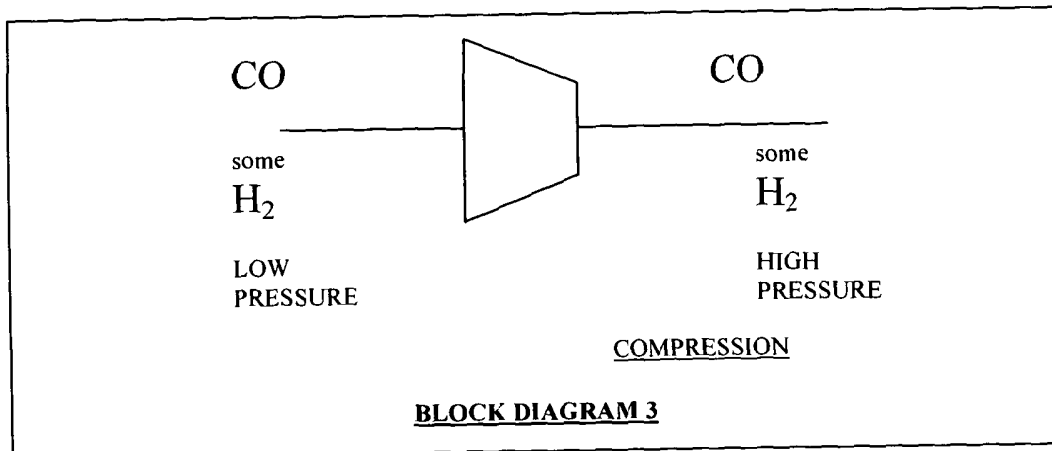


Step Two

15 In a second step, this gas stream is typically washed clean of dust and the unwanted carbon dioxide and hydrogen sulphide are then removed. The removal of the carbon dioxide and hydrogen sulphide is typically achieved by a process known as temperature swing adsorption (TSA).

**Step Three**

In a third step the CO gas is compressed to a pressure level suitable for the SHIFT REACTION and the METHANOL SYNTHESIS REACTION.



5

Step Four

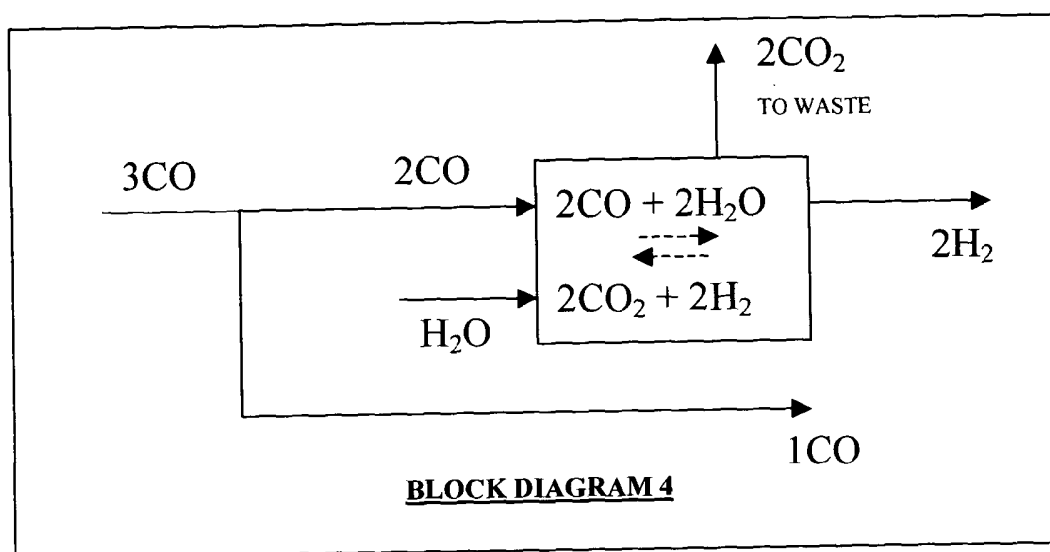
In the fourth step the hydrogen for the reaction is generated by the reduction of water in a process known as the SHIFT REACTION.

- 10 Approximately two thirds of the carbon monoxide (CO) gas stream is diverted to the SHIFT REACTOR, and one third is used to provide the carbon source for the SYNTHESIS REACTION.

In this reaction water is reduced by the action of the reducing agent, which is carbon monoxide.

The waste product of this reaction is carbon dioxide which is exhausted to the atmosphere.

The product of this reaction is hydrogen.



Step Five

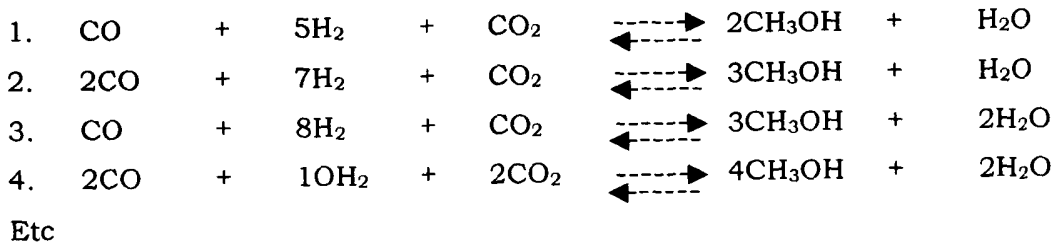
In the fifth step the synthesis gas is proportioned and then directed into the SYNTHESIS REACTOR. The reaction typically takes place at 50 - 90 BAR. Some carbon dioxide is added to the synthesis gas stream to cool down the reaction by the reverse shift reaction. This prevents catalyst sintering and extends catalyst life

15

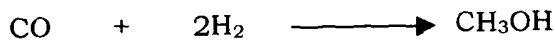
The gas is typically added to the METHANOL SYNTHESIS REACTOR at the top of the reactor, and at two or more further intermediate stages to allow the reaction to progress, which would otherwise be stopped by equilibrium considerations. The reaction is exothermic and the intermediate gas injection, called quench injection, lowers the temperature and moves the gas mixture away from equilibrium, allowing methanol formation.

20

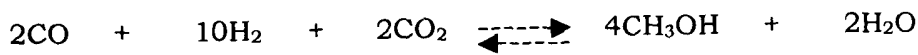
A number of reactions occur in the synthesis reactor, which may typically be represented as:



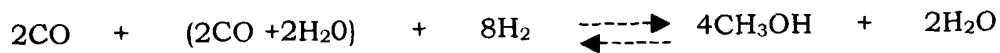
- 5 These reactions are all essentially equivalent to the same reaction, namely,



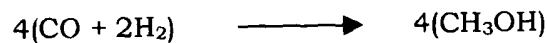
once the reverse shift reaction is accounted for. Thus, for example, in 4 above



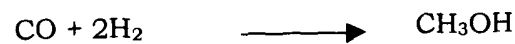
could equally be written



When water is removed from both sides of the equation the following results:



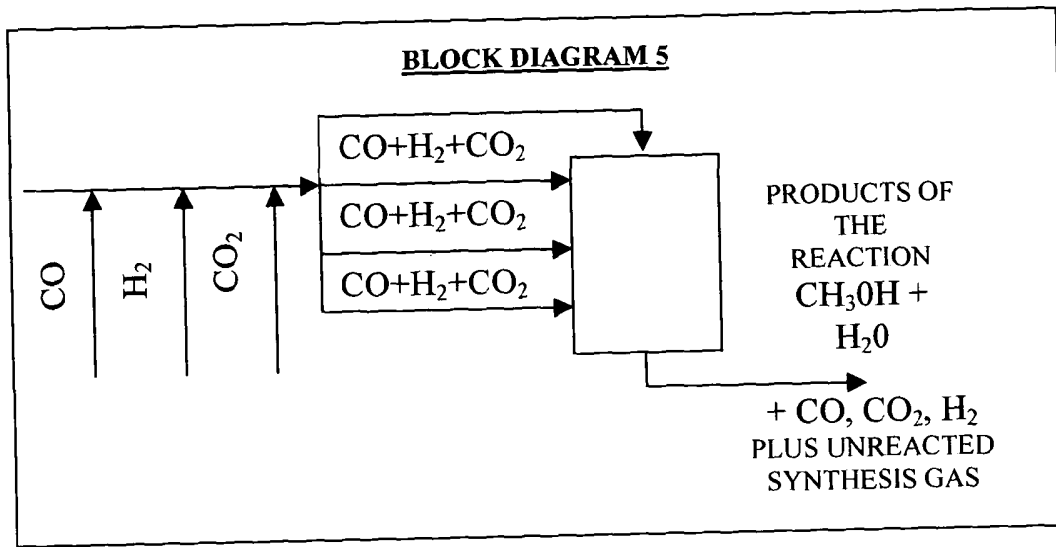
- 10 or



Thus the effect of adding carbon dioxide is to increase the quantity of water by-product of the reaction.

- 15 The actual quantity of methanol produced remains unchanged.

The methanol synthesis reactor is equipped with a recycle compressor.

**Step Six**

In the next step the product stream is cooled down to condense out the methanol and the water.

5

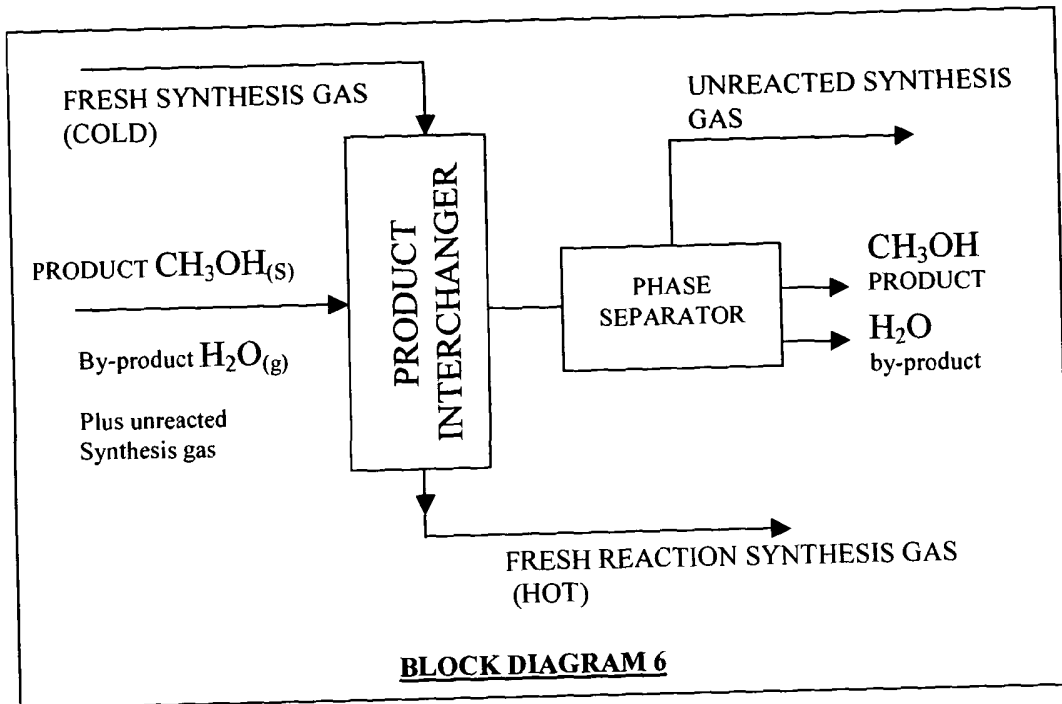
This is typically conducted in a heat exchange known as an interchanger, against the incoming fresh synthesis gas, which requires heating up.

The liquid methanol product and by-product water are condensed and recovered.

10

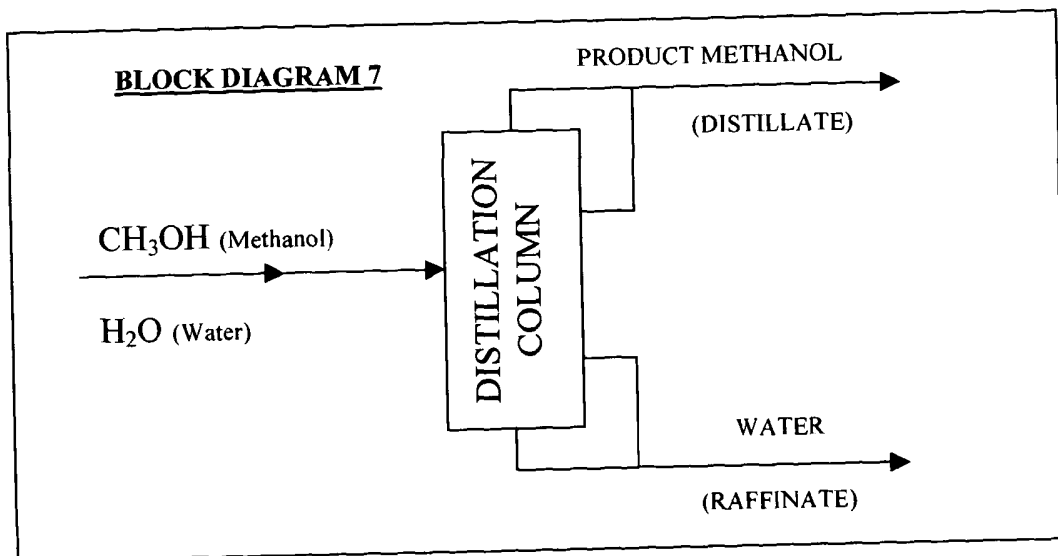
The unreacted synthesis gas is mixed with the fresh hot synthesis gas and passed to the recycle compressor. This compressor ensures that the reactants are maintained at the correct pressure.

15

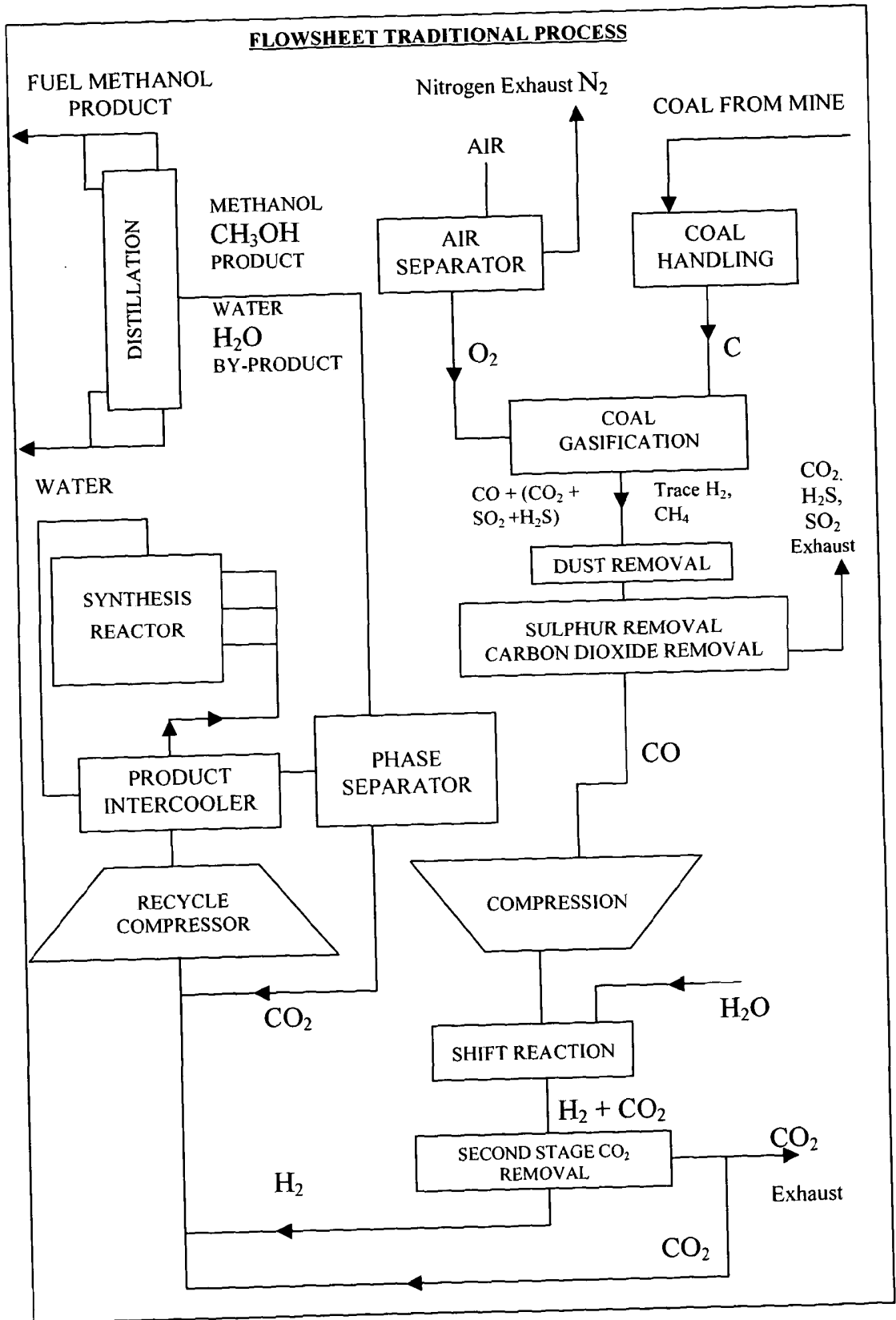
**Step Seven**

The products of the reaction which are essentially pure methanol (the reaction is approximately 98% selective to CH_3OH as product) and water are distilled to provide fuel grade methanol by coarse distillation.

The water by-product is purified for recycling within the process.



The combined process flow scheme is illustrated overleaf as a block diagram.



In the manufacture of methanol using a coal feedstock, the following points should be noted.

- After the gasification section three kilogramme.moles of carbon monoxide are produced for each kilogramme.mole of methanol that is produced for sale.

The other two kilogramme.moles (kg.moles) of carbon monoxide are used to reduce water and thereby produce hydrogen gas (H₂ gas) by the shift reaction



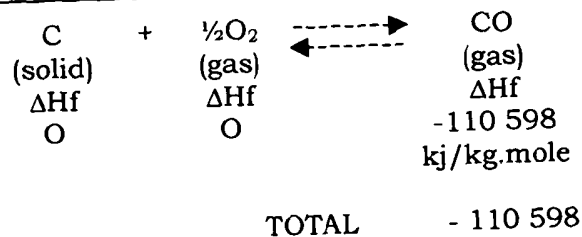
In this reaction, the CO₂ gas is exhausted to the atmosphere, contributing to the global increase in Carbon Dioxide levels.

Only one third of the carbon that is processed into Carbon Monoxide in the gasification section is incorporated into the product methanol, and only about a quarter of the carbon (or coal) feedstock is incorporated into the final product as a result of unavoidable process inefficiencies, including the gasifier efficiency.

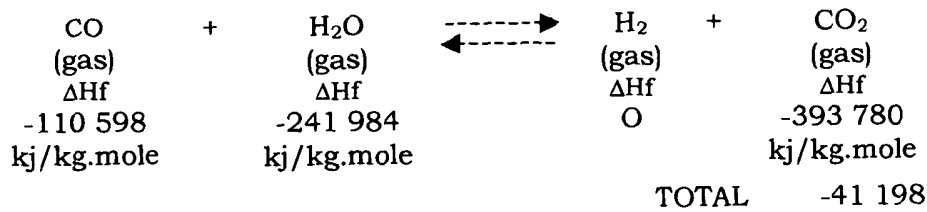
- The majority of the coal (Carbon) is therefore used as a method of splitting the water molecule (H₂O) using CHEMICAL ENERGY.

- In the process for the manufacture of methanol from a coal feedstock, the following major reactions occur. The heats of formation are shown below each:

A. GASIFICATION REACTION



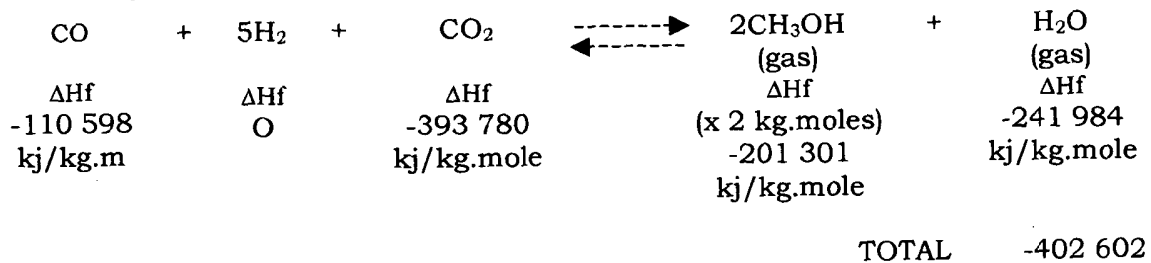
This reaction is strongly exothermic.

B. SHIFT REACTION

The reaction is weakly exothermic.

C. SYNTHESIS REACTION

5 This may be typically represented by the following:



This reaction is strongly exothermic.

METHANOL PRODUCTION PROCESS EMPLOYED BY THE INVENTION

10 According to the invention, carbon dioxide exhaust, typically from cellulosic/lignitic agricultural waste, is used as the carbonaceous raw material for the manufacture of methanol.

15 The carbon dioxide will typically be diluted with a large amount of excess air used for combustion, and will contain a significant quantity of particulate matter, as well as sulphur containing compounds, mainly Sulphur Dioxide.

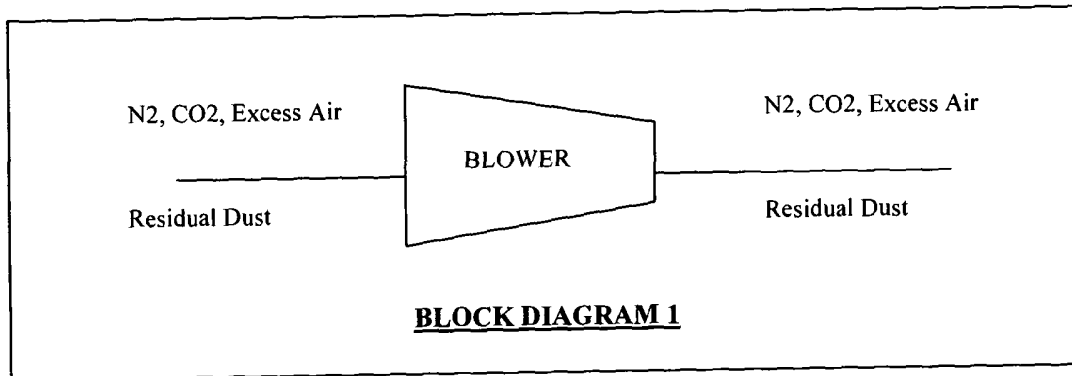
The gas collection point should be situated after the normal dust collection units, that is after the bag filters or electrostatic precipitators

20

The carbon source is useless as a reducing medium, since it is fully oxidised. It is entirely ineffective in its normal role as a reactant, and cannot be used to undertake the formation of hydrogen gas by capturing oxygen from the water molecule.

Step One

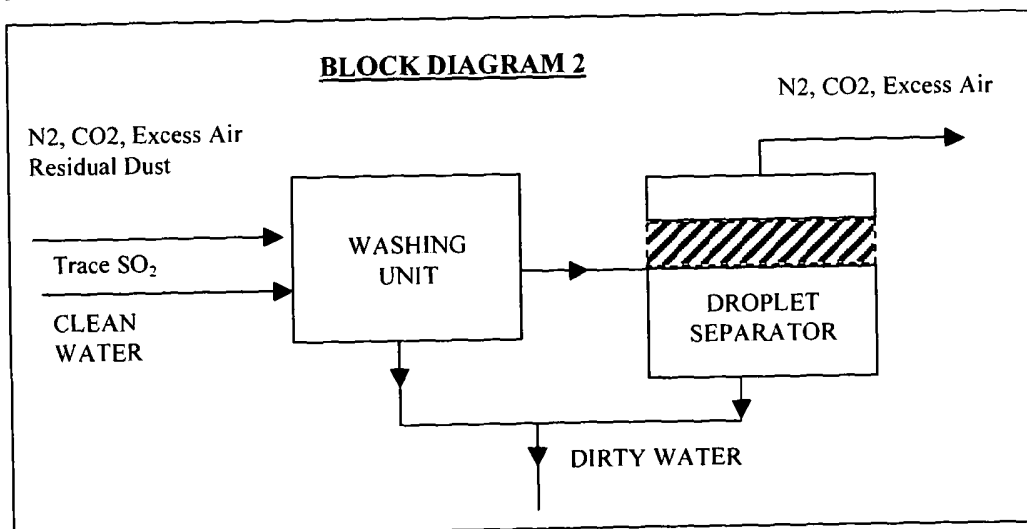
In the first step of the process, the carbon dioxide gas, which is mixed with a large quantity of excess air and nitrogen, together with some sulphur containing compounds and residual dust is raised in pressure by a few inches water gauge (inches wg) in order to pass it through the WASHING UNIT. This is achieved by using a BLOWER.

**Step Two**

The Carbon Dioxide gas stream is now passed through a WASHING UNIT to remove the residual dust. This unit will typically comprise a set of water spray nozzles situated along the diameter of a venturi pressure recovery constriction.

A number of venturis may be placed in series.

Following from this wash, the gas, which is saturated with water is passed through a DROPLET SEPARATOR to remove dirty water droplets, using a physical separation method.



Step Three

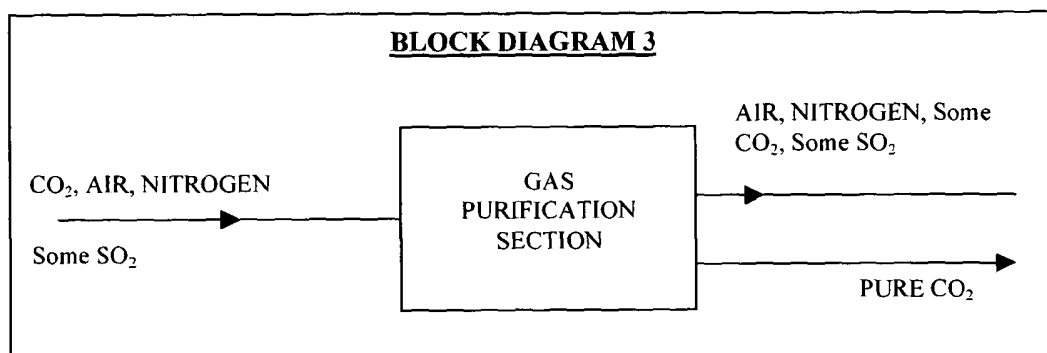
The carbon dioxide stream, which is now substantially free of dust, but which contains N₂, Air and some Sulphur containing compounds, typically SO₂, is now processed in order to provide a source of pure Carbon Dioxide (CO₂). This is achieved in the GAS PURIFICATION SECTION.

This typically comprises a temperature and/or pressure swing adsorption unit. A number of proprietary technologies are available to achieve this.

10 The residual SO₂ and other impurities are removed from the CO₂ stream at this stage.

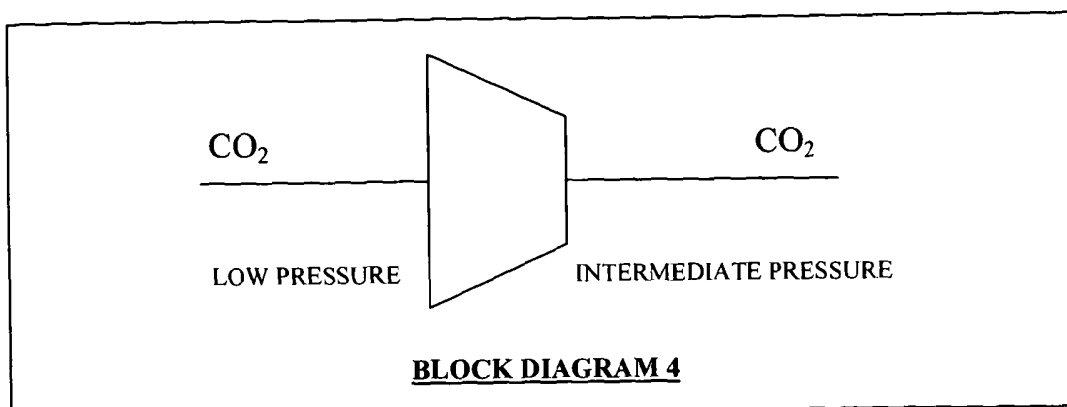
Refrigeration of the adsorbent liquid may be required at this stage.

15 If pressure swing adsorption is used, the exhaust comprising mainly excess air and nitrogen may be passed through a turbine in order to economize on compression costs.

**Step Four**

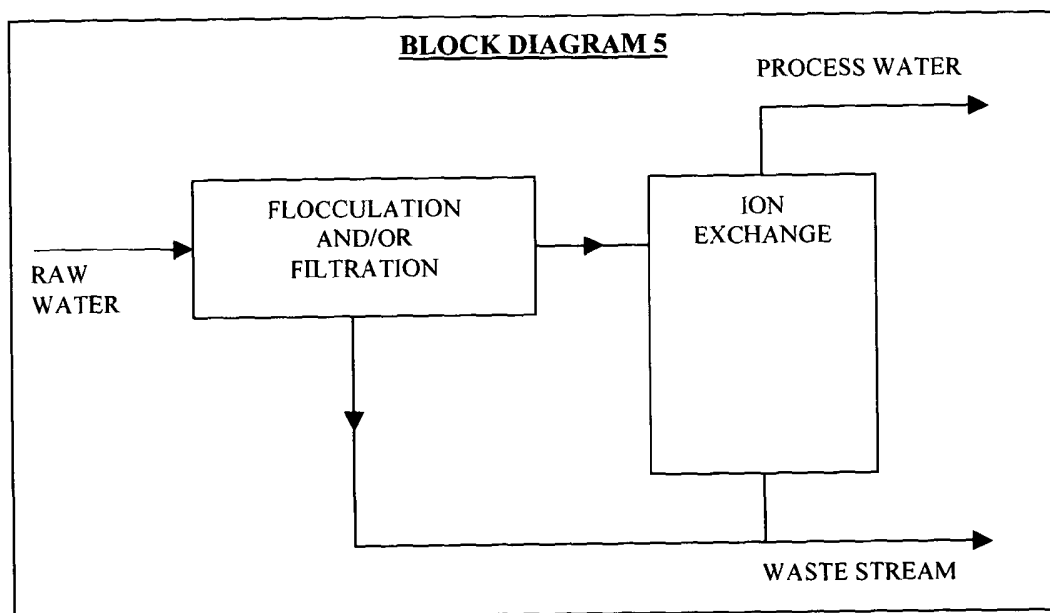
20 The pure carbon dioxide (CO₂) is now compressed prior to the REVERSE SHIFT REACTION.

Typically this will take place at about 50-90 BAR.

**Step Five**

In another section of the methanol facility HYDROGEN GAS is prepared by
5 electrolysis of water.

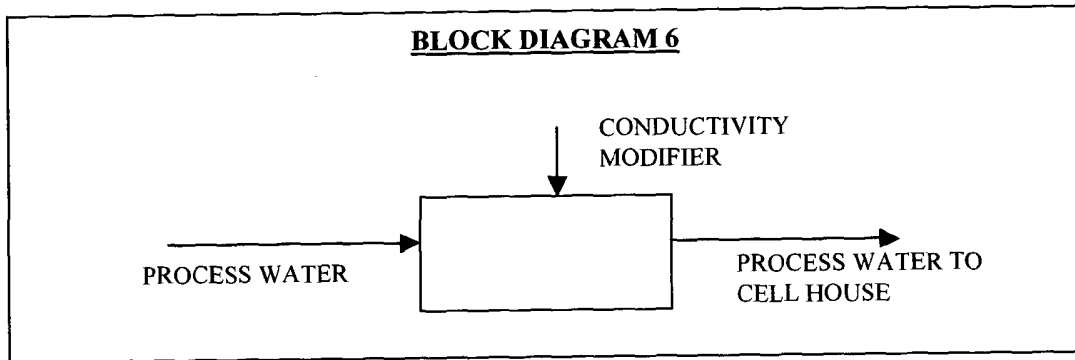
Raw material WATER is purified by filtration followed by removal of electrolytic
impurities, typically salts of various trace elements, as well as dissolved
carbonates, etc. The removal of ionic species is typically conducted in an ION
10 EXCHANGE TOWER.



Step Six

The process water is now treated with a CONDUCTIVITY MODIFIER, which optimises the electricital efficiency of the electrolyte cells. This is typically potassium hydroxide.

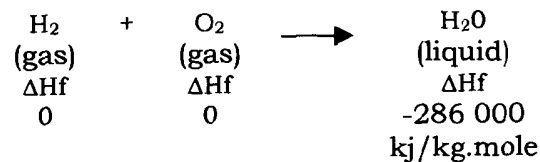
5

**Step Seven**

The process water is now electrolysed to produce HYDROGEN GAS. This is essentially the core of the entire process.

10

A very large amount of electrical energy is required at this stage, since water is a stable molecule and has a highly negative heat of formation as follows:

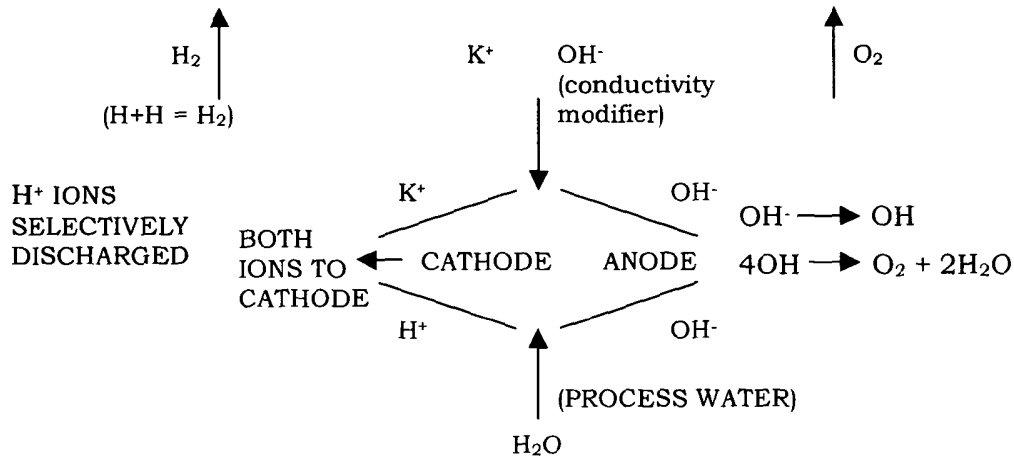


15 As well as employing a very large power input, the cell house will be physically very large in extent, and will require a considerable input of construction material.

20 Nevertheless, the technology is well known and proprietary electrolytic cells are available from a number of vendors.

The function of the electrolytic cell is to break down the water molecule by the action of ELECTROLYSIS.

The basic process of ELECTROLYSIS OF WATER is described in outline below:



The product HYDROGEN is generated at the CATHODE and is captured as the raw material for the process.

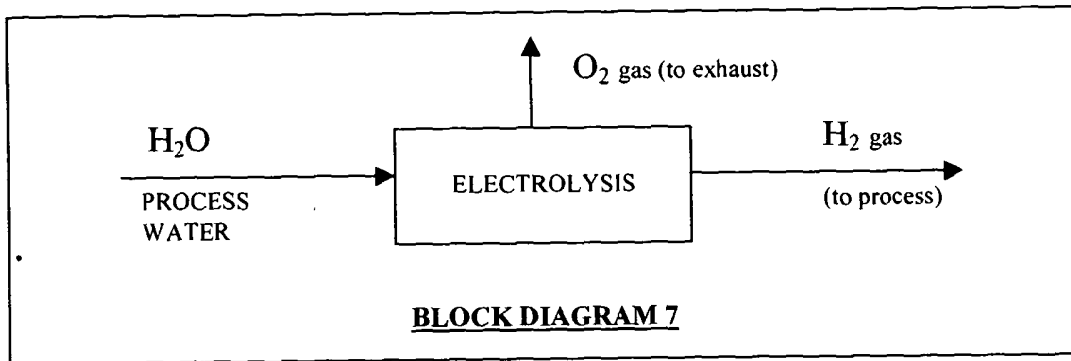
The by-product OXYGEN is generated at the ANODE, and, because it will be produced in quantities too large for commercial exploitation, will mainly be exhausted into the atmosphere. For electrolysis units conjoined to coal based power plants, the oxygen may be used to reduce excess combustion air and lower residual waste carbon in the ash.

Some oxygen may be removed for commercial sale.

The amount of electrical energy is extremely large, and is typically generated using a THERMO-NUCLEAR POWER STATION for large projects involved with traditional liquid fuel displacement.

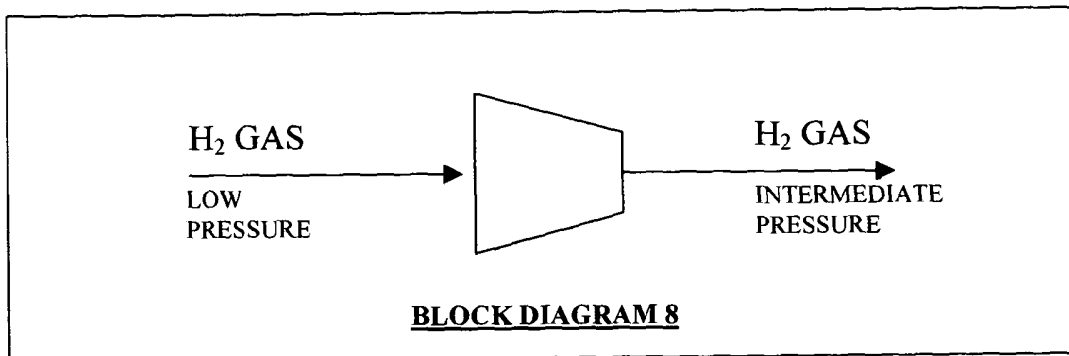
For the generation of 1 KG.MOLE PER SECOND of hydrogen gas at the cathode of the (combined) electrolytic cell, assuming a 5% efficiency loss in conversion of electrical energy to chemical energy requires an electrical input of about 300 MEGAWATTS.

Thus 2 kg mass of hydrogen generation per second requires 306 MW of electrical power.

**Step Eight**

The hydrogen gas produced by the ELECTROLYTIC cell is collected and compressed, in a first stage compression, to enable reaction against the purified and compressed CARBON DIOXIDE.

5

**Step Nine**

The purified and compressed CARBON DIOXIDE is now reacted against the HYDROGEN gas to produce the CARBON MONOXIDE gas required for the synthesis reaction.

10

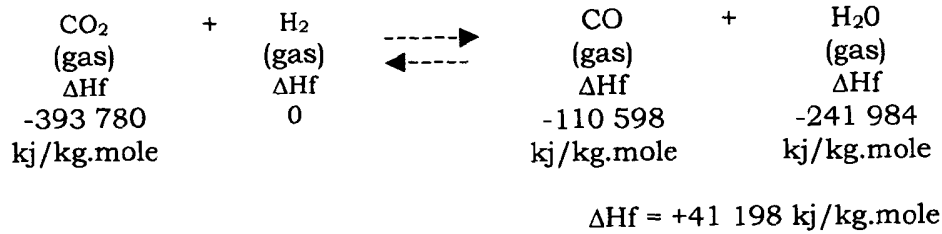
Approximately one sixth of the HYDROGEN GAS stream is directed, along with approximately half of the CARBON DIOXIDE gas stream, into the REVERSE SHIFT REACTOR.

15

These proportions will vary somewhat dependent on the catalyst type, the operating pressure of the SYNTHESIS REACTION, and the quench gas injection arrangement around the reactor.

20

The heats of formation of the REACTANTS and PRODUCTS involved in the REVERSE SHIFT ACTION are as follows:



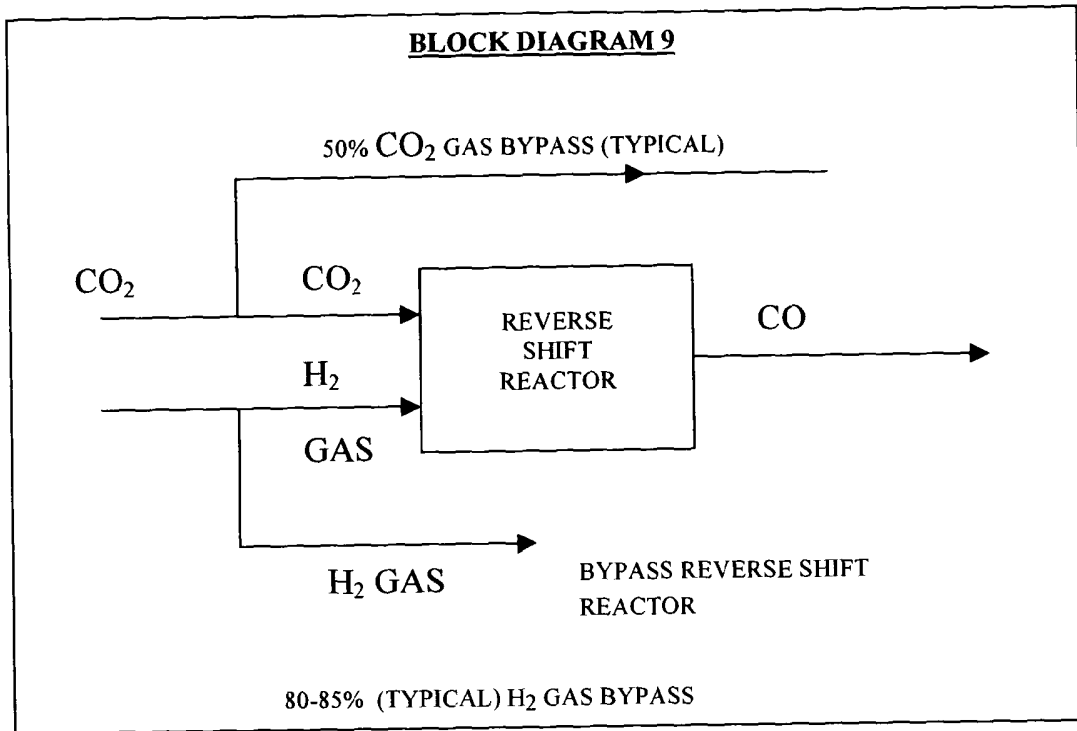
- 5 There is thus a net positive heat of formation according to HESS'S LAW OF CONSTANT HEAT SUMMATION.

The process will absorb approximately 41.2 MW of power per KG.MOLE of Hydrogen consumed to form CARBON MONOXIDE.

10

However, since only a relatively small portion of the HYDROGEN generated by the electrolytic cells is involved in the REVERSE SHIFT REACTION, this does not amount to a significant heat input.

- 15 Thermodynamic integration of the entire methanol manufacturing process will allow the REVERSE SHIFT REACTION endothermic power input to be transferred from the SYNTHESIS REACTOR by heat exchange, in typical energy integration schemes.

**Step Ten**

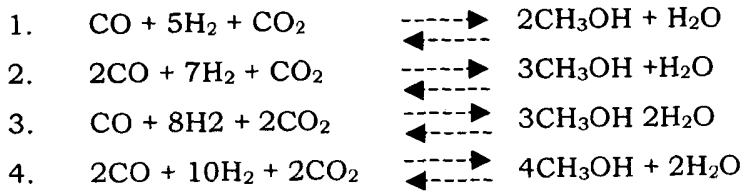
(Note: The following steps are as for the coal based flowsheet.)

- 5 In the tenth step the synthesis gas is proportioned and then directed into the SYNTHESIS REACTOR. The reaction typically takes place at 50 – 90 BAR. Some carbon dioxide is added to the synthesis gas stream to cool down the reaction by the reverse shift reaction. This prevents catalyst sintering and extends catalyst life

10

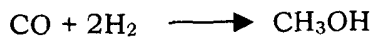
- The gas is typically added to the METHANOL SYNTHESIS REACTOR at the top of the reactor, and at two or more further intermediate stages to allow the reaction to progress, which would otherwise be stopped by equilibrium considerations. The reaction is exothermic and the intermediate gas injection, called quench injection, lowers the temperature and moves the gas mixture
- 15 away from the equilibrium, allowing methanol formation.

A number of reactions occur in the synthesis reactor, which may typically be represented as:

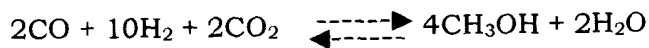


Etc....

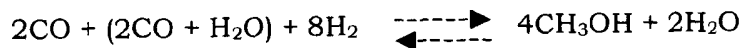
- 5 These reactions are all essentially equivalent to the same reaction, namely,



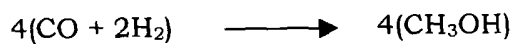
once the reverse shift reaction is accounted for. Thus, for example, in 4 above



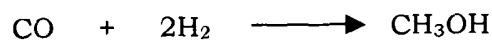
could equally be written



When water is removed from both sides of the equation the following results:



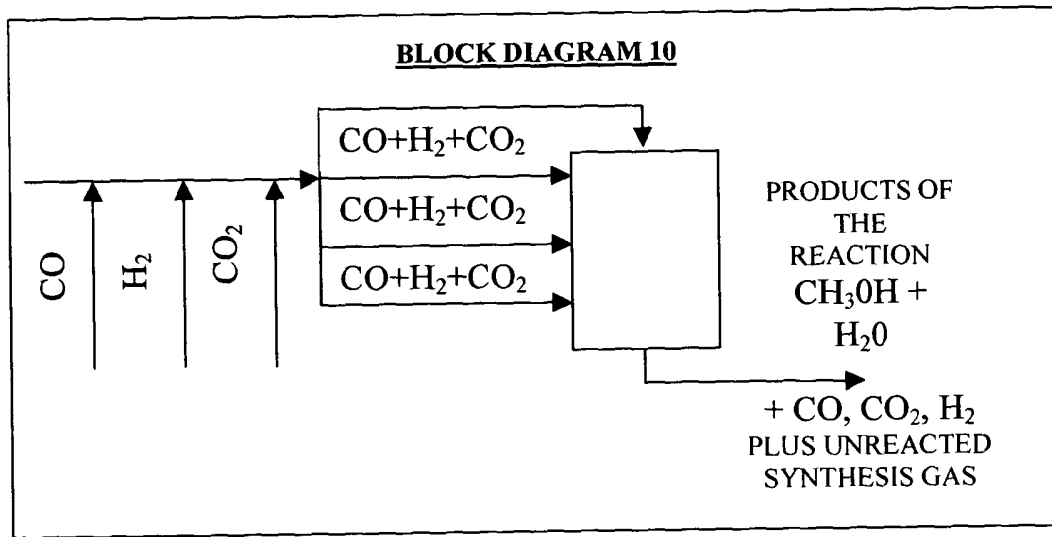
10 or



Thus the effect of adding carbon dioxide is to increase the quantity of water by-product of the reaction.

- 15 The actual quantity of methanol produced remains unchanged.

The methanol synthesis reactor is equipped with a recycle compressor.

**Step Eleven**

In the next step the product stream is cooled down to condense out the methanol and the water.

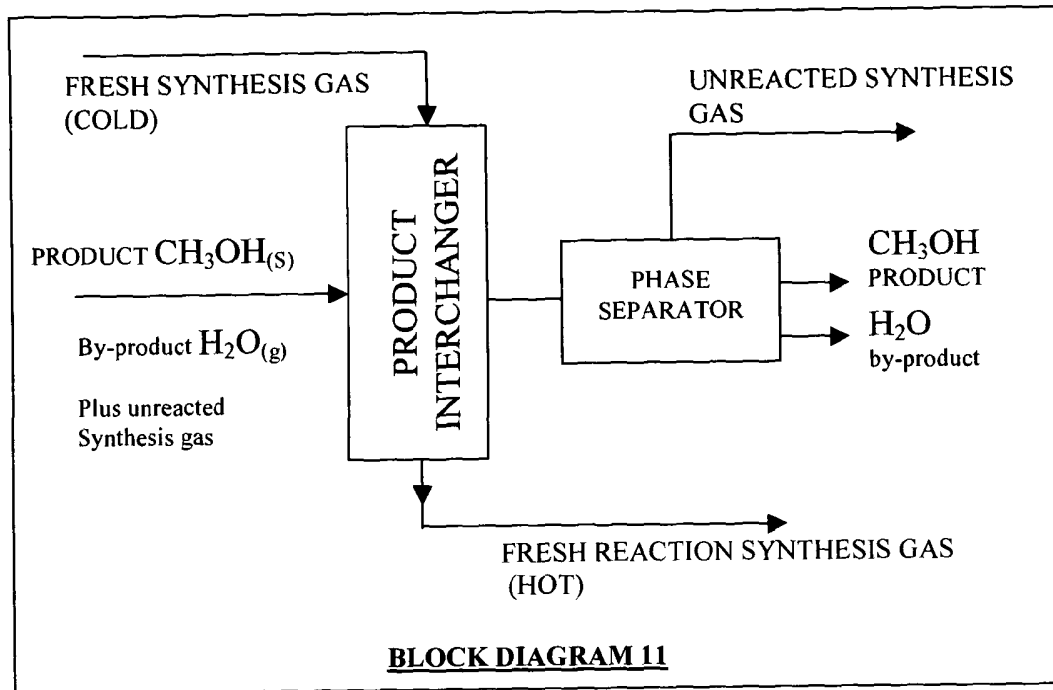
5

This is typically conducted in a heat exchange known as an interchanger, against the incoming fresh synthesis gas, which requires heating up.

The liquid methanol product and by-product water are condensed and recovered.

10

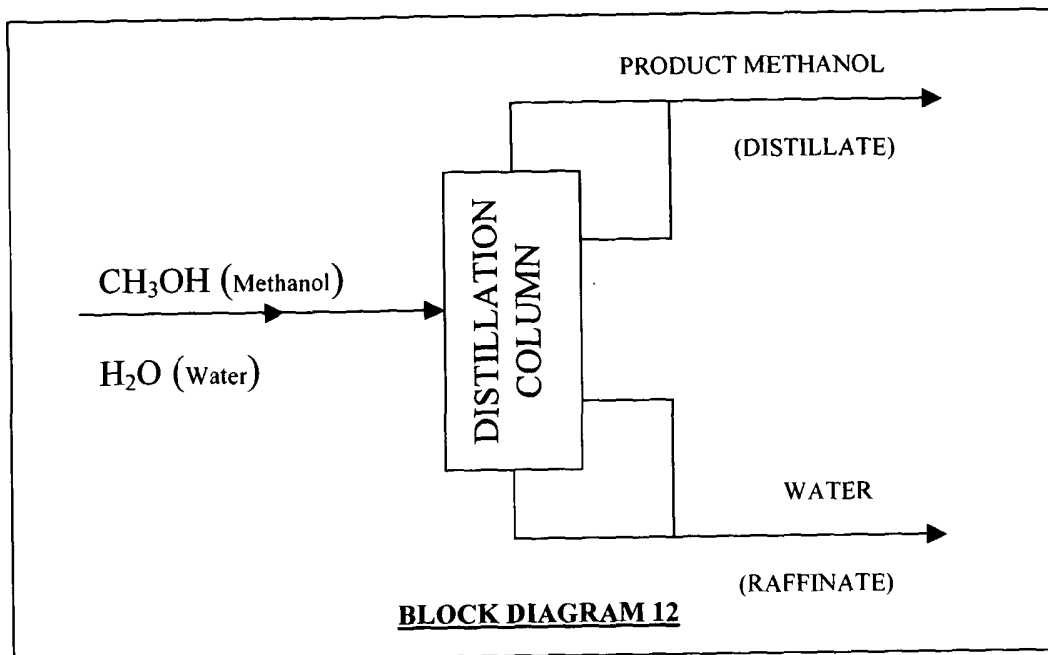
The unreacted synthesis gas is mixed with the fresh hot synthesis gas and passed to the recycle compressor. This compressor ensures that the reactants are maintained at the correct pressure.



Step Twelve

The products of the reaction which are essentially pure methanol (the reaction is approximately 98% selective to CH_3OH as product) and water are distilled to provide fuel grade methanol by coarse distillation.

The water by-product is purified for recycling within the process.

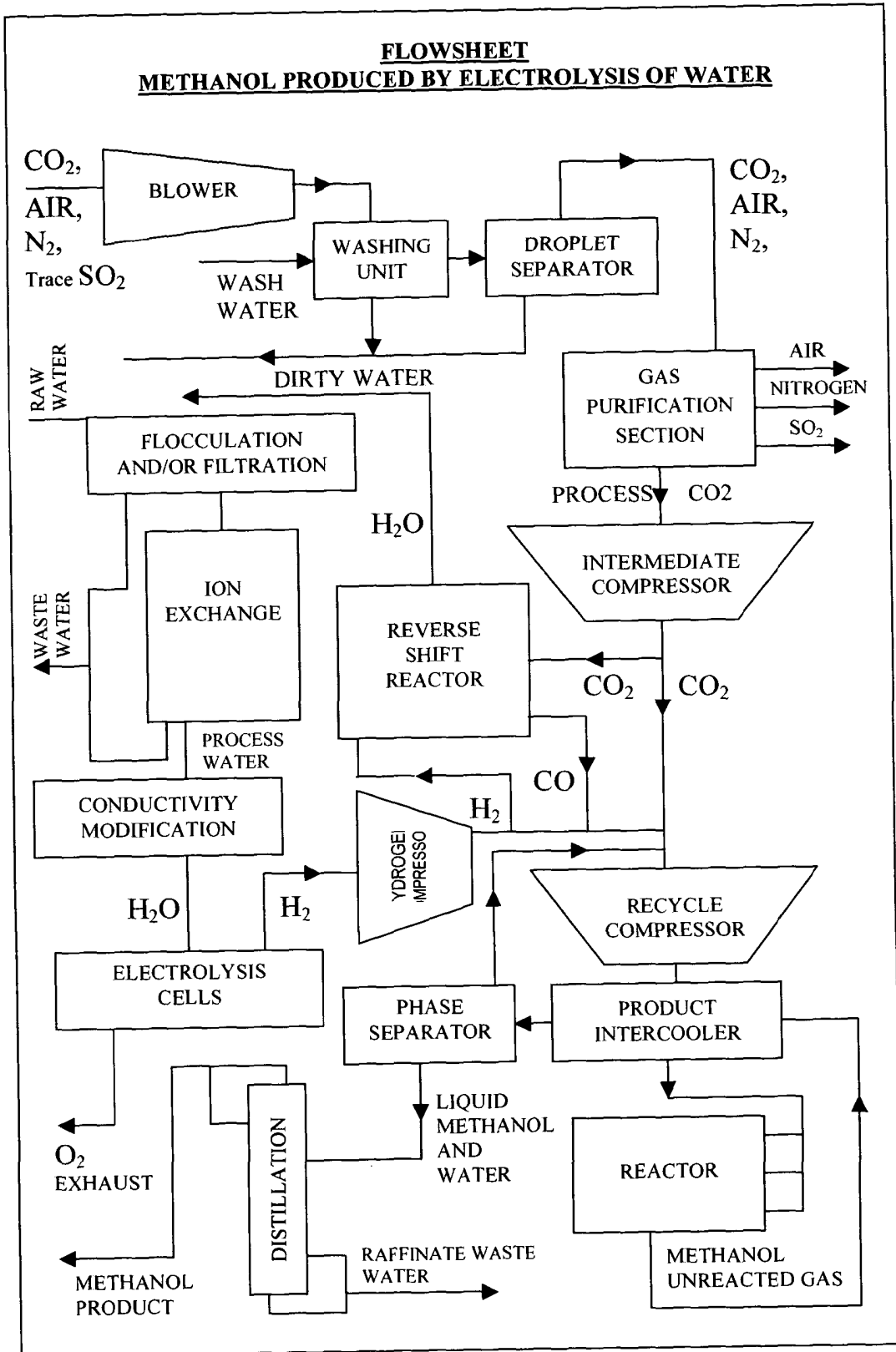


The combined process flow scheme is illustrated below as a block diagram.

In the manufacture of methanol using wind, hydroelectric or nuclear generated
 5 electricity to electrolyse water and produce hydrogen gas, the following points
 are relevant:

- The raw material carbon takes the form of Carbon Dioxide (CO₂).
- The only other raw material for the manufacture of methanol is water. After
 10 purification and conductivity modification, the raw material water is
 electrolysed to produce hydrogen.
- The major effluent from the plant is oxygen which is released to the
 atmosphere.
- From an economic viewpoint the following salient features emerge:
 - The raw materials for the process, Carbon Dioxide and Water require a
 15 relatively basic cleanup prior to processing.

From an economic point of view the two major traditional ways of producing
 methanol are compared with the nuclear electrolysis method as an overview.



METHANOL FROM COAL

(Raw Material – Coal)

Raw material is low opportunity cost, high ash coal. (Limited export potential).

5

The cost of coal mining, coal beneficiation and handling, coal gasification and ash disposal is high. This represents approximately 50% of the capital cost input.

10 Other variable costs are low.

Fixed costs (Maintenance and Personnel) are relatively high as a result of the high proportion of solids handling equipment and gasifiers which are in general high maintenance items.

15

The process of converting low value coal to high value methanol is typically referred to as a HIGH VALE ADDED operation.

METHANOL FROM NATURAL GAS

20 (Raw Material – Typically Natural Gas)

Raw material is usually high cost and has a number of alternative uses.

25 Fixed costs for a gas based plant, maintenance and personnel, are much lower than for a coal based plant.

All of the equipment downstream of the production of the required synthesis gas is identical (or nearly identical) to that for the coal based methanol plant.

30 The process of converting expensive Natural Gas into high value methanol is typically referred to as a LOW VALUE ADDED operation.

METHANOL FROM WASTE CO₂, CONVERTED BY ELECTROLYSIS

(Raw Material - Carbon Dioxide Produced by Burning Agricultural Waste;
- River Water)

5 Raw Material is essentially at zero cost.

The Electrolysis method of methanol manufacture is essentially a DIRECT ENERGY CONVERSION PROCESS.

10 All of the chemical energy in the methanol comes from the electrical energy generated by the power plant.

The value of the chemical energy in the methanol is greater than the value of the raw electrical energy generated.

15

This pays for the chemical synthesis equipment, capital requirement and all of the fixed costs.

Fixed costs are low, and essentially similar to those for a gas based plant.

20

The major item of capital equipment is the electrolysis cell house.

The electricity cost for the conversion represents practically all of the total variable cost of production.

25

The process of converting essentially valueless carbon dioxide exhaust and raw water to high value methanol using high value electricity may be referred to as a DIRECT ENERGY CONVERSION process.

30

MASS AND ENERGY BALANCE**Methanol Produced by Electrolysis of Water, in Combination with Waste Carbon Dioxide**

5

BASIS 4 400 TONNES/DAY OF METHANOL PRODUCT

$$\begin{aligned}
 & 4\ 400\ \text{Tonnes/Day} \\
 & = 183.333\ \text{Tonnes/hr} \\
 & = 50.925\ \text{Kg/second}
 \end{aligned}$$

KG.MOLES/SECOND OF PRODUCT METHANOL

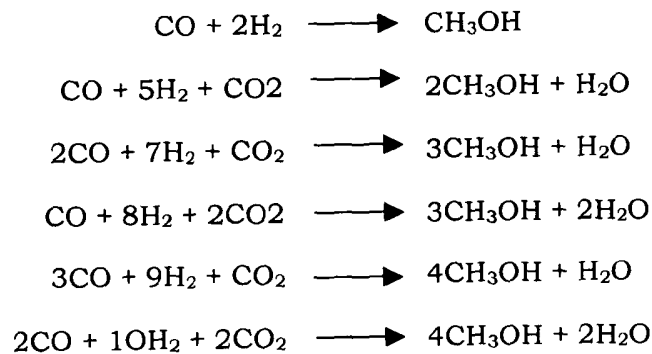
10

Molecular Weight of Methanol CH₃OH = 32.043

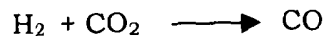
$$\text{KG.MOLE/SEC} = \frac{50.925}{32.043} = 1.589$$

KG.MOLES/SECOND OF HYDROGEN GENERATED

The reaction formulae may be variously represented as:

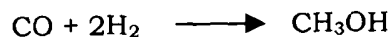


- 15 These reactions are, in fact, all equivalent one to the other, as can be seen when it is taken into account that in the REVERSE SHIFT ACTION



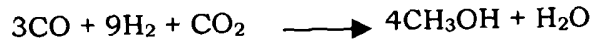
One kg of CO is, in fact, equivalent to one kg.mole of H₂.

Thus the formula



20

indicates 3 EQUIVALENT moles of H₂ to produce 1 mole of CH₃OH, as does the formula



where 12 EQUIVALENT moles of H₂ are required to produce 4 moles of CH₃OH.

5 KG.MOLES H₂ REQUIRED TO BE GENERATED PER SECOND

$$= 3 \times 1.589$$

$$= 4.767 \text{ kg.moles}$$

This is equivalent to 9.534 kg/second.

10 PURIFIED DE-IONISED WATER REQUIREMENT FOR THE ELECTROLYTIC CELL HOUSE

KG.MOLES DE-IONISED WATER REQUIRED/SECOND

$$= 4.767 \text{ kg.moles}$$

$$= \mathbf{85.85 \text{ kg/second}}$$

$$= 309.07 \text{ tonnes/hr}$$

$$= \underline{7417.75 \text{ tonnes/day}}$$

CARBON DIOXIDE REQUIREMENT

15 All of the carbon in the carbon dioxide entering the synthesis plant, appears in the methanol product.

KG.MOLES OF CO₂ REQUIRED

$$= 1.589 \text{ kg.moles/second}$$

$$= \mathbf{69.91 \text{ kg/second}}$$

$$= 251.69 \text{ tonnes/hr}$$

$$= \underline{6040.7 \text{ tonnes/day}}$$

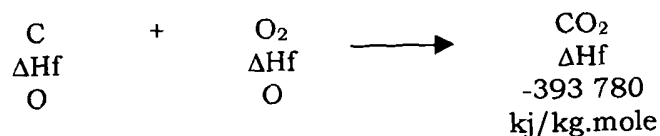
20 **Note:** SIZE OF CONJOINED CONVENTIONAL FOSSIL FUEL BURNING POWER PLANT

The approximate minimum size of the power plant linked to the methanol facility is as follows:

KG.MOLES/SECOND OF CARBON

$$= 1.589$$

Heat of combustion of Carbon



5

Energy released per second by the burning of 1.589 kg.moles of Carbon to Carbon Dioxide:

$$= 1.589 \times 393\,780$$

$$= 625.72 \text{ MW}$$

10 The approximate efficiency of a coal fired power station in conversion of chemical energy to electrical energy is 40%.

The minimum size of the conjoined fossil fuel burning power station is thus:

$$625 \times 0.4 \approx 250 \text{ MW}$$

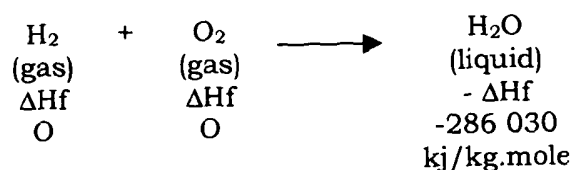
15 Since not all of the CO₂ will be recovered from the existing facility, an existing plant size of 300-400 MW would probably be required.

Electrical Power Required for the Methanol Synthesis Plant

20 The electrical power required for the electrolysis cells which generate hydrogen gas and oxygen gas from water is calculated as follows:

KG.MOLES/SECOND REQUIRED

$$\text{H}_2 \text{ (gas)} = 4.767$$



25

Assuming a 5% conversion loss, the electrical power required is:

$$\frac{4.767 \text{ kg.moles}}{\text{sec}} \times \frac{286\,030 \times 1.05 \text{ kj}}{\text{kg.mole}} = \underline{1432 \text{ MW}}$$

Thus a nuclear power plant of approximate capacity 1500 MW will be associated with a conventional power plant of approximately one third of the size.

5

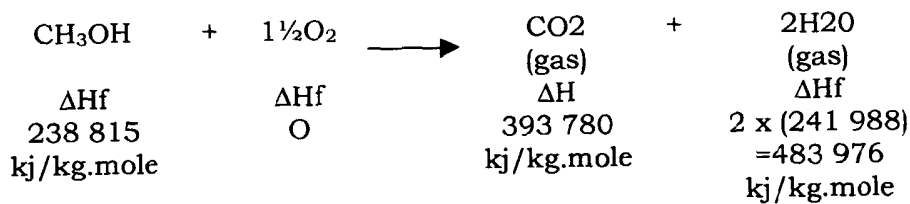
CHEMICAL ENERGY STORED IN THE METHANOL MOLECULE

It is instructive to compare electrical power input into the chemical synthesis plant with the chemical energy that is stored in the methanol molecule.

10

Methanol manufactured per second = 1.589 kg.moles

On combustion



Net heat = 638 941 kj/kg.mole

FOR 1.589 KG.MOLE/SECOND

CHEMICAL POWER POTENTIAL

$$= 1.589 \times 638\,941$$

$$= 1015 \text{ MW}$$

15

Thus an ELECTRICAL POWER of approximately 1432 MW is converted into a CHEMICAL POWER of 1015 MW.

20 The majority of the balance is the loss incurred as heat of vaporisation of water and of methanol.

ECONOMICS OF THE MANUFACTURE OF METHANOL FUEL FROM WASTE AGRICULTURAL PRODUCE, UNITED STATES OF AMERICA

The economics of the above conversion is of overriding importance.

5

Essentially, the economics of conversion of carbon dioxide obtained from the burning of waste agriculturally produced cellulosic/lignitic material is similar to that for the conversion of the carbon dioxide exhaust from fossil fuel power stations.

10

These economics revolve mainly around:

a) The cost and availability of electric power to conduct the electrolysis of water, which provides the hydrogen for the methanol synthesis.

15

b) Economy of scale - the physical size of the synthetic fuel manufacturing facility.

20

c) Transportation costs and infrastructure required to transport the (essentially bulky) cellulosic material to the synthetic fuel facility.

d) Any extraneous financial incentives/disincentives which are prevalent in many national economies and particularly in the agricultural sector.

25 The physical basis for the synthetic production of methanol is described for the corn belt of the United States of America as follows:

Provision of Electricity

30 Statistically, the mid-West of the United States, comprising the States of North and South Dakota, Nebraska, Kansas, Iowa and the western portions of Montana and Wyoming are well suited to the generation of electricity by wind turbine.

35 Indeed, it has been pointed out recently that it is unfortunate geographically

that the areas in the United States most suitable to the generation of electricity by wind turbine are those areas which are sparsely populated and in which the population is static or shrinking. (Precisely the areas above.)

5 The provision of electricity by wind turbine is not particularly suitable for reticulation for normal domestic use, since the quantity of electricity generated at any particular time is at the vagary of the instantaneous wind speed. Cities undergo a cyclical demand pattern with peaks coinciding with domestic human activity. Provision of electricity by wind turbine for this use is awkward, and
10 must be supplemented by a controllable power source.

The generation of electricity by wind turbine is, however, well suited to a continuous production process in which the instantaneous production rate is not critical and may be readily increased or decreased at short notice.

15 The methanol synthesis satisfies this requirement by virtue of its simplicity. The product of the synthesis reaction is almost entirely methanol (with water as a by-product) and the major co-products are ethanol and propanol, which are simply retained in the product.

20 Under these conditions, namely continuous absorption of electricity generation independent of cyclical demand, and of electricity turbines situated in an intrinsically suitable windy area, the cost of the electricity per kw.hr will be in the order of US¢ 5.5-6.0/kw.hr, which is closely similar to that for thermal
25 power stations.

Harvesting, Transportation and Combustion of the Waste Cellulosic Material

30 The waste cellulosic/lignitic material in the case of maize accounts for approximately 58% by dry mass of the crop.

After removing the cobs from the plants and shelling the maize, the residue comprising stalks, stems and husks must be collected and compressed into a
35 form suitable for transportation.

Ideally, transportation distance to the methanol/ethanol synthesis station should be minimised.

5 What is envisaged in this respect is some form of standardised “modular” alcohol synthesis station, occurring at regular intervals in the relevant agricultural area on some form of grid basis.

10 The combustible material would be offloaded at the station and used as the fuel for electricity generation from a standard thermal power station equipped with turbo-alternator sets.

15 From the point of view of economics, and to allow a realistic overview of the “true” economics of the process, the cellulosic material should be accorded a value according to its equivalent calorific content in the area in which it is used.

In other words, a typical heat of combustion of cellulosic/lignitic material is of the order of 15 800 kJ/kg and that of a medium grade coal suitable for power generation 24 600 kJ/kg (for a coal containing 24% ash).

20 In, for example, Nebraska, such a coal would cost (say) US\$30/tonne delivered to the power station.

A credit of US\$19.26 would then be accorded to each tonne of cellulosic material delivered.

25 Electricity generated from this thermal power station would then be purchased by the methanol synthesis facility along with wind turbine generated electricity, as well as intermittent importation from other (unspecified sources) via the electrical grid system as required for optimum economic operation of the facility.

30 Depending on the transportation distance, it would appear that the calorific value “credit” accorded to the material of approximately US\$20/tonne would more than cover the cost of harvesting, baling and transportation to the power station.

The quantities involved are explored quantitatively in a mass and energy balance in order to provide a more substantial appreciation of the economics of and the economic factors involved in the process.

5 **MASS AND ENERGY BALANCE**

BASIS 1 000 KG OF METHANOL produced from waste cellulosic material

10 **Quantity of Waste Cellulosic Material Required** (All weights refer to dry weight)

For simplicity all material is accorded the stoichiometric formula $C_6H_{10}O_5$. (MW 162)

15 One tonne of cellulosic material contains $6.173 \text{ kg/moles} \times 6 = 37.037 \text{ kg/moles}$ of carbon.

Mass of carbon = 444.4 kg

20 ($= \frac{72}{162} \times 1000$)

One tonne of methanol (CH_3OH) (MW 32) contains $\frac{12}{32} \times 1000 = 375 \text{ kg}$ of carbon.

25 One tonne of waste cellulosic material therefore produces $\frac{444.4}{375} = 1.185$ tonne of methanol.

Electricity Requirement

30 The electricity consumption to provide hydrogen gas by electrolysis for reaction with the carbon dioxide is calculated.

Kg moles of H_2 required per tonne of methanol

35 Kg moles of methanol = 31.25

Reaction Stoichiometry



5

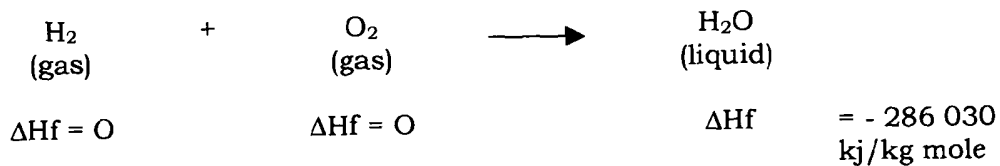
Kg moles of hydrogen required

$$= 31.25 \times 3$$

$$= 93.75 \text{ kg moles.}$$

10

From the heat of formation of water



15 Energy requirement per tonne of methanol

$$= 3 \times 31.25 \times 286\,030$$

$$= \underline{2.6815 \times 10^7 \text{ kj}}$$

20 Assuming a 5% efficiency loss this amounts to

$$\underline{2.822 \times 10^7 \text{ kj}}$$

25 The quantity of electrical energy required to perform the electrolysis, per tonne of methanol is then

$$\frac{2.822 \times 10^7 \text{ kw.hr}}{3\,600}$$

30

$$= \underline{7.83 \times 10^3 \text{ kw.hr}}$$

Electrical Energy Cost

The cost of electrical energy is assumed at US¢ 6.0/kw.hr independent of the electrical energy source.

5

In actual operation three sources of electrical energy will be used as follows:

- Electrical energy generated on site by the burning of the waste cellulosic material
- Electrical energy provided by wind turbines
- Imported electricity from the grid system, with a generally non-specific form of generation.

10

15

In addition to these three sources of electrical energy it is also envisaged that the electricity generating station on site will operate with a partial feedstock of coal, on either a normal or intermittent basis. This will ensure that the synthesis facility operates at an economic utilisation capacity when there is a transportation interruption or poor harvest or other circumstances leading to feedstock starvation.

20

The electrical energy cost per tonne of methanol produced, including the on site requirements of carbon dioxide and hydrogen compression, and other electrical requirements is of the order of

25

$$8.2 \times 10^3 \text{ kw.hr.}$$

The electricity cost at US¢ 6/kw.hr is then US\$492/tonne.

30

Since carbon dioxide raw material has already been accounted, this essentially represents the variable cost of production.

35

Proportion of Electricity Provided by the Burning of Cellulosic Material

It has already been assumed that the cellulosic/lignitic maize plant waste will be used in the generation of electricity to be sold to the methanol synthesis plant at
 5 US\$ 6/kw.hr.

Nevertheless, it is of importance to calculate the proportion of the electrical energy that must be imported to the site, relative to the proportion generated on site.

10

One tonne of methanol is accompanied by the importation of 844 kg of cellulosic material (dry basis).

The calorific value of this material is approximately 1 580 kj/kg.

15

One tonne of methanol is thus accompanied by the release of:

$$\frac{844 \times 15\,800}{3\,600} = 3\,704 \text{ kw.hr of heat}$$

20

Typically in a thermal power station approximately 35-40% of the heat energy is translated to electrical energy.

The quantity of electrical energy generated on site will thus be of the order of:

25

$$0.375 \times 3\,704 = 1.389 \times 10^3 \text{ kw.hr}$$

The proportion of the electricity generated on site to the proportion of imported electricity is thus:

30

$$\frac{1.39 \times 10^3}{8.2 \times 10^3} = 0.169 \text{ or } 17\%$$

Thus 17% of the electricity requirement is generated on site, and 83% is
 35 imported.

Economics of Manufacture (Continued) - Capital Cost and Fixed Costs of Production

Specific fixed costs, that is primarily the cost of labour and maintenance per
 5 tonne of fuel produced, are, by and large, proportional to the specific capital cost
 of the manufacturing facility.

In this regard, economics of scale are important.

10 Typically, a power law with exponent 0.6 is applicable to the relative capital cost
 as a function of relative capacity.

Thus a facility producing, say, 2 000 tonnes/day of methanol does not cost then
 times as much as a facility producing 200 tonnes/day, but:

15

$$\left[\frac{2\,000}{200} \right]^{0.6} = 10^{0.6} = 3.98$$

or 4 times as much.

20 The cost per litre of methanol produced of capital repayment, labour, and
 maintenance is thus, to a significant extent, dependent on the scale of the
 operation.

25 For a facility producing 2 200 tonnes/day of methanol, which is the approximate
 size of the facility envisaged, the following figures are assumed:

Capital Cost - US\$1 617.9 m

30 Annual Fixed Cost of Production - US\$38.9 m

Adopting these figures, and including the cost of electricity at US 6.0¢/kw.hr, a
 financial model of the production economics may be built up.

35 This model includes a taxation regime, incorporating an initial allowance of 50%
 of the capital cost of the facility granted during the first year of production, and

two “wear and tear” taxation allowances, each of 25% of the initial capital cost in the next two succeeding years.

Farming Crop Price for Waste Material

5

It is envisaged that the methanol production economics must include a payment made to the farmer, over and above the transportation costs of the maize cellulosic/lignitic waste to the processing facility.

10 This will provide an incentive for the farmer to deliver the cellulose to the manufacturing facility, and also to explore the economics of different maize varieties, which have a greater proportion of incorporated non-grain hydrocarbon material.

15 As a provisional return, a credit of US7.0¢ on each litre of methanol fuel produced is envisaged, payable to the farmer for the production of the raw material cellulose, over and above the credit of US\$19.26 per tonne accepted as a credit by the power station for its calorific value.

20 This latter credit, as detailed above, does not appear as an additional cost burden to the methanol produced since electricity is produced and properly accounted for as a variable cost input to the manufacturing facility.

25 Since the specific gravity of methanol is 0.79, and 1 tonne of waste cellulosic material produces 1.185 tonnes of methanol, the credit per kg dry mass of cellulosic/lignitic material is:

$$\frac{7}{0.79} \times 1.185 = \text{US}\$ 10.5/\text{kg}$$

30 For material containing 12% moisture (average for “dry” cellulose), the credit would be

$$\text{US}\$ 9.2\text{¢} / \text{kg}.$$

Farming Credit per Hectare

Since the waste material accounts for approximately 58% of the mass of the crop, and an average crop of shelled maize is 4.5 tonnes/hectare, the quantity of cellulosic material per hectare, on a dry mass basis is approximately 6.2 tonnes.

A credit of approximately US\$650/ha would accrue to the farmer over and above transportation costs to the methanol synthesis facility, and the normal maize crop.

Combined Production Economics

For a methanol synthesis plant operating at a production rate of 2 200 tonnes/day, and employing imported electricity generated (mainly) by wind turbines at a cost of US6.0¢/kw.hr, the following sample economic breakdown pertains:

Variable Cost	¢/litre
Electricity	38.9
Cost of Cellulose	7.0
Fixed Cost	
Personnel Costs	1.7
Maintenance Costs	1.7
Other	0.9
Capital Repayments/Distribution	5.0
Taxation	5.0
TOTAL	71.7 ¢/litre

Cost per Gallon of Fuel

The cost per gallon of fuel is then approximately:

$$3.785 \times 71.7 = \text{US\$}2.71/\text{gallon}$$

Calorific Value Cost of the Fuel

Since the calorific value of the fuel is only 51% of that of petroleum, the actual cost per unit calorific value is approximately:

5

$$\frac{2.71}{0.51} = \text{US\$}5.31/\text{gallon}$$

Cost to the Consumer - Petroleum Usage

10

As a substitute for petroleum, methanol is more efficient if employed in purpose modified engines incorporating a higher compressions ratio.

In this case the proportion of chemical energy translated to mechanical energy (or the increase in miles per gallon) is about 40%. If this is factored into the cost equation (FOR PETROL VEHICLES ONLY), the actual cost of the fuel to the consumer is of the order of

15

$$\text{US\$}3.20/\text{gallon}$$

20

PRODUCTION ECONOMICS - FINANCIAL MODEL

5 The economics of the production of fuel using agricultural waste carbon dioxide as a carbon source is of crucial importance to the practical implementation of the invention.

In this respect a financial analysis is presented as a part of the background to the invention, for the production of methanol.

10 The production economics of the carbon dioxide energy conversion process are primarily dependent on the cost of electrical energy at the synthesis plant, and secondarily on the capital cost of the synthesis plant.

15 For a natural gas based methanol synthesis plant, the economics of production are primarily dependant on the cost of the natural gas, and secondarily on the capital cost of the synthesis plant.

20 For a coal based methanol synthesis plant, using as a raw material high ash coal with essentially zero opportunity cost (no export potential) the major financial consideration is the overall capital cost of the facility. Fixed costs of production (mechanical maintenance and personnel) are a secondary financial consideration.

The financial parameters that are used in the evaluation are:

- 25
- Net present value at zero cost of capital
 - Net present value at a weighted average cost of capital above the inflation rate
 - Internal Rate of Return (non-inflationary), and
 - Internal Rate of Return (inflationary).

30 For the comparative financial analysis the following input parameters are of especial relevance:

CAPITAL COST

Each technology has been assigned a base case capital cost, at fixed production rate. This production rate is set at 4400 tonnes/day. Note that this is the size
 5 of the New Zealand Synfuel facility, erected in the mid-1980s.

The capital cost in each case reflects not only the direct cost of chemical plant construction, including off sites and utilities, but also includes:

- Indirect costs
 - 10 - field distributables
 - contractor and sub-contractor home offices.
- Capitalized engineering
- Capitalized spares
- Venture costs
- 15 • Insurances and levies
- Start-up and commissioning costs
- Inflation and interest during construction
- Contingency.

20 The indirect and other costs typically make up greater proportion of the capital input than the direct construction costs.

For the three types of Methanol Synthesis plant the following inclusive capital costs of implementation are representative.

25

Base Case Production Rate - 4400 Tonnes/Day

<u>Technology</u>	<u>Capital Cost US\$m</u>
NATURAL GAS REFORMING	2037.2

Notes: In a sense this represents a base-case as most methanol plants
 30 worldwide use natural gas as a raw material.

Technology	Capital Cost US\$m
COAL GASIFICATION	3395.4

Notes: A coal based methanol plant is approximately 67% more expensive in terms of capital compared to gas based synthesis plant.

Technology	Capital Cost US\$m
WASTE CO ₂ ELECTROLYTIC H ₂	2452.2

5

Notes: For the exhaust CO₂ synthesis the main additional capital cost elements are the electrolytic cells and the CO₂ recovery and SO₂ stripping sections at the front end of the synthesis facility.

10 The major cost saving compared of the natural gas synthesis is the steam reformer section which is not a part of the flow sheet. However, this is essentially replaced by the reverse shift reactor.

CAPITAL COST - PRODUCTION RATIO FACTORING

15

For alternative rates of production the capital cost is calculated at the production ratio, factored to a power of 0.6.

20 Thus for the same three cases producing 2,200 tonnes per day, or exactly half of the base case of 4400 tonnes per day, the capital cost is not 50% of the base case but

$$\left[\frac{2200}{4400} \right]^{0.6} = 0.659$$

25

Thus the cost is not half, but two thirds, which is typical of industrial experience with loss of economy of scale.

CAPITAL COST – EXPENDITURE PROFILE

For all of the scenarios, it is assumed that the capital is expended over a three and one half year period, and the following proportions are expended.

5

YEAR 1	23.3%
YEAR 2	40.0%
YEAR 3	30.0%
YEAR 4	6.7% (half year)

It is assumed that commissioning starts after the first quarter year 4, and that nameplate production is achieved in quarters 3 and 4.

10 For smaller synthesis plants (circa 500 tonnes/day and lower) this time scale is longer than would be typically anticipated, but is in any event conservative and will not inflate economic expectation.

FIXED COSTS OF PRODUCTION

15

Each technology has been assigned a fixed cost base of production which is typical of the technology used.

Fixed costs of production typically comprise for the main part (ca 80%)
20 personnel and maintenance costs.

The following base case fixed costs of production are assumed for the investments.

Annual Fixed Costs of Production by Technology

25

Base Case Production Rate 4400 Tonnes

30

<u>Technology</u>	<u>Annual Fixed Cost of Production</u>
	<u>US\$/Annum</u>
NATURAL GAS REFORMING	51.9
COAL GASIFICATION	89.6
WASTE CO ₂ , ELECTROLYTIC H ₂	58.9

For alternative rates of production in the fixed costs of production are calculated at the production ratio factored to a power of 0.6.

In essence the ratio of fixed costs of production will follow the ratio of installed capital cost.

In the calculation of the fixed costs of production for the waste CO₂, electrolytic H₂ method of production, it has been assumed that the electrolytic cells, which are relatively capital intensive are not maintenance or personnel intensive.

10

VARIABLE COSTS OF PRODUCTION

General Introduction

Whilst the capital cost of the methanol plant installations will vary regionally and globally, the range of variation is limited of the order of 30%.

In areas remote from the primary manufacture of the major equipment items and where extensive infrastructure is required the cost will be higher. In areas where the methanol plant may be situated adjacent to existing service facilities (brownfield site) a lower capital cost may be anticipated.

20

The same basic range of variability may be anticipated for the fixed costs of production.

The primary financial parameter, for both natural gas based and electrolytic hydrogen based synthesis facilities, namely that of variable cost is considerably more difficult to anticipate, and may be expected to cover a much wider range. It is difficult to anticipate the variable cost structures that will pertain through the life of the investment.

25

It is also difficult to allocate a variable cost that will pertain to an "average" investment, for the purposes of this financial comparison.

5 **Natural Gas**

For large (world scale) projects the equity and loan partners, because of the large capital investment, will require some assurance that the variable cost of production will fall in a range at least in the early payback period, that will to some extent, guarantee their investment.

10

Thus a pricing arrangement will in most cases be a requisite for project approval.

This may take the form of an interest in the development of a previously
15 undeveloped gas field which is dedicated or primarily dedicated to the production facility. Typically the developers of the gas field would enter into some form of financial arrangement with the methanol synthesis company, such as a take or pay arrangement.

20 Such an arrangement might or might not be applicable through the entire discount period of the methanol synthesis plant.

However, under such an arrangement the gas price would be to a greater or lesser extent decoupled from spot price fluctuations in energy prices.

25 Essentially, for facilities exhibiting massive economy of scale, it must be anticipated that the average price of natural gas raw material is considerably lower than the market price for the high opportunity cost commodity.

Such methanol plants would be dedicated primarily to the production of
30 methanol as an automotive fuel as the production would be impossible to accommodate in any alternative way.

Whilst the methanol produced from such plants is relatively inexpensive the number of locations worldwide where access to a supply of natural gas with a low opportunity cost is severely limited.

5 Most regions in the world with a large natural gas resource have over a period of time developed market outlets for the raw material, or have a regional operational development plant in place which renders the resource of medium to high opportunity cost.

10 Thus in the financial analysis which follows, whilst a low cost of natural gas is assumed for world scale production units, this is provisional upon a limited number of such opportunities being available.

For smaller production facilities the assumed cost of the natural gas is higher

15

For the smallest natural gas based facilities, it is assumed that the cost of the gas is that which pertains to general consumption (spot prices)

20 In the financial analysis which follows larger facilities will have access to a cheaper supply of natural gas. Whilst this is a generalization, and in fact many small plants may have access to low cost niche sources of gas, it is a practicable simplifying assumption.

COAL COST

25

The same general remarks pertaining to the supply of natural gas to a synthetic fuels facility pertain to the supply of a coal feedstock.

30 There is, however, a fundamental difference in that coal is more abundant than natural gas, and sourcing of dedicated low opportunity cost coalfields, specifically to service liquid fuels facilities exhibiting economy of scale is easier than that for natural gas.

Whilst natural gas and crude oil pricing is generally closely linked, pricing of coal is, to some extent decoupled, since many coal reserves have a low or zero opportunity value.

- 5 For the purposes of this economic evaluation, large synthesis facilities will have access to lower priced coal than smaller facilities.

Variable Costs - Electricity

- 10 For the purposes of this economic appraisal, electricity costs pertaining in the United States of America are taken as a benchmark.

15 Unlike coal costs and natural gas costs, which typically vary over a wide range, electricity costs in the USA for plants coming on line in 2013 cover an essentially small price band.

The electricity costs projected for 2013 in the United States area as follows:

Coal	5.0¢ kw/hr
Natural Gas	5.35¢ kw/hr
Wind	5.85¢ kw/hr
Nuclear	6.45¢ kw/hr

- 20 The following should be noted with regard to electricity cost:
- For large synthetic fuel facilities exhibiting economy of scale, the fuel synthesis facility will be constructed in tandem with electricity generating plant (or power station).
 - The projected cost of 6.0¢ kw/hr for general electricity supply to the
25 electricity grid system, should be lowered by a factor representative of continuous power supply at nameplate capacity.
 - Since a power station operating in this capacity will evince superior economics, and will not be subject to off-peak load reduction, some form of electricity price structure at a lower rate than that pertaining for general use
30 should be established.
 - For the purpose of this economic appraisal a 12% discount below costs applicable to variable demand users is assumed.

- For small facilities a price level of 5¢ kw/hr is assumed. This reflects a balance between cheap power at off-peak periods, and the requirement to oversize the liquid fuels synthesis facility to accommodate variable production rate.

5

Assumed Fiscal Regimen

A once-off Initial Allowance of 50% of the capital cost of the manufacturing facility is assumed in the first year of production.

10

This is followed by two equal tranches of 50% of the remainder, termed the Wear and Tear allowance, in the two years following:

- Corporation taxation of 42.5% is payable on taxable income
- Inflation is assumed at 4.5% per annum
- Cost of capital is assumed at 3% above the inflation rate.

15

Comparative Economic Appraisal

Comparative economic appraisal is carried out for the manufacture of METHANOL by three different process routes:

20

- Coal Raw Material
- Natural Gas Raw Material
- Waste CO₂/Electrolytic H₂ Raw Material.

The economic appraisal is carried out at four different scales of production:

25

- A. 4400 tonnes/day
- B. 1000 tonnes/day
- C. 250 tonnes/day.

30

Case A is representative of a liquid automotive fuels displacement initiative, whilst Case C would be more representative of an electricity storage initiative, with Case B of an intermediate nature.

METHANOL FINANCIAL ANALYSIS

Case: 4400 Tonnes/Day
Description: VARIABILITY AROUND VARIABLE COST
Selling Price at Factory Gate: 60¢ per Litre
Equivalent Petrol Price: 1.20 per litre

Manufacturing Facility Type		INPUT PARAMETERS			IRR Non-Inflation	OUTPUT PARAMETERS					
		Capital Cost	Fixed Cost	Variable Cost		IRR Infl 4.5%	NPV Real 0% WACC	NPV Real 3% WACC	NPV Infl 7.5% WACC	Tax Payable Non-Infl	Tax Payable 4.5% Infl
				US/\$ Tonne							
COAL BASED	H			45	14	19	8649	4708	4289	7020	14727
	M	3395.4	89.6	35	15	20	9096	4989	4589	7377	15347
	L			25	15	20	9543	5270	4891	7733	15968
				US\$/MMBTU							
GAS BASED	H			15	13	18	4200	2256	2052	3411	6856
	M	2037.2	51.9	11	18	22	635.4	3610	3395	4961	9663
	L			9	20	24	7490	4335	4002	5676	11171
				US\$/KWHR							
WASTE CO ₂ ELECTROLYTIC H ₂	H			6.3	8	11	2684	1143	968	2226	4928
	M	2452.2	58.9	5.67	9	14	3575	1712	1510	2937	6228
	L			5.2	11	15	4239	2315	1909	3467	7203

5

Case: 4400 Tonnes/Day
Description: VARIABILITY AROUND CAPITAL COST
Selling Price at Factory Gate: 60¢ per Litre
Equivalent Petrol Price: 1.20 per litre

Manufacturing Facility Type		INPUT PARAMETERS			IRR Non-Inflation	OUTPUT PARAMETERS					
		Capital Cost	Fixed Cost	Variable Cost		IRR Infl 4.5%	NPV Real 0% WACC	NPV Real 3% WACC	NPV Infl 7.5% WACC	Tax Payable Non-Infl	Tax Payable 4.5% Infl
				US/\$ Tonne							
COAL BASED	H	4244.3			12	17	8608	4499	4043	7016	15054
	M	3395.4	89.6	35	15	20	9096	4989	4589	7377	15347
	L	2546.6			20	24	9808	5653	5202	7513	15509
GAS BASED	H	2546.6			14	18	5965	3242	2973	4840	9653
	M	2037.2	51.9	11	18	22	635.4	3610	3395	4961	9663
	L	1527.9			23	27	6713	3951	3668	5111	9909
WASTE CO ₂ ELECTROLYTIC H ₂	H	3065.3			7	11	3223	1343	1129	2676	5963
	M	2452.2	58.9	5.67	9	14	3575	1712	1510	2937	6228
	L	1839			13	17	3927	2073	1880	3198	6492

Case: 4400 Tonnes/Day
Description: VARIABILITY AROUND CAPITAL COST
Selling Price at Factory Gate: 55¢ per Litre
Equivalent Petrol Price: 1.10 per litre

Manufacturing Facility Type		INPUT PARAMETERS			IRR Non-Inflation	OUTPUT PARAMETERS					
		Capital Cost	Fixed Cost	Variable Cost		IRR Infl 4.5%	NPV Real 0% WACC	NPV Real 3% WACC	NPV Infl 7.5% WACC	Tax Payable Non-Infl	Tax Payable 4.5% Infl
				US/\$ Tonne							
COAL BASED	H	4244.3			11	15	7463	3775	3356	6101	13317
	M	3395.4	89.6	35	13	18	7951	4269	3864	6462	13678
	L	2546.6			17	23	8527	4826	4528	6735	13757
GAS BASED				US\$/MMBTU							
	H	2546.6			12	16	4819	2521	2280	3926	7996
	M	2037.2	51.9	11	15	20	5112	2815	2626	4143	8139
	L	1527.9			20	25	5567	3236	2979	4197	8260
WASTE CO ₂ ELECTROLYTIC H ₂				US¢/KWHR							
	H	3065.3			5	9	2077	598	414	1762	4295
	M	2452.2	58.9	5.67	7	11	2429	978	808	2023	4561
	L	1839			10	14	2782	1348	1192	2283	4820

Case: 4400 Tonnes/Day
Description: VARIABILITY AROUND VARIABLE COST
Selling Price at Factory Gate: 55¢ per Litre
Equivalent Petrol Price: 1.10 per litre

5

Manufacturing Facility Type		INPUT PARAMETERS			IRR Non-Inflation	OUTPUT PARAMETERS					
		Capital Cost	Fixed Cost	Variable Cost		IRR Infl 4.5%	NPV Real 0% WACC	NPV Real 3% WACC	NPV Infl 7.5% WACC	Tax Payable Non-Infl	Tax Payable 4.5% Infl
				US/\$ Tonne							
COAL BASED	H			45	13	17	7504	3988	3599	6106	12992
	M	3395.4	89.6	35	13	18	7951	4269	3864	6462	13678
	L			25	14	19	8397	4550	4127	6819	14363
GAS BASED				US\$/MMBTU							
	H			15	11	15	3055	1533	1370	2497	5179
	M	2037.2	51.9	11	15	20	5112	2815	2626	4143	8139
	L			9	17	22	6209	3508	3305	4899	9532
WASTE CO ₂ ELECTROLYTIC H ₂											
	H			6.3	5	8	1539	397	254	1312	3256
	M	2452.2	58.9	5.67	7	11	2429	978	808	2023	4561
	L			5.2	8	12	3093	1405	1216	2553	5530

Case: 1000 Tonnes/Day
Description: VARIABILITY AROUND CAPITAL COST
Selling Price at Factory Gate: 65¢ per Litre
Equivalent Petrol Price: 1.30 per litre

Manufacturing Facility Type		INPUT PARAMETERS			IRR Non-Inflation	OUTPUT PARAMETERS					
		Capital Cost	Fixed Cost	Variable Cost		IRR Infl 4.5%	NPV Real 0% WACC	NPV Real 3% WACC	NPV Infl 7.5% WACC	Tax Payable Non-Infl	Tax Payable 4.5% Infl
COAL BASED	H	1744.7			6	10	1458	521	403	1224	3013
	M	1396	36.8	45	8	12	1659	735	624	1372	3164
	L	1046.8			11	15	1860	943	839	1520	3313
GAS BASED				US\$/MMBTU							
	H	1046.8			7	11	934	363	296	779	1771
	M	837.4	21.3	13.5	9	13	1054	491	429	868	1859
	L	628.1			12	16	1175	614	555	957	1950
WASTE CO ₂ ELECTROLYTIC H ₂	H	1260			4	7	619	89	21	537	1422
	M	1008	24.2	5.4	6	9	763	249	187	644	1530
	L	756			8	12	908	404	347	751	1639

Case: 1000 Tonnes/Day
Description: VARIABILITY AROUND VARIABLE COST
Selling Price at Factory Gate: 65¢ per Litre
Equivalent Petrol Price: 1.30 per litre

Manufacturing Facility Type		INPUT PARAMETERS			IRR Non-Inflation	OUTPUT PARAMETERS					
		Capital Cost	Fixed Cost	Variable Cost		IRR Infl 4.5%	NPV Real 0% WACC	NPV Real 3% WACC	NPV Infl 7.5% WACC	Tax Payable Non-Infl	Tax Payable 4.5% Infl
COAL BASED	H			55	8	12	1557	669	562	1291	3007
	M	1396	36.8	45	8	12	1659	735	624	1372	3164
	L			35	8	13	1761	800	686	1453	3320
GAS BASED				US\$/MMBTU							
	H			17	6	10	645	230	180.5	541	1256
	M	837.4	21.3	13.5	9	13	1054	491	429	868	1859
	L			10.5	11	15	1405	711	637	1149	2379
WASTE CO ₂ ELECTROLYTIC H ₂	H			6.0	4	8	571	122	65	490	1250
	M	1008	24.2	5.4	6	9	763	249	187	644	1530
	L			5.0	6	10	892	333	267	746	1718

Case: 1000 Tonnes/Day
Description: VARIABILITY AROUND CAPITAL COST
Selling Price at Factory Gate: 60¢ per Litre
Equivalent Petrol Price: 1.20 per litre

Manufacturing Facility Type		INPUT PARAMETERS			IRR Non-Inflation	OUTPUT PARAMETERS					
		Capital Cost	Fixed Cost	Variable Cost		IRR Infl 4.5%	NPV Real 0% WACC	NPV Real 3% WACC	NPV Infl 7.5% WACC	Tax Payable Non-Infl	Tax Payable 4.5% Infl
				US\$/Tonne							
COAL BASED	H	1744.7			5	9	1198	350	240	1016	2617
	M	1396	36.8	45	7	11	1399	567	467	1164	2763
	L	1046.8			10	14	1599	777	682	1312	2915
GAS BASED	H	1046.8			5	9	674	194	134	571	1391
	M	837.4	21.3	13.5	7	11	794	323	269	660	1479
	L	628.1			10	14	915	449	399	749	1570
WASTE CO ₂ ELECTROLYTIC H ₂	H	1260			2	6	358.2	-87	-149	329	149
	M	1008	24.2	5.4	4	7	503	77	22	463	1150
	L	756			6	10	648	236	167	543	1258

Case: 1000 Tonnes/Day
Description: VARIABILITY AROUND VARIABLE COST
Selling Price at Factory Gate: 60¢ per Litre
Equivalent Petrol Price: 1.20 per litre

5

Manufacturing Facility Type		INPUT PARAMETERS			IRR Non-Inflation	OUTPUT PARAMETERS					
		Capital Cost	Fixed Cost	Variable Cost		IRR Infl 4.5%	NPV Real 0% WACC	NPV Real 3% WACC	NPV Infl 7.5% WACC	Tax Payable Non-Infl	Tax Payable 4.5% Infl
				COAL US\$/Tonne							
COAL BASED	H			55	7	11	1297	501	402	1083	2611
	M	1396	36.8	45	7	11	1399	567	467	1164	2763
	L			35	7	12	1500	633	528	1245	2920
GAS BASED	H			US\$/MMBTU 17	4	7	384	58.7	16.2	333	876
	M	837.4	21.3	13.5	7	11	794	323	269	660	1479
	L			10.5	9	13	1145	546	480	941	1997
WASTE CO ₂ ELECTROLYTIC H ₂	H			6	2	6	310	-54	-104	282	869
	M	1008	24.2	5.4	4	7	503	77	22	463	1150
	L			5.0	5	8	632	162	104	539	1337

Case: 250 Tonnes/Day
Description: VARIABILITY AROUND VARIABLE COST
Selling Price at Factory Gate: 70¢ per Litre
Equivalent Petrol Price: 1.40 per litre

Manufacturing Facility Type		INPUT PARAMETERS			IRR Non-Inflation	OUTPUT PARAMETERS					
		Capital Cost	Fixed Cost	Variable Cost		IRR Infl 4.5%	NPV Real 0% WACC	NPV Real 3% WACC	NPV Infl 7.5% WACC	Tax Payable Non-Infl	Tax Payable 4.5% Infl
COAL BASED	H			55	3	7	219.5	-10.4	-42.7	196	609
	M	607.5	16.0	50	3	7	232	-1.7	-34.5	206	629
	L			45	3	7	245	6.9	-26.3	216	646
GAS BASED	H			18.0	1	5	58	-52	-68	58	228
	M	364.5	9.3	14	4	7	17.5	27	7.3	151.5	399
	L			8.5	7	11	336	131	107	280	637
WASTE CO ₂ ELECTROLYTIC H ₂	H			5.5	2	5	84	-59	-79	81.9	303
	M	439	10.5	5.0	2	6	124	-31	-53	114	362
	L			4.0	4	7	204	23	0	128	479

Case: 250 Tonnes/Day
Description: VARIABILITY AROUND CAPITAL COST
Selling Price at Factory Gate: 70¢ per Litre
Equivalent Petrol Price: 1.40 per litre

5

Manufacturing Facility Type		INPUT PARAMETERS			IRR Non-Inflation	OUTPUT PARAMETERS					
		Capital Cost	Fixed Cost	Variable Cost		IRR Infl 4.5%	NPV Real 0% WACC	NPV Real 3% WACC	NPV Infl 7.5% WACC	Tax Payable Non-Infl	Tax Payable 4.5% Infl
COAL BASED	H	759.44			2	5	149	-103	-139	142	564
	M	607.5	16	50	3	7	232	-1.7	-34.5	206	629
	L	455.7			5	9	320	96	67	271	694
GAS BASED	H	455.6			2	6	122.5	-33	-54	113	360
	M	364.5	9.3	14	4	7	175	27	7.3	151.5	399
	L	273.4			6	10	227	84	67	190	439
WASTE CO ₂ ELECTROLYTIC H ₂	H	548			1	4	61	-106	-129	67	315
	M	439	10.5	5.0	2	6	124	-31	-53	114	362
	L	329.1			4	8	187	40	21	160	409

Case: 250 Tonnes/Day
Description: VARIABILITY AROUND VARIABLE COST
Selling Price at Factory Gate: 65¢ per Litre
Equivalent Petrol Price: 1.30 per litre

Manufacturing Facility Type	INPUT PARAMETERS			IRR Non-Inflation	OUTPUT PARAMETERS						
	Capital Cost	Fixed Cost	Variable Cost		IRR Infl 4.5%	NPV Real 0% WACC	NPV Real 3% WACC	NPV Infl 7.5% WACC	Tax Payable Non-Infl	Tax Payable 4.5% Infl	
			US\$/Tonne								
COAL BASED	H		55	2	6	154	-55	-85	144	509	
	M	607.5	16.0	50	2	6	167	-46	-77	154	530
	L			45	2	6	179	-37	-68	164	549
GAS BASED			US\$/MMBTU								
	H		18.0	0	3	-21	-107	-114	19.5	132	
	M	364.5	9.3	14.0	2	6	109	-17.6	-34.8	100	304
L			8.5	6	9	271	89	67	228	541	
WASTE CO ₂ ELECTROLYTIC H ₂	H		5.5	0	3	19	-106	-124	30	208	
	M	439	10.5	5.0	1	4	59	-77	-96	62	267
	L			4.0	2	6	139	-21	-42	126	384

Case: 250 Tonnes/Day
Description: VARIABILITY AROUND CAPITAL COST
Selling Price at Factory Gate: 65¢ per Litre
Equivalent Petrol Price: 1.30 per litre

Manufacturing Facility Type	INPUT PARAMETERS			IRR Non-Inflation	OUTPUT PARAMETERS						
	Capital Cost	Fixed Cost	Variable Cost		IRR Infl 4.5%	NPV Real 0% WACC	NPV Real 3% WACC	NPV Infl 7.5% WACC	Tax Payable Non-Infl	Tax Payable 4.5% Infl	
COAL BASED	H	759.44		1	4	79.8	-149	-183	89.6	464	
	M	607.5	16.0	50	2	6	167	-46	-77	154	530
	L	455.7			4	8	254	52.5	25.8	219	594
GAS BASED	H	455.6			1	4	57.4	-79	-98	61	266
	M	364.5	9.3	14.0	2	6	109	-17.6	-34.8	100	304
	L	273.4			5	8	162	41.3	26.2	138	343
WASTE CO ₂ ELECTROLYTIC H ₂	H	548			0	3	-21	-161	-175	32	220
	M	439	10.5	5.0	1	4	59	-77	-96	62	267
	L	329.1			3	6	122	-4	-21	109	319

SYNTHETIC METHANOL PRODUCTION - FINANCIAL ANALYSIS

- MEDIUM PRESSURE PROCESS
- COPPER CATALYST SUPPORTED ON ALUMINA

NOTES - FINANCIAL

- 1 BOTH INFLATIONARY AND NON-INFLATIONARY FINANCIAL ANALYSES ARE PERFORMED
- 2 INFLATION RATE OVER THE DISCOUNT PERIOD IS ASSUMED AT 4.5 PERCENT
- 3 NON-INFLATIONARY FINANCIAL FIGURES ARE REFERRED TO IN THE SPREADSHEET AS "REAL"

TAX REGIME

- 4 COMPANY TAXATION IS INCLUDED AT A RATE OF 42.5%
- 5 AN INITIAL CAPITAL ALLOWANCE OF 50% IS ALLOWABLE IN THE FIRST PRODUCTION YEAR
- 6 WEAR AND TEAR ALLOWANCE OF 50% OF THE BALANCE FOLLOWS FOR THE FOLLOWING TWO SUCCESSIVE YEARS

FINANCIAL ANALYSES PERFORMED

- 7 INTERNAL RATE OF RETURN ON INFLATIONARY NET CASH FLOW
- 8 INTERNAL RATE OF RETURN ON NON-INFLATIONARY (REAL) NET CASH FLOWS
- 9 NET PRESENT VALUE AT ZERO COST OF CAPITAL PERFORMED OVER THE NON-INFLATIONARY (REAL) CASH FLOWS
- 10 NET PRESENT VALUE AT A STATED COST OF CAPITAL IN PERCENTAGE TERMS ABOVE THE INFLATION RATE PERFORMED OVER THE NON-INFLATIONARY NET CASH FLOWS
- 11 NET PRESENT VALUE AT A STATED COST OF CAPITAL PERFORMED OVER THE INFLATIONARY NET CASH FLOWS

TIME SCALE

- 12 CONSTRUCTION COMMENCES BEGINNING FIRST QUARTER 2011
- 13 FIRST PRODUCTION BEGINNING 3RD QUARTER 2014
- 14 DISCOUNT PERIOD FROM 2011 TO 2036

NOTES - CAPITAL COST

- 15 A BASE CASE CAPITAL COST OF US\$7200 MILLION IS ASSUMED
- 16 CAPITAL COST IS FACTORED AT PROPORTIONAL PRODUCTION TO POWER 0.6
- 17 CAPEX IS APPROXIMATELY
 - 23 PERCENT IN YEAR ONE
 - 40 PERCENT IN YEAR TWO
 - 30 PERCENT IN YEAR THREE
 - 7 PERCENT UP TO BEGINNING THIRD QUARTER YEAR FOUR
- 18 CAPITAL EXPENDITURE PROPORTIONS ARE AS DETAILED BELOW

NOTES - COST OF COAL

- 19 LOW OPPORTUNITY VALUE HIGH ASH COAL/LIGNITE IS ASSUMED AS RAW MATERIAL
- 20 COAL MINE IS INTEGRAL WITH THE SYNTHETIC FUELS FACILITY
- 21 A TRANSFER PRICE IS ASSUMED WHICH WILL ALLOW THE COAL MINE TO OPERATE UNDER
 - ESSENTIALLY THE SAME FINANCIAL PARAMETERS OF IRR AND NPV AS THE FUEL FACILITY
- 22 COAL COST IS FACTORED ACCORDING TO PRODUCTION RATE

NOTES - PRODUCTION RATE

- 23 BASE CASE IS 15400 METRIC TONNES PER DAY OF METHANOL
- 24 PRODUCTION OF METHANOL IS MODULAR-EACH SYNTHESIS REACTOR CAPACITY 2200 TONNES/DAY

25 OCCUPANCY AT NAMEPLATE CAPACITY IS ASSUMED AT 90 PERCENT

26 ROLLING SHUTDOWN FOR PLANT MAINTENANCE IS ASSUMED

NOTES - FIXED COSTS OF PRODUCTION

27 BASE CASE FIXED COSTS ARE ASSUMED AT US\$190 MILLION/ANNUM

28 FIXED COSTS ARE FACTORED ACCORDING TO PRODUCTION RATE

NOTES - TECHNOLOGY

29 HIGH PRESSURE (APPROX 30 BAR) NON-SLAGGING GASIFIERS

30 RECTISOL GAS CLEANING

31 SYNTHESIS CONDUCTED AT 80 BAR

32 COARSE DISTILLATION (FUEL GRADE)

33 CARBON CAPTURE AND STORAGE ASSUMED

Number of Synthesis Modules			2						
Size of each synthesis module			2200	tonnes/day					
Nominal Daily Production			4400						
Capital Additions					Capex Percent	Capex Proportions	Basecase Capex	Percentage Capex Installation	
	Coal Preparation and Gasification		950.7135882	US\$ Millions	0.28	28	US\$7200M	YEAR 1	0.233333333
	Gas cleanup, stage1 CO2 removal		305.5865105	US\$ Millions	0.09	9	Exponent	YEAR 2	0.4
	Shift reaction, compression, stage2 CO2 removal		407.4486807	US\$ Millions	0.12	12	0.6	YEAR 3	0.3
	Synthesis Reaction		475.3567941	US\$ Millions	0.14	14	Basecase production	YEAR 4	0.066666667
	Distillation Section	Wastewater treatment	271.6324538	US\$ Millions	0.08	8	15400 T/D		
	Utilities and Offsites		746.9892479	US\$ Millions	0.22	22	Scaling Factor	(PLANT)	
	Carbon Capture		237.678397	US\$ Millions	0.07	7	0.471584121		
Total Capital Additions			3395.405672	US\$ Millions		100	Scaling Factor	(COAL COST)	
							0.323846166		
Online Time			90	%					
Equivalent online time at nameplate production rate			328.725						
Density of methanol			790	Kg/m3					

Realised Selling Price of methanol FOB Factory perimeter						70 US cents/litre			
Tonnes of Methanol produced				1446390	Tonnes / annum				
Kilo - litres of metanol produced				1830873.418					
Gross sales of Methanol per annum				1281611392	US\$ per annum				
				1281.611392	Million US\$ / annum				
Percentage of ash in coal				27	%		Base case -coal		
Tonnes of coal required per annum				3.571428571	Million Tonnes / annum		9.125 pure		
Cost of coal				35	US\$ per tonne				
Fixed Costs							Base Case	Percentage Fixed Costs	
							Fixed Costs	Salaries	40
	Payroll	35.84039321	US\$M				190	Maintenance	40
	Maintenance	35.84039321	US\$M					Other	20
	Other	17.9201966	US\$M						
Fixed Costs Total		89.60098301	US\$M						
									All Figures In Millions Of United States Dollars

Year	2011	2012	2013	2014	2015	2016
Inflation Rate	4.5	4.5	4.5	4.5	4.5	4.5
Inflation Index	1	1.045	1.092025	1.1411661	1.1925186	1.2461819
Gross Sales (real)	0	0	0	640.8057	1281.6114	1281.6114
Gross Sales (inflated)	0	0	0	731.26575	1528.3454	1597.121
Fixed Costs real	0	0	0	64.512708	89.600983	89.600983
Fixed Costs (inflated)	0	0	0	73.619717	106.85084	111.65913
Fixed Costs (inflated)						
Cost of coal (real)	0	0	0	62.5	125	125
Cost of coal (inflated)	0	0	0	71.322883	149.06483	155.77274
Fixed and Variable Costs-(real)	0	0	0	127.01271	214.60098	214.60098
Fixed and Variable Costs (inflated)	0	0	0	144.9426	255.91566	267.43187
Cash Flow (real)	0	0	0	513.79299	1067.0104	1067.0104
Cash Flow (inflated)	0	0	0	586.32315	1272.4298	1329.6891
Taxable Value of Plant (real)	0	792.26132	2150.4236	3169.0453	1697.7028	848.85142
Capital Additions During Year (real)	792.26132	1358.1623	1018.6217	226.36038	0	0
Cumulative Capital Additions (real)	792.26132	2150.4236	3169.0453	3395.4057	3395.4057	3395.4057
Initial Allowance (real)	0	0	0	1697.7028	0	0
Wear And Tear Allowance (real)	0	0	0	0	848.85142	848.85142

Year	2011	2012	2013	2014	2015	2016
Tax Allowance (real)	0	0	0	1697.7028	848.85142	848.85142
Taxable Value of Plant (inflated)	0	792.26132	2211.5409	3323.9013	1791.108	895.55401
Capital Additions During Year (inflated)	792.26132	1419.2796	1112.3604	258.3148	0	
Cumulative Capital Additions (inflated)	792.26132	2211.5409	3323.9013	3582.2161	3582.2161	3582.2161
Initial Allowance (inflated)	0			1791.108		
Wear And Tear Allowance (inflated)	0				895.55401	895.55401
Tax Allowance (inflated)				1791.108	895.55401	895.55401
Annual Taxable Income (real)	0	0	0	-1183.91	218.15899	218.15899
Annual Taxable Income (inflated)	0	0	0	-1204.785	376.87575	434.13509
Tax Loss Carried Forward (real)				-1183.91	-965.7509	-747.5919
Tax Loss Carried Forward(inflated)				-1204.785	-827.9091	-393.774
Taxable Income (real)	0	0	0	0	0	0
Taxable Income(inflated)	0	0	0	0	0	40.361046
Tax Payable (real)	0	0	0	0	0	0
Tax Payable (inflated)	0	0	0	0	0	17.153444
Trading Cash Flow After Tax (real)	0	0	0	513.79299	1067.0104	1067.0104
Trading cash flow after tax(inf)	0	0	0	586.32315	1272.4298	1312.5357
Net Cash Flow(real)	-792.2613	-1358.162	-1018.622	287.43261	1067.0104	1067.0104
Net Cash Flow(inflated)	-792.2613	-1419.28	-1112.36	328.00836	1272.4298	1312.5357
Cumulative cash flow (real)	-792.2613	-2150.424	-3169.045	-2881.613	-1814.602	-747.5919
Cumulative cash flow(inflated)	-792.2613	-2211.541	-3323.901	-2995.893	-1723.463	-410.9275

Year	2017	2018	2019	2020	2021	2022
Inflation Rate	4.5	4.5	4.5	4.5	4.5	4.5
Inflation Index	1.3022601	1.3608618	1.4221006	1.4860951	1.5529694	1.622853
Gross Sales (real)	1281.6114	1281.6114	1281.6114	1281.6114	1281.6114	1281.6114
Gross Sales (inflated)	1668.9914	1744.096	1822.5803	1904.5965	1990.3033	2079.867
Fixed Costs real	89.600983	89.600983	89.600983	89.600983	89.600983	89.600983
Fixed Costs (inflated)	116.68379	121.93456	127.42161	133.15559	139.14759	145.40923
Fixed Costs (inflated)						
Cost of coal (real)	125	125	125	125	125	125
Cost of coal (inflated)	162.78252	170.10773	177.76258	185.76189	194.12118	202.85663
Fixed and Variable Costs-(real)	214.60098	214.60098	214.60098	214.60098	214.60098	214.60098
Fixed and Variable Costs (inflated)	279.4663	292.04229	305.18419	318.91748	333.26876	348.26586
Cash Flow (real)	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104
Cash Flow (inflated)	1389.5251	1452.0537	1517.3962	1585.679	1657.0345	1731.6011
Taxable Value of Plant (real)	0	0	0	0	0	0
Capital Additions During Year (real)	0	0	0	0	0	0
Cumulative Capital Additions (real)	3395.4057	3395.4057	3395.4057	3395.4057	3395.4057	3395.4057
Initial Allowance (real)	0	0	0	0	0	0
Wear And Tear Allowance (real)	0	0	0	0	0	0
Tax Allowance (real)	0	0	0	0	0	0
Taxable Value of Plant (inflated)	0	0				
Capital Additions During Year (inflated)						
Cumulative Capital Additions (inflated)						
Initial Allowance (inflated)						
Wear And Tear Allowance (inflated)						
Tax Allowance (inflated)						
Annual Taxable Income (real)	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104
Annual Taxable Income (inflated)	1389.5251	1452.0537	1517.3962	1585.679	1657.0345	1731.6011
Tax Loss Carried Forward (real)	0	0	0	0	0	0
Tax Loss Carried Forward(inflated)	0	0	0	0	0	0
Taxable Income (real)	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104
Taxable Income(inflated)	1389.5251	1452.0537	1517.3962	1585.679	1657.0345	1731.6011

Year	2017	2018	2019	2020	2021	2022
Tax Payable (real)	453.47942	453.47942	453.47942	453.47942	453.47942	453.47942
Tax Payable (inflated)	590.54817	617.12284	644.89337	673.91357	704.23968	735.93046
Trading Cash Flow After Tax (real)	613.53099	613.53099	613.53099	613.53099	613.53099	613.53099
Trading cash flow after tax(inf)	798.97694	834.9309	872.50279	911.76542	952.79486	995.67063
Net Cash Flow(real)	613.53099	613.53099	613.53099	613.53099	613.53099	613.53099
Net Cash Flow(inflated)	798.97694	834.9309	872.50279	911.76542	952.79486	995.67063
Cumulative cash flow (real)	-134.0609	479.47011	1093.0011	1706.5321	2320.0631	2933.594
Cumulative cash flow(inflated)	388.04945	1222.9804	2095.4831	3007.2486	3960.0434	4955.714

Year	2023	2024	2025	2026	2027	2028
Inflation Rate	4.5	4.5	4.5	4.5	4.5	4.5
Inflation Index	1.6958814	1.7721961	1.8519449	1.9352824	2.0223702	2.1133768
Gross Sales (real)	1281.6114	1281.6114	1281.6114	1281.6114	1281.6114	1281.6114
Gross Sales (inflated)	2173.461	2271.2667	2373.4737	2480.28	2591.8926	2708.5278
Fixed Costs real	89.600983	89.600983	89.600983	89.600983	89.600983	89.600983
Fixed Costs (inflated)	151.95264	158.79051	165.93609	173.40321	181.20635	189.36064
Fixed Costs (inflated)						
Cost of coal (real)	125	125	125	125	125	125
Cost of coal (inflated)	211.98518	221.52451	231.49312	241.91031	252.79627	264.1721
Fixed and Variable Costs-(real)	214.60098	214.60098	214.60098	214.60098	214.60098	214.60098
Fixed and Variable Costs (inflated)	363.93782	380.31502	397.4292	415.31351	434.00262	453.53274
Cash Flow (real)	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104
Cash Flow (inflated)	1809.5231	1890.9517	1976.0445	2064.9665	2157.89	2254.9951
Taxable Value of Plant (real)	0	0	0	0	0	0
Capital Additions During Year (real)	0	0	0	0	0	0
Cumulative Capital Additions (real)	3395.4057	3395.4057	3395.4057	3395.4057	3395.4057	3395.4057
Initial Allowance (real)	0	0	0	0	0	0
Wear And Tear Allowance (real)	0	0	0	0	0	0
Tax Allowance (real)	0	0	0	0	0	0
Taxable Value of Plant (inflated)						
Capital Additions During Year (inflated)						
Cumulative Capital Additions (inflated)						
Initial Allowance (inflated)						
Wear And Tear Allowance (inflated)						
Tax Allowance (inflated)						
Annual Taxable Income (real)	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104
Annual Taxable Income (inflated)	1809.5231	1890.9517	1976.0445	2064.9665	2157.89	2254.9951
Tax Loss Carried Forward (real)	0	0	0	0	0	0
Tax Loss Carried Forward(inflated)	0	0	0	0	0	0
Taxable Income (real)	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104
Taxable Income(inflated)	1809.5231	1890.9517	1976.0445	2064.9665	2157.89	2254.9951
Tax Payable (real)	453.47942	453.47942	453.47942	453.47942	453.47942	453.47942
Tax Payable (inflated)	769.04734	803.65447	839.81892	877.61077	917.10325	958.3729
Trading Cash Flow After Tax (real)	613.53099	613.53099	613.53099	613.53099	613.53099	613.53099
Trading cash flow after tax(inf)	1040.4758	1087.2972	1136.2256	1187.3557	1240.7868	1296.6222
Net Cash Flow(real)	613.53099	613.53099	613.53099	613.53099	613.53099	613.53099
Net Cash Flow(inflated)	1040.4758	1087.2972	1136.2256	1187.3557	1240.7868	1296.6222
Cumulative cash flow (real)	3547.125	4160.656	4774.187	5387.718	6001.249	6614.78
Cumulative cash flow(inflated)	5996.1899	7083.4871	8219.7127	9407.0684	10647.855	11944.477

Year	2029	2030	2031	2032	2033	2034
Inflation Rate	4.5	4.5	4.5	4.5	4.5	4.5
Inflation Index	2.2084788	2.3078603	2.411714	2.5202412	2.633652	2.7521663
Gross Sales (real)	1281.6114	1281.6114	1281.6114	1281.6114	1281.6114	1281.6114
Gross Sales (inflated)	2830.4115	2957.7801	3090.8802	3229.9698	3375.3184	3527.2077
Fixed Costs real	89.600983	89.600983	89.600983	89.600983	89.600983	89.600983
Fixed Costs (inflated)	197.88187	206.78655	216.09195	225.81609	235.97781	246.59681
Fixed Costs (inflated)						
Cost of coal (real)	125	125	125	125	125	125
Cost of coal (inflated)	276.05985	288.48254	301.46425	315.03014	329.2065	344.02079
Fixed and Variable Costs-(real)	214.60098	214.60098	214.60098	214.60098	214.60098	214.60098
Fixed and Variable Costs (inflated)	473.94171	495.26909	517.5562	540.84623	565.18431	590.6176
Cash Flow (real)	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104
Cash Flow (inflated)	2356.4698	2462.511	2573.324	2689.1235	2810.1341	2936.5901
Taxable Value of Plant (real)	0	0	0	0	0	0
Capital Additions During Year (real)	0	0	0	0	0	0
Cumulative Capital Additions (real)	3395.4057	3395.4057	3395.4057	3395.4057	3395.4057	3395.4057
Initial Allowance (real)	0	0	0	0	0	0
Wear And Tear Allowance (real)	0	0	0	0	0	0
Tax Allowance (real)	0	0	0	0	0	0
Taxable Value of Plant (inflated)						
Capital Additions During Year (inflated)						
Cumulative Capital Additions (inflated)						
Initial Allowance (inflated)						
Wear And Tear Allowance (inflated)						
Tax Allowance (inflated)						
Annual Taxable Income (real)	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104
Annual Taxable Income (inflated)	2356.4698	2462.511	2573.324	2689.1235	2810.1341	2936.5901
Tax Loss Carried Forward (real)	0	0	0	0	0	0
Tax Loss Carried Forward(inflated)						
Taxable Income (real)	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104	1067.0104
Taxable Income(inflated)	2356.4698	2462.511	2573.324	2689.1235	2810.1341	2936.5901
Tax Payable (real)	453.47942	453.47942	453.47942	453.47942	453.47942	453.47942
Tax Payable (inflated)	1001.4997	1046.5672	1093.6627	1142.8775	1194.307	1248.0508
Trading Cash Flow After Tax (real)	613.53099	613.53099	613.53099	613.53099	613.53099	613.53099
Trading cash flow after tax(inf)	1354.9702	1415.9438	1479.6613	1546.246	1615.8271	1688.5393
Net Cash Flow(real)	613.53099	613.53099	613.53099	613.53099	613.53099	613.53099
Net Cash Flow(inflated)	1354.9702	1415.9438	1479.6613	1546.246	1615.8271	1688.5393
Cumulative cash flow (real)	7228.3109	7841.8419	8455.3729	9068.9039	9682.4349	10295.966
Cumulative cash flow(inflated)	13299.447	14715.391	16195.053	17741.299	19357.126	21045.665

Year	2035	2036
Inflation Rate	4.5	4.5
Inflation Index	2.8760138	3.0054345
Gross Sales (real)	1281.6114	1281.6114
Gross Sales (inflated)	3685.9321	3851.799
Fixed Costs real	89.600983	89.600983
Fixed Costs (inflated)	257.69367	269.28988
Fixed Costs (inflated)		
Cost of coal (real)	125	125
Cost of coal (inflated)	359.50173	375.67931
Fixed and Variable Costs-(real)	214.60098	214.60098
Fixed and Variable Costs (inflated)	617.1954	644.96919
Cash Flow (real)	1067.0104	1067.0104

Year	2035	2036
Cash Flow (inflated)	3068.7367	3206.8298
Taxable Value of Plant (real)	0	0
Capital Additions During Year (real)	0	0
Cumulative Capital Additions (real)	3395.4057	3395.4057
Initial Allowance (real)	0	0
Wear And Tear Allowance (real)	0	0
Tax Allowance (real)	0	0
Taxable Value of Plant (inflated)		
Capital Additions During Year (inflated)		
Cumulative Capital Additions (inflated)		
Initial Allowance (inflated)		
Wear And Tear Allowance (inflated)		
Tax Allowance (inflated)		
Annual Taxable Income (real)	1067.0104	1067.0104
Annual Taxable Income (inflated)	3068.7367	3206.8298
Tax Loss Carried Forward (real)		
Tax Loss Carried Forward (inflated)		
Taxable Income (real)	1067.0104	1067.0104
Taxable Income (inflated)	3068.7367	3206.8298
Tax Payable (real)	453.47942	453.47942
Tax Payable (inflated)	1304.2131	1362.9027
Trading Cash Flow After Tax (real)	613.53099	613.53099
Trading cash flow after tax (inf)	1764.5236	1843.9272
Net Cash Flow (real)	613.53099	613.53099
Net Cash Flow (inflated)	1764.5236	1843.9272
Cumulative cash flow (real)	10909.497	11523.028
Cumulative cash flow (inflated)	22810.189	24654.116

SELLING PRICE OF METHANOL	70	US CENTS PER LITRE FOB FACTORY GATE
INFLATION RATE OVER DISCOUNT PERIOD		4.5%
WEIGHTED AVERAGE COST OF CAPITAL-NON INFLATIONARY		3%
WEIGHTED AVERAGE COST OF CAPITAL -INFLATIONARY		7.5%
INTERNAL RATE OF RETURN- (IRR) NON-INFLATIONARY		0.1769219
INTERNAL RATE OF RETURN-INFLATIONARY		0.2294787
NET PRESENT VALUE AT ZERO COST OF CAPITAL		11523.028
NET PRESENT VALUE AT WACC-NON-INFLATIONARY		6536.1281
NET PRESENT VALUE AT WACC-INFLATIONARY		6122.013
TAX PAYABLE TO REVENUE AUTHORITY (REAL)		US\$M 9069.5885
TAX PAYABLE TO REVENUE AUTHORITY (INFLATED)		US\$M 18543.49

NUCLEAR ELECTROLYSIS METHANOL SYNTHESIS - FINANCIAL ANALYSIS

- SYNTHETIC METHANOL PRODUCTION - MEDIUM PRESSURE PROCESS
- COPPER CATALYST SUPPORTED ON ALUMINA
- WASTE CARBON DIOXIDE IS USED FROM COAL-BASED POWER PLANTS
- THERMO-NUCLEAR ELECTRICITY IS USED IN THE ELECTROLYSIS OF WATER TO MANUFACTURE HYDROGEN
- THE THERMO-NUCLEAR POWER PLANT IS SITUATED ADJACENT TO THE CONVENTIONAL POWER PLANT

NOTES - FINANCIAL

- 1 BOTH INFLATIONARY AND NON-INFLATIONARY FINANCIAL ANALYSES ARE PERFORMED
- 2 INFLATION RATE OVER THE DISCOUNT PERIOD IS ASSUMED AT 4.2 PERCENT
- 3 NON-INFLATIONARY FINANCIAL FIGURES ARE REFERRED TO IN THE SPREADSHEET AS "REAL"

TAX REGIME

- 4 COMPANY TAXATION IS INCLUDED AT A RATE OF 42.5%
- 5 AN INITIAL CAPITAL ALLOWANCE OF 50% IS ALLOWABLE IN THE FIRST PRODUCTION YEAR
- 6 WEAR AND TEAR ALLOWANCE OF 50% OF THE BALANCE FOLLOWS FOR THE FOLLOWING TWO SUCCESSIVE YEARS

FINANCIAL ANALYSES PERFORMED

- 7 INTERNAL RATE OF RETURN ON INFLATIONARY NET CASH FLOW
- 8 INTERNAL RATE OF RETURN ON NON-INFLATIONARY (REAL) NET CASH FLOWS
- 9 NET PRESENT VALUE AT ZERO COST OF CAPITAL PERFORMED OVER THE NON-INFLATIONARY (REAL) CASH FLOWS
- 10 NET PRESENT VALUE AT A STATED COST OF CAPITAL IN PERCENTAGE TERMS ABOVE THE INFLATION RATE PERFORMED OVER THE NON-INFLATIONARY NET CASH FLOWS
- 11 NET PRESENT VALUE AT A STATED COST OF CAPITAL PERFORMED OVER THE INFLATIONARY NET CASH FLOWS

TIME SCALE

- 12 CONSTRUCTION COMMENCES BEGINNING FIRST QUARTER 2011
- 13 FIRST PRODUCTION BEGINNING 3RD QUARTER 2014
- 14 DISCOUNT PERIOD FROM 2011 TO 2036

NOTES - CAPITAL COST

- 15 A BASE CASE CAPITAL COST OF US\$5200 MILLION IS ASSUMED FOR A PRODUCTION RATE OF 15400 TONNES/ANNUM
- 16 CAPITAL COST IS FACTORED AT PROPORTIONAL PRODUCTION TO POWER 0.6
- 17 CAPEX IS APPROXIMATELY
 - 23 PERCENT IN YEAR ONE
 - 40 PERCENT IN YEAR TWO
 - 30 PERCENT IN YEAR THREE
 - 7 PERCENT UP TO BEGINNING THIRD QUARTER YEAR FOUR
- 18 CAPITAL EXPENDITURE PROPORTIONS ARE AS DETAILED BELOW

NOTES - COST OF ELECTRICITY

- 19 ELECTRICITY IS PURCHASED FROM A THERMO-NUCLEAR POWER PLANT DEDICATED TO THE METHANOL SYNTHESIS PLANT
FOR HIGH PRODUCTION RATES >2000 TONNE/DAY
- 20 THE NUCLEAR POWER STATION OPERATES ON AN INDEPENDENT FINANCIAL BASIS
- 21 FOR LOWER PRODUCTION RATES A NON-CO2 EXHAUST MIX MAY BE ASSUMED OR OFF-PEAK POWER STORAGE BY ALCOHOL MANUFACTURE

NOTES - PRODUCTION RATE

- 23 BASE CASE IS 15400 METRIC TONNES PER DAY OF METHANOL
- 24 PRODUCTION OF METHANOL IS MODULAR-EACH SYNTHESIS REACTOR CAPACITY 2200 TONNES/DAY
- 25 OCCUPANCY AT NAMEPLATE CAPACITY IS ASSUMED AT 90 PERCENT
- 26 ROLLING SHUTDOWN FOR PLANT MAINTENANCE IS ASSUMED

NOTES - FIXED COSTS OF PRODUCTION

- 27 BASE CASE FIXED COSTS ARE ASSUMED AT
- 28 FIXED COSTS ARE FACTORED ACCORDING TO PRODUCTION RATE

NOTES - TECHNOLOGY

- 29 CARBON DIOXIDE EXHAUST FROM CONVENTIONAL POWER PLANT IS EMPLOYED AS THE CARBONACEOUS FEEDSTOCK
- 30 THE CO2 GAS IS RAISED IN PRESSURE BY A BLOWER AT A POINT AFTER THE DUST COLLECTION PLANT
- 31 THE GAS IS WASHED CLEAN OF DUST
- 32 PURE CO2 GAS IS SEPARATED FROM THE GAS STREAM CONTAINING EXCESS AIR ,NITROGEN, AND SO2
THIS IS ACHIEVED BY TEMPERATURE AND/OR PRESSURE SWING GAS ADSORPTION
- 33 THE PURIFIED CO2 GAS STREAM IS COMPRESSED
- 34 RAW WATER IS PURIFIED BY FLOCCULATION/FILTRATION FOLLOWED BY ION EXCHANGE
- 35 A CONDUCTIVITY MODIFIER IS ADDED
- 36 THE WATER IS ELECTROLYSED AND HYDROGEN IS DISCHARGED AT THE CATHODE
- 37 THE H2 GAS IS COLLECTED AND COMPRESSED
- 38 A PORTION OF THE H2 GAS IS REACTED AGAINST A PORTION OF THE CO2 GAS IN THE REVERSE SHIFT REACTOR TO FORM CO
- 39 THE GASES ARE PROPORTIONED INTO THE SYNTHESIS REACTOR IN THE NORMAL WAY
- 40 COARSE DISTILLATION IS UNDERTAKEN-FUEL GRADE METHANOL IS PRODUCED

Number of Synthesis Modules	2							
Size of each synthesis module	2200	tonnes/day						
Nominal Daily Production	4400							
Capital Additions			Capex Percent	Capex Proportions	Basecase Capex		Percentage Capex Installation	
Electrolytic Cell House	686.6264804	US\$ Millions	0.28	28	5200	US\$M	YEAR 1	0.233333333
Gas Cleanup CO2 Capture	220.7013687	US\$ Millions	0.09	9	Exponent		YEAR 2	0.4
Compression, Reverse Shift Reaction	294.2684916	US\$ Millions	0.12	12	0.6		YEAR 3	0.3
Synthesis Reaction	343.3132402	US\$ Millions	0.14	14	Basecase production		YEAR 4	0.066666667
Distillation Section - Wastewater Treatment	196.1789944	US\$ Millions	0.08	8	15400	T/D		
Utilities and Offsites	539.4922346	US\$ Millions	0.22	22	Scaling Factor	(PLANT)		
Electrical Integration With Existing Power Plant	171.6566201	US\$ Millions	0.07	7	0.471584121			
Total Capital Additions	2452.23743	US\$ Millions		100				
Online Time	90	%						
Equivalent online time at nameplate production rate	328.725							
Density of methanol	790	Kg/m3	Days					
Realised Selling Price of methanol fob Factory perimeter					65 US cents/litre			
Tonnes of Methanol produced		1446390	Tonnes/annum					
Kilo -litres of metanol produced		1830873.418						
Gross sales of Methanol per annum		1190067722	US\$ per annum					
		1190.067722	Million US\$ per annum			Base Case Power Plant Size		
						750	Megawatts	Per 2200 tonne/day module
Capacity Of Nuclear Power Plant		1500	Megawatt			Base Case Electricity		
Nameplate Power Consumption		1431.999899	Megawatt					
Gigawatt.hrs required per annum		11297.62	Gigawatt.Hrs			39541.67	GIGA WATT.HRS/ANNUM	
Cost Of Electricity From Thermo-Nuclear Power Plant		4	U.S.cents per Kilowatt.Hr					

		0.04	Million U.S.Dollars per Gigawatt.Hr					
		4000000				Base Case	Percentage Fixed Costs	
Fixed Costs	US\$M					Fixed Costs	Salaries	40
Payroll	23.57920606					125	Maintenance	40
Maintenance	23.57920606						Other	20
Other	11.78960303							
Fixed Costs Total	58.94801514							
All Figures In Millions Of United States Dollars								

Year	2011	2012	2013	2014	2015	2016
Inflation Rate	4.2	4.2	4.2	4.2	4.2	4.2
Inflation Index	1	1.042	1.085764	1.1313661	1.1788835	1.2283966
Gross Sales (real)	0	0	0	595.03386	1190.0677	1190.0677
Gross Sales (inflated)	0	0	0	673.20113	1402.9512	1461.8751
Fixed Costs real	0	0	0	42.442571	58.948015	58.948015
Fixed Costs (inflated)	0	0	0	48.018085	69.49284	72.41154
Fixed Costs (inflated)						
Cost Of Electricity (real)	0	0	0	225.9524	451.9048	451.9048
Cost of Electricity (inflated)	0	0	0	255.63488	532.7431	555.11831
Fixed and Variable Costs-(real)	0	0	0	268.39497	510.85282	510.85282
Fixed and Variable Costs (inflated)	0	0	0	303.65297	602.23594	627.52985
Cash Flow (real)	0	0	0	326.63889	679.21491	679.21491
Cash Flow (inflated)	0	0	0	369.54816	800.71522	834.34526
Taxable Value of Plant (real)	0	572.18873	1553.0837	2288.7549	1226.1187	613.05936
Capital Additions During Year (real)	572.18873	980.89497	735.67123	163.4825	0	0
Cumulative Capital Additions (real)	572.18873	1553.0837	2288.7549	2452.2374	2452.2374	2452.2374
Initial Allowance (real)	0	0	0	1226.1187	0	0
Wear And Tear Allowance (real)	0	0	0	0	613.05936	613.05936
Tax Allowance (real)	0	0	0	1226.1187	613.05936	613.05936
Taxable Value of Plant (inflated)	0	572.18873	1594.2813	2393.0466	1289.0026	644.5013
Capital Additions During Year (inflated)	572.18873	1022.0926	798.76534	184.95855	0	0
Cumulative Capital Additions (inflated)	572.18873	1594.2813	2393.0466	2578.0052	2578.0052	2578.0052
Initial Allowance (inflated)	0			1289.0026		
Wear And Tear Allowance (inflated)	0				644.5013	644.5013
Tax Allowance (inflated)				1289.0026	644.5013	644.5013
Annual Taxable Income (real)	0	0	0	-899.4798	66.155549	66.155549
Annual Taxable Income (inflated)	0	0	0	-919.4544	156.21393	189.84397
Tax Loss Carried Forward (real)				-899.4798	-833.3243	-767.1687
Tax Loss Carried Forward (inflated)				-919.4544	-763.2405	-573.3965
Taxable Income (real)	0	0	0	0	0	0
Taxable Income (inflated)	0	0	0	0	0	0
Tax Payable (real)	0	0	0	0	0	0
Tax Payable (inflated)	0	0	0	0	0	0
Trading Cash Flow After Tax (real)	0	0	0	326.63889	679.21491	679.21491
Trading cash flow after tax (inf)	0	0	0	369.54816	800.71522	834.34526

Year	2011	2012	2013	2014	2015	2016
Net Cash Flow(real)	-572.1887	-980.895	-735.6712	163.15639	679.21491	679.21491
Net Cash Flow(inflated)	-572.1887	-1022.093	-798.7653	184.58961	800.71522	834.34526
Cumulative cash flow (real)	-572.1887	-1553.084	-2288.755	-2125.599	-1446.384	-767.1687
Cumulative cash flow(inflated)	-572.1887	-1594.281	-2393.047	-2208.457	-1407.742	-573.3965

Year	2017	2018	2019	2020	2021	2022
Inflation Rate	4.2	4.2	4.2	4.2	4.2	4.2
Inflation Index	1.2799892	1.3337488	1.3897662	1.4481364	1.5089581	1.5723344
Gross Sales (real)	1190.0677	1190.0677	1190.0677	1190.0677	1190.0677	1190.0677
Gross Sales (inflated)	1523.2739	1587.2514	1653.9159	1723.3804	1795.7624	1871.1844
Fixed Costs real	58.948015	58.948015	58.948015	58.948015	58.948015	58.948015
Fixed Costs (inflated)	75.452824	78.621843	81.92396	85.364767	88.950087	92.68599
Fixed Costs (inflated)						
Cost Of Electricity (real)	451.9048	451.9048	451.9048	451.9048	451.9048	451.9048
Cost of Electricity (inflated)	578.43327	602.72747	628.04203	654.41979	681.90542	710.54545
Fixed and Variable Costs-(real)	510.85282	510.85282	510.85282	510.85282	510.85282	510.85282
Fixed and Variable Costs (inflated)	653.8861	681.34932	709.96599	739.78456	770.85551	803.23144
Cash Flow (real)	679.21491	679.21491	679.21491	679.21491	679.21491	679.21491
Cash Flow (inflated)	869.38776	905.90205	943.94993	983.59583	1024.9069	1067.9529
Taxable Value of Plant (real)	0	0	0	0	0	0
Capital Additions During Year (real)	0		0	0	0	0
Cumulative Capital Additions (real)	2452.2374	2452.2374	2452.2374	2452.2374	2452.2374	2452.2374
Initial Allowance (real)	0	0	0	0	0	0
Wear And Tear Allowance (real)	0	0	0	0	0	0
Tax Allowance (real)	0	0	0	0	0	0
Taxable Value of Plant (inflated)	0	0				
Capital Additions During Year (inflated)						
Cumulative Capital Additions (inflated)						
Initial Allowance (inflated)						
Wear And Tear Allowance (inflated)						
Tax Allowance (inflated)						
Annual Taxable Income (real)	679.21491	679.21491	679.21491	679.21491	679.21491	679.21491
Annual Taxable Income (inflated)	869.38776	905.90205	943.94993	983.59583	1024.9069	1067.9529
Tax Loss Carried Forward (real)	-87.95382	0	0	0	0	0
Tax Loss Carried Forward(inflated)	0	0	0	0	0	0
Taxable Income (real)	591.26109	679.21491	679.21491	679.21491	679.21491	679.21491
Taxable Income(inflated)	869.38776	905.90205	943.94993	983.59583	1024.9069	1067.9529
Tax Payable (real)	251.28596	288.66634	288.66634	288.66634	288.66634	288.66634
Tax Payable (inflated)	369.4898	385.00837	401.17872	418.02823	435.58541	453.88
Trading Cash Flow After Tax (real)	427.92895	390.54857	390.54857	390.54857	390.54857	390.54857
Trading cash flow after tax(inf)	499.89796	520.89368	542.77121	565.5676	589.32144	614.07294
Net Cash Flow(real)	427.92895	390.54857	390.54857	390.54857	390.54857	390.54857
Net Cash Flow(inflated)	499.89796	520.89368	542.77121	565.5676	589.32144	614.07294
Cumulative cash flow (real)	-339.2398	51.308789	441.85736	832.40593	1222.9545	1613.5031
Cumulative cash flow(inflated)	-73.49857	447.3951	990.16632	1555.7339	2145.0554	2759.1283

Year	2023	2024	2025	2026	2027	2028
Inflation Rate	4.2	4.2	4.2	4.2	4.2	4.2
Inflation Index	1.6383724	1.7071841	1.7788858	1.853599	1.9314501	2.0125711
Gross Sales (real)	1190.0677	1190.0677	1190.0677	1190.0677	1190.0677	1190.0677
Gross Sales (inflated)	1949.7741	2031.6646	2116.9946	2205.9083	2298.5565	2395.0959
Fixed Costs real	58.948015	58.948015	58.948015	58.948015	58.948015	58.948015
Fixed Costs (inflated)	96.578802	100.63511	104.86179	109.26598	113.85515	118.63707
Fixed Costs (inflated)						
Cost Of Electricity (real)	451.9048	451.9048	451.9048	451.9048	451.9048	451.9048
Cost of Electricity (inflated)	740.38836	771.48467	803.88703	837.65028	872.83159	909.49052
Fixed and Variable Costs-(real)	510.85282	510.85282	510.85282	510.85282	510.85282	510.85282
Fixed and Variable Costs (inflated)	836.96716	872.11978	908.74881	946.91626	986.68675	1028.1276
Cash Flow (real)	679.21491	679.21491	679.21491	679.21491	679.21491	679.21491
Cash Flow (inflated)	1112.807	1159.5449	1208.2457	1258.9921	1311.8697	1366.9683
Taxable Value of Plant (real)	0	0	0	0	0	0
Capital Additions During Year (real)	0	0	0	0	0	0
Cumulative Capital Additions (real)	2452.2374	2452.2374	2452.2374	2452.2374	2452.2374	2452.2374
Initial Allowance (real)	0	0	0	0	0	0
Wear And Tear Allowance (real)	0	0	0	0	0	0
Tax Allowance (real)	0	0	0	0	0	0
Taxable Value of Plant (inflated)						
Capital Additions During Year (inflated)						
Cumulative Capital Additions (inflated)						
Initial Allowance (inflated)						
Wear And Tear Allowance (inflated)						
Tax Allowance (inflated)						
Annual Taxable Income (real)	679.21491	679.21491	679.21491	679.21491	679.21491	679.21491
Annual Taxable Income (inflated)	1112.807	1159.5449	1208.2457	1258.9921	1311.8697	1366.9683
Tax Loss Carried Forward (real)	0	0	0	0	0	0
Tax Loss Carried Forward(inflated)	0	0	0	0	0	0
Taxable Income (real)	679.21491	679.21491	679.21491	679.21491	679.21491	679.21491
Taxable Income(inflated)	1112.807	1159.5449	1208.2457	1258.9921	1311.8697	1366.9683
Tax Payable (real)	288.66634	288.66634	288.66634	288.66634	288.66634	288.66634
Tax Payable (inflated)	472.94296	492.80657	513.50444	535.07163	557.54464	580.96151
Trading Cash Flow After Tax (real)	390.54857	390.54857	390.54857	390.54857	390.54857	390.54857
Trading cash flow after tax(inf)	639.86401	666.73829	694.7413	723.92044	754.3251	786.00675
Net Cash Flow(real)	390.54857	390.54857	390.54857	390.54857	390.54857	390.54857
Net Cash Flow(inflated)	639.86401	666.73829	694.7413	723.92044	754.3251	786.00675
Cumulative cash flow (real)	2004.0516	2394.6002	2785.1488	3175.6974	3566.2459	3956.7945
Cumulative cash flow(inflated)	3398.9923	4065.7306	4760.4719	5484.3923	6238.7174	7024.7242

Year	2029	2030	2031	2032	2033	2034
Inflation Rate	4.2	4.2	4.2	4.2	4.2	4.2
Inflation Index	2.097099	2.1851772	2.2769546	2.3725867	2.4722354	2.5760693
Gross Sales (real)	1190.0677	1190.0677	1190.0677	1190.0677	1190.0677	1190.0677
Gross Sales (inflated)	2495.6899	2600.5089	2709.7302	2823.5389	2942.1275	3065.6969
Fixed Costs real	58.948015	58.948015	58.948015	58.948015	58.948015	58.948015
Fixed Costs (inflated)	123.61983	128.81186	134.22196	139.85928	145.73337	151.85417
Fixed Costs (inflated)						
Cost Of Electricity (real)	451.9048	451.9048	451.9048	451.9048	451.9048	451.9048
Cost of Electricity (inflated)	947.68912	987.49207	1028.9667	1072.1833	1117.215	1164.1381
Fixed and Variable Costs-(real)	510.85282	510.85282	510.85282	510.85282	510.85282	510.85282

Year	2029	2030	2031	2032	2033	2034
Fixed and Variable Costs (inflated)	1071.3089	1116.3039	1163.1887	1212.0426	1262.9484	1315.9922
Cash Flow (real)	679.21491	679.21491	679.21491	679.21491	679.21491	679.21491
Cash Flow (inflated)	1424.3809	1484.2049	1546.5415	1611.4963	1679.1791	1749.7046
Taxable Value of Plant (real)	0	0	0	0	0	0
Capital Additions During Year (real)	0	0	0	0	0	0
Cumulative Capital Additions (real)	2452.2374	2452.2374	2452.2374	2452.2374	2452.2374	2452.2374
Initial Allowance (real)	0	0	0	0	0	0
Wear And Tear Allowance (real)	0	0	0	0	0	0
Tax Allowance (real)	0	0	0	0	0	0
Taxable Value of Plant (inflated)						
Capital Additions During Year (inflated)						
Cumulative Capital Additions (inflated)						
Initial Allowance (inflated)						
Wear And Tear Allowance (inflated)						
Tax Allowance (inflated)						
Annual Taxable Income (real)	679.21491	679.21491	679.21491	679.21491	679.21491	679.21491
Annual Taxable Income (inflated)	1424.3809	1484.2049	1546.5415	1611.4963	1679.1791	1749.7046
Tax Loss Carried Forward (real)	0	0	0	0	0	
Tax Loss Carried Forward (inflated)						
Taxable Income (real)	679.21491	679.21491	679.21491	679.21491	679.21491	679.21491
Taxable Income (inflated)	1424.3809	1484.2049	1546.5415	1611.4963	1679.1791	1749.7046
Tax Payable (real)	288.66634	288.66634	288.66634	288.66634	288.66634	288.66634
Tax Payable (inflated)	605.36189	630.78709	657.28015	684.88592	713.65113	743.62447
Trading Cash Flow After Tax (real)	390.54857	390.54857	390.54857	390.54857	390.54857	390.54857
Trading cash flow after tax (inf)	819.01903	853.41783	889.26138	926.61036	965.528	1006.0802
Net Cash Flow (real)	390.54857	390.54857	390.54857	390.54857	390.54857	390.54857
Net Cash Flow (inflated)	819.01903	853.41783	889.26138	926.61036	965.528	1006.0802
Cumulative cash flow (real)	4347.3431	4737.8916	5128.4402	5518.9888	5909.5374	6300.0859
Cumulative cash flow (inflated)	7843.7432	8697.1611	9586.4224	10513.033	11478.561	12484.641

Year	2035	2036
Inflation Rate	4.2	4.2
Inflation Index	2.6842642	2.7970033
Gross Sales (real)	1190.0677	1190.0677
Gross Sales (inflated)	3194.4562	3328.6233
Fixed Costs real	58.948015	58.948015
Fixed Costs (inflated)	158.23205	164.87779
Fixed Costs (inflated)		
Cost Of Electricity (real)	451.9048	451.9048
Cost of Electricity (inflated)	1213.0319	1263.9792
Fixed and Variable Costs (real)	510.85282	510.85282
Fixed and Variable Costs (inflated)	1371.2639	1428.857
Cash Flow (real)	679.21491	679.21491
Cash Flow (inflated)	1823.1922	1899.7663
Taxable Value of Plant (real)	0	0
Capital Additions During Year (real)	0	0
Cumulative Capital Additions (real)	2452.2374	2452.2374
Initial Allowance (real)	0	0
Wear And Tear Allowance (real)	0	0
Tax Allowance (real)	0	0

Year	2035	2036
Taxable Value of Plant (inflated)		
Capital Additions During Year (inflated)		
Cumulative Capital Additions (inflated)		
Initial Allowance (inflated)		
Wear And Tear Allowance (inflated)		
Tax Allowance (inflated)		
Annual Taxable Income (real)	679.21491	679.21491
Annual Taxable Income (inflated)	1823.1922	1899.7663
Tax Loss Carried Forward (real)		
Tax Loss Carried Forward(inflated)		
Taxable Income (real)	679.21491	679.21491
Taxable Income(inflated)	1823.1922	1899.7663
Tax Payable (real)	288.66634	288.66634
Tax Payable (inflated)	774.8567	807.40068
Trading Cash Flow After Tax (real)	390.54857	390.54857
Trading cash flow after tax(inf)	1048.3355	1092.3656
Net Cash Flow(real)	390.54857	390.54857
Net Cash Flow(inflated)	1048.3355	1092.3656
Cumulative cash flow (real)	6690.6345	7081.1831
Cumulative cash flow(inflated)	13532.977	14625.342

SELLING PRICE OF METHANOL	65	US CENTS PER LITRE	FOB. FACTORY GATE
COST OF ELECTRICITY U.S.CENTS/KWHR			4
SIZE OF NUCLEAR POWER PLANT		1500	MEGAWATTS
TONNES OF METHANOL PRODUCED PER ANNUM		1446390	TONNES
INFLATION RATE OVER DISCOUNT PERIOD		4.2	PERCENT
WEIGHTED AVERAGE COST OF CAPITAL - NON-INFLATIONARY		3	PERCENT
WEIGHTED AVERAGE COST OF CAPITAL - INFLATIONARY		7.2	PERCENT
INTERNAL RATE OF RETURN- (IRR) NON-INFLATIONARY		0.15642809	
INTERNAL RATE OF RETURN - INFLATIONARY		0.20369557	
NET PRESENT VALUE AT ZERO COST OF CAPITAL		7081.18307	
NET PRESENT VALUE AT WACC - NON-INFLATIONARY		3925.0771	
NET PRESENT VALUE AT WACC-INFLATIONARY		3674.98373	
CUMULATIVE TAX PAID TO REVENUE AUTHORITY	(REAL)	5735.94633	US\$M
CUMULATIVE TAX PAID TO REVENUE AUTHORITY	(INF)	11233.8503	US\$M

SYNTHETIC METHANOL - NATURAL GAS BASED PRODUCTION
FINANCIAL ANALYSIS

- MEDIUM PRESSURE PROCESS
- COPPER CATALYST SUPPORTED ON ALUMINA

NOTES - FINANCIAL

- 1 BOTH INFLATIONARY AND NON-INFLATIONARY FINANCIAL ANALYSES ARE PERFORMED
- 2 INFLATION RATE OVER THE DISCOUNT PERIOD IS ASSUMED AT 4.2 PERCENT
- 3 NON-INFLATIONARY FINANCIAL FIGURES ARE REFERRED TO IN THE SPREADSHEET AS "REAL"
- TAX REGIME
- 4 COMPANY TAXATION IS INCLUDED AT A RATE OF 42.5%
- 5 AN INITIAL CAPITAL ALLOWANCE OF 50% IS ALLOWABLE IN THE FIRST PRODUCTION YEAR
- 6 WEAR AND TEAR ALLOWANCE OF 50% OF THE BALANCE FOLLOWS FOR THE FOLLOWING TWO SUCCESSIVE YEARS
- FINANCIAL ANALYSES PERFORMED
- 7 INTERNAL RATE OF RETURN ON INFLATIONARY NET CASH FLOW
- 8 INTERNAL RATE OF RETURN ON NON-INFLATIONARY (REAL) NET CASH FLOWS
- 9 NET PRESENT VALUE AT ZERO COST OF CAPITAL PERFORMED OVER THE NON-INFLATIONARY (REAL) CASH FLOWS
- 10 NET PRESENT VALUE AT A STATED COST OF CAPITAL IN PERCENTAGE TERMS ABOVE THE INFLATION RATE PERFORMED OVER THE NON-INFLATIONARY NET CASH FLOWS
- 11 NET PRESENT VALUE AT A STATED COST OF CAPITAL PERFORMED OVER THE INFLATIONARY NET CASH FLOWS
- TIME SCALE
- 12 CONSTRUCTION COMMENCES BEGINNING FIRST QUARTER 2011
- 13 FIRST PRODUCTION BEGINNING 3RD QUARTER 2014
- 14 DISCOUNT PERIOD FROM 2011 TO 2036

NOTES - CAPITAL COST

- 15 A BASE CASE CAPITAL COST OF US\$4320 IS ASSUMED FOR A PRODUCTION RATE OF 15400 TONNES/ANNUM
- 16 CAPITAL COST IS FACTORED AT PROPORTIONAL PRODUCTION TO POWER 0.6
- 17 CAPEX IS APPROXIMATELY
 - 23 PERCENT IN YEAR ONE
 - 40 PERCENT IN YEAR TWO
 - 30 PERCENT IN YEAR THREE
 - 7 PERCENT UP TO BEGINNING THIRD QUARTER YEAR FOUR
- 18 CAPITAL EXPENDITURE PROPORTIONS ARE AS DETAILED BELOW

NOTES - COST OF NATURAL GAS

- 19 NATURAL GAS IS IMPORTED TO THE METHANOL SYNTHESIS FACILITY COST 8.5 US\$/MMBTU
- 20 THE GAS PRODUCTION FACILITY OPERATES ON A SEPARATE FINANCIAL BASIS

NOTES - PRODUCTION RATE

- 21 BASE CASE IS 15400 METRIC TONNES PER DAY OF METHANOL
 22 PRODUCTION OF METHANOL IS MODULAR-EACH SYNTHESIS REACTOR CAPACITY 2200 TONNES/DAY
 23 OCCUPANCY AT NAMEPLATE CAPACITY IS ASSUMED AT 90 PERCENT
 24 ROLLING SHUTDOWN FOR PLANT MAINTENANCE IS ASSUMED

NOTES - FIXED COSTS OF PRODUCTION

- 25 BASE CASE FIXED COSTS ARE ASSUMED AT US\$110 MILLION/ANNUM
 26 FIXED COSTS ARE FACTORED ACCORDING TO PRODUCTION RATE

NOTES - TECHNOLOGY

- 27 NATURAL GAS (CH₄) IS EMPLOYED AS THE CARBONACEOUS FEEDSTOCK
 28 STEAM REFORMATION OF THE CH₄ IS CARRIED OUT OVER A NICKEL CATALYST

 29 THE REFORMATION TECHNOLOGY IS AS FOLLOWS:CH₄+H₂O=3H₂+CO
 30 THE CARBON DIOXIDE REQUIRED TO MODIFY THE SYNTHESIS REACTION IS OBTAINED BY COMBUSTION OF NATURAL GAS TO POWER THE STEAM REFORMATION REACTION
 31 THE PURIFIED CO₂ GAS STREAM IS COMPRESSED
 32 THE GASES ARE PROPORTIONED INTO THE SYNTHESIS REACTOR IN THE NORMAL WAY

 33 THE SYNTHESIS REACTOR IS EQUIPPED WITH RECYCLE COMPRESSION
 34 COARSE DISTILLATION IS UNDERTAKEN-FUEL GRADE METHANOL IS PRODUCED

Number of Synthesis Modules		0.113636364							
Size of each synthesis module		2200	tonnes/day						
Nominal Daily Production		250							
Capital Additions				Capex Percent	Capex Proportions	Basecase Capex		Percentage Capex Installation	
Steam reformation		102.0688804	US\$ Millions	0.28	28	4320	US\$M	YEAR 1	0.233333333
Gas Cleanup CO ₂ Capture		32.8078544	US\$ Millions	0.09	9	Exponent		YEAR 2	0.4
Compression,Reverse Shift Reaction		43.74380587	US\$ Millions	0.12	12	0.6		YEAR 3	0.3
Synthesis Reaction		51.03444018	US\$ Millions	0.14	14	Basecase production		YEAR 4	0.066666667
Distillation Section	Wastewater treatment	29.16253725	US\$ Millions	0.08	8	15400	T/D		
Utilities and Offsites		80.19697743	US\$ Millions	0.22	22	Scaling Factor	(PLANT)		
Carbon Capture		25.51722009	US\$ Millions	0.07	7	0.084382342			
Total Capital Additions		364.5317156	US\$ Millions		100	Scaling Factor	(NATURAL GAS COST)		
						0.024511922			
Online Time		90	%						
Equivalent online time at nameplate production rate		328.725	Days						

Density of methanol		790	Kg/m3						
Realised Selling Price of methanol fob Factory perimeter						70 US cents/litre			
Tonnes of Methanol produced			82181.25	Tonnes/annum					
Kilo -litres of methanol produced			104026.8987						
Gross sales of Methanol per annum			72818829.11	United States Dollars per annum					
			72.81882911	Million United States Dollars/annum			Base Case Power Plant Size		
							750 MW		Per 2200 tonne/day module
Quantity of natural gas required per tonne in MMBTU			29.1	MMBTU					
			30.7005	GIGA JOULES					
Nameplate Power Consumption			0.088832465	GIGAWATT					
Natural Gas Price per MMBTU			8.5	U.S.\$/MMBTU					
							Base Case	Percentage Fixed Costs	
Fixed Costs	US\$M						Fixed Costs	Salaries	40
Payroll	3.712823029						110	Maintenance	40
Maintenance	3.712823029							Other	20
Other	1.856411515								
Fixed Costs Total	9.282057573								
All Figures In Millions Of United States Dollars									

Year	2011	2012	2013	2014	2015	2016	2017
Inflation Rate	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Inflation Index	1	1.042	1.085764	1.1313661	1.1788835	1.2283966	1.2799892
Gross Sales (real)	0	0	0	36.409415	72.818829	72.818829	72.818829
Gross Sales (inflated)	0	0	0	41.192377	85.844913	89.4504	93.207317
Fixed Costs real	0	0	0	6.6830815	9.2820576	9.2820576	9.2820576
Fixed Costs (inflated)	0	0	0	7.5610117	10.942464	11.402048	11.880934
Fixed Costs (inflated)							
Cost Of Electricity (real)	0	0	0	0	20.327532	20.327532	20.327532
Cost of Electricity (inflated)	0	0	0	0	23.963792	24.970271	26.019022
Fixed and Variable Costs-(real)	0	0	0	6.6830815	29.60959	29.60959	29.60959
Fixed and Variable Costs (inflated)	0	0	0	7.5610117	34.906256	36.372318	37.899956
Cash Flow (real)	0	0	0	29.726333	43.209239	43.209239	43.209239
Cash Flow (inflated)	0	0	0	33.631365	50.938658	53.078081	55.307361
Taxable Value of Plant (real)	0	85.0574	230.87009	340.2296	182.26586	91.132929	0

Year	2011	2012	2013	2014	2015	2016	2017
Capital Additions During Year (real)	85.0574	145.81269	109.35951	24.302114	0	0	0
Cumulative Capital Additions (real)	85.0574	230.87009	340.2296	364.53172	364.53172	364.53172	364.53172
Initial Allowance (real)	0	0	0	182.26586	0	0	0
Wear And Tear Allowance (real)	0	0	0	0	91.132929	91.132929	0
Tax Allowance (real)	0	0	0	182.26586	91.132929	91.132929	0
Taxable Value of Plant (inflated)	0	85.0574	236.99422	355.73284	191.61372	95.806858	0
Capital Additions During Year (inflated)	85.0574	151.93682	118.73862	27.494588	0		
Cumulative Capital Additions (inflated)	85.0574	236.99422	355.73284	383.22743	383.22743	383.22743	
Initial Allowance (inflated)	0			191.61372			
Wear And Tear Allowance (inflated)	0				95.806858	95.806858	
Tax Allowance (inflated)				191.61372	95.806858	95.806858	
Annual Taxable Income (real)	0	0	0	-152.5395	-47.92369	-47.92369	43.209239
Annual Taxable Income (inflated)	0	0	0	-157.9824	-44.8682	-42.72878	55.307361
Tax Loss Carried Forward (real)				-152.5395	-200.4632	-248.3869	-205.1777
Tax Loss Carried Forward(inflated)				-157.9824	-202.8506	-245.5793	-190.272
Taxable Income (real)	0	0	0	0	0	0	0
Taxable Income(inflated)	0	0	0	0	0	0	0
Tax Payable (real)	0	0	0	0	0	0	0
Tax Payable (inflated)	0	0	0	0	0	0	0
Trading Cash Flow After Tax (real)	0	0	0	29.726333	43.209239	43.209239	43.209239
Trading cash flow after tax(inf)	0	0	0	33.631365	50.938658	53.078081	55.307361
Net Cash Flow(real)	-85.0574	-145.8127	-109.3595	5.4242187	43.209239	43.209239	43.209239
Net Cash Flow(inflated)	-85.0574	-151.9368	-118.7386	6.1367771	50.938658	53.078081	55.307361
Cumulative cash flow (real)	-85.0574	-230.8701	-340.2296	-334.8054	-291.5961	-248.3869	-205.1777
Cumulative cash flow(inflated)	-85.0574	-236.9942	-355.7328	-349.5961	-298.6574	-245.5793	-190.272

Year	2018	2019	2020	2021	2022	2023	2024
Inflation Rate	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Inflation Index	1.3337488	1.3897662	1.4481364	1.5089581	1.5723344	1.6383724	1.7071841
Gross Sales (real)	72.818829	72.818829	72.818829	72.818829	72.818829	72.818829	72.818829
Gross Sales (inflated)	97.122024	101.20115	105.4516	109.88056	114.49555	119.30436	124.31514
Fixed Costs real	9.2820576	9.2820576	9.2820576	9.2820576	9.2820576	9.2820576	9.2820576
Fixed Costs (inflated)	12.379933	12.89989	13.441685	14.006236	14.594498	15.207467	15.846181
Fixed Costs (inflated)							
Cost Of Electricity (real)	20.327532	20.327532	20.327532	20.327532	20.327532	20.327532	20.327532
Cost of Electricity (inflated)	27.111821	28.250518	29.437039	30.673395	31.961678	33.304068	34.702839
Fixed and Variable Costs-(real)	29.60959	29.60959	29.60959	29.60959	29.60959	29.60959	29.60959
Fixed and Variable Costs (inflated)	39.491754	41.150408	42.878725	44.679631	46.556176	48.511535	50.54902
Cash Flow (real)	43.209239	43.209239	43.209239	43.209239	43.209239	43.209239	43.209239
Cash Flow (inflated)	57.63027	60.050741	62.572872	65.200933	67.939372	70.792826	73.766125
Taxable Value of Plant (real)	0	0	0	0	0	0	0
Capital Additions During Year (real)		0	0	0	0	0	0
Cumulative Capital Additions (real)	364.53172	364.53172	364.53172	364.53172	364.53172	364.53172	364.53172
Initial Allowance (real)	0	0	0	0	0	0	0
Wear And Tear Allowance (real)	0	0	0	0	0	0	0
Tax Allowance (real)	0	0	0	0	0	0	0
Taxable Value of Plant (inflated)	0						

Year	2018	2019	2020	2021	2022	2023	2024
Capital Additions During Year (inflated)							
Cumulative Capital Additions (inflated)							
Initial Allowance (inflated)							
Wear And Tear Allowance (inflated)							
Tax Allowance (inflated)							
Annual Taxable Income (real)	43.209239	43.209239	43.209239	43.209239	43.209239	43.209239	43.209239
Annual Taxable Income (inflated)	57.63027	60.050741	62.572872	65.200933	67.939372	70.792826	73.766125
Tax Loss Carried Forward (real)	-161.9684	-118.7592	-75.54995	-32.34071	0	0	0
Tax Loss Carried Forward(inflated)	-132.6417	-72.59096	-10.01808	0	0	0	0
Taxable Income (real)	0	0	0	10.868532	43.209239	43.209239	43.209239
Taxable Income(inflated)	0	0	52.55479	65.200933	67.939372	70.792826	73.766125
Tax Payable (real)	0	0	0	4.6191262	18.363927	18.363927	18.363927
Tax Payable (inflated)	0	0	22.335786	27.710397	28.874233	30.086951	31.350603
Trading Cash Flow After Tax (real)	43.209239	43.209239	43.209239	38.590113	24.845313	24.845313	24.845313
Trading cash flow after tax(inf)	57.63027	60.050741	40.237087	37.490537	39.065139	40.705875	42.415522
Net Cash Flow(real)	43.209239	43.209239	43.209239	38.590113	24.845313	24.845313	24.845313
Net Cash Flow(inflated)	57.63027	60.050741	40.237087	37.490537	39.065139	40.705875	42.415522
Cumulative cash flow (real)	-161.9684	-118.7592	-75.54995	-36.95983	-12.11452	12.730792	37.576105
Cumulative cash flow(inflated)	-132.6417	-72.59096	-32.35387	5.1366681	44.201807	84.907682	127.3232

Year	2025	2026	2027	2028	2029	2030	2031
Inflation Rate	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Inflation Index	1.7788858	1.853599	1.9314501	2.0125711	2.097099	2.1851772	2.2769546
Gross Sales (real)	72.818829	72.818829	72.818829	72.818829	72.818829	72.818829	72.818829
Gross Sales (inflated)	129.53638	134.97691	140.64594	146.55307	152.7083	159.12205	165.80517
Fixed Costs real	9.2820576	9.2820576	9.2820576	9.2820576	9.2820576	9.2820576	9.2820576
Fixed Costs (inflated)	16.51172	17.205213	17.927831	18.6808	19.465394	20.282941	21.134824
Fixed Costs (inflated)							
Cost Of Electricity (real)	20.327532	20.327532	20.327532	20.327532	20.327532	20.327532	20.327532
Cost of Electricity (inflated)	36.160358	37.679093	39.261615	40.910603	42.628848	44.41926	46.284869
Fixed and Variable Costs-(real)	29.60959	29.60959	29.60959	29.60959	29.60959	29.60959	29.60959
Fixed and Variable Costs (inflated)	52.672078	54.884306	57.189447	59.591403	62.094242	64.7022	67.419693
Cash Flow (real)	43.209239	43.209239	43.209239	43.209239	43.209239	43.209239	43.209239
Cash Flow (inflated)	76.864302	80.092602	83.456492	86.961664	90.614054	94.419845	98.385478
Taxable Value of Plant (real)	0	0	0	0	0	0	0
Capital Additions During Year (real)	0	0	0	0	0	0	0
Cumulative Capital Additions (real)	364.53172	364.53172	364.53172	364.53172	364.53172	364.53172	364.53172
Initial Allowance (real)	0	0	0	0	0	0	0
Wear And Tear Allowance (real)	0	0	0	0	0	0	0
Tax Allowance (real)	0	0	0	0	0	0	0
Taxable Value of Plant (inflated)							
Capital Additions During Year (inflated)							
Cumulative Capital Additions (inflated)							
Initial Allowance (inflated)							
Wear And Tear Allowance (inflated)							
Tax Allowance (inflated)							

Year	2025	2026	2027	2028	2029	2030	2031
Annual Taxable Income (real)	43.209239	43.209239	43.209239	43.209239	43.209239	43.209239	43.209239
Annual Taxable Income (inflated)	76.864302	80.092602	83.456492	86.961664	90.614054	94.419845	98.385478
Tax Loss Carried Forward (real)	0	0	0	0	0	0	0
Tax Loss Carried Forward(inflated)	0	0	0	0			
Taxable Income (real)	43.209239	43.209239	43.209239	43.209239	43.209239	43.209239	43.209239
Taxable Income(inflated)	76.864302	80.092602	83.456492	86.961664	90.614054	94.419845	98.385478
Tax Payable (real)	18.363927	18.363927	18.363927	18.363927	18.363927	18.363927	18.363927
Tax Payable (inflated)	32.667328	34.039356	35.469009	36.958707	38.510973	40.128434	41.813828
Trading Cash Flow After Tax (real)	24.845313	24.845313	24.845313	24.845313	24.845313	24.845313	24.845313
Trading cash flow after tax(inf)	44.196974	46.053246	47.987483	50.002957	52.103081	54.291411	56.57165
Net Cash Flow(real)	24.845313	24.845313	24.845313	24.845313	24.845313	24.845313	24.845313
Net Cash Flow(inflated)	44.196974	46.053246	47.987483	50.002957	52.103081	54.291411	56.57165
Cumulative cash flow (real)	62.421417	87.26673	112.11204	136.95736	161.80267	186.64798	211.49329
Cumulative cash flow(inflated)	171.52018	217.57342	265.56091	315.56386	367.66694	421.95836	478.53001

Year	2032	2033	2034	2035	2036
Inflation Rate	4.2	4.2	4.2	4.2	4.2
Inflation Index	2.3725867	2.4722354	2.5760693	2.6842642	2.7970033
Gross Sales (real)	72.818829	72.818829	72.818829	72.818829	72.818829
Gross Sales (inflated)	172.76899	180.02529	187.58635	195.46497	203.6745
Fixed Costs real	9.2820576	9.2820576	9.2820576	9.2820576	9.2820576
Fixed Costs (inflated)	22.022487	22.947431	23.911223	24.915495	25.961945
Fixed Costs (inflated)					
Cost Of Electricity (real)	20.327532	20.327532	20.327532	20.327532	20.327532
Cost of Electricity (inflated)	48.228833	50.254444	52.365131	54.564466	56.856174
Fixed and Variable Costs-(real)	29.60959	29.60959	29.60959	29.60959	29.60959
Fixed and Variable Costs (inflated)	70.25132	73.201875	76.276354	79.479961	82.818119
Cash Flow (real)	43.209239	43.209239	43.209239	43.209239	43.209239
Cash Flow (inflated)	102.51767	106.82341	111.30999	115.98501	120.85638
Taxable Value of Plant (real)	0	0	0	0	0
Capital Additions During Year (real)	0	0	0	0	0
Cumulative Capital Additions (real)	364.53172	364.53172	364.53172	364.53172	364.53172
Initial Allowance (real)	0	0	0	0	0
Wear And Tear Allowance (real)	0	0	0	0	0
Tax Allowance (real)	0	0	0	0	0
Taxable Value of Plant (inflated)					
Capital Additions During Year (inflated)					
Cumulative Capital Additions (inflated)					
Initial Allowance (inflated)					
Wear And Tear Allowance (inflated)					
Tax Allowance (inflated)					
Annual Taxable Income (real)	43.209239	43.209239	43.209239	43.209239	43.209239
Annual Taxable Income (inflated)	102.51767	106.82341	111.30999	115.98501	120.85638
Tax Loss Carried Forward (real)	0	0			
Tax Loss Carried Forward(inflated)					
Taxable Income (real)	43.209239	43.209239	43.209239	43.209239	43.209239

Year	2032	2033	2034	2035	2036
Taxable Income(inflated)	102.51767	106.82341	111.30999	115.98501	120.85638
Tax Payable (real)	18.363927	18.363927	18.363927	18.363927	18.363927
Tax Payable (inflated)	43.570009	45.399949	47.306747	49.293631	51.363963
Trading Cash Flow After Tax (real)	24.845313	24.845313	24.845313	24.845313	24.845313
Trading cash flow after tax(inf)	58.947659	61.423461	64.003246	66.691383	69.492421
Net Cash Flow(real)	24.845313	24.845313	24.845313	24.845313	24.845313
Net Cash Flow(inflated)	58.947659	61.423461	64.003246	66.691383	69.492421
Cumulative cash flow (real)	236.33861	261.18392	286.02923	310.87454	335.71986
Cumulative cash flow(inflated)	537.47766	598.90113	662.90437	729.59575	799.08817

SELLING PRICE OF METHANOL	70	US CENTS PER LITRE FOB. FACTORY GATE
COST OF NATURAL GAS U.S.\$/MMBTU	8.5	U.S.\$/MMBTU
QUANTITY OF NATURAL GAS REQUIRED PER TONNE	29.1	MMBTU
TONNES OF METHANOL PRODUCED PER ANNUM	82181.25	TONNES
INFLATION RATE OVER DISCOUNT PERIOD	4.2	PERCENT
WEIGHTED AVERAGE COST OF CAPITAL - NON-INFLATIONARY	3	PERCENT
WEIGHTED AVERAGE COST OF CAPITAL - INFLATIONARY	7.2	PERCENT
INTERNAL RATE OF RETURN -(IRR) NON-INFLATIONARY	0.06649636	
INTERNAL RATE OF RETURN - INFLATIONARY	0.10540022	
NET PRESENT VALUE AT ZERO COST OF CAPITAL	335.719856	
NET PRESENT VALUE AT WACC - NON-INFLATIONARY	130.910445	
NET PRESENT VALUE AT WACC - INFLATIONARY	106.79737	
TAX PAYABLE TO REVENUE AUTHORITY (REAL)	280.078027	
TAX PAYABLE TO REVENUE AUTHORITY (INFLATED)	636.879905	

5

PRODUCTION COST COMPARED TO ETHANOL

The production cost of methanol manufactured by combination of carbon dioxide with electrolytically produced hydrogen, is compared against the cost of ethanol manufactured from maize.

10

The production cost of **ethanol** from maize is reported to be US\$1.09 per gallon or US28.8¢ /litre.

15 This fuel is retailed at \$2.62/gallon as E85.

The production cost of **methanol** on the same basis as that used for ethanol production should not include the cost of the cellulose, apart from the transportation costs, since this material is produced at present.

In the table above, the portion of the cost devoted to dividends, retained earnings and taxation should also be omitted.

5 On this basis, the cost of the fuel per litre is calculated to be US54.7¢ /litre.

However, on an equivalent calorific basis, the cost is increased by the relative calorific values.

10 **Equivalent Cost Per Litre of Methanol**

The heat of combustion of methanol is 64.5 M BTU/Gal, and that of ethanol is 76.5 M BTU/Gal.

15 The equivalent production cost of methanol per litre is then calculated as

$$\text{US54.7¢} \times \frac{76.5}{64.5} = \text{US64.9¢}$$

20 **Discussion Comparison of Economics of Methanol and Ethanol Production**

It is notoriously difficult to compare economics of production cost, because of arguments for and against inclusion of certain cost factors.

25 For example, if the payback on the investment in the farmland is not included in the ethanol production cost, is this not equivalent to considering that the payback of the methanol manufacturing facility should not be included in the direct production cost? The logic for this argument is that the land itself represents a synthesis facility, albeit using photosynthesis, which is a natural
30 process, as the synthesis route.

In this respect, it is identical to the methanol synthesis plant.

35 The major difference is that once the land has been paid for, it is assumed not to require replacement, unlike the methanol synthesis plant which requires replacement at regular intervals of approximately 20 years.

Many interesting points of discussion relevant to the economics of the production of ethanol and methanol, as well as to wider issues must be raised to gain a more complete understanding of what is essentially involved in these enterprises. These cannot be examined in detail in this précis of the exposition of a new technology to provide liquid automotive fuel from a renewable resource.

The following briefly summarised points represent most of the important features which should be considered:

10

(A) The technology employs waste cellulosic/lignitic material from an existing crop to increase the production of organically renewable alcohol by a factor of approximately 6.5-7 (a 650-700% increase)

15

(B) The six to sevenfold increase in the production of alcohol fuel is achieved without an increase in the area of monoculture (maize) under cultivation.

(C) The technology maximises the useful recovery of carbon dioxide that has been fixed by photosynthesis. This is achieved in two ways:

20

a. Carbon dioxide released by the fermentation process is recovered and converted in its turn to alcohol fuel

b. Waste cellulosic/lignitic material that is not normally converted to sugar by hydrolysis is converted to alcohol fuel.

25

(D) The technology interferes with the complex interaction between corn utilisation as a fuel and corn utilisation as a foodstuff in a less direct way than the production of ethanol.

30

Whilst some of the waste material from the production of maize is earmarked for silage, the above semi-quantitative illustration assumes that only 60% of the waste cellulosic material is available for conversion to methanol.

(E) In the case of the corn belt of the Unites States, the production of methanol is achieved through the use of a natural resource that would not otherwise be utilised, namely that of wind power.

5 An ideal electricity source from many viewpoints is electricity from wind turbines. The quantities required and the practicability of utilising wind power is explored below.

10 The corn belt is characterised by a low (and slowly shrinking) human population with generally fairly strong and consistent windy conditions.

This windy condition cannot in general be exploited to provide electricity to more populous areas, because of the distances involved in reticulation.

15 However, the use of wind turbines to provide electricity for alcohol production stations, located on a grid system throughout the corn belt would minimise reticulation problems.

20 Wind turbines are most suited to continuous production processes in which the instantaneous utilisation capacity is not of any overriding significance, and in which production capacity may be readily varied.

The methanol production process, because of its simplicity, fulfils these requirements.

25

Furthermore, storage of both feedstock gases, namely carbon dioxide and hydrogen may be economically undertaken to assist in smoothing out the production rate.

30 **(F)** The use of wind power as the primary energy source for the production of hydrogen gas by electrolysis, renders the entire process of methanol fuel production sustainable without recourse to the exploitation of fossil fuel or nuclear energy.

35 In the production of ethanol, energy balances indicate that significant

quantities of energy must be absorbed in transportation, fertilizers and steam heating of the vats in which the breakdown of starch and fermentation processes occur.

5 **(G)** It is envisaged that, with the increase in the quantity of alcohol fuel produced, by a factor of 6-7, most vehicular transportation in the corn belt will be by means of alcohol fuelled vehicles.

10 **(H)** In addition to the manufacture of methanol fuel by the process of combination of carbon dioxide and electrolytic hydrogen, an obvious synergy is the production of ammonium nitrate fertilizer using the same process.

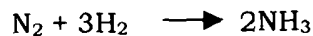
The methanol formation reaction:

15



is substantially the same as the ammonia formation reaction

20



The anhydrous ammonia plant in fact has the identical "frontend" to the methanol manufacturing plant.

25 The process of combination of electrolytic hydrogen with atmospheric nitrogen was pioneered in Norway in order to take advantage of a seasonal surge in Hydro-Electric power in Norway.

30 The process is well known and provided the original impetus for the Norwegian fertilizer industry.

It is, however, not widely used, since until recently the economics of production of anhydrous ammonia, by the steam reformation of natural gas, have been considerably superior.

However, since a major portion of the cost of fertilizer is transportation, the co-production of ammonium nitrate fertilizer with the methanol is likely to be the most economic source.

5 In this case, three of the major inputs to the farming region, namely transportation, fuel and ammonium nitrate fertilizer will be provided by renewable resources.

10 **(I)** For strategic reasons, there is a lobby in the United States which favours local production of at least a sizeable percentage of the liquid automotive fuel consumed in the United States.

15 These strategic reasons revolve mainly around price dislocations outside of the control of the United States' economy, as well as continuous or semi-continuous political and/or military embroilment as the United States negotiates a position for itself in the worldwide market place.

20 Renewable resource fuel produced in much larger quantities than at present will provide a permanent source of supply, albeit initially at a small percentage level of the US requirement.

25 An increase in production of alcohol fuel by a factor of 650-700% will partially fulfil this requirement for strategic local manufacture, on a sustainable basis.

30 **(J)** There is, additionally, a lobby in the United States which favours renewable resource carbon based fuel production, in order that carbon dioxide emissions to atmosphere are reduced to prevent, primarily, "global warming".

Conjoined with this lobby is a further interest group which is concerned that exploitation of coal and oil reserves, whilst not particularly damaging to the environment, is proceeding at too rapid a pace.

35 In other words, this lobby is concerned with a too rapid and thoughtless

depletion of coal and oil reserves, which can never be replaced, but regards the increase in the atmospheric carbon dioxide level to be either a minor or irrelevant issue, which has not been responsibly quantified.

5 The requirements of both interest groups in this conjoined lobby will be satisfied by the production of methanol fuel from renewable resources, provided the economics of production are sufficiently low to sustain this method of production.

10 **(K)** Generation of electricity wind turbines is essentially a youthful technology, and has only been implemented on a large scale over the last 10-15 years.

One aspect of the investment in this form of electricity generation that requires exploration in the future, is the write-off period of the investment.

15

In other words, how long does a wind turbine last?

20

After what period of time will the routine maintenance to the wind turbine reach such an intensity that it is more economic to dismantle the wind turbine and replace it with a new one?

25

May wind turbines be built to accept modular replacement units on a regular maintenance schedule, and on this basis never actually require to be replaced as a unit? (This represents the "grandfather's axe" theory of processing equipment renovation.)

30

If, for example, the erection of wind turbines to supply the methanol synthesis units is conducted on the economic basis of a 20 year write-off period, at a delivered cost of US6.0¢/kw.hr to the synthesis plant, it will be of interest to calculate the cost after this period of time has elapsed.

It is possible that on a long term basis electricity costs may be lowered significantly below the US6.0¢/kw.hr mark.

5 **(L)** Modularisation of methanol synthesis facilities, and the employment of “LCM” (low cost methanol production technology) may be used to increase process efficiency and lower fixed costs of production, if the technology is widespread over the corn belt region.

10 The process will also gain impetus from engineering design and innovation in related technology to produce methanol from power station exhaust.

(M) Similarly, the widespread production of methanol as a liquid automotive fuel, will lead to advances in purpose-designed engine technology, maximising compression ratios, and increasing mechanical efficiency.

15

(N) All of the above points lead to a fuller understanding of the wider issues involved in methanol production on a large scale.

20 The fact remains that in the short term and ignoring the monetary implications of the broader issues, such as the size of the national standing army, navy and air force, which pertain to fuel security, the fuel is on a strict fiscal basis more expensive than ethanol and imported petroleum.

25 The extent to which the fuel should be subsidized or, alternatively, exempted from taxation, must be closely examined with particular reference to:

- Strategic fuel security issues
- Environmental issues
- Food/fuel competition issues
- 30 - Regional economic growth
- Long term fuel security goals
- Short term cost
- Long term cost.

35

SYNERGIES THAT SHOULD BE UNDERTAKEN IN THE DEVELOPMENT OF RENEWABLE RESOURCE METHANOL

There are a number of synergies that should be undertaken to maximise the efficiency of production, to maximise the capture of the carbon fixed by photosynthesis, and to minimise fossil fuel use.

These synergies are:

S1 The process of fermentation is accompanied by the unavoidable release of carbon dioxide back to the atmosphere as a consequence of the metabolic process.

This carbon dioxide is stoichiometrically equivalent to one third of the carbon contained in the maize starch.

In order to maximise the useful conversion of carbon captured by photosynthesis, the methanol synthesis station should ideally be co-located with the ethanol production station.

S2 Co-location of methanol synthesis plant with ethanol synthesis plant will allow a number of additional synergies as follows:

- Transportation of both grain and cellulosic/lignitic waste will be to the same terminus
- Personnel requirement for a conjoined facility will be lower than for separate facilities
- Blending of the methanol/ethanol to a standard composition may be carried out
- Provision of steam to the starch hydrolysis and sugar fermentation vats may be provided by the burning of the cellulosic waste, in conjunction with or replacing electricity generation
- Environmental impact will be lessened.

S3 The entire ammonium nitrate fertilizer requirement may be produced on site as an obvious synergy.

5 The process of anhydrous ammonia manufacture using atmospheric nitrogen and electrolytically produced hydrogen is well known, and has been developed on a large scale in Norway.

10 Whilst this production route has not normally been competitive against anhydrous ammonia production using a natural gas feedstock, it is likely that in this specific circumstance, it will prove to compete economically.

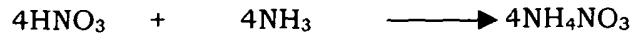
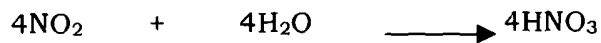
The reasons for this relate to the following circumstances which pertain generally, and also specifically, to the corn belt of the United States:

- 15 - Natural gas prices have risen very rapidly in the last few years, in tandem with the crude oil price. In the absence of any other factors, this has, in any event, closed the gap in the production price between the standard methane gas reformation process and the electrolytic hydrogen process.
- 20 - In the production of ammonium nitrate fertilizer, the cost of transport is a major factor. Essentially one of three choices must be made in a typical transportation/usage scenario:
- 25 i) Transport low weight anhydrous ammonia in specialised pressure tankers to a nitric acid/ammonium nitrate conversion facility located at or near a point of sale terminus.

30 This involves relatively low transportation tonnages, but a sophisticated onloading/offloading regime, and specialised transportation tankers. There is also a fairly stringent safety requirement since anhydrous ammonia is both highly toxic and flammable, and has a high vapour pressure under ambient conditions.

- ii) Convert the anhydrous ammonia to nitric acid and ammonium nitrate fertilizer at a manufacturing plant in the same industrial complex as the anhydrous ammonia plant.

5 The stoichiometric reactions involved are as follows (for illustrative process - the oxidisation of nitrogen is in fact complex):



10 Thus instead of transporting 34 tonnes of anhydrous ammonia, 80 tonnes of ammonium nitrate must be transported from this stoichiometric analysis.

15 Actually, the quantity is slightly greater, since the ammonium nitrate prills contain a deactivating agent, usually magnesium/calcium carbonate, and also contain approximately 12% water, as the product is somewhat hygroscopic.

20 The transportation may be readily undertaken by any non-specialised transport contractor, but the physical weight is considerably higher.

- iii) The third option is to transport the base raw material to a factory situated at the consumption or point of sale terminus, in this case, the corn belt.

25

This raw material is typically a methane gas feedstock, sourced typically from coastal refineries, oil fields or coal bed methane deposits, or, alternatively, a coal feedstock.

30

In the process under review, the feedstock for the production of the

ammonium nitrate fertilizer is river water. This water is available at essentially zero cost at the manufacturing site.

5 The motive force to conduct the breakdown of the water by electrolysis is electricity which is reticulated to the manufacturing plant.

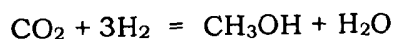
Thus the ammonium nitrate is manufactured at point of sale, which releases the cost burden of transportation.

10 The cost of transportation of ammonium nitrate fertilizer is obviously highly variable, and depends fundamentally on how far removed the point of sale terminus is from the manufacturing plant, as well as the development of the transportation
15 infrastructure, and the number of offloading/onloading operations that must be undertaken.

In the case of the corn belt, transportation costs make up a significant portion of the delivered cost of the fertilizer in many
20 areas. This further erodes the margin between the delivered cost of the fertilizer manufactured using the standard natural gas reformation process for hydrogen generation, and the electrolytic hydrogen process.

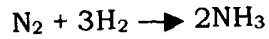
25 - The conversion to alcohol fuel of the carbon dioxide generated by burning of waste cellulosic/lignitic material is carried out by reaction with electrolytically produced hydrogen.

This reaction is represented as:



The manufacture of the anhydrous ammonia is carried out by a fundamentally similar process, namely the reaction of a gas with no
35 calorific value with electrolytically produced hydrogen gas.

The anhydrous ammonia formation reaction is essentially similar



5

The significance of this is that if the anhydrous ammonia plant is located together with the methanol manufacturing plant, there is complete commonality of the hydrogen production section of the combined facility.

10

Thus the water purification, ion exchange plant, cell house, hydrogen capture and first stage hydrogen compression is common.

15

This synergy may be used to lower costs by economy of scale, mainly in the region of the electrolysis cell house.

20

There is also synergy possible in both production scheduling and in instantaneous electricity generation from the wind turbines.

25

For example, in the event of a shortage for whatever reason of waste cellulosic/lignitic material, and a high electrical production (windy conditions), anhydrous ammonia production could be increased, and the ammonium nitrate stored for later sale. This production scheduling should also be linked with carbon dioxide liquefaction and storage, and also (the more complex and expensive) hydrogen liquefaction and storage.

30

S4 A fourth synergy that should be undertaken is the capture of the ash from the burning of the cellulosic/lignitic material, for incorporation into either the ammonium nitrate fertilizer, or other fertilizers imported to the site.

35

The production of the carbon dioxide arising from the burning of the agricultural "waste" will be accompanied by the oxidation of the trace elements incorporated into the material ("ash"). This ash must be

completely removed from the carbon dioxide raw material by (provisionally) bag filtration, followed by wet scrubbing.

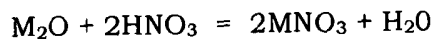
5 Since trace elements are removed from the soil, with incorporation into the agricultural produce, these trace elements must be returned to the soil.

10 Further work must be conducted in order to quantify the best compound suitable for incorporation of the ash into the fertilizer for return to the agricultural fields.

It may be that the oxides are suitable. Incorporation as nitrates could be simply achieved, since nitric acid will be available at each (proposed) ammonium nitrate fertilizer manufacturing station.

15 In this case the ash as oxides would typically be converted to highly soluble assimilable trace elements by the standard oxide/acid reaction, namely:

20 - For monovalent trace metals

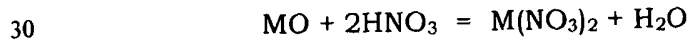


where M is the metal

25

or

- For bivalent trace metals



It is possible that waste material from the existing starch hydrolysis and sugar fermentation processes may be considered for treatment in a similar way.

35

S5 As a further synergy it is envisaged that on site electricity generation by steam generation using the calorific value of the waste agricultural material, may be supplemented by electricity generation using coal. This could be by the installation of a boiler designed to accept either waste agricultural produce or coal or a combination of the two.

The logic of this would be to optimise continuous production under all predicted electricity supply conditions, and agricultural production conditions.

This is best illustrated by example:

- Scenario Situation
- Extremely Windy Conditions
 - Excess Electrical Generation

- Production Scenario
- Excess hydrogen gas liquified and placed in storage, using excess electrical capacity
 - Liquid carbon dioxide from storage vapourised and used as feed for the methanol plant, which operates at high capacity
 - Anhydrous ammonia plant at high capacity to absorb excess electrical generation and minimise hydrogen storage
 - On site electricity generation increased to a maximum Generation of a maximum carbon dioxide for methanol production taken from storage

- Scenario Situation
- Still Conditions
 - Insufficient Wind to Service Cell House

- Production Scenario
- Hydrogen gas vapourised from liquid hydrogen storage to supply methanol plant
 - Carbon dioxide is used directly from the boiler off-gas. Excess carbon dioxide is produced and

liquefied for use later (under windy production scenario)

- Methanol plant operates at low capacity
- Anhydrous ammonia plant at low capacity or offline
- On site electricity generation is at a minimum but will service the electricity requirements of the methanol plant (apart from the major source of electricity consumption, the cell house)
- Carbon dioxide capture and liquefaction is at a maximum

- Scenario Situation
- Still Conditions
 - Insufficient Wind to Service Cell House
- and
- Supply of Cellulosic/Lignitic Material Exhausted

Production - As above

- Scenario
- On site generation of electricity is at a minimum, but coal is used as the calorific source
 - Waste carbon dioxide is still captured as before

5 Note that the use of coal instead of cellulose/lignite may occur annually on a regular basis, related to the crop cycle, as well as on an irregular basis related to the annual tonnage produced, which typically varies over a wide range.

10 Production scheduling, together with the quantification and optimisation of storage must take into account the annual crop cycle, as well as the known variability in wind strength on a month by month basis from historical weather records.

15 Thus, for example, it may be beneficial to maximise the co-production of ethanol by fermentation during months which are typically windy, so that

the carbon dioxide by-product may be utilised without recourse to burning the cellulose by-product.

Storage volumes of:

- 5 - Liquid hydrogen
- Liquid carbon dioxide
- Grain
- Cellulose/lignite
- 10 - Ammonium nitrate fertilizer

may be optimised, together with the size of the methanol and anhydrous ammonia synthesis plants, the on site boiler station, and the cell house generating hydrogen.

15 Mathematical modelling to optimise production scheduling, as well as synthesis plant nameplate capacity, cell house nameplate capacity and storage volumes must take into account seasonal weather patterns, together with the annual agricultural cycle.

20 Considerable variability in both the crop production and the actual wind experienced (electricity generation), around the statistical mean will be encountered. In this respect, the mathematical modelling should incorporate a stochastic (random number) element, superimposed upon the historical average values.

25 This will give a further insight into actual production scheduling and the frequency and extent of production rate changes and production regime.

METHANOL GENERATING STATION QUANTIFICATION OF BASIC INPUTS

The basic inputs are presented for a methanol generating station situated in the
5 corn belt and producing 2 200 tonnes/day of methanol.

Quantity of Raw Material Cellulose/Lignite

One tonne of waste cellulosic/lignitic material, accorded the stoichiometric
10 formula $C_6H_{10}O_5$ (MW 162) contains:

37.037 kg moles of carbon

= 444.4 kg of carbon

15

One tonne of methanol (CH_3OH , MW 32) contains

31.25 kg moles of carbon

20

= 375 kg of carbon

One tonne of waste cellulosic material therefore produces 1.185 tonnes of
methanol.

Quantity of Cellulosic Material Required per Day

= $\frac{2\ 200}{1.185} = 1\ 856.54$ tonnes

30

Quantity of Cellulose Material Required per Annum

Assume a 90% availability of the production facility at nameplate capacity.

The quantity of cellulosic/lignitic maize plant "waste" is then

35

$365 \times 0.9 \times 1\ 856.54 = 609\ 873$ tonnes

or

Approximately 610 000 tonnes (dry mass)

5 Mass, with a moisture content of 12%

$$= \underline{983\ 058\ \text{tonnes}}$$

10 **Acreege of Land Under Cultivation Required to Produce This Quantity of Material**

It is assumed that 40% of the crop in the region is not available for conversion to methanol, but is converted to silage for cattle feed.

15 One hectare of arable land typically produces 4.5 tonnes of maize.

The grain accounts for 42% by dry mass of the maize plant including the grain.

Thus the crop of cellulosic/lignitic matter per hectare is approximately

20

$$4.5 \times \frac{58}{42} = 6.2\ \text{tonnes}$$

Hectares under cultivation required

25

$$= \frac{609\ 873}{6.2} = 98\ 366\ \text{ha}$$

To a close approximation 100 000 ha under cultivation is required to service the plant.

30

However, it is assumed that 40% of the crop is not available.

Thus the area under cultivation is:

$$\frac{98\,366}{0.6} = 163\,944 \text{ ha}$$

5

Approximately 165 000 ha under cultivation will service the methanol plant.

Approximate Spacing of Methanol Stations throughout the Corn Belt

10 Assume that half of the land on average lies fallow at any time. Further assume that half of the land under cultivation with maize as a monoculture.

$$\begin{aligned} \text{Land area required} &= 4 \times 165\,000 \text{ ha} \\ &= \underline{660\,000 \text{ ha}} \end{aligned}$$

15

This is equivalent to 6 600 km², or a square block of side 81.2 km.

The methanol stations, as a rough approximation, will be situated 60-100 km apart.

20

It is envisaged that some form of planning to implement the scheme on a grid basis will be undertaken, in the event that the scheme is adopted.

Electricity Input

25

Basis 2 200 tonnes/day - CH₃OH

On Site Electricity Generation

30 The calorific value of the cellulosic/lignitic material is approximately 15 800 kJ/kg.

The quantity of material required is:

$$1\,856.5 \quad \text{tonnes/day}$$

77.35 tonnes/hour

21.5 kg/sec

Heat generated by the burning of the cellulose is:

$$5 \quad 21.5 \times 15\,800 \frac{\text{kJ} \times \text{kg}}{\text{kg} \text{ sec}}$$

$$= 339\,700 \text{ kg/sec}$$

$$\approx 340 \text{ MW}$$

10

The quantity of electrical energy generated on site will be approximately 35-40% of this, since the conversion of heat energy to electrical energy is typically of this order.

15 Electrical energy generated on site

$$= 0.375 \times 339\,700 \text{ kJ/sec}$$

$$= \underline{127.4 \text{ MW}}$$

20

This quantity of electrical power will be sufficient to run all the ancillary equipment for both the methanol plant and the anhydrous ammonia plant at the synthesis station, including:

- All pumps and drives
- 25 - The main hydrogen and carbon dioxide compressors
- Cooling water pumps
- Carbon dioxide and hydrogen cryogenic storage compressors.

30 The quantity of carbon dioxide produced is in the ratio of the molecular weight of carbon dioxide and of carbohydrate matter

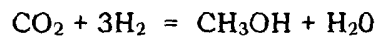
i.e. CO₂ MW 44

C₆H₁₀O₅ MW 162

The Quantity of Carbon Dioxide Produced

$$\begin{aligned}
 &= \frac{6 \times 44 \times 1\,856.5}{162} \\
 &= 1.629 \times 1\,856.5 \\
 &= 3\,025.4 \text{ tonnes/day} \\
 &\quad 126.06 \text{ tonnes/hr} \\
 &\quad \underline{35.0 \text{ kg/sec}}
 \end{aligned}$$

According to the methanol formation reaction



3 moles of hydrogen gas are required to produce 1 mole of methanol.

This hydrogen gas is produced by the electrolysis of water.

According to the heat of formation the following applies:

H ₂ (gas)	+	½O ₂ (gas)	→	H ₂ O (liquid)
ΔH _f		ΔH _f		ΔH _f
= 0		= 0		- 286 030
kJ/kg mole		kJ/kg mole		kJ/kg mole

The quantity of hydrogen required in kg moles per second is

$$\text{H}_2 \text{ requirement} = 2.3835 \text{ kg moles/second}$$

This will provide the hydrogen requirement for

$$\frac{2.3835}{3} = 0.7945 \text{ kg moles/second methanol}$$

which is equivalent to

$$\begin{aligned}
 0.7945 \times 32 &= 25\,424 \text{ kg/sec} \\
 &= 91\,700 \text{ kg/hour} \\
 &= 2\,200 \text{ tonnes/day}
 \end{aligned}$$

The electrical power required is thus, according to the stoichiometry

$$\begin{aligned}
 2.39 \times 286\,030 \text{ kJ/sec} \\
 = 683.6 \text{ MW}
 \end{aligned}$$

With a 5% conversion loss this amounts to 720 MW.

Since approximately 127 MW is generated on site, the balance of 593 MW, or 600 MW must be imported.

GENERATION OF IMPORTED ELECTRICITY BY WIND TURBINE

- *Number and Location of Wind Turbine Generating Sets*

It is assumed, as above, that the land area required to provide stubble to feed the on site boiler, is of the order of 660 000 ha, then the methanol stations, on a square grid system will be approximately 81 km apart.

The size of an individual electricity generating turbine is variable.

There is a tendency towards larger and larger wind turbines as they provide economy of scale.

For the purposes of this exploratory quantification, it is assumed that the wind turbines will be of uniform construction and supply 500 kw or 0.5 MW under an average wind condition.

On this basis 1 200 wind turbines would be required to service the methanol synthesis facility. The most economic physical arrangement would be for the turbines to be clustered relatively closely to the terminus. This would maximise the proximity of the turbines to each other, reducing routine maintenance cost, and to the manufacturing terminus, reducing reticulation cost.

Purchase of Electricity Generating Wind Turbines by Farmers in the Corn Belt

The preponderance of electricity generation by wind turbines in this scenario will promote the generation of electricity by this means for domestic general agricultural usage.

Private ownership of wind turbines by farmers may be promoted, as a partial buffer against variable production rate at the methanol synthesis facility.

Whilst, to a considerable extent, windy conditions are seasonal and a dearth of electrical power or an overabundance of electrical power would affect, in many instances, an entire region, short term fluctuations would be eased to some extent by private ownership.

This would operate essentially in the following way:

- During windy conditions (above average electricity generation) the farmer would be encouraged to undertake operations which are energy intensive, such as pumping water for irrigation
- During still conditions (below average electricity generation) the farmer would be encouraged to export electricity.

Purchase of wind turbines by farmers and smallholders in Denmark has accelerated greatly in recent years, and approximately 30% of the national power requirement is now satisfied by wind turbine.

Provision of a Stable Production Environment at the Methanol Synthesis Station without Wastage of Electricity

Since by far the greatest cost in the manufacture of the methanol is the variable

cost of the electricity which is used to produce hydrogen gas by electrolysis of water, the process economics revolve mostly around this issue.

It has been assumed that electricity will be produced at an average cost of
5 US6.0¢/kw.hr (six United States cents per kilowatt hour), using on site
electricity generation to provide approximately 17% of the power demand, and
wind turbines to supply the rest.

Obviously, if the methanol plant was constructed to accommodate a capacity
10 much greater than the average of 2 200 tonnes/day, say three times the average
capacity and amounting to 6 600 tonnes/day, most of the electricity supply
could be accommodated.

This, however, would prove uneconomic on the grounds of capital cost.

15

The most cost effective method of maximising the usage of electricity generated
by the wind turbines must be determined, incorporating a number of strategies.

These strategies will include the following **Stabilisation Techniques** (STs):

20

ST1 Provision of Storage for Liquefied Hydrogen

This provision is over and above the provision of a hydrogen gasholder, which is
a normal part of the production process.

25

Provision of storage for liquid hydrogen will allow the electrolysis cells to operate
at full capacity during gusty periods, to take advantage of the additional
electricity. This hydrogen storage will not amount, however, to more than
(approximately) the requirement for 12 hours production at normal rates.

30

This is equivalent to 137.5 tonnes of hydrogen.

Because the liquid density of hydrogen is very low at 0.071 tonnes/m³ (71
kg/tonne), the storage volume would be 1 936.5 or 2 000m³.

A storage volume much greater than this should not be contemplated from capital cost and safety considerations.

5 The hydrogen storage will allow steady operation of the methanol synthesis plant, during normal diurnal electricity variation fluctuations.

ST2 Importation of Electricity at Off-peak Periods

10 It is also envisaged that during the seasonal period when (statistically) generation of electricity by wind turbine is at a minimum, electricity will be imported.

In order for this to be most economic, the bulk of the electricity will be imported at a specifically negotiated tariff during off-peak periods.

15

During this period the electrolytic cells will operate a high occupancy, and the methanol plant will operate using hydrogen produced directly by electrolysis of water.

20 It is envisaged that, in addition to this, the hydrogen gas storage will be filled.

During the peak period, when the cost of imported electricity will be higher, less electricity is imported to the methanol synthesis plant, and hydrogen is utilised from storage.

25

ST3 Oversizing of the Electrolysis Cell Segment of the Synthesis Plant

30 In order for the importation of electricity at off-peak periods to be accompanied by normal plant operation and the relegation of hydrogen to storage, the electrolytic cell house must be oversized relative to the nameplate capacity of the synthesis plant.

ST4 Co-production of Anhydrous Ammonia, Nitric Acid and Ammonium Nitrate

Co-production of anhydrous ammonia using the same essential process route,
5 that of provision of hydrogen by electrolysis, may be undertaken.

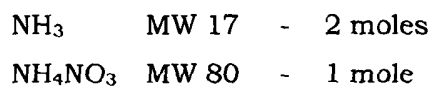
The ammonium nitrate requirement per hectare of maize is approximately
350kg.

10 The area under cultivation, assuming 60% of the stubble is harvested and
earmarked for methanol production, is (approximately) 16 000 ha.

Annual production of ammonium nitrate fertilizer is therefore

$$\begin{aligned}
 15 \quad & 165\,000 \times 0.35 \text{ tonnes} \\
 & = 57\,750 \text{ tonnes/annum} \\
 & = \underline{175 \text{ tonnes/day}}
 \end{aligned}$$

The quantity of anhydrous ammonia required for this is calculated from the
20 stoichiometry as follows:



$$\begin{aligned}
 25 \quad & \text{Tonnes/day NH}_3 = \frac{175 \times 34}{80} \\
 & = \underline{74.4 \text{ tonnes/day}}
 \end{aligned}$$

30 The size of the fertilizer plant is in fact much less than the size of the methanol
plant in terms of both physical production and electricity consumption.

The anhydrous ammonia plant will consume only approximately 4% of the
electricity consumed by the methanol plant.

35

Nevertheless if the ammonia synthesis is operated on a campaign basis, for say

4-5 months of the year, then this percentage may be constrained to rise to (say) 10-12%.

5 If the ammonium nitrate fertilizer production campaign could be made to coincide with the windiest months of the year, the co-production of ammonium nitrate fertilizer with methanol could provide a further stabilisation factor in production rate.

ST5 Methanol Synthesis Rate Variation

10

Methanol synthesis is sufficiently simple in practice to be amenable to relatively rapid production rate variation by a combination of techniques including reactor pressure, gas composition, inlet temperature and quench gas control.

15 The synthesis section of the methanol plant could be sized to accommodate diurnal electricity supply variation.

ST6 Sale of Electricity by Farmers

20 As mentioned above a portion of the electricity supply could be provided by regional farmers. Sale of electricity into the grid would be discouraged during peak generation (windy) periods and encouraged during still periods.

ST7 Export of Electricity

25

Electricity exports could be planned in advance to neighbouring regions during the season when, statistically, a surplus of electricity generation would occur.

30 Thus, neighbouring regions could import electricity at a negotiated preferential tariff, when the corn belt electricity production by wind turbine is statistically in excess of the alcohol fuel station demand.

35 This electricity should preferably be imported by regions supplied by coal burning power stations, rather than nuclear power stations, in order to effect an appreciable cost saving. Coal based thermal power stations could operate at a

lower rate during these periods with a variable cost saving in the coal consumption. For nuclear power plants variable costs are lower in proportion than for coal based plants.

5 **ST8** Carbon Dioxide Storage

In the same way that hydrogen storage provides production rate stabilisation, carbon dioxide storage will allow operation under low electricity generation periods.

10

Under these conditions the on site boiler will produce an excess of carbon dioxide which may be compressed and liquefied.

The quantity of carbon dioxide stored is envisaged to be similar to that of hydrogen storage in terms of production hours.

15

ST9 On Site Boiler Rate Change

The on site boiler provides most of the carbon dioxide requirement for the methanol plant, but only a small portion of the electricity requirement.

20

During windy periods (above average electricity generation), more carbon dioxide must be produced, and so the on site boiler will (to some extent) exacerbate the electricity surplus by being operated at a high production rate.

25

During still periods the on site boiler must be operated at a low rate, so that carbon dioxide is not exhausted to atmosphere.

The on site boiler may therefore not be used as a stabilisation method, but will exacerbate the variation in electricity generation rate, if all of the carbon dioxide generated is to be captured as alcohol fuel.

30

Under extreme conditions, it is envisaged that the boiler must be run to supply the on site power requirement, with the cell house offline.

Under these conditions all methanol production would be from hydrogen in storage, and carbon dioxide would be placed into storage and any excess above the storage limit vented to atmosphere.

- 5 A requirement for the successful implementation of these production stabilisation techniques is linkage of the alcohol production centres to an electrical grid system.

10 Mathematical modelling must be employed, using climatic data as a basic input together with the seasonal cropping and fertilisation cycle. Superimposed on this, semi-random number (stochastic) mathematical modelling will indicate the occurrence and severity of unscheduled electricity imports and exports, and storage capacity overrun.

- 15 The objective of this modelling will be to attempt to secure a delivered electricity cost at a minimum level, and also to minimise the capital cost associated with the synthesis facilities themselves, together with raw material and finished product storage volumes.

CONCLUSION

The production of methanol in the corn belt of the United States has been explored in some detail.

5

The production of methanol from waste product of sugar manufacture, namely bagasse, is similar in all fundamental respects.

Economics of production revolve mainly around the major variable cost of production, which is the electricity cost, which, in this case, could be nuclear, hydroelectric, wind turbine or a combination.

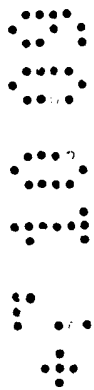
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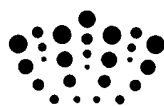
CLAIMS

1. A method of economically converting agricultural by-product cellulose/lignite to methanol fuel.
5
2. A method of converting the exhaust carbon dioxide from the process of fermentation to methanol fuel.
3. Through a conjunction of Claims 1 and 2, a method of co-producing
10 methanol fuel with ethanol fuel, to produce a manifold increase in the alcohol fuel produced from an agricultural region. In the case of the corn belt of the USA a sixfold to sevenfold increase in alcohol fuel is attainable.
4. A method of utilising electricity generated by wind turbines to produce
15 methanol fuel by combination of electrolytic hydrogen with carbon dioxide generated by burning of agricultural waste in a power station.
5. A method of economically producing ammonium nitrate fertilizer in
20 conjunction with the methanol, using electrolytically produced hydrogen gas, using substantially wind turbines as the power source.
6. A method of combining synergetically a number of related power
25 production and fuel production requirements to lower overall cost of synthetic methanol production in an agricultural region.
7. In combination with Claims 5 and 6, a method of substantially eliminating the burning of fossil fuels entirely from the production of a carbon based liquid automotive fuel supply.

REVISED CLAIMS: Patent No. GB0819334.4

1. A method of economically converting agricultural by-product cellulose/lignite to methanol by gasification of the by-product agricultural material to carbon dioxide, and reaction of the said carbon dioxide with hydrogen gas obtained by the electrolysis of water, to form substantially methanol with water as by-product.
2. A method of economically converting the carbon dioxide that is universally exhausted by the process of fermentation, and in particular the fermentation process to produce ethanol fuel, to methanol by the process of reacting the exhausted carbon dioxide against hydrogen gas, which hydrogen gas is produced by the electrolysis of water.
3. Through a conjunction of CLAIMS 1 and 2, a method of co-producing methanol with ethanol fuel to produce a manifold increase in the alcohol fuel produced from an agricultural region without increase in the area or tonnage of the crop under cultivation, typically to provide a six-fold to seven-fold increase in the quantity of alcohol fuel.
4. A method of producing hydrogen gas using electricity generated by external sources, and in particular wind turbines, in conjunction with electricity produced from power stations employing waste agricultural produce as the calorific fuel.





Application No: GB0819334.4

Examiner: Mr Martin Price

Claims searched: 1-4

Date of search: 19 March 2009

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-3	GB 2100282 A Industrias Villares - see e.g. the abstract and page 1 paragraph 1
X	1-3	US 2004/0180971 A1 Inoue - see e.g. claims 1 and 12 and paragraph 0002
X	1-3	CN 101225319 A Univ Beijing - see WPI abstract number 2008-M51374
X	1-4	GB 2448685 A Johnston - the whole document
X	1-4	WO 2008/041921 A1 Morphic Technologies - the whole document
X	1-3	WO 2006/113293 A1 USC - the whole document
X	1-4	WO 00/25380 A3 Quadrise - the whole document
X	1-4	WO 95/31423 A1 CC Energy - the whole document

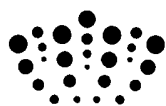
Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

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Worldwide search of patent documents classified in the following areas of the IPC

C07C; C10L

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
C10L	0001/02	01/01/2006
C01C	0001/18	01/01/2006
C07C	0031/04	01/01/2006
C07C	0031/08	01/01/2006