Sustainable Thermal Energy management Network

Report on the 2014 NEPIC International Bioresources Conference

Contents

1 Introduction

The 2014 International Bioresources Conference, organised by NEPIC, the North East Process Industries Cluster membership organisation, took place on the 19th of June at the Vermont Hotel in Newcastle upon Tyne, UK. Senior industrialists, business leaders, scientists, academics and agriculturalists from across the world, including China, Denmark & Brazil, presented their achievements in the novel and commercially viable use of renewable energy and Bioresources. The event was attended by around a hundred delegates with representation from commercial companies, government and researchers.

The next section describes presentations which provided overview analyses of Bioresources-related activity. Later sections describe presentations about specific achievements with technology. The field of Bioresources includes a wide variety of technologies, methods and objectives, and so any discussion or measurement of success must take into account the nature of the technologies and the specific objectives of, and benefits envisaged from their use. The schedule of presentations in the conference agenda, presented later show the groupings and structure within which they were presented. This report further categorises them into 4 themes and provides an account of each presentation.

2 Analysis presentations

The chairman's introductory speech mentioned the history and success of the North East region in the area of carbon management and highlighted that the Teesside area has been named the "first low carbon region" in the UK. The first overview presentation described next highlighted the role of North East England in broader UK low carbon development.

2.1 "Overview of bioresources activity in North East England" – NEPIC

John Brady of NEPIC identified the North East region, especially the Tees Valley as a hub of industrial activity with representation from most of the major chemical companies in the world. It was reiterated that the region has a history of innovation and is making an impact in the area of renewable energy and low carbon technologies.

The presentation considered the challenge of the EU Renewable Energy Directive, in accordance with which 15% of the UK's energy demand must be met from renewable sources by 2020. Mr Brady stated that the size of this challenge can be equated to the "scale of opportunity". For illustration purposes, the UK targets could be broken down to a number of individual targets and scenarios for how they could be met can be considered resulting in the following extract from the presentation:

- 30% electricity, if all wind, will require ~ 15,000 turbines
- 12% heat target, if met by biomass alone, will require ~ 20 million tonnes of wood in UK by 2020
- 10% transport target, if met by biofuel alone, will require ~ 6.5 billion litres bioethanol and biodiesel in UK by 2020

It was asserted that these challenges represent an "incredible opportunity" for renewable products and building a low carbon economy in the chemical sector.

Progress to date includes investments of over 1.5 billion pounds over several sectors including renewable fuels, biopharmaceuticals, electric cars and a number of Centres of Excellence which all translate into over1.5 billion pounds of investment in the region.

Opportunities for future investment were identified including in the areas of advanced gasification, bio-energy, pyrolysis, electric & hydrogen vehicles and industrial CCS among many others. There are 6 universities and research centres, and a number of technology centres (e.g. NAREC, NOF energy) in the region, as shown in figure 1 below, which can make this advancement possible.

Figure 1: Centres of technology and innovation in North East UK

As an example, the use of CO_2 as a raw material "building block" was highlighted. CO_2 is commonly reacted with Ammonia to produce Urea, and with Phenol to produce Salicylic acid (Aspirin). However recently there has been opportunity to react CO_2 with epoxide to produce Cyclic carbonate to be used for lithium ion batteries. An advanced lithium-ion battery plant now operates in Sunderland, with production of 60,000 units a year. In 2013 the first British-built, LEAF EVs began production in Sunderland, with initial annual production capacity of around 50,000 vehicles. There is very good infrastructure to support electric vehicles in the region – the North East is the most connected region in the UK with over 1136 charge points.

Applications of synthetic gas were also highlighted as an area of large opportunity. The extract slide from the presentation below shows the wide variety of uses.

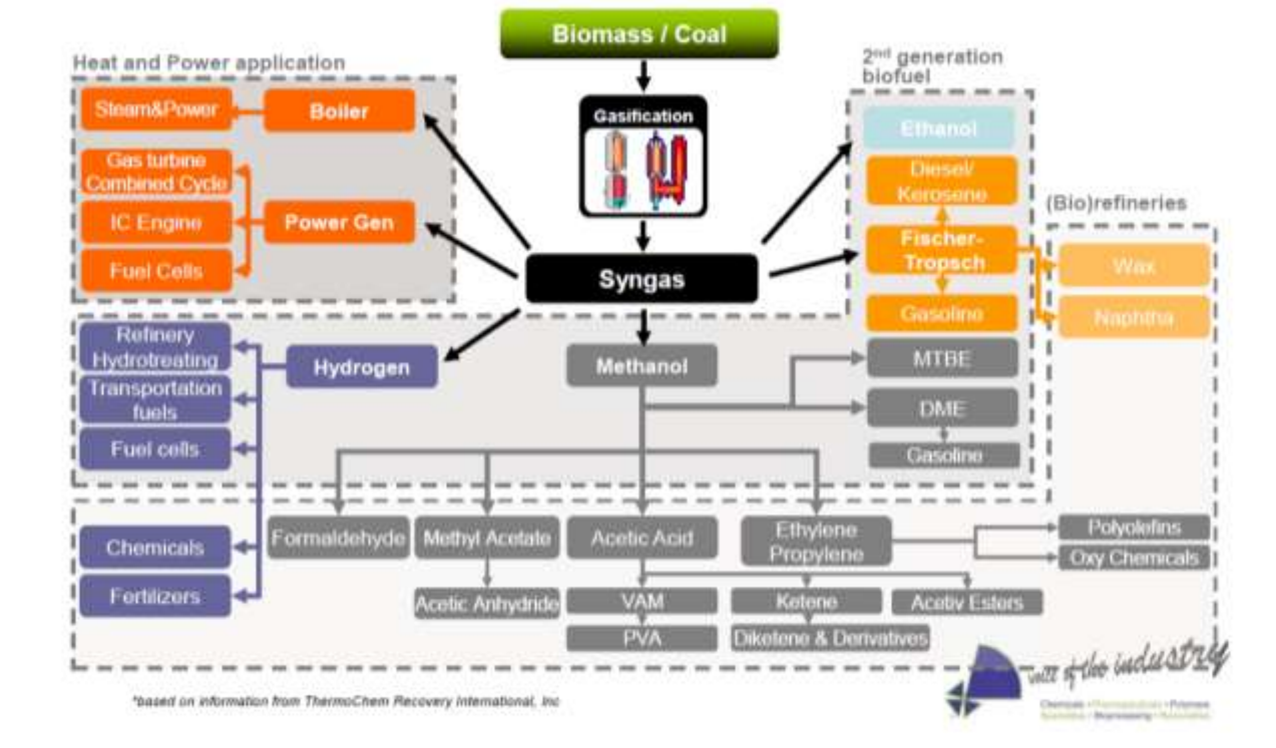

Figure 2: "Syngas applications & Synergy for Tees Valley Chemical/Process industry", extract from presentation

2.2 "Renewable Energy and the Low carbon Economy - A global Perspective" – PWC

A global view and an analysis of trends in renewable energy were provided by Rich Hall, head of sustainability in the North at PricewaterhouseCoopers LLP. The presentation identified strong rationale for growth and importance of renewable energy, followed by a review of investment trends in the area.

Increased demand to address climate change, regulatory and policy initiatives and the expansion of carbon markets, all of which are necessary to foster energy security provide a practical rationale for the importance of renewable energy. Adding on to this is the prediction that 50% more energy will be needed to sustain a world population of 8.3 billion by 2030.

The world faces a critical situation in a Food-Water-Energy "Nexus" which links energy to food and water provision. The energy trilemma of decarbonisation, affordability and security of supply was highlighted – it is not possible to balance perfectly the three elements and there is a need to find trade-offs.

The global markets anticipate that energy prices will continue to rise (albeit individual periods of price drops) and DECC UK assessment suggests that future policies on sustainability will contribute to this rise. The focus has moved from carbon to affordability.

"*An interconnected trading bloc of emerging markets has developed. Intra-E7 trade flows have grown nearly twice as fast as E7-G7 flows over the last decade and over five times as fast as intra-G7 trade flows*."

Data on trends in investment from 2004 to 2014 were presented including totals, by region and by sector. The overall trend seen consistent increase followed by reduction in investment since 2011. Table 1 below shows performance of Index and funds.

INDEX	Funds
NEX - Growth from Jan 2012	Public markets - up
NASDAQ - Growth from Jan 2012	VC/PE - flat to down
S&P 500 - Growth from Jan 2012	Asset - down

Table 1 : performance of Index & Funds

The main investors with medium and high-level activity were identified. Long-term growth was cited as a major objective of investment. Other objectives were funding development, yield and growth and geographic diversification. Table 2 below shows investor groups and examples of investments.

Funders	Examples
Chinese state-owned enterprises	State Grid, China Southern power
Sovereign wealth funds	Government of Singapore investment corporation, Qatar investment Authority
Infrastructure funds	Hastings, First State investments
Pension and insurance direct investors	Allianz Capital Partners, Pension fund association (Japan)
Investment holding companies, investment banks and other institutional investors	Berkshire Hathaway, Goldman Sachs
Japanese trading houses	Mitsubishi Corporation, Mitsui&Co. Maruberi Corporation
Domestic corporates (excl. China state-owned)	NRG Energy, Gazprom

Table 2: main investors

Immediate prospects in renewable energy are shown by the following trends:

Optimistic	*Pessimistic*
Increase in investor capability	Funds in circulation down for Q1 2014
Increasing carbon targets	Marco-economic uncertainty
Individual deals high in Q1 2014	Political uncertainty
Indexes continue to rise	Stretched balance sheets

2.3 "Building a Hydrogen technology Infrastructure in the North East of England" – Regeneration Services, Redcar and Cleveland Borough Council, UK

This presentation gave an overview of the state of utilisation of hydrogen technology in the North East region. Past projects and opportunities for future ventures were presented. The extract in Figure 3 below highlights multiple opportunities and benefits to be achieved from the utilisation of hydrogen energy.

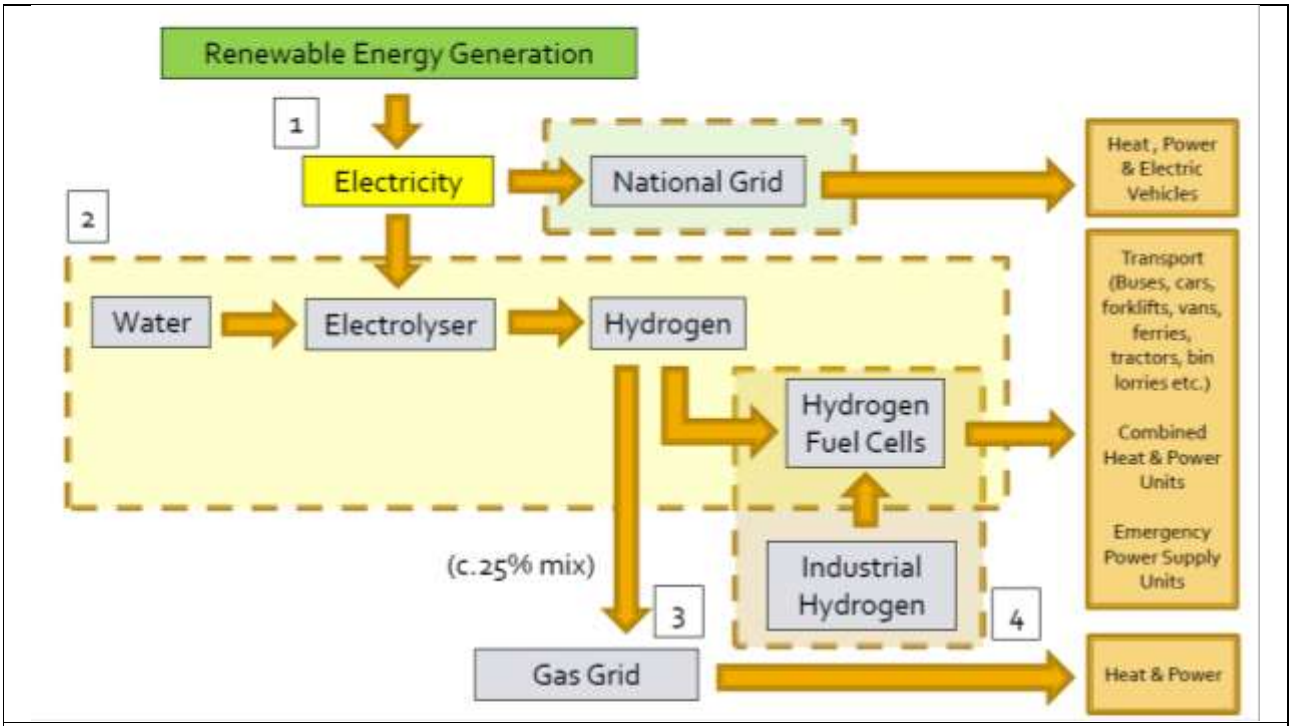

Figure 3: opportunities for utilisation of hydrogen energy

This is a new commercial sector with very high growth potential. One example of a successful venture is the Hydrogen Fuel Cell Electric Vehicle (FCEV) technology which has recently met technical targets for commercialisation. Current developments in this field:

- Toyota hydrogen vehicles will be available in 2015 for less than $50,000. The car will launch in California first. $200 million has been earmarked to build 20 filling stations in California by 2015 with a further 40 the year after.
- Hyundai/Kia to sell 500 fuel cell vehicles in 2012, and increase production.
- Daimler to begin series production of FCEVs in 2014 and make a major investment in Canada to build a full cell production factory.
- In the UK, Transport for London (TfL) is operating 8 hydrogen buses and have had 15 hydrogen fuelled taxis operating since the London Olympics.
- Commercial scale stations built in Swindon and at Milbrook proving ground.

Previous successful projects in other locations can provide valuable lessons for strategic future development. These include the Aberdeen Hydrogen project, which made use of wind energy and fuel cell systems and resulted in a fleet of Hydrogen fuel cell buses and filling stations. It was also possible to inject hydrogen into the grid and a creation of a merchant H_2 market.

The HyTrEc Project (www.hytrec.eu), of which Gateshead College is a member, aims to improve access to and advance the adoption of hydrogen as an alternative energy vector across Europe through innovative training schemes like a vocational hydrogen safety and infrastructure training package.

The Tees Valley and North East Hydrogen Working Group are working towards becoming a recognised UK Cluster Group. Current membership includes:

- Gateshead College (Skills Academy for Sustainable Manufacturing and Innovation)
- Newcastle University
- Sunderland City Council
- Newcastle City Council
- Redcar and Cleveland Borough Council
- Tees Valley Unlimited (Tees Valley's Local Enterprise Partnership)
- NE Local Enterprise Partnership (Local Enterprise Partnership for North East -excluding Tees Valley)
- NE Combined Authority (Economic Development and Transport Body for North East - excluding Tees Valley)
- Connect Tees Valley (Transport Partnership body for all 5 Tees Valley Local Authorities)
- NEPIC (North East Process industry Cluster)
- CENEX UK (Centre of Excellence for Low Carbon and Fuel Cell technologies)

They identify that North East England has specific strengths for Hydrogen technology development and intents to produce a Hydrogen strategy and action plan towards positioning NE within the Global, EU and UK H_2market by making best use of existing resources (syngas technology, downstream availability of Hydrogen and large scale underground storage facilities). Specific regional strengths identified are:

- NE England produces 50% of the UK's hydrogen, with the major producers located here.
- Two new facilities are currently being built in Teesside, to produce H2 from waste.
- Equipment manufacturers that make fuelling stations already based in NE.
- A major Automobile OEM in the region (Nissan) is already an active member of the UKH2Mobility project.
- Large underground, salt cavern storage capability for H2 on Teesside.
- Existing underground gas distribution and storage network on Teesside.
- Well located to make use of offshore wind power generated by Round 3 offshore wind farms (Dogger Bank, in particular) and local Syngas production (from coal gasification/fracking activities).
- Specific knowledge/research base in NE universities and colleges.

As an action they propose to replicate the successful Aberdeen Hydrogen Project, with a focus on storage, distribution, transport and combined heat and power (making use of natural H2 storage facilities and available industrial H2 in NE England).

3 Technology presentations

The remaining presentations were scheduled as in the agenda shown below with Q&A after each plenary session.

3.1 Schedule of presentations in conference agenda

Plenary 1: Renewables and Industrial Symbiosis

"Robust yeast for ethanol production and other chemicals" - Fermentec (Brazil)

"Facilitating the Future and Accessing Renewable Gas" - National Grid (UK)

"Transforming Drax through BiomassDraxPower)" -Drax Power Limited (UK)

"New Bio-energy technologies and industrial Symbiosis" - Symbiosis Centre (Denmark)

Plenary 2: Low Carbon Technologies

"clean syngas from under the seabed" – Five Quarter (UK)

"What's waste got to do with Biofuels and biochemicals?" -SITA (UK)

"Some Actions on Bioresources in China and the Industrial Utilization of Straw Biomass" - Nanjing Tech University (China)

"Depolymerisation of waste plastics to generate purified fuels" - Plasma Energy (India)

Plenary 3: Utilisation of CO2/Hydrogen Economy

"A Global Pioneer in Industrial Carbon Capture & Storage" - Tees Valley Unlimited & NEPIC PICCSI Group

"CO2-based Polyols for Polyurethane Applications" - Novomer (USA)

"Carbon Capture & Utilisation from Power Generation" - Net Power (USA)

"Overview of the CO2 conversion technologies at the Antwerp CCU-cluster" – VITO, Antwerp University (Belgium)

"Building a Hydrogen technology Infrastructure in the North East of England" - Redcar and Cleveland Borough Council, UK

Four themes can be identified and the next sections present the technologies within these themes although many of the ventures described can be related to more than one theme:

Theme A- use of biomass to produce fuel

Theme B- use of biomass to produce other useful materials

Theme C- synergy & symbiosis

Theme D- carbon capture, storage & conversion to useful materials

3.2 Theme A- use of biomass to produce fuel

3.2.1 "Facilitating the Future and Accessing Renewable Gas" – National Grid (UK)

In the UK a grid infrastructure links the gas suppliers to the consumers. Gas from suppliers leaves the transmission system and enters the regional distribution networks which transport and deliver the gas to consumers. National Grid, an international company which operates in the UK and north eastern USA owns the UK's gas transmission infrastructure and 4 of the 8 regional distribution networks. The presentation by Stuart Easterbrook from National Grid Gas Distribution was about their initiative to create connections the gas distribution networks which allow bio-methane producers to inject their renewable gas into the pipeline and grid network.

The addition of bio-methane into the grid is important for the UK as it will help minimise its carbon footprint, reduce reliance on fossil fuels, and increase energy security by diversifying supply. Bio-methane is cost effective and should reduce the price of heating for consumers.

National Grid is striving to reach its target of an 80% reduction in carbon emissions by 2050. They aim to connect 80 bio-methane production initiatives to its gas distribution network by 2021 and foresee that more than 80 would be achieved. Several projects were under way at the time of the presentation and 1 connected and commissioned. The national Grid website contains updates on the number of bio-methane connections to the grid - at the time of this report 8 projects have been commissioned.

Stuart Easterbrook from National Grid Gas Distribution talked about their experiences connecting the first of these projects across the UK, and the innovative processes that allowed them to successfully connect the first plant in Lindholme, Doncaster in October 2013. The renewable gas made available as part of this initiative provides gas for 3500 homes during winter and over 50000 homes in summer months. A number of innovative connection models are suggested including the already successful 3rd party ownership model where procurement of the grid entry unit is done by the customer. Figure 4 below shows the design of the 3rd party "own & operate" integrated injection unit.

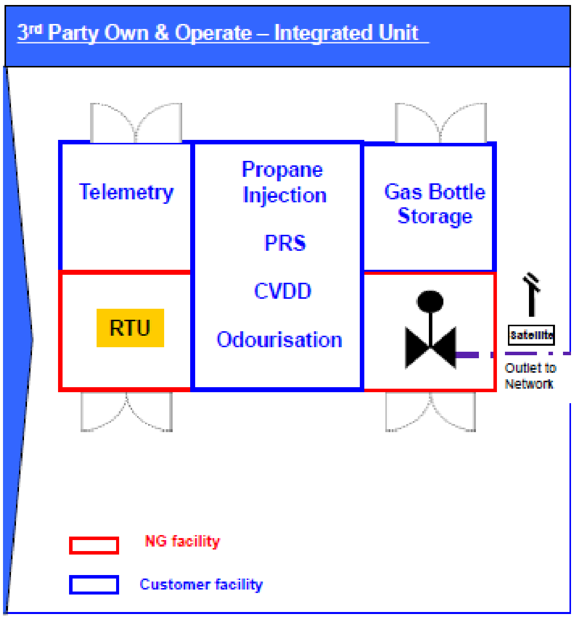

Figure 4: design of integrated injection unit

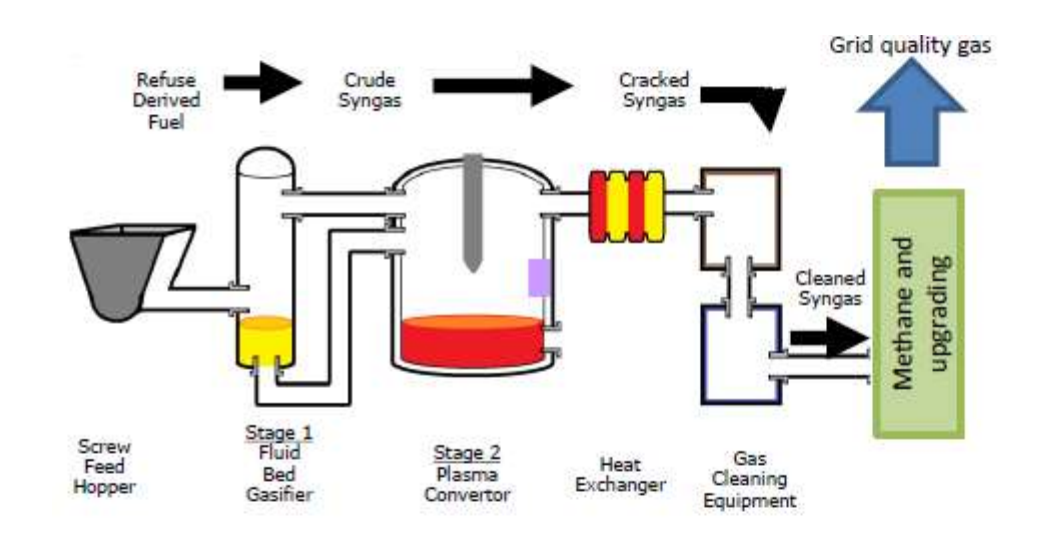

Figure 5: production of high quality synthesis gas

NationalGrid's involvement with a pilot project developing a commercial scale capability for the production of synthetic bio-gas was also discussed. Figure 5 above shows a system design for the provision of clean, high quality synthesis gas, Methanation at moderate scale. Confirmed projects are expected to provide heating for over 8000 homes.

Web: http://www2.nationalgrid.com/uk/our-company/gas/sustainable-gas/

3.2.2 "Transforming Drax through BiomassDraxPower" – Drax Power Limited (UK)

Dr Nigel Burdett, Head of Environment at DraxPower Limited gave a presentation about the transformation of the Yorkshire-based Drax power station from the largest emitter of CO_2 in the UK to the largest renewable energy plant in the UK. Drax was originally built as a 4000MW power station firing coal. Since 2003 coal has been progressively replaced with biomass for co-firing and the first unit converted 100% to biomass in April 2013.

Utilising synergy with paper manufacturers, shown in figure 6 below, Drax imports several million tonnes of wood waste pellets as fuel. The estimated saving is co_2 is over 10Mt per year. The biomass source is pellets made from mainly low-value wood from Canada and the USA. The presentation stressed that this use of biomass does not divert wood from other uses, and that there is no additional deforestation. When a tree is processed, e.g. for use in furniture making, roughly 50 % of the tree is used as timber and the remaining low-value wood is wasted in the form of residues, offcuts and thinnings, which can be utilised as biomass feedstock for energy production within Drax.

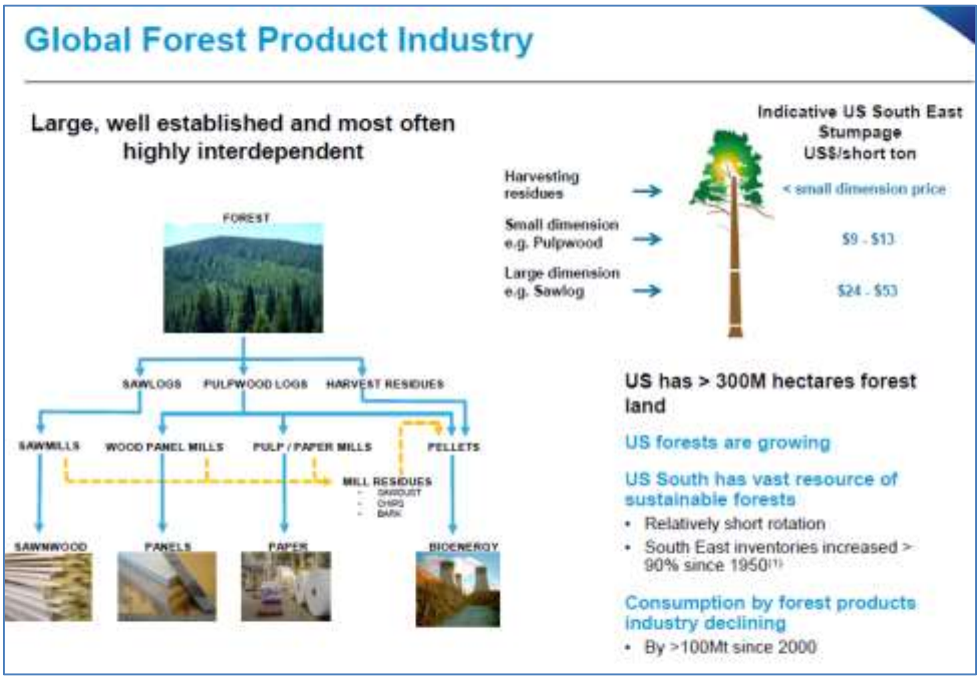

Figure 6: synergy with paper manufacturers

The process is not to be viewed as a simple switch in fuel types, rather a major transformation of the supporting processes and models including logistics, financial arrangements, corporate culture, relationship with government, and engineering. Several challenges exist including legal concerns, logistic issues of transporting the biomass and concerns about sustainability of deforestation. Drax has invested in infrastructure development across the whole supply chain for the construction and operation of rail unloading and storage facilities, biomass delivery as well as modifications to on-site boiler, mill and combustion systems. Coal import relationships provided springboard for biomass port developments and new biomass rail wagons have been built to transport the biomass from the ports to the plant.

Dr Burdett highlighted that biomass is an abundant low-carbon resource and is the world's fourth largest energy source. He stressed that it is important to keep in mind that Biomass is a low- carbon, rather than a zero-carbon, energy source. Current trend in operations shows that initial indications are positive; the supply chain responding and plant operations encouraging. The sustainability of operations is auditable and demonstrable. Future plans are to be predominantly biomass fired and by 2015/6 it is expected that the use of biomass will be up to 8Mt per year.

Web: http://www.drax.com/biomass/

3.2.3 "What's waste got to do with Biofuels and biochemicals?" – SITA (UK)

SITA, a subsidiary of Suez Environment, is a waste management company who work with businesses and local authorities to reduce the impact of their waste. SITA UK is part of a UK investment program of over £2 Billion in new infrastructure and service. Waste is collected, consolidated and separated into resources, which are supplied to third parties for reuse in new products, and fuel which is either sold or used internally. The extract from the presentation below shows the fuel value of the waste collected.

Figure 7: calorific value of different materials

The two main practical considerations are:

- cost of collection may inhibit role out of systems like separate food collection
- some very dense and very sparse populations may need further innovation to make separate food waste collection viable

However they identify a large potential for treating waste in the UK and modelling of waste streams by SITA UK indicates that most expectations are for waste volumes to grow which means that any future developments can rely on feedstock security.

Alongside this, market for the fuel produced is expected to grow with a recent global move to switch to alternative fuels in the cement industry and China's policy goal of 65% alternate fuel usage by 2015. Trends show many industries are also moving towards sustainable fuel sources.

Current options considered are extraction from landfills and in vessel composting. Future and emerging options include anaerobic digestion, gasification & pyrolysis, fermentation etc. and there are significant opportunities in R&D and industrialisation of new technologies.

3.3 Theme B- use of biomass to produce other useful materials

Two organisations presented detailed use of biomass to produce other materials: Fermentec, to produce bio-based chemicals from engineered yeast and Nanjing Tech University to produce a new hard-wearing straw-plastic material from waste rice straw and plastic.

3.3.1 *"Robust yeast for ethanol production and other chemicals" - Fermentec (Brazil)*

Fermentec operates in the optimisation of the industrial process for alcoholic fermentation and in the laboratorial control of all steps in sugar and alcohol production. With a team of professionals that are highly qualified in the areas of Chemistry, Biochemistry, Microbiology and Agronomy, together with is clients, Fermentec contributes to the development and dissemination of new technologies for the advancement of the sugar-energy industry. The main areas are ethanol production, distilled beverages and sugar cane industries.

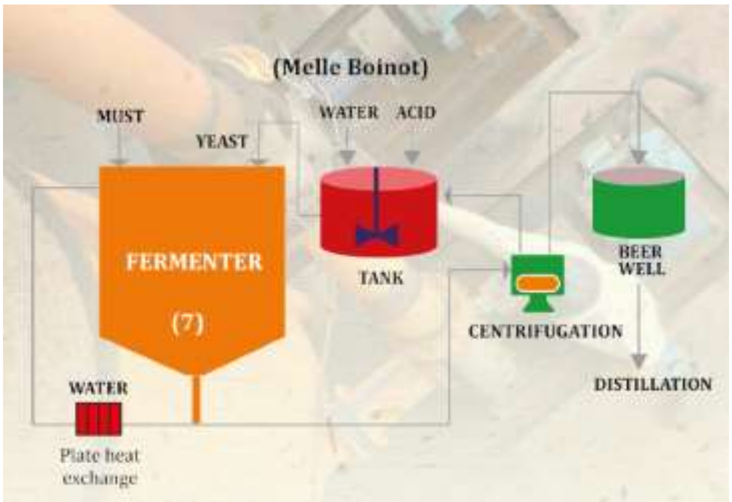

Figure 8: Ethanol production: batch fermentation

Fermentec have developed customised strains of yeast through process driven selection. One of the elements of concern in the process is the growth of bacteria. The important characteristics of the resulting yeast are:

- High fermentation yield
- Resistant to low pH, tolerant of high ethanol concentration
- High viability during fermentation recyclings
- Not flocculant per se
- Good fermentation velocity
- Low residual sugar in fermented wort
- More resistant to bacterial contamination

Web: http://www.fermentec.com.br/en/index.php

3.3.2 *"Some Actions on Bioresources in China and the Industrial Utilization of Straw Biomass" - Institute of Bioresource Engineering, Nanjing Tech University*

The presentation introduced the Bioresources Committee of the China Bioengineering Society and their initiative the "Bioresource Collaborative Innovation Platform (BCIP)"

BCIP is initiated by Nanjing Tech University, governments, social organizations, institutes, and industry enterprises with the aim of supporting the clean utilisation of waste straw. These collaborations have resulted in hardwearing and strong straw based products including rope, building materials and decorative household and consumer products.

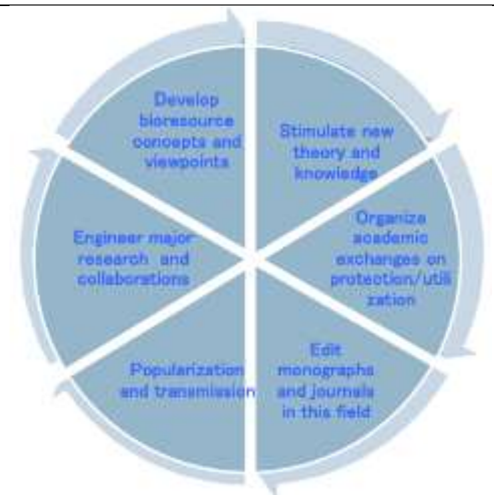

Fig 9 : Roles and responsibilities of the Bioresources committee

Examples of notable initiatives include Jiangsu Jinhe Hi-tech Co. Ltd.'s utilisation of straw-plastics materials in place of wood-plastics and 3D printing technology to produce hotel supplies that meet EU quality standards; Nanjing Jufeng New Materials Co. Ltd is involved in research into the potential of straw to replace wood in wood-plastic products used to produce outdoor flooring and other garden fixtures; a partnership with Nanjing Yonghang Environmental Protection technology Co. Ltd is considering entire houses made from wood/straw plastics to demonstrate the strength of the straw-based materials.

Other marketable products created from modified biomass straw include Antiseptic fruit tray made of activated carbon, Biodegradable preservative film and decorative wall pallets. On going challenges are the full utilisation of waste straw biomass and treating the resultant waste.

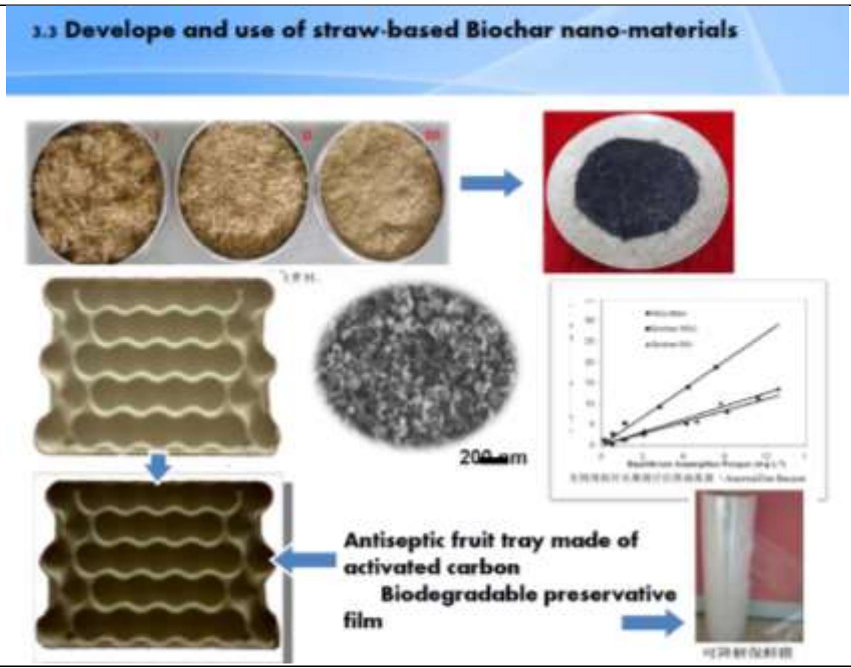

Figure 10: converting straw based biomass to usable products

Web: http://en.njtech.edu.cn/

3.4 Theme C- synergy & symbiosis

The organisations that produce biofuels and other Bioresources use as their raw material, materials produced by other organisations, often treated as waste. This concept is extended by the Symbiosis centre who studies models for creating a greater cooperation and mutually beneficial sharing of materials:

3.4.1 "New Bio-energy technologies and industrial Symbiosis" – Symbiosis Centre (Denmark)

Hans Berndt Jespersen gave an overview of the Kalundborg Symbiosis, "the world's first working industrial symbiosis". Kalundborg was established in 1972 and now operates more than 30 projects. The symbiosis sites provide benefits in CO2 emission reduction and in resource savings of water, natural gypsum and oil.

Several technologies and initiatives are brought together including a Pyroneer, use of biomass in power stations, Micro Algae and Waste Water Treatment and Bio gasification.

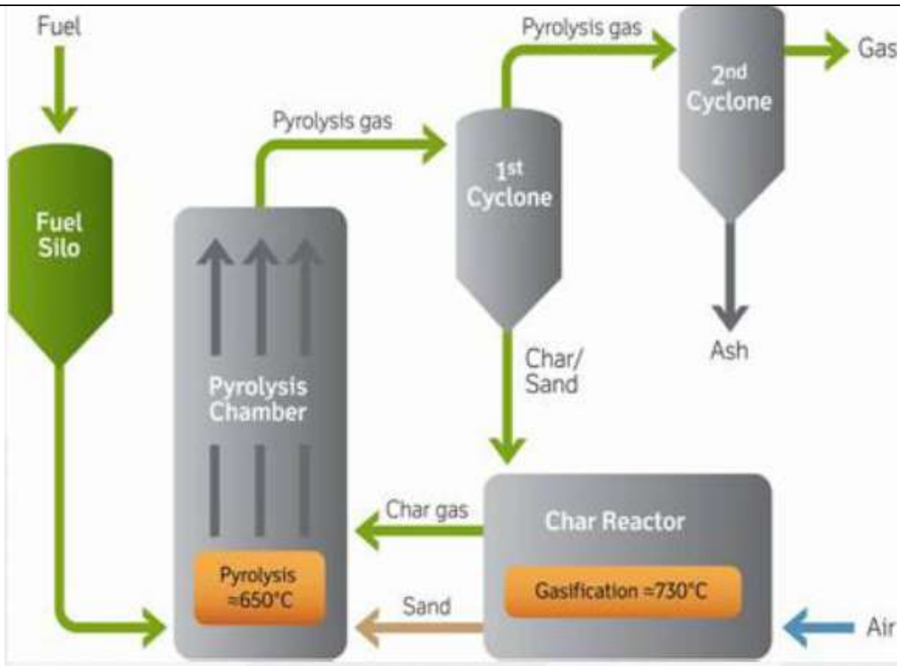

Figure 11: Pyroneer

The centre provides expertise and assistance to communities interested in starting their own industrial symbiosis. The intention is to provide standardised implementations that can be reproduced in other similar sites, and examples are made available online.

The Symbiosis Model provides a workable model for business development encompassing 3 key dimensions:

- Economy: minimising costs, improved bottom line and competitive edge
- Environment: resource efficiency through reuse, recycling, and reduced intake of virgin materials
- Innovation and development: improved introduction and access to new technologies and R&D, job creation and regional development

Web:http://www.symbiosecenter.dk/
Example of symbiosis: http://www.symbiosis.dk/ (Kalundborg symbiosis)

3.4.2 *"Depolymerisation of waste plastics to generate purified fuels" - Plasma Energy Pvt. Ltd (India)*

The company based in India commercialises a novel method for generating purified fuels from waste plastic materials using Depolymerisation providing a valuable solution for waste plastic and rubber disposal. This method involves thermal or thermo-catalytic decomposition of organic materials at elevated temperatures in absence of oxygen. Raw materials for this process include Waste Plastic (HDPE, LDPE, PP, PS, and ABS), Waste Tyres and Rubber.

Electronic scrap and Waste oils. The fuels produced are synthetic oil (Poly-Fuel), synthetic gas and charcoal. Application of the produced fuels includes use for:

- Electricity Generators
- Boilers
- Diesel Pumps
- Furnaces
- Hot Air Generators
- Hot Water Generators
- ThermicFluid Heaters etc.

The table below shows the steps involved:

Figure 12: Steps involved in Catalytic Depolymerisation technology

The products of the Fractional distillation and purification process are:

1) Thinner (mineral turpentine oil / MTO)
2) Gasoline / petrol
3) Kerosene
4) Jet fuel
5) Diesel
6) Heavy oil

The company also markets formulations of Engine oil and Gear oil. Their plant is self sufficient in terms of energy and the company also enjoys a number of operational advantages, namely the ready availability of inexpensive raw materials, ready buyers for purified fuels and the inneccessity of marketing which has contributed to their success. Plans are currently underway for further plants in Singapore and Slovakia.

www.plasmaenergy.in

3.5 Theme D- carbon capture, storage & conversion to useful materials

3.5.1 "Clean syngas from under the seabed" – Five Quarter (UK)

Dr Roddy of Five-quarter talked about their coal mining operations and the unique technical aspects of carbon capture and storage. The company goes beyond conventional mining and burning coal for power production to utilise new ways to use coal to generate energy and industrial feedstock.

Five-Quarter's Deep Gas Winning™ process seeks to gasify coal and associated strata in situ, extracting high energy values from the rocks and capturing all the resulting Co_2, which can then be locked up within products that will endure for centuries, with the surplus returned to ready-made deep sub-surface storage zones (created by the process itself) and the highest standards of protection for ecosystems and water resources applied at the same time. The figure below shows potential end uses from the resulting syngas.

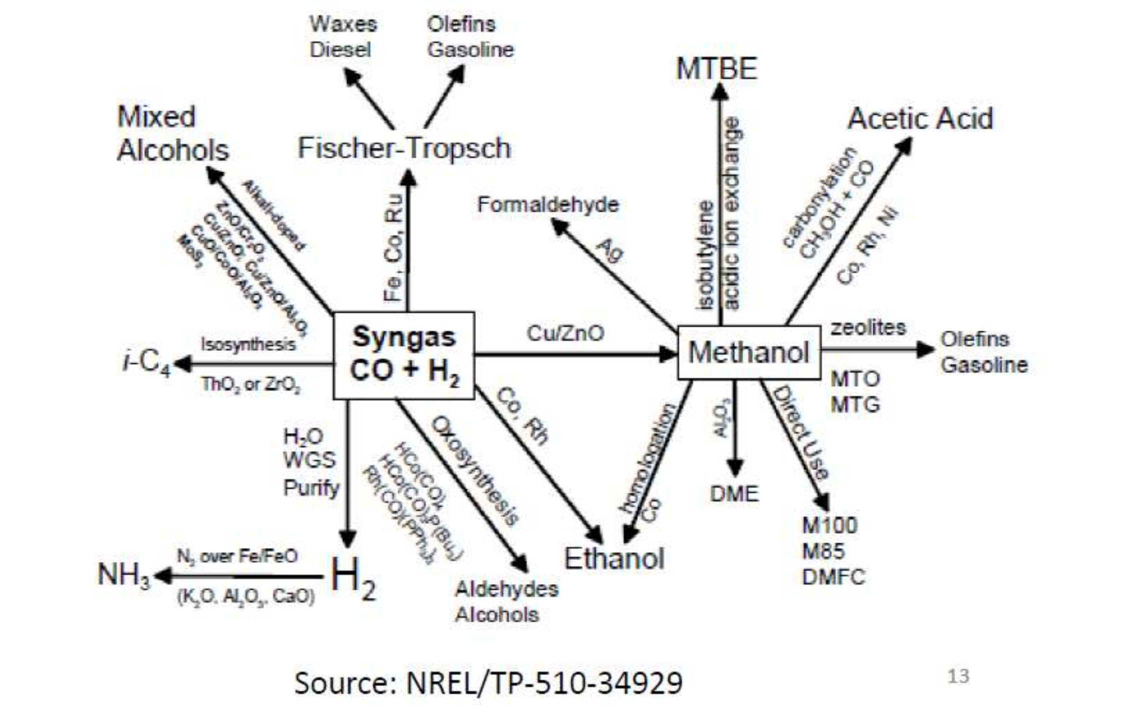

Figure 13: End uses for syngas (whether from biomass or from fossil fuels)

Web: http://www.five-quarter.com/

3.5.2 *"A Global Pioneer in Industrial Carbon Capture & Storage" – Tees Valley Unlimited & NEPIC PICCSI Group*

The presentation started with description of why the UK needs Industrial CC & S followed by an overview of the Teesside industry and why industrial CCS is particularly important to Teesside. TeesValley Unlimited and NEPIC's PICCSI Group are working to find suitable solutions for the region. Industrial CCS needs to develop financing mechanisms and one of the key enablers of recent developments was the awarding of the Tees Valley City Deal to the region.

Reasons indicated for the importance of CCS:

- The only technology currently available to significantly reduce industrial carbon emissions
- Required to meet the UK's legally binding carbon targets
- Technologically proven at a commercial scale on industrial plants

Reasons why CCS is important to the Teesside region:

- Process Industry in Teesside is essential for UK economy – worth £10bn/year
- North East is the only net exporting region in the UK
- Our international competitors are developing it
- One of the most carbon intensive locations in UK
- No other technology currently available to substantially reduce industrial emissions
- Excellent geographical location
- Clear industrial support

The extract from the presentation below shows a working process for CCS.

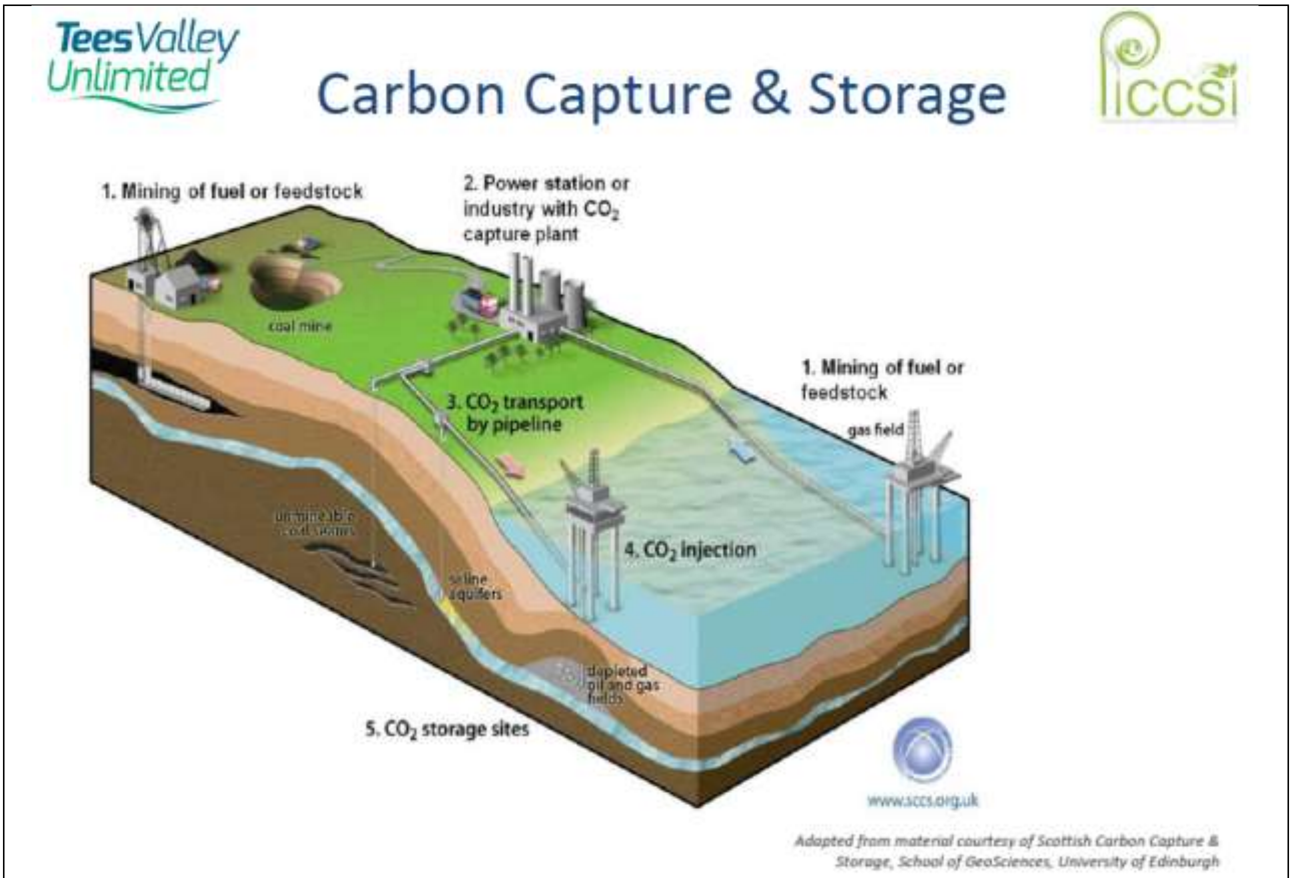

Figure 14: working process for CCS

3.5.3 *"CO2-based Polyols for Polyurethane Applications" – Novomer (USA)*

Novomer have developed novel catalysts which they use to synthetically convert waste carbon into high performance, low cost polymers and chemicals for a variety of applications such as foam and adhesives. Carbon, which would be released to the environment is captured and stored in the materials produced.

CO and CO2 with the use of Novomer's propriety catalysts and other substances are converted to different types of polymers, including elastomers and precise CO2 -based Polyols with a pure Polycarbonate backbone.

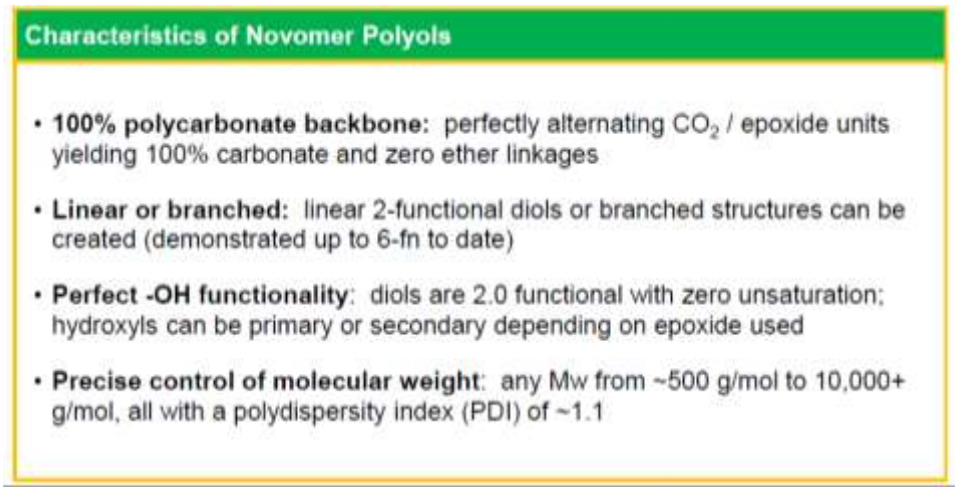

Figure 15: Characteristics of Novomer Polyols

They are high performance polyols that are lower cost and more sustainable than many alternatives as shown in the figure below. Novomer products have a significantly lower carbon footprint when compared to petroleum-based polyols and other thermosets.

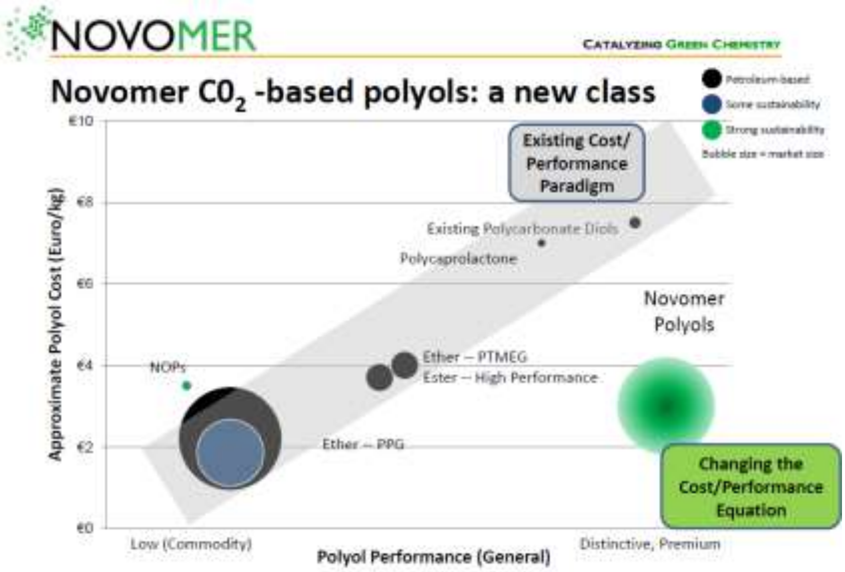

Figure 16 : comparison of polyols

These substances are used to produce commercially useful products such as:

Coatings
- Coil coatings
- Food can coatings
- Beverage can coatings

Thermoset Adhesives
- One & two component
- 100% solids, solvent, and water based

Polyurethane foams
- Rigid Insulation
- Resilient Molded Foam
- Footwear Foams

TPUs and Cast Elastomers
- Thermoplastic Polyurethanes
- Cast PU Elastomers
- Other thermoset chemistries

Novomer, based in the USA was founded in 2004 and has expanded since then with branches around the US and in Switzerland. The company holds several patents and have $50 MM invested from private & public (US DOE) sources.

3 locations: Ithaca, NY (1400+ m2 lab); Rochester, NY (R&D and scale up); Waltham, MA (Corporate Office).

Web: http://www.novomer.com/

3.5.4 "Carbon Capture & Utilisation from Power Generation" – Net Power (USA)

NET Power presents a novel patented power system that produces low-cost electricity from natural gas and generates zero atmospheric emissions. This system is based on an oxy-fuel, supercritical carbon dioxide thermodynamic cycle. Higher efficiency is achieved compared to traditional systems as CO_2 at high pressures is used as the working fluid as opposed to steam.

The waste CO_2 is of inherently of high quality that is "pipeline-ready" and provides an additional income stream. There is an industry demand for high quality CO_2 for applications such as enhanced oil recovery (EOR). The entire cycle itself is lower cost compared to traditional power cycles allowing NET Power to produce lower cost electricity. There is significantly less waste heat compared to steam based power plants. The figure below shows a diagram of the process.

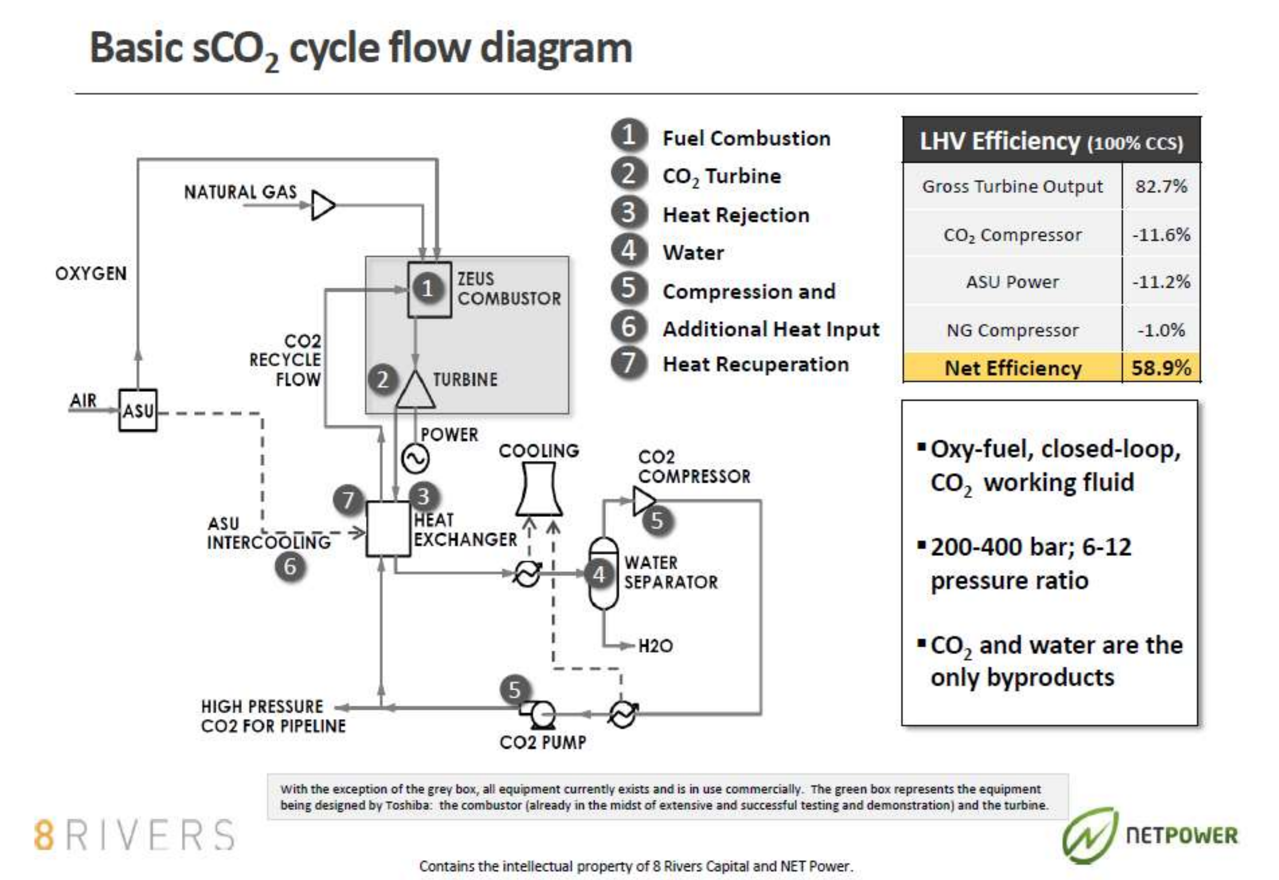

Figure 17: shows a diagram of the process.

This is a new technology that has shown success at each level of development. The first demonstration power plant is under development with partners CB&I, Exelon, Toshiba and 8 Rivers Capital. Once completed, it is expected to be world's first system of its kind producing no air emissions and incorporates CO2 capture as part of the process.

Web: http://www.netpower.com/

3.5.5 *"Overview of the CO2 conversion technologies at the Antwerp CCU-cluster" – VITO, Antwerp University*

This presentation gave an overview of a large number of various innovative CO2 conversion technologies and methods being developed within the Antwerp CCU-cluster by a number of organisations including the University of Antwerp, the port of Antwerp authority, the independent research and consultancy centre, VITO and FISCH.

The Antwerp cluster is viewed as one of the world's largest petrochemical clusters and has achieved cost efficiency through synergy.

A number of different pathways for utilising CO2 are identified, shown in the extract from the presentation below.

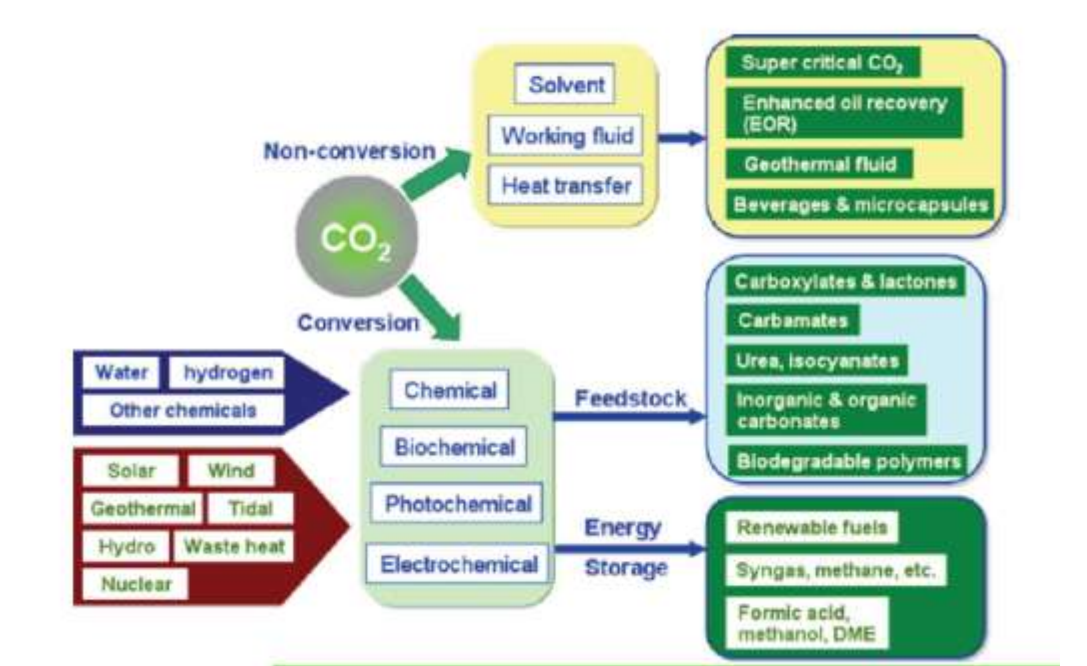

Figure 18: pathways for utilising CO2

A number of methods are being developed in the within the Antwerp CCU-cluster, including:

- Mineral carbonation: Commercialisation
- Organic carbonation: catalyst improvement
- Bioelectrochemical process, upscaling and robustness
- Plasma- assisted splitting of CO2: different plasma's and catalyst improvement
- Photocatalytic CO2 splitting: improvement
- Algae harvesting, disclosure and extraction: from pilot to demonstration phase
- PHB and ethanol production from CO2: improvement of mass transfer to make it economically viable
- Chemical looping: in process recovery of CO2

4 Summary

This report presented an account of the International Bioresources industrial conference organised by NEPIC. The presentations featured new technologies that have been commercially successful and provide a model for maturing technologies in academic and industrial research. They also provide an indicator of potential future research direction and commercialisation potential. Many of the ventures which are supported by government and the industry overview presentations indicate that there is significant financial support available for commercialisation of new technologies. The conference presentations indicate an industrial trend for synergy and the minimisation of waste (products of processes) to be an inherent part of operations planning.