ThermalNet
PyNe/GasNet/CombNet

Crowne Plaza Hotel, Lille, France
Monday 3 April– Thursday 6 April 2006

Meeting Report

Intelligent Energy Europe

Work Package WP2A Workshop
Lille, April 2006

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Feedstocks

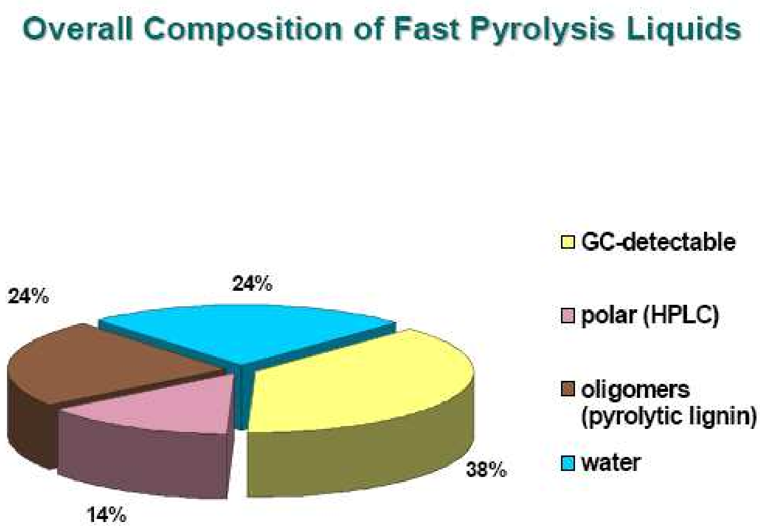
In feedstock issues co-operation with WP2C and EUBIONET will be done. Correlations between feedstocks and liquid quality will be studied by initiating a database containing data on feedstocks, pyrolysis process and conditions, yields, and the properties of feedstocks and products. A questionnaire on these subjects has been circulated within the ThermalNet.

Fuel oil quality

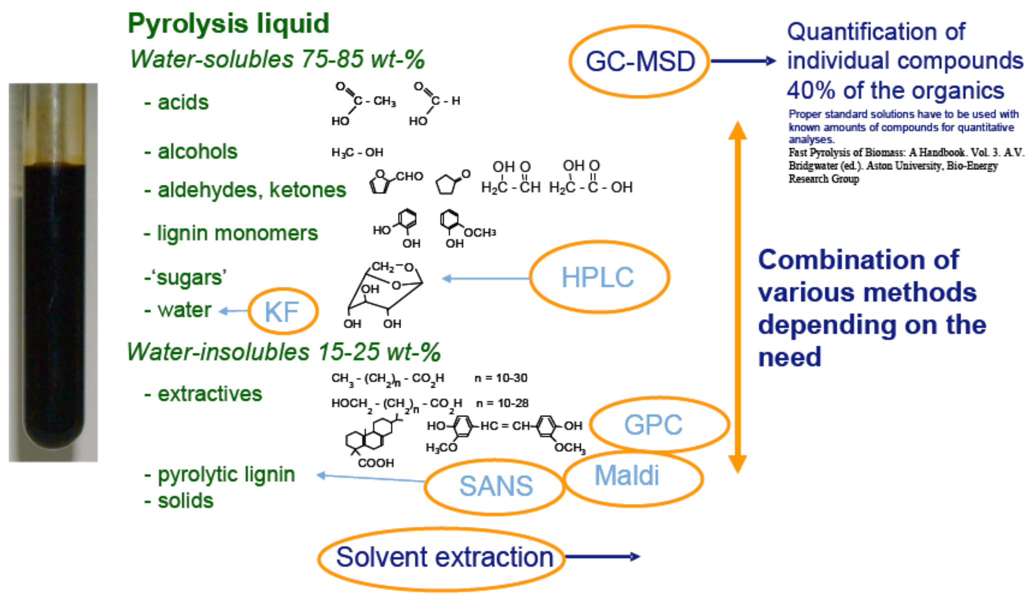
Pyrolysis liquid fuel quality is a critical issue for most end users. alternatives a critical issue.[1] Quality control should cover the whole chain from feedstock processing through pyrolysis to the customer. Feedback from liquid end-users will provide information on the critical properties to be specified and standardised. Methods for quality follow-up and characterisation and analysis will be provided. Fuel oil analyses suitable for pyrolysis liquids were reviewed in earlier studies.[2-4]

Methods for characterisation

Pyrolysis liquid is a complex mixture of various compounds typically present in small quantities. About 40 wt% of pyrolysis liquid can be characterised by GC-MSD methods.

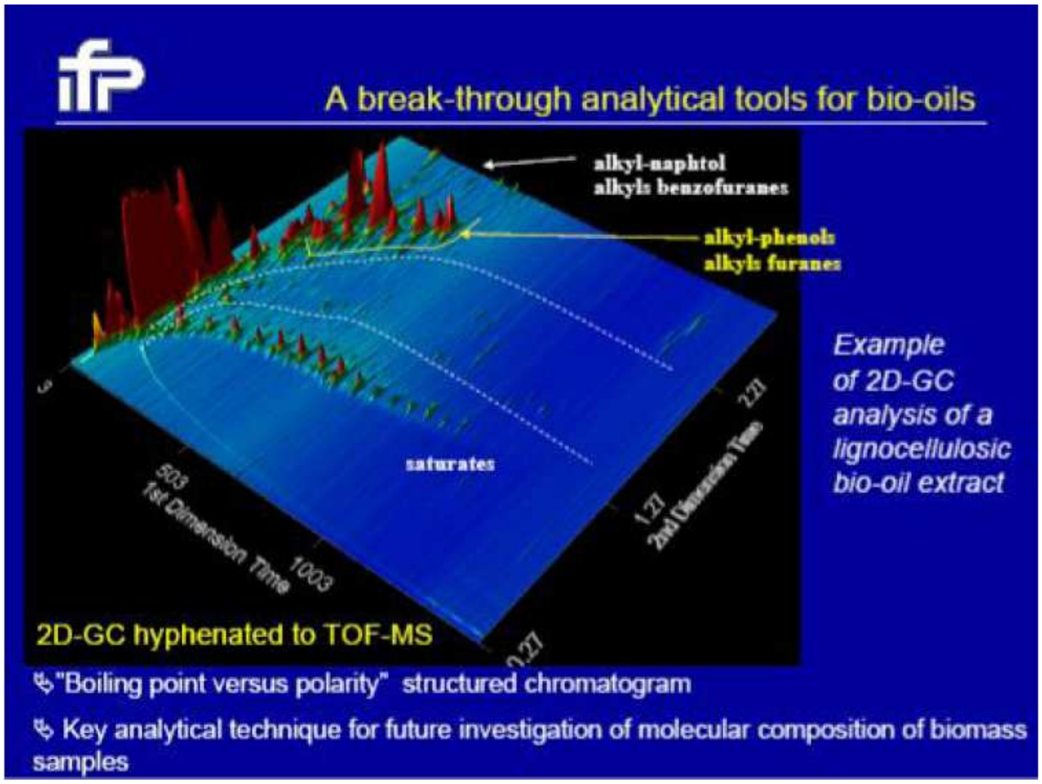


In the latest round robin[5] uniform methods for GC-MSD characterisation as well as a standard samples for calibration was suggested. The whole pyrolysis liquid can be fractionated into compound groups using solvent fractionation methods.[6] These two approaches can also be combined[7] and to get more information on the fractions.

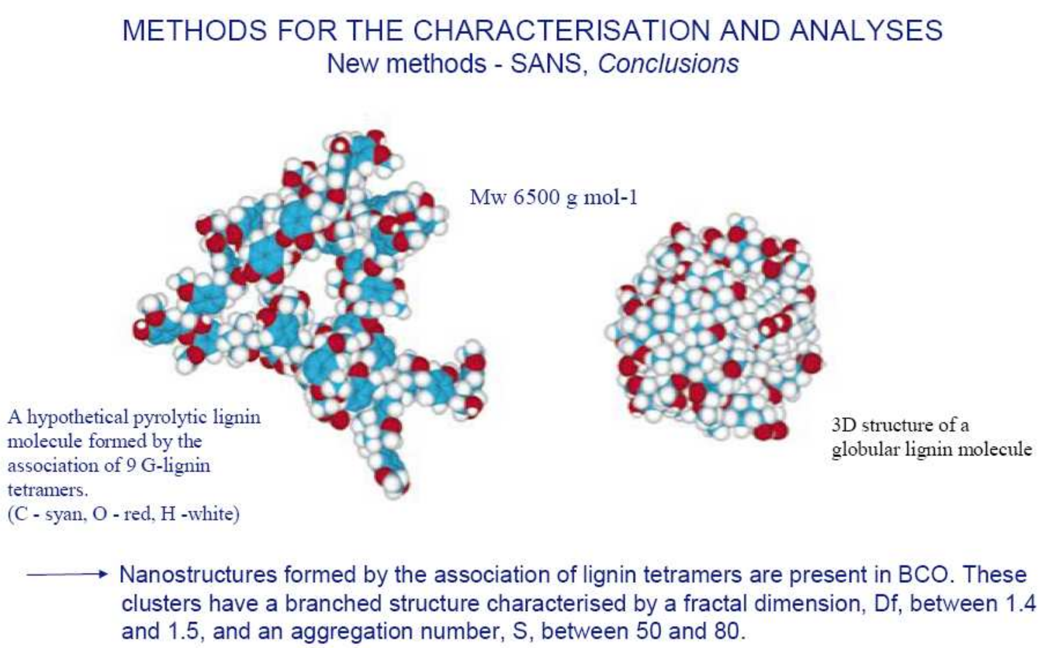


Product groups in pyrolysis liquid and methods of analysis

IFP (Institute Français du Pétrole) presented pyrolysis liquid analyses using IR, 2D-GC, ^{1}H and ^{13}C NMR, TG-MS, and Maldi/TOF/MS. Figure below represents data obtained from on-line hyphenation technique of two different types of columns through a cryogenic modulator. By the method highly structured chromatograms upon 3 dimensions "boiling point" versus "polarity" versus "concentration" can be obtained. In the future IFP will compare various pyrolysis liquids and their fractions and gather also quantified information by sophisticated methods.



The Lille workshop was mainly focused on lignin characterisation of pyrolysis liquid. A recent paper[8] presents the results on using SANS (small angle neutron scattering) on studying the shape and size of high-molecular-mass lignin during ageing of pyrolysis liquid.



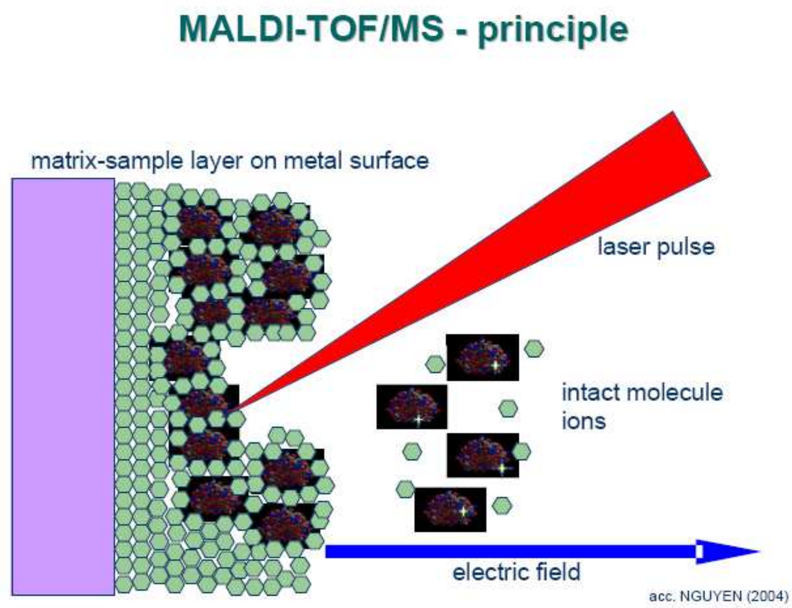
Methods for the characterisation and analysis of lignin

D. Meier represented[9] characterisation of pyrolytic lignin with SEC, Py-FI/MS MALDI-TOF/MS, and LDI-TOF/MS. The amount of pyrolytic lignin in the liquid can be determined by water extraction. The amount of pyrolytic lignin for softwood liquids is 15-21 wt%, and for hardwood liquids 12-19 wt%.

Isolation of pyrolytic lignin

By SEC (Size Exclusion Chromatography) mean Mw (molecular weight) of PL‘s between 700 und 1000 Da (Dalton) was measured. Using Py-FIMS (Pyrolysis-Field Ionisation Mass Spectroscopy) it was shown that PL gives more dimers compared to MWL (milled wood lignin). Maldi-TOF/MS (Matrix assisted laser desorption ionisation – time of flight/mass spectrometry) was suitable for molecules below 200 000 Da, and measurements of fractions with low dispersity was possible. By LDI-TOF/MS good separation in the lower mass range (below 400 Da) was obtained and there were no disturbance by matrix effects. The conclusions for the analyses were:

- The average Mw of the examined PL is between 560 and 840 Da, with a maximum deviation of 20 %, depending on the age (storage time below one week) of the liquid.
- The size of PL-dimers was between 270 and 400 Da.
- The numerous detected masses indicate, in contrast to native lignin, a big variety of different types of side chains or linkages.



Principle of Maldi TOF analysis

References

- Oasmaa, Anja; Peacocke, Cordner; Gust, Steven; Meier, Dietrich; McLellan, Richard. Norms and Standards for Pyrolysis Liquids. End-User Requirements and Specifications. Energy & Fuels., vol. 19 (2005) 5, s. 2155-2163.
- Oasmaa, Anja; Peacocke, Cordner. 2001. VTT Energy, Espoo. 65 p. + app. 34. VTT Publications : 450
- Oasmaa, Anja; Gust, Steven; McLellan, R.; Meier, Dietrich; Peacocke, G. Pyrolysis and Gasification of Biomass and Waste - The Future for Pyrolysis and Gasification of Biomass and Waste: Status, Opportunities and Policies for Europe. Strasbourg, FR, 30 Sept. - 1 Oct. 2002. Bridgwater, A.V. (Ed.). CPL Press. UK (2003), 161-168
- Oasmaa, Anja; Meier, Dietrich. Fast Pyrolysis of Biomass: A Handbook. Vol. 3. A.V. Bridgwater (ed.). Aston University, Bio-Energy Research Group (2005), 19 - 60
- Oasmaa, Anja; Meier, Dietrich. Norms and standards for fast pyrolysis liquids 1. Round robin test. J. Anal. Appl. Pyrolysis., vol. 73 (2005) 2, s. 323 - 334.
- Oasmaa, Anja; Kuoppala, Eeva; Solantausta, Yrjö. Fast Pyrolysis of Forestry Residue. 2. Physicochemical Composition of Product Liquid. Energy and fuels., vol. 17 (2003) 2, s. 433 - 443.
- Oasmaa, Anja. Fuel oil quality properties of wood-based pyrolysis liquids. Academic dissertation. Jyväskylä, Department of Chemistry, University of Jyväskylä, 2003. 32 p. + app. 251 p. Research Report Series, Report; 99. ISBN 951-39-1572-7

Summary of the Workshop on Task 2F
Lille - Modelling

A second workshop was organized in the framework of the Task 2F during the meeting in Lille during April 2006. The following presentations were given:

"Lumped reaction mechanisms of bio-oil devolatilization" by Carmen Branca

Results of an experimental and a modeling activity on bio-oil combustion, carried out at the Dept. of Chemical Engineering of the University of Napoli "Federico II", were illustrated. The process consists of two stages, that is, devolatlization and formation of secondary char, followed by heterogenous oxidation of secondary char. Lumped reaction mechanisms, including the kinetic constants for the former process, were also presented.

"Modeling gasification and combustion of biomass particles" by Colomba Di Blasi

A critical analysis was presented about the state of the art on the modeling of chemical and physical processes occurring during combustion/gasification of biomass particles, as a result of the planned activities of the project. Differences between structural and kinetic mechanisms and simplified and detailed transport models were pointed out. An indication was finally provided about future research needs.

"Biomass Modeling Activities at SINTEF" by Morten Gronli

The features of the CFD model, developed at SINTEF, were illustrated by means of a variety of application including the numerical simulations of practical combustion systems.

Presentations were followed by extensive discussions, involving the meeting Participants, about the various aspects of primary and secondary char reactivity, the validity of bio-oil devolatilization models based on thermogravimetric measurements and Arrhenius-rate laws, the sensitivity of simulation results to input (operating and model) parameters, etc. It was agreed to evaluate the possibility of carrying out a Round Robin study on the reactivity of char, similar to previous investigations carried out for cellulose.

Workshop on gas cleaning

Harrie Knoef, BTG

At the ThermalNet meeting in Lille, France a workshop was organised on gas cleaning with three presentations. Tomas Kåberger form TPS headed the session which was held on 4 April 2006.

The first presentation was made by Sander van Paasen, form ECN Biomass regarding a 700 hour duration test of a complete gasification CHP plant including the novel tar removal system “Olga”. The test was a cooperative effort of ECN with Host (gasifier manufacturer), Dahlman (supplier of the Olga system) and Essent, who supplied the gasengine for this test. The wood consumption was in average about 100 kg/hour and the test showed good performance of the whole system. More information on this test can be found in a separate article.

Prof. Gerard Brem of University Twente presented the integrated filter system of the Pyros system, a flash pyrolysis technology utilizing a rotatung particle separator (RPS), which was alo developed at the same university. The RPS is a cyclone incorporating a rotating filter element with very fine openings. It’s a proven technology for flue gas cleaning and also applied in the food processing industry. The research work started because many liquid and hot gas filtration technologies suffer from different kind of problems. The quench for condensing the pyrolysis oil is also based on the RPS technology, which makes the whole plant rather simple.

In the third and last presentation Prof. Hermann Hofbauer presented an update of the Guessing gasifier installation with the focus on improvements of the gas cleaning system. The operational performance increased steadily over the last years and the availability in 2005 was very good with about 90%. Some main features of the plant is the production of a medium calorific gas without using oxygen and no waste streams except for the fly-ash. One major problem with fouling of the product gas cooler was solved by recycling part of the fly-ash to the fuel intake at the gasifier. The ash cleaned the surfaces of the cooler and also served as a catalyst for tar cracking. The performance of the baghouse filter has been increased by using precoat material. This increased the tar removal considerable; the tar content decreases from about 2 g/Nm^3 to 0.75 g/Nm^3. The remaining tar is almost complete removed by the scrubber using RME as medium. After phase separation of condensate and the RME saturated with tar is recycled to the combustor, which means that no liquid waste stream is produced. A catalytic oxidizer removes about 92% of the CO emission; even after 4,000 hours no de-activation is encountered which is a promising result for minimizing gaseous emissions.

The presentations are available at the website www.thermalnet.co.uk soon for those who attended the meeting.

Economics and LCA of Renewable Transport Fuels
Joint Workshop WP2G and WP3B

Max Lauer

Presentations were given by

- Harold Boerrigter, ECN: "Cost structure of a synthetic fuel plant"
- Edmund Henrich, FZK: "Process, design and economics of the Karlsruhe process"
- Gerfried Jungmeier, JR: "What is the environmental and economic performance of biofuels".

Boerrigter and Henrich reported two completely different approaches on big scale Fischer Tropsch synthetic fuel production and presented both a techno-economic assessment with the aim to evaluate economic viability. ECN investigates a big scale plant, that integrates gasification and Fischer-Tropsch synthesis at a harbor site. FZK investigates decentralized pyrolysis and transport of the bio-oil slurry (including the charcoal) to a centralized gasification/Fischer Tropsch plant.. In the discussion of the two presentations it became clear, that the reliability of assessments of future big scale applications is unsure because of uncertainties in scaling up from small applications and of uncertainties in the assessment of unknown technological solutions. Also the assessment of some costs e.g. infrastructure used respectively needed (transport facilities etc.) was seen as uncertain. In the end it was agreed, that these kind of assessments give the best assessment possible at the moment, but the results should not be overestimated because of the uncertainties remaining in the assessment work. Both of the assessments resulted in cost for the FT-fuels produced of about 15 €/GJ or 55 €ct/l.

Jungmeier reported on the main outcomes of the VIEWLS-project on the economic and environmental performance of different biofuels, also fuels derived from other methods as thermo chemical conversion (biogas, vegetable oil etc.). Concerning the environmental performance he concentrated on the greenhouse gas (GHG) emission of the fuels, discussed the methods and the relevance of this assessment. The assessment of the economic performance of the concepts investigated resulted in expected production cost at the filling station in a range of about 17 €ct/GJ (Biodiesel) and 51 €ct /GJ (MBTE).

WP3B Conditions for the industry for making investments and/or adopting new technologies

Max Lauer

First Max Lauer discussed the original plan to discuss MCDA (multi-criteria-decision-analysis) as a tool for preparing decisions in industry. He reported that obviously the tool is not yet widely used in industrial practice and therefore no practical experience can be presented and discussed. The topic was postponed and will be picked up again, if possible.

In the workshop three presentations were held and discussed:

- Florian Eder (Mondi paper and packaging) “View of a technology user”
- Claus Greil (Lurgi) “View of a technology provider”
- Patricia Thornley (University of Manchester) “Bioenergy project risk”

Florian Eder presented the Mondi industries in order to illustrate his statements. Issues presented and discussed were, that industries have to ask for a payback time as short at 2.5 years (for the overall project). Especially for equipment integrated in the production process (e.g. energy supply) t an availability of 99.5 % and more is essential. For add on technologies (e.g. black liquor gasification) availability can be lower, but pay back time has to be very short. High technological risk related to low experience with new technologies can only been accepted, if a high potential profitability can be expected. Mr. Eder also expressed his interest in joint developments in R&D-projects.

The discussion showed a good understanding of ThermalNet members for the needs of the industries.

Claus Greil shared the experience of Lurgi as a big technology provider on adopting new technologies. He highlighted the need for a strict risk assessment by validating and ranking potential risks and explained the innovation management (five phases from idea to product) implemented at Lurgi. The risk management methods was illustrated with a number of practical examples.

Patricia Thornley stressed the importance of risk assessment and risk management especially for Bioenergy projects and presented a tool (risk matrix) for getting a better overview on risk events to be expected, their probability and the impact of their occurrence.

The risk matrix is an excellent tool for preparing a good basis for decision making and the risk management. Not only technological risks can be integrated, but also other risk categories related to fuel supply problems, political changes etc.).

Pyrolysis Biorefineries: Techno-economic assessment Joint workshop with PyNe Biorefineries task Leader

Max Lauer

The possibility of preparing a comparative assessment of different possibilities of biorefineries based on biomass pyrolysis was discussed and agreed, that the group could do this in the course of the ThermalNet project. It was agreed, that it should be an indicative assessment using easily understandable calculations for a limited number of options. A number of biorefinery concepts were identified for the assessment and the group members agreed to provide technical and economical data. The work will be continued in the next meeting.

Thermalnet-Pyne meeting Barriers Workshop Lille, France, 05 April 2005

A workshop on "technical and non-technical barriers to bioenenergy implementations" was held for all those in attendance at the Thermalnet meeting. The workshop was led by Patricia Thornley, University of Manchester, the barriers work package leader. Around 40 people participated, mainly from the academic research community but with some industrial participation (e.g. Electrabel, Pytec, BTG)

Participants were reminded of the work package objectives, of what is meant by the word "barrier", and of the aim of this PyNe workshop which was to address "technical barriers to the implementation of fast pyrolysis technologies".

Then Patricia explained the structure intended for this workshop, which was to find out which barriers are considered by the group to be the biggest. The approach was threefold.

First, each one feeling competent to participate in the discussions, received 3 postits to write down his/her top three technical barriers preventing the commercialisation of fast pyrolysis systems. These were collected for later use

Secondly, small stickers were distributed under 22 participants (PyNe members and non-Pyne members) and used to create a preliminary ranking of barriers under four different headings, viz. 1) feedstock, 2) pyrolysis oil production 3) pyrolysis oil utilisation and 4) other. This overview was prepared on wall papers by Patricia after the outcomes of the earlier workshop in Innsbruck September 2005. Everyone was requested to put his/her stickers (three per person) on the wall papers near the barrier that he/she considered to be the most important. The 3 stickers could either be distributed over more barriers or all be put to a single barriers. The results of this activity are given in the underneath table

Thirdly, the results of the first two activities were linked together in order to remove duplications and group the various items to a final ranking of five most important barriers. This was done by a discussion with the participants to decide whether a certain item is really a barrier or just a problem and if PyNe can play a role in demolishing a barrier.

The resulting shortlist is:

1. economics of a fast pyrolysis based conversion chain
2. quality of fast pyrolysis oil; need for upgrading; norms and standards
3. real scale demonstration of the fast pyrolysis technology

FEEDSTOCK

	PyNe members (yellow)	Others (green)	Total (if ≥ 5)
Feed quantity and quality	1	2	
Logistics of supply	2		
Physical conditioning			
Cost of feedstock	2	3	**5**
Moisture content			
Environmental impact of processing			
Bulk density / handling			

1 PYROLYSIS OIL PRODUCTION

Oil quality and stability	1	2	
Economy of scale		1	
Full scale demonstration	3	4	**7**
Availability of oil for testing	1		
Knowledge of oil quality from unknown feedstock			
Need for simple operation	1	1	

Cost not competitive	2	1	

2 PYROLYSIS OIL UTILIZATION

Absence of standards	3	2	**5**
Commercial availability of oil			
Oil stability and quality	3	5	**8**
VOC release / handling			
Lack of applications	3	1	
Need for upgrading	4	3	**7**

3 OTHER

Energy efficiency	1		
Lack of practical experience	3	1	
More support from big companies	1		
Whole chain economics	2	7	**9**