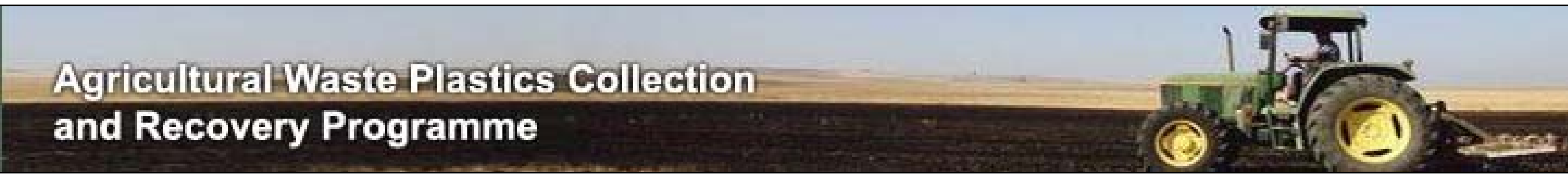


Bowman Process Technology Ltd

valpak

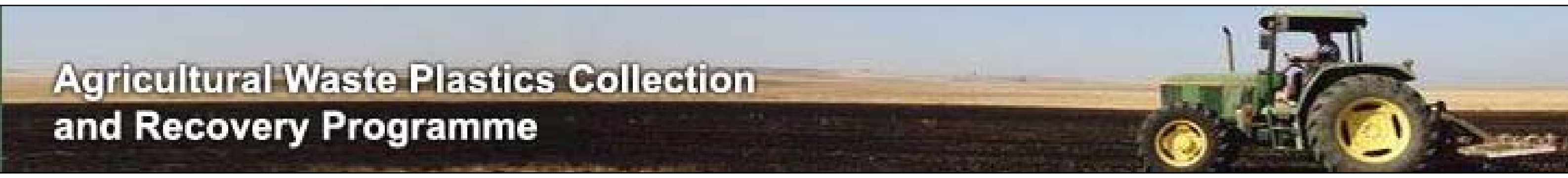
Abbreviated Final Report
Research Project 4/5
Pyrolysis of AWP

Prepared for:

AWP Programme Management Board

June 2007

Website Version



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Background

Report This report summarises the findings, conclusions and recommendations of a research project funded under the Agricultural Waste Plastic (AWP) Programme to investigate the viability of pyrolysis of AWP. The work has been carried out by Nick Takel of Bowman Process Technology and Valpak Ltd.

Purpose As part of developing recommendations for a Producer Responsibility system for non-packaging AWP, the project team required to research the role that recovery would play in setting targets. Proposals were submitted on pyrolysis of AWP by advanced smaller scale pyrolysis units. As there is a lack of published information specifically detailing the suitability of pyrolysis of AWP, the PMB agreed that before a decision could be made whether to fund any proposals, a study should be undertaken to establish:

- information already available on the technology
- information required through further research
- an initial cost model for developing and running smaller-scale pyrolysis plants and their fitness for purpose
- preparation requirements and costs to render the feed material suitable

Introduction

Pyrolysis Numerous processes are available to pyrolyse waste plastics and each presents its own advantages and requirements. They are diverse and include systems claiming to be able to process mixed feeds (e.g. plastics and biomass), catalytic methods and feedstock technologies. These processes have not been widely adopted and although initial economic assessment shows that a case for development can be made, it is not clear cut.

Preparation of Material Pyrolysis processes may require different levels of material preparation. This means that studies of different pyrolysis processes could provide useful data, bracketing the performance of pyrolysis for a diversity of material, including the influence on gaseous product quality, system efficiency, front end mechanical handling issues and yield. Without trials, it is not possible to establish the degree of material preparation required to achieve acceptable/economically beneficial outputs from the pyrolysis of AWP.

Technologies Proposed It is not possible to discriminate between different technologies without actual performance data and more detailed economic data, trial work would increase the available knowledge. Many technologies seem amenable to scale variations.

Post Pyrolysis Process

Analysis of pyrolysis products should be sufficient to assess its suitability for downstream purposes, but the scope of analysis performed should be reviewed prior to conducting any work. Again the contrast in preparation routes may influence gas quality and this may be revealed.

Trial Funding

The funding of trials will assist participating parties in developing their technology for agricultural waste plastic recovery. It may also define infrastructure requirements, should pyrolysis become a significant recovery route for this waste stream. The costs of the trials should be compared with the value of these factors to the programme. More preparation and cost data will become available following trial work, the information used in this study is limited to that readily available. However, an assessment of specific systems has been conducted from what could be gleaned so that a comparison with independently developed costs could be made.

Process Outputs

Pyrolysis Severity

Products of pyrolysis are determined by its severity – high severity typically involves high temperature and higher residence time processing. Products of lower severity processing tend to be liquids at normal temperatures and examples of this type are oil, diesel and petrol products. Higher severity pyrolysis will produce gaseous products such as ethane and propane etc. Most processes result in a mixed material product.

CHP

CHP is particularly effective where there is a local user for all the heat. Likewise LPG or gas production is effective where it can be used locally displacing utilities procured at retail prices. The economic assessment is highly location specific - see the section ‘Economics’ below.

Solid Waste

Pyrolysis will produce a solid waste – this may have some fuel value or have use as aggregate, but conservatively this has been assumed to be special waste for this study. It should not be assumed there are valuable by-products unless this has been demonstrated.

Revenues

Given a suitable quality of product, it is clear that a reasonable revenue return is possible, capable of rewarding a moderate level of combined operating and capital costs. Isolated facilities would be the least readily justified and integration with other facilities would be a key factor in ensuring acceptable economic performance[1], particularly where adjacent facilities are potential users of the pyrolysis products. These conclusions are based on conservative costs and may improve if a different approach is taken.

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[1] It is stressed that isolated does not mean remote or small in scale. It refers to facilities located such that they have no adjacent sinks for heat or direct product use and hence no synergy.

Various pyrolysis systems are available, but they have not been widely adopted to date. Increases in fuel costs over recent years tend to improve their financial justification. The economic analysis performed demonstrates that despite this, a tight control of capital and operating costs is necessary.

Economies of Scale

There is significant potential from economies of scale. The optimum scale will involve compromise, as it may be harder to find co-location partners for larger scale facilities and feed material will need to be supplied from a larger catchment area. Processing AWP with plastic waste from other sources would assist this type of development.

Conclusion

The product quality is determined by the pyrolysis technology and subsequent separation and clean up systems, in combination with the quality and composition of the feed material. Poor gas quality has implications for environmental performance and process economics.

Supply and Handling Requirements

AWP Feedstock

Non-packaging AWP is largely polyolefin in nature; i.e. composed of polyethylenes and polypropylenes (e.g. LDPE, HDPE, PE), and although some other plastics are encountered (such as PET and PVC), it is not unreasonable to consider that these can be minimised through separation at source. Polyolefin materials have a high calorific value and are readily converted to high energy products by pyrolysis. Mixed material products generated by pyrolysis necessitate separation systems that will add costs to their processing (Nb. processing of mixed Polyolefins is acceptable).

Feed Quality

Feed quality will influence the pyrolysis process in two main ways. Firstly, by affecting the quality of product, by introducing contaminating species, and secondly, by utilising some of the energy that is applied to pyrolyse the plastic. The inert contamination such as stone, soil etc. will thus tend to reduce the efficiency of pyrolysis by consuming heat. These materials may be unchanged by pyrolysis but will waste heat by being heated to reaction temperature and then cooled. They will also contribute to the quantity of residue that may require special disposal. The material density of these species is high compared to polyolefin plastic waste (which is less dense than water), so low volumes of these materials can introduce noticeable efficiency reduction. A low yield of plastic from total mass supplied threatens the economics; it is therefore important that these yields be maximised. The economic assessment has assumed that there is a 95% plastic content in the material as fed to the pyrolysis chamber.

Contamination

More active contamination will include biomass and unwanted plastics. Biomass can produce some fuel value products, so can be beneficial to a degree, but will increase solid residues from the process. The latter category will include plastics such as PVC, or plastic material that includes flame retardants. These need to be minimised because they have negative implications on process equipment integrity and longevity, operating costs, product quality and environmental impact.

These issues point to a requirement to ensure feed materials are of suitable quality and it is this requirement that creates the operational niche for such processes. If they can process material that is unsuited to other processes, or can accept material with a lower cost preparation route, they can possibly offer lower cost recovery methods. However, if preparation produces high quality plastic streams these may be suitable for other recovery methods, such as mechanical recycling.

Economics

Economics

The economics of operating pyrolysis facilities were investigated using several approaches. Firstly, an order of cost estimate for capital and operating costs was developed for several example options, and discounted cash flow of their performance assessed using a dynamic Economic Model, designed as part of this research project. Secondly, cost ranges were applied to points in the supply chain to compare alternative disposal and recovery routes. This latter approach relied on readily available cost factors, gathered from numerous sources.

Economic Model & Scenarios

As part of the economic assessment, an Economic Model for pyrolysis of non-packaging AWP was developed using Excel. As this is a dynamic working model, its findings are represented in the report through 26 descriptive models, based on six different scenarios. These scenarios are based on readily available data; they are not process specific.

Figure A Economic Model Basic Scenarios

Scenario	Level of Material Preparation	Capacity pa	Product
A	Comprehensive	4Kt	gas
B	Comprehensive	4Kt	heat & power
C	Minimum	1.2Kt	gas
D	Minimum	1.2Kt	heat & power
E	Minimum	4Kt	gas
F	Minimum	4Kt	heat & power

The 26 models illustrate these scenarios under a variety of conditions, e.g. with various cost data, zero staffing costs, silage film input only or with no special waste produced.

Payback periods were typically several years, varying between 2 and 10 years on a discounted cash flow basis. Clearly there are scenarios which are relatively attractive and others that are unjustifiable.

Example Case Study

One set of results was based on the performance of a pyrolysis unit processing 1,200 te of AWP per year, with minimum material preparation and producing heat and power. If installed as part of a consuming facility (i.e. a facility which can use all of the pyrolysis products) and the degree of integration is high, so that staff and other costs are shared between the activities, a relatively good return is achievable.

Comparison of Disposal & Recovery Routes

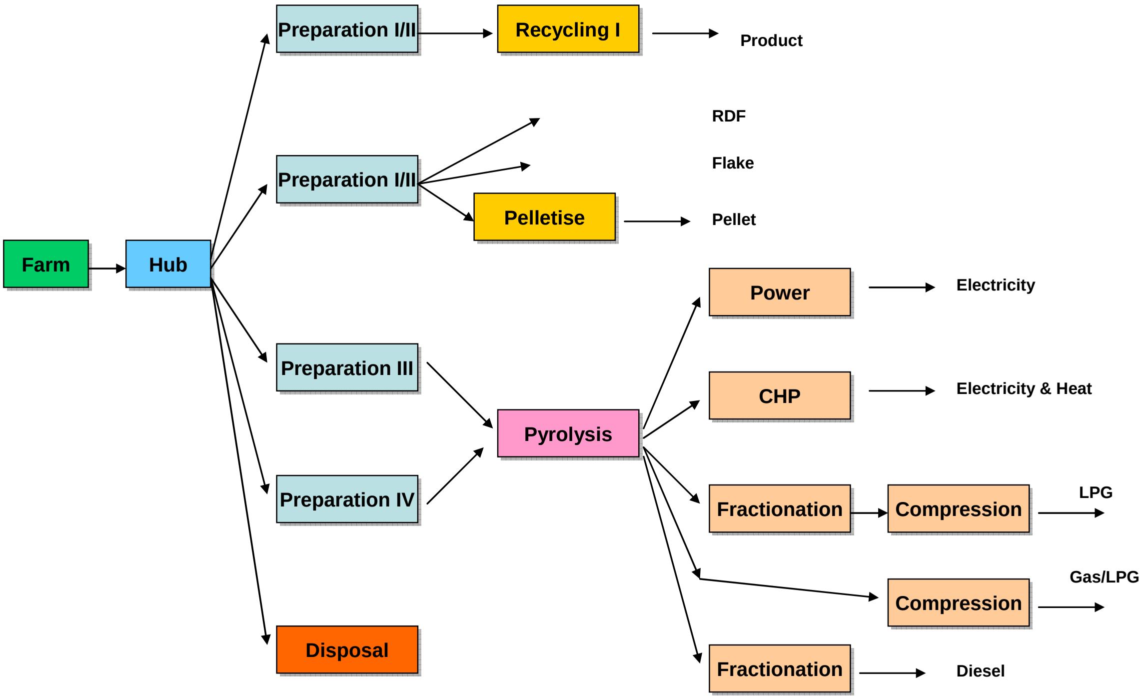
Similar economic assessments can be made to establish whether pyrolysis can compete with mechanical recycling under these circumstances. Where feeds are unsuitable for mechanical recycling or where preparation costs would otherwise be too high, pyrolysis may be compared with landfill to determine the appropriate choice. The determination must include all chain costs and thus the cost of moving waste material through the full disposal or recovery route is necessary to make the comparison.

Recovery route options are illustrated in Figure B below. The preparation types named are[2]:

- Preparation I: Debale, Shred, Wash
- Preparation II: Debale, Shred, Wash, Agglomerate
- Preparation III: Debale, Shred, Agglomerate
- Preparation IV: Debale, Shred

For these routes, Figure C then summarises estimates for high and low costs, revenue and net value per tonne. The revenue returns from pyrolysis products have potential, but when allowance is made for the recovery route costs, the results do not meet the higher net returns that seem possible through mechanical recycling.

Figure B Recovery Route Options



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[2] Note that these are included to provide cost allowances and do not propose recommended recovery routes. Specific routes need to be examined on a case by case basis.

Figure C Estimated Net Value of Recovery Routes

Product	Chain Costs £/te preparation and process exc. collection and baling		Potential Revenue		Net Chain Value £/te preparation and process exc. collection and baling		Enhanced Value £/te (3) as left, using enhanced revenue
	High	Low	High	Low	High	Low	
Disposal	£48/te	£48/te			-£48/te	-£48/te	
Recycling I	£468/te	£239/te	£850/te	£300/te	£611/te	-£168/te	
Pelletisation	£300/te	£162/te	£700/te	£300/te	£538/te	£0/te	
Agglomerate	£150/te	£100/te	£300/te	£300/te	£200/te	£150/te	
RDF	£150/te	£100/te	£30/te	£30/te	-£70/te	-£120/te	
Power	£236/te	£122/te	£238/te	£163/te (4)	£42/te	-£72/te	£116/te
Heat & Power	£236/te	£122/te	£406/te	£332/te (4, 5)	£210/te	£96/te	£284/te
LPG/Gas	£223/te	£119/te	£318/te	£238/te	£118/te	£14/te	£199/te
Diesel	£200/te	£191/te	£293/te	£293/te	£102/te	£93/te	

(3) Where significant additonal revenue is available through displacement of otherwise purchased utility costs etc.

(4) 3.8MWh per tonne of material processed

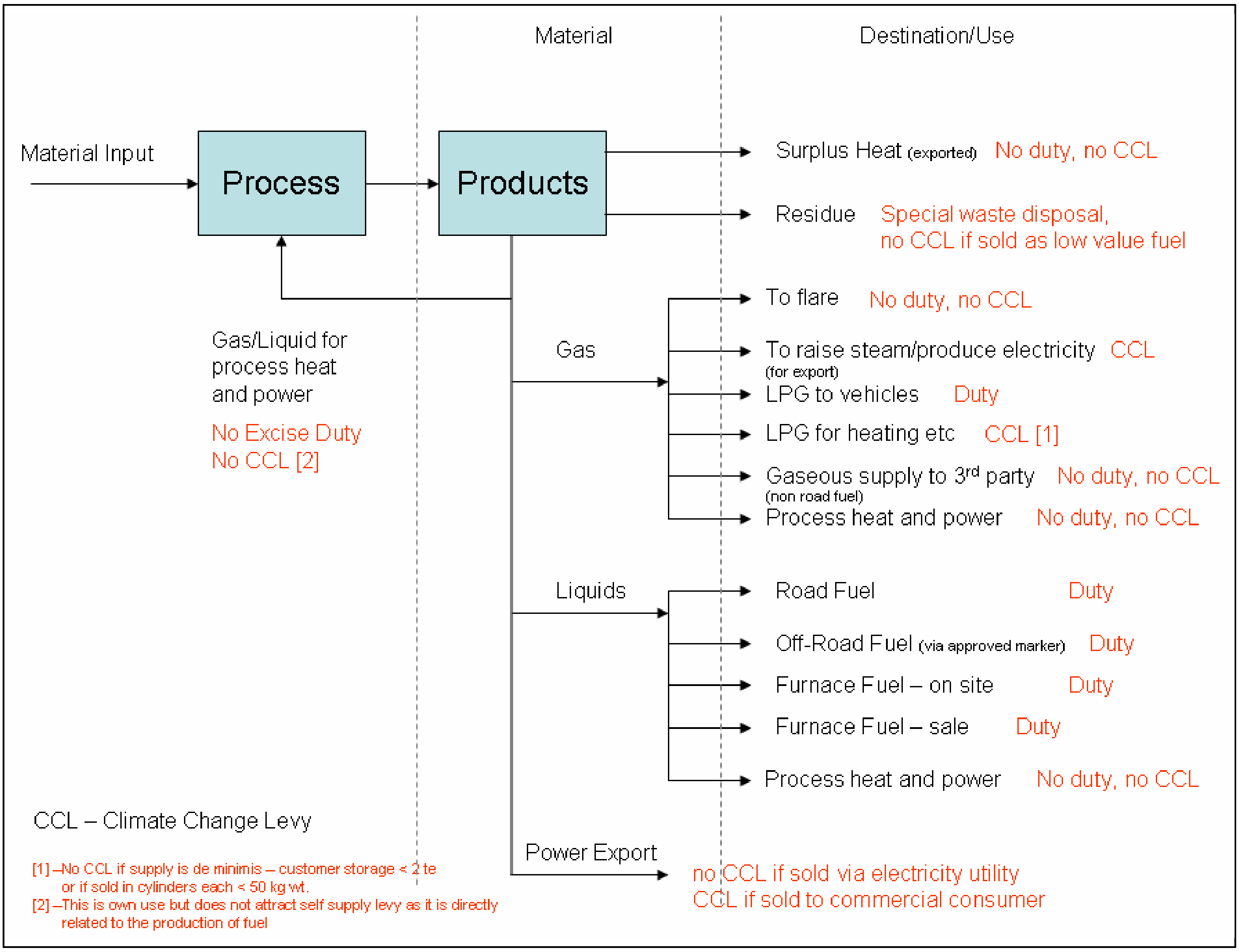
(5) 8.43 MWh of waste heat per tonne of material processed

Tax, Excise Duty & CCL

Tax issues such as excise duty and climate change levy do not distort the economics, but knowledge of them is required to ensure that sale prices for products are not inflated through ignorance. Any measures reducing excise duty on products derived from waste material, or processed through pyrolysis systems, would have a significant impact on their economic justification because additional margin would be equivalent to the change in excise duty.

The self supply of power and heat required to fuel the pyrolysis reaction will not be liable for duty or levy payments. These would only apply to exports. A summary of tax issues and their application to products of pyrolysis is illustrated in Figure D.

Figure D Illustration of the Application of Taxes to Some Pyrolysis Plant Configurations



ROCs

Renewable obligation certificates have significant value where electricity is produced from renewable sources. The plastic content of feed to pyrolysis processes is not eligible because of its fossil origin. The only eligibility would come from the biomass content in the feed and given the anticipated feed composition this would provide little support to the economics.

Conclusions and Recommendations

Potential of Pyrolysis

Pyrolysis has potential to reduce the amount of segregation and preparation required for agricultural plastic waste. This will have an influence on the cost of recovery and on the quantities available to be recycled. There are few models for this recovery route and very little objective economic data. There is potential for significant technical development in the areas of material preparation and recovery through pyrolysis and gasification.

Pyrolysis should not be excluded from the range of recovery options. For pyrolysis systems to be economic it is clear that contamination levels must be below those considered typical for silage wrap (50%) and mulch film (80%). This may also need to be achieved without washing to prevent the preparation cost and material quality approaching that experienced in mechanical recycling routes.

The omissions in information chiefly lie in the ancillary areas (feed preparation, feed and product specification, and downstream processing). Developed technology for pyrolysis largely concentrates on the central technology element and in waste management this is an inappropriate strategy because of the variability of feed and supply circumstances. It is important that research be carried out into preparation and separation issues, in tandem with pyrolysis technology development, as these stages can impose significant technical and cost constraints.

Location and Scale

Pyrolysis plant performance is highly location and scale dependent.

The review of alternative processes indicates that small scale pyrolysis units have not become established, although there continues to be a number of examples offered by various providers.

A survey of realistic location options where the advantages of co-location are most attractive, may prove useful in determining the role that pyrolysis could play in the recovery of agricultural waste plastic.

Plant location is a key determining factor for economic performance. Particularly where staff sharing and direct use of pyrolysis products may be achieved. If these products can be used to displace utilities that would otherwise be purchased at market price, a degree of enhancement of the economic case can be achieved.

Further Trials

Performing the trials will improve knowledge in these areas, in so far as the material processed is representative. However, additional research would be important to assess the risk from the full range of contaminating species that could reasonably enter the pyrolysis system.

There are liability issues for supply of products and the trials would provide limited information regarding this.

Some additional features may be introduced in the trial work to improve their value.

There is significant potential for improving upstream and downstream activities.

Debate in terms of funding this study is related to the value of trial outcomes to the overall project aims.

Risk factors

The main risk factors are technical and economic. Technology is available to clean up many of the emission issues that arise, but are expensive (economic risk). Additional risks include the ability of the installed plant to handle the material supplied (technical in terms of preparation and pyrolysis), whether pyrolysis produces sufficient quality products and the degree to which the economic performance is threatened by the presence of inert materials.

Outputs

It is possible that the products of the pyrolysis process could be defined as a waste material, with consequent handling restriction and sales stigma. Meeting an existing specification for the product exported is not sufficient proof that it is of suitable quality; it has to be demonstrated that the waste origin of the material has not introduced unusual contamination, i.e. not covered or anticipated by the current material standards and specifications.

A suitable standard has to be demonstrated where materials are exported, for the operation to be viable. This will not be applicable for local power and heat generation as these are energy sources and should meet appropriate standards. The trials proposed would indicate the composition of the pyrolysis products and give some guidance.

Revenue from Pyrolysis

The revenue returns from pyrolysis products have potential, although with allowance made for the recovery route costs it is not expected they will meet the higher net returns that seem possible through mechanical recycling. The presence of inert materials can damage revenue returns from the process by introducing inefficiencies. The basis of 5% inerts entering the pyrolysis chamber has been used in this report and the process can yield reasonable returns. The limiting levels acceptable would need to be determined for each specific case, but are unlikely to be above 15%.