*Macromol. Symp.* **135**, 113-120 (1998) 

# Polymer Cracking – New Hydrocarbons from Old Plastics

Stephen Hardman[1], David C. Wilson*[2]

[1] BP Chemicals, Chertsey Road, Sunbury-on-Thames, TW16 7LL, United Kingdom

[2] BP Chemicals, Grangemouth, Scotland, FK3 9XH, United Kingdom

Abstract: The management of packaging waste is a significant issue covered by European Union legislation which sets demanding targets for the recycling of all materials, including plastics. Significant progress has been made by an industry consortium, led by BP Chemicals, in developing technology to help meet the recycling targets.

## INTRODUCTION

The European Union, addressing the management of plastics waste in Europe, has started with packaging plastics (about 60 % of the total). The EU Directive on Packaging and Packaging Waste was adopted by the member states at the end of 1994. The Directive requires that by mid 2001 each of the member states must achieve at least 50 % recovery (diversion from landfill) of all packaging materials, with a material recycling rate of 25 - 45 %. The minimum allowable recycling rate for any material type, e.g. plastics, glass, is 15 %.

## THE NEED FOR FEEDSTOCK RECYCLING

The EU recycling targets are illustrated in Figure 1, showing United Kingdom figures for actual and target plastics waste. The total plastics recovered in Western Europe in 1994 was only 19.7 %, against the minimum target of 50 %. Material recycling was at approximately 6 % compared with the minimum target of 15 %, which for the UK makes approximately 300 kt/y by 2001. Much progress is needed on both fronts over the next four years.

For plastics, material recycling is allowed to include mechanical recycling, where the recovered material is shredded, washed, melted and re-pelletised, and recycling to raw materials which are used as feedstocks for making new products (feedstock recycling).

Mechanical recycling in the UK has so far concentrated on relatively large, homogeneous and uncontaminated items, found mostly in commercial waste. However, these items only account for approximately one-quarter of domestic plastics waste.

 CCC 1022-1360/98/$ 17.50

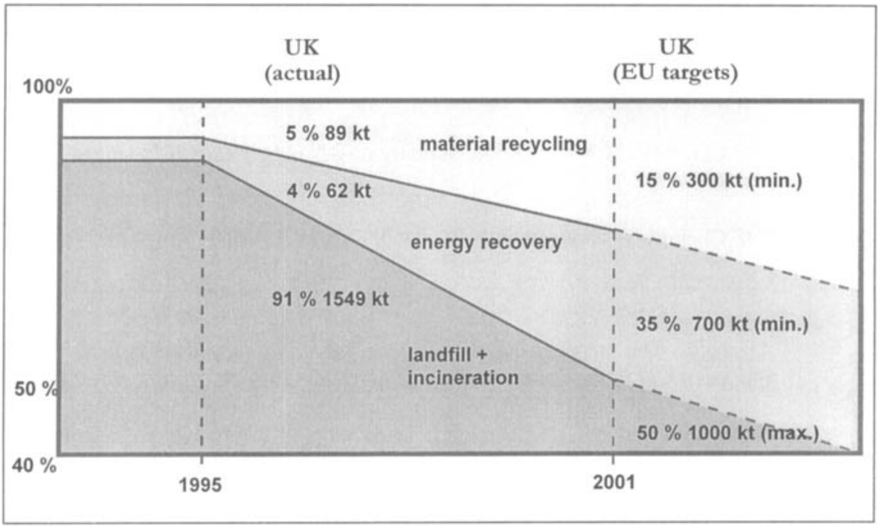


Figure 1. Packaging waste targets

As the plastics packaging items to be recycled become smaller and more contaminated, so the difficulty and cost of recycling increases, and the possible applications for the recycled pellets reduce. Under these conditions the feedstock recycling approach becomes important, as illustrated in Figure 2.

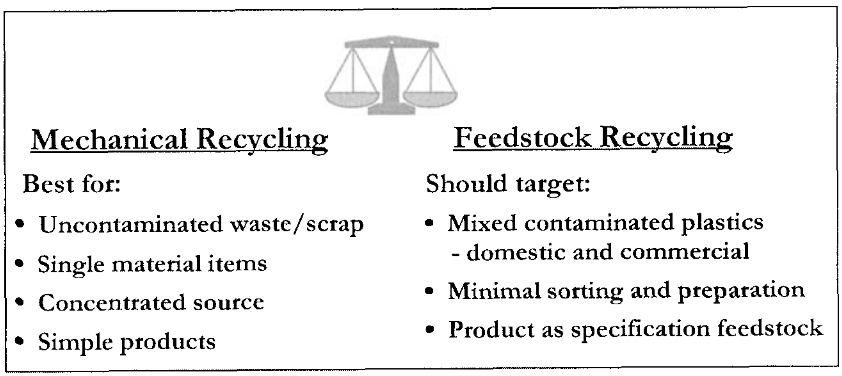


Figure 2. Optimisation of material recycling

The balance between material and feedstock recycling will ultimately depend on the availability and cost of suitable technology. Projections for the UK (Figure 3) show that by 2001, recycling rates for the more accessible sources will already be high, leading to a need for feedstock recycling at a rate of 40 to 50 kt/y.

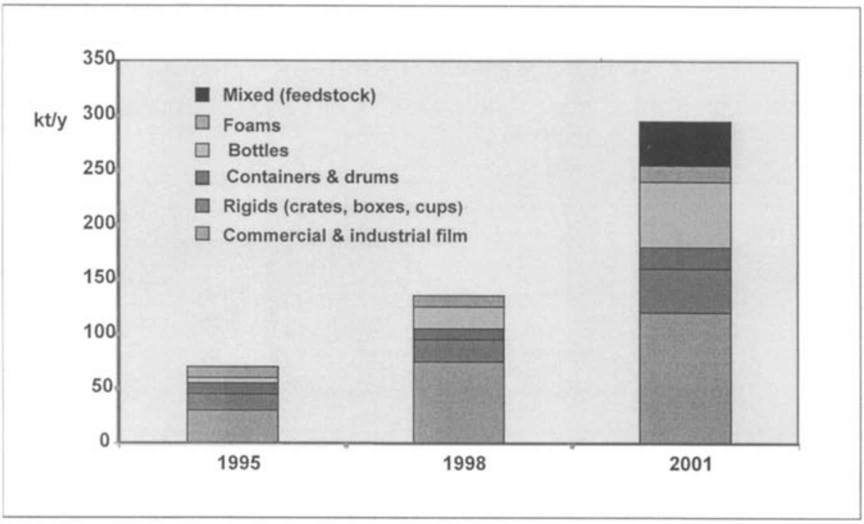


Figure 3. Packaging waste - UK recycling plan

FEEDSTOCK RECYCLING BY POLYMER CRACKING

Recognising in the early 1990's the limitations of mechanical recycling, European plastics producers already began working together to look for better solutions. In 1993 BP Chemicals joined together in an industry consortium with other plastics producers DSM, Elf Atochem, EniChem and Fina, to develop a new technology, Polymer Cracking, as a means to return mixed plastics waste to the mainstream hydrocarbon processing industry. A phased approach was agreed, leading to the point where the technology could be considered suitable for industrial application.

The first phase of the work was concluded in 1995 and achieved proof of the technology concept for packaging waste in a purpose-built pilot plant. The second phase is still in progress and has focused on upgrading the pilot plant to provide proof of the process flowsheet for scale-up, with parallel research to establish the range of non-packaging feeds which could be accepted in the process.

The concept of Polymer Cracking is a simple robust plant which can be used at relatively small scale to prepare feedstocks for existing refinery and petrochemical plants. These are normally very large units, distributed widely throughout Europe. They are in a position to process the plastics-derived feeds together with their normal hydrocarbon feedstocks to produce valuable final products, including new plastics (Figure 4)

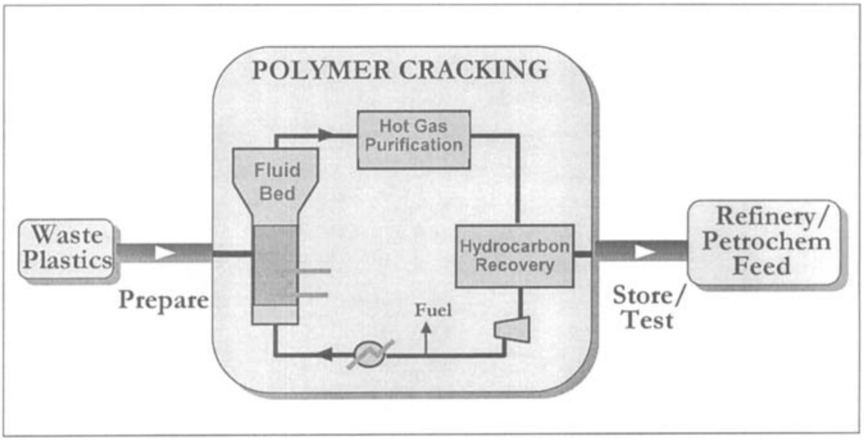


Figure 4. Polymer Cracking concept

Some elementary preparation of the waste plastics feed is required, including size reduction and removal of most non-plastics. This prepared feed is fed directly into the heated fluidised bed reactor which forms the heart of the Polymer Cracking process. The reactor operates at approximately 500 °C in the absence of air. The plastics crack thermally under these conditions to hydrocarbons which vaporise and leave the bed with the fluidising gas. Solid impurities, including metals and some coke, are mostly captured by cyclone and acid gases are neutralised by contacting the hot gas with a solid lime absorbent. The purified gas is cooled, to condense most of the hydrocarbon as valuable distillate feedstock. This is then stored and tested against agreed specifications before transfer to the downstream user plant.

The remaining light hydrocarbon gas is compressed, reheated and returned to the reactor as fluidising gas. Part of the stream will be used as fuel gas for heating the cracking reactor.

CONSORTIUM DEVELOPMENT PHASE I

A 50 kg/h pilot plant was built by the consortium at BP Chemical's Grangemouth site and used to prove the key elements of the process. A range of waste plastics feeds were tested, from Belgium, Germany and Italy. Overall approximately 5 tonnes of waste plastics were processed. Conversion to feedstocks was approximately 80 %, with most of the remainder as fuel gas and some ash and coke, depending on the quality of the plastics waste. The feedstocks were tested by the partners in pilot plants for the main downstream user processes, steam cracking and fluid catalytic cracking (FCC).

A test programme was carried out using waste plastics from Belgium, provided by Fost Plus, taking the material through collection and sorting to processing of the recycled hydrocarbon feedstock. The results are summarised in Figure 5 below. Mixed plastics waste was collected from households and container parks in a typical urban area. This included such items as drink bottles, detergent packaging, packaging films, and toys. The plastics stream was pre-treated and agglomerated ready for sending to Grangemouth.

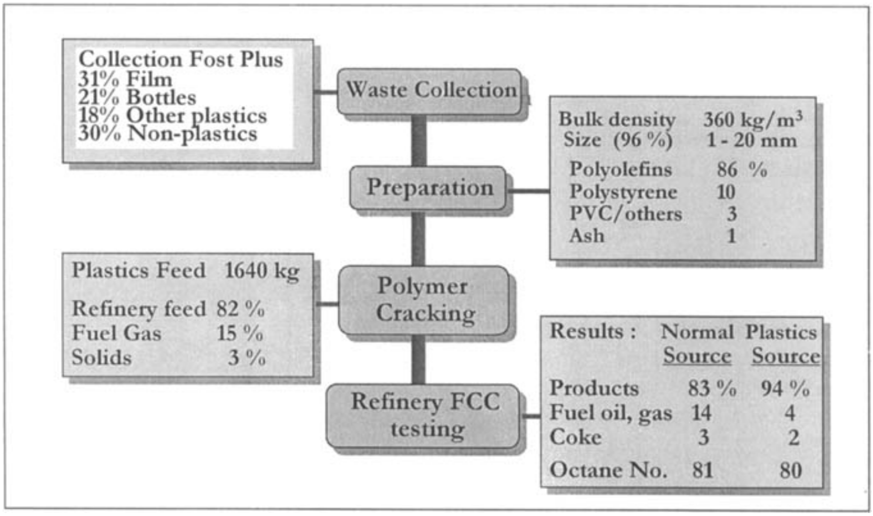


Figure 5. Phase I case study - Belgium

The agglomerated waste was processed in a series of four tests in the pilot plant. Overall conversion to hydrocarbon feedstocks of 82 % was achieved, in line with predictions from smaller scale test results. Fuel gas production was in the range needed to match the energy requirements of an industrial scale plant. The quantity of solids produced relates directly to the amounts of chlorine-containing plastics, which require purification with lime absorbent, and also of non-plastics in the feed stream.

Samples of the produced hydrocarbon feedstock were tested in an FCC pilot plant. Compared to the normal refinery stream, the plastics-derived feed produced more of the valuable LPG and gasoline products. Further testing is planned in an industrial FCC unit in Belgium.

## CONSORTIUM DEVELOPMENT PHASE II

Following the successful proof of concept in Phase I, a second phase of work was approved. The consortium expanded for this phase to include the Association of Plastics Manufacturers in Europe (APME), representing more than forty plastics producing companies; and CREED, the research arm of the waste management company Compagnie Générale des Eaux. A key aim of this Phase was to upgrade the pilot plant with purification and recovery equipment better suited for scale-up (Figure 6). This included a continuous hot lime absorber to increase the efficiency of lime usage in the acid gas absorption step and at the same time to avoid blockages from fine solid particles not recovered in the cyclones. Downstream of the absorber, liquid scrubbing equipment was installed to capture these fine solids into the condensed hydrocarbons, for efficient removal by filtering.

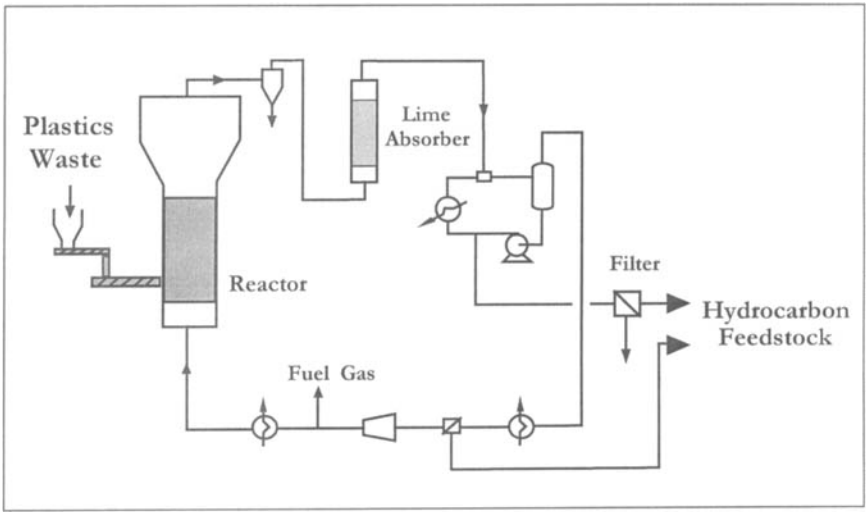


Figure 6. Pilot plant phase II

Testing of the modifications is still in progress but the plant has already completed a target five-day performance test, processing nearly 3 t of waste plastics. The new equipment worked well and hydrocarbon purity was at least as good as Phase I with chlorine levels at 10-15 ppm. Further testing for FCC and steam cracking applications is now in hand with these feedstocks.

An important element in the overall economics of recycling is the cost of feed preparation. Existing procedures have been developed for mechanical recycling. Feedstock recycling is more tolerant and accepts mixed plastics and up to 10 % non-plastics. Opportunities for simplification and cost reduction are therefore being investigated.

The consortium is also investigating possibilities of extending the Polymer Cracking technology to other important waste streams, such as automotive and electrical/ electronic.

However, many components in these areas are rich in polyurethanes or polyamides which makes them less suited to production of specification hydrocarbon feedstocks.. Techniques are being explored for reduction in nitrogen impurities and for low-cost bulk dehalogenation. Small-scale cracking tests have identified particular items which could be relevant, including polyethylene fuel tanks or polypropylene bumpers, and polystyrene electronic equipment casings.

IMPLEMENTATION OF POLYMER CRACKING

In the light of the successful development programme, opportunities are now being investigated for implementation of the technology at industrial scale, following the timetable of the EU directive. The potential application of Polymer Cracking is illustrated in Figure 7, again using the UK as an example.

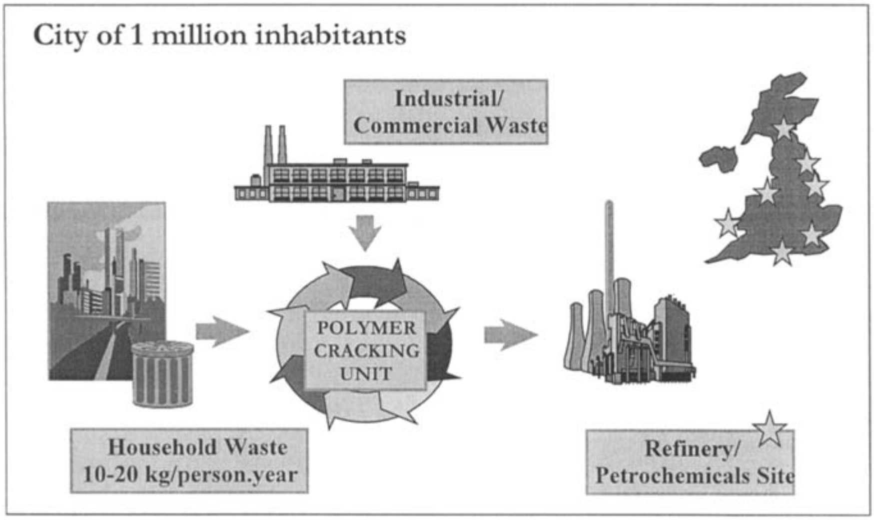


Figure 7. Feedstock recycling potential

For the UK, typical expected recovery of household waste in an efficient scheme is 10-20 kg per person per year. There are also substantial quantities of commercial and industrial plastics wastes. Some of these streams can be recycled mechanically, the remainder can be recycled to feedstock. Therefore a polymer cracking plant of approximately 25 kt/y capacity would support a city or conurbation of one million inhabitants. There are a number of refinery and petrochemicals sites in the UK which could be offered the plastics-derived feedstock.

Location of the polymer cracking plant would be influenced by the relative transport logistics of waste plastics and hydrocarbon feedstocks, but would be simpler at the existing industrial sites.

Compliance schemes are emerging in the UK in response to government legislation. These will provide a mechanism for funding the chain deficit of recycling operations. Other conditions which are important to bring about feedstock recycling are:

- a consistent supply of prepared waste plastics, requiring development of the collection and sorting infrastructure
- collaboration between plastics producers, waste management companies, and local authorities to secure investment funding

## CONCLUSION

Polymer Cracking is an emerging feedstock recycling technology brought about through the commitment of plastics-producing companies to share skills and know-how. The key features of the process have been demonstrated at pilot scale, from the feeding of mixed plastics waste to the downstream conversion of the plastics-derived feedstocks. Opportunities are now being developed for a first plant to contribute towards the EU recycling targets.

## REFERENCES

I. S. Dent, S. Hardman, "*Plastics waste recycling - an alternative approach*", IChemE Environmental Protection Bulletin Issue 044, September 1996

J. H. Brophy, S. Hardman, "Tieftemperaturpyrolyse als Stoffstromvorbereitung", in *Die Wiederverwertung von Kunststoffen*, Carl Hanser Verlag, München 1995, p. 426