Institution:
University of Cambridge

Unit of Assessment:
UoA12

Title of case study:
Enval Limited: a clean-tech company based on EPSRC-funded research

1. Summary of the impact (indicative maximum 100 words)

Research conducted at the University of Cambridge under an EPSRC grant between 1999 and 2002 established the viability of using microwave induced pyrolysis as a process for recovering clean, elemental aluminium and hydrocarbon liquids and gases from waste laminate packaging, thus preventing the need to send this material to landfill. The research has been commercialised by Enval Limited – a multi-award-winning University spin-off founded in 2006 that has attracted approximately £2M funding during the REF period and employs 7 people. A pilot scale unit has been operational since 2011, and the first commercial-scale unit has been constructed and has operated since April 2013.

2. Underpinning research (indicative maximum 500 words)

From 1999 to the present Professor Howard Chase (Lecturer from 1986, Reader from 1996 and Professor since 2000) and Dr Carlos Ludlow-Palafox (Research Associate since 2004) at the University of Cambridge Department of Chemical Engineering (since merged with the Institute of Biotechnology) have been conducting research into the development of a novel process for the recovery of valuable materials from aluminium/organic laminates that occur in packaging waste such as drinks cartons, toothpaste tubes, pet food and cosmetics sachets. In Europe there is potential to recover more than 40,000 tonnes of aluminium per year from drinks cartons alone, but new processes are needed to treat these wastes.

Microwave induced pyrolysis involves the pyrolysis of the waste in a stirred bed of particulate carbon that is heated by microwave radiation, an approach that overcomes the major difficulties that arise from alternative methods. As opposed to incineration, pyrolysis takes place without the combustion of the material, avoiding the production of green-house gases or toxic emissions. Treatment of aluminium-containing laminates by this method recovers the content of aluminium foil as a very high quality metallic aluminium and the organic content is cracked to produce liquid and gas hydrocarbon fractions that can be used both in feedstock recycling (as a hydrocarbon oil) and in energy generation to more than compensate for the consumption of electricity during microwave heating

The potential of recovery of aluminum and hydrocarbons from laminated packaging wastes using microwave induced pyrolysis was first investigated under a grant from EPSRC's WR3 scheme (1999-2002). Development of the technology continued thereafter, which has subsequently led to the design of commercial-scale continuous equipment and a successful worldwide patent application. Professor Chase and Dr Ludlow-Palafox's research elucidated the chemical engineering science that underlies this method of conducting pyrolysis, and utilized that information in the development of the process to the stage suitable for commercial exploitation. Prototype (small-scale) equipment (reactor vessels, and product collection systems) suitable for use in a continuous process was developed and various design exercises to demonstrate the technological, economic and environmental advantages of the process were carried out. These designs subsequently formed the basis of the pilot and commercial scale units operated by Enval Limited. Additional work carried out by Chase and Ludlow-Palafox's research team between 2008-12 have further characterized the influences of various operating parameters (e.g. temperature, residence time, carbon properties) on the nature of the hydrocarbon products obtained from the plastic content of the laminates, and this knowledge has been directly exploited in the design and operation of the commercial units.

3. References to the research (indicative maximum of six references)

*1) UK Patent: PCT GB2004/050043. Title: Pyrolysis reactor and method. Subject: Microwave pyrolysis method for recycling metal/organic laminates into component metals and organic fractions. Inventors: Dr Carlos Ludlow-Palafox and Professor Howard Chase. Priority date: 23 December 2003

2) US Patent Application Publication: US 2008/0099325 A1. Title: Microwave Induced Pyrolysis Reactor and Method. Inventors: Dr Carlos Ludlow-Palafox and Professor Howard Chase. Publication date: 1 May 2008.

*3) Ludlow-Palafox, C. and Chase H. A. (2001). "Microwave-induced pyrolysis of plastic wastes." Industrial & Engineering Chemistry Research **40**(22): 4749-4756.
DOI: 10.1021/ie010202j

*4) Russell, A.D., Lam, S.S., Antreou, E., Ludlow, C & Chase, H.A. Microwave-Assisted Pyrolysis of HDPE using an Activated Carbon Bed. *RSC Advances*, **2**, 6756–6760, (2012), DOI: 10.1039/C2RA20859H.

5) Ludlow, C., White, C. & Chase, H. Laminates: recycling the unrecyclable. *The Chemical Engineer,* **851**, 50-52, (2012). Accessible at: http://www.enval.com/Documents/TCE-May-2012.pdf

EPSRC grant GR/M50904/01. PI Chase, Professor HA; Title: Microwave pyrolysis for waste minimisation: Recovery of aluminium & hydrocarbons from packaging laminates
01 May 1999 to 31 October 2002. Value £228,071

* Denotes those references most indicative of the quality of the research.

4. Details of the impact (indicative maximum 750 words)

Aided by investment from Cambridge Enterprise, Enval Ltd was founded in 2006 by Professor Chase along with Dr. Carlos Ludlow-Palafox and Dr. Alex Domin (another Cambridge PhD Student from the Department) to commercialise the group's research into microwave pyrolysis. In 2010, the company received a grant from the East of England Development Agency for 'Development of a Recycling Process for Laminated Packaging' to develop the capabilities needed to optimize the use and maximize the value of the products generated during the Enval process (ref 7). Further investment in the company has been secured from a syndicate of investors including Cambridge Enterprise and business angels from both Cambridge Capital Group and Cambridge Angels. The company has raised a total of £2.2 M from a variety of sources during the period 1 January 2008 to 31 July 2013. The company now employs 7 people and has premises on 3 sites (ref 6).

Enval's patented technology offers a genuine novel commercial recycling route for plastic/aluminium laminate packaging that has, to date, been unrecyclable. The process is very attractive to waste handlers as it removes the need to send waste laminates to land-fill and enables increasingly-used aluminium laminate packaging to be described as "recyclable" and these are both important objectives for the packaging industry and its customers. The clean aluminium produced by the process is ready for introduction into the secondary aluminium supply chain. Recycled aluminium is valued as being environmentally friendly as it takes approximately 95% less energy to produce secondary aluminium via recycling operations than is otherwise consumed when producing primary aluminium from bauxite. The Enval process is a net producer of electrical energy as the electricity generated on site from the hydrocarbon components of the waste packing is more than sufficient to generate the microwaves needed to drive the process.

In 2008, Enval commenced construction of a one-third commercial scale pilot-plant at its R&D centre in Luton and this unit has been operated since 2011 to demonstrate the benefits of the process to potential customers, treating a variety of materials to demonstrate the effectiveness of the patented technology. Despite generating considerable interest it became clear that given the conservative nature of the waste handling sector, a full commercial scale demonstration unit would be required before orders could be secured.

In 2011 Enval turned to the opposite side of the supply chain of laminated packaging and partnered with both Nestlé and Kraft Foods (now known as Mondelez International outside of the USA) to create a commercial consortium to support the construction of the first commercial scale plant for Enval's patented material recovery technology (ref 10,11). The first commercial-scale unit has been constructed at Alconbury Weald Enterprise Zone, Huntingdon. Commissioning commenced in April 2013, and the unit pyrolyses laminate waste to produce elemental aluminium

and hydrocarbon fuels. Enval have used this unit to showcase the commercial scale technology to prospective customers, in line with the company's aim to develop engineering solutions and produce equipment to be sold, to companies that offer waste handling services. The company is now in advanced negotiations for the sale of similar units with several of the large waste handlers and paper mills engaged in the recycling of drink cartons in Europe and the UK. Enval's Microwave Induced Pyrolysis Units are designed to process 2,000 tonnes of waste per year.

In parallel to the technical development and commercialisation of its proprietary processes, Enval provides environmental life cycle analysis and technology consultancy (based on departmental experience of LCA), with particular emphasis on the pyrolytic recycling of complex flexible packaging materials, establishing the ability of the Enval process to recycle the clients' packaging products. Clients of Enval's consultancy services since 2009 include Albéa, Huhtamaki, Montebello, Kraft Foods, WRAP and Unilever.

Enval has won the "Best New Technology" prize at the National Recycling Awards 2011.

Enval's founders, Dr Carlos Ludlow and Professor Howard Chase, were awarded the prize in the Materials/Chemistry category of the ACES 2011 competition in recognition of the Enval process.

Enval has been selected as a finalist in the "Innovation Award for Environmental Technology" category at the Environment and Energy Awards 2011.

Enval has been ranked Highly Commended in the Sustainable Technology category of the Institution of Chemical Engineers' (IChemE) annual awards (ref 8), held on November 4th 2010, and was a finalist in the "Engineering Project of the Year" award in the same year.

In May 2013 Enval was awarded the prize in the Inspiring New Idea category at the Finance for the Future Awards, in recognition of Enval's creation of a non-competitive Consortium, including Kraft Foods Group, Mondelez International and Nestle, to provide funding for Enval's first commercial unit and to help drive wider deployment of the technology (ref 9).

5. Sources to corroborate the impact (indicative maximum of 10 references)

6) Chairman, Enval - Letter on file

7) East of England Development Agency Grant: Senior Contract Manager, EEDA – Letter on File.

8) IChemE Annual Awards:
http://www.ceb.cam.ac.uk/news.php/124/icheme-awards-for-innovation-and-excellence-2010

9) Inspiring New Idea Award at the Finance for the Future Awards - Press release on file

10) Enval Consortium:
http://www.enval.com/20110722_Kraft_Foods_joins_the_Enval_Consortium.pdf

11) Members of the Consortium:

- Nestle: Group Packaging Manager
- Mondelez: Associate Director, RD&Q Sustainability
- Kraft: Senior Group Leader, Strategic Packaging Research and Innovation