Hydrothermal upgrading of end-of-life plastics

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Introduction

- Mura Technology owns a proprietary patented technology, the Cat-HTR, which is capable of chemically recycling mixed waste plastics back into a liquid hydrocarbons
- Mura Technology Limited
  - ReNew ELP is the first licensee of the technology
  - First 20 ktpa plant is expected to be operational in 2021
- Around 40% of plastics produced today are too complex for traditional mechanical recycling technologies due to the multi-layered laminates, films, mixed polymer sources
- These plastics are either incinerated, sent to landfill or leaked out into the environment, with the lost resources valued at c.£70 billion per year
- Approached the development as a project financier

Development of Cat-HTR

Licella™ ARMSTRONG

Mura Technology Limited

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2007
- Technology developer, Licella, was founded to commercialise the opportunities of Cat-HTR™ for biomass

2008
- Cat-HTR™ pilot plant was commissioned in Somersby, Australia

2011
- Pilot plant opened and commenced trials of biomass and lignite

2014
- Armstrong Capital suggests using end-of-life plastics as a feedstock within the Cat-HTR

2016
- ReNew ELP established, and the Company raised £5.0m in 2017 to fund the Company through the development of the commercial design

Early 2017
- Licella and Armstrong Capital form a joint venture to commercialise the Cat-HTR for processing end-of-life plastics

2018
- ReNew ELP secures a site on the Wilton International site in the UK and receives planning permission for up to four c.20,000 tpa plants[1]

H2 2019
- ReNew ELP seeking to raise c.£20m in senior debt and c.£10m in equity to fund the construction of its first plant, which is scheduled for early 2020

H1 2020 - 2021
- Construction of the first plant in the UK, which is expected to go into production in 2021

Access to commercial demo plant in Australia

Gas scrubber

heat recovery

Generation three commercial reactors

Control room

Product recovery

pumping

Pressure
let
down

Manufacturing Process
Chemical recycling by hydrothermal upgrading

The hydrothermal upgrading technology will convert any plastic or biomass to shorter chain hydrocarbons

Higher temperatures are employed when breaking stronger chemical bonds, so biomass will convert at lower temperature conditions than required for converting plastic carbon to carbon bonds

Using supercritical water provides:

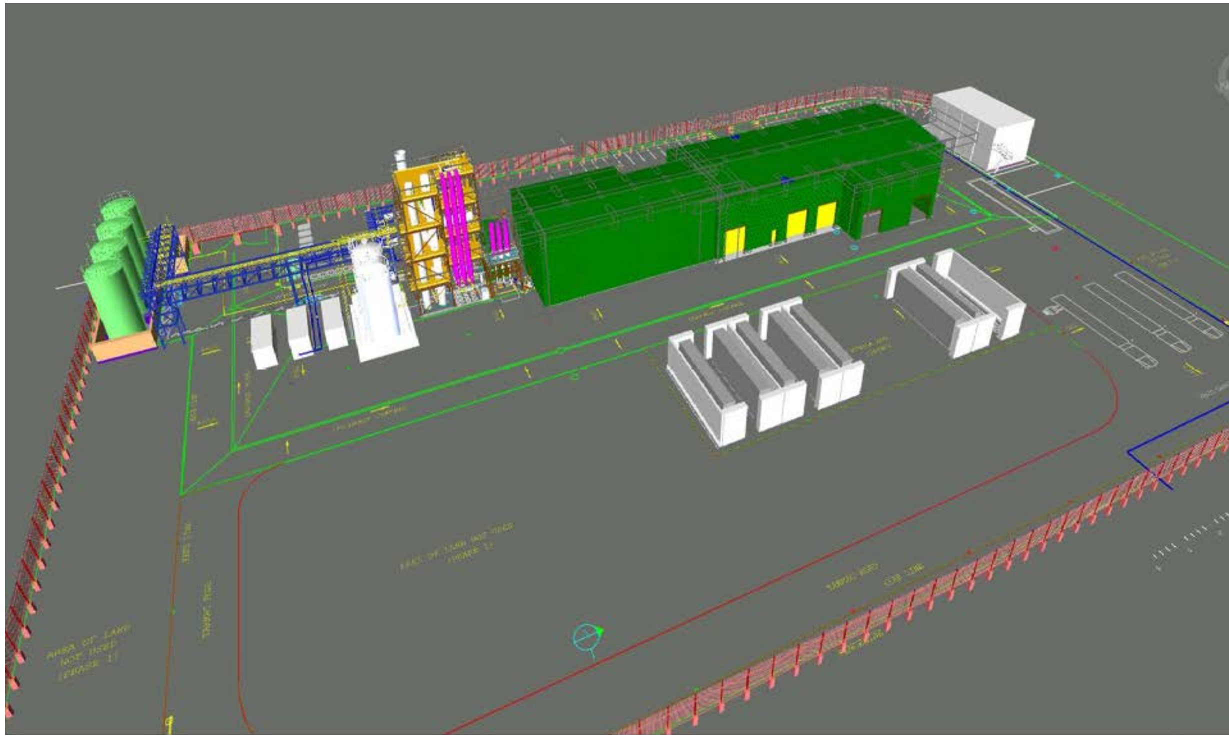
- An organic solvent
- A source of hydrogen to complete the broken chemical chains
- A means of rapid heating that avoids excessive temperature that would lead to excessive cracking
- Ability to scale the process

Over 80% of the mass of plastic (daf) is converted to hydrocarbon product that could be used to make new plastic or other hydrocarbon products.

First project and its associated products focus on converting waste plastic that is predominantly polyethylene and polypropylene.

Financing the project
Our approach to commerciality

- The engineering design needs to be to a ‘bankable’ standard
  - Creditworthiness of the engineering groups and EPC
  - Third party independent technical due diligence
- Commercial contracts need to be in place to support a lender’s needs
- Need to demonstrate that there is no technology risk
  - There are no commercial plants operating at scale
  - No EPC will warrant the operations



Managing technology risk

Technology Underwriting

- A global investment grade insurance company has agreed to underwrite the technology risk
- Engagement consisted of a six month intensive technology due diligence review process involving visits to UK and Australia
- The combination of technical and scientific knowledge, combined with the commercial and financial expertise allowed the insurer to form an opinion of the risk profile of the proposed project before deciding on whether an appropriate product can be applied to insure debt providers against the technical risk of a technology
- The Insurer have confirmed that the technology meets the characteristics sought in terms of insurability, meaning well understood science, demonstrated reliability, and best in practice project engineering

Engineering – Design Approach

Identify key process risk items & mitigation factors:

- Key Equipment Design
- Reactor Design
- Plastic/ Liquid Rheology (fluid properties, heat capacity, viscosity etc.)
- Material Selection
- Solids Accumulation & Contaminant Removal
- Separation Column Design
- Operational Risk

- **Technical Risk Register adopted and maintained throughout Engineering Design Process**
- **Defined Hazard Review Process followed from project KO**
- **Utilised Quantitative Risk Assessments (LOPA) and Cost Benefit Analysis techniques to identify optimal material based on identified failure mechanisms (SCC, thermal cycling, hydrogen embrittlement, fatigue, corrosion etc.)**

Engineering – Design Approach

Plastic/ Liquid Rheology (fluid properties, heat capacity, viscosity etc.)

- Extensive trial campaigns at Licella Test Facility (Somersby Pilot Plant), no scaling needed of reactors
- Viscosity profile through plant (plastic melt through to oil)
- Mixing design and efficiency
- Heat transfer and heater design
- Supercritical v's sub-critical operating characteristics
- Plant trials – modifications to pilot facility
- Rheology and heater efficacy trials
- Mixture of plastics (HDPE/LDPE/PP/PET/PVC)

Supply Agreements – Feedstock

Target materials

- Target material is polyolefins (PE/PP), other acceptable polymers include PET/ PS/ Nylon etc.
- End of life post consumer plastic materials (multi-layer films and rigids). Material which cannot be mechanically recycled
- Multiple sources (MRF, EfW, AD plants)
- No need to separate polymer types – can process mixed plastic waste streams without segregation. Able to process multi-layered material, laminates and composite polymers
- Can process contaminants such as organics, paper, cardboard etc. as converts to gas in the reaction process
- Water based process – no requirement to dry feedstock

The current option for these streams is SRF or RDF production or landfill

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Products

- We produce 4 liquid product fractions:
    - Naphtha
    - Distillate Gas Oil
    - Heavy Gas Oil
    - Heavy Wax Residue
- Each product has multiple uses and end markets
- Conversion conditions can be adjusted to maximise product distribution to the lighter or heavier end of the product range
- Process gas is re-used in the process to generate steam

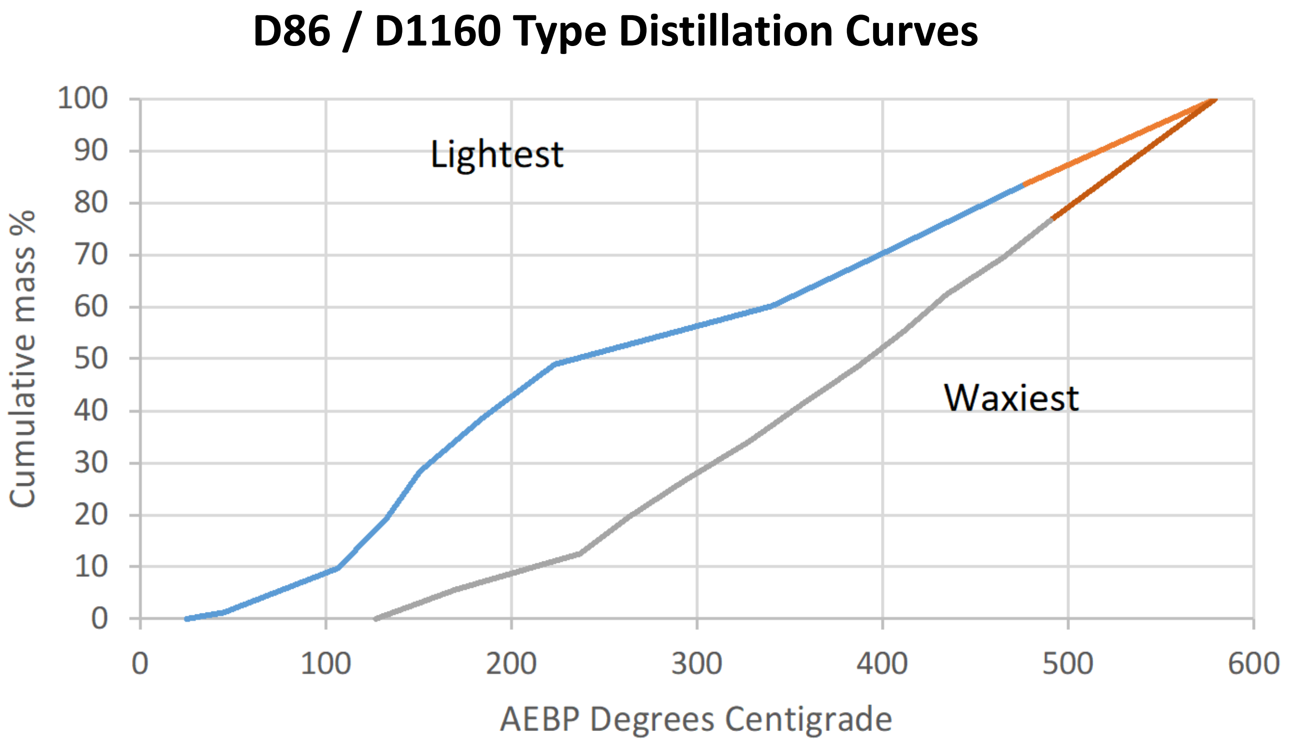
Pilot Plant Data - Analysis

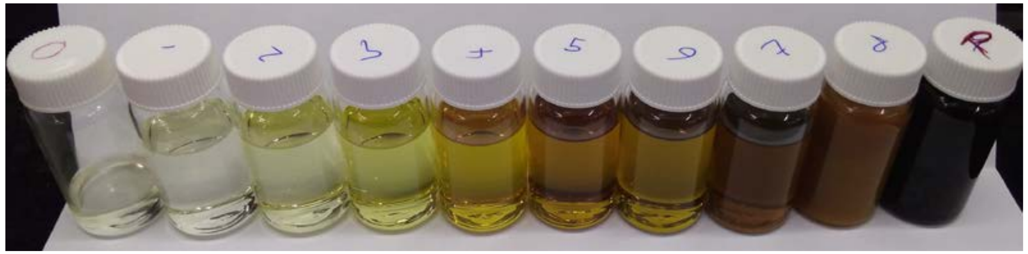
- Extensive analysis on product fractions to Industry standard procedures including:
- Gas Chromatography (ATSM D6730)
- Simulated Distillation (ATSM D86)
- DHA-GC (%Mass/ % vol) (ATSM D6730)
- Liquid Chromatography (HPLC or LC) (ATSM D6591 for Diesel)
- Viscosity (ATSM D445)
- Density (ATSM D5002/ D4502)
- Metals content (ICP-OES)
- CFPP (IP309/612/D6371)
- Total Acid Number (ATSM D664)
- Total and Inorganic Chlorides (UOP 588)
- Total Sulphur (ATSM D5453)

Products

Pilot Plant Data

- Product yields (and fractions) depend mainly on feedstock type and processing intensity
- The graphs highlight some 'ends of the scale' based on pilot plant experience
- Trials have demonstrated that operational flexibility and feedstock input control can support preferential product generation





Environmental Benefits

- **Diversion of plastic from landfill or incineration -** each processing line will process 20,000 tonnes of end of life plastic
- **Scope of plastic feedstock** - can process currently unrecyclable, composite, multi-material and flexible waste plastic
- **> 70% Greenhouse Gas Emission saving** compared to production of hydrocarbons from a fossils source (based on a Life Cycle Assessment (LCA) undertaken for the Teesside plant)
- **Reduces the dependency on fossil fuels** – production of sustainable feedstocks
- **Recycling of process gas -** CAT-HTR re-uses process gas produced to fuel the boilers, reducing dependency on natural gas
- **Minimal waste is produced**- impurities (‘fillers’)in the plastic materials fall out in the heavy wax residue which can be used as a bitumen replacement to make roads

Summary

- **New innovative technology to process currently unrecyclable plastic waste**
- **Expect to complete financing (£30m) in early 2020 for the first commercial plant**
- **Learnt many lessons of how to develop a commercial proposition**
  - Need to understand the detail of the products and real world variability
  - Engineering and technology risks need a rigorous and professional approach from the start
- **We want to continue to innovate and collaborate as an industry participant in further R&D**

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Thanks you for your attention

Any questions?

For more information visit our websites:

www.renewelp.co.uk

www.muratechnology.com