An analysis of the sustainability of UK bioethanol production using miscanthus

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Miscanthus is a lignocellulosic plant with low moisture content. It is rich in carbohydrates and grows on poor soils, meaning it does not compete with food crops for land. It is usually harvested in February and November. The potential ethanol yield using Miscanthus and our novel process is 0.326L/kg.

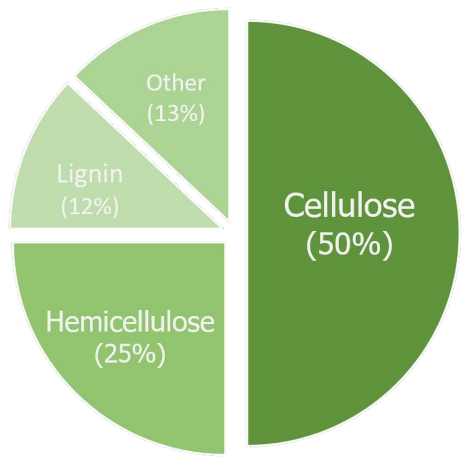


Fig 1. Composition of complex sugars in Miscanthus.

PROBLEM CONTEXT

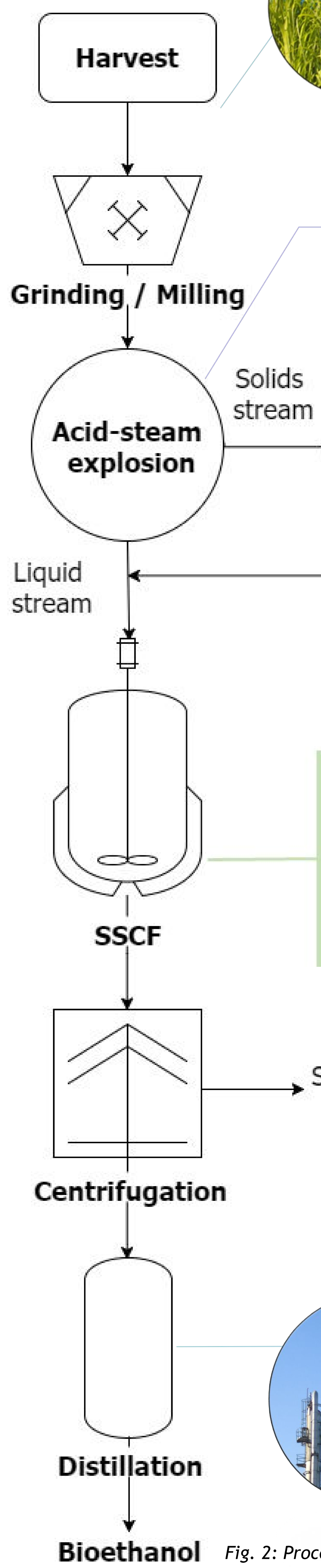
Due to the targets set by the European Union, the demand for an alternative to non-renewable fuels is rising. Bioethanol is a carbon-neutral energy source that has potential to reduce greenhouse gas emissions. However, it struggles to compete with more traditional methods of producing fuels, mainly due to high cost, unfavourable land use and lack of feedstock supply in the UK.

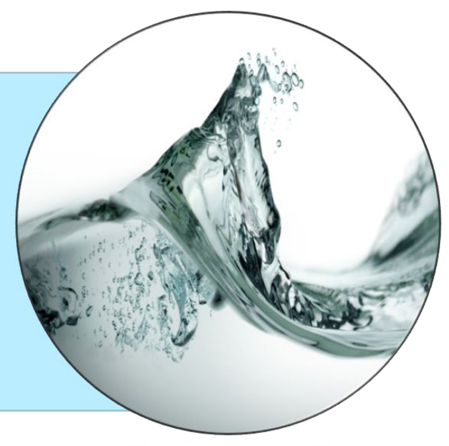
GOAL & SCOPE

Our aim was to analyse the sustainability and feasibility of producing bioethanol from miscanthus. An LCA model was created to determine the environmental impact of producing ethanol from miscanthus, from **cradle to gate**. This allows us to identify and control the biggest contributors to climate change. Our analysis concluded that the use of this lignocellulosic crop is a viable future option to satisfy 5% of the UK's road transport fuel demand.

Acid-catalysed steam explosion uses a high-pressure steam and rapid depressurization to accelerate biomass breakdown. Yield is improved by introducing an acid catalyst. In our process Miscanthus will be pre-treated at 190C for 10 mins, with a diluted sulfuric acid acting as a catalyst. The method was chosen due to its relative low cost and high biomass disruption.

600,000 t/yr — To meet UK's **5%** demand — Operating for **300 days** per year — Using **62** 4 million L reactors





To separate cellulose from the lignin in the solid phase, lignin is dissolved in ethanol. In the future, we are considering recovering the lignin which then could be sold for pelleting and burning.

£2.28/L

If blended 5% with petrol:

- cost of production is **8.3p per L** of ethanol
- Average UK petrol (E5) price is £1.20 per L
- Taking into account VAT and rate duty, revenue is £0.49 per L of petrol

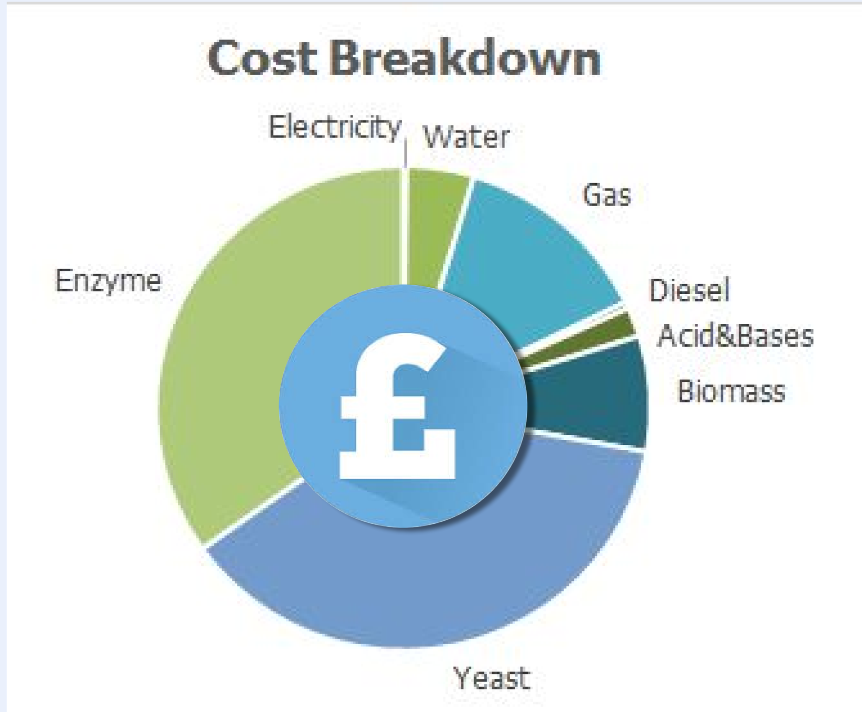


Fig.4: Breakdown of costs by inputs

Simultaneous Saccharification and Co-Fermentation involves a combined fermentation of xylose and glucose as well as the addition of enzymes. For the fermentation stage, genetically modified S. *cerevisiae* yeast cells would be used to ferment glucose and xylose. The yeast would be recycled 5 times before being deactivated using the steam from the pre-treatment step. The working conditions are 40 degrees Celsius, pH 5 and an inoculum concentration of 7% of the working volume. 62 vessels of volume of 4 million litres would be required for this stage.

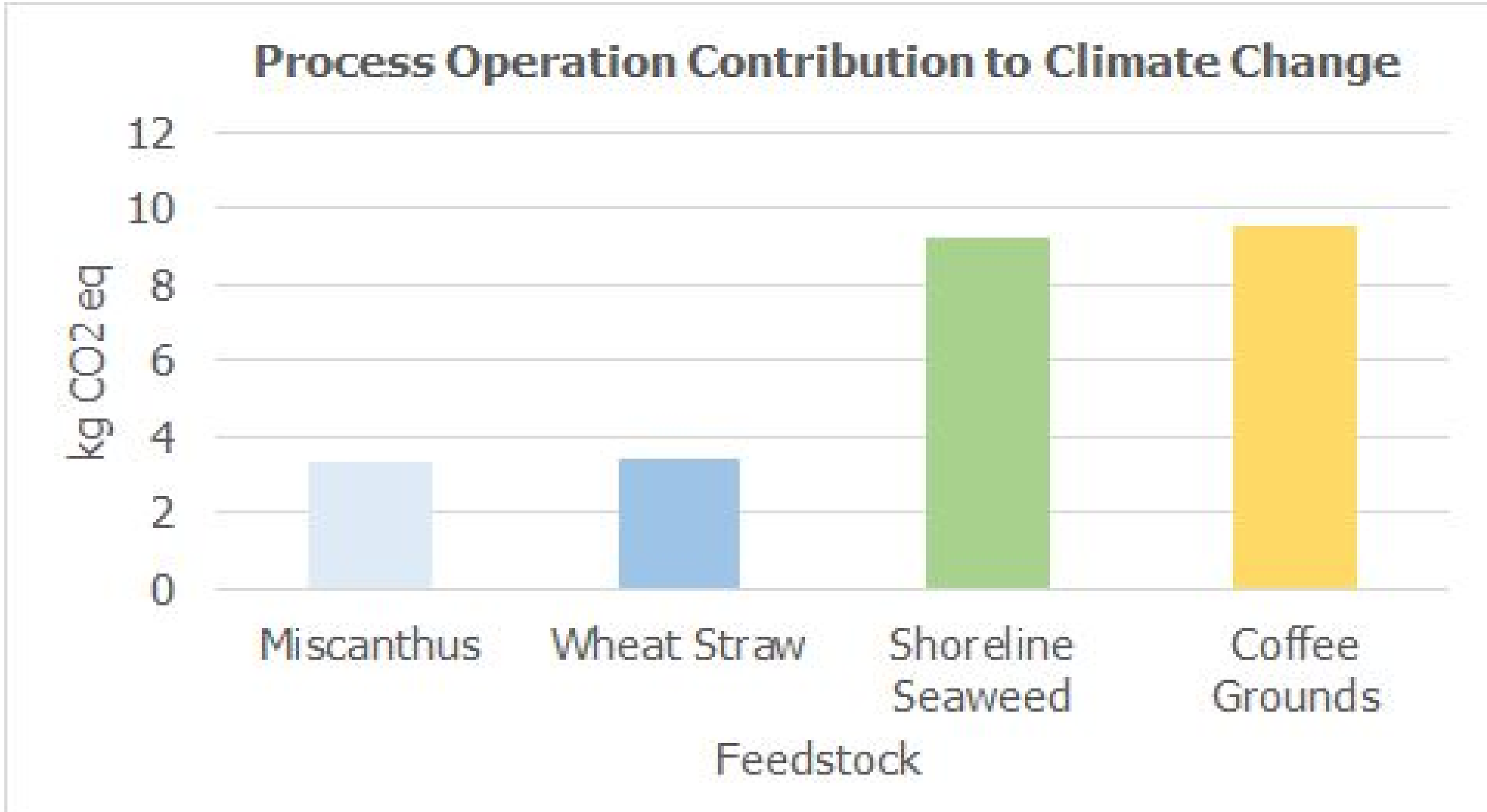


Fig. 5: Comparing contribution of CO2 equivalents to climate change, from process operations, against alternative feedstocks

The ethanol containing supernatant from centrifugation is distilled and a final concentration of ethanol of 94% is obtained.

Fig. 2: Process flow diagram detailing key process operations

Fig. 3: Location of the plant

- Located in Hull, next to the A1033 and the river Humber, convenient for transportation of feedstock and ethanol
- Yorkshire currently produces the majority of miscanthus in the UK.
- Access to nearby floodplains in Yorkshire and Peterborough, potential sites for miscanthus growth

SUMMARY TABLE

ADVANTAGES	LIMITATIONS & FUTURE CONSIDERATIONS
• No competition with food crops for farmland • Miscanthus is suitable for growth in UK and also restores floodplain soils • Recycling of yeast for 5 batches to minimise waste and economic loss • Recovery of heat from steam explosion to deactivate used yeast • Use of GM yeast strains to ferment xylose sugars and improve utilization of feedstock • Similar environmental impact on climate change to wheat straw	• Lignin is unfermentable but could be purified and sold for pelleting/burning in power stations to offset costs • Potential risk of environmental leakage of GM yeast • Limited ethanol concentration tolerance from GM yeast strains • Potential engineering of yeast for production of enzymes and consolidated bioprocessing (*Kang S. et al*, 2004)

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