9-27-2015

A Framework for an Economic Model of Novel Process for the Fractionation of Dried Distillers Grain with Solubles

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ABSTRACT

Background

Bio-refining is the concept of utilising byproducts of *first generation biofuels* such as bioethanol, to generate new revenues from them. Dried Distillers Grain with Solubles (DDGS) is a byproduct from bioethanol production plants and distilleries that is currently used as an animal feed. In the UK the mass of DDGS produced is predicted to increase from 250 to 960 kg/annum[1,2]. **Collaborative research by the Universities of Reading, Bath, Birmingham and UCL aims to valorise DDGS by extracting its component fractions.**

Project Description

A framework was developed **for a decisional tool and economic model of a large-scale DDGS fractionation process**, designed to assess the economic viability of such a process. **The Excel-based** model uses **experimental data**, to generate mass balances, and assumptions from decisional tools developed at UCL for the biopharma industry, to scale-up and **analyse process costs.**

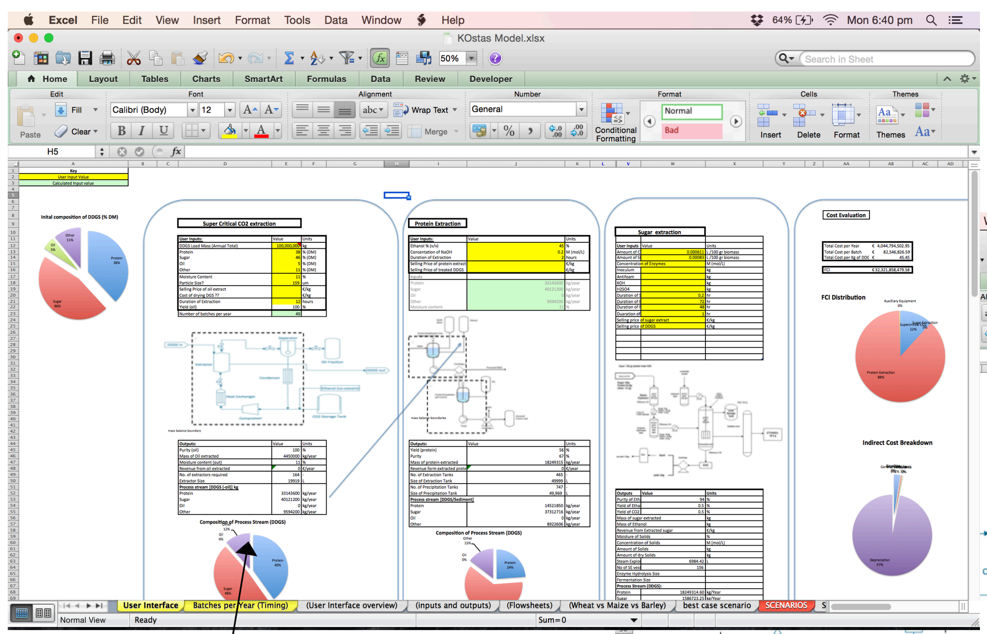
Industrially relevant case studies were used to highlight the **impact of crucial model parameters**, such as moisture content and DDGS load mass on process costs, as well as to identify areas for **future improvements** to the model. The model showed that increased DDGS load mass and lower initial moisture content caused higher COGs/year due to increased equipment and raw material costs.

AIMS AND OBJECTIVES

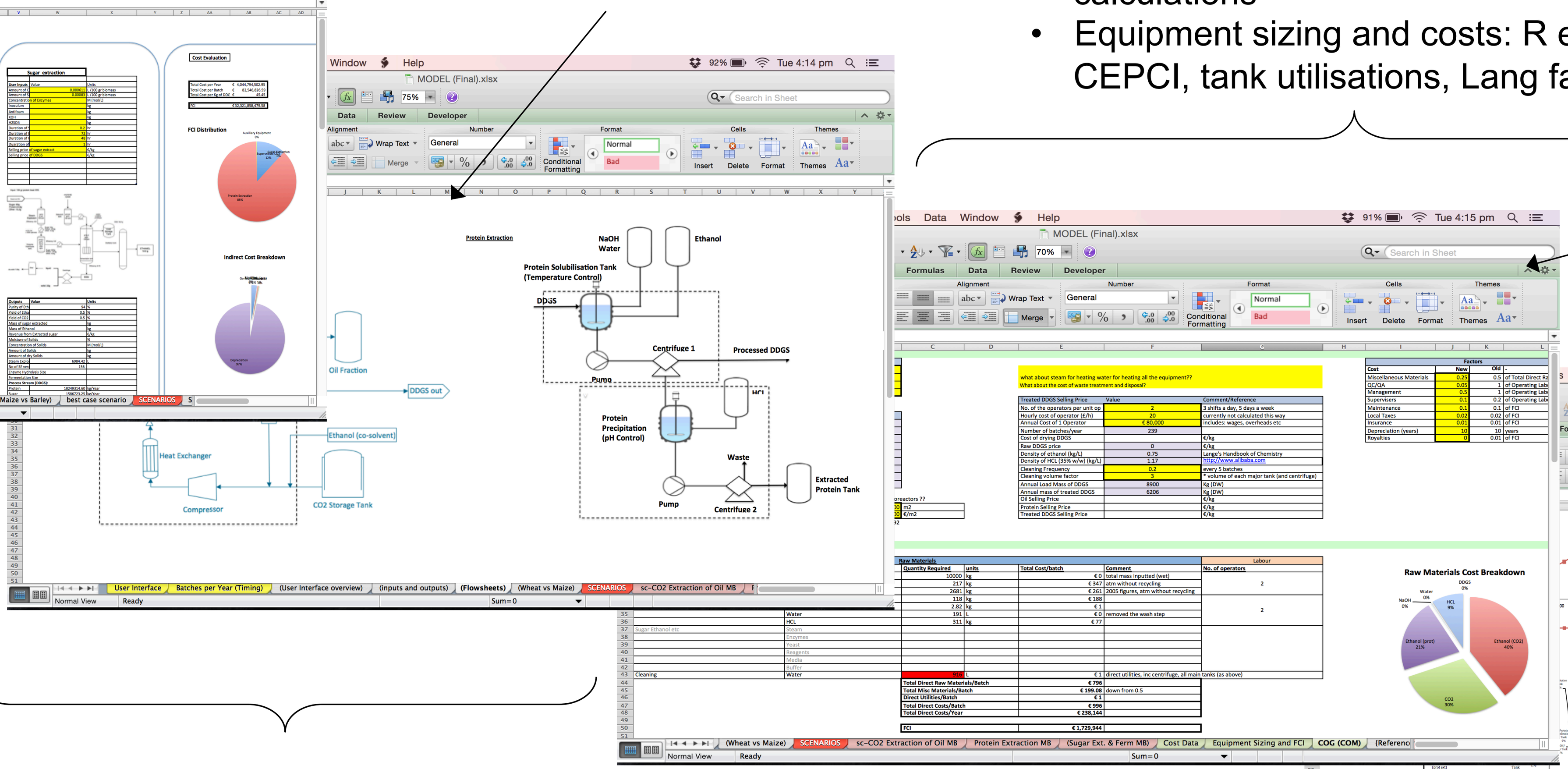
- Predict a large-scale DDGS fractionation process and use experimental small-scale data to conduct a mass balance on the oil and protein extraction steps.
- Accurately model the costs of the unit operations to predict the overall cost of the process
- Create a user interface that allows key information to be easily inputted into the model and provides a visualisation and dynamic analysis of process performance and associated costs.
- Run a series of industrially relevant case studies to assess the effect of initial DDGS load mass (1 - 100 tonnes) and moisture content (11% - 70%) on the costs of the process
- Identify limitations and bottlenecks within the process and assess sensitivity of process costs to changes in key process parameters

Oil Extraction (supercritical CO_2) → Protein Extraction (solubilisation, precipitation, centrifugation) → Sugar Extraction (steam explosion)

MODEL STRUCTURE



Protein Extraction Step
Oil Extraction Step
Sugar Extraction Step



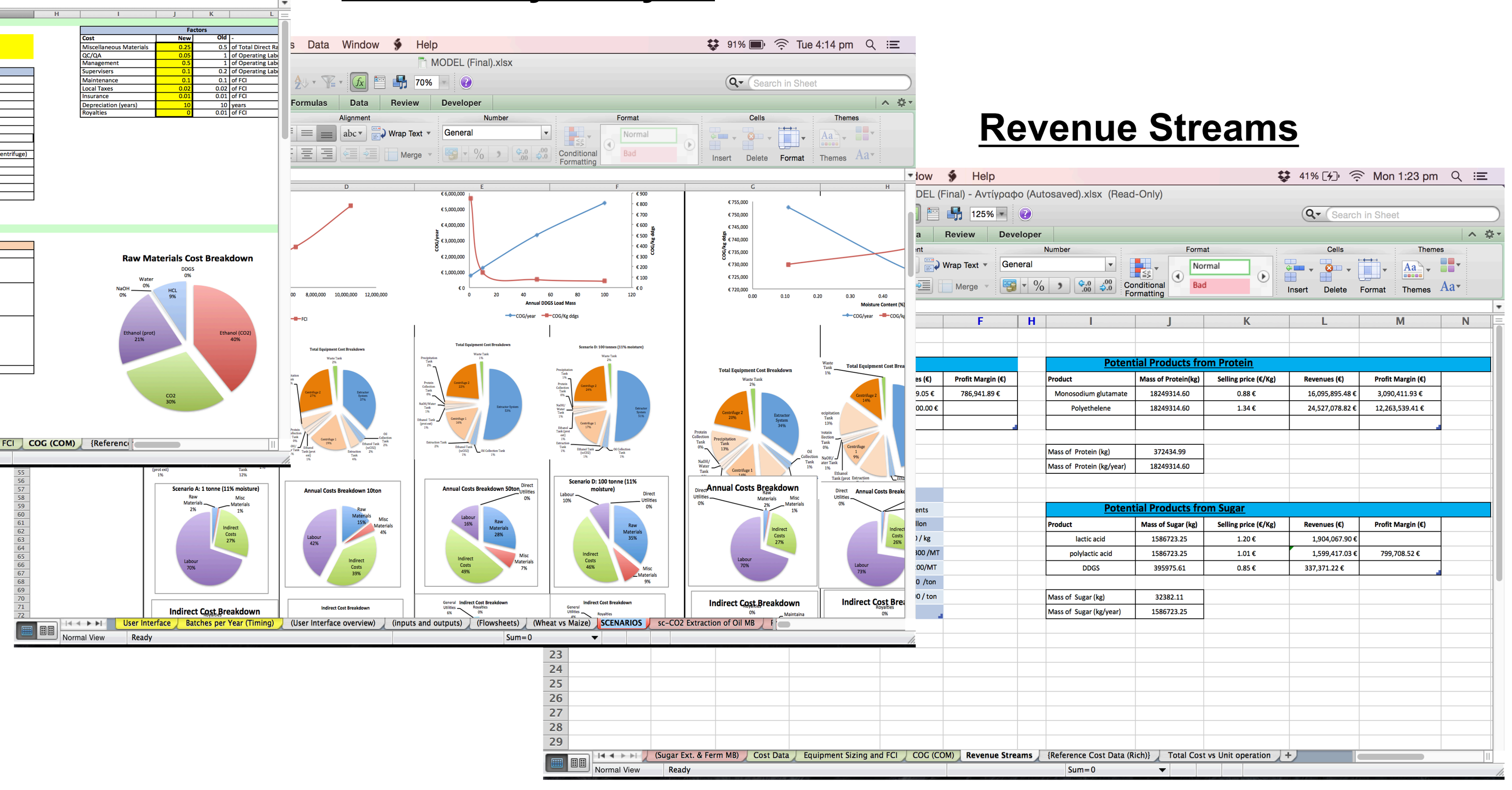
Fixed Capital Investment and Cost of Goods
- Based on cost data and mass balance calculations
- Equipment sizing and costs: R exponents, CEPCI, tank utilisations, Lang factor (2)

Cost of Goods Breakdown

Labour Costs	*Direct Costs*	*Indirect Costs*
Operators	*Raw Materials*	*Maintenance*
Supervisors	*Misc. Mats.*	*Local Taxes*
QCQA	*Direct Utilities*	*Insurance*
Management		*Depreciation*
		General Utilities
		Royalties

Case Study Analysis

Revenue Streams

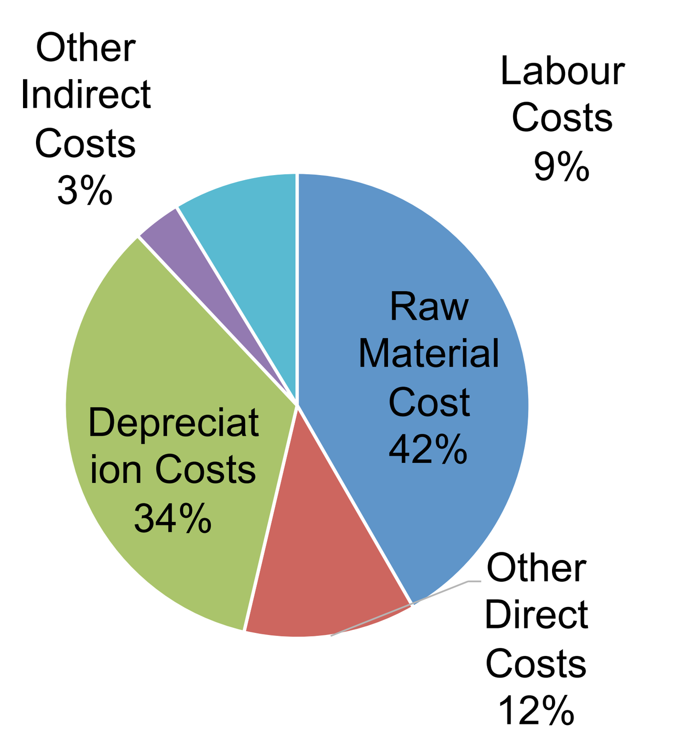


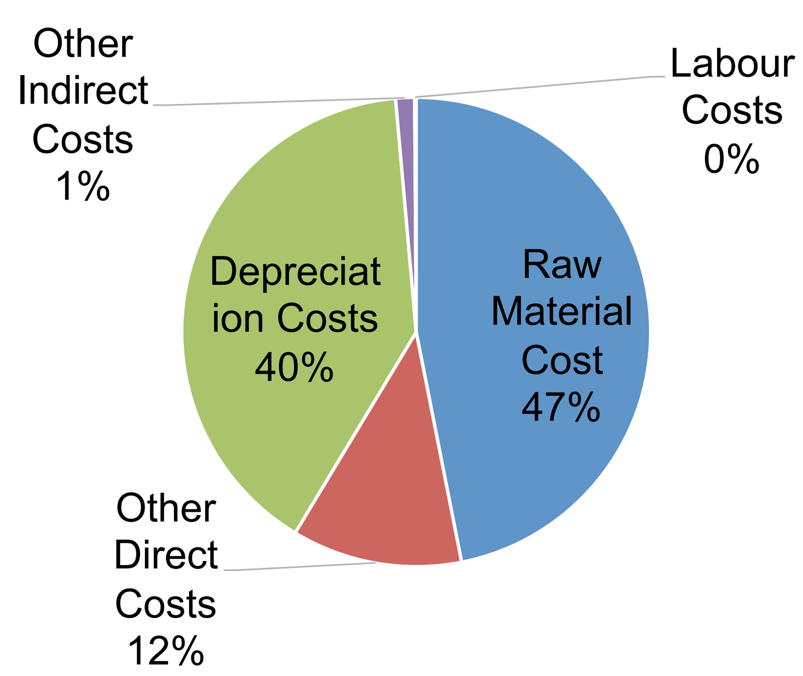
User Interface
- Key process parameters
- Inputs
- Outputs
- Cost breakdowns

Flowsheets and Mass Balances
- DoE equation for protein extraction
- Process conditions, recoveries, densities, centrifugation conditions, recycle factors, durations
- Scale-up criteria and sizing of major components

CASE STUDY RESULTS (Best Case Scenario: 20,000L extractor system, 70,000 L/h centrifuge flow rate)

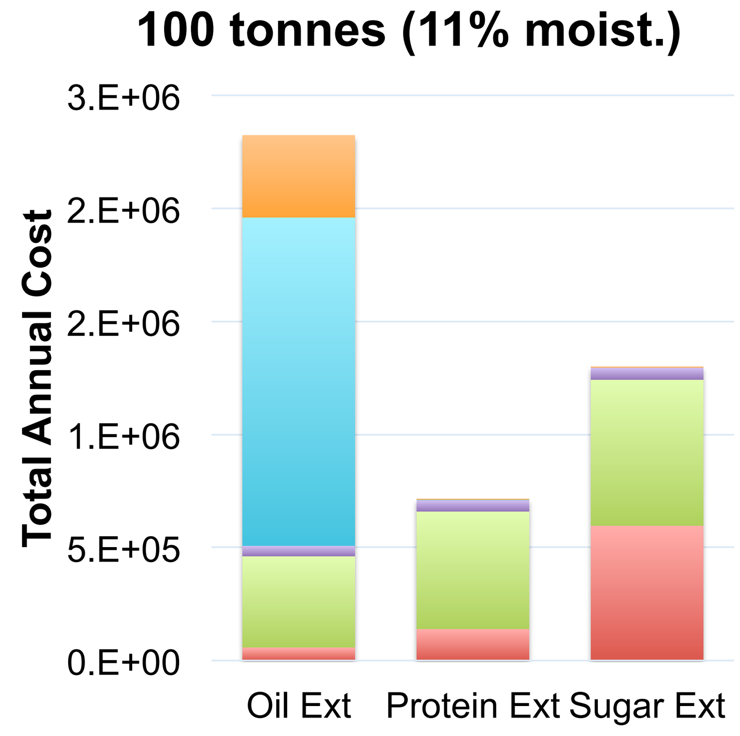
Effect of increasing initial DDGS load mass on total annual costs (€/year)

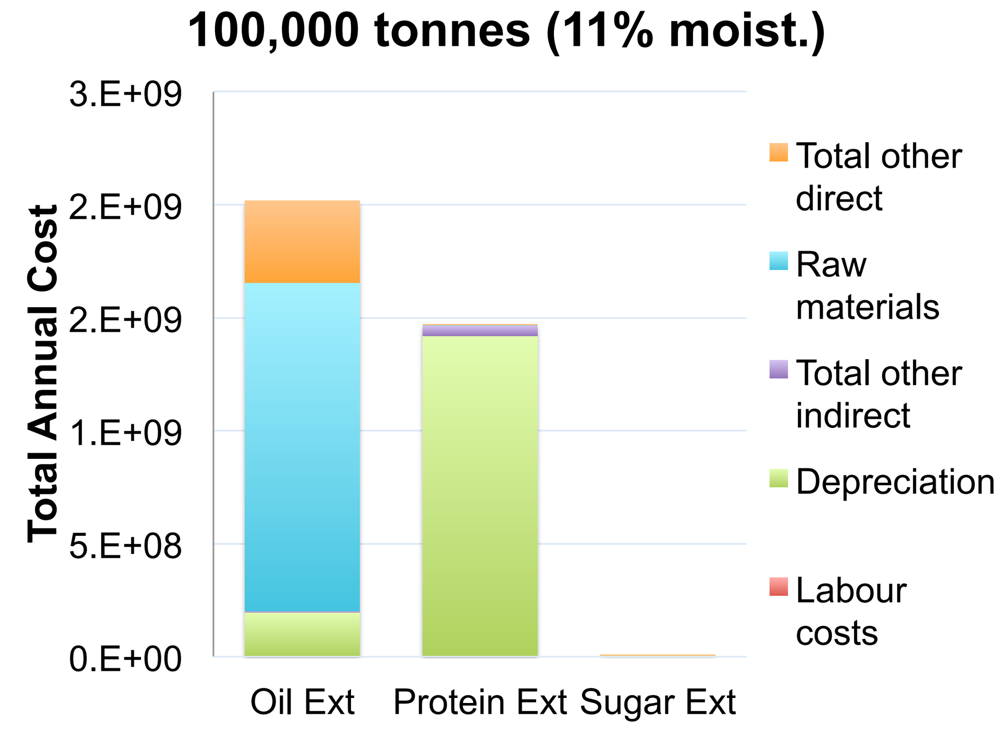




- Labour cost is most significant at smaller scale (operators control multiple pieces of equipment)
- Raw material costs and depreciation become more significant at larger scale
- 100,000t is the most realistic case from industry

Breakdown of total annual cost per unit operation with scale-up





- The model shows oil extraction to be the most expensive step, irrespective of scale
- The main driver of the increased cost when scaling up is depreciation i.e. the **equipment cost (FCI)**
- Sugar step becomes significantly less expensive in comparison at 100,000t

CONCLUSIONS

- An initial framework has been created, modelling the three steps of the fractionation process. The model showed that increased DDGS load mass and lower moisture content caused higher COGs/year due to increased equipment and raw material costs. Further analysis identified the centrifugation step to be the main driver behind the high equipment cost. Therefore an alternative filtration system must be found.
- The model highlights how larger scale impacts cost, however it is difficult to draw accurate conclusions because of the limitations of the model.
- The model has the ability to evaluate the effect of different types of DDGS on costs, further analysis is required to asses the true impact of variations in DDGS composition.
- An assessment of some revenue streams is included in the model, however additional potential high value products from protein need to be identified, such as glutamate derivatives which can be used to produce high value chemicals.

FUTURE WORK

- Make durations a function of material and capacity limits of equipment **to improve the Batches per Year calculation**
- Create DoE equations suitable for large-scale predictions
- Link to optimization and program in C#

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