Development of a strategy (E-Supply) for bioethanol production to support the evolution of a non-food crops sector for Irish agriculture.

DAFF Project Ref No: 05 202
Start date: 01/06/06
End date: 30/12/08

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Please tick below the appropriate area on the research continuum where you feel this project fits

BASIC/FUNDMENTAL ———— APPLIED/PRE COMMERCIAL

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Key words: Biofuels, Energy Supply, Bioethanol, GIS models
1. Rationale for Undertaking the Research

The overall objective of this project was to develop a GIS and Excel based model to assess the potential for domestic supply of feedstock to a bioethanol plant based on different feedstock, plant locations, soil types and policy issues such as the reforms to the CAP, ongoing WTO negotiations and potential changes to the energy crops scheme. A model has been developed that allows the user to select from a number of potential sites (e.g. Mallow/Carlow sugar factories, New Ross port etc.) and assess that sites hinterlands capacity to supply feedstock (Wheat, sugarbeet, straw) to that site based on utilising varying proportions of the existing cropping areas or suitable soils. The results indicate what distance (km) from the plant that feedstock will have to be supplied in order to meet its requirements under that scenario. Of the two sugar factories the Carlow site is much more favourable. The model produced tested 9 locations for the capacity of their hinterlands to grow and supply either wheat, sugarbeet or the cellulose source straw, the reason being they are the most likely feedstock to used for the production of bioethanol in Ireland. The scenarios used were based on historical crop production and future predicted production and the premise that these areas are predicted to continue to decrease into the future unless a bioethanol plant is established. In which case, if a bioethanol were built and operational the predicted reduction in area would not occur. This results in creating scenarios that do not affect what the natural land-use and markets that would be the case if a bioethanol plant were not constructed. It was found that under one scenario using -3.7% of the wheat area, 18% of the barley area, 60% of the former sugarbeet area and 15% of the set-aside area that the Carlow sugar factory could be fully supplied with enough sugarbeet to produce 100,000 tonnes of Ethanol.

Part of this research also examined the E-Supply of biofuels with emphasis on supplying UCD with biomass for their heating sector. UCD was looking to supplement its gas heating with a biomass source in order to reduce its dependency on gas and also to act as a buffer between fluctuating heat demands based on building use. The biomass boiler was fitted under the capital refit scheme from SEAI and was specified at c. 1 MW heat capacity. This unit is to back up the heat demand from UCD’s 2 gas CHP units and is to be available for peak and non peak demand.

2. Research Approach

This research developed a GIS and Excel based model to assess the potential for domestic supply of feedstock to a bioethanol plant based on different feedstock, plant locations, soil types and policy issues such as the reforms to the CAP, ongoing WTO negotiations and potential changes to the energy crops scheme. A geographic information system (GIS), is any system that captures, stores, analyzes, manages, and presents data that are linked to location. The use of GIS software was used in order to accurately quantify the environmental costs of converting land to grow various feedstock from the point of view of the loss/gain of soil carbon and also in relation to the loss or gain of habitat in particular the loss associated with the removal of hedgerows to accommodate larger single productive areas.

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The research that was covered by this project investigated the total bank of land available within Republic of Ireland for growing various bioenergy crops both in terms of the soils that are suitable but also in terms of the efficiency and costs supply as determined by the efficiency of harvesting operations which were found to be directly impacted by average field size within a catchment area.

This project also used a specialised chemical engineering software package Superpro designer v7 to estimate plant capital costs for various ethanol production scenarios based on using various feedstock such as wheat, straw and sugarbeet. Using the outcomes of task one this research showed that smaller decentralised plants are better suited to Irish conditions than a large centralised plant requiring significant levels of imports. With this in mind small 40million litre and a large 200million litre capacity plant were modelled to compare the capital/running costs and the impacts each would have on Irish agriculture.

3. Research Achievements

The project created a GIS model to determine the logistics and probabilities of feedstock supply to a bioethanol plant in Ireland. The model produced tested 9 locations for the capacity of their hinterlands to grow and supply either wheat, sugarbeet or the cellulose source straw, the reason being they are the most likely feedstock to used for the production of bioethanol in Ireland. The scenarios used were based on historical crop production and future predicted production and the premise that these areas are predicted to continue to decrease into the future unless a bioethanol plant is established. In which case, if a bioethanol were built and operational the predicted reduction in area would not occur. This results in creating scenarios that do not affect what the natural land-use and markets that would be the case if a bioethanol plant were not constructed. It was found that under one scenario using -3.7% of the wheat area, 18% of the barley area, 60% of the former sugarbeet area and 15% of the set-aside area that the Carlow sugar factory could be fully supplied with enough sugarbeet to produce 100,000 tonnes of Ethanol.

It was found from the GIS modelling that there are large tracts of land that, despite having good quality soils, the average field size in that area would likely prove inhibitory for large scale supply of biomass from crops. This is because when average field size is below a certain threshold (generally <4ha) harvesting costs for the season rise considerably. This is due to a loss in efficiency resulting from extended periods of non-productive time while machinery is travelling from field to field and reduction in internal field efficiency. This work now allows a more accurate estimate of the upper limit of Ireland’s bioenergy crop potential to be determined. Calculation based on this new data indicates that Ireland’s current bioenergy targets for 2020 represent very closely that upper limit based on current yield estimates for the likely bioenergy crops. Results show that where estimates of bioenergy production capacity are based on solely on soil types a reduction of 10-25% can be used to determine a more realistic figure of the feasibly productive capacity of a catchment area.

As stated earlier, a specialised chemical engineering software package Superpro designer v7 was used to estimate plant capital costs for various ethanol production scenarios based on using various feedstocks such as wheat, straw and sugarbeet. The software effectively allowed the project to build a theoretical chemical process plants in the digital demesne of a PC. For all intents and purposes it reflects very closely the reality of that chemical process from the chemistry and economics of each individual
component to the costs and revenues associated with the inputs and outputs of the system. In this case we have used it to model the process converting various feedstock (starting with wheat) to ethanol. The reason for starting with wheat is that A) it is the most likely feedstock for any Irish ethanol production and B) a model has already been developed for using corn as a feedstock under US economic conditions which can be easily adapted to using wheat. The results showed that an ethanol plant of a 40 million litre capacity would be economically viable with an initial investment of €22,114,000, a gross margin of 16% and an internal rate of return of 19.77%. The unit production cost would be €0.54/litre (assuming a grain price of €160/tonne). The results have shown that an on-going erosion of profitability over the course of the past year, despite higher energy costs that should have added to the competitiveness of ethanol as a fuel. Even large scale plants cannot prove profitable even with full excise relief at present. This has been reflected by industry with two large ethanol plants suspending production, one in Germany and one in Spain. One option that was considered was the integrating of an ethanol facility into existing peat powered stations whereby the heat from the power plant is used to provide energy to the distillation and rectifying columns, this could prove to benefit the economics of both facilities and also help satisfy the CHP directive. After a consultation process with the management of Edenderry power station it was concluded that co-locating an ethanol plant at any peat powered station would be unfeasible due to unpredictable down-times and the low quality (temperature and pressure) of the process steam, also a shortage of adequate water supplies would prove inhibitory.

4. Impact of the Research

The outcomes of this study into the economics of ethanol production are simply that any market penetration of ethanol will either be met through the imports of cheap ethanol from third countries such as Brazil or countries covered by the anything but arms agreement. Alternatively any indigenously produced ethanol (from any agricultural based biomass material) will not be competitive to produce and sell at current feedstock and processing costs and ethanol prices without complete excise relief. Economic sensitivity analysis also indicates that that rising energy costs do not generally benefit ethanol economics to a great extent due to the rise in input costs. The cost of the feedstock, capital, labour and the energy are the major costs in relation to potential ethanol processors. Comparing these costs to major ethanol producers such as the US and Brazil they have much lower labour costs, energy and feedstock costs although they are competing against cheaper gasoline/petrol prices. Feedstock yields using conventional breeding and husbandry techniques may have reached a plateaux or at least a considerable slow down in growth rates for conventional crops such as wheat and sugarbeet especially considering the change in climate over the past two years that appear to be detrimental to both yield and quality. The only potential to significantly increase yields or at least yields per unit of input is through the use of direct gene transfer to produce genetically engineered hybrid varieties such as commonly used in North American corn and soyabeans. Genetic modification of rapeseed, sugarbeet and wheat is ongoing but EU and Irish legislation prohibits their use at present. The value of the feedstock co-products (straw, beet tops) are purely market driven and the market will determine any advancement in the absence of any state intervention. It should also be noted that most forms of biomass will be in higher demand in the future for a range of different uses such as CHP, power stations, biofuels as well as current uses such as animal bedding, soil enrichment and panel board

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manufacture. However, in relation to co-product yields it is well known that plant breeding and the use of hormonal growth suppressants have led to for example shorter stems and therefore straw production in cereals, a trait that can be easily reversed in a relatively short space of time. This would lead to greater abundance of by-product however with the consequence of more difficult harvesting and reduction in seed and straw quality in bad years due to lodging.

Indications are that an ethanol plant of the aforementioned 40million litre capacity would be economically viable with an initial investment of €22,114,000, a gross margin of 16% and an internal rate of return of 19.77%. The unit production cost would be €0.54/litre (assuming a grain price of €160/tonne). The modelled plant was then compared to a similar plant using other feedstock and against the larger 200million litre plant. Analysis was on-going regarding the price fluctuations of ethanol, its feedstocks and also it competitor fuels (petrol and diesel) and also of any by-products produced (distillers grains, beet pulp and biomass), this gave rise to the publication of a bi-monthly publication called the “BRC energy and commodities bulletin” [link] which was circulated to academia and industry in the agri-energy sector which gives them accurate price trends in order to make sound business decisions. This allowed the model cost model (as it evolves) is being re-run according to how prices evolved over time. The results have shown an on-going erosion of profitability over the course of the project, despite higher energy costs that should add to the competitiveness of ethanol as a fuel. Even large scale plants cannot prove profitable even with full Excise relief at present. This has been reflected by industry with two large ethanol plants suspending production, one in Germany and one in Spain. After a consultation process with the management of Edenderry power station it was concluded that co-locating an ethanol plant at any peat powered station would be unfeasible due to unpredictable down-times and the low quality (temperature and pressure) of the process steam, also a shortage of adequate water supplies would prove inhibitory.

The capital costs of a 40million litre ethanol plant would be approximately €22,114,000 using the dry grind process. Of the various sections in the plant the most capital intensive is the co-product processing stage accounting for 33% of the total costs, this assumes the co-product stillage is dried to produce DDGS, if the were supplied to local cattle/pig/poultry produces in its wet for the plant would be much less capital and energy intensive. The plant capital costs estimated (above) were based on a simple conversion of the US component costs to Euro (Irish) terms, based on current estimates of component costs for Ireland sees an almost 40% increase in capital costs. Therefore, a 40million litre plant would cost closer to 30 million euro compared to the 22millin euro previously stated. A 300million litre plant capable of meeting our biofuels obligations would cost in the order of 200million euro. Utility costs are also higher with considerable demand for electricity, gas and water, the costs of which are all higher in the Ireland than in the US.

With regard to the use of the biomass boiler on the UCD campus – the specification was for a wood pellet boiler only which was felt limited the possible scope of the use of biomasses. The quality of woodpellets available has been assessed with considerable variation in quality among the different suppliers. It has been estimated that 1100 tonnes of wood waste are handled weekly by waste management companies in the Dublin area which may be available as a biomass feedstock after either being chipped or pelleted. UCD requires 25tonnes per day of wood pellets to meet its peak demand for heat. A computer program has been designed is now up and running and can be accessed through the web. It gives a good account of the options available in determining the best feasible supply of biomass energy to large industrial complexes. Should the Biomass boiler be online as envisaged for the majority

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of the day, compared to the existing boilers, then costs will have been saved and more carbon credits produced. UCD is a member of the EU trading emissions scheme. The allocation the University has in terms of CO₂ production is approximately 10,000 tonnes per annum. The University is small when compared to other members of the trading emissions scheme however they must still stay below their allotted allowance, in recent years it has. In 2006, UCD produced 9,133 tonnes of emissions, a considerable amount less than the allotted 10,541.

5. Exploitation of the Research

The outcomes of this study into the economics of ethanol production are simply that any market penetration of ethanol will either be met through the imports of cheap ethanol from third countries such as Brazil or countries covered by the everything but arms agreement. Alternatively any indigenously produced ethanol (from any agricultural based biomass material) will not be competitive to produce and sell at current feedstock and processing costs and ethanol prices without complete excise relief. Economic sensitivity analysis also indicates that that rising energy costs do not generally benefit ethanol economics to a great extent due to the rise in input costs. The cost of the feedstock, capital, labour and the energy are the major costs in relation to potential ethanol processors. Comparing these costs to major ethanol producers such as the US and Brazil they have much lower labour costs, energy and feedstock costs although they are competing against cheaper gasoline/petrol prices.

Feedstock yields using conventional breeding and husbandry techniques may have reached a plateaux or at least a considerable slow down in growth rates for conventional crops such as wheat and sugarbeet especially considering the change in climate over the past few years that appear to be detrimental to both yield and quality. The only potential to significantly increase yields or at least yields per unit of input is through the use of direct gene transfer to produce genetically engineered hybrid varieties such as commonly used in north American corn and soyabean. Genetic modification of rapeseed, sugarbeet and wheat is ongoing but EU and Irish legislation prohibits their use at present. The value of the feedstock co-products (straw, beet tops) are purely market driven and the market will determine any advancement in the absence of any state intervention. It should also be noted that most forms of biomass will be in higher demand in the future for a range of different uses such as CHP, power stations, biofuels as well as current uses such as animal bedding, soil enrichment and panel board manufacture. However, in relation to co-product yields it is well known that plant breeding and the use of hormonal growth suppressants have led to for example shorter stems and therefore straw production in cereals, a trait that can be easily reversed in a relatively short space of time. This would lead to greater abundance of by-product however with the consequence of more difficult harvesting and reduction in seed and straw quality in bad years due to lodging.

Capital costs are inherently difficult to estimate but with a clear understanding of how estimates are derived and the tools to derive estimates gained through this research estimating the capital costs of bioenergy projects is not as difficult as was previously the case. This expertise can now be used in assessing the feasibility of proposed biofuel projects in the future. The most suitable locations for an ethanol plant based on proximity infrastructure (natural gas, rail, ports, markets) is either the immediate hinterlands around Navan Co. Meath or Clonmel Co. Tipperary. Based on proximity to feedstock the region of south Laois, north Kilkenny and West Carlow would be most suitable for arable based

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feedstock, for forest residues the East Galway region would be the most central location for a large facility processing forest residues sourced from around the state. The total modelled processing costs including cost of capital (ROE for investors, interest on loans) was calculated to be €0.30/l, €0.30, €0.32, €0.63, €0.63 for Wheat, Triticale, Sugarbeet, Straw and Miscanthus respectively. At current feedstock prices the gross feedstock cost equates to €0.61, €0.62, €0.38, €0.25, and €0.19 per litre for the same feedstock. Allowing for co-product credits the net production costs (excluding taxes) comes to €0.74, €0.73, €0.62, €0.76, €0.69 per litre for each the feedstock. It should be noted that the likely sugarbeet market price considered is an un-economical value for farmers to grow sugarbeet. (It also should be noted that recently grain prices have fallen, while sugar prices have risen which should reverse to some degree the former values stated. While this may aid ethanol competitiveness to some degree it does nothing but highlight the volatility of the markets with which ethanol must engage itself and the associated risk. Oil prices have also fallen which again will reduce the benefit of falling feedstock costs. Significant improvement in the ethanol yield from various biomass material has been achieved in recent years however, the economic competitiveness of ethanol as a fuel is being increasingly compromised by rising input, feedstock and capital costs. Rising oil/energy values have done little to enhance the competitiveness of most biofuels including ethanol. Technology advancements have seen a number of small scale pre-commercial lignocellulose to ethanol production facilities operate, predominantly in the US, Europe, Brazil and China with the US the leading producer of ethanol form lignocellulose material. Advancements have been made in reducing water, labour and energy usage in new and existing ethanol production facilities. There are also advances in engine design that are seeing better efficiency from ethanol blends narrowing the inherent differential due to the lower energy content of ethanol. Finally, commercial car manufacturers are also looking increasingly to hydrous ethanol as means of simplifying the production and distribution systems, hydrous ethanol will also allow for greater energy efficiency of the chain. This research has been further clarified by three ethanol plant tours and discussions with plant managers in the state of Minnesota, USA.

At the time of the project two companies/complexes are interested in having a similar E-Supply Chain produced to examine the pro’s and con’s of whether it would be viable for them to change from the burning of fossil fuels to transferring to renewable or sustainable forms of energy such as a biomass boiler as per the UCD model. While the idea is relatively simple, the programme could very possibly be marketed to other areas of the Energy sector. At the present time two companies/complexes are interested in having a similar E-Supply Chain produced to examine the pro’s and con’s of whether it would be viable for them to change from the burning of fossil fuels to transferring to renewable or sustainable forms of energy. While the idea is relatively simple, the programme could very possibly be marketed to other areas of the Energy sector.

6. **Summary of Research Outputs**

(a) Intellectual Property applications/licences/patents

1. N/A
2. N/A

(b) Innovations adopted by industry

1. N/A
2. N/A

c) Number of companies in receipt of information
2

d) Outcomes with economic potential
1. N/A
2. N/A

e) Outcomes with national/policy/social/environmental potential

What has been achieved is a process of assessing proposed bioenergy facilities based on their location and process system. Previous to this very little in the way assessing a particular site objectively was available. Not only has the process been developed but a whole database of land-uses, infrastructure (road, rail), related industry (ports, feed mills, abattoirs) and natural habitats/resources (water sources, field size distributions) have been compiled into one system so that almost every angle can be taken into consideration when assessing a particular site for a bioenergy system from the method of feedstock supply, to the effect on other related industries and also the potential impact on the natural environment. With the result of an analysis that is objective and quantifiable in relation to the potential impact of a particular bioenergy production facility may have on a particular location. Over the three years since this project started the international view of biofuels has changed dramatically from an almost irrational frenzy to promote biofuels to a currently more cooled global enthusiasm. The feedstock for biofuels in particular are under considerable scrutiny especially their direct/indirect impacts on land-use, society and the environment. This has led in a shift of scientific research from relying on converting oil, starch or sugar crops to biofuels to using lignocellulose material which is considered to be more abundant and cheaper with less detrimental if not beneficial social and environmental impacts. Research from this project should temper such optimism at least in Ireland where even the supply of basic lignocellulose feedstock is largely uneconomical both for fuel producers and growers. This is an increasingly more mainstream line of thought as the commercial realities and technical realities of using this feedstock are becoming more evident and this has led to a totally new direction for biofuels which in some ways goes back to producing fatty acids for biodiesel, this time sourcing the oil form algae. While this has some merits it is not without its limitation and downpoints such as the need for expensive nutrients and capital intensive infrastructure. The most notable and potentially beneficial commercial advancement over the three years has in fact been not of fuel supply but fuel conservation with commercial success of hybrid and diesel vehicles which will likely prove to have more measurable and acceptable environmental benefits for society than biofuels into the near and longer term.

(f) Peer-reviewed publications, International Journal/Book chapters.


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(g) Scientific abstracts or articles including those presented at conferences


(h) National Report
1. Identifying key EU Biofuel Market Drivers, Players and Opportunities, Rory Deverell, November 2009, Published through FC Stone and distributed to their Irish clients.

(i) Popular non-scientific publications
1. Is ethanol still a good investment? Rory Deverell
Bioresources Research Centre Bulletin September 2007

2. Our national landscape: Limitations and opportunities for bioenergy crop production: Rory Deverell
Bioresources Research Centre Bulletin February 2009

(j) Workshops/seminars/ open days at which results were presented (excluding those in (g))
2. The 2007 tillage forum in Teagasc Oakpark, Rory Deverell: Bioethanol production potential in Ireland
3. Presentation presented at the 2007 Irish Tillage and Land-use society (ITLUS) conference, Rory Deverell: Bioethanol production potentials and pathways for Ireland
4. Presentation conducted at Environ 2007, Carlow IT. Bioethanol production potential in Ireland
5. Presentation of research and results of energy crop trails at the 2007 national ploughing championships in Tullamore, 2007, Presentation on bioethanol production and biomass for pellets – given by Rory Deverell and Barry Bowen on UCD stand.

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7. Permanent Researchers

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<th>Institution Name</th>
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<th>Total Time contribution (months)</th>
<th>Average time contribution per permanent staff member</th>
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8. Researchers Funded by RSF

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9. Postgraduate Research

Total Number of PhD theses: 1

Rory Deverell (Due December 2010)
- Modeling Technical, Economic and Environmental Efficiency of Biofuel Production Pathways in Ireland

Total Number of Masters theses: 2

Barry Bowen (February 2008)

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Peter Meehan (February 2008)
- An Assessment of Biomass Feedstock Availability for the Supply of Bioenergy to University College Dublin

10. Project Expenditure

Total expenditure of the project: €132055.94

Total Award by RSF €130612.5

Other sources of funding (specify) €0000000

1.  
2.  

Breakdown of Total Expenditure

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11. Future Strategies

The results of this study give industries and policy makers a tool that allows them to determine with a sufficient degree of accuracy the economic competitiveness of ethanol produced from various biomass materials.

The results of this analysis also enables an analysis of the complete supply chain by examining the economics realities of supplying feedstock against the practical realities of sourcing and transporting the

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material, it is one thing to say a particular feedstock is available, it’s quite another to say if its available economically.

The results from the project showed that there are payback periods ranging from 2.2 to 3.8 years depending on the fuel type and costs which can be achieved through the installation of a biomass boiler. The addition of an alternatively fuelled heating system into the campus heating system would also reduce the facilities susceptibility to price hikes in gas prices and the consequences associated with downtimes in the current heating system. The findings of this study were submitted for publication with the data also being used as a basis for the decision support model.

12. Industry Collaboration
- Clearpower ltd. offered advice and guidance relating to future ethanol production. Edenderry power, plant management offered guidance on feedstock supply chains and energy management.

- Edenderry power ltd. Gave access to technical plant data, Irish grain and feed association gave access to grain and feed statistics