BIOMASS AS FUEL: PROBLEMS AND OPPORTUNITIES

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SUMMARY

Biofuels will be needed to contribute to an improved security and diversity of fuel supply, to abate global warming, to comply with EU Directives and to provide alternative land uses for farmers. But opportunities will be limited by the relatively high cost of biofuels and by the need to develop new supply chains and markets. The best opportunities will arise where specific EU Directive targets have to be met, where low-cost by-product or residue materials are available, or where additional non-fuel income can be generated. The most promising short- to medium-term prospects are likely to be liquid biofuels (in response to the EU Transport Biofuels Directive), heat or biofuel production from wood, and willow production combined with effluent disposal. Some developments in the use of beet or cereals for ethanol production, the use of straw as a heating fuel and the conversion of farm and food wastes to biogas are also desirable. If significant progress is to be achieved, medium- to long-term support measures to bridge the cost gap between biofuels and their mineral equivalents are the first need. This support could be in various forms: excise relief for transport biofuels, establishment grants for energy crops, capital grants for biomass boilers, and an improved price for renewable electricity. New supply chains between farmer and user, and new linkages between growers, food-waste-generating companies, local authorities and environment agencies will also be necessary.

INTRODUCTION

The era of cheap mineral fuel supplies is over. In the case of oil, the depletion of supplies and increase in price has the potential to seriously impact on farming over the next twenty years. For an island nation that currently imports almost 90% of its energy needs, the provision of a secure, environmentally acceptable energy supply at a reasonable cost will be one of the biggest challenges of the coming decades.

The problem can be alleviated by reduced and more efficient use of available energy (better transport systems, more efficient engines, improved building design etc). But a big contribution will have to come from the development of alternative energy sources. Of these sources, biomass along with wind are the only alternative energy sources with significant potential in Ireland in the short- to medium-term future.

There are several other reasons why an increased use of biomass for energy purposes needs to be urgently explored:

- Ireland's problems in controlling greenhouse gas emissions and achieving its Kyoto target have been well documented. Agriculture is perceived as a greenhouse-gas problem, mainly because of its high methane and N_2O emissions. To date the focus has been on ways of reducing these emissions by reducing animal numbers and putting restraints on production. We need to reverse this image and focus on the opportunities for agriculture to play a more active role in greenhouse gas abatement by transferring some production from traditional enterprises to biofuels. Agriculture should aim to be seen less as part of the problem, and more as part of the solution.

- To stimulate liquid biofuel development, the European Commission in 2003 enacted the Transport Biofuels Directive. This requires each Member State to set targets for substitution of fossil transport fuel by biofuel, introduce appropriate measures towards the achievement of those targets, and report yearly on the results achieved. In setting substitution targets, Member States are to have regard for the EU suggestion of 2% by 2005, growing to 5.75% by 2010. The implication is that if Member States fail to achieve the Directive target, mandatory targets and penalties for non-compliance will be introduced. In its first report, Ireland proposed excise relief on 6 million litres of vegetable oil, 1 million litres of biodiesel and 1 million litres of bio-ethanol to achieve a substitution of 0.13% in 2006. The Budget for 2006 has announced an extension of excise relief to 163 million litres of biofuel, to achieve the 2% substitution target by 2008.

- The most recent CAP reform has freed up farmer choice of enterprise. The introduction of a "carbon premium" payment of €45/ha for biofuel production on eligible land is a small but significant indicator of support for change.

- Biofuel technologies are now reaching maturity and achieving widespread acceptance in other countries. For example, biodiesel production now exceeds 1 Mtonne/annum in the EU, and biomass heating and CHP systems are in widespread use, from small stoves to large industrial plant.

- Ireland is becoming more and more dependent on imported fuel, which is now making up nearly 90% of our total energy demand. Even a small amount of native production would reduce our vulnerability. As a rough guide, each 1% of farmed land devoted to biofuels would supply 1% of the total energy requirement.

- The Irish energy market is growing rapidly and already exceeds the farm-gate value of agricultural production. Recent oil price increases are closing the gap between fossil and biomass fuels. Opportunities to divert production from a static food market with falling prices to an expanding energy market with increasing prices are now worthy of close examination.

In spite of the many benefits that might be expected to accrue from the development of biofuels, there remains the basic problem that in many situations biofuels are still not price-competitive with their mineral equivalents. New technologies will also need to be debugged, supply chains have to be established, and potential users will have to be persuaded of the security and reliability of new energy sources. So opportunities will remain limited, and the challenge will be to identify when and in which areas the opportunities will arise. They are most likely to occur in areas where:

1. Market support is most likely to become available
2. Low-cost raw materials with limited alternative markets are available
3. Additional income other than payment for energy can be generated.

Within the various biofuel sectors, each is facing different problems and opportunities. Given the low price on offer for green electricity and the absence of any support for bio-heat, in those areas only applications that use a low-cost raw material or have an additional income stream have a possibility of becoming profitable. The delay in the introduction of excise remission for liquid biofuels has slowed down the development of vegetable oil and bio-ethanol projects, but hopefully this will soon be resolved. The most promising short- to medium-term prospects are therefore likely to be in the following areas:

- Liquid biofuels (in response to the EU Transport Biofuels Directive and the introduction of excise relief on these fuels).
- Projects based on low-cost by-product or residue materials (e.g. wood, straw).
- Projects that have alternative income streams (e.g. from the disposal of organic wastes that will no longer be welcome in land-fills) such as the inclusion of food wastes with animal manure for biogas production, and the use of energy crop sites for disposal of certain effluents.

LIQUID BIOFUELS

The options

In response to the impending scarcity of transport fuels, the European Commission has set substitution targets for alternatives to the current petrol/diesel use as in Table 1, with the aim of achieving a 23% substitution by 2020.

Table 1: Substitution targets for transportation fuels (Commission of European Communities, 2003)

Year	Biofuels	CNG*	Hydrogen	Total
2005	2			2
2010	5.75			5.75
2015	7	5	2	14
2020	8	10	5	23

* Compressed natural gas

Already it is felt that the targets for CNG and hydrogen are not attainable, and that the post-2010 targets for biomass will have to be revised upward if the overall substitution targets are to be reached.

In Ireland, there are only two realistic short-term possibilities for transport biofuel production:

- Oils and fats for diesel engines
- Ethanol from beet or cereals as a fuel extender in petrol engines

In the medium to long term, several other possibilities will arise. The possibility of establishing a liquid biofuel plant based on the Biofine process in Ireland is being actively pursued at present. This is an acid hydrolysis process in which cellulosic materials are broken down mainly to levulinic acid and furfural, platform chemicals that in turn can be converted to several forms of liquid biofuel. The main feedstocks so far utilised in the process are straw, waste paper, cardboard, forest thinnings, wood from construction /demolition waste, willow and miscanthus. The tentative plan for Ireland is a 300 tonne/day plant based initially on wood residues. So the opportunities for farmers as suppliers will be limited, at least in the initial stages.

Ethanol from woody materials will be commercialised over the next ten years. Biomass-to-liquid systems based on very large-scale thermal gasification followed by liquefaction may become a reality. The liquefaction (Fischer Tropsch) process is already in use for mineral fuels; it remains to improve the gasification technology and refine the whole process to make it cost-effective.

Whenever the use of hydrogen as a vehicle fuel in engines or fuel cells becomes a reality, the quest will begin for hydrogen-rich biofuels (e.g. methane, methanol) suitable for these applications.

Oils and fats for diesel engines

Technologies: Oils and fats can be used as engine fuels in two ways:

1. *Converted into biodiesel, no engine modification:* This use is now widely accepted and supported by the vehicle industry. An EU Standard (EN 14214) for biodiesel has been recently ratified. Numerous trials have demonstrated its environmental advantages as a fuel. Over 1 Mt/year is produced and used in the EU and this is still expanding rapidly. It requires substantial plant investment, and processing adds about 5-10 cents/litre to the final cost of the fuel. Several attempts have been made to launch biodiesel projects in Ireland; at present two projects are being actively pursued on the basis of a favourable excise regime emerging soon.
2. *In unprocessed form with modifications to the engine:* This use is relatively new but developing rapidly in Germany, where thousands of engine conversion kits have been installed and are generally working well. The conversion consists of some combination of fuel change-over for starting, fuel pre-heating, extra filtration, increased injection pressure and replacement injectors. Fuel processing cost and industry start-up costs are kept to a minimum. Engine problems are rare if a high oil quality is maintained (Sustainable Energy Ireland, 2004b). This approach has particular relevance in Ireland at present; it needs a relatively low capital investment, the by-product cake can be used locally, and it is possible to start small and expand later. Three small projects are already in operation, a fourth is in construction and several more may be stimulated by the upcoming excise relief scheme.

Raw materials: Currently, the main fuel use of oils/fats in the EU is rape-seed oil processed to biodiesel. The recent CAP review considered but rejected a change to the Area Aid rules that would no longer allow biofuel production on set-aside. Instead, a €45/ha payment on a maximum of 1.5 Mha of eligible land was introduced. This is unlikely to make a major impact, but at least it is a step in the right direction.

A cheaper raw material is recycled vegetable oil (RVO) from caterers. The use of this material in animal feeds has been disrupted by animal health concerns; it is now banned from animal feed throughout the EU. At present most of the RVO collected in Ireland is exported to other EU countries for use as biofuel.

Up to 10 kt/yr of RVO could be used to make good quality biodiesel. Direct use in converted vehicle engines is a long-term possibility, but some more research on cleaning up of the oil will be required before this use could be seriously considered.

Beef tallow, whose market as an animal feed has been disrupted by BSE, is another potential biofuel. Total annual tallow production is about 70 kt, of which almost half is from SRM and is used in boilers in rendering plants. Tallow has three fuel use

possibilities: heating, combined heat and power (CHP) or biodiesel feedstock. All are technically feasible; profitability will decide which comes into practice.

Cost and capacity: While the price difference between these fuels and fossil diesel has narrowed significantly in recent years, they still need some pump-priming support to make them competitive with fossil fuels. While RVO and tallow would come near to being competitive with mineral diesel at current prices of around €0.35-0.40/litre, the production cost of rape-seed oil is in the region of €0.70/litre. So it is clear that excise relief is still needed to allow these fuels to be marketed on a competitive basis in Ireland.

The achievement of the 2% substitution target for diesel would require the production of about 86 million litres of biodiesel or pure plant oil. The biodiesel could include some recovered vegetable oil and tallow as well as rape-seed oil; this would reduce its cost and make it more competitive. Assuming that 30 million litres could be got from RVO or tallow, 56 million litres (~50,000 ha) of rape-seed oil would still be needed. This would be near to our upper limit taking rotational constraints into account. Its profitability would depend on diesel prices remaining high, and a price close to that of diesel being obtained for the biofuel. There would be little scope for further expansion to meet more long-term targets.

Ethanol for petrol engines

Uses: There are two likely ways in which ethanol could be used as fuel for spark-ignition engines in Ireland:

(i) Petrol-ethanol blends could be used in conventional unmodified spark-ignition engines. An EU Directive permits the use of up to 5% ethanol in blends with petrol (Commission of European Communities, 1985). This approach is widely used in the USA., where production has been stimulated by the need to oxygenate mineral fuels to comply with clean air legislation. It has also been boosted by a ban on the addition of MTBE as an octane enhancer to petrol, which began in California and is spreading throughout the US. Ethanol is the natural replacement for MTBE in this situation.

(ii) Blends of the ethanol derivative ETBE and petrol may also be used in unmodified engines. The 1985 Directive authorises up to 15% ETBE in blends. This has been the most favoured approach to ethanol use in the EU and is still widely used in France.

Raw materials: In Ireland, ethanol could be produced from four raw materials: sugar beet, wheat, straw and wood residues. The technology for conversion of beet or wheat is well established, and will be used by several EU countries to meet their 2010 substitution targets.

Achievement of the 2% substitution target would require the production of 70 million litres of ethanol, which could be produced from 15,500 ha of beet or 23,000 ha cereals. National production of cereals is about 2 million tonnes from 300,000 ha. With cereal demand from livestock producers falling, an amount to meet the above target should be readily available. To meet the target from beet would require half the current national production. For ethanol from beet to have any realistic prospect of viability, the use of an existing sugar factory for intake and raw sugar extraction would be essential.

The main problems are the cost of the ethanol produced and the scale needed for viability. From cereals at €100/t, the production cost of ethanol is likely to be about €0.60/litre. From beet at €40/t, in a green-field plant the ethanol cost would be over €0.70/litre; however if existing reception, washing and juice extraction facilities were used the cost would probably come out similar to wheat.

The production of ethanol from materials such as wood residues and straw has been the target of a large research effort over the past 20 years. The development of an efficient process for the breakdown of these materials into fermentable sugars has been the major stumbling block. At this stage there is one pilot plant in operation in Canada, with several more just coming on stream in the USA, Sweden and Spain. But it will be several more years before the first commercially viable plant will be constructed. Even then, there is the possibility that the scale needed for viability may be beyond our reach in Ireland. The price that could be obtained for raw materials supplied to these plants is also still uncertain.

If we are to have any hope of getting ethanol production off the ground in Ireland, we need to start with well-established technology. If the current sugar negotiations lead to a decline in sugar production, this would be an opportunity to provide an alternative opportunity for farmers, factory workers and all that benefit indirectly from the industry. Alternatively, a plant based on cereals with the possibility of later adding a front-end lignocellulose pre-treatment unit would also have attractions.

IMPACTS ON FARM OUTPUT AND ENVIRONMENT

The production of biofuel crops to meet the 2% target would help to reverse the move out of tillage into grass for dry-stock production that has been evident this autumn. The effect of this on agricultural output could be estimated from the 2004 Teagasc National Farm Survey. Outputs from dry-stock and tillage in this survey were as in Table 2.

Table 2: Outputs on tillage and dry-stock farms, Teagasc National Farm Survey 2004

Enterprise	Cattle rearing	Other cattle	Sheep	Mainly tillage
Output (€/farm)	7286	8712	10966	24012
Farm size (ha)	26.9	29.8	38.3	58.7
Output (€/ha)	271	292	286	409

This shows that tillage system output is about €130/ha higher than dry-stock. Spread over 70,000 ha, the maintenance of that amount of land in tillage would make a difference of about €90 million to agricultural output. This would have substantial spin-off effects in sustaining rural agriculture-related businesses as well as on-farm employment. It would also generate exchequer revenue in the form of VAT, income tax etc to help defray the reduction of fuel excise from an expanded MOTR scheme.

The effect on farm profitability of this amount of biofuel production is very difficult to estimate, since the prices that could be paid by processors for biofuel crops are not yet clearly established. It is likely that the initial effect on farm profitability will be small, but that this should improve as energy prices continue to increase.

The effects of the scheme on greenhouse gas emissions can be estimated from Fig. 1. This gives emissions from petrol at about 230 g CO_2 equivalent per km driven, as against 70 g for ethanol produced from wheat. Assuming an average fuel economy of 15 km/litre, the greenhouse gas reduction would be 2.4 kg per litre of ethanol or 168,000t of CO_2 on 70 million litres.

If the diesel substitution is made up of pure plant oil along with biodiesel from a mix of rape-seed oil and RVO, a reduction from 175 to 50 g/km might be expected. At 12 km/litre, this would amount to about 130,000t of CO_2 equivalent from 86 million litres of biofuel.

So the total amount of CO_2 abated by the level of biofuel production supported in the budget would be about 300,000 tonnes This is small when compared to national GHG emissions of over 60 Mt, but significant in terms of the reduction needed for Kyoto compliance.

At the current carbon trading price of about €25/tonne, a 300 kt CO_2 reduction would have a value of €7.5 million. However, at present there is no mechanism available for farmer or processor to recoup this amount. In the event of such a mechanism being introduced, it is unlikely that both carbon trading premium and full excise relief would be available at the same time.

Conclusion

If we are to come near to meeting our initial transportation biofuel substitution targets, we need first to start using our oil/fat resource as engine fuel, either as biodiesel or in modified engines, with a target capacity of about 80 million litres per year. We also need an ethanol plant based on beet or cereals with a similar capacity. If the Biofine project is successfully commercialized and the biofuel market is the most attractive for its produce, it will make a very useful contribution, but still short of our 2010 target.

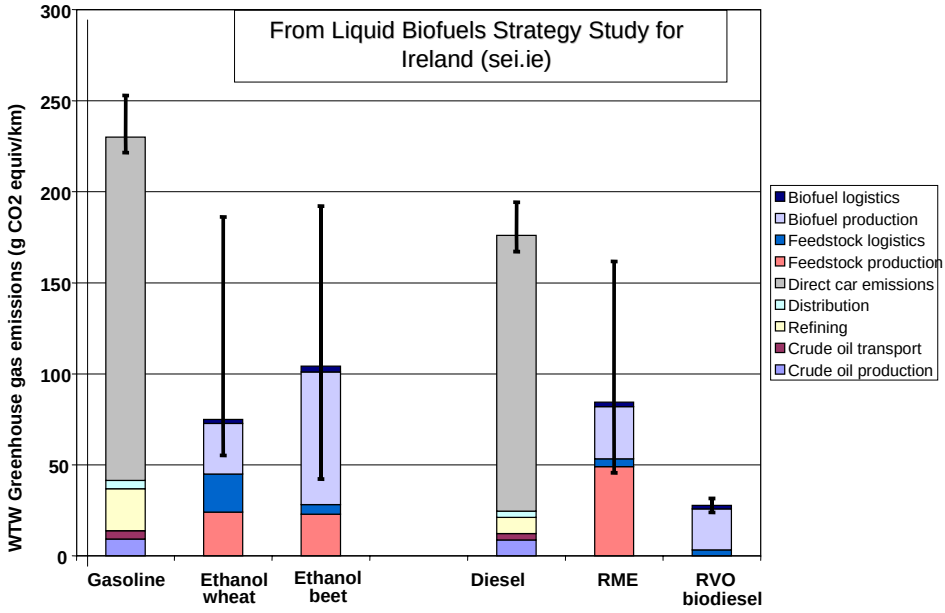

Fig. 1: Estimate of well-to-wheel greenhouse gas emissions from mineral fuels, ethanol and biodiesel (Sustainable Energy Ireland, 2004. Liquid Biofuels Strategy Study for Ireland. www.sei.ie)

The production of these amounts of biofuel would not have a major impact on current farm enterprises, but it would require the establishment of at least one biodiesel plant and one ethanol plant followed by a Biofine plant. This can only happen when investors have reasonable assurance of a profitable outcome for the lifetime of the investment. Reduction of excise on transport biofuels is the support system favoured by the Commission and now implemented in most EU countries. If the proposed excise relief scheme is operated in a way that provides sufficient assurance for investors, then developments in the oils/fats area to use up most of the available resource may happen fairly quickly. But there is need for an initiative from some source to get ethanol production off the ground. In the case of the Biofine plant, the platform chemicals produced may go to other markets if the biofuel market is not attractive. In short, without excise relief we will end up replacing the import of mineral fuels by the import of biofuels. This would be a missed opportunity in terms of supply security, greenhouse gas abatement and diversification of land use.

WOOD RESIDUES AND STRAW FOR HEAT/ELECTRICITY PRODUCTION

Raw materials

COFORD have estimated that residues from forestry and saw-milling will exceed the demand from the panel board industry by increasing amounts over the coming decade

(Table 3). The surplus is estimated to increase from a current level of about 0.5 Mt to over 1 Mt by 2015.

Table 3: Estimate of wood residue surpluses, 2000-2015; production in excess of current demand (ktonne)

Fuel source	**2005**	**2015**
Pulpwood (60% m.c)	95	732
Sawmill residue (45% m.c.)	129	280
Forest residues (45% m.c.)	223	291

The market for cereal straw has also been very weak in recent years. A recent estimate of the outlets for the approx 1 Mt of straw produced is as follows (Sustainable Energy Ireland, 2004c):

Animal bedding	69%
Mushroom compost	8%
Ploughed in	22%

The mushroom industry is in some difficulty, the demand for bedding appears to be declining, and soil incorporation is a very low-value use. An alternative outlet for at least 100,000 tonnes of straw is badly needed to restore some buoyancy to the market. If rape-seed production increases due to a fuel demand for the oil or because of a decline in beet production, the straw would have a similar value to cereal straw.

Technologies

There are three possible ways in which these materials could be used for heat/electricity production:

- They could be used as co-fired fuels with peat in the new-generation peat-burning stations. Wood would present few if any technical problems, straw would be more difficult. But it would require a major re-negotiation of the mechanisms that are currently subsidising peat use to allow this to happen. Any development along these lines would almost certainly focus on wood and not involve straw. Given that the best available price for green electricity is about €0.07/kWh, this gives a value to the electricity generated of about €80/tonne of raw material. This does not hold out much prospect of an adequate return for electricity generator, raw material supplier or investor.

- They could be used as boiler fuel in CHP plants. Small units (<0.5 MW) based on gasification and IC engines have been pioneered in Northern Ireland; problems of low efficiency, high maintenance and high grid connection cost have limited their uptake. A bigger (~2MW) steam turbine plant has just come on stream at a sawmills in Co. Cork. A similar unit is included in a wood pellet plant being built at a sawmill in Enniskillen. The need for a continuous on-site demand for heat limits the possibilities for this type of installation. Again any developments in this area are likely to centre around wood rather than straw.

- They could be used as fuel for boilers in the 0.1-1MW range. Wood would be in chipped form, straw would be baled or chopped. Several biomass boilers of this size were installed in the eighties in the aftermath of the second oil crisis, but most were mothballed when the crisis passed. A small number of new-generation 100-200kW wood-chip and pellet boilers have been installed recently. They are far more energy-efficient and clean-burning, and much easier to operate. They would be suitable for heating buildings with a substantial continuous heat load, such as large rural houses, hotels and hospitals. In addition to a competitive price, a guarantee of a continuous, reliable fuel supply would be essential in persuading a consumer to change to this form of heating. At an oil price of about €0.40/litre delivered, the equivalent value of wood used in this way would be over €100/tonne. Unfortunately the boilers currently being installed would not be suitable for straw.

- They could be pelleted for use in domestic stoves and central heating systems where convenience is a more important consideration than price. A plant to produce 50,000 t of pellets is nearing completion at Ballycassidy Sawmills in Enniskillen. Pellet stoves in the 4-8 kW range have been selling freely. It is likely that a small number of pellet boilers will soon be installed in a range of applications from apartment blocks to hotels. The possibility of producing straw pellets to supply this market remains to be explored.

Conclusion

While there are substantial supplies of both materials available, wood is likely to be developed more rapidly than straw. Wood has somewhat better fuel properties, much of it is already assembled at sawmills, and a range of alternative uses is already emerging. The market will probably develop on three fronts: pellets for stoves and small to medium boilers, chips for larger boilers and perhaps a few more CHP plants at sawmills.

Straw as fuel will be more difficult to develop. Probably its best short-term prospect is as heating fuel either in pellets or chopped or in whole bales. The large boiler fuel market, supplied in baled or pelleted form, may be the best opportunity. A feasibility study is needed on straw pellets. They would have several advantages over loose straw, but their properties, especially ash content, would be inferior to wood pellets. This may limit their use in domestic stoves. The scale necessary for cost-efficient straw pellet production also needs to be clarified.

For both wood and straw, one of the biggest challenges will be to develop supply chains that will satisfy the consumer in terms of price stability, raw material quality and supply reliability. They now have the advantage that their price can be guaranteed

forward to a far greater extent than any mineral fuel. It remains to assure the user about the reliability of the fuel supply and the boiler.

ENERGY CROPS AND WASTE DISPOSAL

Organic waste disposal trends

Waste disposal is a rapidly expanding industry. The 1993 Land-fill Directive (99/31/EC) has put pressure on local authorities to reduce the volume of organic waste going to land-fills. The cost of waste disposal is also increasing sharply. This will create opportunities for other disposal methods. Land spreading is an obvious alternative for some wastes, but food safety and animal health concerns as well as consumer sensitivities will limit spreading on land that is producing food or feed. Spreading on energy crops would be more acceptable, as long as the waste applications do not pollute water. The additional income stream from the waste disposal is likely to have a critical effect on the viability of energy crop production.

Disposal on energy crops

Short-rotation willow is the energy crop that has received most attention in Ireland to date. Miscanthus and hemp have been grown successfully for several years at Oak Park. As long as fuel use is the only source of revenue, at present fuel prices the viability of all energy crops would still be doubtful. To generate additional income, in Northern Ireland the use of willow plantations as disposal sites for two effluents is increasing rapidly:

Municipal sewage sludge: This is applied by injection between the willow rows after each harvest (i.e. every third year) at a rate to match the nutrient uptake of the crop. After an initial trial period, contracts have now been placed that will lead to the disposal of a quarter of their municipal sewage sludge in this way in Northern Ireland. So the evidence is now on our doorsteps that the system works, and that it can be implemented to the benefit of farmers, local authorities, local heat users and the environment. It has been estimated that the disposal of all our municipal sewage sludge would require a willow area of about 3000 ha.

Dilute effluents: These are applied through a trickle irrigation system permanently installed in a way that does not interfere with harvesting. Application volumes are determined by a nutrient management plan, so effluents with a low nutrient content can be applied at a higher rate and yield a higher gate fee. A beginning has been made here with a number of small projects, to date based mainly on brewery effluents. We need to examine the composition of dilute effluents from municipal treatment plants and the food industry and their suitability for disposal on a number of energy crop sites. A study of the capacity of various energy crops, including grass, to take up these effluents, with a view to matching effluents to crops also needs to be undertaken. Liaison is needed with EPA and local authorities about sewage sludge disposal on

energy crop sites. This would open up a potential for several thousand ha of energy crops**.**

Biogas

Many biogas plants are now in operation across Northern Europe, ranging from predominantly single-farm units in Germany to large centralised plants in Denmark. In Germany, green electricity prices have reached a level that is attracting farmers to process energy crops as well as slurry in their digesters. In Ireland, a combination of low electricity prices, short animal housing periods and grass-based animal diets leads to a low income from the production of biogas. For pig producers, while digestion does little to reduce nutrient load, it could facilitate land-spreading of pig manure by reducing smell and ammonia emissions and improving its acceptance by other land-owners. On that basis the investment may be worth considering in some cases. For other farmers, an alternative income source is needed to make a project viable.

Digestion of food wastes displaced from landfills by the Waste Management Directive could provide the additional income needed for viability. A number of projects of this nature were approved in AER VI, but little further progress has been made. Concerns about the land spreading of digested food wastes appear to be the main problems. These will have to be resolved before any further progress can be made.

IMPACTS OF SOLID BIOFUEL DEVELOPMENT ON OUTPUT AND ENVIRONMENT

The most likely short-term solid biofuel developments will be an increase in the use of sawmill and forest residues as boiler fuel in chipped or pelleted form. The main impact of this development will hopefully be to stimulate forest thinning and improve the quality of the final harvest. In the medium-term, the provision of establishment grants for energy crops should stimulate an increase in planting. This area is likely to develop slowly, and no significant impact on land use pattern should be expected for several years.

To estimate the potential for greenhouse gas abatement from the use of solid biofuels, one tonne of biomass residue used as fuel would abate the emission of about 0.75 tonnes of CO_2. So the use of half the wood residues and 10% of straw in this way would contribute about 200,000 tonnes to CO_2 abatement.

CONCLUSION

Somewhat belatedly, we are now seeing a start to a number of small biofuel industries. The main areas of initial development will be in oils and fats, wood for

heating and willow production combined with effluent disposal. We urgently need to see some developments on the use of beet or cereals for ethanol production, the use of straw as a heating fuel and the conversion of farm and food wastes to biogas.

If we are to achieve more rapid and sustained developments in this area, we need action along the following lines:
Market support: While the price gap has greatly reduced, in most cases biofuels are still not competitive with their mineral equivalents; they need some pump-priming support at least in the start-up years. The most widely used mechanisms in other countries are excise relief for transport biofuels and an improved price for electricity from renewable sources. Excise relief is now on the way, but the price available for renewable electricity is inadequate to make biomass projects viable. The high cost of establishing energy crops is an impediment, as is the high cost of modern biomass boilers. Support for biofuel projects can be justified by the global warming abatement, security and diversity of fuel supply, provision of alternative land uses and improved waste disposal options. Since the size of the biomass resource is limited and no exchequer costs would be incurred until the renewable energy is produced, support measures could be introduced with very little risk to the economy.
New supply chains: If a heat market for biomass is to be established, supply chains must be established that convince the consumer on price, reliability and quality.
New alliances: Development of waste disposal options will require liaison between land-owners, local authorities, EPA, and local waste-generating industries.
More effective lobbying: Biofuel industries are a disparate group. They are concerned with different markets, products and technologies, and they have different support needs. As a result, their lobbying tends to be fragmented and ineffective. A co-ordinated effort from all interested parties is needed to project the image of a development that can contribute significantly to the provision of a secure, diverse, environmentally acceptable fuel supply for the future.

In the long term, if we assume that energy demand and price will continue to increase and that the present depressed market for most food and feed products will also continue, then more radical changes in land use may have to be considered. At a rough estimate, each 1% of agricultural land devoted to energy crops could provide about 1% of our primary energy requirement. So agriculture could supply a significant amount of energy with only slight reduction of its food production capacity. But any decision to switch significant areas to energy crops would have to be preceded by a thorough evaluation of all the impacts of such a change on bio-diversity and the rural environment. The immediate objective should be to initiate projects representing a wide range of biofuel technologies as quickly as possible, so that their impacts can be fully evaluated in advance of any long-term land-use decisions.

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