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for power-from-biomass at the scale of 1 to 5 MW_e.

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N.McDonald, Georgina Harrisson and A.J.Limbrick.

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IMPLEMENTATION STUDIES IN FOUR REGIONS OF THE EU FOR POWER-FROM-BIOMASS AT THE SCALE OF 1 TO 5 MW_e.

N.McDonald, Georgina Harrisson and A.J.Limbrick.

Green Land Reclamation Limited

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CONTENTS.

ABSTRACT.

The main objective of the research was to test the conclusions of a feasibility study of the de-centralised production of electricity from biomass carried out under the JOULE II Programme in 1992/93. That study concluded that electricity generation projects were nearly technically and commercially feasible given existing support measures for renewable energy and energy crops within the EU and that future research should concentrate on projects at the scale of 1 to 5 MW_e fuelled with biomass drawn from a range of sources. To provide a rigorous examination of the conclusions in a fully commercial environment, implementation studies were developed for small power stations at four sites in Scotland, England, Italy and Portugal. Of the four plants proposed, two (in Italy and Portugal) are likely to be built in the near future.

The implementation studies have revealed several factors that currently have an impact on the development of power-from-biomass projects. The attitude of local and regional authorities towards such projects is generally positive, but it is essential for project developers to brief officials about their plans at the earliest opportunity, particularly where public opinion about new energy developments is sensitive. There is still a reluctance among developers to use gasification or pyrolysis instead of combustion, because of the perceived technology risk. There is also a much greater reliance on the use of forest residues than energy crops for fuel because of the expense and slow establishment of the latter. Opportunities to use waste heat from the plants appear to be limited, except for drying fuel.

Of the four projects included in the study, the Portuguese plant is the one that is most certain to be built because it has all of the necessary Government support in place and will be financed and developed by Electricidade de Portugal. It will be the first project of its kind in Portugal and, if it proves to be successful, it will probably be replicated to make use of the extensive potential fuel supply from forestry residues. The Italian plant is expected to be implemented in the medium term, subject to the recruitment of a local industrial partner, and successful applications for an electricity sales contract and a Government grant. The Scottish project failed to secure an electricity sales contract backed by the UK Government because the only contract in the field of biomass was awarded, contrary to all expectations, to a smaller and less cost-effective project. It is unlikely that the English project will progress in the foreseeable future because it also failed to secure an electricity sales contract backed by the UK Government.

The economic success of all projects continues to rely on financial support from national governments in the form of either capital grants or subsidised electricity prices.

1. THE JIS PARTNERSHIP.

The partners in the JOULE Implementation Studies (JIS) Project are:

(a) Green Land Reclamation Limited (UK), the Project Co-ordinator a consultant and project manager.

(b) WoodGen Ltd (UK), a project developer.

(c) ENEL SpA, the state electricity company of Italy.

(d) Regione Piemonte, a regional authority in north-west Italy.

(e) Electricidade de Portugal S.A. (EdP), the state electricity company of Portugal.

Details of the participants can be found below.

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2. OBJECTIVES OF THE PROJECT.

A previous feasibility study, carried out under JOULE II (Contract JOU2-CT92-0208) concluded that, given careful selection of a site for a small power station, biomass-fuels to feed it, and appropriate types of conversion technology, it was possible to envisage electricity generation projects that were already nearly technically and commercially feasible, given measures of support for energy crops and for power-from-renewables, such as those already available in several European countries. It also concluded that research effort should be concentrated on projects sized at 1 to 5 MW_e fed by a secure, year-round supply of biomass fuels that might comprise a mixture of materials from a range of sources.

The main objective of the JIS Project was to test the conclusions of the feasibility study through the development of four site-specific implementation schemes for biomass-fuelled power plants in a fully commercial environment that would provide a rigorous examination of their practical validity and illuminate their shortcomings. Implementation studies for projects at the scale of 1 to 5 MW_e were initiated in southern Scotland, southern England, north-west Italy and Portugal.

It was intended that the implementation plan for each of the four sites should be based on an assessment of fuel resources, planning constraints, environmental and social impacts, the potential for sales of electricity and waste heat, and the selection of conversion and other equipment. The plans could then be used to guide future developments and identify any outstanding R&D topics.

The implementation studies necessitated the development and application of a set of methodologies to collect and process all the relevant information on the integrated chain from raw biomass to energy at each location. The work was carried out under a series of tasks, some of which aimed first to develop those methodologies and then to apply them at each site. The tasks were as follows:

(a) Task 1: Selection of study sites.

(b) Task 2: Study of fuel resource and supplies.

(c) Task 3: Selection of conversion technologies.

(d) Task 4: Integration studies.

(e) Task 5: Economic analysis.

(f) Task 6: Review of institutional barriers and externalities.

(g) Task 7: Implementation plans.

(h) Task 8: Dissemination.

3. TECHNICAL DESCRIPTION.

3.1 Selection of study sites.

Each of the four study teams selected a site for its potential plant based on its special knowledge of the particular region and support expressed by local authorities, industry and the public. The importance of various factors to the selection of the site in each case is summarised in Table 3.1.

Table 3.1 Importance of various factors to site selection.

Factor	Italy	Portugal	Scotland	England
Adequate infrastructure	✔	✔	✔	✔
Proximity of large forested areas	✔✔	✔✔	✔✔	✔✔
Local authority interest	✔✔	✔	✔	✔
Central government interest	✔	✔✔	✔	✔
Local industry interest	✔✔	✘	✘	✘
Local farmers interest	✔	✘	✔✔	✔✔
Favourable planning conditions	✔	✘	✔✔	✔✔
Suitability for growing SRF	✘	✘	✔✔	✔✔
Local heat load	✔✔	✘	✘	✘
Availability of cooling water	✘	✔✔	✘	✘

✘ = not relevant
✔ = significant
✔✔ = critical

3.2 Fuel resource and supplies.

Enquiries by questionnaire and interview were made to the full range of potential fuel suppliers in the territory surrounding each site, including farmers, foresters and processing industries. Fuel supplies were sought for a contract-length appropriate to the local conditions which ranged from 5 to 15 years, depending on the source of fuel. All four of the projects will rely significantly on forest residues as a fuel, but only the project in Portugal intends to use them exclusively. The composition of the fuel supply for the projects is shown in Table 3.2. Typical fuel costs are included in Table 4.1.

Table 3.2 Summary of the proposed composition of fuel supplies.

Per cent of types of fuel	Italy	Portugal	Scotland	England
Forest biomass (residues)	88	100	60-100	50-100
Industrial wood-waste	12	0	0	0
Agricultural by-products	0	0	0	0
SRF	0	0	0-40	50-100
Total (tonnes)	**25,000(1)**	**99,500(2)**	**182,000(3)**	**26,000(4)**
Total (tonnes dry weight)	**21,050**	**99,500**	**91,000**	**26,000**

(1) forest residues with 12 to 13 per cent MC, wood-waste about 40 per cent MC.
(2) dry weight.
(3) about 50 per cent MC.
(4) oven dried tonnes.

3.3 Selection of conversion technologies.

Equipment suppliers, turnkey contractors and operating contractors were approached to gather information about the technical capabilities of conversion technologies, their capital and operating costs and the commercial terms under which goods and services might be purchased.

Table 3.3 Summary of conversion technologies selected.

Country	Conversion technology selected	Plant capacity (gross)	Capital cost (ECU)	Annual operating cost (ECU)
Italy	Fixed-grate combustion, steam turbine.	2.38 MW_e 4 MW_{th}	13,869,791	1,763,542
Portugal	Moving-grate combustion, steam turbine	10 MVA	18,050,000	1,711,540
Scotland	Fluidised-bed combustion, steam turbine.	15 MW_e	30,446,548	1,129,905
England	Gasification, reciprocating i.c. engine.	5 MW_e	7,798,655	536,000

Although existing steam-raising technologies have limited thermal efficiency, and there has been a great deal of interest in the use of gasification linked to internal-combustion engines (gas turbines or reciprocating engines) as a means of increasing cycle efficiency, three of the developers chose simple combustion technology to reduce the technology risk associated with their projects. The English project was required by the terms of government support for renewable energy to choose between gasification and pyrolysis.

3.4 Integration studies.

The environmental and social impact of each of the four proposed projects was studied, together with their interaction with the local electricity distribution network. The main environmental impact for all of the plants is expected to come from increased vehicle movements in the vicinity as a result of the haulage of fuel by road. Emissions to air and water will be minimised by the use of suitable abatement technology. All of the projects expected to succeed in their applications for consents from the planning authorities and took care to consult the relevant authorities at the earliest opportunity, especially in cases such as the project in Italy where public opinion about new energy developments is particularly sensitive.

Each of the projects was welcomed by the local community as a source of local employment both through the construction and operation of the plant and in the fuel supply chain.

No technical difficulties were encountered in the integration of the power plants with the local electricity distribution network.

3.5 Financial analysis.

For each proposed plant, estimates were made of the costs of biomass fuel (including harvest, storage and transport), capital costs of construction and costs of operation and maintenance. Further assumptions were made about the sale-prices to be expected for electricity and heat, and any government subsidy likely to be offered. Financial analyses were then carried out using the BIOSIM computer model. There is a strong economic driver to increase the capacity of plants to the upper limit of the scale of 1 to 5 MW_e that was originally envisaged by the scope of the study, to make them more cost-effective and to bring the required sale-price for electricity down towards that paid for energy from fossil fuels. For example, the effect of a 10 percent increase in fuel price on Net Present Value, shown in Table 3.5, is greatest for the Italian project.

Table 3.5 Effect of 10 per cent increase in fuel-price on NPV.

Country	Change in NPV (kECU)	Plant capacity (MW_e)	Change in NPV per MW_e
Scotland	-4296.2	15	-286.41
England	-1545.6	5	-309.12
Italy	-1677.5	2.38	-704.83
Portugal	-1149.21	9	-127.69

3.6 Review of institutional barriers and externalities.

In Italy, support for renewables is provided in the form of an increased tariff, payable to producers of energy from renewable sources. However, this support system appears to be foundering as there is a large deficit in the fund established to provide funding and new projects are unlikely to receive support. Additional support may also be provided by the State in the form of contributions of up to 50 per cent of the costs of the design and construction of innovative plants.

In Portugal, there is currently no specific policy that provides support for renewables but new legislation on tariffs for renewable energy is expected in 1998. Also, no special authorisation is required for projects generating electricity from renewables, below an installed capacity of 10 MVA. The proposed plant in Portugal has received funding from the Government's "ENERGIA" scheme to contribute to the construction costs of the plant. The Government will also subsidise the collection of forest residues for use as a fuel as part of its programme to reduce the outbreak of forest fires.

In the UK, support for renewables comes from a levy on the use of the fossil fuels, paid by electricity consumers, which is used to augment the price paid for the power produced. The mechanism is intended to provide greater support for those technologies that are further from the market (such as power-from-biomass), the level of support decreasing as the competitiveness of the technologies improve.

The externalities associated with electricity production from fossil fuels are not yet accounted for separately in any of the countries included in the study.

3.7 Implementation plans.

The Portuguese project has secured all the necessary funding and authorisations to allow it to proceed. The Government will provide a subsidy for the fuel and a contribution of about 40 per cent of the capital costs of the project. EdP will provide the balance of funding. Construction is expected to begin at the end of 1997 and the plant will be commissioned at the end of 1999.

The project in Italy is expected to proceed, subject to the selection of an industrial partner to host and co-finance the scheme, the conclusion of contracts for the sale of heat and electricity, and the award of a grant from the Government of up to 50 per cent for design and construction. Construction is expected to take two years.

Both the Scottish and English projects failed to secure electricity supply contracts under the Government's Non-Fossil Fuel Obligation in 1997. As such contracts are essential to the success of power-from-biomass projects in the UK, and the Government has no published plan to issue more, neither plant will be built in the foreseeable future.

3.8 Dissemination of results.

Regione Piemonte held a conference in Turin, Italy, on the 14th and 15th May, 1996 to inform local people about the JIS Project and the positive effects that a power-from-biomass plant could have in the area.

WoodGen hosted a conference entitled "Agenda 21 and Sustainable Energy from Biomass in Southern England" in Hampshire, England on the 1st October, 1996.

Green Land planned to hold an international conference in Maidenhead, England, in May, 1997, but, in the light of Government announcements about future power-from-biomass projects, the response was so poor that it had to be cancelled. Instead, a presentation was made at the "4th International Wood Fuel Conference" at Kenilworth, England, in October, 1997.

A second conference was held by Regione Piemonte in Ivrea, Italy, on the 12th June, 1997. It was again held in the area of the proposed biomass plant and the response was excellent, with an attendance of about two hundred people from the local community.

EdP convened a public session to present its project to Mortagua City Chambers in July, 1997, and went on to hold a workshop in Oporto, Portugal, later in the same month, entitled "The role of regional agencies in the development of the biomass market".

4. RESULTS AND CONCLUSIONS.

4.1 Results.

A summary of the characteristics of the power plants that emerged from the implementation studies is presented in Table 4.1.

Table 4.1. Summary of power plant characteristics.

	Italy	Portugal	Scotland	England
Region	Regione Piemonte	Mortagua	Berwickshire	Hampshire
Location	Castellamonte	Aguiera	Charlesfield	Down Farm
Gross output of plant	2.31 to 2.73 MW_e zero to 6.67 MW_{th}	10 MVA	15 MW_e	5 MW_e
Net output of plant	2.17 to 2.59 MW_e zero to 4 MW_{th}	8 MW_e	12.75 MW_e	4.75 MW_e
Energy output	Electricity and heat	Electricity	Electricity	Electricity
Conversion technology	Fixed-grate combustion, steam turbine.	Moving-grate combustion, steam turbine.	Fluidised-bed combustion, steam turbine.	Gasification, reciprocating i.c. engine.
Fuel-types	88 per cent forestry residues, 12 per cent wood-waste.	100 per cent residues from forest clearance.	Forest residues, with SRF phased in (to reach 40 per cent) after first 5 years.	Forest residues, with SRF phased i after the first 5 years.
Fuel supplied (dry tonnes/year)	21,050	99,500	91,000	26,000
Tonnes fuel/MW	8,420 (electricity) 5,262 (heat)	9,950	6,067	5,200
Capital cost (ECU)	13,833,765	18,050,000	30,075,000	7,798,655
Operating Cost (ECU/year)	1,758,961	1,711,540	1,129,905	536,600
Indicative fuel-cost (ECU/dry tonne)	52 (forest biomass) 36 (wood-wastes)	24 (forest residues)	49 (residues) 55 (SRF)	59 (residues) 96 (SRF) 74 (average)
Implementation	Likely	Very likely	Unlikely	Unlikely

4.2 Conclusions.

The implementation studies have revealed several factors that currently have an impact on the development of power-from-biomass projects. The attitude of local and regional authorities towards such projects is generally positive, but it is essential for project developers to brief officials about their plans at the earliest opportunity, particularly where public opinion about new energy developments is sensitive. Constructive dialogue with the authorities can assist with the selection of sites where development is less likely to provoke controversy (such as in Scotland and England) and may play a vital role in the recruitment of suitable industrial partners (as in Italy).

The study revealed a trend for the size of projects, in terms of their output of electricity or heat, to grow beyond the range of 1 to 5 MW_e that was envisaged at the outset. The size of both the Scottish and Portuguese plants was influenced by institutional constraints; the former was increased to the maximum allowed within the bidding process for renewable energy supply contracts in Scotland, to make its electricity sale price competitive, while the latter was designed to maximise output without the need to obtain special authorisation for connection to the electricity distribution network. In England, the developer took account of the need to balance the size of the plant, against the risk of using a comparatively innovative technology. All three plants were designed to maximise the production of electricity because that represented the most lucrative source of income given the institutional frameworks for the support of renewable energy in those countries. The use of waste heat was of secondary importance and was viewed principally as means to dry biomass fuel to improve the efficiency of the conversion process. In Italy, however, the potential for the use of waste heat in a district heating scheme and the opportunity to sell electricity at a favourable price in the early years of the plant's life, allowed the developers to conceive a project sized within the original range of 1 to 5 MW_e.

Although the feasibility study under JOULE II identified up-draught gasification combined with a reciprocating engine as a technology train that could improve the prospects for the commercial development of power-from-biomass projects because of its improved conversion efficiency, it was selected only by the English developer, and only then because the bidding process for renewable energy supply contracts in England constrained him to choose either gasification or pyrolysis. In the other three countries, where there was a free choice of conversion technology, the developers all selected combustion combined with a steam turbine as their preferred method of conversion, although each chose a different type of combustor. It appears that, in practice, the technology risk associated with gasification is still too great for most commercial enterprises to accept.

Another major risk for all projects is the procurement of a suitable and reliable supply of fuel. Some of the fuel supply strategies adopted by the projects in this study have been driven (as foreseen in the JOULE II study) by the need to draw on fuels of more than one type. For example, until relatively recently, it was assumed that most projects developed in the United Kingdom would be fuelled by energy crops such as short-rotation forestry grown on set-aside land. However, farmers have been reluctant to invest in the establishment of such crops because they can see no market for the product in the short term, and that has delayed the development of energy projects. The developers in Scotland and England have realised that the way to break the deadlock is to make use of forest residues in the early years of the project, and to phase in energy crops at a later date once the power station has established a market into which they can be sold.

The project in Portugal will be fuelled exclusively with forestry residues because the use of that material, much of which is currently left on site, is a key element in the Government's programme to reduce the incidence of forest fires that do great damage and are costly to control. The Italian project is sited in a mountain region where energy crops are not viable, so it too will rely heavily on forest residues. However, a significant proportion of its fuel will consist of wood-wastes from local industries. Such wastes could also contribute to the fuel mix for the Scottish and English projects, if they were not precluded by the terms of the contracts for renewable electricity sales drafted by the Government in the UK.

The study has shown that the costs of biomass fuels and capital equipment for small plants to convert them to electricity and heat are still too high to permit such projects to be self-financing. Therefore, the economic success of all four projects relies on an element of support from national governments. In Scotland and England the support takes the form of electricity sales contracts that offer a premium price for power that is linked to inflation over a period of 15 years. The economics of the Italian project are influenced by the availability of not only an electricity sales contract including a premium price index-linked for eight years, but also a capital grant from the Government to cover up to 50 per cent of the costs of the design and construction of the plant. In Portugal, there is a special tariff for energy from renewable sources and the project will receive a capital grant of 40 per cent of the cost of construction from the Government. The Government will also provide incentives to ensure that forest residues are removed from the forests to the power plant.

Of the four projects included in the study, the Portuguese plant is the one that is most certain to be built because it has all of the necessary Government support in place and will be financed and developed by Electricidade de Portugal. It will be the first project of its kind in Portugal and, if it proves to be successful, it will probably be replicated to make use of the extensive potential fuel supply from forestry residues. The Italian plant is expected to be implemented in the medium term, subject to the recruitment of a local industrial partner, and successful applications for an electricity sales contract and a Government grant. The Scottish project failed to secure an electricity sales contract backed by the UK Government because the only contract in the field of biomass was awarded, contrary to all expectations, to a smaller and less cost-effective project. However, the Scottish developer has also applied his expertise elsewhere, and has secured interests in 60 MW of power generation from biomass in England and Wales. It is unlikely that the English project will progress in the foreseeable future because it also failed to secure an electricity sales contract backed by the UK Government.

In contrast to the situation in Scotland, the project was displaced by schemes with a larger generating capacity and a lower electricity sale price.

Power generation from projects fuelled by biomass will clearly need to play a major role in the European Commission's plan to double the contribution made by renewable energy in the EU from 6 to 12 per cent by 2010. This study has demonstrated that there is a continued need for the demonstration of conversion technologies other than combustion to boost the confidence of project developers who are currently unwilling to risk the use of gasification or pyrolysis. Successful supply strategies for multi-fuelling also need to be demonstrated to reduce the risks perceived by developers and financiers. Power-from-biomass is still an emerging technology and continued support from the EC and member states remains a critical factor in its development.

5. EXPLOITATION PLANS AND ANTICIPATED BENEFITS.

A 10 MVA power station, fuelled with forestry residues and supplying electricity to the local electricity distribution network, will be built in central Portugal. It will be the first of its kind in that country and, if demonstrated successfully, is expected to be replicated in other parts of Portugal. A biomass-fuelled co-generation plant is also likely to be built in the Canavese area of north-west Italy, capable of supplying 4 MW_{th} to a district heating scheme and 2.5 MW_e to the local electricity distribution network. Both projects will use conventional combustion technology.

Each of the projects was welcomed by the local community as a source of local employment both through the construction and operation of the plant and in the fuel supply chain.

It is unlikely that either of the projects proposed in the UK will be built, because they failed to secure a viable sale-price for electricity under the UK Government's support scheme for renewable energy projects. However, the developer of the Scottish project has been able to apply knowledge gained from the study to projects in England and Wales with a combined capacity of 60 MW_e that did secure contracts for electricity sales.

A computer programme called BIOSIM, developed specifically for power-from-biomass projects, was used to perform cost-benefit analyses on the proposed projects in this study. The software has potential for wider commercial exploitation as interest grows in power-from-biomass projects.