SCOTLAND’S RENEWABLE RESOURCE 2001 – VOLUME II: CONTEXT

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1 INTRODUCTION

This report – Volume II of the Renewable Energy Study – provides the context against which the findings of the analysis in Volume I should be set.

Section 2 describes previous and new market-based measures aimed at promoting renewable energy. Section 3 provides a brief overview of the electricity industry and the main stream market, in which renewable energy generators and suppliers must increasingly participate. Section 4 reviews the background to planning considerations and Section 5 describes economic and social considerations of relevance to the development of renewable energy in Scotland. Sections 6-14 are largely *updates* to technology descriptions commissioned for the DTI's 1999 Renewable Energy Review, and reported in ETSU's "New and Renewable Energy: Prospects for the 21st Century. Supporting Analysis" [1]. Also, referenced as R-122, it is referred to as R-122 for the remainder of this report.

2 MARKET CONTEXT

2.1 Previous Policy

The Scottish Renewables Obligation (SRO), was the first market support mechanism for renewable energy in Scotland. Modelled on the E&W Non Fossil Fuel Obligation, NFFO, it obliged the two Public Electricity Suppliers (PESs) in Scotland to purchase the output from projects awarded a power purchase contract. Developers bid against each other for SRO contracts in technology bands on the basis of unit (p/kWh) prices, a process which contributed to a reduction in contracted prices over the three tranches (bidding rounds). The three orders were made in December 1994, March 1997 and April 1999. Similar orders were also made in Northern Ireland.

Each order was made on the basis of technology banding, which meant that competition for contracts on p/kWh grounds was within, rather than between, technologies, with government deciding the overall allocation of contracts between technologies. Banding allowed some of the more expensive technologies to secure power purchase contracts, and the award of three SRO 3 contracts to wave energy projects was the first (and to date only) market-based support for wave energy in the UK.

Planning permission was not a prerequisite for award of an SRO contract and most developers sought planning permission after a successful SRO bid. Each contract was for a maximum 15 years duration, and must terminate no later than 20 years from the placing of the Order. This means that from being awarded a contract, a developer has a maximum of 5 years to commission if a project is to benefit from the maximum 15 year power purchase contract. Commissioning more than 5 years after the Order date encroaches upon the allowable contract period.

The SRO and its equivalents were instigated with a view to achieving the (then) government aims of secure, diverse and sustainable energy supplies, emissions reductions and competitive industry, and in so doing to “work towards” a target of 1500 MW Declared Net Capacity (DNC)[1] of new renewables by 2000. Undoubtedly successful in promoting competition, encouraging new technologies and driving down prices, the policy was less successful in meeting capacity targets. While each successive round attempted to compensate for previous failure rates, by 2000 there were nonetheless only 760 MW DNC commissioned, 52 MW DNC of which was in Scotland. Table 2.1 shows the full breakdown of capacity across the UK.

	Contracted (MW DNC)	Status 31 Dec 99 (MW DNC)	Status 31 June 2001 (MW DNC)
Scotland[2]	351	52	87
E&W	3271	693	852
N Ireland	32	15	18
Total	**3654**	**760**	**957**

Table 2.1 SRO, NFFO and SRO status by year 2000 and by 3rd quarter 2001

[1] Government figures are often presented as Declared Net Capacity, DNC. This is to allow for intermittent output such as wind power, to facilitate comparability with conventional baseload output. DNC is calculated by subtracting on-site electrical power consumption and losses from installed capacity and multiplying the remainder by a certain factor - 0.43 in the case of wind power.

[2] Scotland figures include the so-called “Transitional Arrangement” hydro generators, given power purchase contracts in advance of the first SRO.

The shortfall in meeting the year 2000 target has principally been attributed to planning difficulties, prompting a concentration of effort on improving the compatibility of energy and planning policies (see Section 4 for more details). Since the year 2000 some 197 MW DNC have been commissioned, and there remain a number of projects “in the pipeline” which could yet be built. Scotland is expected to reach its nominal share of the target – 150 MW DNC – by around 2003, and indeed may exceed it by 2003 if projects being developed in pursuit of the new obligations (see below) are considered.

2.2 Current Policy

In working towards its target of 10% of electricity from renewables by 2010, and in order to meet a variety of sustainable development objectives, UK government has introduced or announced a range of new “market enablement” mechanisms for renewable energy. At the centre is the successor to the SRO and NFFO – the new Renewables Obligations. These are supported by additional funding and incentives which, with the Obligations, make a package of measures which the government hopes will secure a future for the UK renewable energy industry beyond 2010.

The following sections outline the main new market-based measures which benefit renewable energy, which is in addition to an ongoing programme of Research and Development support.

2.2.1 The New Renewables Obligations

Described briefly in Volume I, the new Renewables Obligations succeed the SRO and the NFFO in providing a guaranteed market for renewables-generated electricity. It *“moves away from the NFFO approach and reflects the Government’s belief that the way forward is to create the market conditions for a thriving, dynamically competitive renewables industry”* (DTI, 2001 [2]).

The Renewables Obligations are the Renewables Obligation (RO) in E&W and the Renewables Obligation Scotland (ROS) in Scotland. There may be a similar obligation in Northern Ireland – government is currently consulting on the options available for development of renewable energy in Northern Ireland [3]. The RO and the ROS each require licensed electricity suppliers to meet a specified proportion of their customer demand from electricity generated from “eligible” renewable energy sources.

Eligible technologies are landfill gas, sewage gas, hydro, onshore and offshore wind, biomass, geothermal, tidal and tidal stream, wave, photovoltaics and energy from waste (EFW) using gasification and pyrolysis. Generally, only plant operational from 1990 onwards is eligible. Hydro capacity greater than 20 MW is only eligible if commissioned after the new order. Old hydro stations up to 20 MW will be eligible if refurbished. Only the non-fossil derived fraction of EFW will be eligible, which must be converted using gasification and/or pyrolysis technology. Co-firing fossil fuels with biomass in stations commissioned prior to 1990 will be eligible under certain rules. Full details on eligibility are contained in the Obligation’s statutory consultations [2, 4].

GB-wide tradable Renewable Obligation Certificates (ROCs) will demonstrate compliance with the Obligations. They can be sold separately to the electricity generated, raising the possibility of intermediary traders in ROCs. Suppliers will have the option of meeting the obligation without contracting directly with renewables generators, while generators will be able to contract with different parties for electricity and ROCs. Because ROCs are tradable across GB (and perhaps, in due course, wider than this), electricity supplied under licence anywhere in GB can redeem a ROC. Output from Scottish generators could be used to secure compliance of a supplier in E&W and vice versa. Output from plant in Northern Ireland will only be eligible if electricity is physically supplied in GB (i.e. the electricity is traded via an interconnector).

It will be left to suppliers to determine with whom to contract, and there will be no fixed contract term or price, which will be a matter for negotiation between contracting parties. To cap the cost of meeting the obligation, suppliers will have the option of paying the “buy-out” price for each kWh shortfall in their obligation, which is also in effect a ceiling on the price of ROCs. Government intends to start the buy-out price at 3 p/kWh.

There is also no equivalent of the SRO technology banding, which in the past allowed the Scottish Executive to choose technology contributions to the overall obligation. Instead, suppliers are free to choose technologies. This is generally expected to favour the cheaper, proven technologies, although other considerations such as the availability of ROCs on the market at any one time, output profiles and development timescales may also play a part in the final technology mix.

Previous work [2] for the DTI concluded that some of the more expensive technologies such as offshore wind and biomass will be required if the 2010 target is to be met. To kick-start the medium-term prospects for these technologies, government is providing technology-specific capital grants, described in more detail in Section 2.2.2 below.

Government has estimated that existing renewables (including large hydro) plus those in the pipeline under the SRO and equivalents will make up some 5% of UK supply by 2003. Therefore a further 5% is required to reach the 2010 target. The exact level of each obligation will be set to accommodate a transfer of existing projects from the old to the new support mechanism, and will be progressively ratcheted up from its introduction in 2002. The intention is that for the most part the ROS and the RO will be identical, requiring both Scottish and E&W suppliers to source equal, additional, amounts of new renewables.

2.2.2 Capital Grants

A total of £89 million for capital grant support is being made available by the DTI and the New Opportunities Fund. It is aimed at “longer-term technologies”, principally offshore wind and biomass projects in E&W, and in Scotland may extend to other marine technologies.

DTI proposes to award grants under a competitive process, with projects requiring the lowest grant per MW of capacity succeeding. Where projects rank equally on per MW criteria, the project requiring the lowest percentage of eligible costs will be chosen. The process for awarding the first round of grants for offshore wind projects across Great Britain has already started.

2.2.3 The Climate Change Levy

From April 2001, supplies of electricity, gas and some other fuels to business users and public bodies have been subject to the Climate Change Levy (CCL). The levy on electricity is collected from licensed electricity suppliers, who bill business customers accordingly. Electricity which is verifiably generated from renewable sources is exempt from the levy. This therefore represents an advantage for renewables on sales to leviable customers.

For 2001/02, the full rate on electricity was set at 0.43 p/kWh[3]. Qualifying[4] renewable energy generators are issued Levy Exemption Certificates (LECs) which, unlike ROCs, must be sold with the electricity to which they refer. Generators and suppliers are free to negotiate the value of a LEC.

The CCL has been a key factor in encouraging some businesses or public bodies to switch to renewable energy tariffs.

2.2.4 Climate Change Levy Receipts

A proportion of the receipts from the CCL will be used to support energy efficiency projects and, to a lesser extent, renewable energy. Funded partly by CCL receipts, government has set up the Carbon Trust, tasked with promoting low carbon technologies to business.

2.2.5 Performance and Innovation Unit

A further £100 million of government funding will be made available to renewable energy technologies identified in a report recently published by the Cabinet's Performance and Innovation Unit (PIU) [5]. Following on from an in-depth review of renewable energy in the UK, and its future prospects, the Unit has recommended additional funding for a range of technologies and activities:

- £25 M for offshore wind
- £15.5 M for development of energy crops
- £18 M for demonstration of new energy crop technologies
- £10 M for community and household schemes
- £10 M for innovative PV schemes
- £10 M for research into "next generation" technologies
- £5 M for demonstration of wave and tidal technologies
- £4 M for grid-related advanced metering and control
- £2.5 M for facilitating best practice in planning

2.2.6 Green Tariffs

Specialised green tariffs have proliferated since full supply-side electricity market opening. The government, through the Energy Saving Trust (EST), operates the "Future Energy" accreditation scheme for green tariffs in the UK. At present, the scheme verifies supplier's offerings against a set of defined criteria. As of April 2000, Future Energy had accredited 15 tariffs and the volume of electricity sold under accredited tariffs in the UK is in excess of 200 GWh/year.

Given the statutory nature of the Renewables Obligation, it is not clear what role green tariffs will play in the new regime. Government has stated that it *"believes that green tariffs should not be used to meet a supplier's costs in fulfilling their obligation but rather the intention is that any green tariff should lead to additional generation, over and above a supplier's*

[3] Certain energy intensive users can sign negotiated energy efficiency agreements with government and thereby qualify for an 80% reduction in the levy. Some other users qualify for reductions or exemptions – see the Finance Act.

[4] There are some slight differences in qualifying criteria for LECs and ROCs

obligation" [2]. There may also be opportunities for suppliers to distinguish themselves through particular renewable energy technology mixes.

2.2.7 UK Carbon Trading Scheme

The UK government is making available up to £215 million over 5 years as incentive payments for companies participating in a voluntary carbon trading scheme [6]. The scheme has been developed by the Emissions Trading Group set up by the CBI and Advisory Committee on Business and the Environment. Renewables projects will benefit indirectly in so far as targets are such that companies may opt to contract with renewable energy in addition, or in preference, to undertaking energy efficiency measures. Only those projects which have not benefited from the Renewables Obligations will be eligible.

3 THE ELECTRICITY INDUSTRY

3.1 Industry Structure

Privatisation of the UK electricity industry in the early 1990s introduced the concept of an electricity market which sought to distinguish between natural monopoly and competitive activities, encouraging efficient operation in the former and competition in the latter. Since privatisation, the industry has comprised companies carrying out one or more of the following activities:

- **Generation**: production of electricity.
- **Transmission**: high voltage transfer of electricity across long distances.
- **Distribution**: medium and low voltage transfer of electricity from the transmission system to customers (or, increasingly, from small power stations to the transmission system). Transmission and distribution networks are considered to be natural monopolies – that is, it would not make sense to have more than one electricity network.
- **Supply**: purchase of electricity from generators and wholesalers, and its sale to customers.

The electricity markets of Scotland and England and Wales (E&W) are presently separate but interconnected. This means that while the industry structure and rules governing participation in each market are different, it is possible to trade between the two markets using the Scotland-England interconnector. An interconnector between Scotland and Northern Ireland has also recently been commissioned.

Differences between the electricity markets stem from the manner in which each was privatised. In Scotland, government privatised the two Scottish Electricity Boards as vertically integrated companies – that is each company or “host” was privatised as an all-in-one transmission, distribution, generation and supply company. In E&W privatisation created just one transmission owner and operator (NGC), twelve regional distribution and supply companies (Regional Electricity Companies), and two generators (National Power and Powergen). Subsequent development has seen divestment of plant by generating companies in E&W, and increasingly stringent controls on ring-fencing of activities for all companies which undertake more than one of the four principal activities.

Government required all of the privatised generation and supply companies in Great Britain to sign long-term power purchase or fuel purchase agreements. In Scotland these contracts are collectively referred to as the “Restructuring Contracts”. The majority of these contracts have now expired, or do not tie up any significant amount of generation. The exception to this is the Nuclear Energy Agreement (NEA) in Scotland. Under the NEA, ScottishPower and Scottish and Southern Energy are committed to purchase between them, all the output from British Energy’s Hunterston B and Torness nuclear stations until 2005.

Generation sold annually under the NEA represents some 45% of electricity generated in Scotland and over 50% of domestic demand. It is an important factor to consider when implementing change in the Scottish electricity market, and is currently subject to a court case between the three contracting parties.

3.2 Generation Mix

Table 3.1 shows Scotland’s generation mix for 1990/91 and 1999/00 (the most recent figures available). While the predominant nuclear, coal and hydro mix at privatisation has remained, oil has been largely replaced by gas. Nuclear has increased its output and small amounts of "other renewables" such as wind and landfill gas have been introduced.

Exports to E&W have increased more than three fold since 1990/91, and are expected to increase still further in the coming years. Trades south across the Scotland-England interconnector have to date largely been for sale of coal-generated electricity, which increases the corresponding share of Scottish demand attributed to the other fuel sources, including renewables.

Source	**90/91**		**99/00**	
	GWh	%	GWh	%
Nuclear	12,143	37.5	18,933	44.3
Coal	12,666	39.1	12,562	29.4
Hydro	3,471	10.7	4,246	9.9
Gas	0	0	6,569	15.4
Oil	4,125	12.7	171	0.4
Other fossil fuels	0	0	0	0
Other renewables	-	-	227	0.5
Total Generated	32,404.6		42,481.5	
Total Consumed in Scotland	29,851		32,037.2	
Net Exported	3,129.9		10,568.4	

Table 3.1 Scotland Energy Statistics [7]

3.3 Electricity Trading Arrangements

Electricity Trading Arrangements are essentially the rules which govern participation in electricity markets. As with industry structure, these have developed separately in E&W and Scotland. It is not possible here to provide an in-depth analysis of the development of trading arrangements, but it is important to understand the very significant changes currently underway in Great Britain.

To understand the direction being taken in the development of trading arrangements across the UK, it is helpful to appreciate the new arrangements introduced in E&W – namely the New Electricity Trading Arrangements, or NETA. These arrangements embody the UK government's and Regulator's aspirations for electricity markets.

3.3.1 NETA

NETA has replaced the former electricity Pool in E&W with a structure based on bilateral contracts. NETA consists of three main elements: (1) A forward market in bilateral contracts supported by a derivatives market in futures and options; (2) A short-term (up to 3.5 hours ahead of delivery) market that generators, suppliers, and large customers can use to adjust their contract positions; and (3) A balancing market (from 3.5 hours ahead of the start of each half hour trading period) in which National Grid Company can buy offers of flexible capacity and load reductions to balance supply and demand. Post-event settlement reconciles differences between contracted and metered positions.

The arrangements are problematic for small and/or unpredictable generators such as wind energy and Combined Heat and Power (CHP) – ultimately depressing its value. The most fundamental problem is that positions on which participants are "cashed out" in settlement must be notified 3.5 hours ahead of delivery. Due to difficulties in forecasting output, intermittent plant are disadvantaged by any advance notice requirements. Furthermore, imbalance charges are designed to be "penal" to encourage forward contracting. Thus the risk associated with exposure to these imbalance charges is greater for less predictable plant.

Ofgem has recently reviewed the experience of small generators in the first 6 months of NETA [8]. It concluded that while profitability may have fallen for all types of generation, output has also fallen for smaller generators, and wind energy plant in particular suffers under NETA due to its unpredictability. DTI has responded by consulting on a number of measures to mitigate for this. It should be noted though that the review did not address problems which might be faced by larger unpredictable generators (e.g. offshore wind farms), which would not benefit from some of the existing mitigating measures.

3.3.2 Scotland Trading Arrangements

While the Scottish market does look to the E&W market for price markers and legal and procedural frameworks, the Scottish market is very different to that in E&W. There has never been an electricity pool in Scotland and, since 1998, trading has been on the basis of regulated "administered arrangements." Very briefly, independent parties can trade bilaterally with each other and the hosts within a framework of allowed trading relationships.

Partly as a result of the way in which the industry was privatised in Scotland, and partly because until latterly there was little envisaged need for new plant, there has not been 'new entry' into the Scottish market to the extent experienced in E&W. The Regulator has stated its intention to introduce *"more competitive arrangements to Scotland"* and has consulted on extending NETA into Scotland under the British Electricity Transmission and Trading Arrangements (BETTA) project. Outline proposals put forward by the Regulator envisage a single system operator, more integrated GB-wide trading arrangements and incorporation of the Scotland-England interconnector into a GB-wide transmission system. However, there are not as yet any firm proposals, or a timetable for introducing new trading arrangements into Scotland. A consultation on BETTA is due shortly.

The Renewables Obligations offer opportunities for a series of new plant in Scotland, from 2002 onwards. This will be a test for the existing trading arrangements, which were not generally designed for the numbers and type of players envisaged. Many new parties are reluctant to enter the Scottish market in the period of uncertainty surrounding the Scottish market, which could limit the realisation of potential for developing renewable energy plant in Scotland.

4 THE PLANNING FRAMEWORK

4.1 Overview

Planning is a devolved matter, with certain functions, including overall management of the system, the responsibility of the Scottish Executive. A framework of structure and local development plans produced by Planning Authorities (PAs), and national policy guidance and advice produced by the Scottish Executive, forms the backbone of the planning system.

Depending on their size, renewable energy power projects require development permission from either a planning authority or the Scottish Executive. The Scottish Ministers are responsible for authorising power plant over 50 MW, or over 1 MW in the case of hydro plant, under a "Section 36" consent process[5]. All other plant fall to be determined by the relevant planning authority. In both cases, the planning framework is material in determination of an application. The consenting process for offshore renewable energy technologies is currently under review.

Scottish Executive policy on planning for renewable energy is contained within the recently-revised NPPG6: Renewable Energy Developments [9]. It reiterates the Scottish Executive's commitment to renewable energy for both environmental and economic objectives, and asks planning authorities to provide positively for its development. Presently under revision, PAN 45: Renewable Energy Developments, contains more detailed, technology-specific practical advice on development of projects.

As and when PA development plans are reviewed, they will take into account this new guidance. Development plans are periodically updated, generally on a 5 year plus cycle. Where up to date guidance is imperative outwith the review period for any development plan, authorities can produce non-statutory supplementary statements. A number of local authorities have published separate renewable energy policy statements or development strategies.

4.2 Environmental Impact Assessment

Environmental Impact Assessment (EIA) Regulations require a formal EIA statement for many development projects. Some renewable energy projects are Schedule 2 developments, meaning that the local authority must determine the need for an EIA. In practice, all but the smallest projects will produce an EIA statement, albeit the level of information required should be commensurate with the size and nature of development.

An EIA formalises the collection and presentation of relevant environmental information to accompany a planning application. Its content is informed by consultation with relevant parties and once produced, can be a useful medium through which to promote understanding of a project. Some guidance on EIA production and interpretation of the Scottish planning regulations (for projects which fall to be determined by the planning authority) is produced by the Scottish Executive [10, 11].

4.3 Experience to Date

Table 4.1 summarises planning progress for all SRO tranches and for NFFO's 3-5. Figures are complied from statistics supplied through an ongoing DTI programme of monitoring the planning progress of SRO, NFFO and NI-NFFO projects [12]. Numbers refer to projects

[5] The relevant planning authority is nonetheless influential under a Section 36 consent.

awarded a power purchase contract. Planning applications sometimes combine two adjacent projects.

The overall approval rate is comparable between Scotland and E&W. Differences in approval rates for wind energy are however notable. This should be interpreted in the context of there being fewer projects in Scotland, which have been developed over a shorter time period. Furthermore, figures quoted do not include projects approved in E&W under the first two NFFO tranches.

	Biomass	Hydro	Landfill Gas	Waste	Wave	Wind
SRO 1-3						
Approved	1	13	11	2	1	20
Submitted	1		5			9
Refused		1				4
No progress	1	14	5	3	2	15
Withdrawn		1		1		1
Total	3	29	21	6	3	49
% Approved	**33**	**45**	**52**	**33**	**33**	**41**
NFFO 3-5						
Approved	9	27	189	14		42
Submitted	1	4	11	1		21
Refused	2	0	1	3		37
No progress	8	35	51	46		86
Withdrawn	2	2	1	1		3
Total	22	68	254	65		189
% Approved	**41**	**40**	**74**	**22**		**22**

Table 4.1 Planning Statistics

Experience gained in the implementation of the SRO will be invaluable in facilitating development under the new obligations. Of those wind energy applications refused in Scotland, two have been on landscape grounds and two on the grounds of interference with bird populations. The hydro application refused was on the grounds of interference with salmon.

More information on technology-specific planning and environmental matters can be found in the relevant technology updates.

4.4 Information from Planning Authorities

As part of the current Scottish resource study, PAs were asked for assistance in sourcing GIS datasets on local constraints. GIS datasets used in the analysis are described in more detail in Section 3 of Volume I. As part of the same exercise, PA's were also asked to provide relevant development plan extracts and policies to assist dataset interpretation. While the policy information received does not represent a comprehensive review of PA renewable energy policies, it provides a useful indication of the nature of local development policies.

A summary of information received is presented in Table 4.2 below. Of 18 councils which provided information on renewable energy policies, it shows the frequency of policies by type. A "Spatial" policy refers to spatially-defined preferred and/or non-preferred zones. A

“Designation hierarchy” is where a policy attributes a hierarchy of protection to different existing designations, in a similar manner to NPPG 6. “Landscape character” guidance is where a policy refers to SNH’s regional landscape character assessments [13], and specifically, comments contained in these assessments on accommodating wind energy in any one area. Some PA’s have adopted more than one of these three approaches.

Policy	Occurrence
Spatial	5
Designation Hierarchy	14
Landscape Character	5

Table 4.2 PA Local Development Policies

Information collated indicates that PA’s take a range of approaches to renewable energy. Policies are at varying stages of development, and the current resource study should be a valuable aid in informing future policy development.

5 ECONOMIC AND SOCIAL CONSIDERATIONS

5.1 Conventional Costs

Section 3 of Volume I summarises average project costs for each technology. In modelling unit costs, the analysis described in Volume I employs a number of simplified financial parameters. In reality, commercial projects are financed on variable terms, using balance sheet and/or external finance and a range of payback periods and returns.

5.2 External Costs and Benefits

External costs and benefits are increasingly recognised and can be variously quantified using methods developed by environmental economists. Broadly speaking, they are those costs and benefits which are not included in the conventional cost, or value, of an activity.

External costs might include conventional costs which arise as a direct or indirect result of an activity, but which are not attributed as a cost to the activity itself – for instance pollution-related health and clean-up costs. They might also include costs which do not directly involve monetary outlay – such as a degradation of biodiversity or an infringement on personally-held values. External benefits might include avoided conventional and external costs, or direct gains such as improvements in air quality or amenity.

The trend towards the “polluter pays” principle is an attempt to rectify direct costs being borne by those other than the polluter. For instance planning permission is now more often granted on the condition that a developer bears eventual site restoration costs.

It is more difficult to reflect non-monetary costs and benefits, although attempts have been made to quantify these in monetary terms. While not reflected in most commercial transactions, government, its agencies and other organisations may seek to take account of non-monetary benefits in decision making, so that for instance grants are awarded after consideration of both conventional and external costs and benefits. This may include quantification of non-monetary costs and benefits, but will more commonly involve a descriptive appraisal.

Renewable energy is generally accepted to be beneficial in terms of the avoided pollutants which would otherwise arise from alternative forms of generation, and market incentives for renewable energy are often justified in these terms. Life cycle analyses go several steps further to compare the costs and benefits arising throughout a project’s development, construction and operation.

5.2.1 Relevant literature

A variety of studies have attempted to compare the “full” costs of conventional and renewable energy generation. This includes the European Commission-funded “ExternE” project [14] which aims to quantify the external costs attributable to a wide range of fuel cycles. The project has run from 1991 to 1998, and there still remains a considerable amount of work in quantifying the full range of externalities.

A report commissioned by Highlands and Islands Enterprise [15] aims to quantify some of the benefits of renewable energy for the Region. The objective of the study is to “*equip Highlands and Islands Enterprise with a firm basis for the assessment of investment and policy options for the development of the renewable energy sector, by quantifying the* *potential importance of the sector to the region, both in the period to 2010 and beyond"* The report is due to be published shortly.

Greenhouse gas inventories for Scotland for 1990, 1995 and 1998 are available [16], and quantify emissions by activity, including electricity generation. They show that electricity generation contributes to around 24% of Scotland's total CO_2 emissions which, while lower than the corresponding UK-wide proportion of 26%, is on a rising trend since the first inventory of 1995. Emissions from the electricity sector have increased by 20 % since 1990 in contrast with a fall of 25 % in UK emissions. This is in the context of increasing exports of electricity to E&W over the same period.

Drawing on the aforementioned greenhouse gas inventories, the Scottish Executive commissioned further work to develop projections of Scottish energy demand and CO_2 emissions to 2020 [17]. Undertaken by AEA Technology, it is based on the DTI's energy model used in Energy Paper 68 "Energy Projections for the UK", to project emissions for four of the 6 scenarios modelled in EP68. Because it essentially takes a subset of the DTI's UK model, the results should be treated with some caution – for instance it assumes a reduction in coal consumption from the year 2000 and a growth in gas consumption, whereas investments made in Scotland's primary coal-fired station would suggest that coal consumption could increase from 2000 in Scotland (albeit that it could be attributed to electricity exports).

The model shows that Scotland's surplus in electricity will, depending on the scenario considered, reverse between 2015 and 2020, to Scotland becoming a net importer of electricity. When all CO_2 emissions are considered, the model shows a downward trend in emissions to 2010 and then a slow increase to 2020. Contributions from the energy and manufacturing industries decline while those from transport and domestic sectors take an increasing share. The model also shows that even when measures in the Scottish Climate Change Programme are instituted, Scotland will still fall short of the UK's CO_2 reduction target (a 20% reduction on 1990 levels by 2010) by 3.4-7.3 %, depending on the scenario considered.

5.3 Social benefits

In its 1999 renewable energy review [18] , the DTI reports that *"it is believed that the manufacture and operation of renewables plant is more labour intensive than for conventional energy sources"* and that in conjunction with export opportunities, achieving the UK's 10% target *"might result in 10-45,000 additional net jobs."* Maximum jobs benefit will be realised in Scotland through retention and gain of manufacturing and assembly activities. Government, Parliament and the Enterprise Agencies have initiated a number of activities aimed at securing renewable energy-related jobs in Scotland.

6 WIND ENERGY

6.1 Technology Status

Wind turbines convert mechanical power from the wind into electrical power via a rotor connected to a generator. The power in the wind is proportional to the cube of the wind speed and to the air density. The rated output from wind turbines can be from a few tens of Watts to multi-MegaWatts. This review concentrates on the larger machines.

Wind energy is a capital-intensive technology with short construction times (typically a few months), low operating costs and zero fuel costs. The economics of wind energy are therefore more sensitive to discount rate and plant capital cost than, for example, are those of fossil or nuclear fuelled generation.

The commercial grid-connected wind energy market is dominated by machines of 750 kW and upwards rated output power, deployed in “wind farms”. Wind farms may be located on land (“onshore”) or in shallow coastal waters offshore. The former range in size from single machines to large projects of 100 MW or more. Offshore technology is in a much earlier stage of development, but is now experiencing rapid growth centred in Northern Europe – there are some 9 offshore wind farms in operation and a 160 MW installation at Horns Rev (in Denmark) under construction.

In the two years since publication of R-122, onshore machine rated capacities have continued their upward trend with > 1.5 MW turbines now in general use in Germany and on some new large UK sites. This upward trend can be expected to level off as turbine size is constrained by access and the (eventually) diminishing returns of larger machines.

Offshore turbines are larger than onshore due to higher infrastructure costs driving more efficient use of foundations. Machines will be built as large as is both technically feasible and commercially viable. Height is lower for a given rating than onshore due to lower wind shear over the sea.

The principal components of a wind turbine are the tower, nacelle and rotor. The tower, which may be of tubular or lattice steel construction[6], is typically 40-60 m or more in height. The nacelle sits on top of this tower on a bearing which allows the turbine to turn (yaw) to face into the wind at all times. The nacelle houses the drive-train which transmits rotor torque, usually by means of a gearbox, to the generator. A cover made from GRP or similar materials houses these components and provides a secure, sheltered working environment for O&M personnel.

Blades are typically upwards of 20 m in length, and made from GRP, wood-epoxy composites and occasionally carbon fibre. Rotors of over 100 m diameter (blades > 50 m each in length), are being developed for the next generation of offshore turbines rates at around 5 MW. The blades are connected to a hub machined from a single steel casting which may incorporate linkages to vary blade pitch. A gearbox converts the 30-40 rpm of the rotor shaft to the generator rotational speed. Brakes act on the rotor shaft to stop the turbine under storm or fault conditions. Control systems monitor and supervise all aspects of machine performance to maximise energy capture and ensure safe operation. Modern wind turbine design variants include fixed and variable rotor speed, and direct drive “gearless” machines are also gaining ground.

For a comprehensive review of all aspects of wind energy, the report for the European Wind Energy Association (EWEA) produced under the European Commission’s “Altener”

[6] Towers for the UK market are almost invariably of tubular construction

programme “Wind Energy – The Facts” [19] is recommended. A detailed set of predictions about wind energy technology developments is made in “Renewable energy technology characterisations”, a joint project of the Office of Power Technologies, Energy Efficiency and Renewable Energy, the US Department of Energy and the Electric Power Research Institute [20].

6.2 Market Status

Over 20 GW of wind energy has already been installed world-wide, and annual growth in the industry has consistently been 20-40%. There is just over 400 MW of commercial wind energy installed in the UK, of which 96 MW is in Scotland. A list of operational Scottish wind farms is shown in Table 6.1 below.

Name	Location	Operational	Capacity (MW)
Hare Hill	Ayrshire	December 2000	13
Burradale Hill	Shetland	December 2000	2
Dun Law	Borders	June 2000	17.16
Burgar Hill	Orkney	April 2000	3.5
Beinn Ghlas	Tayside	June 1999	8.4
Novar	Highlands	October 1997	17
Windy Standard	Galloway	September 1996	21.6
Hagshaw Hill	Lanarkshire	November 1995	15.6
TOTAL			**98.26**

Table 6.1 Total Installed Capacity in Scotland [21]

A further 4 wind farms are under or nearing construction, shown in Table 6.2.

Name	Location	Exp Operational	Capacity (MW)
Beinn an Turc	Kintyre	Imminent	30.36
Deucheran Hill	Kintyre	Imminent	15.75
Bow Beat	Nr Peebles	2002	31.2
Bu Farm	Stronsay	March 2002	2.7
TOTAL			**80.01**

Table 6.2 Wind farms nearing or under construction

A further 5 have received planning permission and are expected to be constructed, shown in Table 6.3 below.

Name	Location	Capacity (MW)
Black Hill	Borders	28.6
Crystal Rig	Borders	49
Tangy	Kintyre	11
Glens of Foudland	Angus	21
Arnish Moor	Isle of Lewis	2.7
TOTAL		**112.3**

Table 6.3 Wind farms with planning permission

6.3 Industry Status

R-122 lists major wind energy industry employers in the UK, since when the advent of the new Obligations and sustained overseas business has promoted expansion for a number of wind energy companies. All of the major developers are active in Scotland, as are a number of specialist consultancy companies.

Scotland's largest wind energy employer is the NOI Scotland factory (formerly Aerpac) in Kirkcaldy. Manufacturing glass-epoxy composite blades between 7-23 m in length, the factory currently employs some 90 people. Employment is expected to grow over the next year to around 120.

The Danish wind turbine manufacturer Vestas is also establishing production facilities near Campbeltown in Kintyre. Initial plans are for the factory to accommodate tower production and wind turbine assembly, creating some 100 jobs by 2002.

Proven World Friendly Energy specialises in small-scale renewable energy systems – principally wind turbines for electricity supply, water pumping and battery charging – but also photovoltaic panels and micro hydro. Based in Kilmarnock and exporting world-wide, the company designs and installs integrated systems, and manufactures the wind and hydro turbines in its Kilmarnock factory.

A recently-completed Scottish Enterprise-funded initiative to assist Scottish companies exploit wind energy-related opportunities, culminated in some 177 businesses registering goods and/or services for potential supply to the wind energy sector [22].

6.3.1 Costs

Present day capital costs for commercial onshore wind farms in North European sites range from £650-800/kW. A typical breakdown of these costs is shown in Table 6.4.

Item	% Total Cost
Turbines, including commissioning & installation	73
Civils	9
Electricals (excl grid connection)	7
Miscellaneous[7]	11

Table 6.4 Typical breakdown of onshore windfarm costs

Given the limited range of existing commercial projects, offshore costs are subject to greater uncertainty. R-122 quotes £1000/kW for 0-10 m sea depth. First published in a GH report for the IEA Greenhouse Gas R&D Programme [23], Table 6.5 reproduces a breakdown of costs for a typical 200 MW project in 15 m water depth, with a total specific cost of some £1100/kW.

[7] Includes planning-related expenditure and mitigation measures

Item	% Total Cost
Turbines, including commissioning & installation	62
Civils	14
Electricals (incl grid connection)	20
Miscellaneous	4

Table 6.5 Typical breakdown of offshore windfarm costs

A literature review on future costs reveals a good deal of speculation about future unit electricity costs from wind farms, but few authoritative indications of future capital costs. Arguably the best reference is "Wind power development – Status and perspectives" published by Risø National Laboratory in August 1998 [24]. This reviewed several independent analyses and concluded that the rate of future wind farm annual capital cost reduction range was likely to be between 1% and 2.5 % over the next 30 years. The same report also noted that, for onshore wind, *"From 1989 to 1996 turbine costs in real terms per kW have decreased by approx. 4% p.a. At the same time, the share for auxiliary costs has decreased. In 1989 almost 29 % of total investment costs were related to other costs than the turbine itself. In 1996 this share had declined to approx. 20 %. Thus the general investment costs per kW have declined by more than 5 % p.a. in the analysed time period."*

Essentially, there are two inter-dependent routes to future wind farm capital cost reductions:

- Improved wind turbine design (which need not result in larger machines, though this has been the trend for more than a decade)
- Increased manufacturing volumes

A comprehensive analysis of the former route is provided in a December 1997 draft "Advanced horizontal axis wind turbines in wind farms" in "Renewable energy technology characterisations" [20]. This forecasts capital cost reductions due to technology improvement without assuming massive increases of production volume. The cost trends for wind turbine component groups are provided with explanations. The predicted reduction of all-in capital cost from $1000/kW (1996) to $655/kW in 2020 is equivalent to an annual reduction rate of approximately 1.75 %. For large wind farms, the lowest costs in 2001 has already fallen to $800/kW.

The emphasis is on the latter route in "Wind Force 10 – a blueprint to achieve 10 % of the world's electricity from wind power by 2020" published jointly by the European Wind Energy Association, the Forum for Energy and Development, and Greenpeace International in October 1999 [25]. The analysis therein, by BTM Consult, is based on industrial learning curve theories developed by the Boston Consulting Group which can be expressed as "progress ratios" i.e. generalised indications of the sensitivity of cost upon production volume for manufactured goods. Wind farm capital costs are forecast to fall from $1000/kW (1998) to $522/kW in 2020, equivalent to an annual reduction rate of approximately 2.9%.

Two other noteworthy references addressing the impacts of increased manufacturing volumes are "Grid-connected wind energy technology: progress and prospects" published by the US National Renewable Energy Laboratory (NREL) in November 1998 [26] and "The effects of increased production on wind turbine costs" prepared for NREL by Princeton Economic Research Inc. in December 1995 [27]. The former predicts that wind turbine costs will fall by about 5% every time industry production doubles, with 4–5 doublings expected by 2030. The latter, which includes a comprehensive review of relevant learning curve papers, anticipates volume discounts of 10-34 % for production volumes ranging from 1,000 to 30,000 turbines.

It is noted that many of the references above are quite old, at least in the context of wind energy, where everything is changing very fast. From its own commercial activities, GH estimates that the 3 % annual reduction ratio is already being achieved.

6.4 Constraints and Opportunities

6.5 Constraints

Planning difficulties, potential interference with aeronautical communications, electrical network limitations and the suggested saturation of *"easier-access high wind speed sites"* are listed as constraints for onshore wind in R-122. Overcapacity is also cited as a constraint in Scotland.

The new NPPG 6 in Scotland seeks to avoid future planning difficulties by promoting a consistent and positive framework for renewable energy. It is too early to judge if this will be successful, and it will take time for it to be reflected in updated development plans.

In view of the extent of radar operations throughout Scotland, and the rest of the UK, it will be important to clarify and resolve the issues surrounding possible conflicts with radar operations. Operators of both civil and military radar cite problems associated with the potential for wind farms to return radar readings. This, in itself, does not necessarily prompt an objection, which will depend on operational procedures, the type and use of the radar and the number of other sources of 'noise' on the radar. A serious constraint in itself is a lack of readily comprehendable information on the nature of the radar problem – there is no one list of all radar sites, or guidance to assist in identifying conflicts or affected 'zones'. While it is recognised as a serious constraint, this makes it impossible for policy makers to evaluate or quantify the nature of the problem, and make any necessary compensatory measures.

The MoD's policy on wind farms in low flying areas, which can be read in full at [28], also potentially disqualifies large areas of Scotland from wind farm development.

Scotland has historically experienced overcapacity. Recent interconnector upgrades, increasing demand, and expected plant closures from around 2010 onwards promise shortfalls post 2010. Previous analysis by GH [29] discusses this issue in more detail. Furthermore, the advent of liberalised markets and environmental objectives alter the perspective on overcapacity.

There is no evidence to suggest any "saturation" of cheaper sites in Scotland. The analysis reported in Volume I, does, nonetheless show that constraints remove some of the cheaper sites and generally restrict the areas of search for developers.

Network limitations are discussed in Volume I and in the NSG report [30]. The network is a significant constraint to the exploitation of the onshore wind resource (as it is for the other large-scale resources), although a change in connection policy could alleviate the transmission bottleneck in SSE's area in the short term. Given the right locational indicators, it should be possible to develop around 1.5 GW in Scotland without any significant network reinforcement – but it is not known if other constraints such as radar would compromise this possibility.

Constraints listed in R-122 for offshore wind can all be considered as valid today, and in the Scottish context. These are possible conflicts with other sea users, cost uncertainties, (although these will reduce sharply as practical experience is gained over the next few years) limitations posed by the network and difficulties of operation in particularly hostile environments. Furthermore, radar and general aeronautical activity is equally a constraint for offshore wind as it is for onshore wind.

6.6 Opportunities

Opportunities highlighted in R-122 emphasise the sheer size of the resource, both onshore and offshore, the exports opportunities available and the potential for more engineering-based jobs. It also highlights possibilities for smaller-scale exploitation of onshore wind in new and emerging niche market openings.

The potential for jobs creation has been recognised by the Executive and the Parliament, and the Enterprise Companies have for some time promoted these opportunities to business. The expansion and diversification possibilities for the offshore engineering sector are particularly relevant in Scotland.

A survey of public attitudes to wind farms, commissioned by the Scottish Executive, found that the most positive attitude to wind farms is among people living closest to the sites [31]. It ascertained feelings about wind farms amongst those living in and around the (then) four operating wind farms in Scotland. It also found that attitudes were more positive after, rather than before, a wind farm was built.

It is also worth reiterating that wind energy – and indeed all the renewable energy technologies considered – can play an important role in meeting government's targets and commitments for the environment.

7 WAVE ENERGY

7.1 Technology Status

Wave energy has re-emerged as a promising sustainable source. Activity around the world is at its highest ever level and numerous demonstration and commercial schemes are expected over the coming years. R-122 gives a detailed summary of the history of wave energy but an update is required to outline progress since this report was researched, and to present the Scottish perspective.

There are currently a wealth of proposals for machines to convert the energy in ocean waves into electricity. Wave energy technology has been thoroughly studied and researched through various national and regional government supported programmes, in various research institutions and by various industrial companies. It seems clear that the sector is nearing commercial readiness with a number of full-scale prototype devices due to be launched during 2002. These new machines are markedly different to earlier concepts and embrace the successful wind energy ethos of modularity and scalability. In addition, the new concepts are designed to make full use of the rapid advances in offshore technology made by the offshore oil and gas sector over the past 20 years.

Wave energy converters fall into two main categories:

- Shoreline & nearshore
- Offshore

Shoreline and nearshore systems are designed to be fixed to the coastline or seabed, and it is envisaged that this will ease installation, operation and maintenance. Offshore systems are deployed in deeper water depths to take advantage of the higher power levels available. Shoreline and nearshore systems are almost exclusively Oscillating Water Column (OWC) devices that use wave action on an enclosed chamber to drive air back and forward through an air turbine. Offshore devices come in many and varied forms – it is not within the scope of this study to describe their operation in detail.

The leading devices and teams in each category are summarised in the following tables. Note that these tables are not exhaustive lists. R-122 provides a more detailed description of some of the devices listed.

Device team	Device name	Device type	Capacity (kW)	Country of origin	Status
Energetech	-	Nearshore OWC	500	Australia	Prototype expected 2002
Wavegen	LIMPET	Shoreline OWC	500	Scotland	Prototype installed and operating under SRO3
Wavegen	OSPREY	Nearshore OWC	2000	Scotland	Osprey I broke up in bad weather on installation. Further installations planned

Table 7.1 Shoreline and Nearshore Devices

Device team	Device name	Device type	Capacity (kW)	Country of origin	Status
Aqua Energy	IPS Buoy	Floating buoy using low-pressure seawater power-take-off system	100	USA	Prototype expected off Washington State 2002
Embley Energy	Sperbuoy	Floating OWC using multiple chambers	Not known	UK	Small-scale prototype tested off SW England during 2001
Ocean Power Technologies	Powerbuoy	Floating buoy using piezo-plastic power take-off system	20	USA	Initial commercial installation expected off Australia during 2002
Ocean Power Delivery	Pelamis	Floating articulated cylinder using high-pressure hydraulics power-take-off system	750	Scotland	Prototype expected during 2002
Seapower International	FWPV	Floating vessel with a sloping ramp facing incoming waves using low-pressure water power-take-off system	750-2000	Sweden	Prototype expected off Shetland during 2002-2003
Teamwork Technology	AWS	Subsea compressible air-piston using direct electrical power-take-off system	2000	Netherlands	Prototype to be installed off Portugal late 2001 or early 2002
Wavegen	HYDRA	Not known	Not known	Scotland	Prototype expected during 2002

Table 7.2 Offshore Devices

7.2 Market Status

Wave energy has already received commercial support within the third Scottish Renewables Order and has been identified as a supported technology within the new Renewables Obligation (England & Wales) and the Renewables Obligation Scotland. Capital support within the RO and the ROS via capital grants has not yet been confirmed but it is anticipated that this will be forthcoming if prototype devices perform as anticipated.

The world-wide market for wave energy systems is still in its infancy. Several commercial installations have been proposed or have received support, as follows:

- **SRO 3**: three power purchase contracts awarded for a total of 2 MW DNC. One device has been installed and is now operating, the other two are expected during 2003.
- **AWS**: it is understood that Teamwork Technology has negotiated a power purchase agreement for its prototype to be installed off Portugal.
- **Ocean Power Technologies**: it is understood that OPT have negotiated a power purchase agreement and carbon credit scheme with an Australian Utility. It is expected that the pilot scheme of around 100 kW will be installed during 2002.
- **Energetech**: it is also understood that Energetech have negotiated a similar power purchase agreement for their first 500 kW prototype machine in Eastern Australia.
- **BC Hydro**: the West Coast Canadian Utility is currently negotiating with several parties for a 4 MW demonstration scheme off Vancouver Island to be run on a commercial basis.

Wave energy has been included as a supported technology within the E&W RO and Scottish ROS. However, it is not as yet cost-competitive with onshore wind energy and capital grant support will be required to support early installations.

It is expected that the market for wave energy will grow rapidly as credibility rises and costs become more certain. A conservative estimate puts the total market for wave energy systems at 2.5-5 GW installed capacity by 2010 [32]. The long-term worldwide market for wave energy systems has been estimated by the World Energy Council to be in excess of 2 TW of installed capacity [33].

7.3 Industry Status

The UK DTI is now pursuing a vigorous R&D programme to support the development and demonstration of some of these new concepts in UK waters. In addition the Scottish Executive is currently concluding a full feasibility study for a UK marine energy test centre off the Orkney Islands.

Scotland has the best wave resource in Europe and two of the world's leading industrial development teams are based in the country. In addition, Scotland has a first class offshore technology and manufacturing background, whose skill base is ideally suited to the rapid development, demonstration and deployment of emerging wave energy technology. Several other countries and regions are however aggressively pursuing support and demonstration programmes.

Scotland's two leading wave energy companies are Ocean Power Delivery Ltd in Edinburgh, and Wavegen in Inverness. Both are SME's with 10-15 employees and are actively developing device concepts and technology. Both teams are expecting to install prototypes of offshore devices at the proposed UK marine energy test centre off the Orkney Islands during 2002. Wavegen has already installed their LIMPET device on Islay, which has been operational since late 2000. In addition, Ocean Power Delivery have a contract under SRO 3 to install a pair of machines off Islay, which will be commissioned during 2003.

Once successful prototypes have been demonstrated, it is expected that there will be commercial support for further installations, leading to significant job creation in the surrounding region. However, both companies are actively pursuing opportunities overseas and it is by no means certain that this major industrial opportunity will be secured for Scotland.

It has been estimated that a significant installation programme in Scotland would lead to around 150 long-term direct jobs for each 10 MW/year of installed capacity [34]. Exports are expected to result in between 750 and 1000 direct jobs per 100 MW/year of export sales [35].

7.4 Costs

Predicted opening costs for various offshore wave energy systems are between 5 and 7 p/kWh. This is higher than current costs for other more mature technologies such as onshore wind energy, but is comparable with current costs of offshore wind, biomass and small-scale hydro, and is significantly less than current and future projected costs for solar photovoltaics.

It is expected that costs will fall to < 4p/kWh by 2010 with long-term costs in the region of 1.5-2.5p/kWh [36].

7.5 Constraints and Opportunities

7.5.1 Constraints

The network in the North West of Scotland would certainly need to be strengthened if the resource is to be exploited in the medium to long-term. This could be through either mainland strengthening or subsea cable to areas of demand further south in Scotland or England, or across to Ireland.

Because it is an emerging technology, wave energy will need targeted support in the short to medium-term.

7.5.2 Opportunities

Scotland has a world class resource and industrial capability, which if exploited offers the potential for Scotland to become a world-leading industrial base for wave energy (and other marine technologies). Given overseas support for other domestic industrial programmes, this is a window of opportunity.

8 SMALL HYDRO

8.1 Technology Status

Most of the hydro stations within Scotland can be described as small (or at best medium) when considered in a global context. The definition of small scale hydro varies considerably around the world. The British Hydropower Association uses the following definitions:

- < 10 kW: Pico
- 10-100 kW: Micro
- 100 kW-20 MW: Small
- 20-100 MW: Medium
- 100 MW: Large

Three further categories also define hydro schemes, namely:

• **Head**	Low Head	< 10m
	Medium Head	10-100m
	High Head	> 100m
• **Operation**	Run of River	No Storage
	Storage	(Daily, Weekly, Monthly etc)
• **Usage**	Grid Connected	
	Auto Production	

The potential for small hydro in Scotland is mostly in medium and high head run of river, grid-connected schemes. In addition there is some potential for small and medium storage schemes and for medium and large pumped storage schemes, as well as for refurbishment of existing storage schemes. Moreover, there is considerable scope for micro and pico auto production schemes in Scotland. The last three categories were not part of the resource analysis reported in Volume I, and the remainder of this section concentrates on small hydro.

8.2 Market Status

Of nearly 110 MW of small hydro contracted under NFFO/SRO, only around 50 MW has been commissioned. SRO projects commissioned or underway are shown in Table 8.1. The NFFO/SRO has been successful (on paper at least) at driving down the electricity bid prices. However it is questionable whether many of the remaining contracted projects can be built economically at the prices at which they were bid.

Scheme	Location	MW DNC	Developer	Status
Loch Poll	Highlands	0.23	Assynt Crofter's Trust	Operational
Stoneywood Mill	Grampian	0.62	Hydro Energy Developments	Construction complete
Cuileig	Highlands	3.00	Scottish Hydro-Electric	Construction complete
Novar	Highlands	0.92	Novar Estate	Operational
Ardtornish	Highlands	0.66	Ardtornish Estate	Operational
Auchtertyre	Central	0.59	Edinburgh Hydro Systems	Operational
Duror	Highlands	0.69	Edinburgh Hydro Systems	Operational
Beochlich	Strathclyde	0.95	Blarghour Power Company	Operational
Little Wyvis	Highlands	0.63		Construction underway
Glen Tarbut	Highlands	0.83	EHS Group International	Operational
TOTAL		**9.12**		

Table 8.1 SRO Hydro schemes commissioned/underway

A total of 21 schemes totalling 13.41 MW DNC also receive support, formerly under the so-called "Scottish Transitional Arrangements." A mixture of existing and new-build projects were awarded power purchase agreements in advance of the first SRO. There were only three SROs to the NFFO's five orders in E&W, and these Scottish transitional arrangements were in recognition of the opportunities available to counterpart generators in E&W.

There have been a number of attempts over the last few years to set up a trading group of small generators, at first comprising existing small hydro generators, but ultimately to include a range of renewables. However it is only recently that the necessary trading framework has been developed, and given other uncertainties in the market, and the costs of market entry for small generators, small-scale independent trading has not to date been a viable option.

As a result of the announcement that refurbished hydro up to 20 MW will receive ROCs, Scottish and Southern Energy is planning to undertake a major refurbishment programme, and it is understood that other major operators will follow suit. SSE's anticipated capacity additions resulting from refurbishment, by area, are shown in Table 8.2.

Area	Unrefurbished installed capacity (MW)	Post-refurbishment annual energy gain (GWh)
Sutherland	37	8
Ross and Cromarty	118	23
Inverness	144	20
Lochaber	43	8
Perth and Kinross	146	25
Stirling	75	12
Argyll and Bute	70	11
Total gain		**107**

Table 8.2 SSE Anticipated Refurbishment [37]

The future for hydro in the UK domestic market, in terms of its size, is limited by the relatively modest resource on effectively a small island land mass. Nonetheless, small hydro can play a valuable role in rural diversification, as demonstrated by a number of existing schemes.

For instance an SRO 1 project at Loch Poll was conceived by the Assynt Crofters Trust, a group of crofters who have purchased land for the crofting community. The hydro project is a key development project for the community, which will provide valuable experience for further diversification. Another scheme near Oban combines small hydro with a fish farming enterprise, and hopes to also expand into biomass fuelled from local forestry.

Schemes may be developed and financed on the strength of a development package which includes a small hydro scheme. The longevity of hydro schemes can often be an important factor in supporting other diversification activities, or indeed, given recent down turns, mainstream agricultural and forestry activities.

Eligibility for ROCs and LECs is essential for small hydro in securing a market for the generated electricity. While not cost competitive with onshore wind, schemes may still be developed – and grant-supported – on the strength of rural development benefits.

8.3 Industry Status

R-122 remains relevant in its description of the hydro industry in the UK. There are some 168 [38] first and second tier companies involved in hydro in the UK, comprising consultants, contractors, manufacturers and developers.

The industry now needs to build on the opportunities provided by ROCs in the domestic market to enable it to move successfully to the exports market.

8.4 Costs

8.4.1 New small hydro

Typical small hydro costs are presented in Section 3 of Volume I, which, including grid connection, equate to range of £900-£3500 per installed kW. Costs vary with the technical characteristics of a scheme, environmental mitigation measures and grid connection parameters.

8.4.2 Refurbishment

SSE quote a refurbishment cost of some £670/kW for a 6.4 MW plant investigated, dropping to around £200-£250/kW for 50 MW + plant [39].

8.5 Constraints and Opportunities

8.5.1 Main Constraints

Increasing environmental regulation has meant that it is increasingly difficult to obtain planning permission and indeed the cost of mitigation measures (e.g. pre and post construction monitoring) can add considerably to CAPEX costs. Moreover the derogation of water availability required under regulations such as the Water Framework Directive may mean that hydro stations built now may not be economically viable in as little as 6-12 years from now. There are derogations with respect to limiting effects on economic activity, but it remains to be seen how they will be applied in practice.

Access to a market for electricity generated is essential. A significant proportion of small hydro will be for a mixture of on-site usage and export to the grid – the arrangements for realising the value in ROCs for electricity consumed on-site will require contracts with licensed electricity suppliers. Market access for small hydro will thus depend on the willingness of suppliers to sign long-term contracts for relatively small amounts of electricity, some of which is consumed on-site. The availability of options to group or consolidate output from small generators may also be important.

8.5.2 Main Opportunities

In Scotland, the key opportunities for small hydro are centred on supporting a wider range of economic development, in particular in rural areas.

An increase in activity in anticipation for the new Renewables Obligations has prompted increased dialogue between industry and the regulating authorities.

The refurbishment market, stimulated by eligibility for ROCs, represents a key opportunity for equipment suppliers.

The overseas market for both small and larger hydro represents a significant opportunity for UK companies.

9 TIDAL STREAM

Superseding R-122, the most up to date and authoritative publication on Tidal Stream status and prospects is the April 01 publication "The Commercial Prospects for Tidal Stream Power" by Binnie, Black & Veatch in association with IT Power Ltd [40]. Commissioned by the DTI, it evaluates the potential for commercial exploitation of tidal stream technology in UK waters. The remainder of this section, while structured according to R-122, reflects the findings contained in the BBV report.

9.1 Technology Status

Tidal Stream technology converts the energy of marine currents, an energy resource predominantly driven by the tides, which are in turn driven by the gravitational fields of the moon and of the sun interacting with that of the earth. Tidal streams are essentially bi-directional (ebb tide and flood tide) and the currents tend to reach their maximum velocity half way between low tide and high tide. The ebb-flood cycle is approximately 12.4 hours, superimposed on which is a modulating effect caused by the relative motion of the sun and the moon – the Spring-Neap cycle, with a period of approximately 336 hours. At Spring tide the amplitude of the diurnal tidal cycle is maximised and at Neap it is minimised. With typical diurnal tidal streams found around most of the Scottish coast, the maximum flow velocity at Springs is approximately twice as great as that at Neaps. Hence the available energy at Springs per unit cross-section of flow is approximately 8 times greater at Springs than at Neaps (due to the cubic relationship between velocity and kinetic energy).

An important point to grasp is that tidal stream energy is predictable, which is of course advantageous when compared to weather-dependent renewable energy resources. A disadvantage is that the energy available during the Neap period is much less than that available during the Springs.

Tidal stream, or marine current technology is at an early stage of development – only a few small-scale experimental devices have been demonstrated. The only commercial technology consists of a few small devices for hanging over the side of small boats to charge batteries. Larger-scale systems intended to lead to the development of grid-connected power from tidal streams are under development, albeit at an early stage.

A tidal stream turbine may be thought of as a wind turbine under water. Examples of better known technologies using similar principles are low head hydro turbines. Many of the basic principles that apply to wind turbines equally apply to tidal stream or marine current turbines. The analytical tools developed for the wind industry can be readily adapted to tidal stream.

Figure 9.1 illustrates the two proven types of rotor capable of efficiently extracting energy from a flow, namely the conventional axial flow turbine (similar to a propeller) as is used for most wind turbines, or the cross-flow turbine (often attributed to Darrieus). There are also possibilities to use lift forces to cause a device to oscillate either linearly or through an arc, like a child's see-saw. Wind turbines using such principles have been advocated and even tested but so far with no commercial success, but it is worth mentioning this option since one developer in the UK is experimenting with such a device for use in tidal streams.

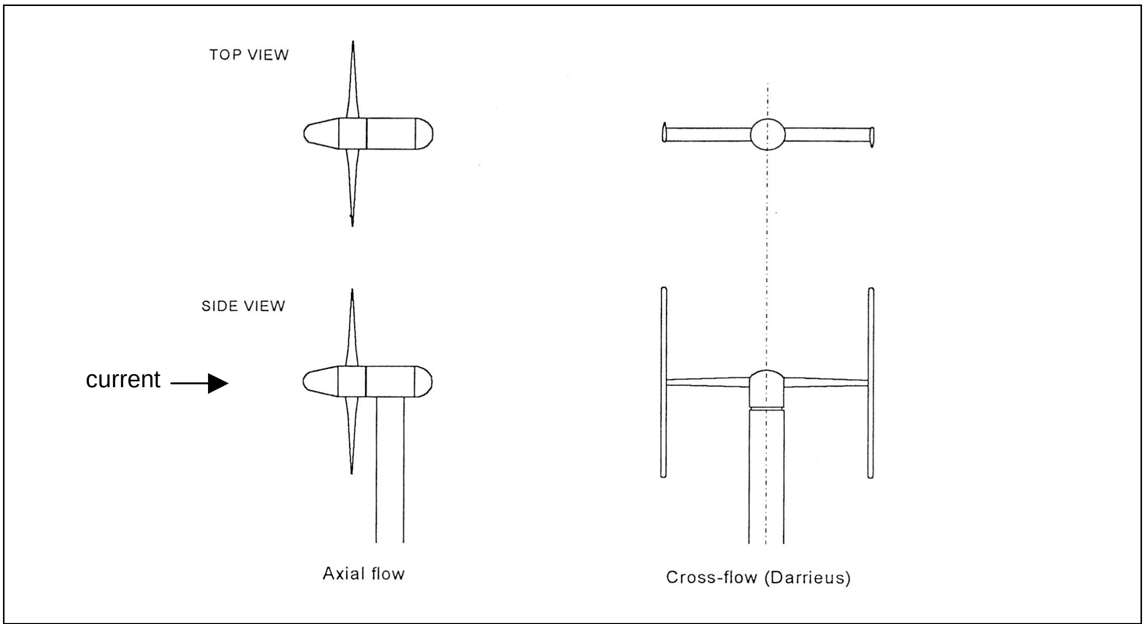

Figure 9.1 The two main possibilities for marine current turbine rotors

Water is 800 times the density of air, and most of the locations where tidal current turbines might successfully be applied experience energy flow densities (kW/m^2) up to 10 times greater than is normal with a wind turbine. This is an asset in the sense that higher energy density leads to a smaller rotor and potentially lower costs, but it also leads to much larger forces than would apply to a wind turbine of the same rated power.

A key requirement for any kinetic energy conversion system is to hold it reliably in place. There are three main options: mounting a structure on (or embedded in) the seabed; suspension from a floating vessel; or possibly support from a tension-buoy type of mooring between the surface and the seabed. Figure 9.2 illustrates the former two options. A major difficulty with a floating system will be both resisting the forces trying to move and uproot the anchor and coping with wave motion in rough weather. Transmission of the power to the shore from a floating device is also more problematic as flexible electrical connections will be required.

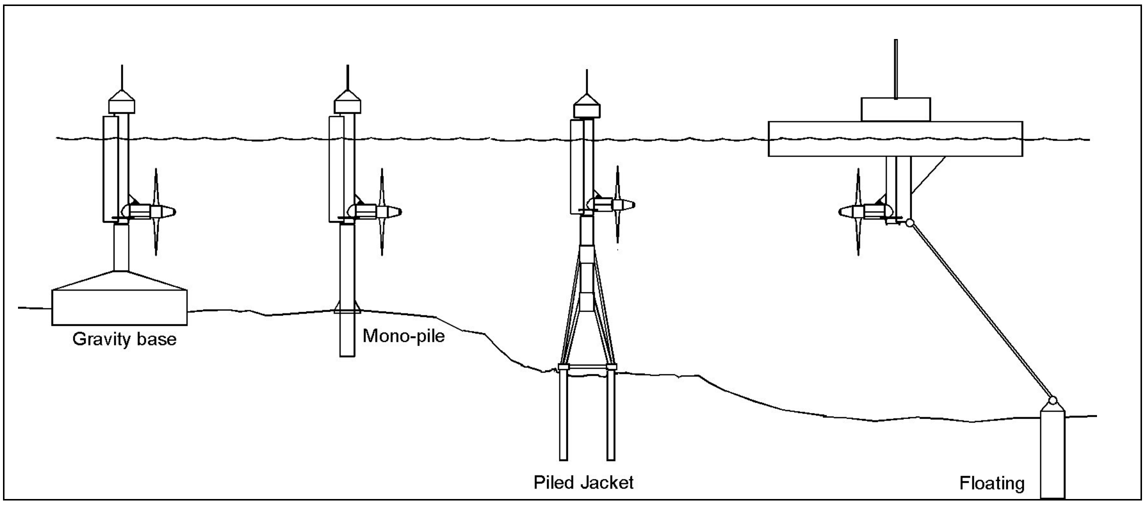

Figure 9.2 Mounting an axial flow rotor in a tidal stream

Because tidal turbines depend on a bi-directional flow (rather than the multi-directional flow that wind turbines receive), axial flow systems can be deployed across the direction of flow relatively close together. To utilise the available sea-space efficiently, any moored system would need to be designed not to move much from its position, and in practice multiple moorings would be developed.

Most seabed mounted devices are only suitable for use in relatively shallow waters. the minimum depth to permit submergence of an adequately sized rotor is probably about 15 m at low tide while the maximum with present day technology for pile mounted systems is around 50 m at low tide. Many locations with high velocity currents have depths within this range.

The main options being explored in the UK at present are as follows:

- **Marine Current Turbines**: MCT, with support from the DTI and the EC, and in conjunction with European partners, is developing an axial flow turbine system mounted on a monopile. A 300 kW system is due to be installed off the coast of Devon during 2002. This system uses a gearbox to drive a generator. The design is at an advanced stage.
- **Engineering Business**: an oscillating see-saw like device which pumps hydraulic fluid so as to drive a hydraulic motor and hence a generator is under development by the Engineering Business Ltd, also with support from the DTI [41]. It is believed this will be rated at around 200 kW.
- **Tidal Hydraulics**: based in Wales, Tidal Hydraulics is developing a device based on numerous small axial flow rotors set into a frame mounted on the seabed. It is believed to have attracted some financial support from the Welsh Assembly.
- **Edinburgh University**: Prof. Stephen Salter of Edinburgh University has proposed a large floating cross-flow rotor system but it is thought that this remains at a conceptual stage of development.
- **JA Consult**: J A Consult is developing a semi-submersible, buoyant, axial flow concept. A prototype (1.5m diameter rotor) is currently being tested in the river Thames at Chiswick, and is being monitored and assessed under DTI contract. For pictures and more information see [42].

The UK has a lead in this field at present, but experimental devices, all with axial flow rotors, are under development in the Netherlands, Norway, Italy and Canada.

ETSU consider that *"the most advanced tidal stream generator concept is that proposed by Marine Current Turbines Ltd"* [43]. MCT's concept has been subjected to a detailed DTI-financed review [40], the primary objective of which was to assess the design's cost-effectiveness.

9.2 Market Status

There are no commercial revenue-earning tidal stream systems in operation anywhere. It is one of the newest renewable energy concepts to be explored and it is only recently (i.e. this year) that for example the UK government has taken a serious interest in it, following the positive recommendations of both the aforementioned BBV report and those from the House of Commons Science and Technology Select Committee [36].

No longer in operation, there was one demonstration project at Loch Linnhe, in 1994. Undertaken by Scottish Nuclear Ltd, IT Power Ltd and the National Engineering Laboratory, it tested a 3.5 m diameter axial flow turbine suspended below a floating catamaran pontoon. For more details see Appendix C of [40].

9.3 Industry Status

Industrial interest in tidal stream is in its infancy. The following involvement's are known:

- A consortium of UK and German companies are involved in an R&D programme led by MCT. Participating organisations and their expertise are as follows:
  - Marine Current Turbines Ltd., (London): development of tidal stream energy technology
  - Seacore Ltd., (Gweek, Cornwall): placing of offshore monopiles from jackup barges
  - Bendalls Engineering Ltd., (Carlisle): manufacture of large precision steel fabrications and pressure vessels
  - Corus Group UK Ltd, (Teeside): technical inputs and raw materials
  - I T Power Ltd., (Basingstoke): design
  - Jahnel-Kestermann Getreib GmbH, (Bochum, Germany): manufacture of wind turbine and marine gearboxes and transmission components
  - IEE Kassel, (Kassel University, Germany): technical inputs, in particular on electrical control system
- The Engineering Business Ltd, Hexham, as discussed in Section 9.1.
- Tidal Hydraulics Ltd in Wales, as discussed in Section 9.1.
- Blue Energy, a Canadian company in British Colombia proposes a so-called "tidal fence": a wall of massive concrete blocks, each with a hole in it housing a cross flow type of turbine. These blocks would be deployed continuously to form a wall across the straits between the mainland and a convenient island.
- Hammerfest Stroem AS, a Norwegian utility is developing a seabed mounted axial-flow system of about 300kW.
- Teamwork Technology in the Netherlands is marketing a small floating axial flow device rated at 25kW, primarily for use on rivers. They are also working on wave energy systems.
- A company called Enermar in Italy is reputed to be developing a 130kW prototype cross-flow type of turbine
- Aquantis in USA, (owned by the founder of Zond wind systems, which subsequently became the Enron Wind Corporation) is in the process of designing and developing marine current turbine technology.
- J A Consult, based in London, as discussed in Section 9.1.

Apart from commercial interest in the technology, several universities are, or have been, working in this field, including Robert Gordon University (Aberdeen), Southampton University and Edinburgh University. The first two of these have active research programmes supported by government agencies.

9.4 Costs

Based on projected costs from MCT for medium-scale commercial development, modelled unit costs range from 3-6 p/kWh (see analysis in Volume I) for deployment up to 2010. The cost of electricity from tidal stream is highly sensitive to current velocity, and there are significant project overheads relating to mobilisation of installation equipment and grid connection. Some of the most energetic locations are relatively inaccessible (e.g. Pentland Skerries) so it is likely that the more accessible locations will be developed first, which will be less energetic and have generating costs somewhere nearer the middle of this range, i.e. around 4-5 p/kWh. More analysis is needed both on the technology and on the resource to obtain firmer and more detailed estimates of the eventual true costs. There is as yet no practical experience to underpin costs for commercial schemes, which is a primary requirement for tidal stream (and other developing technologies) over the coming years.

9.5 Constraints and Opportunities

9.5.1 Constraints

A possible market constraint is the likely competitiveness of the technology compared with other renewable energy options. Analysis shows that it will be competitive in the medium to long-term, but this is contingent on successful demonstration.

As with other marine technologies, reliability is a particularly important issue and attention will need to be given to making the generating plant as robust as possible and in providing reliable diagnostic and monitoring systems.

It is not expected that environmental impact will in practice be a major inhibiting factor, since locations with unusually high currents of the kind necessary for cost-effective power generation tend to have scoured seabeds consisting of hard surfaces such as rock. Thus rare species are unlikely to be affected, and those that do frequent such locations are also unlikely to suffer any ill effects.

Concern for the safety of marine mammals is often expressed in the context of tidal current turbines, but it must be noted that rotor blade velocities are necessarily low to avoid cavitation (maximum tip speed of about 15 m/s) and virtually all marine fauna who frequent high current areas can swim at similar or greater speeds. In fact a ship's propeller, which is accepted usually without question for widespread use at sea, is in practice a far greater hazard to fish and marine mammals as it rotates at far greater speeds and it is carried on a moving vessel that can in many cases travel faster than the fauna. Although the turbines will emit underwater noise, this will serve to warn marine mammals to keep away and is unlikely to be of an intensity or level to cause any serious environmental hazard.

The deployment of large numbers of marine current turbines will raise issues of conflicts over use of specific sea-areas with both general marine traffic and with fishing. In fact large projects will probably need to be surrounded by an Exclusion Zone. However, again, areas with strong currents in close proximity to the shore which are needed for marine current energy generation, tend to be less than ideal for either safe marine travel or for fishing activities. The turbine structures will need to be clearly marked as hazards to shipping (using lights and foghorns in poor visibility) but they may in fact act as navigation aids in marking the extremity of a safe passage rather more clearly than natural features such as rocks.

Visual intrusion is an issue in some locations, but the technology for tidal current energy generation will have a low visual profile with not much of the system visible above the water.

Installation, including onshore associated works, will of course cause some local disruption but it is unlikely to be any more severe than for most construction works.

9.5.2 Opportunities

Tidal stream energy might be useful not just for bulk electricity production but also for niche markets in Scotland, namely the provision of power for remote islands and communities, especially those lacking any connection to the mainland electricity grid, and also as an embedded power source to reinforce grid extremities.

While it is premature to quantify the exact market size and its value, opportunities for tidal stream technology, if reliable and cost-effective systems can be successfully developed, are significant. There are certainly opportunities to use tidal stream technology in many parts of the world, including areas in addition to Europe, such as SE Asia, N and S America and Australasia. Some of the most promising tidal stream resources seem to be in the UK (notably Scotland and the Channel Islands), France, Greece, Norway, USA, Canada, Philippines, Indonesia, Taiwan, China, Japan, New Zealand and no doubt other areas yet to be investigated.

The potential to capitalise on offshore structures by combining tidal stream with other marine technologies like offshore wind and wave energy represents an opportunity for all marine technologies.

10 FORESTRY RESIDUES

10.1 Technology Status

10.1.1 Forest Management

Forest residues arise as a result of the principal forestry operations; thinning and harvesting.

- **Thinning** operations are carried out throughout the growing period of a commercial plantation (typically at 5-year intervals in the case of Scotland) in order to optimise the growing volume of the standing crop and as a supplementary source of revenue. The early thinning operations in the life of a timber crop yield very low volumes of 'merchantable' timber and thus the forest products can be considered to be only suitable for pulping/residue purposes.

- **Harvesting** operations take place when a crop reaches Maximum Annual Increment (MAI), typically 50 years for spruce spp. in Scotland, or for other commercial/biophysical reasons. Commercial plantations are harvested automatically with standardised timber specifications. The 'merchantable' volume is defined by the felling point (i.e. where the stump flair finishes) up to a 7 cm top diameter. This volume is further sub-divided to give a number of products (green logs, red logs and stakes). The residues are often referred to as the 'lop and top' and include the discarded branches, the wood beyond the 7cm diameter limit and the tree stump. A number of factors are taken into account when considering harvesting of spruce plantations in Scotland including susceptibility to windblow (due to high wind speeds and low rooting depths), fungal disease, the costs associated with extraction and the logistics of transportation and processing.

In addition to the operations set out above, dedicated whole tree harvested for the production of energy should not be discounted, especially in light of the current global trend in timber prices, however this represents a significant change in current forestry practice in Scotland so should be viewed as a future alternative rather than a base case scenario.

10.1.2 Energy Content

The most common species of standing tree in Scotland is Sitka spruce, a Canadian softwood variety with an average energy content of 19.5 GJ/odt or 9.4 GJ/t (wet) representing a moisture content of 51.8%. Other common species include Corsican Pine with an average energy content of 18.2 GJ/odt or 7.1 GJ/t (wet) and Norway Spruce with a slightly higher average energy content of 20.5 GJ/odt.

10.2 Market Status

There are no commercial, operational electricity-generating forestry residue-fuelled plant in Scotland. Of the three SRO contracts awarded to biomass schemes (one for each tranche), two are for forestry residue-fuelled schemes. An SRO 2, 2 MW forestry residue-fuelled plant for Arran was recently granted planning permission. A 12.9 MW SRO 3 plant proposed for Inverness-shire is in the early stages of development.

10.3 Industry Status

R-122 remains a valid summary of industry status. Of those key players listed, the developer and equipment supplier Border Biofuels, formerly based in the Scottish Borders and now in Edinburgh, is the most active Scotland-based company.

10.4 Costs

Typical biomass plant costs are around £M 1.6-2 per MW installed. There are a number of drivers that may affect the economics of forest residue utilisation into the 21st century. These include the introduction of the Renewables Obligation, and the introduction of domestic and international climate change policies which could recognise sustainably managed forests as carbon offsets. However, these drivers need to realise an additional source of revenue that offers acceptable and sustainable margins in their own right, and when compared with the economics of other renewable energy technologies which may offer much more competitive rates of return at the same or similar locations.

In order to raise finance for the development of forest residue-based biomass projects, a fuel supply model and long-term contract is vital to cover the supply risk. This model will need to take into account the fuel supply logistics and in Scotland this may be the key constraint to the utilisation of forest residues to generate electricity.

10.5 Constraints and Opportunities

10.5.1 Constraints

- Harvesting and transportation costs: the current practice of harvesting and leaving a brash mat (not a purely Scottish practice) serves a number of purposes including the prevention of forwarding compaction and nutrient recycling, but underlying the practice is the prohibitive cost associated with the collection of forest residues. For a project to be feasible, the delivered fuel costs need to be fixed into long-term fuel supply contracts at a price that allows the project to make sustainable returns.
- Inertia: like any other established industry, the forestry industry will suffer from inertia until it can be perceive that the collection, transportation and combustion/gasification of forest residues makes economic sense.

10.5.2 Opportunities

- With over half of the UK’s standing forests, good potential exists in Scotland for the conversion of residues that arise as a result of forestry operations to thermal and/or electrical energy. As forest production in Scotland reaches a peak over the next 30 years (as a result of intensive private sector planting in the 1960s) and the price of timber continues to fall, the utilisation of forest residues for energy could provide a much-needed additional source of revenue for the Scottish forestry industry.
- Opportunities for small-scale biomass projects supporting localised rural development and provision of employment for remote rural populations: the geographic distribution of the standing forests in Scotland in relation to the population distribution is likely to limit the viability of developing multiple large scale forest residue-based projects (where the economics are much more favourable because of economies of scale) in the short-term but could result in fewer smaller projects within the longer term as the projects become more commercially acceptable.

- Carbon offset benefits for sustainable forest management (maybe through the UK Emissions Trading Scheme)

11 ENERGY CROPS

11.1 Technology Status

For a broad overview of technology and practice, see R-122, to which these sections should be viewed as supplementary.

A number of different crops have been grown in the past for the purpose of generating energy. These crops have included wood, straw and miscanthus for direct generation (harvest to generate) and others such as corn for processing to be used as biofuels (harvest to process to generate). This section focuses on the potential for the utilisation of energy crops in Scotland for the direct generation of electricity but excludes straw (see Section 12 for utilisation of agricultural wastes, including straw).

In the case of Scotland certain crops cannot be utilised for the generation of electricity because of physical growth limitations. Miscanthus is a good example of an energy crop whose use is restricted by the low temperatures in Scotland, whereas short-rotation coppice (SRC) of tree species, in particular willow, offers a more successful uptake rate and potentially high, sustainable yields.

Willow species seem to offer the most suitable characteristics for utilisation as an energy crop in Scotland according to its tolerance of poor edaphic and climatic environments. The tree has an average energy content of 18.6 GJ/odt or 10.5 GJ/t (wet), representing a moisture content of 43.5 %, with coppiced stems used widely around the world for a number of years for purposes such as for burning as fuel wood or for fencing.

Towers *et al*, in "Assessing the Potential for Short Rotation Coppice in Scotland" [44] refer to biomass plant location as being subject to not only the *"physical infrastructure of road and electricity networks but also the biological potential of the surrounding areas to provide a secure supply of feedstock in a cost effective way"*. This point is particularly important to consider and serves to distinguish the utilisation of energy crops, where the resource is still theoretical, from the utilisation of forest residues where a standing resource is present but geographically distributed according to very different criteria. In the context of biomass generation, predictable fuel supply is important in the development of fuel supply models that satisfy the project finance requirements and this factor in the development of the industry should not be understated.

11.2 Market Status

Again, R-122 should be consulted for UK-wide background on the market. The market for energy crops in Scotland is undeveloped due to a number of physical, political and environmental constraints. The starting point for an analysis of the potential market for the utilisation of energy crops is the physical suitability of the land to offer suitable uptake rates and adequate yields. Figure 11.1 below indicates the suitability distribution across Scotland using the results of the MLURI/ETSU project.

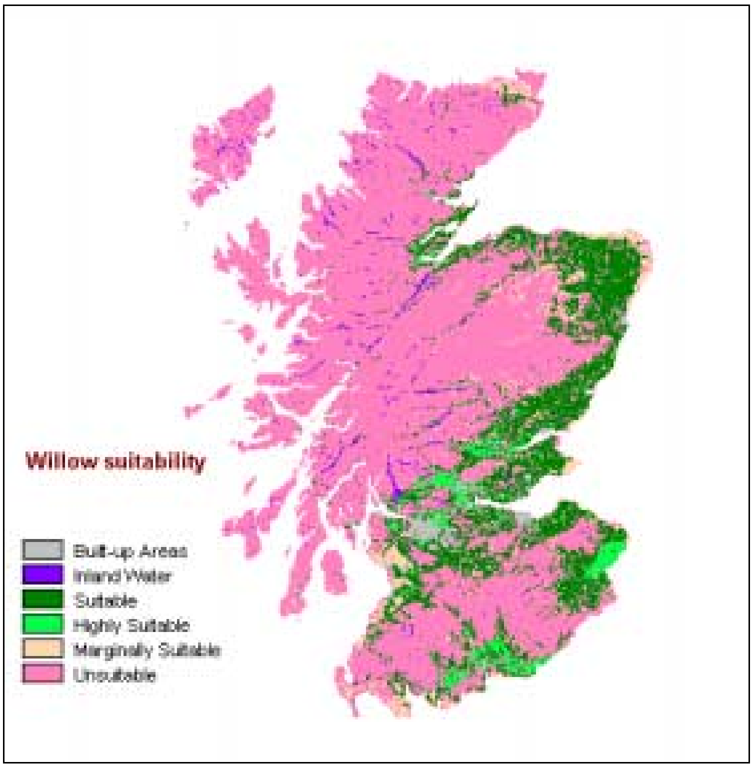

Figure 11.1 Land Suitability Map for Willow species in Scotland

11.2.1 Planting incentives

Specific incentive schemes to encourage the planting of energy crops in Scotland have been discussed with the latest (1999) Rural Development Programme public consultation, resulting in limited interest. An establishment grant for SRC is available through the Forestry Commission's Woodland Grant Scheme, in the form a grant towards the cost of planting SRC on appropriate sites. The scheme distinguishes between planting on set aside land (as part of the Arable Area Payment Scheme), where £400 per hectare is available, and all other land where £600 per hectare is available. There has, however, been considerable interest in this area since December 2001, with current evidence pointing towards a support mechanism in the near future [45].

The Scottish Executive is also consulting on removing certain planning-related protection for prime agricultural land.

11.2.2 Generation incentives

Energy crops are eligible for ROCs under the new Obligations, and in addition energy crop projects will be eligible for a proportion of the £89 million of capital grants that the UK Government has set aside in order to support early offshore wind and energy crops. Biomass, and specifically energy crops projects also benefit from a proportion of the £100 million allocated to support renewables, following the outcome of an energy review by the Performance and Innovation Unit of the Cabinet Office (see Section 2.2.5).

11.3 Industry Status

R-122 remains a current of the industry. There are no commercial energy crop developments in Scotland at present.

11.4 Costs

R-122 presents a table of costs illustrating possible development of costs, based on technology (then under construction) in the first (and only) commercial-scale energy crops plant – the willow-fuelled ARBRE plant in Yorkshire. Table 11.1 below updates these costs based on the final ARBRE costs (ARBRE is due to commission imminently).

Key Parameters	ARBRE	2nd Gen	3rd Gen	Future
Size (MW_e)	8	35	35 - 40	35 – 40[8]
Start up	2001/02	2004/05	2008	2025
Equipment & Building Costs (£M)	18.4	60[9]	45	30
Engineering, development & management costs (£M)	5.8	10.1	10	5[10]
Specific Investment cost (not including land or finance) (£/kW_e)	3000	2000	1560	940
Discount Factor		15%	12%	12%
Fuel Costs (£/GJ)	3.2	2.0	1.5[11]	1.5
Electricity Conversion efficiency (based on wood @50% moisture) (%)	30 %	c. 38 %	c. 44%	44%[12]
Hectares planted[13]	1500	8000-10000	7000-8600	See Footnote 12
Electricity Price (p /kWh)	10.0	7.5	6.0	4.0

Table 11.1 Energy Crops – possible evolution of costs based on new gasification technology [46]

[8] Higher capacities could potentially be achieved in the longer term
[9] Projected equipment & building costs subject to large variation
[10] Engineering, development & management costs subject to large variation
[11] Based on optimistic assumptions
[12] A very high chance this will increase if earlier programmes have been at scale
[13] Hectares planted depends substantially on yields/ha.

11.5 Constraints and Opportunities

11.5.1 Constraints

- Inertia:

Inertia could be overcome through historic record of successful SRC uptake and/or biomass project track record.

- Historic land use trends

Implementation of SRC will require changes long-established in land use patterns.

- Harvesting and transportation costs

These are likely to limit the cost-effectiveness of fuel supply.

11.6 Opportunities

- Diversification opportunities for the agricultural sector
- Potential to plant considerable fuel supply resource according to site location (i.e. tailor made fuel supply logistics)
- Resource proximity to key centres of population
- Industry knowledge and experience: as the forestry centre of the UK, Scotland has extensive expertise and experience in the forest management and processing industries.
- Carbon offset benefits for sustainable crop management (maybe through the UK Emissions Trading Scheme)

12 AGRICULTURAL WASTES

R-122 remains a valid and up-to-date summary of the status of agricultural wastes. This section concentrates on summarising some basic parameters and commenting on any Scotland-specific factors. The majority of the text is reproduced directly from [47].

12.1 Technology Status

12.1.1 Straw

Straw production in Scotland is concentrated along the east coast. The Scottish Agricultural College (SAC) Farm Management Handbook [48] indicates mid-range straw yields of 5.2 t/ha from wheat, 5.6 t/ha from winter barley and 4.1 t/ha from spring barley. Although a large proportion of a standing crop of rape consists of straw, this tends to shatter into small pieces during harvesting, therefore only small amounts of rape straw, perhaps in the region of 2.5 t/ha, can actually be collected using conventional baling techniques. Oat straw it is generally the most valuable as livestock feed, and unlikely to be used for energy production.

Although large quantities of energy could in theory be produced from this resource, it can be argued that there is very little “available” straw in Scotland – nearly all is used as feed or bedding for animals, or to protect horticultural crops (mainly carrots and strawberries). Therefore the potential for straw-fired power stations seems small. R-122 indicates local straw production exceeding local straw demand by 273,000 tonnes in Grampian and 235,000 tonnes in Tayside, but there is a very substantial transfer of straw from the arable farms in the east to livestock farms in the west. The arable farming areas of Scotland are all quite close to hilly livestock areas, with nothing analogous to the large straw surpluses in Norfolk, Cambridgeshire, Lincolnshire and East Yorkshire.

There might be little change in the quantity of straw produced in future years, but animal welfare considerations are likely to bring an increased demand for straw bedding, leaving less available for energy production and leading to an increase in the price of straw. Gross energy value is about 4.15 MWh/t for straw at 15 % moisture content (4.88 MWh/t DM). A power station converting this energy into electricity at 30 % efficiency would therefore generate 1.46 MWh_e/t DM.

12.1.2 Poultry Manure

Most of Scotland's poultry are kept in Moray, Aberdeenshire, Tayside, Fife, Clackmannanshire and Lothian. It is estimated that 75 % of all laying hens in Scotland are currently housed in cages, from which a slurry (which may have undergone a degree of air-drying) can be collected. This slurry can be used in an anaerobic digester together with cattle or pig slurry, but it is difficult to digest poultry slurry alone on account of its high nitrogen content.

Other laying hens, together with the majority of young birds and nearly all poultry for meat production, are housed on a bedding of wood shavings, straw, etc. The mixture of manure and bedding is relatively dry, and can be burned in a power station.

Data on manure quantities have been published in the Scottish Executive’s Code of Good Practice for the Prevention of Environmental Pollution from Agricultural Activity (the PEPFAA code). Each laying hen produces about 0.115 litres of excreta per day, with a moisture content of 70 %. Hens kept on a litter system have 1 kg of bedding material per bird per year, and the litter removed usually has a moisture content of about 30 %. Broilers use around 0.5 kg bedding per bird for each crop, with seven crops per year giving an annual total of 3.5 kg per bird place.

Gross energy value is in the region of 3.29 MWh/t for poultry litter at 30 % moisture content (4.7 MWh/t DM), therefore conversion into electricity at 30% efficiency would yield about 1.41 MWh_e/t DM.

Fewer laying hens will be kept in cages in future (because of welfare considerations), resulting in more dry litter and less wet manure. The current designs of cage will be phased out, though cages offering enhanced welfare standards may still be in use, and perhaps only 25 % of laying hens will be in cages by 2025. However, changes in housing for laying hens would make little difference to the total amount of dry litter in Scotland, which is dominated by broiler production.

The Westfield power station in Fife is designed to use 110,000 tonnes of poultry litter per year (almost half the estimated production from Scotland) and could be expected to take most of the surplus litter from Fife, Tayside, Clackmannanshire and West Lothian. Output of litter would not be sufficient for any other power station of similar size (unless co-fired with forestry residue, SRC or straw). If smaller scale power stations were to become viable, the most likely location would be Aberdeenshire (estimated total litter production 60,000 tonnes/year).

12.1.3 Cattle Slurry

Nearly all the cattle in Scotland spend part of their lives at grass, during which time the manure cannot be collected. When housed, many are kept on straw bedding, producing solid farmyard manure which is not readily usable as a fuel. Calculations have to take into account numbers of animals, the winter housing period for different classes of stock in different parts of the country, and the proportion housed in a way that permits collection of semi-liquid slurry. This slurry is potentially suitable for methane production by anaerobic digestion.

Winter housing periods for dairy cows can vary from five months in the warmer parts of SW Scotland to eight months in the coldest areas. In summer the slurry from dairy cows is only collectable at milking times. On some farms the cows may be housed during the night, but allowed out to graze between milkings, for periods in spring and autumn. Some dairy cows in the mainly arable areas of eastern Scotland are kept on straw bedding, but in the north and west the majority (estimated to be over 90 %) are housed in cubicle or similar systems from which slurry can be collected. Beef cattle are typically housed for rather shorter periods than dairy cows, and in arable areas a higher proportion of them are kept on straw bedding. The housing period and the proportion of slurry collectable have been estimated separately for each geographical area.

The volume of excreta produced are typically assumed to be 57 litres/day for each milking cow, 30 litres/day for beef animals more than 12 months old, and 15 litres/day for cattle of 6-12 months old. Excreta typically have a dry matter content of 10 %. On many farms the volume collected is greater because milking parlour washings, roof water and/or yard water drain into the slurry containers, but such ingress of water does not increase the total dry matter collected. Dilution of the slurry does have serious implications for energy production, because a high proportion of the biogas may have to be used to maintain the temperature of the digester vessel, and transport costs for a centralised digester system are very sensitive to dry matter content.

A digester using cattle slurry throughout the year would need associated storage facilities for about half the annual throughput, unless an alternative feedstock were available during the summer.

12.1.4 Pig Slurry

Much of Scotland's pig herd is concentrated in Aberdeenshire. Adult sows and boars are now generally kept on straw bedding or in outdoor production systems. Most of the slurry is produced by ‘finishing’ pigs, and it is thought that about 70% are currently housed on slatted floors that permit collection of slurry suitable for anaerobic digestion. Average slurry production from finishing pig is assumed to be 4 litres/day at 10% dry matter.

The trend towards housing pigs on straw bedding rather than slurry-based systems seems set to continue, for welfare reasons. This would obviously reduce the amount of slurry available for anaerobic digestion. On the other hand, there may be more stringent controls in future on storage and spreading of animal manures, and pressure on farmers to reduce odour emissions, which would tend to encourage use of anaerobic digesters.

Pig slurry (in contrast to slurry from dairy cattle) is generally produced throughout the year. As with cattle slurry, dilution can seriously affect the digester performance and transport costs.

12.1.5 Other Wet Wastes

Other wet wastes are produced during on-farm grading and trimming of vegetables. Production is highly seasonal, so these would only to be useful in energy production where an anaerobic digester was already justified for non-seasonal wastes such as pig slurry.

Centralised anaerobic digesters are most likely to be viable if co-fuelled with non-farm wastes from abattoirs, food processing factories, etc.

12.1.6 Solid Farmyard Manure

Large quantities of energy are locked up in the excreta and straw that make up solid farmyard manure (FYM) from cattle and pigs kept on straw bedding, but practical systems are not yet available to exploit this source. The compacted nature of the material, together with the binding effect of its straw content, mean that FYM will not readily flow through a digester vessel, while the moisture content renders it unsuitable for direct combustion.

12.2 Market Status

Just one SRO contract has been awarded to an agricultural waste-fuelled plant, namely the 10 MW poultry litter at Westfield in Fife, which was recently (this year) commissioned. It is designed to use 110,000 tonnes of poultry litter annually – which is almost half the estimated total Scottish production – and could be expected to take most of the surplus litter from Fife, Tayside, Clackmannanshire and West Lothian. Output of litter would not be sufficient for any other power station of similar size in Scotland, unless co-fired with other fuels such as forestry residue, SRC or straw. A new project proposed for Corby, Northamptonshire [49] will consume approximately 240,000 tonnes of mixed biofuels including straw, poultry litter and commercial packaging wastes.

If smaller scale power stations were to become viable, the most likely location would be Aberdeenshire (estimated total litter production 60,000 tonnes/year).

Straw burners are used on a small number of farms in Scotland, mainly for domestic space heating – but use of straw as a fuel is less common in Scotland than in the arable areas of England. It is very unlikely that any area of Scotland could supply straw fuel for a power station comparable to the 38 MW plant commissioned in September 2000 in Ely, Cambridgeshire, which uses around 200,000 tonnes of straw annually.

12.3 Industry Status

R-122 remains a valid summary of key industries active in the development of biomass plant. EPRL, based in Bristol and with a Scottish subsidiary, successfully developed the Westfield poultry biomass plant.

12.4 Costs

Recently-constructed power stations quote capital costs of some £1600/kW for combustion of straw (38 MW plant at Ely) to £1800/kW for a similar-sized plant combusting poultry litter (38.5 MW plant in Thetford, Norfolk). Economies of scale are very apparent, with a quoted cost of £2200/kW for the smaller 10 MW poultry litter plant at Westfield, Fife.

Anaerobic digester plant are generally much smaller than those using straw or poultry litter, with capital costs likely to be in the range of £4,000/kW for a 1 MW installation [50, 51]. An increasing number of farms may find it necessary to treat slurry in the future, particularly to reduce odours. Financial viability of a digester system is likely to depend more on the benefit of waste treatment than on the energy-related revenue. In particular, 'gate fees' (payments to the digester operator for treatment and disposal of wastes) may form a major part of the income stream.

12.5 Constraints and Opportunities

Output of agricultural wastes will undoubtedly be influenced by political and economic factors (CAP reforms, enlargement of the EU, world population growth, etc) and technological advances. Decisions on the need to secure food supplies and energy supplies from within UK are a matter for political judgement. However, the pattern of agriculture throughout Scotland is determined mainly by soil type, topography and climate. Thus crop production will almost certainly remain concentrated in the east, and dairying in the south west. Intensive livestock (pigs and poultry) can in principle be produced anywhere, but are likely to remain in the arable areas where feed can be grown locally. Even if the climate in the west of the country changed to become better suited to cropping, the limitation imposed by soils and topography would remain.

Crop yields have risen greatly over the past 50 years, but any restrictions on fertiliser and pesticide use could inhibit further increase. Concern over nitrate and phosphate levels in ground water is likely to result in further restrictions on use of fertiliser or on spreading of fertilisers and manures.

Measures such as declaration of Nitrate Vulnerable Zones and the forthcoming Water Framework Directive are intended to avoid application of more nutrients than the plants can take up, and should therefore have little effect on crop production. If less animal manure is applied to land, more slurry and poultry litter may be available for power stations. Any major move to organic farming could reduce the amount of surplus manure.

Animal welfare considerations are forcing a return to straw bedding rather than slurry-based systems in some areas (less cattle/pig slurry for digestion, but more poultry litter for combustion). If production of crops and animals becomes less profitable, the supply of straw and manures for use in power stations will be reduced. In the past, increased affluence has generally been followed by an increase in demand for animal products, but consideration for animal welfare and human health (e.g. increase in vegetarianism) might alter that pattern.

World prices for agricultural commodities are intimately linked to energy prices, because the largest energy input to agriculture is in manufacture of nitrogenous fertiliser. Any major increase in energy costs could lead to a reduction in use of inorganic fertilisers, and a consequent reduction in availability of animal manures for power generation.

Foot and mouth disease (FMD) has reduced livestock numbers in the south of Scotland during 2001. The affected areas are generally best suited to cattle and sheep production, and a change from livestock to arable seems unlikely. Parts of SW Scotland could probably grow good crops of SRC, but high rainfall might make winter harvesting operations very difficult in some areas. FMD may encourage older farmers to retire, but their land is likely to be amalgamated with neighbouring units and remain in production. The long term effects of FMD on production of agricultural wastes may be quite small, unless substantial areas revert to low-quality grazing or are taken over for forestry.

13 LANDFILL GAS

13.1 Technology Status

Landfilling of waste remains the dominant technique for the disposal of most of the Scotland's waste and, although it is recognized that this is ultimately unsustainable, the practice is set to continue for a number of years.

The degradation of organic waste within a landfill site is complex but the result is a mixture of methane, carbon dioxide, oxygen, nitrogen and many hundreds of trace gasses as well as water vapour, which is collectively known as 'landfill gas'. Typical landfill gas contains [52] 55% methane, 30% carbon dioxide, 10% nitrogen, 4% oxygen and balance of trace elements. It has been estimated that the total number of minor constituents in landfill gas is in excess of 350 many of which are organic compounds. Many factors influence the exact composition of landfill gas from any particular site and methane concentrations can vary significantly.

Older landfill sites, built under the 'dilute and disperse' model, in which liquids were allowed to drain freely from the site, tend to be poorly sealed to the ingress of air and as a result methane concentrations fall under the influence of the extraction systems. More modern fully-lined sites tend to exhibit higher methane and lower oxygen concentrations as a direct result of the improved sealing techniques. Similarly the efficiency with which the gas can be collected will be improved on landfills with improved engineering.

Landfill gas has a calorific value of approximately half that of natural gas, a figure of 17.5MJ/Nm^3 is used in the resource analysis (presented in Volume I). However it should be recognised that the net calorific value will alter depending on the concentrations of other elements within the gas. In particular the presence of hydrogen, formed in the early stages of anaerobic digestion, will increase this value.

Landfill gas utilisation technology has advanced significantly from the installations developed under the original NFFO 1 in 1991. The majority of landfill gas projects utilize internal spark ignition engines with an electrical output range of between 300kW and 1.4MW. The use of 'dual fuel' installations has diminished to near zero although, on some of the large projects, where the operator wishes to use higher capacity engines, this is still an option. Turbine technology has not proved popular in the UK although it has been used in a number of larger installations in the US.

Significant improvements in the reliability and availability of landfill gas plants has been made through improvements in oil and metallurgical technology and these have been matched by improvement in the management of projects. In particular the requirement for extensive gas cleaning technology has, with the exception of highly contaminated sites, been obviated by improvements in the operation and control of the plant as well as technical advances.

There have been few improvements in the technology used to extract the gas from landfill sites. Indeed many operators are now taking a low cost approach to the design and installation of the gas extraction system. This has resulted in a lower capital cost but a slightly increased operational cost.

The limiting factor in availability on many landfill gas plants is the fuel resource. On operational sites access to the gas is often limited by the requirement to transport and place waste, thereby restricting access to areas of relatively new waste that are often rich in gas. Improvements have been made in the assessment of the landfill gas resource and modern computer models have been empirically 'tuned' to provide higher accuracies in the prediction of gas generation rates.

On well managed landfill gas projects, plant availabilities of between 92.5% and 97.5% are regularly achieved but this figure can be a low as 85% where access to the gas is constrained by the site engineering.

There are a number of UK companies providing and installing equipment for extraction, flaring and delivery of landfill gas to power generation projects. Engine technology is almost exclusively imported, with Austria, Germany and the US providing the majority of installations in the UK.

Many of the generating sets used for electricity production from landfill gas are also available in a CHP package. However to date, other than one Scottish site where heat is used to raise the temperature of a leachate treatment plant, there is no heat recovery equipment installed or planned.

For further information, also see [53].

13.2 Market Status

Power generation from landfill gas has been supported in Scotland under the Scottish Renewables Order (SRO). Table 13.1 gives indicates the status of projects currently contracted under the three tranches of the SRO.

Site Name	Capacity MW	Commissioned Date
Greengairs Landfill Scheme	1.89	01/10/96
Greengairs Landfill Scheme	1.89	01/05/96
Dalmacoulter Landfill Scheme	0.96	Not commissioned
Summerston Landfill	2.78	28/07/99
Auchinlea Landfill	1.69	Not commissioned
Greenagairs phase 3	1.96	13/08/1999
Greengairs phase 4	1.96	13/08/1999
Summerston 2 Landfill	1.35	Not Commissioned
Greengairs V	2.2	Not Commissioned
Greengairs VI	2.2	Not Commissioned
Garlaff Landfill	1.3	Not Commissioned
Auchencarroch Landfill	1.98	Not Commissioned
Binn Farm Landfill	1.92	Not Commissioned
Kaimes Landfill Site	2.4	Not Commissioned
Tarbothill Landfill	2.2	Not Commissioned
Riggend Landfill	0.95	Not Commissioned
Drumshangie (Dalmacoulter 2)	0.95	Not Commissioned
Dunlop Landfill	2.41	Not Commissioned
Melville Landfill	2.18	Not Commissioned
Greenoakhill Landfill	3.94	Part Commissioned (2MW)
Contracted Total	**39.11**	
Commissioned Total	**12.48**	
% Capacity Commissioned to date	**32%**	

Table 13.1 SRO contracted landfill status

13.3 Industry Status

There are a number of project developers currently active in Scotland and these can be divided into two distinct groups, namely, waste management companies whose main activity is the operation of the landfill site itself, and project developers who specialize in landfill gas power generation. These are summarised in Table 13.2 below.

Waste Management Companies	
Shanks Waste Solutions	Scotland
Hanson Waste Management	England
(Now owned by Waste Recycling Group)	
Patersons of Greenoakhill	Scotland
Project Developers	
Hyder Industrial	Wales
CLP Envirogas	England
The Ener.G group	England

Table 13.2 Project developers active in Scotland

13.4 Costs

13.5 Installation Costs

Installation costs for landfill gas projects have fallen in line with both the significant competition in the gas extraction equipment market and the increased production rate for engines in the 1 MW to 1.3 MW range.

Equipment costs versus capacity for a small sample of landfill gas power generation projects is given in Figure 13.1 below. The projects for which this financial information was available includes projects installed under all the NFFO and SRO contracts and the predicted cost of projects yet to be commissioned under these schemes. The data also includes some projects that are an extension of existing installations. The installed equipment costs do not include the costs of engineering or financing landfill gas projects but represents only the costs of engines, gas extraction systems and civil engineering. It should be noted that some of the cases studied were developments on sites with existing gas extraction systems that have been transferred to the project developer, reducing the capital costs.

As can be determined from Figure 13.1, there is a significant variation in the installed equipment cost ranging from £260/kW to £750/kW with an average of £526/kW. A survey of project developers active in Scotland, undertaken as part of the current resource study, provided a range of installation costs (excluding the cost of grid connections) of £480/kW (this developer did not include the costs of the gas extraction system) to £560/kW and this is broadly in line with Figure 13.1.

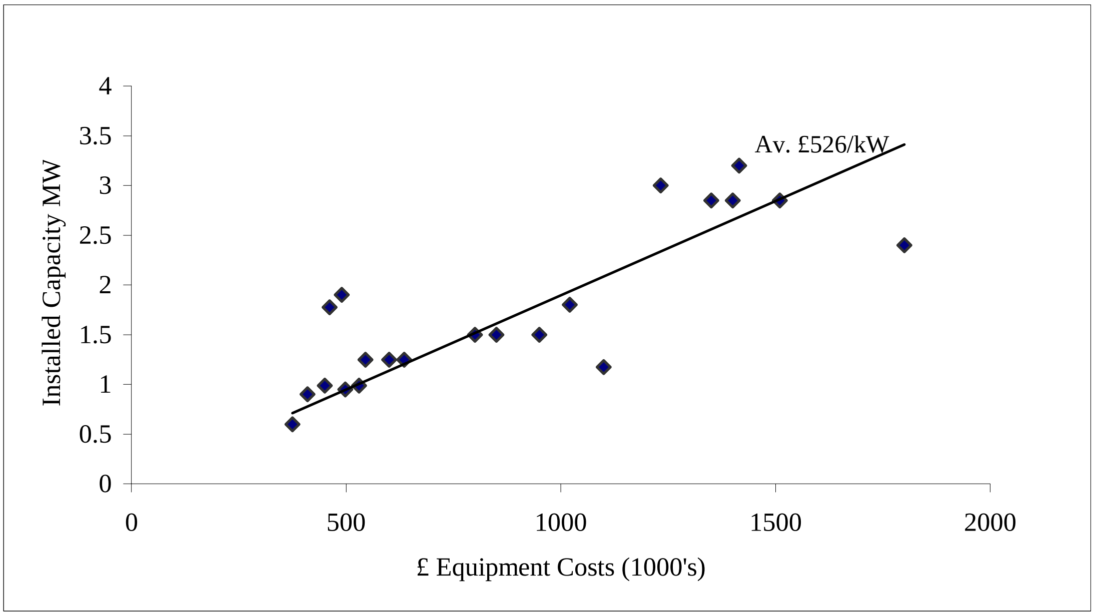

Figure 13.1 Equipment costs

Installation costs for landfill gas plant have been decreasing steadily over the past few years. There are three main factors in this:

- There is a very competitive market in the supply and installation of gas extraction systems. From three main UK suppliers in 1991 there are now over twenty companies providing part or complete gas extraction and flaring plants
- The strength of Sterling against the Euro has reduced the most popular engine costs.
- The main project developers were awarded significant numbers of NFFO5 and SRO3 contracts allowing these to be aggregated to reduce finance and equipment costs.

13.5.1 Operational Costs

Operational costs remain the major factor in the economic performance of landfill gas projects. Rigorous maintenance procedures must be in place to ensure the reliable operation of the projects. On all but the smallest closed landfills, the operation and maintenance of the gas collections system will account for around 30% of the labour costs.

Maintenance of the gas engines is a continuous, almost daily, requirement. Sites that achieve high availabilities are almost invariably those with permanent engineering staff. Table 13.3 below shows the typical parts and oil requirements for a modern landfill gas engine averaged over a twenty year life span. Staffing requirements vary considerably from operator to operator, some preferring lower availabilities and remote operation while others choose to provide full time staff including 24 hour call-out facilities.

Maintenance Item	Average cost / kWh
Oil including analysis	£0.00076[14]
Parts	£0.0035 to £0.0041[15]
Labour	£0.0055 to £0.0085
Insurance and Administration	£0.0008 to £0.0013
TOTAL	**£0.0105 to £0.0146**

Table 13.3 Maintenance costs

Considerable cost savings are available with increased plant capacity, particularly in labour costs, however, other than the Greengairs landfill, it is unlikely that any Scottish projects will be able to take advantage of this as the average current plant size is (contracted under the SRO) 2MW.

All the ‘non waste management’ developers paid a royalty to the landfill site owners for rights to the gas. The value of this royalty is commercially sensitive but from the Authors experience this can range from 0% of revenue (the site owner only receiving the benefit of capital investment in the gas collection scheme) to 20% of revenue on larger projects.

13.6 Constraints and Opportunities

13.6.1 Constraints

Geographical

A number of distinct constraints on the development of landfill gas projects in Scotland can be identified as follows:

- Many existing landfill sites are in remote locations where the cost of grid connection for small projects is prohibitive.
- Many project developers operate on the basis of a central engineering facility servicing a number of smaller plants. Where there is a single isolated project the costs of engineering and support are high.
- Several plants, known to the author, appear to have restrictions based on grid capacity. This may be a function of remoteness, but it is also known that at least one proposed plant is currently unable to obtain a grid connection.

Legislative

The EU Landfill directive severely restricts the rate of input of organic material to landfill to 75% of the 1995 level by 2008 and 25% of the 1995 level by 2018. Inevitably as this directive is enforced the amount of landfill gas produced by each tonne of waste will decline with the organic fraction. However at present there is little evidence that the target set by the directive is going to be achieved.

[14] At oil price of £0.75/L
[15] At € 1.61 / £1

Waste management practice

With the increasing difficulty in obtaining waste management licenses there has been a trend for increasing centralisation of landfill operations. The few new landfill sites that have obtained both license and planning permissions in Scotland over the last years have all, as a condition of their permission, been well engineered large sites. This has meant that waste is now transported over greater distances, and, although this has other environmental issues, gas availability and control is better on these sites.

It is therefore expected that the reduction in organic fraction of the waste will largely be offset against the increased efficiency of gas collection on the remaining large landfill sites. It is therefore predicted that, while landfill gas power generation will not increase greatly, it will continue to provide a high quality base load renewable energy resource within Scotland.

13.6.2 Opportunities

Diversion of organic waste from landfill does not obviate the requirement for a disposal mechanism. With the development of larger scale anaerobic digestion technology it is expected that landfill gas will gradually be replaced by biogas projects. Anaerobic digestion has distinct advantages over aerobic (or composting) technologies, providing improved energy generation (since there is a 100% collection efficiency and cleaner gas), efficient pathogen reduction and a potentially marketable compost.

14 MUNICIPAL SOLID WASTE

14.1 Technology Status

14.1.1 Technology options

R-122 concentrates on combustion (or incineration) of MSW, since when interest in alternative gasification and pyrolysis technologies has increased. Combustion is essentially burning waste with an excess of oxygen to raise steam for driving a steam turbine. Gasification and pyrolysis both involve much higher temperatures with a controlled and limited amount of oxygen (gasification) or with no oxygen (pyrolysis). Waste is heated to derive fuel gas mixtures, which, in the case of pyrolysis can also be condensed into a transportable fuel oil. Gases can be used to fuel conventional boilers, internal combustion engines or gas turbines.

Gasification and pyrolysis promise better conversion efficiencies than combustion when used in conjunction with gas engines and turbines. Primarily though, the potential benefits of gasification and pyrolysis are that they offer more flexible waste management options – offering more scope for recovery and re-use of materials and a wider (and smaller) range of plant sizes. Also, because exhaust gases contain less pollutants than with combustion, less pollutants are released and environmental mitigation costs are lower.

While there are over 100 waste-fuelled gasification and/or pyrolysis facilities operating or ordered worldwide [54], there is some variation in systems and technologies employed, and more operational experience is required for the technologies to be considered fully commercially proven. Furthermore, there is still a belief in some quarters that these technologies are only commercially viable at the smaller end of the scale (annual throughputs of 100,000 tonnes or less).

14.1.2 Waste management

Regulatory pressures and policy drivers on the waste management industry have intensified following the adoption of the Landfill Directive (at the European level), Packaging Regulations, the National Waste Strategy for Scotland – and the associated Area Waste Plans – and the soon to be adopted new Renewables Obligations.

The Landfill Directive [55] requires alternatives to landfilling to be developed, and targets are unlikely to be met without a contribution from energy recovery technologies. Key requirements of the Directive are as follows:

- A reduction of biodegradable municipal waste disposed of in landfill to 75% of 1995 levels by 2006; to 50% by 2009; and to 35% by 2016
- A majority of whole tyres banned from landfill from 2003. Shredded tyres banned from landfill from 2006
- No liquid wastes, infectious clinical wastes or explosive, corrosive, oxidising or flammable wastes to be disposed of to landfill by 2001
- No co-disposal of hazardous and non-hazardous waste

Packaging Regulations oblige users to recycle or, to an extent, recover (including energy recovery) certain percentages of packaging, or purchase Packaging Recycling Notes (PRNs, tradable credits for recycling or recovering).

Scotland's National Waste Strategy, [56] published in 1999, establishes 11 Waste Strategy Areas (WSAs) responsible for developing Areas Waste Plans. It sets out a waste hierarchy which, in descending order, comprises waste minimisation, re-use, recovery (recycling, composting and energy recovery) and lastly, landfill. On energy recovery it states that "*the future of energy from waste probably lies in emerging cleaner technology such as pyrolysis, gasification or anaerobic digestion.*" SEPA has also published guidance for the development of Area Waste Plans [57], which advises that "*Energy from Waste produced by various technologies will prove to be an important aspect of integrated waste management in the future and should be considered only after reuse and recycling options are exhausted*."

While the Scottish Executive will still have a role in overseeing the Area Waste Plans, to ensure that national objectives are met, the primary determinant of the role of energy recovery in Scotland will be the outcome of the Area Waste Plans. Some 2 WSAs – Forth Valley and Argyll and Bute – have issued draft waste plans and a further 6 have published "issues" papers for consultation [58].

As part of a wider strategy which includes minimisation and recycling, the Forth Valley Area Waste Plan envisages an EFW plant by 2020, or if targets are not met, "*earlier than 2013*". The Plan "*rules out incineration as a way of producing energy from waste"* stating that *"the future of energy from waste may lie with cleaner technologies such as pyrolysis or gasification.*"

Argyll and Bute's Plan also proposes, as part of a wider strategy, gasification or pyrolysis of waste from around 2010. It acknowledges that it may be practicable to share such a plant across WSAs.

14.2 Market Status

Support for the entire output of all EFW plant was available under SRO. Six contracts in total were awarded, one of which – the 8.3 MW Baldovie combustion plant in Dundee – is operational. A second 7.2 MW gasification and pyrolysis project in Dumfries and Galloway was recently awarded planning permission. There is also an operational combustion plant in Lerwick, Shetland, which was developed without an SRO contract.

Support under the new Renewables Obligations will only be available for energy recovery from the biodegradable fraction of waste, using gasification and pyrolysis technologies. This might be expected to have a limiting effect on the development of EFW plant, but it may in fact have little impact (in itself) for two reasons:

- First, the combination of council waste gate fee revenues, electricity revenues (without any additional 'green' value under the NFFO or otherwise) and some revenues from recycled materials, proved sufficient in a waste contract for incineration, signed recently in Wales. There is no strong reason to suppose that these project economics will worsen solely because of lack of support in the new Obligations. The biggest impediment to the commissioning of new EFW capacity is more likely to be planning risk.
- Second, there have been significant advances in gasification and pyrolysis technologies since 1998. Compact Power, a British company, commissioned a gasification/pyrolysis plant near Bristol in Spring 2001, and received planning permission for a second plant (the previously mentioned SRO contracted plant) in Dumfries and Galloway in Summer 2001. Brightstar Environmental, a subsidiary of Australia's Energy Developments Limited signed a 4-year contract with Derby County Council in Summer 2001 to use its SWERF gasification technology to manage the Council's waste. In September 2001,

Kent County Council selected Brightstar as preferred tenderer for a 20-year municipal waste contract.

These contracts demonstrate that gasification/pyrolysis technologies are entering the mainstream of waste management practice in Britain. Further inroads are expected in the near term, given the partial support from the new Obligations and Councils' increasing awareness of these new technologies. In conurbations such as the Glasgow area, where waste arisings are relatively high, conventional incineration technologies may be chosen, and indeed the Glasgow and Clyde Valley WSA waste options paper suggests at least one mass burn plant (as well as gasification/pyrolysis facilities), for all options which contain an element of EFW.

Notwithstanding the influx of new technologies, conventional incineration still plays an active role in new waste contracts, especially now that their emissions have stricter controls under the Integrated Pollution Prevention and Control Regulations. The Dundee EFW plant, commissioned in 1999, utilises a 'fluidised-bed' boiler. An integrated waste management facility under construction in Neath Port Talbot will utilise a 'moving-grate' boiler using pre-sorted and densified refuse-derived fuel. Both technologies are being proposed at other sites in England and Wales.

Integrated waste management centres or parks where combinations of recycling, composting and/or energy recovery take place may become prevalent in the future. Such waste centres are currently being proposed in Aberdeen County Council, Argll and Bute and Dumfries and Galloway.

14.3 Industry Status

In addition to the firms mentioned in R-122, the following companies are involved in the two SRO projects either commissioned or in receipt of planning:

- Baldovie, Dundee: the project was developed by Dundee Energy Recycling Ltd, a joint venture between BICC, Kvaerner and Dundee City Council.
- Dargaval, nr Dumfries: Batneec (Dumfries) developed the project, which uses a combined pyrolysis and gasification technology developed by Bristol-based Compact Power.

Shanks Waste Solutions has also recently signed a waste management contract with Argyll and Bute council, and is preferred bidder for Dumfries and Galloway.

14.4 Costs

Costs for conventional mass burn technology are quoted in section 3 of Volume I at £M4.05/MW. There is a lack of data on commercial costs for gasification and pyrolysis. Compact Power [59] quote around £M10 for a 32,000 tonne plant, which, depending on the fuel, equates to around £M3-3.8/MW. Independent commentators say that *"many studies have shown that gasification and pyrolysis can be commercially feasible. But, in our experience, project costs are rarely significantly lower than conventional alternatives. Individual projects need to be considered on a case-by-case basis to determine whether the economics are viable."* [54]

14.5 Opportunities and Constraints

14.5.1 Opportunities

- The Integrated Pollution Prevention and Control (IPPC) Regulations

The IPPC regulations provide EFW project developers with an opportunity to demonstrate that modern EFW plants using conventional technologies operate with emissions below prescribed levels. The IPPC regime is a lot more rigorous than the previous regime, so a successful application should allay the concerns and fears of the general public.

14.5.2 Constraints

- Planning risk

Failure to obtain planning permission for proposed EFW plant is the biggest impediment to achieving the resource potential. Reasons for such failure include:

- Public fears about the level of dioxins and other chemicals in emissions from EFW plant
- Poor site selection;
- Local politics.

It is hoped that the introduction of Area Waste Plans would improve the chances of well thought-out EFW schemes gaining planning permission by identifying suitable brownfield sites that may be used.

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