Chapter 4: Energy Case Studies

The Cadamstown/Ballyboy project has two relatively unusual features. One is that it intends to produce its energy from three sources, water, wind and biomass. The second is that it intends to develop a direct line distribution system, the first in the Irish Republic. One of the case histories below therefore concerns the use of two energy sources, the other two are about direct line electricity grids.

1. Blackwater Valley Museum, Co, Armagh

The closest parallel we have been able to find to the project's multi-source feature in actual use in Britain and Ireland is at the Blackwater Valley Museum in Benburb, Co. Armagh, where the museum has a 75 kW Francis turbine in the river Blackwater producing on average 55 kW which is exported to the grid. Since 1999, the museum also has a wood fuelled, combined heat and power unit providing heat for space heating and domestic hot water at the museum and which supplies the grid with enough electricity for around 400 dwellings. The CHP plant, the first continuous feed, zero liquid waste, downdraft CHP unit operating on wood chips in the world, was installed to provide alternative farm income The fuel for the gasification plant will eventually be a mixture of wood from existing forests and coppiced willow from local farmers. However, until grants are available to encourage farmers to grow willow, the unit uses chipped sawmill waste which is delivered by lorry to the museum twice a week.

There is a significant potential for willow coppice in Northern Ireland since it has about 1,000,000 hectares of agricultural land and it is estimated that around 70,000 hectares could be turned over to arable coppice in the counties Fermanagh and Tyrone alone without the loss of farm income. Nearly 80% of the growing work is carried out from December to March, which allows farmers to diversify into a winter crop. Over the 15 year supply contract approximately €2 million will be spent locally on fuel and labour.

Studies in the UK show that sustainable yields in the excess of 12 oven dry tonnes per hectare per year can be expected (oven dry is defined as containing approximately 5% water – chemically bound in the wood). The gross calorific value of the oven dry wood chips is around 5.4 kWh/kg. According to the ETSU (the British Energy Agency) study "Renewable Energy Resources in Northern Ireland", the potential accessible resource of electricity generated from coppice energy crops grown on 70,000 hectares is 170 GWh/year. This is equivalent to a 54 MW power station. From an environmental point of view the use of willow coppice as an energy source is attractive. Apart from the saved CO_2-emssions, the emissions of SO_2 and NO_x are considerably lower than the emissions associated when burning fossil fuels.

The Wood Fuelled CHP Unit

The wood fuelled CHP unit was built in Northern Ireland by Exus Energy. It first dries the wood using waste heat from its co-generation unit from approximately 50% water content to 10 - 15%. In the gasifier, the wood chips are heated in a restricted airflow, which converts them to a combustible gas and clean char. The gas consists of hydrogen, carbon monoxide and methane plus carbon dioxide and nitrogen.

The gas is cleaned, cooled, mixed with air and fed into the engine. 5 - 10% of the fuel is diesel, which is supplied as the ignition source is the compression ignition. The size of the co-generation unit was dictated by the electricity supply contract of 200 kWe, This produces 400 kWt of heat after drying the feed to the unit, approximately the requirement of the museum. The electricity is produced at a voltage of 415 V. This is transformed to 11 kV and carried away on the NIE grid. The engine exhausts contain a considerable amount of heat, which is recovered by diverting it through heat an exchanger. Heat from the engine jacket is also recovered. This energy is partly used for drying the wood chips and partly for the heating of the museum.

There is a back up oil boiler for the museum when the CHP-unit is out for maintenance or on very cold winter days. There is insufficient surplus heat to supply other buildings. The plant, which cost €280,000 is capable of 24 hours per day, unmanned operation for a period of six days after which the residual charcoal is removed and the wood chips store replenished. Its life should be similar to that for a conventional steam electricity plant. All over energy efficiency is 70%. Yearly production of heat and electricity is 1300 MWh and 2600 MWh respectively. The price the museum gets for the electricity for the electricity is the price at which it buys it, 0.11 € per kWh.

Evaluation

It is claimed that the project has successfully demonstrated the technical potential for small-scale wood gasification for co-generation purposes. Doubts, however, persist about the reliability of the Exus equipment and two telephone calls to the company for further information on this aspect went unanswered. What is known is that a wood-fired CHP plant which the company installed at the Beddington Zero Energy Development Project (BedZed), an innovative mixed workspace and housing development outside London, has given trouble. Exus Energy designed, installed and commissioned a 130kWe CHP unit there to provide the site's entire domestic electricity and heat demand. Nevertheless, we believe that tried and tested CHP equipment suitable for burning chipped willow and Sitka spruce is available from companies in Germany and Austria.

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2. Woking Borough Council

CHP direct line networks have the advantage that a small network reduces distribution losses (which represent around 6-10% on a typical national system). They also avoid all the charges for connection to the national grid, plus the charges levied by it for the use of the transmission network and the distribution network.

Woking Borough Council had already set up seven small community heating networks for its sheltered housing facilities by 2002 with electrical output varying between 20kW and 50kW. These supplied the tenants with electricity and heat from cogeneration units and purchased top-up electricity at bulk rates from the grid although in practice they were designed to run with 80% of the electricity used in house and 20% sold as ‘spill” to the public system, thus cancelling out standby and top up charges. Tenants paid an estimated amount each month and this was corrected from time to time when their actual consumption was measured during service visits. The old public electricity service cables were left and could be reconnected by anyone who wanted to go back to the national public supply. None had done so as the residents saved between €110 and €180 per year depending on the size of their house.

Before 2001, British law restricted the size of these networks but, aware this was to be changed, Woking decided to investigate the setting up of a company to manage its energy services. It commissioned a study with a government grant to investigate the securest legal framework to establish an ESCo. This led it to set up an Environmental and Energy Services Company (EESCo), Thameswey Ltd, in 1999 as a wholly municipally owned non-profit making company which can enter into partnerships to deliver energy services to customers.

Thameswey set up a subsidiary to do this, Thameswey Energy Ltd. in 2000 in which it holds a 19% share. The remaining 81% is held by a Danish company, ESCo International A/S, which is owned by Miljø-Sam Holding APS. This in turn is owned by a Danish pension fund and Hedeselskab, a foundation committed to environmental projects which owns of a Danish green energy company. This balance of ownership was necessary since the capital expenditure of any company that is owned 20% or more by a local authority is automatically added to that of the local authority, so limiting the local authority’s expenditure.

Thameswey Energy Ltd then prepared a total energy scheme for the centre of Woking. This scheme serves the civic offices, two hotels, a conference and events centre, a leisure complex, a night club and a multi-storey car park. The system has included 1.46 MWe of conventional CHP, 163 cubic metres of thermal storage and 1.4MW of absorption cooling, supplied to the clients by separate heat and chilled water pipes and both high and low voltage direct line networks. The system runs a permanent surplus of about 30% which is exported to the council’s other sites. Since it never needs back up, the system operates in island mode and can supply all the needs of the properties connected to the system. Woking’s intention is that Thameswey should install CHP or other green energy systems in all its properties by 2007.

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3. Dundalk Institute of Technology

Dundalk Institute of Technology (DkIT) installed a Vestas V52-850kW wind turbine in the early autumn of 2005. This is intended to operate as an "autoproducer", i.e. supplying Dundalk IT needs first, with any excess flowing out to the grid. but, in order for permission to be obtained to connect the turbine into the Institute's electrical system and thus, indirectly to the grid, the Institute had to undertake not to supply the grid at all.

photomontage showing the Dundalk Institute of Technology campus, the turbine and the Irish Sea in the background.

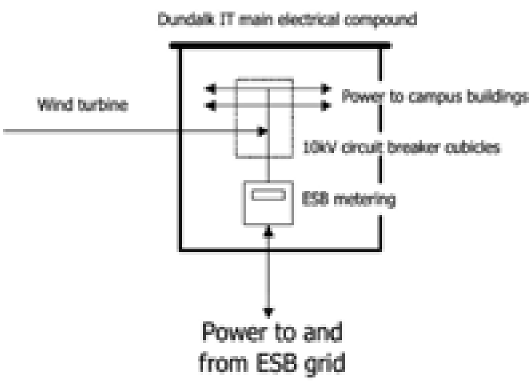
This situation arose because the ESB National Grid had called a moratorium on grid connections for wind projects in December 2003. After the agreement of a new grid code for wind turbines, this moratorium was lifted in October 2004 but there was a huge backlog of projects awaiting connection. The National Grid stated that connections would resume in the order in which they had been received. This meant that, if it said that it would supply at the turbine's full rated capacity, DkIT would have to wait some years for its turbine to be connected. If, however, it said that it would never supply more than 499kW to the grid, the project would fall outside the queuing arrangement and, under the regulations, be eligible for immediate connection. However, the National Grid said that the connection would have to be negotiated with the Commission for Energy Regulation first and, since DkIT already had the turbine in place and wanted to connect up straight away and not after an indefinite delay, it agreed not to supply the grid at all.

This will cost the project an estimated income of €50,000 a year from selling its electricity into the grid under an agreement it has with the green electricity supplier Airtricity. However the net loss is only around €25,000 as it will not have to pay 'Use of system' charges of €2,000 a month. At the time of writing, DkIT was planning to open the negotiations with the CER.

DkIT was paying the price of being a pioneer. Its turbine is believed to be the first large commercial one on a college campus in the world. It will supply most of DkIT's electrical needs. Because of its location on the east coast, which is less windy than the west of the country, the load factor will be approximately 30%, rather than the 40% that characterises typical Irish windfarms. In spite of this, the economics are favourable since the electricity produced will offset power purchase at the retail rate. The turbine will pay for itself in reduced electricity bills in less than six years even if electricity does not increase in price over the period.

A grant of €427,000 was made to the project by Sustainable Energy Ireland on the basis that it had great potential for replication since many businesses and institutions are located at relatively high wind sites and could potentially supply a portion of their electricity from a wind turbine, in similar fashion to a CHP plant. The remainder of funding was secured internally, with no need to approach financial institutions.

The wind turbine is connected into the internal DkIT 10kV grid as shown in Figure 1. Power will be metered in both directions when CER approval is given so that, when the turbine produces more than is needed on campus, the surplus which goes to Airtricity through the grid can be measured. Until then, DkIT will try not to supply power but has no way of preventing this happening short of closing the turbine down. When the turbine produces insufficient power for the campus, then the needed extra amount automatically will come in from the grid to make up the difference. Because wind turbine supply almost never exactly matches DkIT demand, the connection to the grid is essential to balance supply and demand.



Much of the electricity produced will displace retail power purchase, i.e. the electricity produced by the wind turbine is worth the retail (not wholesale) rate per kilowatt-hour. This effectively doubles the value of electricity produced.

Fig. 3.1 Proposed Dundalk IT grid connection

The terms and conditions for distribution-connected wind turbines are laid down in the ESB Distribution Grid Code. The DkIT turbine could have been categorised either as an “Autoproducer” or as a “Generator under 2MW” but since DkIT is using its electricity locally, it was designated an Autoproducer. It is possible to be either an “importing” or an “exporting” autoproducer, and these incur different connection fees and ‘use of system’ charges. If the turbine’s maximum export capacity (MEC) exceeds its maximum import capacity (MIC) then the operator is an Exporting Autoproducer and vice versa.

During the planning of the project, an economic model was used to calculate its financial prospects. Factors such as ‘use of system’ charges, maximum demand charges, the cost of supplied electricity (depending on time of day and day of week), value for emissions trading (to be implemented in Ireland in 2005), value for electricity bought by Airtricity, etc. were included in the calculations. It was assumed that DkIT’s electricity demand will increase by 5% annually as planned campus construction takes place, but that in 2010 demand will level off as any new demand will be balanced by energy conservation measures. The total turbine project cost for the 850kW turbine is €1,127,000. This is rather high due to the fact that Dundalk IT must pay VAT. However its electricity bills are reduced by the price of electricity including VAT.

As can be seen in table 1, the turbine pays for itself in less than nine years at even with the assumption of no electricity price increases. Larger turbines were not analysed by the model since the local grid will not accommodate turbines greater than one megawatt in capacity.

Note that the annual savings is a net figure, which has been reduced by annual expenses such as O&M, rates (taxes) and other costs totaling €37,000 per annum. It is unlikely that Dundalk Institute of Technology would have pursued the project without the grant support, which makes the project economics very attractive.

Turbine	Wind (m/s)	annual Gwh	Load Factor	% to grid	net annual savings (x1000)	simple payback (no grant)	IRR (no grant)	simple payback (w/grant)	IRR (with grant)
V52	6.6	2.214	30%	39	€126.3	8.8 years	0%	5.5 years	14.6%

Table 1 – Results of economic analysis for DkIT wind turbine operating as an importing autoproducer.

EVALUATION

The grid connection problems experienced by this project have very important lessons for Cadamstown and Ballyboy – namely, that unless a lot of electricity is being sold into the grid, it may not be worthwhile selling any at all because of the use-of-system charges and the additional bureaucracy.

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4. Rural Generation Ltd.

Rural Generation is a small private limited company formed in 1996 by John Gilliland to commercialize an R & D project undertaken by the Department of Agriculture in Northern Ireland involving gasifying willow chip to produce heat and power. Mr. Gilliland had been looking at alterative land uses from the 1990s and had planted some willow coppice in 1994 in association with the Horticulture and Plant Breeding Station at Loughgall, Co. Armagh, on his Brook Hall Estate in Co Derry. Further plantings have taken place since and the farm now has 45 hectares of which 15 hectares are harvested each year.

Willows may be planted from March to June, and planting can be by hand or by automatic planter, which is normal on areas greater than 1 acre. The planter shown is capable of planting 4 rows at a time. Willows are usually planted in double rows, with cuttings 70cm apart in each row, with a space of 1.4m between double rows. A cutting 20cm long is taken from a rod approximately 3m long. The cutting is put into the ground vertically without an established root system. Cuttings are usually planted at 14,000 to the hectare.

Willows will grow in most soils, except highly organic. Ground preparation is important, and includes ploughing, power harrow and rolling. Rabbit fencing is critical for the first six months of growth, until the willows are established. The only pest that is likely to cause problems at the early stage is the leatherjacket, which will eat the cuttings unless treated.

Typically in the first year the willows will grow to a height of approximately 1.5m. They will grow a single stem. It is normal to mix 5 or 6 different clonal types when planting. Willows are susceptible to attack by rust, which will affect the leaves. While rust will not actually kill the plant it will effectively destroy the willows ability to transpire through the leaf and will severely stunt growth. The use of poly-clonal types will completely eradicate damage from rust.

In the winter at the end of the first year of growth the willows are cut back to ground level, usually using a finger bar mower. When the plant re-grows in spring of the second year it will “multi-shoot” and 5 or 6 stems will be reproduced from the original single stem plant. This coppicing is done to increase the yield. After cut back the willow will usually grow 3-4m in the first year. It will continue to grow for another two years after which time it is harvested. Further harvesting usually takes place every three years. This has been found to provide the best yield because if crops are harvested every one or two years their bulk yield is small while past year three, the percentage increase in bulk yield is marginal.

Brook Hall Estate uses a modified Claas forage harvester that makes chip. This is fed directly into trailers and taken back to the farmyard. The willow normally yields approximately 30 dry tonnes of chip per harvest. As the harvest is only done every three years this equates to 10 dry tonnes per hectare per annum. The harvester can cut up to 8 hectares per day in good conditions. Even though the harvesting is usually carried out in January or February the ground tends to be dry as a result of the willow establishment.

Willow harvest, Brook Hall Estate, 2002

Traditionally willow is harvested by rod. This can be carried out by using a strimmer, or by a mechanical rod harvester. The main benefit of rod harvesting is that is avoids the necessity for drying the willow before combustion. At harvest time willow is usually about 55% moisture content. If chipped, the chips will have to be dried or the biomass will effectively create a compost heap, with a considerable loss of combustible material.

If rod harvested, the rods can be stacked at the end of the field, and by early summer they will have dried naturally to approximately 35% moisture content without any degradation of the fuel.

Rod harvesting is labour intensive, and is impractical for large areas. However, for smaller plots, and where drying facilities are not available, rod harvesting is far more cost effective.

Table 4.1: Establishment Costs of Short Rotation Coppice Willows

Actual costs per hectare	
Ground preparation	**€ 98**
Ploughing, power harrow and roll	
Mechanical planting	**€ 448**
Carriage, tractor and step planter hire	
Willow cuttings	**€ 1,386**
15,000 cuttings/ha, carriage and cold store	
Rabbit fencing	**€ 611**
Labour and material	
Cut back, after first year's growth	**€ 41**
Reciprocating finger bar mower	
Weed and pest control	**€ 424**
Including pre ploughing and post cut back	
Total establishment costs	**€ 3,008/ha**

Table 4.1 gives an indication of the cost of planting willow coppice per hectare. The total indicative cost is approximately €3,000 per hectare. This includes for mechanical planting, cuttings, fencing and weed control which is important in the first year of growth. Planting costs in Scandinavia are approximately €2,000 per hectare because their industry has established a "critical mass" which ensures economies of scale particularly with regard to the cost of cuttings and the hire of mechanical planters. As the industry develops in this country it is expected that establishment costs will fall.

Table 4.2: Willow Costs Per Rotation

1.	**Harvest Cost – depending on system employed**	**€ 490-€815**
2.	**Weed Control**	**€ 116**
	Weedazol, 10 litres per hectare; simazine, 4 litres per hectare	
3.	**Fertiliser – optional**	**€ 103**
	100kg of nitrogen per hectare	
	20kg of phosphate per hectare	
	100kg of potash per hectare	
Total of Rotational Costs		**€ 709-€1034/ha**

Table 4.2 shows the typical cost of maintaining and harvesting the willows per rotation. The harvesting cost depends on whether it is by hand or by machine and on the volume i.e. a large area, in excess of 10 hectares, harvested by machine is likely to be around €600 per hectare.

Heat from biomass

Gasifier and generator building with grid connection, Brook Hall Estate

Rural Generation Limited has taken on the Irish agency for Farm 2000 boilers. There are several different boiler types within the range including Big Bale boilers, High Temperature boilers and automatic feed Swebo boilers. Big Bale boilers were originally designed to accommodate full size round bales. It is now more usual to burn waste products such as timber, cardboard or paper than to burn materials that have a value such as straw.

The automatic feed Swebo boilers consist of a full storage hopper, a combustion chamber and a modified boiler. In automatic feed mode the wood chips or willow chips within the hopper are delivered to the round combustion chamber by a screw auger. The rate of combustion and the amount of heat produced can be regulated by the auger speed. Full combustion takes place within the ceramic pot, and a flame is then feed into the boiler chamber, where the water is heated.

The automatic feed systems can also be operated in manual mode, where the fuel is fed directly into the boiler through the usual door. This allows the operator to use a range of waste fuels such as cardboard, paper, logs etc. While it is labour intensive it can be cost effective if the fuel has no cost.

(Figure 6D6) Woodchip Heat/Energy Cost Comparison

Woodchips (30% moisture) Delivered cost per tonne into Boiler/silo	Energy cost from Woodchip (approx. Efficiency 75%) in cents/KWH	Oil 22c /litre 4.98	Oil 25c /litre 5.70	Oil 28c /litre 6.41	Oil 31.5c /litre 7.13	Oil 34.5c /litre 7.86	Without VAT Heat cost in cents/kWh at 75% efficiency
€48	1.75	57%	50%	44%	40%	36%	
€67	2.03	68%	58%	52%	46%	42%	
€86	2.33	78%	67%	59%	53%	48%	
€73	2.61	88%	76%	68	60%	54%	
€82	2.91	96%	83%	74%	66%	60%	

Table 5 shows the comparative cost of wood chips versus oil. For example, if wood chips are being purchased at €73 per ton, and heating oil is costing 0.34.5c per litre then the heating bill for a system running on wood chips will be 54% of the comparative bill for an oil fired systems. Since heating oil is now over 60 cents a litre, the potential savings are very large.

It is worth noting that these costs are based on wood chips with 30% moisture content. However, the willow chips produced by Rural Generation typically have moisture content of approximately 10%. Therefore, the savings will be greater because the calorific value of timber rises as the moisture content falls. Taking the €73/0.22p per litre oil scenario, for wood chips at 10% moisture the comparative cost would be 34% i.e. heating by wood chip would be 34% of the cost of heating by oil.

A gasifier was built under a Non Fossil Fuel Obligation (NFFO) contract at Brook Hall Estate in Derry with a capacity of 95kWe and 200kWth. It has been producing heat and power for the past eight years. The gasifier has been modified continuously as part of a managed development programme and is now capable of producing 200m_ of wood gas per hour. This wood gas is used to drive a diesel engine that in turn is linked to a generator. The generator produces electricity, which is exported to the Northern Ireland grid via the transformer shown in Figure 4. The gasifier comprises a 9m_ stainless steel hopper, which holds wood chip or willow chip. This feeds a down draft gasifier that is linked to an Iveco diesel engine. The system runs in batch mode and typically operates for 12/14 hours per day producing electricity and thermal energy. The thermal energy (hot water) is used to dry cereals on the 400-hectare Brook Hall Farm. The heat is also used in the winter months to dry willow chip that will subsequently be used in the gasifier.

The capital cost of the gasifier was approximately €2,000 per kW. This includes containerised units, hopper, control system, electricity generating system, safety mechanisms, heat exchangers on the engine exhaust and the engine cooling system and all installation and commissioning. The cost does not allow for structural modifications to accommodate the CHP unit, compressed air supply, fuel storage silo or grid connection costs.

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