Energy Use in Agriculture

Teagasc

Agriculture and Food Development Authority

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FOREWORD

There are many factors at the present time that influence us to consider renewable energy options. On the wider scale we need to tackle climate change by reducing the level of greenhouse gases in the earth's atmosphere. At a national level we need to improve our energy security by reducing our dependence on imported fossil fuels. At an independent farm level, an investment in renewable energy can both reduce the high cost of energy inputs and provide an additional source of income for the business. It also will give a green image to our production which is of increasing importance in the market-place.

In farming, energy costs may only represent a small percentage of turnover, but reducing them can directly increase profits and competitiveness. Continued research and development is essential to the future success of the agriculture and forestry sectors in contributing to the growth of renewable energy. It is equally important that the roll out of the findings of that research through knowledge exchange and technology transfer activities is delivered efficiently to the sector.

Reducing energy use makes perfect sense; it saves money, enhances corporate reputation and helps everyone in the fight against climate change. Looking ahead, Teagasc are keen to ensure that the agricultural community are represented in the renewable energy area. We will work with our stakeholder base and take their views as policy evolves in this area.

I hope you find this publication informative and beneficial in reducing your energy costs either through implementing better on-farm efficiencies or through the deployment of renewable technologies.

G. E. Boyle

Professor Gerry Boyle
Teagasc, Director

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CONTENTS

FOREWORD 2

ACKNOWLEDGEMENTS 3

CONTENTS 4

INTRODUCTION 5

SECTION 1

ENERGY EFFICIENCY IN AGRICULTURE 6

INCREASING DAIRY ENERGY EFFICIENCY 7

ENERGY USE ON PIG FARMS 15

ENERGY USE IN POULTRY FARMING 21

ENERGY DEMAND-REDUCTION TECHNOLOGIES FOR POULTRY FARMS 25

OPPORTUNITIES FOR ENERGY EFFICIENCIES IN CROP & GRASSLAND OPERATIONS 28

ENERGY EFFICIENCY IN HORTICULTURE 37

SECTION 2

INTRODUCTION 48

ANAEROBIC DIGESTION (AD) POTENTIAL 49

BIOMASS - COMBINED HEAT & POWER 55

HYDROELECTRICITY 58

MICRO-GENERATION FROM WIND 62

SOLAR PANELS 66

SOLAR PV 69

PRODUCING HEAT FROM BIOMASS ON THE FARM 72

GROUND/AIR/WATER HEAT PUMPS 77

APPENDICES

- APPENDIX 1 82
- APPENDIX 2 84
- APPENDIX 3 85
- APPENDIX 4 86

Section 1

Energy Efficiency in Agriculture

Farming has a dual role to play in the renewable sector; growing and supplying bioenergy feedstocks and in the generation of renewable energy, through on-farm technologies (both for consumption on-farm and also potentially to be exported onto the electricity grid). Aside from the provision of feedstocks, Irelands land-base is a key provider of wind energy; either for accommodation of large-scale onshore wind turbines or micro-generation level wind power.

Energy efficiency is the first step you take to reduce your energy bills. You carry out an energy audit on your unit to identify any savings that can be made by doing things differently. Once these savings have been made then the renewable energy options can be considered.

In addition to economic benefits, there are of course social and environmental advantages to reducing energy consumption, such as preserving fossil fuel supply and minimising the impact of climate change. With many produce buyers now demanding that farmers and growers demonstrate their green credentials, being energy efficient can only serve to enhance your business.

This publication is aimed at growers, livestock farmers and anyone in the agricultural and horticultural sectors. Focusing on low and no-cost measures and actions which will have the quickest payback, this overview demonstrates the best energy saving opportunities for the sector and will help in:

Assessing the potential for energy savings and indicating key areas for improvement.
Raising awareness of energy conservation amongst staff and motivating them to reduce waste.
Appraising the overall performance of a horticultural or agricultural business.

The agricultural and horticultural sectors encompass a wide range of activities such as pig and poultry farming, dairy farming, crop growing and storage, yet there are a number of common areas where energy is wasted. A cut in energy costs ultimately results in the same bottom line benefit as an increase in sales. Controlling energy usage also has a beneficial effect on crops, livestock and produce.

SECTION 1

ENERGY EFFICIENCY IN AGRICULTURE

INCREASING DAIRY ENERGY EFFICIENCY

Key Points

- The average cost of electricity measured on 21 commercial dairy farms in 2010 was 0.49 cent per litre. There is a large variation in energy costs on dairy farms, from 0.23 cent per litre up to 0.76 cent per litre

- The main forms of energy consumption on dairy farms are milk cooling equipment and the requirement for hot water which is dictated by the number of milking units and the level of automation on the milking machine

- The main factors that drive energy cost reduction are effective plate cooling and use of night rate electricity

- When planning an expanded dairy facility energy efficiency should be a high priority to avoid excessive energy bills over the lifetime of the facility

Annual savings can be made on dairy farms by monitoring energy consumption and putting in place a number of good house keeping measures.

Introduction

A large increase in milk production without the adequate inclusion of energy efficient technology will result in a dramatic increase in energy consumption. Building in energy efficient technology from the beginning of a new installation is much easier and more cost effective than adding it at a later date.

Energy saving technologies – Dairy production

Description of measures	Comments
Energy monitoring/ management / benchmarking	Energy monitoring is a key factor in successfully managing energy use. Industry monitoring will establish robust industry benchmarks.
Field operations savings	Depends largely on equipment selection, set-up of equipment, ballasting, tyre inflation and general optimisation of field operations.
Optimise milk cooling systems	Good maintenance, using a well configured plate cooler, and in longer term adopting a high efficiency milk cooling system.
Basic improvements in water heating	Insulation, control, correct tariffs
Lighting system improvements	The adoption of high efficiency lighting fittings and better control and configuration. Clean windows and sky lights to maximise natural daylight and reduce the dependence on artificial lighting.
High efficiency motors and variable speed drives	Applicable to feeding systems, manure management, vacuum pumping where the load factor on motors is high.

Drivers of Energy Consumption

Data collected from 21 commercial dairy farms in 2010 as part of the DairyMan project is summarised below in Figure 1. Detailed energy audits were carried out on these farms from May to October 2010 to quantify the electricity consumption attributed to the dairy and milking operations. There was a large variety within the group in terms of herd size (46 to170 cows) the average herd size was 106. Milking parlour size varied from 8 units to 20 units with contrasting levels of automation and management practices. These variations inevitably led to a wide range in both energy consumed per litre of milk produced (from 53 to 108 Watts per litre produced) and cost per litre (from 0.23 to 0.76 Cent per litre produced).

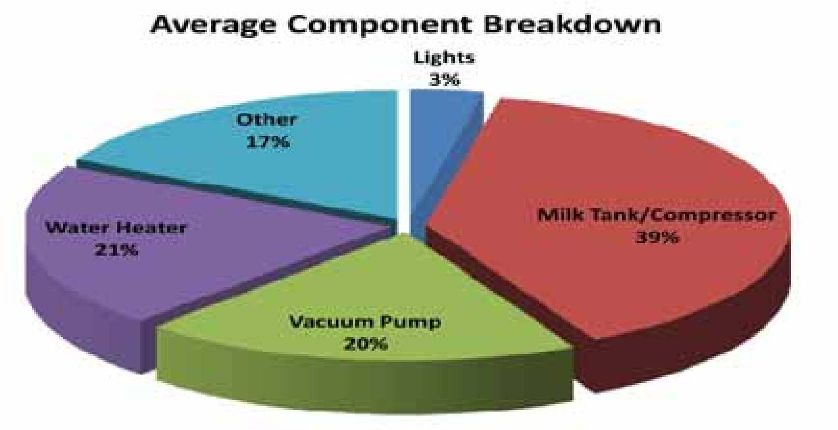
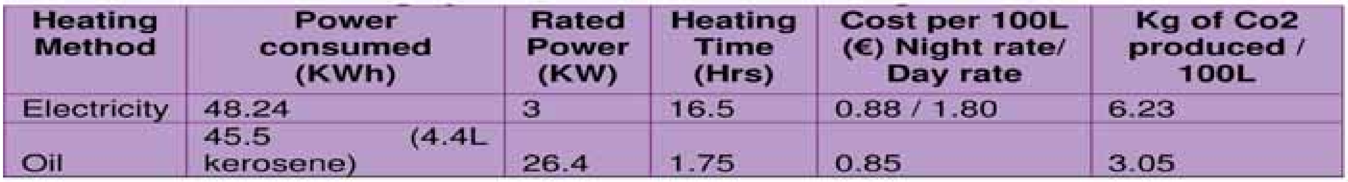


Figure 1 – Average component consumption on 21 commercial dairy farms

Water heating

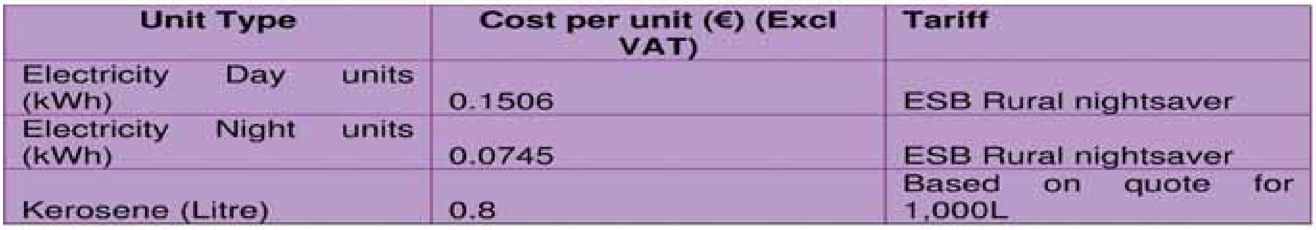
An adequate and reliable supply of hot water is an essential element in the production of high quality milk on any dairy farm. Water used for cleaning milking systems and bulk milk storage tanks must be available in adequate quantities and at required temperatures for each cleaning process. Failure to have adequate supplies of hot water at required temperatures can lead to rapid increases in bacterial contamination and subsequent reduction in milk quality. Hot water requirements vary from farm to farm and are directly related to the number of milking units, pipeline sizes and lengths, and system accessories (receivers, recorder jars or milk meters, ACRs, etc.). Farmers should be aware that with enlarged milking parlours and increased levels of automation come higher running costs due to the augmented requirement for hot wash cycles. Generally, a minimum hot water requirement is 9 litres of 80°C water per milking unit for each hot wash cycle plus a reserve for bulk tank washing. Table 1 shows the results of a water heating trial at Teagasc Moorepark. In this study 500 litres of water was heated from 14°C to 80°C with a 3 kW immersion element and a 26.4 kW oil fired burner running on kerosene. Table 2 shows oil and electricity tariffs used in the calculations (correct on 21/03/2011).

Table 1 – Effect of heating system on the cost of heating water



Heating Method	Power consumed (KWh)	Rated Power (KW)	Heating Time (Hrs)	Cost per 100L (€) Night rate/ Day rate	Kg of Co2 produced / 100L
Electricity	48.24	3	16.5	0.88 / 1.80	6.23
Oil	45.5 (4.4L kerosene)	26.4	1.75	0.85	3.05

Table 2 – Oil and electricity tariffs used in cost analysis



Unit Type	Cost per unit (€) (Excl VAT)	Tariff
Electricity Day units (kWh)	0.1506	ESB Rural nightsaver
Electricity Night units (kWh)	0.0745	ESB Rural nightsaver
Kerosene (Litre)	0.8	Based on quote for 1,000L

26.4 kW oil fired burner running on kerosene

3 kW Electrical heating immersion system with water softener. Note pipes should be lagged.

Common problems with water heating systems include

- Timers not working or set incorrectly. The intention with using a timer is to turn on and off the water heater so that water is heated when night rate electricity is available. Night rate retails at half the price of day rate (15c/kWh v 7 c/kWh). Night rate kicks in at 11pm to 8pm in winter and 12am to 9am in summer. A power cut can throw the timers out. The easy way around this is to use a timer with its own battery so it's not dependent on power to drive the timer.
- Hot water pipes not insulated. Stand off losses can reduce the efficiency of the heating system. All hot water piping should be insulated with good quality insulation. Uninsulated pipes will reduce the temperature of the water travelling from the water heater to the wash trough resulting in less effective washing.
- Limescale coating electric elements reducing efficiency. Hard water causes lime scale build up on electrical elements. This leads to higher running costs and you will shorten the life of the element. Water softeners should be used in areas of hard water.
- A leak as small as one litre per hour can waste 8500 litres of hot water and 3800 kWh per year. Identifying and elimination of leaks can be done with minimal effort.

Heat Recovery (HR)

Heat recovery systems transfer energy from the cooling systems refrigerant to water in a storage tank thus raising the temperature of the water. Supplementary heating of heat recovery water by electricity or oil is always required to achieve the desired temperature of 80 degrees Celsius. The heat recovery tank should be used as a buffer tank only, a second tank to heat the water to 80 degrees is always required. The heat recovery tank should pre feed the final temperature water tank. Electrical elements or oil burners should not be connected to a heat recovery tank. Installing HR is a specialised job and should only be done by a registered refrigeration technician with experience of heat recovery. Incorrect installation will stress the compressors and drive higher power consumption as well as decreasing compressor life. When installed by qualified refrigeration engineer as part of a new cooling system upgrade it is much safer. A guarantee should be sought for all heat recovery installations

Heat Recovery System

Risks

- Installation of a HR system by anyone other than the original manufacturer/commissioner of the system will almost certainly void the warranty.
- Many older cooling systems still operate on old refrigerant R12 (ozone depleting chemical) or similar, this is now no longer available. Upgrading an old system to heat recovery involves changing to new 404A (non-ozone depleting) refrigerant which is expensive as is not recommended.

Milk Cooling

On a typical Irish dairy farm, the cooling process is completed in two stages; pre-cooling and refrigeration. Pre-Cooling is achieved by passing the hot milk through a Plate Heat Exchanger (PHE) before entry to the bulk tank. Cold water is pumped through the opposite side of the PHE. The cold water absorbs a portion of the heat, thus pre-cooling the milk. A PHE is designed to run at certain operating conditions; each PHE has a specific milk to water flow ratio and extra plates can be added to accommodate for very large milk flow rates. The goal of pre-cooling is to bring the milk temperature as close as possible to that of the water.

PHE manufactures recommend milk to water flow ratios of between 1:2.5 and 1:3 depending on the model. If a PHE is sized correctly in relation to the output of the milk pump and the correct ratio of water is supplied then the power consumed during the refrigeration stage can be dramatically reduced.

Table 3 shows the results of PHE testing carried out at Teagasc AGRIC. A PHE was analysed at varying milk to water flow rates and with an increasing number of plates. The milk and water entry temperatures were set to 35°C and 10°C respectively and the milk exiting temperature from each test was recorded.

Bulk tank requires heated water for cleaning

The most noticeable result from the above test is the reduction in milk exiting temperature corresponding with the increased milk to water ratio. However it takes an ever increasing water flow rate to reduce the milk temperature, as the ratio increases the cooling effect per litre of water is reduced.

Table 3 – Milk exit temperatures (C) for a PHE ratio and plate capacity test

	Milk:Water ratio			
No. Plates	**1:1**	**1:2**	**1:3**	**1:4**
25	20.8	16.8	14.8	13.7
45	20.4	15.9	14.0	12.9

The Plate Heat Exchanger (PHE) should be sized correctly
to ensure the correct milk to water flow rates.
A PHE can half the costs of cooling milk.
Reuse the heated water elsewhere to
make even more savings.

Another observation from the test is the influence of increased plate capacity on milk temperature. The extra plates have a moderate effect on the performance of the PHE. The addition of extra plates to the heat exchanger increases its heat transfer area however this also increases the number of flow channels, thus reducing the milk flow velocity and water flow velocity at a set flow rate. This reduction in flow velocities retards the heat transfer rate in the PHE. The resulting effect is that increasing the number of plates on a PHE produces only a modest increase in cooling performance.

Pre-cooling of milk in-line by well or mains water before it enters the tank has a number of advantages. These include:

1. Economy – cooling costs can be reduced by up to 50% depending on the temperature and supply of water and the operational efficiency of the cooler, e.g. water to milk flow.
2. Milk quality – pre-cooling ensures a lower milk blend temperature, which helps to curtail the growth of bacteria.
3. The tepid water from the pre-cooler can be used for udder washing, yard washing and for stock.
4. Pre-cooling milk will reduce cooling times when compared to equivalent systems without pre-cooling

Some of the benefits of pre-cooling will be undone if the bulk tank cooling unit is not installed and maintained properly. It is important to ensure a good airflow to and from the condensing unit (radiator). Anything that restricts the supply of fresh air and /or causes the recirculation of warm air will increase running costs and reduce compressor life. It is very common to see condensing units on farms that are damaged, partially blocked and recalculating warm air.

Vacuum Pumps

International and Irish Milk Quality Co-operative Society (IMQCS) standards are a basis for installing a new milking machine. New revisions of these standards were introduced in 1989, 2004 and 2008. One of the changes that has been implemented over the years was an increase in recommended vacuum pump capacity for a given size of milking machine for example in 1989 the recommended vacuum pump capacity was 1400 l/min for a 20 unit milking machine. In 2008 the recommendation was 2422 l/min. This is because modern milking machines require a large vacuum reserve for washing due to large milk-line bores. However during milking the plant consumption is a fraction of the vacuum pump capacity resulting in large amounts of air being drawn in through the regulator. Addition of a variable speed drive (VSD) to the vacuum pumps of these large modern milking machines can result in savings of over 60% on vacuum pump running costs which would be a saving of €410 per year for the average 100 cow farm.

The VSD is able to adjust the rate of air removal from the milking system by changing the speed of the vacuum pump motor to equal the rate air is admitted to the system at a given vacuum level. All of the energy used to move air through the conventional vacuum regulator is saved. Variable speed drive “vacuum regulators” consist of a sensing element, a controller, and a variable frequency motor drive. The variable frequency motor drive is a device that converts standard line voltage at 50Hz to a variable frequency and variable voltage output to drive a 3 phase induction motor. By reducing the frequency and voltage supplied to the motor, the speed and the power consumed by the motor will be reduced. As with conventional, mechanical regulators, placement of the sensing element of a variable speed regulator is very important. The sensing element should be located as close to the receiver as possible.

The addition of a Variable Speed Drive can result in savings of over 60% on vacuum pump running costs

Dairy Lighting

Moisture resistant double fluorescents or high bay metal halide lamps are the most common types of lighting used on Irish dairy farms. Similar size dairies using metal halide lights can use over three times more electricity on lighting than a farm using fluorescent type lights.

Key Risks

- Modern fluorescent tube fittings tend to interfere with milking parlours automatic cow identification systems, reducing the effective distance from the cows’ ear tag to the antenna.

- The underlying reason for this is the use of high frequency switching ballasts within the light fittings themselves. These ballasts give out high frequency nuisance signals which interfere with the automatic identification antenna.

Key Points

- Switch start or magnetic ballast fluorescent tubes (double five foot T8 58W switch start) fluorescent tube are still commercially available and where automatic identification systems are installed these lights are the best option
- Where automatic cow identification is not installed T5 high efficiency fluorescent tubes (double five foot 58w T5) are the best option
- Low pressure sodium (LPS) lights are the most efficient solution for lighting external areas where colour perception is not a priority.

Well lit parlour with 2 rows of double fluorescent fittings

Conclusion

We have seen that energy consumption is driven mainly by milk cooling equipment and the requirement for hot water in a given milking installation. Energy costs in turn are governed by the rate at which that energy is billed at. Night rate is charged at €0.0745 per kWh and day rate is charged at €0.1506 per kWh therefore it is strongly recommended to use night rate electricity as much as possible. Night rate hours are from 11pm to 8am during winter time and 12 midnight to 9am for summer time. Where appliances, such as electrical water heaters, are required to operate during night rate hours, digital time clocks with battery backup should be used. Analogue timers without battery back up will become out of sync in power failures.

New technologies to reduce dairy farm electricity consumption are being identified and evaluated on an ongoing basis as part of the larger energy research programme in Teagasc Animal and Grassland Research and Innovation Centre. This programme aims to promote a more energy efficient approach to dairy farming, which in the long term will result in lower energy input costs.

ENERGY USE ON PIG FARMS

"There can be economy only where there is efficiency"
Benjamin Disraeli

Key Points

- Check your tariff. Larger units may negotiate better terms with electricity supply companies.

- Ensure a good control system for heating in farrowing and first stage weaner rooms that is working in tandem with the ventilation system.

- Savings with low energy lighting can be very significant.

- Good insulation and draught proofing is critical.

Introduction

Energy is a resource that must be used efficiently and effectively. It makes no sense to waste it. In pig production the cost of energy is 3.3% of the total production cost (Pigsys data, 2010). Against a background of rising fuel costs there is concern that it could become a more significant cost in the future. Typically a 1000 sow integrated pig unit (i.e. rearing pigs from birth to slaughter) will spend over €80,000 each year on fuel and electricity (often recorded as heat/power/light) for the production of pigs. Therefore it is important to monitor energy use and reduce any wastage that may occur on individual farms.

What is the energy usage on pig farms?

In 2005 the Carbon Trust UK published data on energy usage on pig farms in the UK. The data shown in Table 4 describes "typical" and "good practice" energy usage figures. The "typical" figures are the expected energy usage measured in kilowatt hours (kWh), while the "good practice" figures represent the better energy performance being achieved on individual farms.

Dry feeding systems for loose sows like above require less energy than wet feeding systems.

Table 4 – Energy usage in each section of pig production

Production Stage	Energy technology	Typical per pig produced	Good practice per pig produced	Main influence
Farrowing	Heating, lighting and ventilation	8kWh	4kWh	Use of box creeps with thermostatic control gives the lowest running cost. Under-floor heating pads are generally more efficient than infra-red bulbs.
Weaning	Heating, lighting and ventilation	9kWh	3kWh	Major issues are the insulation of buildings (or kennels) and most importantly the control of ventilation.
Finishing	Ventilation and lighting	10kWh	6kWh	Efficient fan selection, good design of inlets and outlets and system cleaning are the key points to minimising energy use.
Feeding system	Motive power, pumping, conveying	3kWh	1kWh	Dry feeding systems use a small amount of energy for conveying. Wet feeding is generally more energy intensive because of the need to mix pump feed and pressurise pipework.
Manure handling	Motive power, pumping, scraping	6kWh	2kWh	Selection of high efficiency pumps aerators and separators.
TOTAL		**36kWh**	**16kWh**	

Source Carbon Trust UK 2005

If energy usage is in line with “good practice” there is still scope for improvement but it is less urgent than if the figure is in line with “typical” usage figures.

In 2006 a Teagasc survey of 8 Irish Pig Farms with a total of 4701 sows (approximately 3% of the National Pig Herd) showed an average usage of 27kWh per pig produced (with a range of 17 to 37 kWh/pig produced – Reference: Clarke).

The other source of data available is from 76 pig farms recording on the Teagasc Pigsys system (2010). The energy cost (heat, power and light) is €3.39 per pig produced. This Pigsys data comes from approximately 33% of the national pig herd.

Larger units may be in better position to negotiate good payment terms from an energy supplier and this should be pursued by all pig producers. This article concentrates on methods of improving energy efficiency thereby reducing energy usage in pig production.

Areas that require monitoring on pig farms:

Farrowing rooms

Approximately 20-25% of electricity usage on the farm is consumed here. The ideal is to have a farrowing room temperature of 24°C once the first piglet is born in the room. This should be reduced to no more than 20°C when the youngest piglet in the room is over 2 days old. Pig producers may use paper to supplement the heat source at farrowing rather than an infra red bulb. If the average gestation period is 115 days, it is not necessary to heat up the creep area on day 113 of gestation. Poor temperature control can lead to unnecessary overheating of pads resulting in wasted heat production and wasted ventilation energy. This applies particularly in the first two weeks after farrowing.

The optimum temperature in a farrowing house is 24ºC once the first piglet is born in the house.

Weaner rooms

First stage [i.e. from 6kg to approximately 17kg liveweight]
At least 25% of the energy usage on the pig farm is consumed in this area. The aim is to have newly weaned pigs kept at 28°C to 29°C initially, with a reduction of approximately 2°C in room temperature each week thereafter. Typical usage of 10.3 kWh can be expected, with the breakdown of 7.5 units for heating, 2 units for light and 0.8 units for ventilation as shown in Table 5.

Table 5 - Weaner house energy consumption: typical and good practice

Energy Consumption (kWh)	**Typical**	**Good Practice**	**Potential saving %**
Heat	7.5	3	60%
Light	2	1	50%
Ventilation	0.8	0.6	25%

Source: Carbon Trust 2005

Good practice suggests a heating requirement of 3 kWh/pig, a light requirement of 1 kWh/pig and a ventilation requirement of 0.6 kWh/pig or an annual saving of 5.7 kWh per pig sold (relative to the "typical" or average consumption). To achieve this it is critical to check if the ventilation system is working in tandem with the heating system. The ventilation system may control house temperature at a massive cost to the electrical consumption if the two systems are not working in tandem with each other. A lag time may occur before the temperature sensor shuts off the "call" for heat. This problem can be compounded by the fan cutting in to remove the excess heat provided. Air quality will be fine but at a cost to energy usage.

Is there a potential to make cost effective improvements to reduce heat input? There may be scope to do so if weaning weights have increased. An extra one kilo body weight at weaning can reduce energy consumption by 8% in this stage of growth. So weaning heavier pigs will reduce the energy requirement.

The issues of lighting and ventilation systems are dealt with separately below.

Grower – Finisher rooms

One third of the electrical energy is consumed in this area. Ventilation and feeding systems are the main users of energy here; lighting systems generally have lower level of energy usage. If the ventilation system chosen is ACNV (Automatically Controlled Natural Ventilation) and the feeding system is a liquid based one the power usage leans heavily towards the feeding system. Where the ventilation system is fan powered with restricted inlets and the feeding system is an augered wet/dry system, the consumption pattern may be reversed.

General electrical consumption, common to all areas on the pig farm:

Ventilation

The control unit regulates cold air in and balances it with warm air out depending on desired house temperatures.

Pig houses are ventilated to control the levels of gas (ie carbon dioxide, ammonia, methane and hydrogen sulphide are the main ones) and airborne pathogens in the pigs environment. This is done to achieve good growth performance in terms of growth rates and feed conversion efficiencies. Some pig houses are controlled without the use of mechanical fans to pull fresh air through the house. This system relies on the "stack" effect which relies on warm air rising and being replaced by cooler fresh air from outside the building and is referred to as natural ventilation. The only energy used in this system is to control the air inlet and outlets in the building. This system has very low running costs but may be a difficult system to manage particularly in very changeable weather. Mechanical ventilation relies on fans, air inlets and controllers to manage the volume of air to be moved through a house. This system has higher running costs because of the use of fans.

Fans

Fans are "ever ready" to consume electricity, sometimes with no advantage to improving the pig environment. How often do you see fans at full speed in a dry sow house in mid winter, or first stage weaner houses with fans at full speed and heaters glowing? Remember that when fans are set, either manually or on a curve, they will carry out that function, be it correct or incorrect until the settings are changed.

When assessing or choosing a fan – the following should be checked at a minimum:

- Fan size must be matched to the stock type (ie weaners, finishers etc.) and numbers to be accommodated in the pig house to be ventilated. Will the fans move adequate air to keep the air in the pig house fresh?
- Inlet size versus fan capacity – is there a risk of over ventilating the room thereby chilling pigs and wasting energy doing so?
- Fan efficiency: How much air is moved by the fan versus the power required by the fan? You need to check the data sheet provided by the manufacturer to get this information.
- The "back pressure" is the resistance to air flow at the fan outlet. This needs to be factored into the equation also to determine fan efficiency. This efficiency may vary with different fan sizes and models supplied by different manufacturers.

Fan size must be matched to the type of stock

Natural Power Ventilation

This is a new system which is designed to work as a naturally ventilated house when possible. It could be described as an adaptation of the natural system with the ability to mechanically ventilate when necessary. Extra air outlets are installed to allow the natural ventilation system operate. When there is a need for additional ventilation the fans begin to operate. This system may have a higher initial capital cost but is achieving a reduction in electricity usage for ventilation of approximately 80% for finishing houses where this was monitored on 3 farms and compared with similar mechanically ventilated houses.

This comparison did not measure pig performance in the houses and it is assumed that the pigs achieved similar growth performance in each housing system.

External view of Natural Power ventilated finishing house. Air inlets to the side and warm exits through roof mounted outlets.

Internal view of outlets for Natural Power ventilated house.

Insulation of pig buildings

The provision of heat in buildings is very wasteful if there is a poor level of insulation in the building. The walls and ceilings should be insulated to achieve suitable U values. Check the insulation to see if it has been damaged by pests. The temperature fluctuation in the pig house should also be checked by using maximum-minimum thermometers to monitor if house temperatures vary considerably between day and night-time.

A well insulated building - notice snow not melting on roof.

Lighting

A typical 500 sow integrated pig farm has 5,000m^2 floor area to illuminate, approximately 10m^2 per sow and progeny. Lighting power consumption accounts for 10-15% of electricity supplied onto the farm, (i.e. 2 to 4 kWh per pig produced).

The standard incandescent (Tungsten) bulb is 5% efficient at converting energy to light and has an expected life of 1,000 hours versus a fluorescent at 7,000 to 16,000 hours. The compact fluorescents have been heavily promoted in recent years. They provide good energy efficiency and are easily fitted into the incandescent bulb holder. They are expensive to buy. They are unreliable in terms of light output when dimmed below 50%.

Table 6 shows the “lumen efficacy” of different light sources. The higher the lumen efficacy the more efficient the source is at producing light.

The new energy efficient standard is the T-5 fluorescent tube with a dimmable electronic ballast, mounted in weatherproof housing (plastic) with a gasketed diffuser. These units are four times as efficient as regular incandescents and last 16 times longer.

Table 6 - Relative energy efficiencies of various light sources

Lamp Type	Lamp Size (W)	Lumen Efficacy (Lumens/kW)	Typical Lamp Hours	Energy Usage (kWh/pig)
Incandescent [Tungsten]	25-200	36-71	1,000	2.4
Compact Fluorescent	5-50	47-82	8,000+	0.4-0.8
Fluorescent T-5 Strip	32-120	66 - 82	16,000+	0.4-0.8

Source: SEAI

For efficiency, choose the T-5 (16 mm) tube instead of the T-8 (25 mm). Electronic control will further reduce energy usage by 20% and extend lamp life by 50%.

Natural lighting in pig houses reduces energy use and creates a better working environment.

Example of electricity savings in a finisher pig room:

Finisher Room is 14 metres wide by 13.1 metres long.
Fully slatted floor. Six pens with 36 pigs/pen selling pigs at 98kg liveweight.

Current Lighting

8 single T8 bulbs (F58W/33) 1500mm long hanging at a 3 metre height – evenly spaced in the room.
This requires: 58watt by 8 bulbs by 8 hours by 365days = 1355 kWh of electricity.

Suggested Lighting

10 T5 bulbs – replacing existing bulbs to give the same light output.
This requires: 35watt by 10 bulbs by 8 hours by 365days = 1022 kWh of electricity.

Electricity saving is 330kWh/room/year giving the same light output.

Notes:

1. *A conversion factor of 10.5kWh was used per litre of kerosene to calculate energy usage.*
2. *The section on heat pumps in this booklet should also be read for other potential savings that could apply to pig farms.*

ENERGY USE IN POULTRY FARMING

Key Points

- Specify as high performing ventilation equipment as possible
- All fans and ducts should be included in the 'end of batch' clean, and filters should be replaced. Dirty ducts and fans can increase running costs by 60%.
- Ensure the minimum winter ventilation rate is controlled accurately where heating is used in the building. If the level is too high then heating costs will increase significantly. Too low a level will produce foul air conditions.
- Replace tungsten lights with energy efficient alternatives such as fluorescent or sodium lamps to save 70% of lighting costs.

Introduction

SEAI, through its business support programme, visited a number of poultry farms to offer advice, mentoring and simple assessment of energy use to owners and managers. Walk-through surveys of buildings and facilities were also undertaken. The information collected from this exercise informs this guide. While the survey sample was small and may not fully reflect the current state of the industry in Ireland, it can, however, offer guidance for future direction and associated benefits that can be derived in an industry where margins are tight and where cheaper foreign imports are a real threat to th sustainability of the industry.

The industry energy benchmark for chickens, based on the small sample survey, was estimated to be 0.71kWh of energy per bird; a UK study has indicated that typical consumption there is on average 0.39kWh per bird. The Irish market processes on average 80 million birds, therefore the potential energy saving is estimated to be 25.6 GWh. This equates to 6,500 tonnes of CO_2 savings annually. In addition, based on current fuel prices, the industry could benefit from a savings monetary injection of approximately €1 million per annum.

Energy saving technologies – Poultry meat production

Description of measures	**Comments**
Energy monitoring/management /benchmarking	Energy monitoring is a key factor in successfully managing energy use. Industry monitoring will establish robust industry standards.
Building sealing and insulation	Wide range of activities from simple sealing to total building re-insulation.
Fan and duct system optimisation	.Key issues ventilation duct design, choice of fans.
Lighting system improvements	The adoption of high efficiency lighting fittings and better control and configuration.
Control system optimisation	Through better control of temperature, less waste through over-ventilation
High efficiency motors and variable speed drives.	Applicable to feeding systems and manure management systems where the load factor on the motor is high.

Background

Poultry farming, like pig farming, is an energy-intensive operation and although energy may account for a small percentage of the product sales value, it is an area that can be greatly improved upon, helping farms to contain escalating costs, maintain financial viability and gain a marketing edge on their competitors. Energy usage can be minimised and costs reduced through the selection of equipment, lighting, insulation, controls and through implementing good housekeeping measures.

Lighting, heating, ventilation and air circulation equipment are the biggest energy consumers and are therefore the areas that offer the most potential for savings. Poultry welfare is important and improving farm energy performance often results in an improved environment for the poultry, with potential production efficiency gains through improved bird growth.

This report is based on site visits and findings in relation to a number of poultry farms audited under the SEAI's advice, mentoring, assessment and support programme. The farms varied in degree of complexity and diversity of activity, including egg production and broilers for meat production. They had the following characteristics:

- Egg production and packaging facilities
- Poultry birds for meat production facilities
- Large poultry meat production facilities

Poultry Farm Analysis

Fig 2 shows the breakdown of energy consumption by end use area as a percentage of total use. In terms of overall energy demand, space heating accounts for over 80% of total consumption. With regard to electrical energy use, lighting, ventilation and fans account for over 80% of the electrical energy consumption. It is clear that the link between ventilation and heating needs careful management; particularly in winter time when over-ventilation can significantly increase energy costs.

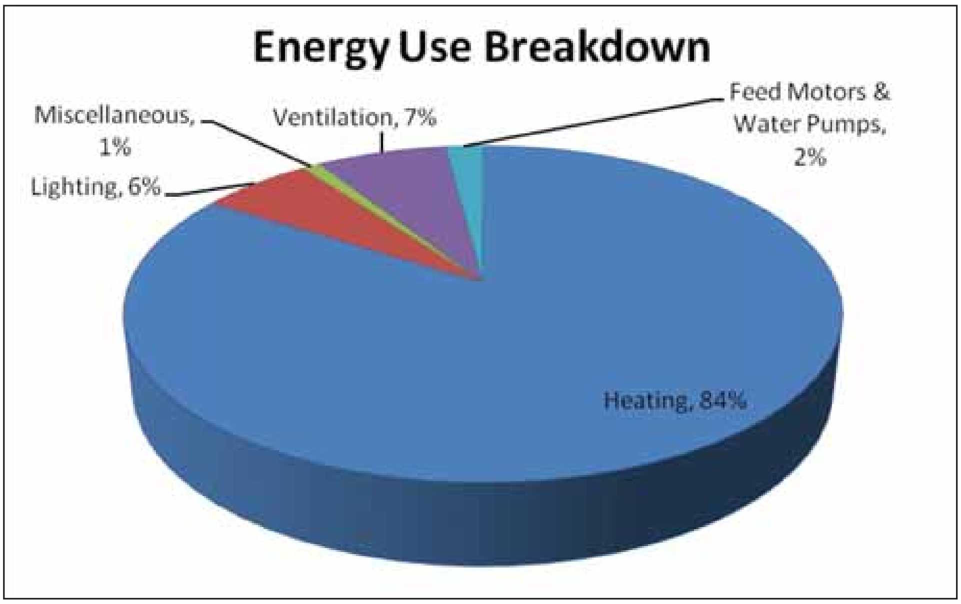


Figure 2: Poultry meat production – energy use by end use area as a percentage of total consumption

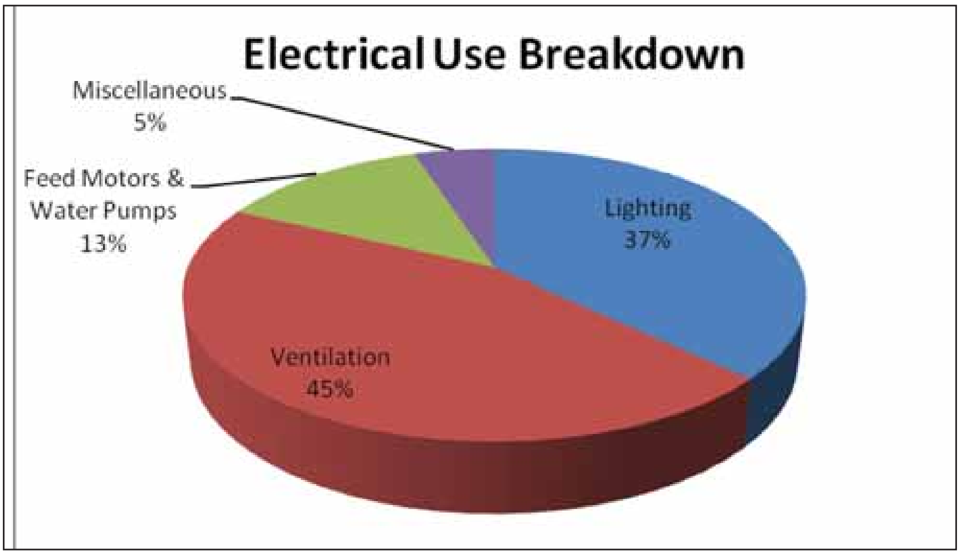


Figure 3: Poultry meat production – breakdown of electrical energy use as a percentage of total electrical consumption

Energy Performance Indicators (EPIs)

Energy performance indicators (EPIs) are valuable indicators of energy performance and how efficiently a plant is operated. Producers can use them to compare their own farm performance with best practice sites, to set targets and to manage performance as part of routine performance management. EPIs can help to identify areas for potential savings and also areas that need to be targeted for improvement. Regular assessments should be carried out, even on a daily basis initially, so that any abnormal trends can be detected and acted upon immediately to reduce any long-term impact.

The EPI best suited to poultry farms is ‘energy usage per chicken produced’ or ‘per kilogram (kg) of chicken live weight’ and, in the case of egg producers, ‘per chicken or per egg’. The benchmarking process involves identifying and collating the total thermal and electrical energy consumed during a given period and dividing it by the agreed production units for the period being assessed for the particular facility.

The following tables and charts show average figures for Irish farms and the available figures for typical and best practice farms in England and Wales. Given that the UK climate is very similar to Irish conditions, these provide a useful indicator as to how efficient or inefficient Irish farms might be, and the potential for improvement or opportunities that might exist.

Table 7: Poultry meat producers: actual calculated EPIs versus consumption figures for England and Wales

Total energy consumption, poultry meat farms					**Potential Saving**	
Unit Size	EPI	Actual	Typical	Best Practice[1]	Typical	Best Practice
Over 200,000 birds	kWh/bird total energy	0.71	0.39	0.33	45%	54%

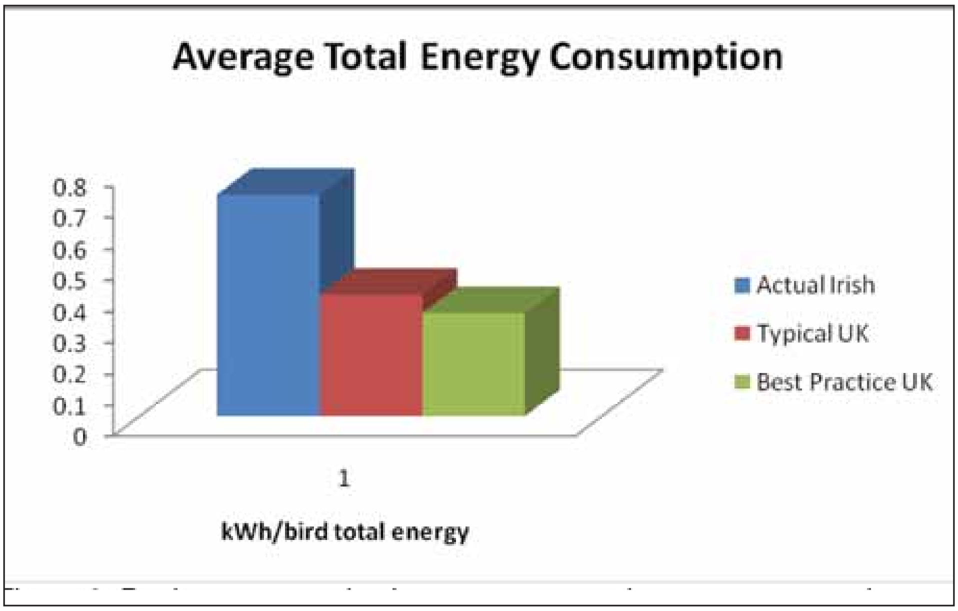


Figure 4: Poultry meat production – average total energy consumption versus consumption figures for England and Wales

Table 8: Egg producers: actual calculated EPIs per farm versus consumption figures for England and Wales

Egg producers: Total electrical energy consumption					**Potential Saving**	
Up to 75,000 birds	EPI	Actual	Typical	Best Practice2	Actual	Best Practice
	kWh/bird	4.12	3.9	2.25	6%	45%

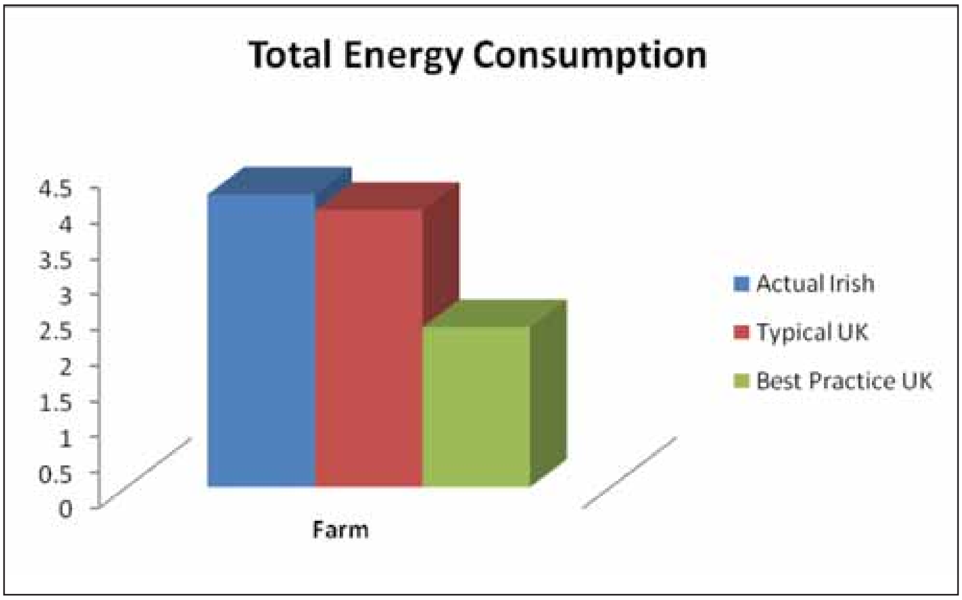


Figure 5 – Egg production – total energy consumption versus consumption figures for England and Wales (source: Managing Energy and Carbon: The farmer's guide to energy audits)

ENERGY DEMAND-REDUCTION TECHNOLOGIES FOR POULTRY FARMS

Organisation/Technical/People Opportunities

Effective energy management requires a balanced approach in three key areas: Organisation/Information involves senior management commitment, a clear energy policy, strategy and objectives, human and financial resources to implement initiatives, proper systems for energy purchase, data collection, analysis, reporting and a capital investment programme.

Technical solutions include, but are not limited to, space heating, ventilation, air conditioning, lighting, hot water, office equipment, computer suites, catering, building fabric, doors, windows, insulation, power factor correction, controls and Building Energy Management Systems (BEMS).

People solutions involve raising energy awareness and motivation of all employees, the professional development of staff who manage energy and the use of energy teams for implementing no-cost measures. It also involves providing energy training for maintenance/operational staff, caterers, cleaning and security staff.

Retrofit solutions for energy saving include:

Building Energy Management Systems

Developments in modern communications have brought considerable changes for businesses, from individual building management systems to telephone systems and information systems. All computer-orientated functions are essentially linked through one interface. Building Energy Management Systems are also available, which provide options for analysis of energy use on a regular basis, for monitoring boiler, lighting or fan running times, for switching off equipment, for zone control of heating and numerous other applications. Savings of between 10% and 30% of energy consumption are possible. A good monitoring and targeting programme should be included as a management tool to assist in the overall management programme.

Boiler and space heating systems (where utilised)

Efficiency of oil and gas-fired boilers is extremely important. Regular servicing of burners and cleaning of heat transfer surfaces is recommended, potentially yielding savings of between 10% and 15%. The installation of modern modular and high-efficiency condensing boilers (up to 95% as against 80% or worse) should be considered in new and retrofit projects. These can be installed to heat appropriate zones, providing extra control and reducing unnecessary runs of pipe work.

Insulation and air tightness

The energy needed for heating and ventilation can be reduced by improving wall, roof and floor insulation (if undertaking a complete refurbishment). This will help to keep buildings warm in winter and cool in summer.

Production performance improves as more uniform temperature is achieved. A balance needs to be struck between the levels of insulation and the density of birds, otherwise overheating could occur in summer time or excessive levels of ventilation will be required to maintain proper environmental conditions.

There are many ways of applying insulation to older buildings including: insulated panels on the inner surfaces; filling attic spaces with low-density injected polyurethane foam, or applying external insulation.

Avoiding air leaks is important in the control of heating costs during brooding, especially in winter months.

Simple and relatively cheap adjustments and repairs to ventilation flaps, fan ducts and doors will very quickly yield savings in heating costs.

Temperature and ventilation controls

Multiple sensor controls for heating and ventilation provide greater accuracy and should be installed directly above the birds. Controls for heating and ventilation in the same building should be interlinked to avoid each one 'fighting' against the other.

Excessive ventilation in heated poultry production facilities during cold weather can dramatically increase heating energy and will have a big impact on heating running costs, sometimes by as much as 30%. Good control equipment and ventilation systems, which are capable of delivering low-level and accurate amounts of ventilation, are essential to attain reduced running costs.

Lighting

Advancements in indoor/outdoor lighting technology means that electricity consumption for lighting can be significantly reduced. Older incandescent and tungsten halogen lighting can now be replaced with high frequency dimmable fittings, yielding savings of over 40%. High/low-pressure sodium lighting can be used outside buildings. Tungsten halogen with occupancy detection should only be used when lights are on for short periods of time.

Variable Speed Drives (VSD) on fans and pumps

Varying the air volumes being moved around the houses in line with requirements can impact on the energy used by fans. Reducing the speed of a pump or fan by 20%, using a variable speed drive (VSD), could save 50% of the energy consumed. This is useful for applications like pumping, conveying or ventilation where output requirements often change, and so ideally requires a constantly variable control. Water pumps and conveying systems can benefit from this technology, especially when speed is linked to the flow or pressure requirement of the system.

Brooding curtains

Brooding curtains restrain the chicks to a smaller portion of the house, allowing them to stay warm without the expense of heating the entire house. To perform efficiently, they should form a tight seal along the ceiling, walls, and floor. This prevents cool air from the rest of the house seeping into the brooding area. Another advantage is that it prevents leaching moisture out of the litter pack and chilling the chicks. When using bird boards, set them back 300mm or so into the non-brooding part of the house; this creates a tighter seal and lessens the likelihood of leaks. Install a heavy conduit or pipe in the bottom hem of the brood curtain for a tighter seal. Any holes in the curtains should also be sealed.

Air circulation

By circulating pre-warmed air into the poultry house, less heat and consequently less energy is needed to keep the birds warm. Attics can be a useful source of free heated air.

Ceiling (or attic) inlets are an effective way of keeping the flock warm during cooler months without increasing heating costs. They work in a similar manner to sidewall inlets, but are placed in the ceiling of the poultry house and draw heated air in from the attic.

The effectiveness of ceiling inlets is linked to their placement, the number of ventilation fans in use, and the static pressure in the house. While this can often be controlled by a static pressure inlet control, the number of inlets in use generally varies based on the age of the flock and the temperature outside.

Circulation fans

The hottest air in a poultry house is near the ceiling as air warmed by the birds rises upwards.
Slow-moving circulating fans should be used to push hot air back down to the floor; the more uniform the house temperature, the lower the heating costs. The air must move gently around the floor, as air moving with a high velocity will chill the chickens.

The main benefit of proper heat circulation is that the conventional heating system does not need to operate as frequently, which means less wear and tear on the brooders, and less fuel is needed.Fuel savings are estimated to be between 10% and 20%.

Radiant heating

Radiant heaters are fired with propane or natural gas and may be considered as a space heating option. Fuel savings are possible with radiant heaters as manufacturers typically recommend installing 15% less heating capacity for radiant heaters than for direct air heating systems.

One distinct advantage of radiant heating in poultry farms is that it provides better heating for the litter pack. The heat is transferred directly to the floor of the house, which prevents the birds' body heat from being drained into the floor through their feet, and results in warmer birds and drier litter. Another advantage is that they can be mounted much higher in the house, so they do not need to be raised or lowered in the working space. They also heat the floor evenly, preventing the hot spots typically seen with pancake or radiant brooder heaters. The warmth spreads farther towards the side walls giving the birds a larger comfort zone.

Some manufacturers also offer two-stage or dual-stage heating. The burner can be set at a higher or lower output, depending on need. The higher setting is used only for times of severe cold. This reduces the amount of warm-up time and prevents temperature spikes, thus helping to save fuel and extending equipment life. The big drawback however is the potential fire hazard of a dusty environment near the ceiling where they are mounted.

Conclusion

Reducing energy use makes good business sense; it saves money, provides a competitive advantage, enhances farm reputation and plays a part in reducing carbon emissions and thus reducing green house gas emissions.

From the calculated EPIs shown in Table 7 it is clear that there is considerable scope for energy savings on the chicken farms assessed in the SEAI advice mentoring and assessment programme. Management should immediately put a plan in place to upgrade and improve their farm energy systems

Areas identified with potential for improvement include:

- Monitoring and targeting programme on energy use
- Airtightness and ventilation losses
- Use of appropriate heating and control systems
- Regular maintenance including combustion efficiency testing
- Replacement of old space-heating burners
- Fitting of automatically controlled natural ventilation (ACNV) systems
- Upgrading insulation

While energy data for egg production was very limited, as egg production facilities are rarely heated, it is assumed that all energy consumption is related to lighting and ventilation. An analysis of available data, (see Table 8), indicates that the farms in question could save up to 45% of their energy consumption.

Areas for savings identified on these farms included:

- Installation of high frequency lighting
- Proper maintenance and control of ventilation fans
- Cleaning of fans.

OPPORTUNITIES FOR ENERGY EFFICIENCIES IN CROP & GRASSLAND OPERATIONS

Key Points

- Estimate current fuel using purchasing records, brim to brim tractor fills or tractor electronic fuel meters.
- Consider fuel consumption when selecting tillage systems or silage harvesting systems. Min-till can halve fuel costs in crop establishment.
- Only cultivate the soil as deep as necessary. Reducing depth will save fuel and total machine costs
- Match machines within your system as far as possible to avoid having high-powered tractors working inefficiently with smaller implements.
- Choose specific types, makes and models of machines with fuel consumption as a key criterion. Difference in fuel use can be substantial.
- Drive efficiently by planning field work carefully to maximise working time in the field and ensuring that diesel engines are correctly loaded.
- Maintain tractors and implements carefully to ensure they can operate efficiently.

The energy inputs to tillage crop production are considerable with most farms using about 85 litres of diesel per ha in field operations alone to produce cereal crops. This is a considerable cost and it will increase as fuel costs rise. There is scope to reduce fuel use and consequently energy costs with the added bonus of reducing our carbon footprint.

While energy is used in the manufacture of inputs such as fertiliser, agrochemicals, machinery etc, this section will focus primarily on the direct energy or fuel used on the farm in crop production harvesting and storage.

KNOW YOUR FUEL USE

While there are many standard fuel consumption figures about (Table 9), there is huge variation in these figures in individual situations. The first step to reducing or optimising fuel use is to know how much fuel you are using. It's perhaps surprising that most growers / operators have very little idea how much fuel they use!

How do I measure?

- Fuel use can be estimated at different levels. On an all-tillage farm, an overall fuel use figure can be achieved by simply recording the quantity of fuel purchased during the year and allowing for stocks (usually by starting and ending with a full storage tank). This can then be simply divided by the number of hectares grown or tonnes produced to give a per hectare or per tonne fuel consumption figure. Make sure that you start and stop at the right point however so that one full cycle of operations is included.

Correct forward speed and engine speed selection will ensure optimal engine loading and low fuel consumption.

- Where accurate fuel consumption figures on a single operation are required, it's often possible to get an estimate by brimming the tractor fuel tank, recording the amount of work done and any fuel added and brimming the tank again. The more fuel used between measurement points in this assessment, the more accurate the measurement is likely to be. Of course a fuel delivery meter on your tank is essential for this technique and it will only work if the tractor is constantly at one task. Fuel used travelling to/from the working field can make the results difficult to interpret.

- Many modern tractors now have electronic fuel meters which records the amount of fuel being used by the tractor at a given time. Coupled with an area meter, these can give useful instantaneous readings of fuel use and can be used to monitor the effects of changing machine setting (e.g. working depth) on fuel use. While these can be accurate, it is important to check accuracy with a brim to brim measurement.

To get benefit from these systems the data must be recorded whether a simple notebook, a laptop or an 'app' on your smartphone is used.

Table 9: Typical fuel requirements for field operations (from Witney, B.D. 1988)

Operation	**Fuel consumption (l/ha)**
Subsoiling	15
Ploughing	21
Heavy Cultivation	13
Light Cultivation	8
Rotary Cultivation	13
Fertiliser Distribution	3
Grain Drilling	4
Rolling	4
Spraying	1
Combine harvesting	11

FUEL REDUCTION OPTIONS

There are many factors which influence the amount of fuel used on tillage farms. We would not consider changing many of theses because they are part of the system, but are still worth noting particularly when comparing fuel use between farms.These include:

- Crop choice: e.g. Producing potatoes will consume more fuel than cereals
- Soil type: Heavier soils are generally more expensive to cultivate
- Field size and distance to field: this can be very important when considering land rental
- Weather: Very dry conditions during cultivation or the need to repair damage (e.g. subsoiling) after working the soil in wet conditions can use extra energy

There are also a range of factors which we can more easily change or plan to change over time. These include:

1) Change of system e.g. cultivation system
2) Machine types used in the system and their setting
3) Matching of machines within system and on farm
4) Choice of specific machine/power unit
5) Operation of the machine in the fields
6) Tyre choice etc.

Minimum tillage because of its shallower working depth has a much lower power and fuel demand than ploughed based systems.

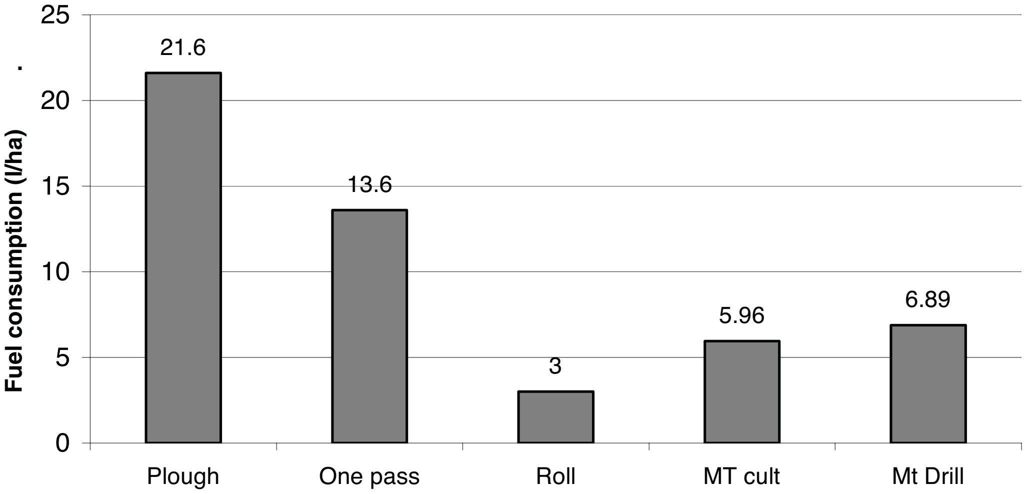


Fig 6: Estimated fuel consumption for different cultivation operations.

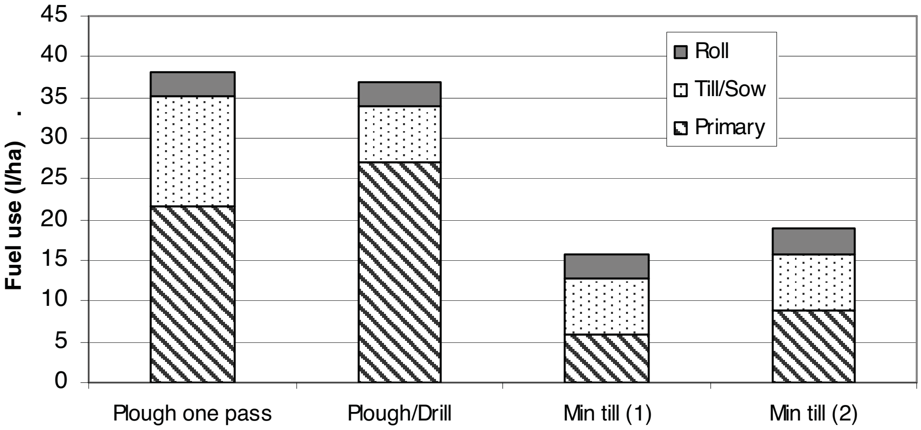


Fig 7: Fuel consumption for different establishment systems

1. Change of system

There are not many 'step' changes in fuel consumption that can be achieved in many areas of mechanisation on farms, but cultivation system is one of these. Different cultivation operations use vastly different amounts of fuel (Fig 6). The type of cultivation system used can dramatically impact on fuel use as the depth and intensity with which we work the soil is the main factor in fuel and energy use:

- Minimum tillage where cultivation is restricted to just one shallow pass of a stubble cultivator followed by sowing with a cultivator drill can more than halve fuel costs (Figure 7)
- The saving in fuel is in direct proportion to the depth to which the soil is cultivated.
- The decision to adopt min-till can not be taken on the basis of fuel costs alone as the system has other advantages and disadvantages which must be considered.
- Direct drilling can reduce fuel costs further. However for most growers direct drilling is not an option due to establishment, yield and weed difficulties.

2. Machine type and setting

The type of machine chosen can impact on fuel use:

- For cultivations, both the depth and intensity of tillage have a huge impact on power demand and fuel use.
- Modern ploughs tend to be operated at considerable depths. Ploughing at 175mm deep instead of 250mm could reduce the fuel demand by 30%.
- Working depth should be determined by what is required rather than what the machine can do in all cultivation operations.
- Intensive cultivation will also consume power. The use of a slow pass of a rotary power harrow to break up a heavy clay soil after ploughing demands a huge amount of energy compared to a top-down approach with draft cultivators working directly on the stubble.
- There are other areas of adjustment in tillage machinery that can impact on power and fuel use: rotor speed in a power harrow; breaker board positioning on a cultivator; straw chopper setting on a combine, correct draft angle and adjustment on a plough etc.

3. Matching of machines within the system and on the farm

The size and working capacity of machinery has increased dramatically over the years. While this can bring great benefits to users, the risk of mis-matching machine sizes can result in fuel being wasted. Perhaps the biggest offender here is tractor size. If a very large high-powered tractor is used on a small implement it will often use a lot more fuel than a smaller tractor at the same task. This is not a case for justifying extra tractors or larger implements, but a common sense approach to tractor/implement matching.

- Aim for a well balanced machinery system with sizes and capacities of individual machines well matched.
- Where this cannot be achieved, consider hiring a tractor or using a contractor if one task demands a significantly higher power demand than all others.

Example: A farmer uses one main-line tractor for virtually all his needs. The 90kW model (120hp) operates a 4 furrow plough, 3m one pass, fertilizer spreader and sprayer, working on a relatively light soil. As the ploughing operation puts the system under pressure, he is considering purchasing a 5 furrow reversible plough; but this would require a much heavier 120- 130 kW (160-175hp) tractor to handle the lift requirement. This tractor would tend to be less fuel efficient at the other tasks. In this case the grower should consider tractor or contractor hire for the ploughing task – although the options would need to be carefully costed.

- Lighter machines tend to consume less fuel. Newer tractors with engine power boost facilities are often beneficial as they are light and relatively powerful. However, they are limited where demanding slow speed traction is required.

Proper matching of tractors and implements will result in more efficient engine loading and lower fuel use

Table 10: The effect of a 2.3 l/hr (heavy work) and 1.2 l/hr (light load) fuel consumption difference on annual fuel costs (€/year)

	Heavy work			Light Work		
Fuel price (€/l)	**0.3**	**0.55**	**0.7**	**0.3**	**0.55**	**0.7**
Hrs /year						
500	339	620	790	175	321	409
1000	677	1241	1580	351	643	819
1500	1016	1862	2370	526	965	1228
2000	1354	2483	3161	702	1287	1638

4. Choice of specific machine /power unit.

The particular make, model and specification of machine can impact significantly on fuel costs. With tractors in particular, there can be considerable differences in fuel consumption:

- Always consider fuel consumption when purchasing a tractor and ask the dealer for specific fuel consumption figures for the model being considered. The OECD test report figures are best if they are available.
- Remember the specification of the tractor can impact on fuel use: gearbox type, hydraulic systems spec, tyre choice air conditioning etc can all have an effect.
- The difference between models can have a dramatic effect on annual fuel use. It is not unusual to have differences of up to 18%. In work this could amount to between 1.2 and 2.3 litres per hour with an 80kW tractor depending on the type of work resulting in a significant annual cost difference (Table 10)
- Other self-propelled machines can have large power differences also.
- Implement / machine choice is also important. Well designed cultivation equipment can have lower draft or pull requiring less fuel than poorer designs

5. Operation of the machine in the field

The way in which machinery is operated in the field can have a huge impact on fuel use.
There are many aspects to field operation that are worth considering.

- A loaded diesel engine consumes much less fuel for the work it produces than a partially loaded one.
  - Where possible match the implement to the machine.
  - Shift up a gear and throttle back until the engine is loaded but with reserve in hand.
  - Make the most of the tremendous torque characteristics of modern engines by loading them
  - Learn how to get the most from sophisticated transmission systems such as CVT units or autoshifting power-shift units by consulting instruction material or dealer/demonstrator.
  - Where road work is significant, chose a 50k transmission option even to allow you operate at 35kmh at reduced engine speed
  - Always use the economy PTO speed option (540E or 750) where the tractor has sufficient power to operate the machine (sprayer, spreader, topper etc)
- Only carry as much weight around the field as is necessary
  - Discard all ballast weights, loaders etc unless they are needed for traction or function.
  - Choose light machines/implements/ tractors unless heavy equipment gives a proven advantage
- Be efficient in your field work.
  - Avoid all unnecessary driving – plan your work within the field carefully to reduce headland turning and 'short' ground.
  - Where land is dispersed, consider farming in blocks of specific crops to avoid unnecessary road travel. A winter cereal crop typically has 14 field operations associated with it. Growing winter barley and winter wheat side by side in two locations, rather than one crop in each location, could result in 28 extra road journeys needed in a season!
  - Turn off the tractor when it is not needed – a good battery and starter can save fuel and engine wear.

Use the economy PTO option to reduce engine speed at low power demand operations like fertiliser spreading

6. Maintenance

Maintenance has an important role to play in fuel use.

- With diesel engines, clean air filters are essential for low fuel consumption. Clean fuel filters are needed to avoid restricting power and to protect the very delicate fuel system. The correct lubricating oil specification and a proper functioning cooling system can also impact on fuel use.
- Be very careful about getting the power output of your tractor increased either electronically (referred to as chipping) or mechanically (older tractors). Despite the claims, some of these fuelling adjustments can adversely affect fuel consumption. It depends on the tractor engine; the type of electronic adjustment (chipping or sensor signal processing) and the adjustment carried out.
- With many machines proper maintenance frequently has a role in energy saving by allowing the

machine to work more efficiently or to be set or adjusted more precisely for the work required.

- Repairs to soil engaging parts need to be carried out carefully. For example welding hardwearing steel to plough boards or shares may appear economic but can increase plough draft and fuel use.

Proper engine maintenance can help reduce fuel use

TYRES AND FUEL USE

Tyres can impact on fuel use through its impact on rolling resistance and wheel slip.

The rolling resistance of a tyre is the energy that is required to pull that laden tyre on the field or on the road. There is a conflict between tyre needs for efficient use on the road and in the field.

- For tyres in the field, prevention of sinkage or rut formation is the priority in reducing rolling resistance. This is achieved by having a large tyre that exerts a low ground pressure. Reducing pressures to the lowest allowable level will also reduce sinkage.
- On the road, rolling resistance is reduced by having a flexible sidewall but also where possible a smaller tyre where there is less heat generated through flexing.
- In the field large diameter tyres will also be easier to pull in conditions where there is some rut formation.
- Radial tyres have slightly lower rolling resistance in the field (usually have a slightly larger contact patch and lower ground pressure) and on the road (more flexible sidewalls)
- On the road, a smaller tyre with flexible side walls is more efficient and easier pull (e.g. truck type radial).
- For field machinery, select tyres that are large enough to be able to carry their axle load at:

<1.5 bar for combines
<1.0 bar for ploughing
< 0.8 bar for cultivations

Wheel slip wastes fuel but, tyres cannot effectively pull on the soil without some level of wheel slip.

- For a given tractor size, the lower the speed at which you try to transmit power, the greater the likelihood of wheel slip. A 120kW tractor hauling a 5 furrow plough at 6 km/h will have a much higher traction force and will tend to cause much more slip than if it was pulling a 4m cultivator at 12km/h
- Where you have a choice higher speed draft operations are less likely to cause wheel slip.
- Slip can be reduced by adding weight to the axle and by increasing the contact area between the tyre and the ground.

- Adding weight (ballast) without increasing tyre size, may reduce slip but will increase rolling resistance through greater rut formation. It will also cause compaction.
- The approach should be to calculate the weight required to minimise slip based on speed and power and then to select a tyre size that will allow this load to be carried at low pressures to avoid compaction and sinkage.

Wider tyres sink less and have a lower rolling distance in the field

OPPORTUNITIES FOR ENERGY SAVING IN GRASSLAND SYSTEMS

Introduction

With grassland, the fuel used in field-based operations depends very much on the farming system practiced. Summer grazing of beef for example requires minimal machinery input. Systems which conserve and feed a lot of silage will have a greater field machine input for making and feeding silage and spreading animal slurry.

Silage system

With conventional clamp silage, there are opportunities to influence the amount of fuel used by selecting particular systems.

- Most silage is harvested by precision chop harvesters which chop grass finely and deliver it to the trailer by blowing it through a chute. While these systems are simple, convenient and reliable, high speed chopping and pneumatic delivery of grass is very energy demanding.
- Pick up wagons rely on slow speed slicing of the grass and mechanical pushing of the grass into the trailer and this system uses approximately 50% of the power and fuel that a conventional chopper system would consume.
- In an overall harvesting system a conventional precision chop system in Irish conditions uses about 1.6 litres of diesel per tonne (22%DM) harvested while a pick- up wagon system consumes 0.9 and 1.2 litres per tonne.At today's prices this would amount to a cost saving of between €3.00 and €7.00 per acre on fuel with the wagon system.
- While baled silage is also reasonably efficient to the point where it is wrapped, in practice, bale transport systems are less efficient than bulk silage transport systems.
- Wilting of grass can have a huge impact on efficiency

The pick-up wagon system requires less power and uses less fuel than precision chop systems.

reducing the harvesting fuel use, and particularly the fuel used to haul trailers. If a grass crop with a dry-matter yield of 6t is harvested fresh at 18%DM or wilted to 25% or 35% DM, the weight harvested per hectare reduces from 33t to 24t or to 17t.

- All of the practices mentioned under the tillage machinery section apply such as:
  - Machinery matching within the system
  - Choice of specific machine
  - Operation in the field
  - Maintenance

Other field operations

Other field operations include slurry application, fertiliser spreading, topping and rolling.

- Transporting of slurry is expensive as water is the main material being transported. Reducing the transport distance will reduce the fuel cost (and increase workrate), but soil nutrient content will determine the scope for selection of slurry application sites.

- Tyre equipment for slurry tankers is particularly important with large diameter low pressure tyres reducing field rolling resistance.

- The need for topping can be minimised by good grassland management

- Rolling is not always necessary.

Feeding livestock

There are many factors which contribute to the fuel used when feeding livestock. While not by any means the only factor, fuel should be considered in all the decision processes associated with feeding systems:

- Feeding layout: Large distances between the feeding location and feed storage can result in excessive labour and machine costs and fuel costs. Carefully plan feed storage and building layout to reduce feed time and cost

- Systems used. The more processing or mixing of feeds; the greater the energy cost. This must be set against the benefits of the extra processing. A diet feeder system has an extra mechanised element; however the additional fuel cost involved is relatively small but not insignificant.

- Maintenance of loading equipment, either tractors or loaders, is frequently poor. Fuel system and starter/battery maintenance is important and frequently tractors and loaders at these tasks will require more maintenance than those involved in field work.

ENERGY EFFICIENCY IN HORTICULTURE

Key Points

- Monitor energy use and track your consumption against production/ output levels. If possibly equate energy use to specific tasks, kWh/mm irrigation etc. This data will allow you to establish baseline consumption and help you set realistic reduction targets.
- Implement a turn it off / close it/ turn it down campaign with your staff.
- Check the insulation and sealing of stores/cold rooms. Repair/replace damaged insulation, door seals etc and fill gaps around pipes and cable entry points.
- Clean and maintain all fans, ducts etc
- Calibrate control sensors on a regular basis and identify the best position for them
- Maintain refrigeration equipment regularly, paying particular attention to refrigerant levels and airflow over the evaporator and condenser coils
- Clean lights regularly (including both bulb and fitting) When repairing or upgrading lights consider upgrading to the energy efficient option including electronic fluorescents, discharge lights or even LED's
- Match tractor and implement combinations for optimum output. Pay particular attention to the detailed points including maintenance, tyre pressure setting and ballasting
- Repair water leaks in irrigation pipes and be careful with pump settings and operation. Consider installing variable speed drives on pump sets.
- Use simple automatic controls such as time switches, occupancy sensors and thermostats on energy consuming equipment in worker facilities.

Introduction

Ever increasing energy prices, combined with the need to grow crops with a low "carbon footprint" mean that horticultural producers are facing increasing financial and social pressure from the multiples and the public to improve their energy efficiency. A recent UK study has estimated that energy costs in horticulture will increase by 20% by 2020. While most producers are aware of the challenges facing them, identifying the precise energy saving opportunities can be difficult.

In order to commence an energy efficiency plan the above set of guidelines were produced by Chris Plackett of FEC Services and presented at the UK Vegetable Industry conference 2011 (Ref 1).

By following and recording energy usage while adhering to some or all of these guidelines, growers should be able to start identifying areas in which they can reduce energy usage.

Fans help prevent temperature stratification within the glasshouse

Heating in Mushroom Production

Key Points

- Insulation of the hot water distribution pipe-work
- Change the tariff to benefit the cheaper night rate
- Installing low energy lighting
- Installing and managing and integrated environmental control system

Introduction

Energy costs are the second highest cost involved in producing mushrooms, after staffing costs. Mushrooms need to be maintained between 18º and 25ºC while growing. Between each crop the growing house should be 'cooked out' using steam to heat the house to 70ºC for at least 8 hours. During warm weather cooling systems are required to maintain optimal growing conditions.

A new high insulated mushroom growing unit made from reinforced panels. The modern unit is located in Tullow,. Carlow.

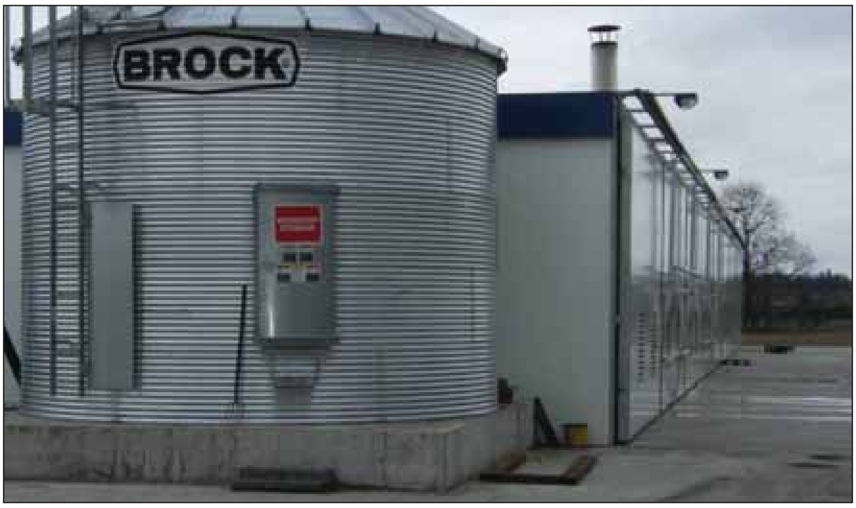
A case study was conducted by Teagasc with two commercial growers to investigate the benefits of using a solid fuel boiler instead of an oil boiler.

	Mushroom Farm A	Mushroom Farm B
Fuel	Oil	Wood Pellet
Boiler Size	-	932 KW
Weekly compost fill	115 t.	150 t.
Fuel cost/yr	€143,550	€66,365
Capital Cost € (excluding grants)	75,000 (est)	160,000

Based on these figures it is costing Farm A 282% (Farm A €1,248 /t compared to Farm B €442.43 /t) more in energy costs for every ton of compost filled. While a solid fuel boiler is approx. twice the cost of an oil boiler you would expect to recoup these costs within 2/3 years.

Energy saving technologies – Mushroom production

Description of measures	Comments
Energy monitoring/management/benchmarking	Energy monitoring is a key factor in successfully managing energy use. Industry
	monitoring will establish robust industry benchmarks.
Heating system upgrade and management	Control, insulation, flue gas dampers, condensate returns
Refrigeration system management, maintenance	.Control, maintenance, insulation
Lighting system improvements	The adoption of high efficiency lighting fittings with better control and configuration
High efficiency motors and variable speed drives	Applicable to processing, ventilation, conveying, milling, packing where the load factor on the motors is high.



I MW Wood pellet boiler and storage facility on a mushroom farm outside Tullow, Carlow. The boiler produces heat for the mushroom house at 18ºC and 25ºC depending on cycle and it also provides steam to 'Steam Out' houses after growing cycle.

Energy Efficiency in Glasshouses

Key Points

- Structures
- Temperature control
- Humidity control
- Minimum pipe temperature
- Crop lighting
- Heating systems
- Thermal screens

Introduction

New build glasshouses are increasing in height year on year. Most new production houses in Ireland are between 4.5m -5.5m in height. Over 2010 and 2011 the cost of constructing new glasshouses has been approx. €44-48 m^2 for 4.5m houses and €47-52 m^2 for 5.5m^2 (These figures are for the glasshouse only and do not include concrete flooring etc). As the height of houses increases the use of environmental control systems to efficiently control temperature and humidity is essential. Reducing the heating set point in glasshouses can typically reduce energy usage by between 10-13%. Achieving this while maintaining crop yields and quality is a challenge. One approach tested in the UK has been based around Temperature Integration (T.I.).

A wood chip boiler heating a 0.8 ha glasshouse which grow bedding and pot plants outside Gorey in Co. Wexford.
The wood chip is stored above and gravity fed by auger into the boiler in the bunker below.

Wood chip being fed through and auger system to the boiler.

Temperature Integration (TI)

Briefly, with TI you increase the vent temperature to gain energy credits from solar gain, and these are spent by lowering heating set-points at times when energy use would be high. Trials incorporating humidity control have indicated energy savings of between 6-12%.

Example 1: A trial using basic TI was conducted at a commercial tomato growing facility in Lancashire. They achieved energy savings of 8.4% in year 1 and 5.9% in year 2. The average annual energy saving was 39 kWh/m^2. There was no loss in yield or quality. Humidity controls were set to vent when unsafe levels (<90%) were achieved to prevent Botrytis. Reducing day time ventilation in year 1 led to better CO^2 utilisation, with an increase in yield of 4.3%.

Example 2: A commercial crop of Poinsettia was grown using Basic TI. After week 45 TI was ended as due to the heating requirement of the crop lowering the potential for savings was minimal. High quality plants were produced, however extra dwarfing agent applications were required for height control. Within the first 8 weeks of the trial there were energy savings of 15%. Savings declined after this due to increased requirement for venting for humidity control. Overall the energy saving was approximately 12%.

Minimum Pipe Heat

Minimum pipe temperatures are set points used to force heat into a greenhouse even if it is not required to maintain the required glasshouse temperature. This is done to help with humidity control and ensure heat stores are empty by sunrise to maximise CO_2 enrichment during the daytime.

The amount of heat emitted by a standard pipe rail heating system (1 loop per 1.6m row of plants) varies depending on pipe temperature, glasshouse temperature and heating water flow rate. The true figure can only be determined through a detailed study of each circuit, however for simplicity "For every 10ºC difference between the pipe temperature and greenhouse temperature 300 kW of heat will be emitted per hectare". The amount of fuel used to produce 1 kWh of heat depend on your boiler efficiency. Assuming a boiler efficiency of 80% 1.25 kWh of fuel will convert to 1 kWh of heat.

Table11 below gives the kWh of fuel used per hectare for a range of heating pipe temperature increments and durations.

Table 11: kWh of fuel use at varying pipe temperatures

Increase in pipe temperature °C	Hours at this level values in kWh					
	1	2	4	6	8	10
5	188	375	750	1125	1500	1875
10	375	750	1500	2250	3000	3750
15	563	1125	2250	3375	4500	5625
20	750	1500	3000	4500	6000	7500
25	938	1875	3750	5625	7500	9375
30	1125	2250	4500	6750	9000	11250

In order to calculate the actual cost:

- Take the appropriate figure from the table, e.g. 5ºC extra for 8 hours = 1500 kWh of extra fuel
- Multiply it by the cost of the fuel you use e.g. 5c/kWh
- Cost per ha = €75 per 8 hour event

Cost of CO_2

Assuming the fuel is natural gas 1 kWh will produce 0.19 kg of CO_2. Taking the example above of 1500 kWh of natural gas will produce 0.28 tonnes of CO_2, costing €75 for the gas (€0.05 /kWh). This would mean the cost per tonne of CO_2 would be €268 on gas to produce 1 tonne of CO_2.

Conversion factors for Kerosene are:
- 1 Litre contains 10.3 kWh
- 1 Litre produces 2.5 Kg CO_2
- 1 kWh produces 0.25 kg CO_2

(Reference: Growsave factsheet Update no.7 www.growsave.co.uk)

Humidity Control

Proper Humidity control is essential in maintaining yields and preventing disease outbreaks. However humidity control is expensive and in tomato production can account for around 20% of the energy usage (assuming venting is set for 85% RH). By relaxing control to 85-90% RH, you can expect to reduce overall energy use by around 12%.

A UK study has indicated that the most energy efficient way to control humidity is to vent first, then reheat to maintain temperature. This can be achieved by having a humidity influence on the vent set-point and /or by introducing a minimum vent which is dependent on the humidity. Heating is then used to maintain temperature.

In practice it is often necessary to use a combination of heating and ventilation to control humidity and it is good energy efficiency practise to use ventilation first. This is because ventilation removes moisture by exchanging a proportion of the moisture laden glasshouse air with drier air from outside. However relying solely on ventilation can lead to a drop in glasshouse temperature and heating has usually to be used after ventilation to restore the internal temperature. The alternative approach to heat first only increase the moisture holding capacity of the glasshouse air and does not remove moisture. Ventilation will have to be used at some stage to remove moisture and to rectify the overheating of the glasshouse, resulting in a loss of warm air, increasing energy use.

A key aim of humidity control must be to avoid condensation occurring on the plants, since moisture films are ideal for fungal growth, germination and disease spread. Condensation occurs when plant temperature falls below the dew point of the surrounding air and water condenses out of the air on to the cooler plant surfaces. This can occur at safe relative humidity/ humidity deficit levels and stems and fruits are at greatest risk of attracting condensation because these have high thermal inertia and are likely to be cooler than the moisture laden air at key times of the day.

Aggressive humidity control increases energy use. A simulation model developed by Dr. Paul Hamer estimates that setting the humidity control set point at 90% RH rather than 80% RH decreases annual energy use from 590 kWh/m^2 to 400 kWh/m^2.

Thermal Screens

Retractable energy saving screens are preferable to fixed screens as they offer greater flexibility in managing humidity and the effect of solar radiation. They typically have a high light transmission, good insulating effect giving instantaneous energy savings of approx 40%, allow the transmission of water vapour, have anti-condensation properties and are virtually non-shrinkable. In general they are made of polyester strips and have high light transmission (80% Direct and 88% Diffuse). Side screens can also help insulate and give approx 5-8% energy saving. As of 2011 the cost of installing screens was approx €6-7m^2 although this cost can be slightly more when installing them in an existing glasshouse. Once installed the screens should have a working life of 8-12 years depending on frequency of use. One point to note is that when retracting screens in the morning, this should be done in increments as the sudden introduction of cold air from above the screens can shock plants.

Annual energy savings of around 13% were achieved in a commercial tomato trial using retractable screens in the UK. Savings were principally achieved between weeks 41 and 17, with no loss of yield. A further trial on sweet pepper using retractable screens saved up to 15.5% more heating energy (90 kWh/m^2) than a temporary screen.

Retracted energy saving thermal screen

In order to achieve this they kept the retractable screen closed until week 3, there after the screen was opened when outside light levels exceeded 175 W/m^2 .Below these levels its operation depended on the difference between inside and outside temperature alone. This gave more effective control since the temperature difference automatically adjusted the heating strategy. When it was dark and the wind speed was less than $3m/^s$ the screen was closed whenever the outside temperature was 7ºC or more below the inside temperature. As wind speed increase the difference should be reduced as increased wind speed causes additional heat looses in a glasshouse.

Thermal screen control set points used in pepper production

Factor	Time Period	Value	Range
Radiation Limit	All the Time	175 W/m^2	N/A
Inside-Outside temperature difference	10:30 – 14:00 14:00 – 10:30	9^oC 7^oC	N/A N/A
Wind influence on temperature difference	All the Time	Proportional decrease of up to 3^oC	3-6 m/s
Light influence on temperature difference	All the Time	Proportional increase of up to 8^oC	0-175 W/m^2

* recreated from HDC Factsheet PC227a

Screens and humidity

Closed screens can increase the glasshouse humidity and controlled gapping possibly followed by venting and reheating is necessary to control this. Controlled gapping allows cold, dry air above the screen to mix with the moisture laden air beneath and will frequently be sufficient to control humidity without needing the vent and reheat. Screen gaping is generally set to operate on a humidity influence so that the screen gap gradually increases to around 15% as humidity rises. Beyond this point gapping will have no further effect and it will be necessary to retract the screen fully, vent and reheat.

It can be expensive in energy terms trying to prevent the glasshouse air temperature falling when screens are removed in the morning and the warm air under the screen is replaced by unheated air from above. Best practise is to allow the glasshouse temperature to start falling around one hour before the screens are removed, allow it to remain low for several hours then to gradually increase it, making use of solar gain. This planned temperature reduction is known as DROP and will save up to 1.5 -2% of energy.

Energy saving technologies – Horticultural production

Description of measures	Comments
Energy monitoring/management/benchmarking	Energy monitoring is a key factor in successfully managing energy use. Industry monitoring will establish robust industry benchmarks.
Boiler efficiency and control	Wide range of activities from simple sealing to total building re-insulation
Climate Control computer application	Key issues are ventilation duct design, choice of fans.
Glass maintenance and sealing	Through better control of temperature, more efficiency speed control, less waste through over ventilation.
Lighting system improvements	The adoption of high efficiency lighting fittings and better control and configuration.
High efficiency motors and variable speed drives	Applicable to feeding systems, waste management and egg collection where the load factors on motors is high.

CO_2 Enrichment

For some crops CO_2 enrichment is essential to increase yields. Dry weight increases and therefore yield increases depend on optimal photosynthesis in the crop canopy. This process is dependent on CO_2 concentration. However burning fuel to create CO_2 can increase fuel bills dramatically. Therefore it is essential to ensure the benefits outweigh the costs. It is important to remember that plant response to CO_2 is not linear. Normal background CO_2 levels are approximately 380ppm, which during the day in the summer can fall to 200 ppm. Preventing this decrease by supplementing CO_2 levels will lead to between a 5-15% increase in yield. In large scale commercial production it is now common practice to increase CO_2 levels to much higher levels than ambient. By increasing CO_2 levels to between 800-1000 ppm in a tomato crop you can expect a 20-30% increase in yield. However it should be noted that some crops, such as cucumber are sensitive to CO_2 at these levels.

Well insulated heat storage tanks are essential to reduce the cost of CO_2 enrichment

Flue gases from natural gas boilers and CHP boilers can be used for CO_2 enrichment. CHP units produce more CO_2per unit of heat output than a boiler, however with reciprocating engines a catalytic converter is necessary to prevent pollutants entering the glasshouse. Currently, using the flue gases from biomass boilers cannot be used as a CO_2 source. There is technology which may make this possible in the future but it is currently extremely expensive to achieve. In order to produce 1Kg of CO_2, it is necessary to combust 5.26 kWh of natural gas, 0.4 litres of Kerosene and 0.66 litres of LPG.

Plastic distribution pipe for CO_2 runs under the crop

As CO_2 is required during daylight hours, it is necessary to combust fuel to produce CO_2. The excess heat produced, which is not required in the glasshouse needs to be stored. This can be done in insulated hot water storage tanks. A heat storage capacity of 150-200m^3/Ha of glass is typically recommended.

Distributing CO_2 evenly around the Glasshouse is important. On benched growing systems it is now best practice to install perforated plastic tubes under the growing benches.

Horticultural Lighting

Supplementary lighting can account for 15% or more of growers total ‘delivered energy’. Photosynthetically Active Radiation (PAR) determines growth and yield and is measured as W/m^2 or Ìmol/m^2/s. High pressure sodium lamps are still the primary choice for supplementary lighting. 600W and 1000W lamps are more energy efficient than 400W lamps but need to be mounted higher (further from crop). Lamps should be replaced after 10,000 hours of operation and reflectors should be cleaned regularly. Lux is a measure of how bright a light source appears to the human eye and is an appropriate measure of lighting in commercial horticulture. Light sensors that measure in lux give much greater weight to green/yellow light than to PAR and give a misleading indication of the potential value of a light source for plant growth.

Light Source	**µmol/m^2/s per W/m^2**	**Lux per W/m^2**
Daylight	4.57	249
High pressure sodium (HPS)	4.98	408
Metal halide (MH)	4.59	328
Warm white fluorescent	4.67	356
Incandescent	5.00	251

* recreated from HDC Factsheet 09/09

Supplementary lightning is most beneficial when natural light levels are low. Operating times should be chosen so as to give a long daily photoperiod. Settings should be used to turn and lighting off when outside light levels are high. Tungsten lamps, can in some cases be replaced by compact fluorescent lamps for photoperiodic lighting. However these need to deliver similar levels of PAR and direct lamp replacement may not be possible. LED lights have significant future potential for use in horticultural applications since it should be possible to design these to provide precisely specified spectral outputs. However significant technological advances need to be achieved for this technology to be used on a large scale. The heat from supplementary lighting can offset glasshouse heating costs. A trial of a lightning installation over an ornamental crop provided additional heating of 60 kWh/m^2/year.

Typical Lamp efficiencies based on manufacturers data and the published data

Lamp	**Voltage (v)**	**Ballast Type**	**Actual Power (w)**	**Lamp output (µmol/s)**	**Lamp efficiency (µmol/s/input W)**	**Comparative efficiency (%)**
Standard HPS 400W	230	Electromagnetic	450	630	1.40	-
Horticultural HPS 400W	230	Electromagnetic	450	725	1.61	+15
Horticultural HPS 600W	230	Electromagnetic	670	1100	1.64	+17
Horticultural HPS 600W	400	Electromagnetic	670	1150	1.72	+23
Horticultural HPS 600W	400	Electronic	635	1150	1.81	+29
MH 400 W	230	Electromagnetic	450	540	1.20	-14

* recreated from HDC Factsheet 09/09

Supports and Grants

Most of the technologies described here are eligible for grant aid under the “Scheme of Investment Aid for the Development of the Commercial Horticulture Sector”. Under this scheme you can apply to receive grant aid of up to 40% of the cost of horticultural equipment or buildings. In regards to glasshouse construction the typical grant awarded for new build glasshouse’s has been around 20-25%, with equipment and heating systems usually grant aided at a higher percentage. In order to receive grant aid you need to be actively operating as a growing enterprise.

Growers who are members of producer organizations may be able to apply for a grant to update equipment and facilities through their PO.

If you are investigating the potential of installing a CHP or a new boiler it is possible to apply for funding for a feasibility study of new investment through your local ‘Leader’ organisation.

SECTION 2

RENEWABLE ENERGY IN AGRICULTURE

Section 2

Renewables in Agriculture

Introduction
Meeting the demand for a high quality food supply against a background of climate change and the need to make a reduction in our greenhouse gas emissions presents a major challenge for the farming community.

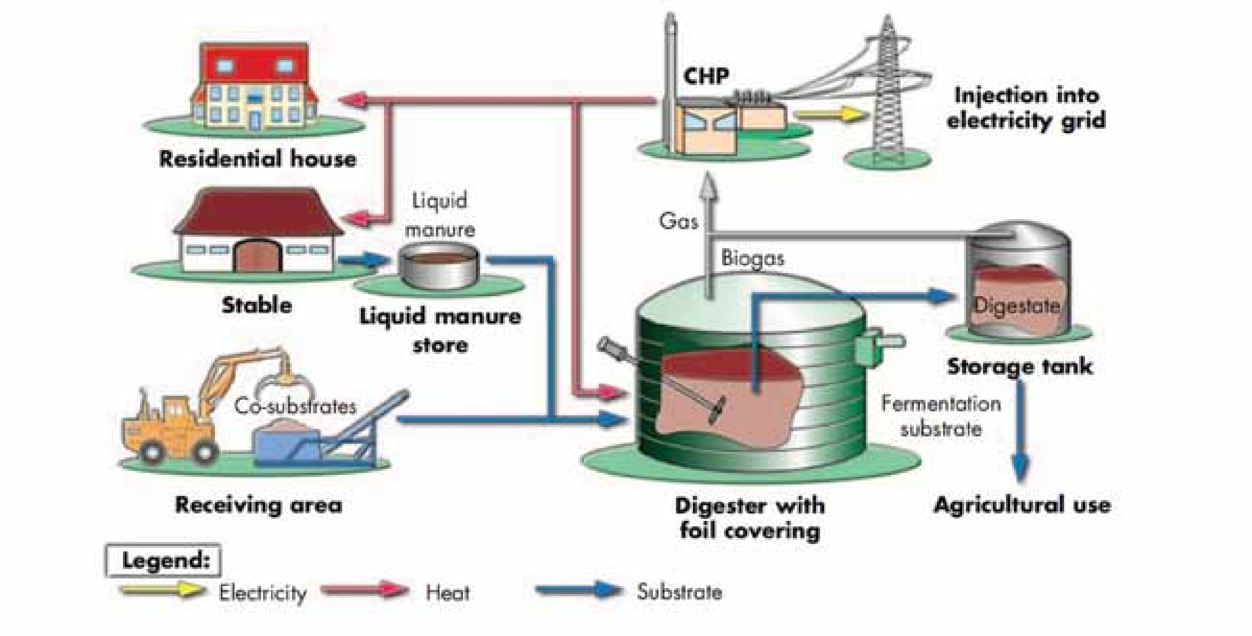
It is widely recognised that the land based sector can make a valuable contribution to the development of renewable energy whilst benefiting by exploiting the opportunities that the production and utilisation of renewable energy offers.

Waste or by-product materials such as wood residues, straw, tallow, and recovered vegetable oil would produce relatively small amounts of energy but as reasonably priced feedstocks they can contribute to liquid biofuel development. Animal manures have a large potential, and their digestion could play a key role in the reduction of methane and ammonia emissions. Digestion of all pig and dairy slurry should be a medium-term target.

The most promising technologies for the conversion of farm biomass to energy are:
Direct combustion or gasification of wood or other energy crops in heating or Combined Heat & Power (CHP) plants or as domestic fuel.
Methane production from animal slurries, used in heating or CHP plants.
Vegetable oils and animal fats as engine fuels or CHP plants: This would entail the conversion of either the fuel (to biodiesel) or the engine.

In all these areas, technologies are now well established and in practical use in other EU countries. Such incentives as have been available in Ireland to date to stimulate renewable energy production have not been sufficient to stimulate the establishment of viable projects. To allow a beginning to be made, two changes are needed immediately: In order to support renewable electricity a REFIT (Renewable Energy Feed In Tariff) tariff sufficient to generate activity for Anaerobic Digestion (AD) CHP, combustion CHP and co-firing at power stations is needed. If the domestic and commercial heat market is to develop a form of support will be required to encourage the installation of biomass boilers and their associated supply chains. Indigenous liquid biofuel production has all but ceased since the introduction of the Biofuel Obligation Scheme, therefore if we are to deliver on self-sufficiency in transport the support mechanisms need to be addressed.

ANAEROBIC DIGESTION (AD) POTENTIAL



Schematic of the AD Process
Scource: SEAI

Anaerobic digestion (AD) uses bacteria to convert organic matter into methane and nitrous oxide in the absence of oxygen. Farm wastes can be used in an AD facility to produce methane, which can be used to produce heat and power or as a transport fuel. On combustion methane is converted to the less damaging carbon dioxide and releases energy which can be used in place of fossil fuels for heat and power. Whilst there are currently no realistic plans to trap the gaseous emissions from farm animals systems the use of AD is now a well established technology used increasingly in Europe and elsewhere. The gas, once cleaned, can also be passed through an internal combustion engine either for the generation of electricity or as a fuel for vehicles. The gas produced often called biogas, and the power it generates is increasingly valuable, as it will assist towards the achievement of targets for renewable energy production.

Energy Potential of Agricultural Slurries

Some 132 million tonnes of agricultural slurries, wastewaters, effluent and sludge are generated in Ireland annually. The energy potential of agricultural slurries from AD are presented in table 12. Poultry manure has the highest per tonne energy potential at 0.131 MWh of electricity per tonne. The energy potential of cattle, pig and poultry manure is estimated at 2,598 GWh (Giga Watt hours) or approximately 10% of the total electricity supplied in the Irish electricity market which requires about 26,000 GWh annually.

Cattle manure can be digested to produce biogas which can be converted to heat and electricity or Combined Heat & Power (CHP)

Table 12: Indicative Energy Potential From Livestock Slurries

Livestock	Population June 2010 '000	Wet Tonnes/year (millions)	Potential Biogas m^3/year (millions)	Potential Electricity MWh/year	Electricity MWh/tonne feedstock
Cattle	6,606	80.4	1,768.8	2,492,400	0.031
Pigs	1,485	1.9	41.8	53,200	0.028
Poultry	13,968	0.4	30.0	52,400	0.131
Total		**82.7**	**1,840.6**	**2,598,000**	

Table 13: Biogas from Agriculture and Abattoir Wastes

	Biogas (m^3) per tonne organic material	Energy equivalence in heating oil (litres)
Cattle Slurry	22	13
Pig Slurry	22	14
Poultry Manure	50-100	33-65
Abattoir gastro-intestinal waste	40-60	26-39
Abatoir fatty waste	>100	>65

Drivers

There are some reasons why there is now renewed interest in anaerobic digestion. The rise in cost of Fossil fuel derived energy has concentrated minds on the alternatives. The growing awareness of climate change has lead to directives from Europe forcing the Irish government to control the "greenhouse" gas emissions.

Specifically the landfill directive 1999/31/EC has set targets for the reduction of the amount of biodegradable matter that is sent to landfill. The majority of this material must either be composted, digested, rendered or incinerated. The process, for material of animal origin, is tightly controlled by the Animal By-Products regulations. The increasing cost of land-filling is focussing the minds of land-filling and food processing companies for alternative disposal options.

Farm scale biogas plant in Germany, co-digesting maize silage and pig slurry.

The control of nutrient run-off from farmland may also help the development of digestion as strict standards for water quality and control of nitrates and phosphates may mean that in some areas digestion is favoured over inorganic fertilisers.

Benefits of AD

Anaerobic digestion of animal slurry and other feedstocks could bring several potential national benefits. It would allow the methane to be harnessed for energy use, while at the same time reducing greenhouse gas emissions normally emitted during manure and waste storage, artificial fertiliser use, and emissions from soils after spreading any fertiliser. It would also alleviate smells, reduce artificial fertiliser use and potentially reduce nutrient loss to the environment. Currently only a handful of farm digesters have been erected to date, largely due to the difficulties in achieving economic viability.

Anaerobic digestion of pig slurry has the potential to reduce emissions by the equivalent of 144 kg of CO_2 per tonne of pig-meat produced. On this basis, 75% adoption by the pig sector in Ireland would reduce emissions by 16,000 tonnes of CO_2 per year. If digestion were economically viable, a high adoption rate should be achievable in this sector as the technology would fit in easily on the large centralised units that now make up most of the industry. Also these units are having increasing difficulty finding land nearby for spreading, and the smells from slurry spreading are becoming an increasing problem. Digestate does not have an offensive odour, and the nutrient availability is improved and more reliable, therefore it is ikely more farmers would be willing to use digested slurry as a fertiliser, probably making it easier to find land for spreading. Anaerobic digestion could provide a solution to the management of manure from intensive agriculture, if economic viability can be achieved.

Digestion would also be applicable to the dairy industry, but is likely to have a much slower uptake. Cattle slurry is only produced during part of the year, when the animals are housed. Many dairy units are too small to justify an on-farm digester and too geographically dispersed to supply a centralised unit. Smells are less of a problem than with pig slurry, and to date on most dairy farms the land bank is adequate to take all the slurry. However, there are situations where the farm is suited to having a digester, particularly where there is a high heat demand. Beef production has had so many recent problems and is generally so unprofitable that it is difficult to envisage the sector making a significant investment in digesters in the near future.

If digestion could be introduced at the levels projected above in the pig and dairy sectors, a total of about 80,000 t/year of CO_2 could be abated, and methane with an energy content of about 80 TJ (22 GWh) produced. Some of this could be used for on-site heating, but it is likely that most of it would be used in electricity production for export to the national grid. The main reason for lack of investment in digesters to date is that the financial payback is longer (>5 years) than that currently acceptable to financing institutions. If digesters were rewarded for the benefits they provide to national interests, for which the farmer cannot currently gain value, economic viability could be reached.

Viability of AD

Looking to the future, there are a number of scenarios in which biogas production could become viable. The first would be a substantial increase in the price available for renewable electricity. The present price paid to on-farm digester operators in Germany is from €0.11- 0.23/kWh, and this is stimulating rapid development of the sector. The Department of Communications, Energy and Natural Resources have proposed an increased guaranteed price electricity price under REFIT (Renewable Energy Feed in Tariff) of €0.11–€0.15 /kWh for the production of electricity from biogas. This level of pricing will not stimulate farm based AD production. The high cost of growing grass, maize or other forage crops for AD production would be prohibitive at this level of REFIT.

An engine based CHP power plant has an efficiency of up to 90% and produces 35% electricity and 65% heat.

Another scenario that might stimulate development would be the co-digestion of animal manure along with organic wastes with an attached gate fee. Disposal of food wastes is an increasing problem and several digestion options could be considered. On-farm digestion of a combination of animal manure and local food and catering wastes would be one possibility. If these wastes were processed in a digester prior to spreading there would be a significant improvement in the benefit both to agriculture and the environment. A gate fee per tonne could be levied by the digester for taking these wastes, but much of this value is required to pay for additional costs resulting at the digester. These wastes also generally have a higher energy content and current management of them (landfill) produces significant greenhouse gas emissions, therefore it would be very attractive to process them in a digester. However, because they generally contain animal by-products there are added processing requirements and restrictions on where and when the digestate can be utilised. These requirements increase capital and processing costs and restrict the number of locations where such plants can be located.

Some companies dry and pelletise the digestate and sell it as a nutrient source for flower beds and gardens.

Another method of improving the financial return from digesters, is to develop a method of rewarding the digester owner for the environmental benefits that can result. Both a Danish research report in 2002 and a report from the EPA in 2005, state that over 50% of the value of anaerobic digesters is in national benefit and for which currently digester owners in Ireland are not rewarded for. These benefits include, reduction in greenhouse gas emissions in many ways, avoided costs related to other waste management solutions, improved water and air quality and rural development benefits.

AD in Austria & Germany

In Austria about 10% of new plants digest energy crops only, 65% digest energy crops with animal manures, the remainder also include other organic wastes (less financially supported by the Austrian government). Only a small proportion of plants digest only one feedstock (3.1%). The remainder use 2-7 different materials with over half using 4 or 5 feedstocks.

Pig manure is used in 61% of the plants and cow manure 39%. Energy crops used are listed in the table below. Maize is clearly very important. Grass specifically rye grass, may be an alternative in areas that do not grow maize well. In the future further crops such as switchgrass, reed canary grass or other giant grasses may be considered as feedstocks for digesters.

Table 14: Use of energy crops in German AD plants

Crop	Frequency of use
Maize	92%
Cereals	50%
Whole Crop Silage	48%
Grass Silage	37%
Grass	8%
Corn Cob Mix	5%
Maize Grains	4%
Sunflowers	2%

Maize silage used as a feedstock in Germany

Siting of plants

In Ireland plants will need to be sited in areas where there is a supply of animal manures, potential for growing energy crops and ideally a source of other organic wastes. To increase the options for including organic wastes such as municipal green wastes or food processing wastes, the successful plants will either be near a centre of population, or allied to a food processing plant in a rural location.

Constraints

There are a number of factors that would dictate against investment in an anaerobic digestion system on farm scale. These would be:

- Insufficient access to a suitable feedstock
- Process costs associated with Animal By-Product regulations and cost of permit to apply digestate to land.
- Lack of continuity of supply of feedstock (could be addressed by storage facilities)
- Insufficient need for power on-site and a prohibitively expensive grid connection.
- Insufficient need for “waste” heat produced
- Lack of land that can utilise the digestate usefully
- Periodic shut downs when no staff will be available

Is it worth investing in a farm scale anaerobic digester?

- The economics of operating an AD plant are improving making this technology worth considering. It is clear that a plant fed only with animal manure will need to be very large to produce enough gas to payback its costs. This is more likely to be appropriate as a central plant taking material from a number of farms.
- Approval to apply digestate to land should be investigated at an early stage.
- Other sources of organic matter will considerably more gas than manures so adding these in the digester will give more gas, and boost energy production.
- If the farm can produce crops specifically to feed the digester, at a cost less than the value of the extra gas output, then it may be possible to reduce the payback period.
- If the digester is able to dispose of organic waste then the extra income received could cover the extra cost of pasteurisation equipment and also reduce the payback period.
- The treatment of farm wastes to reduce pathogen load, increase the value as a fertiliser and reduce odour emissions may also help to justify the system installation.

BIOMASS - COMBINED HEAT & POWER

Combined Heat and Power (CHP) is the utilisation of waste heat from electricity generation thereby improving the overall efficiency of power generation. CHP is therefore the simultaneous generation of usable heat and power in a single process. CHP is sometimes referred to as co-generation. Electricity production on its own is extremely inefficient. In practice the maximum attainable conversion for electricity is around 40% with the heat generally being lost in the cooling towers. In order to achieve a design economic optimum the heat produced during the process needs to be utilised.

Biomass CHP

CHP can be powered by biomass (plant material, vegetation, or agricultural waste) or biogas (methane produced by the aerobic or anaerobic digestion of biomass). In the current environment of volatile fossil fuel costs, using an opportunity fuel such as agricultural residuals or tree thinnings might provide the best economics for a project, as well as allow the project to qualify for additional incentives due to the renewable and clean attributes of the fuel.

Sizing a CHP system

The dimensioning of both the electrical and thermal (heat) output will determine the overall efficiency of a project. Generators which are connected directly to the grid can be designed to be heat controlled. CHP systems have the optimum dimensioning when they have the greatest possible annual running time in heat provision. For economic reasons a running time in excess of 5,000 hours should be reached thereby distributing the investment costs over a larger energy volume and the electricity supplied from the CHP system is cheaper per unit. CHP systems are dimensioned to cover the basic load. The CHP system should cover 50 – 80% of annual power and heat requirements. If a CHP system is to be installed in combination with a boiler, in practice a thermal dimensioning of the CHP system to 20% of the boiler output makes sense in order to ensure a running time of over 5,000 hours per year. If a selected unit is too large, it may well be uneconomic as the annual running times are too low. Conversely if the annual running times are too low the full potential economic and ecological benefits are not achieved.

Biomass CHP in Ireland

Graingers sawmills in Enniskeane Co. Cork have installed a 1.8 MWe and 4 MW thermal CHP and Munster Joinery located at Ballydesmond, Co. Cork have installed a 2.8 MWe. For Anaerobic digestion (AD) the Dublin sewage treatment works operates a 4 MWe but There are also AD CHP in Dundalk, Drogheda, Swords, Clonmel, Greystones and Tullamore sewage treatment works. There are also some water treatment AD CHP plants around the country.

Technologies

The main technologies which currently prevail in CHP applications are steam engines, Organic Rankine Cycle (ORC) units, and gasification systems with the possibility of hot air and Sterling engines on the smaller scale operations.

Stirling engine at Oak Park

Until recently, CHP plants fired from biomass have only been available in large sizes (>2MW of electricity). However, small scale biomass CHP plants have started to become available commercially in more recent years. The biomass CHP plant at Oak Park is an example of a small scale plant that has recently become available. The plant is designed and manufactured in Denmark by the Stirling Danish company. The 35 kWel plant uses wood chips as a fuel. The wood chips are gasified (i.e. turned into a gas) in the first step in the process. The gas is then conducted into a gas boiler where it is burned to generate heat. Heat generated in the boiler is used to heat hot water but the heat is also conducted via heat exchangers into an external combustion engine called a Stirling engine where the heat is used to turn the engine and generate electricity. The plant which was funded through the Teagasc Vision Fund Programme and was commissioned during the early part of 2011.

Fuel requirements

The fuel required for a biomass CHP system will be determined by the number of operating hours which should exceed 5,000 hours. The typical running time would be 6,570 hours per year for small scale biomass CHP. Due to maintenance and downtime no plant will operate 100% of the time. The calorific value of wood chip at 50% moisture is 7,960 kWh/tonne or 7.96 MWh/tonne. Fuel requirement is also determined by the load factor which is a measure of efficiency of a system. It's the actual amount of kilowatt-hours delivered on a system in a designated period of time as opposed to the total possible kilowatt-hours that could be delivered on a system in a designated period of time. The ratio of the average load supplied during a designated period to the peak load occurring in that period, in kilowatts. The typical load factor operating parameter for small scale biomass CHP is 80%.The power to heat ratio is typically 1:4 or up to 1:5 and the overall efficiency of a biomass CHP system should be about 80% i.e. 80% of the input fuel is converted to heat or power energy.

Taking the Example 3 MWe biomass CHP

A 3 MWe biomass CHP unit running at maximum output of 6,570 hours per year with an overall efficiency will produce (3 x 6,570) = 19,710 MWh / year of electricity. Taking the heat output at 4:1 (heat: electricity) is 78,840 MWh / year of heat.

The combined heat and power output is 98,550 MWh / year. The overall expected efficiency would be 80% therefore the total fuel intake would be 98,550/0.8 = 123,188 MWh. The fuel input to meet this demand is (123,188 / 7.96) 15,475 tonnes of chip (50% moisture) per year. Willow produces 40 tonnes of fresh material per hectare every second year. This would require approximately 387 hectares of willow per year growing on a two year rotation therefore a total cropped area of 774 hectares of willow to meet the demands of this 3 MWe CHP application.

Carbon savings

Based on the average emission factors for Ireland (SEI, www.sei.ie/Publications/Statistics_Publications/Emission_Factors) heat at 63,072 MWh x 0.257 t/MWh (assuming kerosene at 0.257 kg CO_2 per kWh) saves 16,209 tonnes of CO_2 per year and on the electricity side it's a saving of 15,768 x 0.5428 t/MWh (assuming electricity at 0.5428 kg CO_2 per kWh of electricity) saves 8,559 tonnes of CO_2. Therefore the total saving with this 3MW electrical CHP is 24,768 tonnes CO_2 per annum.

Outputs of $3MW_e$ biomass CHP unit

Electrical output	15,768 MWh / year
Heat Output	63,072 MWh / year
Combined Output	78,840 MWh / year
Input	35,674 tonnes of chip per year[1]
CO_2 savings	24,768 tonnes CO_2 per annum

Economics

A 3 MWe CHP unit would cost approximately €16 million on a greenfield site. Table 15 below indicates the savings based on the proposed REFIT price of €120 MWh for electricity and the price of heat originating from a medium fuel oil boiler based on SEAI values.

Table 15: Income and expenditure

Annual income and savings	
Sale of electricity @ €120 / MWh	€1.89 million
Saving from heat (replacing oil costing €73.2 / MWh)	€4.62 million
Total Savings	**€6.51 million**
Annual Costs	
Woodchip @ €80 per tonne[1] including delivery	€2.85 million
Operation & maintenance	€0.5 million
Total costs	**€3.35 million**
Annual savings	**€3.16 million**

[1] Wood chip has not been dried 55% moisture content

The simple payback for the CHP unit is approximately (€16 million / €3.16 million) 5 years when compared to heat from an oil fuelled system and power from the national grid. The biggest problem in most cases is getting project finance. The payback period will decrease as the cost of fossil fuel oil increases.

You can also put a value on the carbon for a large energy user who is part of the EU emissions trading scheme. If you could trade the carbon at an approximate value of €20 per tonne (www.pointcarbon.com) the installers would have an approximate additional saving of €495,360 per annum. The price of carbon is predicted to rise to €40 per tonne by 2020 as more sectors will become part of the EU Emissions Trading Scheme.

Issues

If biomass CHP is to be seriously considered the barriers to district heating must be reduced. There are currently no direct supports for district heating infrastructure therefore a parallel support for district heating should be considered. The 30% capital support from SEAI's biomass CHP programme is no longer available. The grant aid of 40% towards CHP feasibility studies is also no longer available. CHP technology awareness in Ireland is relatively low and training should be provided to energy professionals to enhance the knowledge of CHP in Ireland. In the short term much CHP technology will be imported, however if Ireland were to develop significant research and manufacturing capabilities for CHP technology this would lead to significant indirect job creation.

HYDROELECTRICITY

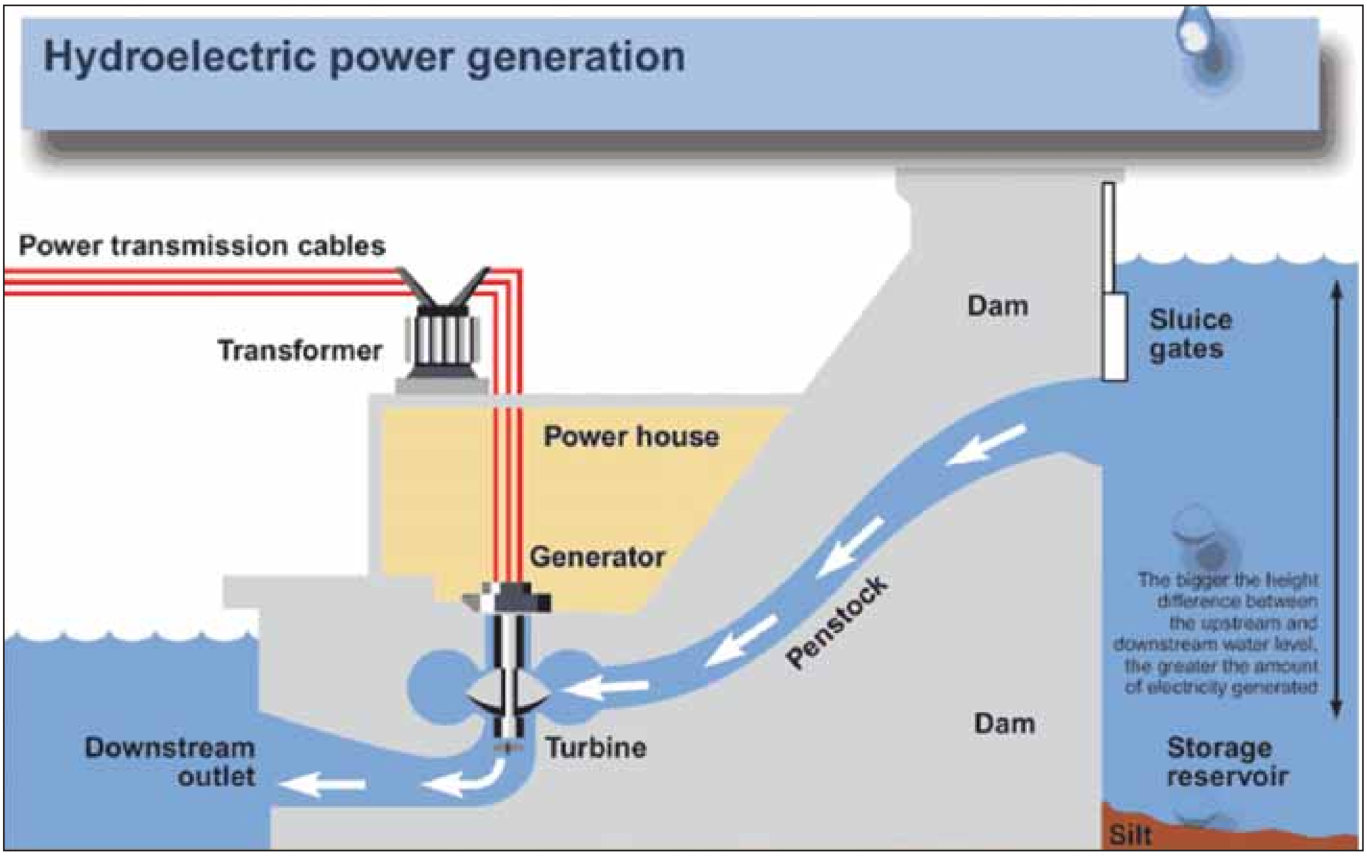
Hydropower is probably the oldest renewable energy technology, with water wheels used over 2,000 years ago. The technology is now very advanced with large-scale hydroelectricity one of the most common renewable energy technologies in the world for the production of electricity. There are numerous old mill sites, rivers and streams around the country which could be suitable for producing hydropower.

Principle of the technology

Hydropower or hydroelectricity converts stored potential energy of water held at a height to kinetic (moving) energy to drive a turbine, which then generates electricity. A drop or 'head' of water and a flow rate is required for the generation of hydropower. It is generally better to have more of a head than a flow since this reduces the size of the equipment.

The basic requirements for hydropower schemes are:

- Good rainfall
- Adequate flow and/or water pressure
- A water intake, usually above a weir or behind a dam
- A water transport system, which will channel the water
- A flow control system
- A turbine and generator
- An outflow



Schematic of hydropower generation

There are three main types of hydropower system: Run of River where the turbine is situated within the flowing water), Diversion (where the supply of water is taken from a dammed river or lake to a remote powerhouse containing the turbine and generator and then returned or Pumped Storage (which includes two reservoirs and water is pumped back up to the top at times of low demand).

Scales

A micro-hydro scheme is usually under 100kW. A minimum of about 25kW for commercial schemes is required. A mini-scheme is usually between 100kW and 1MW and a small scheme is between 1 and 10MW. There are no commercially defined sizes however the EC define small as up to 10MW.

Efficiency

The efficiency of converting the energy from the water to electricity is between 50% (for micro systems) to about 80% for a small system.

Calculating hydropower

Before embarking on any hydropower generation project it is essential to survey the proposed site to calculate the amount of available hydropower. The two vital factors to consider will be the flow and the head of the stream or river. The flow is the amount of water which can be captured and re-directed to turn the turbine generator. The head is the distance the water will fall on its way to the generator.

The larger the flow – i.e. the more water there is, and the higher the head – i.e. the higher the distance the water falls – the more energy is available for conversion to electricity. Double the flow and double the power, double the head and double the power again.

A low head site has a head of below 10metres. In this case you need to have a good volume of water flow if you are going to generate much electricity. A high head site has a head above 20 metres. In this case you can get away with having a lesser flow of water.

The key equation is the following:
Power = Head x Flow x Gravity x Efficiency Factor

- where **power** is measured in Watts, **head** in metres, **flow** in litres per second, and acceleration due to gravity in metres per second per second. The Efficiency factor accounts for energy losses in the turbine design, and it converts theoretically available power into actual usable power.

The acceleration due to gravity is approximately 9.81 metres per second per second – i.e. each second an object is falling, its speed increases by 9.81 metres per second (until it reaches its terminal velocity). Therefore it is very simple to calculate how much hydropower
you have.

Example

Head of 12 metres
Assumed efficiency = 50%
Flow of 200 litres per second
Power = 12 x 200 x 9.81 x 0.5 = 11,775 Watts or 11.7kW

Turbine installed in Donegal – Source D Twomey

Types of turbine design

All turbines have a power-speed characteristic. They will tend to run most efficiently at a particular speed, head of flow combination.

A turbine design speed is largely determined by the head under which it operates. Turbines can be classified as high head, medium head or low head machines. Turbines are also divided by their principle way of operating and can be either impulse or reaction turbines. The range of common design types is given in the table below.

	High head	Medium head	Low head
Impulse Turbines	Pelton Turgo	Cross-flow Multi-jet Pelton Turgo	Cross-flow
Reaction turbines		Francis	Propeller Kaplan

Economics

Most of the costs incurred in a hydro scheme will usually occur at the building stage of the project. Once the project is operational it can run for several years without substantial further expenditure.

Projects will vary in terms of the investment costs required. The Cost table above outlines the various cos s which will be encountered along the way. Costs will reduce with economies of scale for larger projects. Industry sources have given estimates of €5,000 per kW to develophydroelectricity projects.

Costs
Machinery
Civil works
Electrical works
External costs – Planning & Engineering
Sub Total
Leasing
Metering
Rates
Maintenance
Insurance
Sub total
Returns
50 kW – will produce producing 219,000 kWh per year @ 9c kWh, assuming year round availability of flow.

If all the power is been used on site 15 cent + (is off-set) what ever indicator is used to work out what electricity prices will increase every year. If the power is sold off site the price is 9 cent at the moment this may change if carbon tax is introduced.

The Archimedes Screw now used for over 2,000 years as a pump is becoming a popular technology choice for low-head hydro-power generators.
Source F O'Brolchain

Planning and Feasibility

All greenfield sites require planning permission. It is best to discuss plans with the relevant fisheries board before applying for planning so that most if not all of their views are taken in to account. Natural streams have seasonally variable flow, and the feasibility of all year round generation needs to be assessed. The hydro unit will impact on the river system; therefore Local Authority planners will send all applications to the local Fisheries Board hence it is best practice to get their views. The main issues are quantity of water been abstracted, the length of channel affected by reduced flows between the intake and the tailrace, the need for screens to comply with the 1959 Fisheries Consolidation Act and a fish survey on the section of river been selected for the project.

Advantages and disadvantages of hydropower

Advantages

- Predictable output – as long as there is a consistent flow of water at a usable head.
- New build and retro build opportunities – as long as planning permission can be obtained
- Long hardware life – about 100 years for most of the equipment, and parts are widely available and reliable
- High efficiencies (compared to Wind or Solar PV)
- Stand alone or connected to grid possible

Disadvantages

- Very site specific – there have to be certain site requirements for the hydropower scheme to be granted planning permission and for economic extraction of energy.
- Geographically dispersed – sites for an effective scheme are usually in remote locations
- Need consent to "extract water" – permission is required to avoid harming other riparian water users, or wildlife in the river or upsetting the local eco-system.
- Limited resource availability – this is dependent on rainfall.

Further information:

Contact: Dan Twomey Water Power Eng, Carrigeen, Banteer, Co. Cork 029/58177
www.dantwomeywaterpowerengineering.ie

Or Fiacc O'Brolchain, 13 Marlboro Rd, Dublin 4 01/6680043 www.waterpowerservices.ie
Or Tobin Engineers, Market Street Castlebar Co. Mayo 094/9021401 www.tobin.ie

MICRO-GENERATION FROM WIND

Anyone can put up a wind turbine on their property without being required to seek planning permission if the tower does not exceed 10m in height, the rotor diameter is not greater than 6m and other pre-conditions such as distance from boundaries are satisfied. These dimensions allow for turbines that can generate up to 11kW (3 phase) but the most popular installations are 5kW (single phase) turbines.

Background

Most wind turbines in Ireland consist of 3 turbine blades rotating around a horizontal hub (a Horizontal Axis Wind Turbine or HAWT). When the blades face into the wind the force of the wind force the blades to turn. The rotating blades turn a shaft (rotor) and then magnetic fields cause this mechanical (rotating) energy to convert to electrical energy within the generator. In most turbines a gearbox is used to increase the rotational speed for the generator. However there are gearless turbines available. The windspeed has to be over a certain level to overcome inertia for the blades to turn. This is usually about 3-4 m/s for most wind turbines. Turbines generate maximum rated power at about 15m/s. At about 25m/s the wind turbine will cut out to prevent damage to the turbine. A wind turbine generates electricity for 75-80% of the time however its power output in kWh varies depending on the wind speed from zero to maximum output.

Microgeneration payment

Anybody producing electricity can avail of an export payment linked to the economic cost of procuring electricity in the wholesale market. The value of the export payment offered by the electricity suppliers is 9.00cent / kWh, which is only available to eligible customers until December 2011 and revised accordingly for the 2011/2012 tariff year as part of a scheduled annual tariff review. The micro-generation announcement of a guaranteed price of 10 cent per kWh for all electricity users for the first 3,000 kilowatt-hours of electricity produced per annum for three years and an extra 9 cent per kWh for ESB Customer Supply (ESBCS) customers does fall short of international standards and discriminates against farmers and households who receive their electricity from a source other than ESBCS.

Domestic only

The tariff is available to domestic micro-generators only due to VAT and other taxation issues. There have been requests made to the CER to include small to medium businesses however there are some issues which must be resolved between electricity suppliers and non-domestic customers before this happens.

Micro-generation parameters

The technical parameters for micro-generation is 25A with a single low voltage 230V (5.75kW) connection and 16A with a three phase low voltage connection. In practice, these definitions cover micro-generators that are rated at or below 11kW.

Outstanding issues

Micro-generators need high support and long term contracts, guaranteed or priority access to the grid. Access to the grid for micro-generators is quick and simple using the NC6 form and the ‘inform and concent’ process.A number of lobby groups are requesting grants and an appropriate finance package to offset the capital costs associated with the purchasing of micro-generation technology e.g. reduced VAT rates or PSO funding to pay a guaranteed tariff over a guaranteed period of time. Such policies would require the approval of DCENR and the Department of Finance.

Import / export metering

Micro-generators are being provided with import/export or so called ‘interval meters’ to measure the units of electricity exported to the grid. The first 4,000 micro-generators applying are not being charged the cost of the meter or for it’s installation. This limit will be reviewed in the event that a significantly large amount of micro-generators having interval meters installed which can relay information automatically to the national grid.

Efficiency

The efficiency of converting wind power to electrical power can vary from <20% - 33% depending on the site and the technology.

Scales

Sizes of wind turbines can vary from between 1kW and 3MW. Each scale of wind turbine is loosely defined as:

- Micro and roof mounted 1kW to 6kW – e.g. Eeargh Lighthouse (on the most western of the Aran Islands) where a stand alone 2.2kW turbine was installed in 1996 to power the marine navigation light and other systems.
- Small scale mast mounted 2.5kW to 50kW
- Medium scale on-site 50kW to 300kW
- Large scale on-site 600kW to 2MW
- Wind farm scale 1.5 to 3MW e.g. Coomatalin Wind Farm in County Cork, with 4 x 1.5MW GE turbines installed in 2005 by Airtricity.

Advantages and disadvantages of wind power

Wind power in general has the following advantages and disadvantages:

Advantages include:

- Increased capacity has reduced costs – the technology has reduced in price with increased demand for turbines (although at present for large scale systems there is a shortage of parts due to supply not keeping up with demand, and so prices at present are relatively high).
- Payback as low as a few years is achievable – large scale systems usually give the quickest payback
- Significant experience with technology – the first wind mill was used as early as the 6th century AD. Following the oil crisis of the 1970’s the technology was accelerated and is now well proven and reliable.
- Roof or building mounted as well as stand-alone systems are possible – stand alone systems are not grid-connected (charging batteries for boats, on houses etc.)
- A second hand market for turbines is available – this is due to the high demand for turbine parts due to current shortage.
- Bespoke developers for all scales of turbines – there is a list of the European Wind Energy Association, which include developers (see http://www.ewea.org).

Disadvantages include:

- Intermittency and matching supply with demand – the wind doesn’t always blow at the same time as demand for electricity. This is usually helped by exporting electricity to the grid at times of low demand or charging a battery in the case of a stand alone system.
- Public perception – there is some public opposition to the technology due mainly to fear of spoiling the landscape, adversely affect house prices and perception of high noise levels from the turbines.
- Planning issues – e.g. interference with radio wave signals, objections from the public.

- Small systems are affected by local obstacles – small systems which have lower towers are more affected by obstacles such as trees and houses, which disturb the wind flow, thus reducing the maximum power available from the wind.

Capital Costs (small scale)

The initial capital cost of a decent-sized turbine is high. A good quality 5 kW turbine will cost €22,000 to €30,000. These turbines work on an efficiency of 20-30% depending on the site and the localised wind speed. In order to measure wind speed accurately you need a calibrated anemometer which is very expensive. Maps are available which show the distribution of wind speed over Ireland on the SEI website www.seai.ie .

Guide to wind turbine outputs ***Energy output in kWh/week***

Average wind Speed	**Wind Turbine Rotor Diameter** **1m**	**2m**	**3m**	**5m**
3m/s	0.5	2.5	6	6
4m/s	1.5	6	15	10
5m/s	3	12	25	75
6m/s	4	17	40	

To explain this, lets look at a 5 kW turbine. If it was working constantly it would produce 43,800 kWh (5kw x 24 hr x 365 days). However the wind is not constant. So a 5 kW turbine working at 25% efficiency will produce 10,950 kWh (43,800 x 0.25).

Payment for energy produced

If you used all the energy yourself the calculation is simple. It would be 10,950 kWh multiplied by 15ckWh (the current price of electricity including VAT, that you replaced). That totals €1,642. If you use 4,000 kWh per year for you domestic house the saving is 4,000 x 0.15 cent/kWh = €600/year together with that exported back to the grid 3,000 kWh x 0.19 cent/kWh = €570 and 3,950 kWh x 0.09ckWh = €355. The total between saving on electricity purchased and exported to the grid is €1,525. Therefore the higher your electricity bills that you offset by using home produced electricity the better the payback.

Small scale 6 kW wind turbine - Source Efgem.

Payback

This price means that payback of the capital cost of €25,000 to install the turbine would take 16.4 years (€25,000 / €1,525) assuming all the electricity is used on-site. In practice there will be times when there will be very low or no demand for power on the premises and the excess will be exported to the grid. This is a simple payback and does not include the cost of borrowing the money. However it also does not include the predicted increasing energy costs which will more than likely lower the payback. Farmers can write-off 12.5% of the capital cost of the turbine over the first eight years.

Surplus energy produced

Up to now surplus energy produced was just dumped on to the grid for free. Given the fact that there is more wind at night when your usage is low, over 50% of the energy produced could have been dumped. Even if you used part of it at night, you are replacing night rate electricity which costs just 7c/kWh.
ESB group have now changed their position in recent times and will now pay for the power produced. This will give added national benefits in national carbon savings. Germany pays a higher price for the renewable green electricity produced and allow farmers to sell all the electricity into the grid and buy back what they need at a cheaper price. This is what’s needed to give a real boost to start harvesting electricity.

Functionality

Wind energy works. The problem is that even in a good site the payback period is lengthy in Ireland. To ensure you reach that payback period you will need to install quality equipment. If electricity prices rise the payback will improve.

Further information: Martin McCarthy from, The Sustainable Energy Authority of Ireland - Renewable Energy Information Office, Unit A, West Cork Technology Park, Clonakilty, Co. Cork can be contacted on 023-886 3395.

SOLAR PANELS

Solar heating can still be effective on cloudy days

Introduction

Solar thermal collectors convert solar radiation into thermal energy. This is typically used to heat water for hot water application such as bats and showers. There are also options to heat water or even air for space heating applications. Direct sunlight provides for the most effective energy collection, but solar heating is still effective on cloudy days. Solar thermal technology has very low maintenance, and can reliably provide 50% or more of a buildings hot water requirements, depending on the demand and the type of system installed. However it has an improved payback time for sites with a significant low temperature hot water requirement such as residences and swimming pools. Most dairy herds are producing their largest volumes of milk during the summer months when solar gain is at its maximum. Therefore we will look at the potential of solar on dairy units.

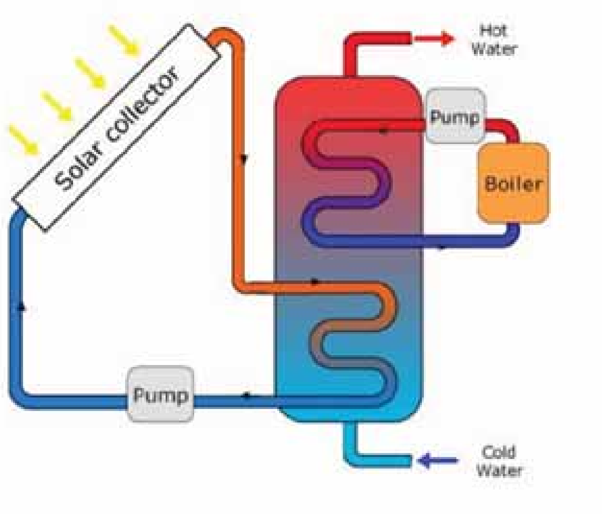
Types of system

Solar thermal collectors are modular and either ‘building integrated’, i.e. forming part of the cladding system, or ‘bolt on’. Arrays are typically pitched at about 30º and orientated between southeast and southwest, and its important that overshadowing is avoided. In Ireland heat exchangers are used to transfer the heat collected from the solar collector circuit to the hot water store or circuit. The two main types of solar collectors are flat plate and evacuated tubes. The main difference between the two technologies is that evacuated tubes, while more expensive, are able to achieve higher efficiencies, requiring less space on a roof to achieve the same energy yield.

Sizing

The amount of solar panels needed, will depend on the amount of hot water required to wash the milking machine and bulk tank. The heated water needs to be 80-85ºC. Most domestic solar systems are set to cut off at 65ºC. Solar systems can get water over 80ºC but there would always need to be a booster system to lift temperatures. Ideally this would be night rate electricity or oil to reduce costs. A 10 unit parlour will require 130-150 litres of hot water per day. A 30 unit requires over 400 litres/day.

The solar panels will feed into highly-insulated buffer tanks which are normally 1.5 times the water requirement. This allows more water to be heated on sunny days, which is saved until it’s needed. The insulated tanks mean that temperatures drop just 1ºC per day. A range of software packages are available to calculate the size of a solar system for different applications and configurations.



Schematic of solar heating

RETScreen http://www.retscreen.net
Polysun http://www.solarenergy.ch/spf
TSol http://www.valentin.de

Typical dimensions of solar collectors for dwellings

Number of People	Evacuated Tube (m^2)	Flat Plate (m^2)
2	1.5 to 2	2 to 3
4	3 to 4	4 to 6
6	4 to 6	6 to 9

The above figures are affected by orientation, angle, solar fraction and storage losses. They will also vary according to levels of solar radiation e.g. smaller areas are required in the south-east of the country.

Economics

Currently to heat 136 litres of hot water from 8ºC to 82ºC takes 12 kWh of electrical energy. At current electricity prices 15c/kWh this is €1.80 a day. With cows being milked 280 days per year the cost of heating water is €504. Solar can heat the water to bring about a saving of 60% on the water heating costs. It will therefore reduce the costs to €202 a year creating a saving of €302 per year.

Payback

Payback will be determined by the capital cost of the solar panel system and associated plumbing expenses. A 10 unit parlour with a requirement for 136 litres of hot water per day will cost in the region of €3,800 plus VAT of 21%. The cost of installation would be €1,200 + VAT of 13.5%. This would give a total cost of €5,000. In this instance making a saving of €302 per year the payback is €5,000 / €302 = 16.5 years. If night rate electricity is being used at 7c/kWh then the payback goes out to 35.5 years in this example.

Note that these figures do not take any maintenance costs or part repair costs into account and when purchasing these costs should be factored in calculating the overall payback which could very well push out the pay back period even further. Consult your supplier on these costs.

Payback on solar installation

Unit Parlour	Hot Water Requirement	Energy Required to heat water	Dairy Heating Costs Day rate	Dairy Heating Costs Night rate	Costs system overall	Saving 60% per/annum	Saving 60% night rate	Payback years No grant Day rate	Payback years No grant night
10	136 L	12 kWh	€1.80	€0.84	€5,000	€302	€141	**16.5**	**35.5**
20	272 L	23 kWh	€3.45	€1.61	€7,500	€580	€270	**12.9**	**27.7**
30	408 L	35 kWh	€5.25	€2.45	€10,000	€882	€412	**11.3**	**24.3**
40	544 L	47 kWh	€7.05	€3.29	€13,000	€1,184	€552	**10.9**	**23.5**
80	1088 L	94 kWh	€14.10	€6.58	€24,000	€2,369	€1,105	**10.1**	**21.7**

The above payback does not take the cost of borrowing the money into account over the payback period but significantly it also does not take account of the increase in energy prices over the lifetime of the product. These can be quite substantial and in fact are probably the biggest single contributing factor influencing the payback period. If the inflation rate of electricity is high it can have a dramatic effect on the payment period, i.e. bring it way down.

Costs

Payback can vary according to factors such as capital cost, running costs, utilization of the system, but the biggest factor is often the cost of the fuel being displaced. The table to follow illustrates how to calculate payback.

The main costs associated with solar are the panels themselves. They cost in the region of €1,200 per m^2 including VAT. The plumbing and installation usually costs the same regardless of the size of the unit however it work out at approximately €1,500 including VAT per installation. Generally approximately 1 m^2 of solar panel will provide enough hot water for 60 litres. Water could be heated to 70ºC on hot summer days however the average figure over the year will be between 40-50ºC. The evacuated tubes are more efficient at capturingsolar gain than the flat plate and are to be recommended for dairy farm situations.

CO_2 Saving

The CO_2 saving resulting from the use of solar water heating will depend on the solar fraction delivered, the type of fuel displaced and the efficiency of the boiler system.

Planning Permission

Planning permission is the responsibility of each Local Authority – so check with them if in doubt. Recent changes to Building Regulations (regarding microrenewables) has given exemption of planning permission to solar panels as follows:

The installation of solar panels up to 12sq. metres aperture area, or 50% of total roof area, whichever is less, will be exempted development subject to the following conditions:

- A 15cm maximum distance between the plane of a pitched roof and a solar panel.
- A 50 cm maximum distance between the plane of a flat roof and the solar panel, and
- That panels should be at least 50cm from the edge of the roof.

The exemptions provide for the same 12 sq metre aperture area in respect of free-standing arrays as applies to building mounted panels. Therefore, and as in the case with building mounted panels, arrays of this size and under are exempt from planning permission requirements, subject to some conditions. These require that:

- Stand-alone panels must be no more than 2m in height
- Such panels must be located behind the front wall of the house, and
- A minimum space of 25 sq m of useable space must remain for householders own private use.

SOLAR PV

Introduction to Solar PV technology

Solar PV panels – Source Efgem

Solar Photovoltaic (PV) technology works on the principle that energy from the sun is converted to electricity. PV cells are used to convert solar radiation into Direct Current (DC) electricity. The DC electricity is then inverted to AC electricity for use in buildings or for export to the grid. A PV cell consists of one or two layers of a semi-conducting material, usually silicon. When light shines on the cell an electric field is created across the layers, causing electricity to flow. The greater the intensity of the light is, the greater the flow of electricity. So even on cloudy days diffuse sunlight will produce electricity but less than on clear sunny days.

Types of PV cells

There are different types of PV cells with different properties and efficiencies. The main types of PV cell are described below.

Monocrystaline silicon cells are made using cells from a single silicon crystal. This is the most efficient of the technologies (around 15%). The downside of this type of cell is its high cost due to more complicated manufacturing processes.
Multicrystaline silicon cells are made from cells from an ingot of melted and recrystalised silicon. These are cheaper to produce than monocrystaline cells but have a reduced efficiency at about 8-12%.
Amorphous silicon cells are composed of silicon atoms in a thin layer. This is a “thin film” technology. Amorphous silicon can be deposited on a wide range of substrates, both rigid and flexible, making it ideal for curved surfaces. The main disadvantage of amorphous silicon is its low efficiencies, between 4 and 8%. However, they are cheap to produce compared to other types of PV cell.
Many cells are joined to form **PV modules.** These are connected together to form PV arrays.

Scales

The size of a typical PV array for a typical building varies, depending on load requirements and the type of cell used. Typical domestic systems are around 1.5Wp, which is sufficient for about a third of the average family’s supply (assuming gas is used for space heating requirements). This array would cover about
10-15m^2 of roof area.

Summary of efficiency of each main type of PV cell

Technology	**Efficiency range**
Amorphous silicon PV	4 – 8%
Poly-crystaline silicon PV	8 – 12%
Mono-crystaline PV	14 – 16%

Performance

The amount of electricity that can be generated from a PV array is dependant on various factors;

- Energy available from the sun kWh/m^2/yr
- Angle and orientation of array (south facing array would gain the maximum level of sunlight and it is best to orientate the arrays depending on the latitude of location)
- Whether automatic tracking of the array is employed (the angle of array can be adjusted automatically to maximise energy extraction from the sun)

- Whether there is any shading or dirt on the PV array or not (shading significantly reduces power output of the array)
- Area of the PV array
- Type of PV cell (efficiency of each type varies as summarised below)
- Temperature – solar modules need to be kept cool to be efficient

Advantages and disadvantages of Solar PV

Advantages include:

- Direct conversion of light into energy
- Low maintenance and long-lasting i.e. no moving parts. The PV arrays may need cleaning from time to time
- Can be building integrated PV (BIPV) or stand alone (PV tiles can be produced replacing standard tiles on buildings)
- Often the lowest cost solution for off-grid remote power applications (telecommunications, navigation etc.)
- Widespread application on domestic and commercial buildings, and parts are widely available.

Disadvantages include:

- Costs about 7 times that of grid connected electricity
- Large surfaces are required and correct orientation essential
- Most industrial installations to date based on ‘green credentials’ rather than economics.

Peak Sun Hours

The kilowatt-hours a PV module will deliver, depends on the amount of sunshine (solar insolation) it gets as well as factors such as temperature and orientation. To perform this calculation we use a metric known as “Peak Sun Hours”.

For example, in theory and ideally, a 75W module should deliver (75W x daylight hours) watt- hours per day. In mid June Carlow would get 17.5 hours of sunlight. They may expect to get, for an ideally sited 75W photovoltaic: 75W x 17.5 hours = 1312.5 watt-hours for the day. In practice though, an ideally sited 75W photovoltaic is likely to deliver only 75W x peak sun hours. In mid June this could be 75W x 4.8 hours = 360 watt-hours or 0.360 kWh.

Further losses can be got through shading, inverter efficiency and so on. When designing a system we therefore need to know the number of peak sun hours for a particular location and for a particular time of the year.

On a day in the middle of winter in Carlow, the 75 watt PV module will deliver: 75 watts x peak sun hours = 75 watts x 1.8 = 135 watt-hours or 0.135 kilowatt-hours). On a day in the middle of summer in Carlow, the 75 watt PV module will deliver: 75 watts x peak sun hours = 75 watts x 4.8 = 360 watt-hours or 0.360 kWh. There is obviously a vast seasonal variation in output, from photovoltaic’s.

Example of PV

If a PV system is comprised of 100 watt panels, and is mounted in Carlow at a tilt angle of 52 degrees. If we assume that 18 panels are installed the total kilowatt rating of this system will be 100 watt x 18 = 1,800 watts or 1.8 kW.

In mid winter: Peak Sun Hours x kilowatt rating. 1.8 Kilowatts x peak sun hours = 1.8 kilowatts x 1.8 = 3.24 kilowatt-hours.

In mid summer: Peak Sun Hours = 4.8 Kilowatt hours x 1.8 (hours of peak sun) = 8.64 kWh.

In one year the annual peak sun hours for Carlow is approximately 1,200 peak sun hours = 1.8 kilowatt x 1,200 = 2,160 kWh.
Each panel would cost approximately €400 giving a total cost of €7,200 and if you add on installation costs the overall charge would reach €10,000 for the installation.

Payback

The simplest payback is if we assume all the electricity produced is consumed on site. 2,100 x €0.15 cent (the cost of purchasing electricity from the network) = €315 per year. This would give a pay-back of €10,000/€315 = 31.7 years.
The only way in which PV can be made viable in Ireland will be the introduction of a suitable feed-in tariff which has led to increased PV adoption in many other countries.

PRODUCING HEAT FROM BIOMASS ON THE FARM

Biomass has been used as a source of heat for millennia. Methods for burning biomass havedeveloped considerably in that time from combustion in an open pit to combustion in a fireplace to sophisticated microprocessor controlled combustion systems with the capability of burning challenging biofuels.

The combustion of wood logs in open fires as well as in solid fuel cookers is reasonably common in farmhouses. Additionally, back boilers are often fitted to both open fires and solid fuel cookers to generate domestic hot water. However, a wide range of modern biomass stoves and boilers now exist which can be used to produce heat on the farm from a wide range of biomass feedstocks. Biomass stoves and boilers are currently more expensive than their fossil fuel counterparts. However, significant savings in annual fuel bills can be realized if existing biomass resources on the farm can be used to generate heat.

The first step in the decision making process is to decide how much heat is needed. Heat may be needed to heat a single room, a dwelling, several dwellings or to assist in farm activities such as grain drying.

Stoves

Stoves are typically used to heat small areas (eg room sized areas) and can be either free standing or installed as inserts into fireplaces. When fitted with a boiler, they can also be used to heat water. Stoves can be fuelled with wood logs, wood pellets or briquettes. Pellet stoves typically have a hopper which can be recharged with pellets at intervals. Wood log stoves are recharged by opening a door at the front of the stove.

Pellet Boilers

Pellets are a densified form of biomass and, as a consequence can be stored tidily in a small area. Pellet boilers were developed in the 1990s and are now common in most European countries. Pellet boilers are typically automatically controlled and allow continuous pellet combustion in which the fuel is fed automatically into the combustion chamber by means of an auger. Most pellet boilers are equipped with a pellet storage bin which is sufficient for a few days of operation. A wide range of pellet boilers are now commercially available. Wood pellets are the most common fuel although some pellet boilers can also burn pellets made from other feedstocks (eg straw), some pellet boilers can also burn grain. Typical sizes of pellet boilers range from 15-35kW although many wood chip boilers can also use pellets as a feedstock.

Wood log boilers

Seasoned wood logs can be burned in boilers. Such boilers are typically batch fed at intervals of up to a number of days depending on heat demand. Some models are gasification boilers in which the wood is heated initially to produce a gas which is subsequently burned in a separate combustion chamber. Wood log boilers typically have heat capacities ranging from 15-150kW and are often fitted with a heat storage tank with a volume of 1-5m^3 to enable optimum combustion at nominal load.

Wood Chip Boilers

A large range of woodchip boilers are now commercially available. Such boilers are generally too big to heat a normal sized farmhouse but could be used on a farm to heat a large house or several houses or in situations where additional heat is needed for another purpose eg grain drying. Wood chip boilers range in size from 35kW-1MW. Most boilers require woodchips with a moisture content less than 30% for efficient combustion although pre-ovens can be used if moist wood chips need to be used. All woodchip boilers can also use willow chips as a feedstock. Some woodchip boilers can also use Miscanthus in chipped or pelleted form.

Straw and Waste Boilers

Boilers are available which can burn straw bales in different sizes (eg small square bales, large square bales, round bales). Cereal straw is the most common fuel for these boilers although bales of rape/linseed/bean straw can also be used as feedstocks. Some large boilers which are commercially available can also be used to burn various waste on the farm eg pallets, waste grain and rapemeal.

Biomass Feedstocks

Farmers like all consumers with biomass boilers and stoves can purchase biomass in the form of pellets, chips and logs to use in their boilers and stoves. Consumers should be aware that there are standards for all types of biomass. COFORD have produced a number of practical guides for log wood, wood chips and wood pellets which are available as COFORD Connect notes (http://www.coford.ie/publications/cofordconnects/). Information on wood fuel quality can also be obtained from the Sustainable Energy Authority of Ireland (http://www.seai.ie/Renewables/Bioenergy/Wood_Energy/Fuels/).

However, farmers unlike other consumers, have the option of using biomass grown on their farm or certain wastes that may accumulate on their farms as a fuel for combustion. In this way, farmers can insulate themselves from variations in the price of both fossil fuels and even biomass fuels which would otherwise need to be purchased outside the farm. Biomass fuels which can be grown on the farm include

Cereal Grains

Oats burn more easily than other cereal grains and are suitable for a wide range of soils. Black oats have been used recently to counter accusations of ‘burning food’ which have been made against the practice of grain burning. However, for farmers growing oats for their own consumption, a highly yielding variety of feed oats can be used. Grain moisture should be close to 15% in order to ensure safe storage and efficient combustion. As a general rule, approximately 2 acres of oats will heat a normal sized domestic dwelling over the winter period.

Straw

Cereal straw can be burned in certain boilers in a range of bale sizes. It is generally advised that straw should be left for a number a days before baling. It is important that the straw is baled when it is dry however, and stored in a shed. It is also advisable to slacken off the pressure on the baler in order to make low/medium density bales as high density bales to not burn very well. Rape straw, bean straw and linseed/flax straw can also be used although rape straw burns with an unpleasant odour. Following combustion, ash can be returned to the field to complete the nutrient cycle.

Farm forestry

Wood supplies for combustion can be obtained from woodland on the farm and either chipped or cut into logs. Wood for chipping is best left to season first whereas logs will season much faster than whole trees or branches. Farmers with existing farm forestry should be able to obtain wood supplies from forestry thinnings if their forestry is at least 12-15 years old in situations where thinning is advised as a management practise. Alternatively, farmers may wish to consider devoting a part of their land to forestry in order to provide heat for their home and other applications on the farm. Whereas conventional forestry takes a long time to mature, short rotation forestry can provide a supply of wood biomass in a shorter period of time.

Miscanthus

Miscanthus can be grown on the farm to provide an additional income stream from the annual sale of the harvested biomass. Part of the biomass may be used to provide heat on the farm. *Miscanthus* can be burnt as chips in suitable wood chip boilers. Alternatively, *Miscanthus* can be burnt as bales in boilers designed for straw bales. Although *Miscanthus* takes 3-4 years after sowing before mature yields are reached, this energy crop will provide a fast supply of biomass which can be harvested annually with commonly available farm machinery.

Willow

Willow, like Miscanthus, is typically grown to provide an additional income stream on the farm but can also be used to generate heat on the farm. Willow can be harvested as whole stems and left to season before it is chipped. Alternatively, willow can be harvested as chips which need to be dried down to a moisture content below 25% before use. While drying can be expensive, a low cost method (~€5/tonne) of drying willow chips has been developed by Teagasc in which a clamp of willow chips is ventilated with ambient air for 12 hours a day for approximately 3 months. Willow chips can be used in wood chip boilers. More recently, experiments have been conducted with harvesting equipment which can produce bales of willow. While such machinery is still under development, burning willow bales in straw burning boilers represents another way in which willow can be used to generate heat on the farm.

Certification

Boilers and stoves need to be tested in order to demonstrate compliance with EU standards. Boilers up to 300kw should have been tested to demonstrate compliance with standard EN303-5 whereas stoves need to be tested to demonstrate compliance with standard EN 14785. These standards stipulate minimu acceptable standards for construction, efficency and emissions. It is important to ensure that any boiler or stove that is being considered for purchase has been tested to these standards.

Buying a Biomass Boiler/Stove

The first step in acquiring a boiler/stove is to decide on the size of device needed for the particular application. It is very important not to oversize your boiler for a given project. For example putting in a 100 kW boiler to provide heat for a building that only requires a 50 kW rated boiler is like getting a 150 hp tractor to do the same work a 35 hp tractor could do. You end up putting in more fuel to get the same level of work output. The process becomes inefficient. As a a rule of thumb a modern home requires approximately 70 watts of output from the boiler for every square metre of floor area. 100m^2 home requires 7 kW boiler 150m^2 home requires 10.5 kW boiler This will depend on insulation and other energy efficiency measures adopted.

Once the size has been determined, the purchaser can then proceed to investigate the boilers/stoves that are available in that particular size. At this stage, a farmer should consider if there are biomass feedstocks on the farm which could be used as feedstocks. If feedstocks other than wood are to be used, consideration needs to be given to the purchase of a multifuel boiler which can burn fuels other than wood. Before the boiler/stove is purchased, it is important to consider the installation requirements for the device and how it can be integrated into a pre-existing heating system if relevant. Advice on the design of wood-chip and pellet storage facilities is available as Coford Connect Notes (http://www.coford.ie/publications/cofordconnects/).

Additional Information

It's important to be aware of the energy values of various fuels in comparison to Oil

Fuel	**Energy Density GJ/t (kWh/T)**
Log Wood air dry 20% MC	15 (4170)
Wood Chip 20% MC	15.2 (4225)
Wood Pellets	18 (5004)
Grain	16 (4448)
Miscanthus (bale)	17 (4726)
Coal (lignite-anthracite)	20-30 (5560 – 8340)
Heating Oil	42 (11,676)
Natural Gas	54 (15,012)

How much fuel is used by a wood chip boiler?

Wood Chip boilers burn 1 Kg of wood chip (15% moisture) to provide 4 kW output. A 150 m^2 building requires 10.5 kW heat output. This will utilise (10.5 / 4) 2.625 Kg's of wood chip per hour.

How much energy will 1 ha of willow produce?

1 tonne of fresh willow produces 1,944 kWh of energy
= 1.9 kWh per Kg
= To convert this to MJ / Kg = 6.84 Mj / Kg or 6.84 Gj/tonne (1.9 / 0.278)
1 ha produces 22 x 1,944 kWh = 42,768 kWh / ha or 154 Gj / ha

Comparison to Oil

1,000 litres of oil contain 36.68 Gj of energy. Therefore 1 ha of willow contains (154 / 36.68 GJ/1,000 litres) = 4,200 litres of heating oil.

Calculating your woodchip fuel storage requirements

Boiler Output	**18 kW**	**80kW**	**350kW**
Floor Area	260 m^2	1150 m^2	5000m^2
Fuel Input	6.25 Kg/Hr (25 kW)	25 Kg/hr (100 kW)	200 Kg/hr (400 kW)
1m^3 / 150 Kg Storage	24 hrs	6 hrs	Too Small
4m^3 / 600 Kg Storage^2	4 days	24 hrs	6 hrs
16m^3 / 2400 Kg Storage	16 days	4 days	24 hrs
48m^3 / 7200 Kg Storage	Too Big	12 days	3 days

		Cost	Saving/yr
Large farmhouse 5000 litres oil	@ 0.70 cpl	€3,500	
5,000 litres is equivalent to: 12.7 t woodchip (20%MC @ ?140/t)		€1,778	€1,722
Or 10.5 t wood pellets	@ €200/t	€2,100	€1,400
or 11.5 t Oats	@ €180	€2,070	€1,430
	@ €100	€1,150	€2,350

Ground/Air/Water Heat Pumps

Heat pumps are used to capture solar energy, which is stored in the air ground or water, and to deliver that energy to heat a building. They can also be used to take heat energy from a building and deliver it to the air, ground or water, thus cooling a building.

Heat pumps cool by capturing energy at certain temperature and delivering it at higher temperature elsewhere. This occurs in a closed circuit with fluid evaporating to take up heat at one temperature, and then being compressed and condensed to release the heat at another temperature in a condenser, before being expanded in readiness for the evaporator and a repeat of the cycle.

The process requires energy to drive it (typically electricity to run the compressor). However for each unit of energy to drive the process more units of energy are captured and delivered. The ratio of energy delivered to energy input is referred to as the Coefficient of Performance or COP. Some typical values for the different sources are shown in the table below.

Source of heat	**Source Temperature**	**COP**
Air	0 to 5	3.5
Ground	5 to 10	4
Water	12	4.5

The COP of heat pumps is greater if the temperature difference between source and delivery temperatures is less. This explains why a ground source heat pump is more efficient over a heating season than an air source heat pump, which is extracting energy from air, which is often at lower temperatures (in the air) than the ground.

Pros & Cons of each type of system

Types of System	**Advantages**	**Disadvantages**
Air source	Can be used anywhere Takes up little space Cheaper	Not as efficient Noise can be an issue High running costs
Ground source / Closed loop	Can access heat in ground anywhere. Horizontal systems are cheaper but take up space. Borehole systems are more efficient and take up less space.	Installation costs can be high. Nee a certain amount of space for ground collectors.
Water source / Open loop	Most cost efficient for very large systems as less infrastructure required. Also most efficient if tapping into deep water sources with higher temperatures.	Only possible near to a water source such as an acquifer, lake or river.

Sizing

Heat pump size has to be matched to the building heating requirements. The more closely this can be achieved the better as capital costs tend to go up pro rata with size (unlike gas or oil boilers for example). The size of collector has to be calculated accurately as well to ensure that the system performs well. If the collector is too small then it will overcool the ground and the system will struggle to achieve best efficiency. If it is too large then it will be an unnecessary expense.

The more pipe there is in the ground the more potential there is to collect heat. However the ground and soil conditions affect heat exchange between the ground and the pipe. (See table below)

Ground Conditions	**Specific Heat Capacity Capacity W/m**	**Area per kWth (m^2)**
Dry loose soil	10	75
Damp packed soil	20 — 30	38 — 25
Saturated Sand Gravel	40	19

Assumes spacing of 0.8m for loose soil and 0.5m for damp well packed soil
Typical installation depth 0.8m to 1.5m. PE- Pipe Hard PN 10 (DN 20 or 25)

Similarly a borehole loop collector will have more or less capacity to collect heat according to the geology concerned.

Ground Conditions	**Specific Heat Collection Capacity W/m**	**Loop Length Per kWth (m^2)**
Dry sediment	3	25
Shale, slate	55	14
Solid stove with high conductivity	80	9.5
Underground with high groundwater flow	100	7.5

Suppliers

There are a large number of installers in Ireland. There are over 1,000 installers in Ireland offering over 200 models of heat pump.

Standards

EN 14511 is the relevant European standard for testing heat pumps. Heat pumps should achieve a certain COP rating, as tested under EN14511.

Certain COP s to be achieved under EN 14511

Brine/Water	4
Air/Water	3
Water/Water	4.5
Direct Evaporation	4

Integration

Heat pumps can provide all the hot water and space heating requirements of a house or other building. However, the capital cost of a system to meet the peak space heating requirement can be high and therefore some design strategies advocate using a “top up” heater for those few occasions when maximum heating is required. Commonly this top up heating is supplied by an electrical emersion heater in a buffer tank or by an electric flow heater. Alternatively a completely separate heating system could be employed to provide supplementary heating, such as a pellet room heater. Heat pumps, depending on the make and model, can struggle to make temperatures over 50 to 60 degrees Celcius. As a consequence it may be necessary to boost the temperature using an electric immersion heater or a second heat exchange element heated via a supplementary heat source.

Ground Source Heat Pumps (GSHP) systems are not suitable for directly replacing conventional water-based central heating systems, which have been designed to operate at temperatures in excess of 60ºC. If the building insulation is improved, the reduced heating requirement may then be met using a lower distribution temperature. Alternatively the radiator area can be increased.

A drop in circulating temperature of 20ºC would require an increase in emitter surface of 30-40 per cent to meet the same heat output.

The Ideal, which is more readily achieved in new-build, is to have a low temperature distribution system such as underfloor heating. Alternatives include air distribution systems or oversized radiators. Underfloor heating provides a thermal buffer which is another advantage as this helps to reduce the possibility of the heat pump cycling on and off too often. It is also possible to introduce a buffer tank which will achieve the same effect. Consult the manufacturer whether this is required for a particular installation.

Costs

At the time of publication there is no grant available towards the capital costs of a heat pump system. When calculating financial viability remember to factor in the offset cost of an alternative heating system, such as a gas boiler (and possibly the laying of a gas supply or installation of an oil tank, if the alternative is oil). Heat pumps look much more viable especially where there is a cooling demand and their capital cost can be spread over the heating and cooling savings. This results in a much faster payback.

Financial savings for a heat pump replacing a boiler

Cost of gas boiler	2,000
Cost of heat pump	10,000
Grant for heat pump	0
Price of gas kWh	5 cent
Price of electricity (c/kWh night rate)	7 cent
Heat requirement (kWh)	22,000
Gas boiler efficiency	85%
Gas input (kWh)	25,882
Heat Pumps COP	4.0
Electricity input (kWh)	5,500
Boiler energy costs (25,882 x 0.05)	1,294
Heat pump energy costs	385
Heat pump additional costs	8,000
Heat pump annual heating cost savings	989
Simple payback (years)	8.1

Heat pumps look much more viable when there is also a cooling demand as their capital cost can be spread over the heating and cooling savings. This results in much shorter paybacks. However, the rate for electricity will effectively determine the payback and with a cooling system we can assume a normal electricity (day rate tariff of 15 cent per kWh).

Financial savings of a heat pump replacing a boiler and air conditioner

Cost of gas boiler	2,000
Cost of air conditioner	2,000
Cost of heat pump	10,000
Grant for heat pump	0
Price of gas per kWh	5 cent
Price of electricity (kWh) Normal rate	15 cent
Heat requirement (kWh)	22,000
Gas boiler efficiency	85%
Gas input (kWh)	25,882
Cooling requirement (kWh)	12,000
Air conditioning COP	3.0
A/C Electricity input (kWh)	4,000
Heat Pumps COP (heating)	4.0
Heat Pumps COP (cooling)	5.0
Electricity input (kWh) (heating)	5,500
Electricity input (kWh) (cooling)	2,400
Boiler energy costs	1,294
Air conditioning energy costs (4,000 x 0.15)	600
Heat pump energy costs (5,500 x 0.15 + 2,400 x 0.15)	1,185
Heat pump additional cost less grant	6,000
Heat pump annual cooling and heating savings	709
Simple payback (years)	8.4

The costing's assume a standard tariff for cooling however in some cases it is possible to manipulate the operation of a ground source heat pump to maximise the benefit of a night rate tariff. This will reduce the cost and shorten the payback. If this is to be the operational strategy then this has to be considered during the design and specification stage, to ensure the right capacity of heat pump and collector is installed.

CO_2 Savings

This will depend on the COP of the heat pump and the fuel being displaced.

Example of CO_2 saving calculation

Heat requirement	20,000 kWh
Fossil fuel boiler efficiency	90%
Fossil fuel input	22,222 kWh
Heat pump COP	4
Electricity input	5,000 kWh
Gas CO_2 emissions factor	0.198 kg/kWh
Oil CO_2 emissions factor	0.264 kg/kWh
Electricity CO_2 emissions factor	0.651 kg/kWh
CO_2 emissions from gas (22,222 x 0.198)	4,400 kg CO_2
CO_2 emissions from oil (22,222 x 0.264)	5,867 kg CO_2
CO_2 emissions from heat pump (5,000 x 0.651)	3,255 kg CO_2
CO_2 savings against gas	1.15 tonnes CO_2
CO_2 savings against oil	2.61 tonnes CO_2

Planning issues

Planning permission is the responsibility of each local authority – so check with them if in doubt. Recent changes to Building Regulations has given exemption of planning permission to heat pumps – with restrictions on noise from air source heat pumps. Further details are outlined below.

The two types of ground source heat pumps currently available are horizontal and vertical closed loop systems. Each system consists of lengths of buried pipe in the ground, either in horizontal or vertical trenches. The regulation provides exemptions for both types. The only condition attached to the exemption for ground-source heat pumps is that on installation of the apparatus there should be no more than 1 metre alteration to ground level.

- Air-source heat pumps are also exempt provided that:
- Noise levels at the nearest neighbouring inhabited dwelling are <43dB(A), or <5dB(A) above background noise.
- Air source heat pumps are at least 50 cm from the edge of roof, and
- The pump is located to the rear or behind the front wall of the house.

Further information is available at **http://www.environ.ie/en/DevelopmentandHousing**

Electrical requirements

Heat pumps can increase the peak power requirements – particularly for a house. The ESB usually require a 16kVA connection for a single phase installation. ESB typically requires a soft starter.

Ground Water

Boreholes can have an effect on groundwater and so the EPA should be consulted when considering a heat pump system with a vertical collector system or an open loop system.

APPENDICES

APPENDIX 1

Glossary of Terms

MPRN = Meter Point Reference Number

The MPRN (Meter Point Reference Number) number identifies your connection to the ESB Network and is unique to your home.

Volt (V) = a unit of electrical voltage
A volt is the electrical force required to push current through an electrical circuit. Most domestic homes in Ireland are supplied at a nominal voltage of 230V (single phase).
Most businesses are supplied at a nominal voltage of 400V (three phase), which is frequently referred to as 'Low Voltage'.

Kilovolt (kV) = 1000 volts
This is the term normally used for medium and high voltages, e.g. 20 kV = 20,000 volts.

Amp (A) = a unit of electric current
An amp is the measurement of current flowing in an electrical circuit. Its full name is an 'ampere'.

Kilovolt-Ampere (kVA) = 1000 volt-amperes
This is a term used to describe the level of 'apparent' power imported or consumed by your business, and is the basis of your Maximum Import Capacity (MIC) contract with ESB Networks.

Watt (W) = a unit of electric power
A watt is the unit of measurement of 'active/real' power. The power used in a basic electrical circuit is the volts multiplied by the amps.
1 volt passing a current of **1 amp** through a basic circuit means that 1 watt of electric power is consumed.

Kilowatt (kW) = 1000 watts (W)
A kW is the term normally used for 'active/real' electric power, sometimes referred to as 'Demand' or 'Load'.
Electric power is made up of two components:

- Active/real power (kW)
- Reactive/wattless power (kVAr)

When these are combined they are referred to as the 'apparent' power (kVA).

Maximum Demand (MD)
Maximum Demand is the highest electricity demand recorded during a specific period - this term applies only to large businesses on the Maximum Demand price plan.

Megawatt (MW) = 1000 kilowatts (kW)
A megawatt is sometimes used as a unit of measurement for large electric loads provided to busines customers.

Kilowatt hour (kWh) = 1000 watts for 1 hour

This is the basic unit of electricity consumption and refers to the **real/active electric load (kW) used over time.**

In simple terms, 1 kWh is the amount of energy consumed by an electrical device (e.g. an electric heater) that is rated at 1kW (1000 watts) for 1 hour. A further example is ten 100-watt light bulbs used for 1 hour.

A kWh is the **basic unit of electricity consumption used by ESB Electric Ireland to bill customers** for the active/real power they use.

Megawatt hour (MWh) = 1000 kilowatt hours (kWh): As a kWh is to a kilowatt, so a MWh (megawatt hour) is to a megawatt. It is used when measuring electricity consumption to large business premises.

Wattless unit (kVArh) = 1000 reactive volt-amperes for 1 hour

It is the unit of measurement for 'reactive/wattless' power consumed. Electric power is made up of two components 'active/real' power (kW) and 'reactive/wattless' power (kVAr). When these are combined they give the 'apparent' power (kVA). 'Reactive/ wattless' power is measured on its own electricity meter in large business premises. Large motors require 'reactive/wattless' power to operate correctly. Business owners can reduce/eliminate reactive power by fitting power factor correction equipment.

Power factor = 1 or less

This is a term used to describe the relationship between 'active/real' power (kW), 'reactive/wattless' power (kVAr), and 'apparent' power (kVA). **Power factor is always 1 or less.** If the power factor is 1 then the 'active/real power' (kW) being used is equal to the 'apparent' power (kVA). If the power factor is less than 1, e.g. 0.98, then some 'reactive/wattless' power is being consumed.

ESB Electric Ireland will only charge for reactive/wattless power when the power factor goes below 0.95, e.g. 0.94.

Load factor

Load factor is the **ratio of average electricity consumption to the peak consumption in a business premises during a specific period.**

It shows whether the electricity consumption in a business is stable or has extreme peaks. The lower the load factor the more 'peaky' the loads. A very poor load factor would be less than 20%.
Annual Load Factor =

100% x Total annual units (Day kWh and Night kWh)
Maximum Demand (MD) x 8760 (total hours in year)

Daytime Load Factor =

100% x Total Day Units (kWh)
Maximum demand (MD) x 15 hours x 365

Appendix 2

Steps towards efficiency

Step 1: Understand your energy use
Look at your site and identify the major areas of energy consumption. Check the condition and operation of equipment and monitor power consumption over, say, one week to obtain a base figure against which energy efficiency improvements can be measured.

Step 2: Identify your opportunities
Compile an energy checklist. Walk around your building(s) and complete the checklist at different times of day (including after hours) to identify where energy savings can be made.

Step 3: Prioritise your actions
Draw up an action plan detailing a schedule of improvements that need to be made and when, along with who will be responsible for them.

Step 4: Seek specialist help
It may be possible to implement some energy saving measures in-house but others may require specialist assistance. Discuss the more complex or expensive options with a qualified technician.

Step 5: Make the changes and measure the savings
Implement your energy saving actions and measure against original consumption figures. This will assist future management decisions regarding your energy priorities.

Step 6: Continue to manage your business for energy efficiency
Enforce policies, systems and procedures to ensure that your business operates efficiently and that savings are maintained in the future.

APPENDIX 3 – LIGHT LEVELS

To know how to reduce energy costs it is important to understand the terms used to measure light.

- Lumens - light output from a lamp is measured in the term "lumens" (lm). For example, a 40 watt (W) incandescent light bulb produces about 13 lumens per watt or 13 lm/W.
- Lux - the light level at the working surface is measured in lux.Typical light levels in animal pens and corner areas of sheds can be less than 5 lux. Outside on a bright sunny day in mid summer the light level will be around 80,000 lux.
- Average Rated Life - the average time it takes for 50% of light bulbs to fail.
- Colour Rendering Indexes (CRI) - the measurement of the light sources ability to render colours the same way sunlight does

General characteristics of light sources used for indoor lighting of livestock and poultry facilities.

Lamp Type	Lamp Size (W)	CRI	Efficiency (Ballast losses not included) Lumens/w)	Typical Lamp Life (hr)
Incandescent	25 – 200	100	11 - 20	750 – 5,000
Halogen	50 – 150	100	18 – 25	2,000 - 3,000
Fluorescent T8	32	75	88	20,000
Fluorescent T5	28	85	104	20,000
Fluorescent T5HO	54	85	93	20,000
Compact Fluorescent	5 – 57	80 – 90	50 – 80	10,000
Metal Halide	35 – 70 400	60 – 80	60 – 94	7,500 – 10,000 20,000 (higher wattages – longer life)
High Pressure Sodium	35 – 400	20 – 80	63 – 125	15,000 – 24,000
Light Emitting Diode	1.2 – 1.4	70 – 90	16 – 53	60,000 – 100,000 (White is lower)

Light Output of Compact Fluorescent compared to Incandescent Bulbs (in Lumens)

Incandescent	**Light Bulbs**	**Compact Fluorescent**	**Light Bulbs**
Watts	**Lumens**	**Watts**	**Lumens**
25	270	5	250
40	510	7	400
52	780	9	600
60	860	15	900
90	1,540	18	1,250
100	1,680	26	1,800

Source: hydronetworks.com/en/efficiency/downloads/PowerSaver_02_lighting.pdf

Recommended Illumination Levels for Dairy Livestock Facilities

Work area or Task	**Minimum Light intensity in Lux**
Parlour, pit and near udder	500
Parlour, stalls and return lanes	200
Parlour holding area	100
Milk room, general	200
Milk room, washing	750 – 100
Slatted Shed with feed passage	200

(Source ASAE, 1993;NFEC, 1993; MWPS, 1992; Leech and Person, 1993)

Appendix 4: Contacts

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