Carlow Kilkenny Energy Agency
Castle Hill, Carlow, Ireland
tel: +353 (0)59 9143871
fax: +353 (0)59 9143290
email: info@carlowkilkennyenergy.com
web: www.carlowkilkennyenergy.com

Carlow Renewable Energy Resource

A Study of the Renewable Energy Resource in Co. Carlow

STUDY COMPLETED BY:
CARLOW KILKENNY ENERGY AGENCY

ON BEHALF OF:
CARLOW COUNTY COUNCIL
CARLOW COUNTY DEVELOPMENT BOARD

February 2005

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Disclaimer
This is a research document and in no way represents the policies of Carlow County Council.
This study is intended to provide a reference for those interested in developing renewable energy projects in Co. Carlow. It is essential that potential developers conduct their own feasibility analysis for any specific project. For smaller applications, local suppliers and installers can provide guidance.
The authors shall take no responsibility and accept no liability whatsoever for any inaccuracy, errors or emissions or for the consequences arising from the use of the information in this report.

Executive Summary

Major Findings

There is a huge renewable energy resource waiting to be tapped into in Co. Carlow. Full exploitation of the Accessible renewable energy resources in the County would mean that Co. Carlow could meet 50% of its primary energy requirements from local renewable energy resources.

Current technology allows energy users the opportunity to access this resource for their homes or businesses, in many cases at a cost competitive with fossil fuels, and with the convenience and reliability of fossil fuel systems. This is especially the case for solar heating panels and geothermal heat pumps as well as wood fuelled heating systems.

A longer term view is necessary for renewable electricity production using photovoltaic panels and small scale wind turbines. But these technologies can be successfully implemented in certain circumstances.

On a commercial scale, Co. Carlow offers a number of opportunities for wind and small-scale hydro power developments. Also, by using the large resource of existing agricultural residues such as wood, straw and animal slurries as well as dedicated energy crops, there is good potential for the development of energy from biomass projects generating both electricity and heat.

The table below summarises the extent of the renewable energy resources available in the county and the potential for useful energy to be derived from it.

	Total energy resource	Accessible energy resource	Potential useful energy (Electricity only)	Potential useful energy (Heat only)	Installed capacity (Electricity only)	Installed capacity (Heat only)
	MWH	**MWH**	**MWHe**	**MWHth**	**kWe**	**kWth**
Wood	26,655	8,400	1,680-3,360	5,040-6,720	220-440	1,150-1,530
Straw	240,000	35,000	7,000-14,000	21,000-28,000	900-1,900	4,800-6,400
Agricultural slurry	174,000	20,400	4,080-8,160	12,240-16,320	500-1,100	2,800-3,700
SRC willow	3,120,000	192,000	38,400-76,800	115,200-153,600	5,000-10,000	26,000-35,000
Rape seed oil	814,720	47,472	4,800,000 litres per year			
Sewage sludge	745	745	149-298	447-596	20-40	100-140
Landfill gas	9,300	4,730	940-1,880	2,820-3,760	130-250	640-860
Solar Thermal	-	3,000/year	-	750-1,500/yr	-	-
Solar Photovoltaic	-	3,000/year	150-450/yr	-	-	-
Geothermal	-	4,725/year	-	3,150-3,540/yr	-	-
Wind Energy (Small)	36,880	369	369	-	184	-
Wind Energy (Large)	3,000,000	675,000	675,000	-	270,000	-
Hydropower	11,636	6,605	6,605	-	1,040	-

Note: the scope of this study did not include an assessment of the current energy use in the County. As a reference to the Accessible Energy Resource, the total primary energy requirement in Ireland (2003) is approximately 160Terawatthours. Taken as a percentage of population, this represents a primary energy requirement in Co. Carlow of 2,000,000MWH per year (1.3%).

1. Introduction

1.1. Benefits of renewable Energy

1.1.1. Direct benefits for users of renewable energy

- Almost every energy user has at least one source of renewable energy available to them, from the geothermal heat in back gardens to the solar energy falling on roofs.
- Modern renewable energy systems can provide a high level of automation, reliability and responsiveness, operate with high energy conversion efficiency and produce very low or zero emissions.
- Many companies are now offering a wide range of renewable energy services and equipment for domestic, commercial and industrial energy users.
- Locally sourced renewable energies can provide clean, sustainable, and cost effective sources of heat, electricity, and transport fuel. Significant savings can be made by using renewable energy in terms of both energy costs and CO_2 emissions reduction when compared to using fossil fuel.
- Renewable energies can offer stable, predictable and long term energy prices, not affected by geo-political issues.
- For certain renewable energy developments, grant aid may be available to support projects.

1.1.2. Benefits to the economy and environment

There are many environmental benefits associated with using renewable energy:

- The main environmental benefit of using renewable energy is the reduction in greenhouse gas emissions. This will in turn reduce the fines resulting from not meeting our Kyoto and EU targets for greenhouse gas emissions reductions and renewable energy implementation.
- Renewable energy technologies produce little or no pollution, whereas energy from fossil fuels is a primary source of air, water, and soil pollution. Pollutants, such as carbon monoxide, sulphur dioxide, nitrogen dioxide, and particulate matter all impact negatively on the local environment.
- Using locally sourced renewable energies also reduces the harmful emissions and pollution risks associated with the transport of fossil fuels.
- Using the renewable energy sources available locally reduces fossil fuel imports, thus improving the balance of payments for the exchequer and keeping money within the local economy.
- Using renewable energy reduces exposure to fluctuations in fossil fuel price and security of supply, especially oil.
- Renewable energy offers the opportunity to create new jobs in rural areas as well as providing alternative land uses for farmers.

1.2. Policies underpinning Renewable Energy

Throughout Europe, renewable energy is now getting the political and economic emphasis required to make a meaningful contribution to reducing dangerous emissions. In parallel, there is now real concern that with global fossil fuel reserves diminishing and held in increasingly unstable areas of the world, the EU must take action to secure energy supplies.

- The EU is committed, under the Kyoto protocol, to reducing greenhouse gas emissions to 8% below 1990 levels by the period 2008-2012.
- EU member states have each introduced significant new policies to encourage the development of different types of renewable energy. Overall, the EU has called for an increase in the contribution from renewable sources to total energy consumption from the present 6% to 12% by 2010.
- It is widely expected that an EU wide system of taxing carbon emissions will be introduced within the next 2-3 years, which will follow the "polluter pays" principle. Within this context, Ireland has much to do to reach challenging targets

Although starting late, Ireland is now placing considerable emphasis on its renewable strategy, offering long term purchase contracts for renewable power and committing significant additional funds through the National Development Plan (www.ndp.ie) and Sustainable Energy Ireland (www.sei.ie) to encourage the industry as a whole.

- Ireland's Kyoto target is to limit CO_2 emissions growth to 13% above 1990 levels by 2012. This level has been significantly exceeded, and in a business as usual scenario, is expected to be 35% above 1990 levels by 2010. This will result in significant financial or economic penalties.
- Ireland currently imports greater than 90% of its primary fuel needs. This is amongst the highest in the EU and means that Ireland has potentially the lowest security of supply within Europe.
- Renewable energy in Ireland currently accounts for only 2% of usage and approximately 5-6% of capacity.

The Green Paper on Sustainable Energy available from the Department of Communications, Marine and Natural Resources (www.dcmnr.ie), states in relation to the role of Local Authorities that:

> ***"Counties ought to be self-reliant for energy"***
>
> and
>
> ***"Local Authorities could require integrated energy planning for applications for housing and commercial developments e.g. the Developer would have to demonstrate that the carbon intensity of fuel sources for housing were being kept to the minimum"***

The Carlow County council Draft Development plan 2003 states in relation to sustainable energy (Sect. 3.7 Energy Supply):

"The Council will seek to provide positively for the development of appropriate renewable energy sources, which makes use of the natural resources of the county in an environmentally acceptable manner."

"The Council will encourage the development of wind energy, in accordance with government policy. The assessment of wind energy proposals will have regard to the "Guidelines for Planning Authorities on Wind Farm Development", published by the Department of the Environment, and "Planning Guidelines for Wind Energy", published by the Irish Planning Institute."

"Visually and environmentally sensitive locations should be avoided such as natural Heritage Areas, Special Areas of Conservation, Special Protection Areas, Landscape Conservation Areas, and those in proximity to protected structures."

"The planning authority shall encourage the development of innovative and sustainable energy production, use and conservation practices such as biomass development, energy reuse and recovery from industrial and institutional sources and geothermal energy exploitation."

"All new development will be required to have regard to energy efficiency, materials recovery and environmentally responsible design"

The Carlow County Development Board - "Strategy, and its Action Plan 2002-2012", states in relation to sustainable energy:

(Sect. 5.6 - Theme F - Environment)

> ***"The environment section of the strategy is focused on promoting sustainable environmental practices, and on encouraging the community of County Carlow to share responsibility for the environment. It does this by focusing on education and awareness, community involvement, waste management, water quality, air quality, noise pollution, dereliction of the built environment, renewable energy and radon emissions."***
>
> ***"The long-term well-being of rural communities is particularly dependent on sustainable use of local resources. There is a range of natural and man-made resources that facilitate the health and well-being of rural as well as urban areas. These include clean air and water, unspoilt landscape, natural resources, wind and other renewable energy resources and the built heritage. The protection and enhancement of these resources will benefit from community education and participation and this strategy is particularly focused on such approaches but also acknowledges and strongly supports the need for strict enforcement measures in environmental matters."***
>
> ***"The CDB has identified eleven strategic objectives to achieve its goal of a protected and enhanced environment in County Carlow as follows:***
>
> ***……To investigate the potential for and encourage the use of a diverse range of renewable energy sources in County Carlow"***

1.3. Terms of reference

The terms of reference for this study to assess the renewable energy resource in Co. Carlow are summarised below:

1. Identify the distribution of renewable energy resources throughout the county based on existing and extrapolated data.

2. Quantify the total size of each resource based on existing and extrapolated data.

3. Evaluate the exploitable resource based on, environmental and planning considerations, available technology, and accessibility to the electricity grid as appropriate.

4. Produce a renewable energy resource database and map series, and a report detailing the findings of the study.

5. Based on the above, to produce recommendations and outline a strategic action plan, in conjunction with the County Development Board, for the development of renewable energy in Co. Carlow in the context of National and European Union commitments to Sustainable Energy.

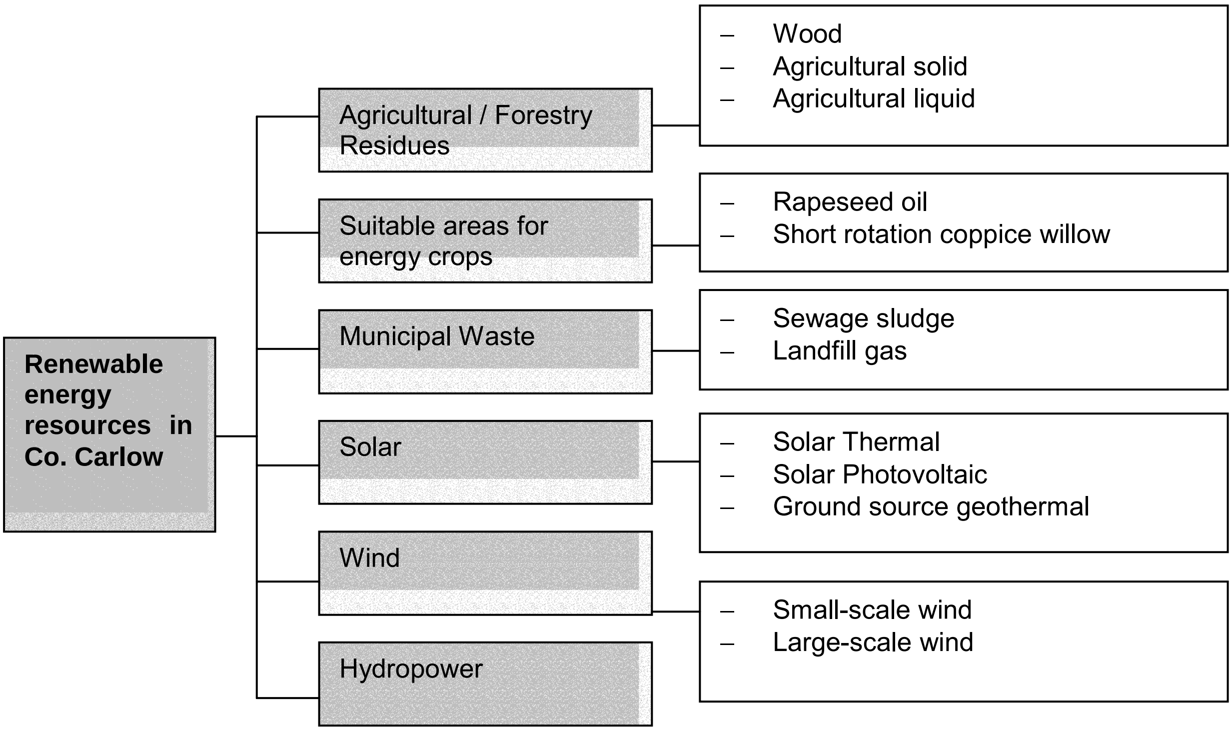
1.4. Study objectives

The aim of this study is to achieve the following:

- Increase and where necessary enhance the information available on Co. Carlow's Renewable Energy resource by reinterpreting existing data and bringing all the data together in one document
- Model the information so that it is possible to integrate it with future County Development plans
- Provide the data in a clear and easily accessible format in order to allow residents, businesses and community groups in Co. Carlow to assess the potential for renewable energy development in their own locality
- Increase awareness of the potential for renewable energy in Co. Carlow
- Use the data compiled to identify strategies and develop an Action Plan for renewable energy development in the County
- Create a positive environmental and economic impact in the County through increased use of locally sourced renewable energy

1.5. Methodology and analysis approach

The types of Renewable Energy Resources available in the County, which may be suitable for exploitation, were identified as follows:



The renewable energy resources are assessed in terms of total energy resource, accessible resource and potential useful energy as appropriate.

- **Total energy resource** relates to the theoretical maximum resource potential that exists in the county.

- **Accessible resource** considers alternative uses or disposal outlets for each resource, suitable area or locations available, access to the electricity grid, and planning or environmental considerations.

- **Potential useful energy** considers economies of scale and the geographical distribution of resources where appropriate and applies this to the energy conversion efficiencies of the applicable technologies.

1.5.1. Resource and distribution assessment methodology

In order to identify the distribution of renewable energy resources throughout the county and to quantify the size of each resource, the following reports and data-sets were utilised:

Agricultural residues: CSO and Teagasc agricultural statistics, Land Parcel Identification System data for Co. Carlow (Department of Agriculture), Teagasc soil map, Forest Inventory and Planning System and planting statistics (Forest Service). These datasets were correlated with appropriate biomass expansion factors and projected output variations to calculate the distribution of the resource and total annual energy available.

Dedicated energy crops: Teagasc soil map, Geology of Co. Carlow (GSI), Land Parcel Identification System data for Co. Carlow (Department of Agriculture). These datasets were correlated with appropriate growth rates and projected output potential to calculate the distribution of this potential resource and associated annual energy output.

Municipal Waste: National Waste Databases (EPA), Carlow Landfill Register & Wastewater Treatment Plants (Carlow County Council). The information relating to the volume and composition of wastes in Co. Carlow available in these datasets was used to calculate the distribution of this resource and associated energy capacity.

Solar: GIS Assessment of Solar Energy Resource in Europe (European Commission, - Joint Research Centre). For solar thermal and photovoltaic, the solar resource data was tailored for Co. Carlow to give hourly radiation levels in each month of the year.
To assess the suitability for ground source heat pumps, the Teagasc soil map was used to assess the length of and area required for underground piping for typical installations. For vertical ground source heat pumps The Teagasc soil map was used as the basis for calculating borehole length requirements.

Wind: The Wind Atlas for Ireland (SEI) was used as the basis for determining the total wind energy resource in the county. This was matched with NHA and SAC maps to exclude areas unsuitable for large-scale wind energy development. The wind atlas was correlated with CSO data for farm sizes to estimate the potential for small-scale wind turbines.

Hydropower: The Hydropower resource was based on the data available in Total Renewable Energy Resource in Ireland (ESBI/ETSU) and combined with ESB grid data to identify the most suitable sites for development.

To evaluate the potential useful energy, the accessible resource was matched with expected conversion efficiencies for the various applicable technologies.

All GIS analysis and mapping was carried out using MapInfo.

2. Renewable Energy Resources

2.1. *Agricultural / Forestry residues*

Agricultural wood residues in Co. Carlow are available mainly in the form of logging residues and first thinnings from conventional forestry

2.1.1. Wood residues

Definition: Logging Residues
Wood currently left in forests after logging. It comprises thin tops, branches, dead wood, and bent or rotten material.

Considerations for development
A percentage of this material must be left on the forest floor and allowed to decompose to return nutrients to the soil. Excess removal may reduce the permanent humus matter in soil, which may impact on the growth and health of future plantations. On soft wet soils this material acts as brash mats allowing access for heavy machinery.

Total energy resource
The table below presents the estimate of total harvestable residue projections from 2005 - 2010, based on data from Coford (2003). Based on this, the total energy resource available from logging residues has been derived based on an energy content of the residues of 2.5MWH per m^3.

Year	2005	2006	2007	2008	2009	2010	Avg.
Residue resource (m^3)	4,000	2,000	3,000	3,000	4,000	3,000	3,126
Total energy resource (MWH)	10,000	5,000	7,500	7,500	10,000	7,500	7,815

This is equivalent to an average annual energy resource of 7,815 Megawatt hours per year from logging residues in Co. Carlow.

Accessible energy resource
Assuming a percentage of this material should be left in the forest for environmental reasons and accounting for some material which may not be suitable for extraction, the resulting accessible energy resource is approximately 50% of the total resource or an average of 4,000MWH per year.

Potential useful energy
Based on this accessible resource, the annual potential useful energy from electricity only and heat only generation is given in the table below for various conversion efficiencies, typical of wood burning technologies. Where there is potential for CHP, the heat available would typically be of equal quantity to electricity.

The potential installed capacity is:
- 0.1-0.2MW electrical with plant operating at 85% uptime
- 0.55-0.73MW installed heating capacity with a seasonal efficiency of 50%

Electricity only		Heat only	
Efficiency	*MWH/Year*	*Efficiency*	*MWH/Year*
20%	800	60%	2,400
30%	1,200	70%	2,800
40%	1,600	80%	3,200

Definition: First Thinnings
Thinning is the removal of a proportion of the trees in a crop. This is necessary to provide more growing space for the remaining trees to achieve higher-grade timber at clear felling.
In this assessment, first thinnings will be considered. In a high yielding crop, first thinning can take place after 15-20 years.

Considerations for development
Care needs to be taken to avoid damage to remaining trees and their roots during thinning. Harvesting should be done in winter to avoid stump infection by fungus. In forests where thinning is currently economical, there is competition for the resource for pallet production and from board mills.

Total energy resource
The first thinnings resource currently becoming available in Co. Carlow was planted between 1986 and 1988 and is now due for first thinning. The table below presents the estimate of total area of public and private first thinning projections for 2005 - 2015, based on data from the Department of Marine and Natural Resources (2001).
The volume of material available is then calculated on the basis of a yield volume of 70m^3 /Ha.
The total energy resource available from this material has been derived based on an energy content of the material of 2.5MWH per m^3.

Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Year planted	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Area (Hectares)	59	121	109	93	112	117	138	106	87	134
Residue resource (m^3)	4,144	8,470	7,655	6,489	7,826	8,197	9,674	7,399	6,094	9,412
Total energy resource (MWH)	10,360	21,175	19,136	16,223	19,565	20,493	24,185	18,498	15,236	23,529

This is equivalent to an average annual energy resource of 18,840MWH per year from logging residues in Co. Carlow over the next 10 years.

Accessible energy resource
Theoretically all of the first thinning material produced could be available for energy if a sufficient price were to be paid. However, for the purposes of this assessment, the calculation for the available energy resource is based on the assumption of a competing pallet and pulpwood market for 93%-62% of the material over the period 2005-2015 (Coford, 2003), with the remaining excess available for energy use.

Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Accessible energy resource (MWH)	725	2,211	2,656	2,810	4,062	4,959	6,685	5,749	5,259	8,941

The resulting accessible energy resource therefore averages approximately 4,400MWH per year.

Potential useful energy
Based on this accessible resource, the annual potential useful energy from electricity only, and heat only generation is given in the table below for various conversion efficiencies, typical of wood burning technology. Where there is potential for CHP, the heat available would typically be of equal quantity to electricity.

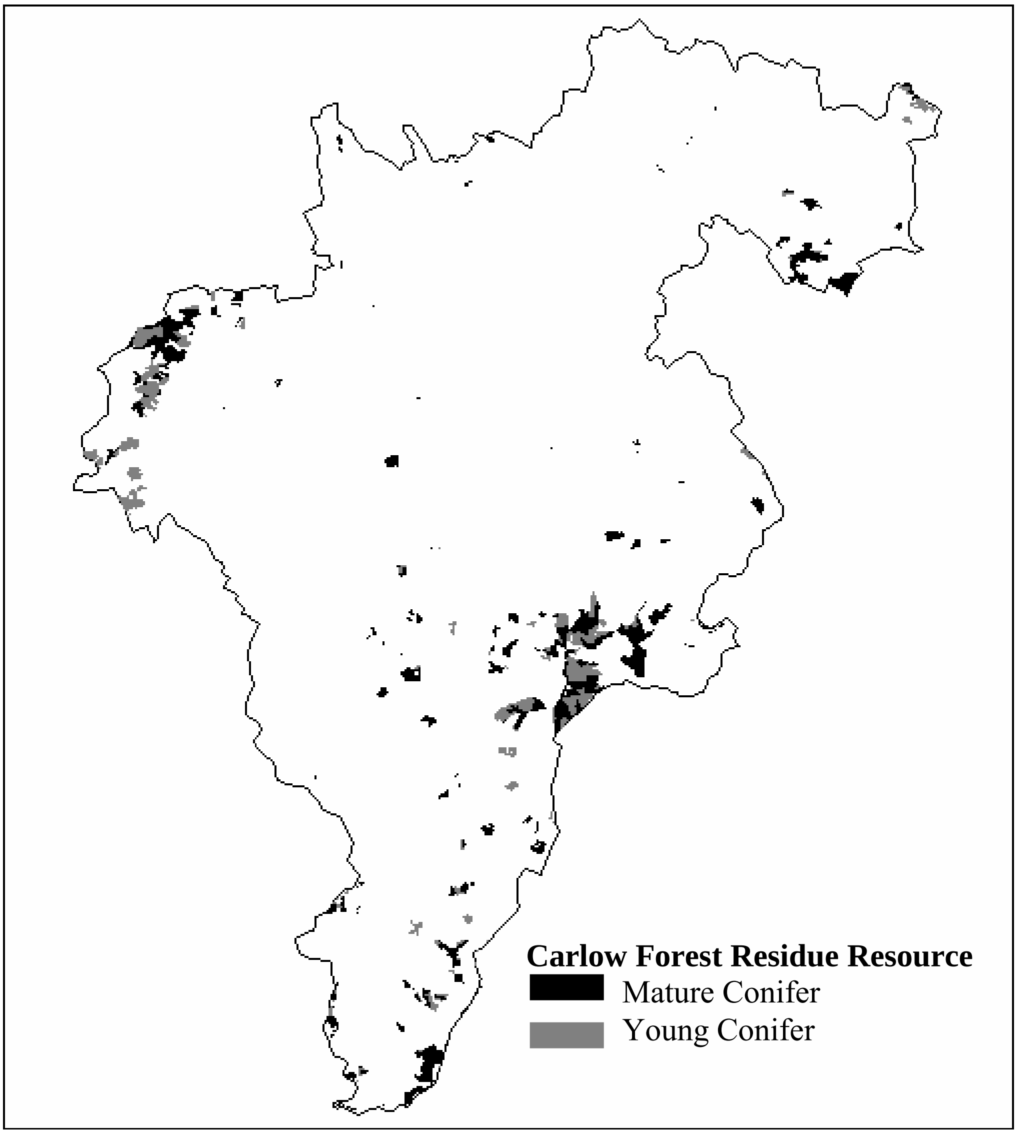
The potential installed capacity is:

- 0.12-0.24MW electrical with plant operating at 85% uptime
- 0.6-0.8MW installed heating capacity with a seasonal efficiency of 50%

Electricity only		Heat only	
Efficiency	*MWH/Year*	*Efficiency*	*MWH/Year*
20%	880	60%	2,640
30%	1,320	70%	3,080
40%	1,760	80%	3,520

Resource distribution

The map below illustrates the distribution of forest based wood residues available in Co. Carlow. The Mature Conifer represents the distribution of potential logging residues while the Young Conifer represents forested area due to be thinned. Most of the forestry is based around the Castlecomer plateau and the Blackstairs Mountains.



2.1.2. Agricultural solid

Definition: Straw
The main solid agricultural residue available in Co. Carlow is Straw from arable crops such as wheat, oats and barley.

Considerations for development
No increased environmental burden results from using straw for energy use. It is currently harvested for animal bedding and in some cases for fodder and the production of mushroom compost. The low density of the material would result in high transport costs compared to e.g. wood fuel.

Total energy resource
According to the Census of Agriculture - June 2000, Table 15 (CSO, 2003), there is approximately 13,690 hectares of straw harvested annually in Co. Carlow. At 4.5 tonnes of straw harvested per hectare, the total yield amounts to over 60,000 tonnes per year. This may vary by up to 30% due to climatic conditions during the growing season and harvesting technique.

The calorific value of straw is on average 4MWH per tonne at 20%m.c. (Nikolalsen et al. 1998). This is equivalent to a total energy resource of 240,000 Megawatt hours per year from straw in Co. Carlow.

Accessible energy resource
The accessible straw energy resource is estimated to be in the range of 7% - 22% of the total energy resource (M.C. O'Sullivan, 2003). This is based on the resource remaining after alternative uses such as animal bedding, compost production and fodder, i.e. the straw which is stored for later use or reincorporated into the soil as a fertiliser or soil structure improver. The range is based on annual variations in straw production levels due to climatic conditions.

The resulting accessible energy resource is therefore in the range of 16,800MWH - 52,800MWH per year. This gives an average accessible energy resource of 35,000MWH per year.

Potential useful energy
Based on this accessible resource, the annual potential useful energy from electricity only, and heat only generation is given in the table below for various conversion efficiencies. Where there is potential for CHP, the heat available would typically be of equal quantity to electricity.

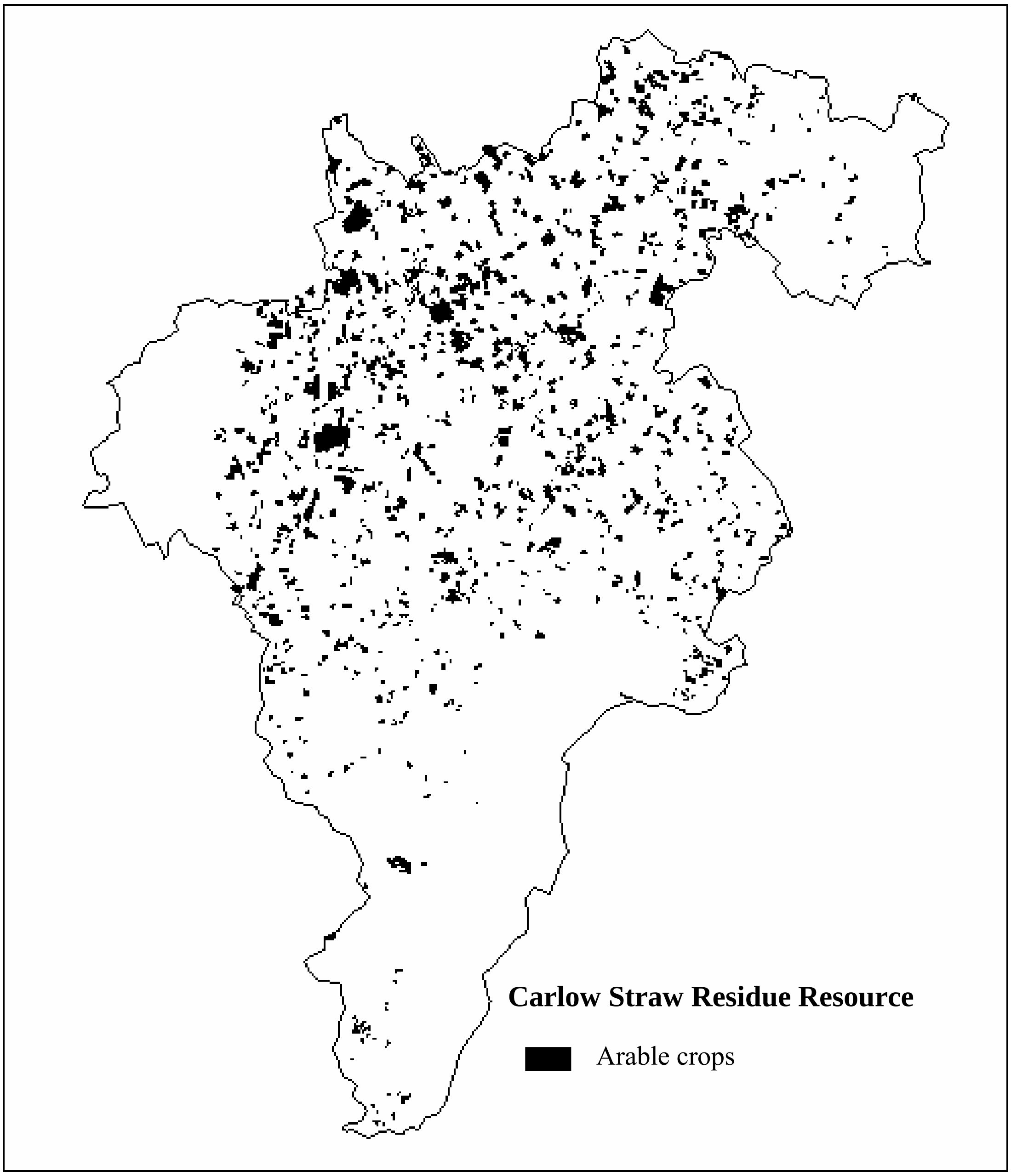
The potential installed capacity is:

- 0.9-1.9MW electrical with plant operating at 85% uptime
- 4.8-6.4MW installed heating capacity with a seasonal efficiency of 50%

Electricity only		**Heat only**	
Efficiency	*MWH/Year*	*Efficiency*	*MWH/Year*
20%	7,000	60%	21,000
30%	10,500	70%	24,500
40%	14,000	80%	28,000

Resource distribution

The map below illustrates the distribution of arable crops in the county. As can be seen, arable crops are more densely cultivated in the north west of the county, decreasing outwards from there.



2.1.3. Agricultural liquid

Definition
Farm slurry from pigs and cattle. Only available for energy use from housed animals.

Considerations for development
The presence of bedding material may cause handling problems. Land must be available to apply the residual liqueur. A market for the anaerobic digestion by-product, which can be processed as nutrient rich, low pathogen organic fertiliser, must be available to facilitate financial viability. Lack of economies of scale for single farm based plants and requirement for specially trained operators may be a limiting factor. Transport costs for centralised plants may be significant.

Total energy resource

- According to the CSO Census of Agriculture - June 2000, Table 12, there are approximately 96,000 cattle in Co. Carlow. The total resource from these animals amounts to approximately 103,000 tonnes dry solids per annum (1.07tn_{ds}/yr/animal). Based the same source, there are approximately 21,000 pigs in the county, yielding 2,740 tonnes dry solids per annum (0.12tn_{ds}/yr/animal), giving a total of 105,740tn_{ds}/yr.
- While biogas yield can vary widely, depending mainly on the technology used and retention time, a biogas yield of approximately 250m^3 per tonne of dry solids could be expected. This gives a total annual biogas resource of 26,435,000m^3 per annum.
- The energy content of this biogas is ~6.6 kWh/m^3, thus the total energy resource is 174,000MWH per annum.

Accessible energy resource

- Approximately 10% of cattle manure and 75% of pig manure may be available for energy use, considering mainly the length of time the animals spend housed, totalling 10,300 and 2,055 tonnes dry solids per annum respectively. This is equivalent to a biogas resource of 3,088,000m^3 of per annum.
- The accessible energy resource is therefore in the region of 20,400MWH per year.

Potential useful energy
Based on this accessible resource, the annual potential useful energy from electricity only, and heat only generation is given in the table below for various conversion efficiencies.

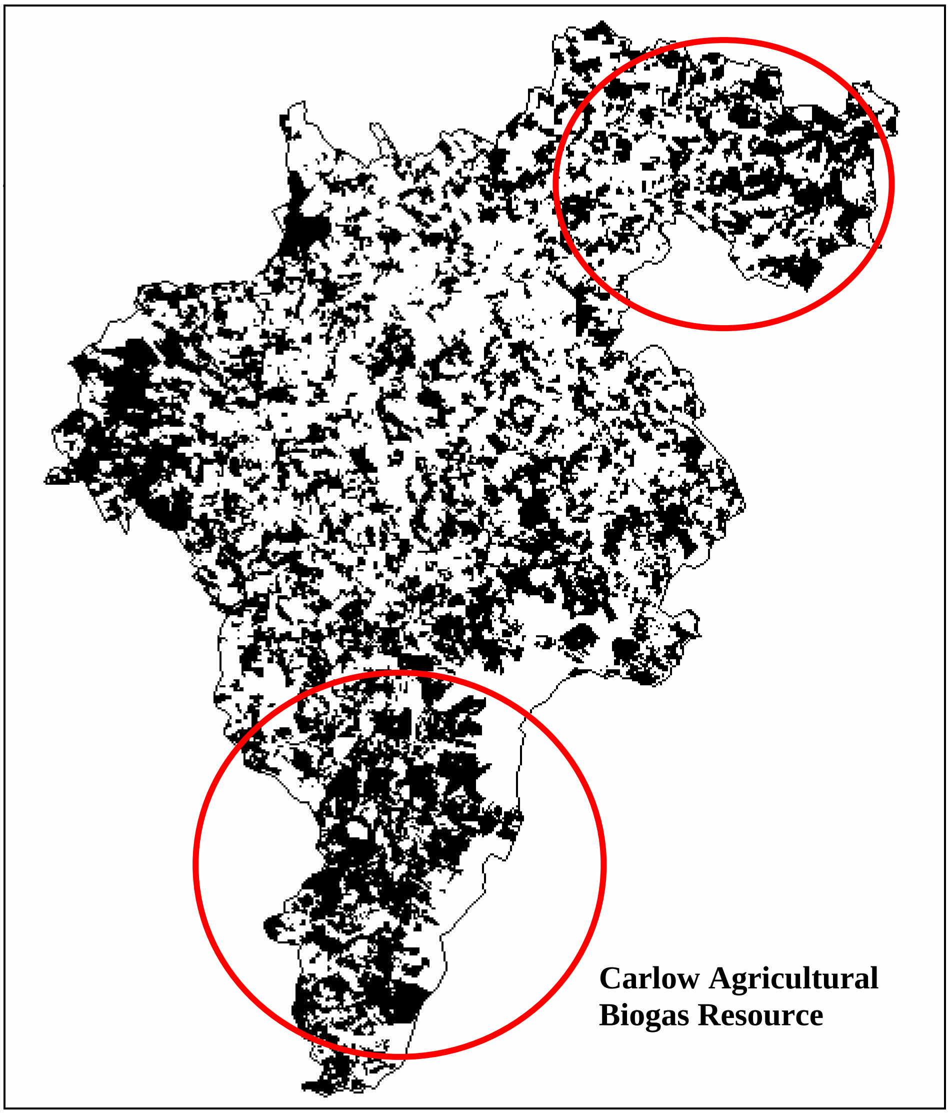
The potential installed capacity is:

- 0.5-1.1MW electrical with plant operating at 85% uptime
- 2.8-3.7MW installed heating capacity with a seasonal efficiency of 50%

Electricity only		**Heat only**	
Efficiency	*MWH/Year*	*Efficiency*	*MWH/Year*
20%	4,080	60%	12,240
30%	6,120	70%	14,280
40%	8,160	80%	16,320

Resource distribution

The map below illustrates the distribution of forage land use in the county. This map is intended to demonstrate the areas where livestock farming is most prevalent. Dairy farming is most densely carried out in the south and Northeast of the county, indicating that transport costs would be minimised by developing biogas plant in these regions.



Dedicated energy crops

The two main energy crops being considered in Ireland are short rotation coppiced willow or poplar and rapeseed oil.

Definition
Short rotation forestry uses fast growing, high yielding varieties of tree, planted at a high density to produce the maximum quantity of wood biomass per hectare.

Considerations for development
Reasonable quality agricultural land is necessary which will result in competition with arable crops. Plantations are generally environmentally beneficial (increased biodiversity, soil improvements). The crop can be used for bioremediation of organic wastes to improve viability.
An environmental impact assessment is necessary for plantations greater than 70Ha as with conventional forestry.

2.2.1. Short rotation forestry

Total energy resource
There are a number of demonstration plantations of short rotation forestry in Co. Carlow, but on their own these are insignificant energy resources. However, the potential total energy resource is significant. For the purpose of this assessment, areas for the cultivation of short rotation forestry have been identified, based on soil type, which are:

- most suitable (average yield - 12ODT/Ha[1].), and
- adequate (average yield - 8ODT/Ha.)

Areas which are unsuitable or unavailable due to being mountainous, existing forestry or urbanisation have been excluded.

The table below presents the scale of the suitable and adequate areas and the potential energy yield from short rotation forestry (energy content - 5MWH/ODT).

Short Rotation Forestry - TER	***Area (Ha.)***	***Yield (ODT/Yr.)***	***Total energy resource (MWH/Yr.)***
Most suitable	32,000	384,000	1,920,000
Adequate	30,000	240,000	1,200,000
Total	62,000	624,000	3,120,000

Accessible energy resource
In recent years it was assumed that set-aside land would have been the only areas considered to have economic potential for growing short rotation forestry, as set-aside payments could be received by the farmer. However, given recent Common Agricultural Policy reforms, it is possible that a significantly larger proportion of agricultural land could become economically viable for dedicated energy crops.

[1] ODT: Oven Dry Tonnes - a theoretical description of a wood energy resource at 0% moisture content.

Whatever the case, it is expected that short rotation forestry would only be established as a fuel source for specific energy projects. Therefore, for the purpose of this assessment, calculations of the potential energy resource available by establishing short rotation forestry on 5%, 10% and 15% of the most suitable land, are taken as a reasonable assumption for a change of land use to dedicated energy crops. The resulting accessible energy yields are shown in the table below

Short Rotation Forestry - AER	***Area (Ha.)***	***Yield (ODT/Yr.)***	***Accessible energy resource (MWH/Yr.)***
5% of most suitable land	1,600	19,200	96,000
10% of most suitable land	3,200	38,400	192,000
15% of most suitable land	4,800	57,600	288,000

Potential useful energy

Based on this potentially accessible resource, the annual potential useful energy from electricity only and heat only generation is given in the table below for various conversion efficiencies.

5% of most suitable land			
Electricity only		**Heat only**	
Efficiency	*MWH/Year*	*Efficiency*	*MWH/Year*
20%	19,200	60%	57,600
30%	28,800	70%	67,200
40%	38,400	80%	76,800
Potential installed capacity			
3-5MW operating at 85% uptime		13-18MW seasonal efficiency of 50%	

10% of most suitable land			
Electricity only		**Heat only**	
Efficiency	*MWH/Year*	*Efficiency*	*MWH/Year*
20%	38,400	60%	115,200
30%	57,600	70%	134,400
40%	76,800	80%	153,600
Potential installed capacity			
5-10MW operating at 85% uptime		26-35MW seasonal efficiency of 50%	

15% of most suitable land			
Electricity only		**Heat only**	
Efficiency	*MWH/Year*	*Efficiency*	*MWH/Year*
20%	57,600	60%	172,800
30%	86,400	70%	201,600
40%	115,200	80%	230,400
Potential installed capacity			
8-15MW operating at 85% uptime		39-53MW seasonal efficiency of 50%	

2.2.2. Rapeseed oil

Definition	***Considerations for development***
Arable crop grown specifically as an energy crop or for potable oils and industrial uses.	Requires good quality agricultural land as with SRF. Plantations are generally environmentally beneficial (increased biodiversity). The crop may be susceptible to harvesting risks if weather is unsuitable.

Total energy resource
There is a small area of rapeseed farmed in Co. Carlow. However, similarly to short rotation forestry, this resource is minor compared the potential total energy resource. As such, a similar resource assessment method has been used. This assessment also accounts for the fact that similar soil types are most suitable for rapeseed and short rotation forestry.

For the purpose of this assessment, areas have been identified for the cultivation of rapeseed, which are:

- most suitable (average seed yield - 3.4 T/Ha.), and
- adequate (average seed yield - 2.6T/Ha.).

Areas which are unsuitable or unavailable due to being mountainous, existing forestry or urbanisation have been excluded.

- Whether the oil is extracted by crushing the seed or by solvent extraction, there is approximately 0.4 tonnes of pure plant oil available per tonne of rapeseed.
- Under a transesterification process to convert the pure plant oil to biodiesel, approximately 97% of the oil remains.
- There is 1,136 litres in 1 tonne of biodiesel, with an energy content per litre equal to 94% that of conventional diesel (9.89kWh/Litre compared to 10.52kWh/Litre).

Based on these figures, the table below summarises the typical biodiesel resource available *per hectare per year* of "most suitable" land in Co. Carlow.

A	**B**	**C**	**D**	**E**	**F**	**G**
Area	Rapeseed yield (Harvesting)	Pure Plant Oil yield (Crushing)	Biodiesel (Transeste-rification)	Biodiesel	Conventional diesel equivalent	Energy
Ha.	Tonne/Ha.	Tonne/Ha.	Tonne/Ha.	Litre/Ha.	Litre/Ha.	MWh/Ha.
	A x 3.4	B x 0.4	C x .97	D x 1,136	E x 0.94	E x 0.00989
1	**3.4**	**1.36**	**1.32**	**1,500**	**1,410**	**14.82**

The table below presents the scale of the suitable and adequate areas and the potential total energy resource from rapeseed in Co. Carlow.

	Area (Ha.)	***Biodiesel (Litres/Yr.)***	***Total energy resource (MWH/Yr.)***
Most suitable	32,000	48,000,000	474,720
Adequate	30,000	34,380,000	340,000
Total	62,000	82,380,000	814,720

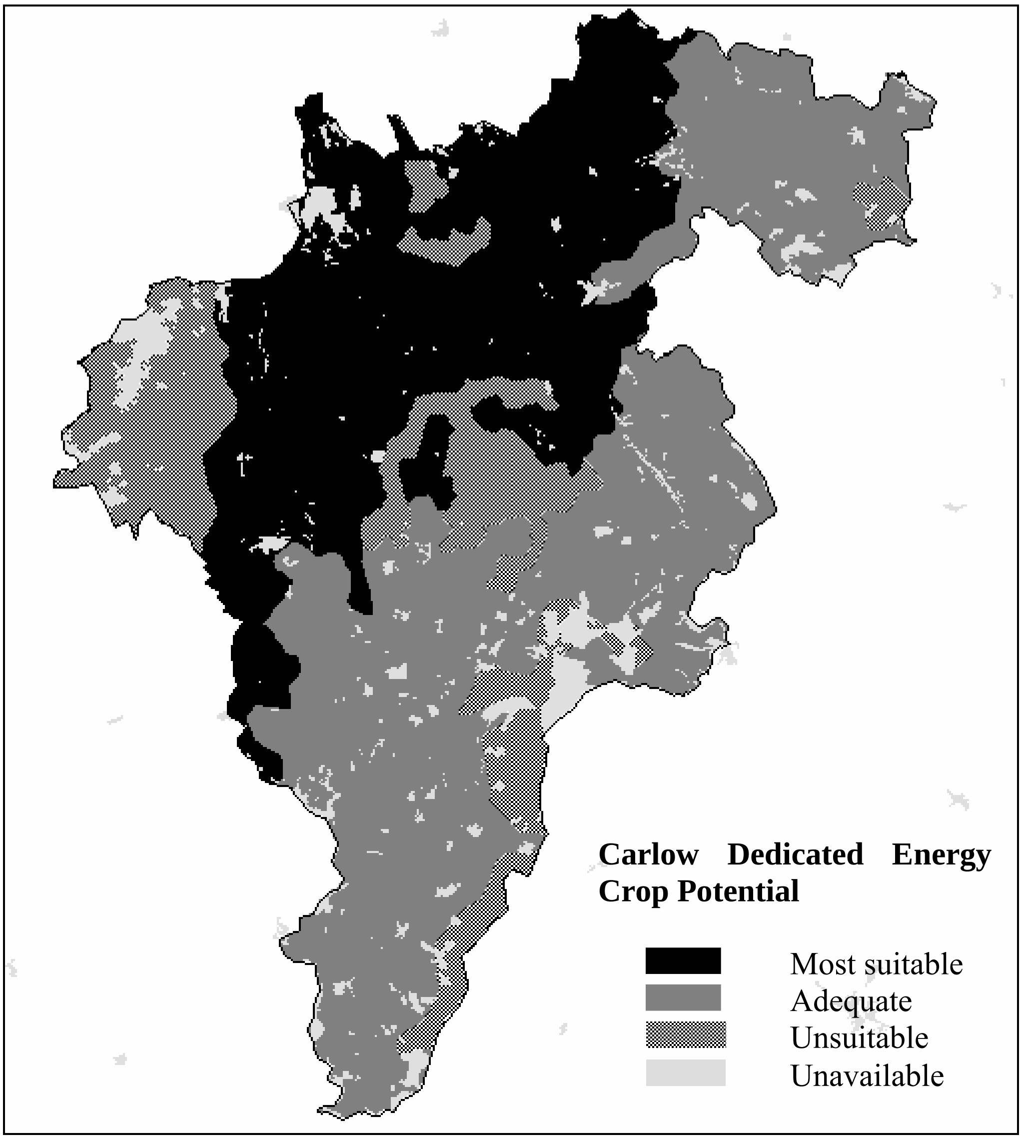
Accessible energy resource

For the purpose of this assessment, calculations of the potential energy resource available from rapeseed oil on 5%, 10% and 15% of the most suitable land are given as a reasonable assumption for a change of land use.

	Area (Ha.)	*Biodiesel (Litres/Yr.)*	*Accessible energy resource (MWH)*
5% of most suitable land	1,600	2,400,000	23,736
10% of most suitable land	3,200	4,800,000	47,472
15% of most suitable land	4,800	7,200,000	71,208

Resource distribution

The map below illustrates the suitability of areas in Co. Carlow for dedicated energy crops. As would be expected, the most suitable areas correspond with distribution of arable crops in the north west of the county.



2.3. *Municipal waste*

2.3.1. Sewage sludge

Definition
This is the by-product of urban wastewater treatment plants.

Considerations for development
Concentrated resource only available in large population centres with municipal sewage treatment plants. After anaerobic digestion land must be available for spreading residues. A high carbon dioxide:methane ratio means the biogas can only be used in specialised burners unless further pre-treatment of the biogas is carried out.

Total energy resource
According to the Environmental Protection Agency (EPA, 2004) the sludge generated at waste water treatment plants in Co. Carlow in both 2002 and 2003 totalled 546 tonnes of dry solids per year.
Given an average biogas yield through anaerobic digestion of 220m^3 per tonne of dry solids, the total resource is 120,120m^3 of biogas per annum containing 60% to 70% methane.
This methane gives the biogas an energy content of about 6.2kWh/m^3. Therefore the total energy resource is 745Megawatt hours per annum

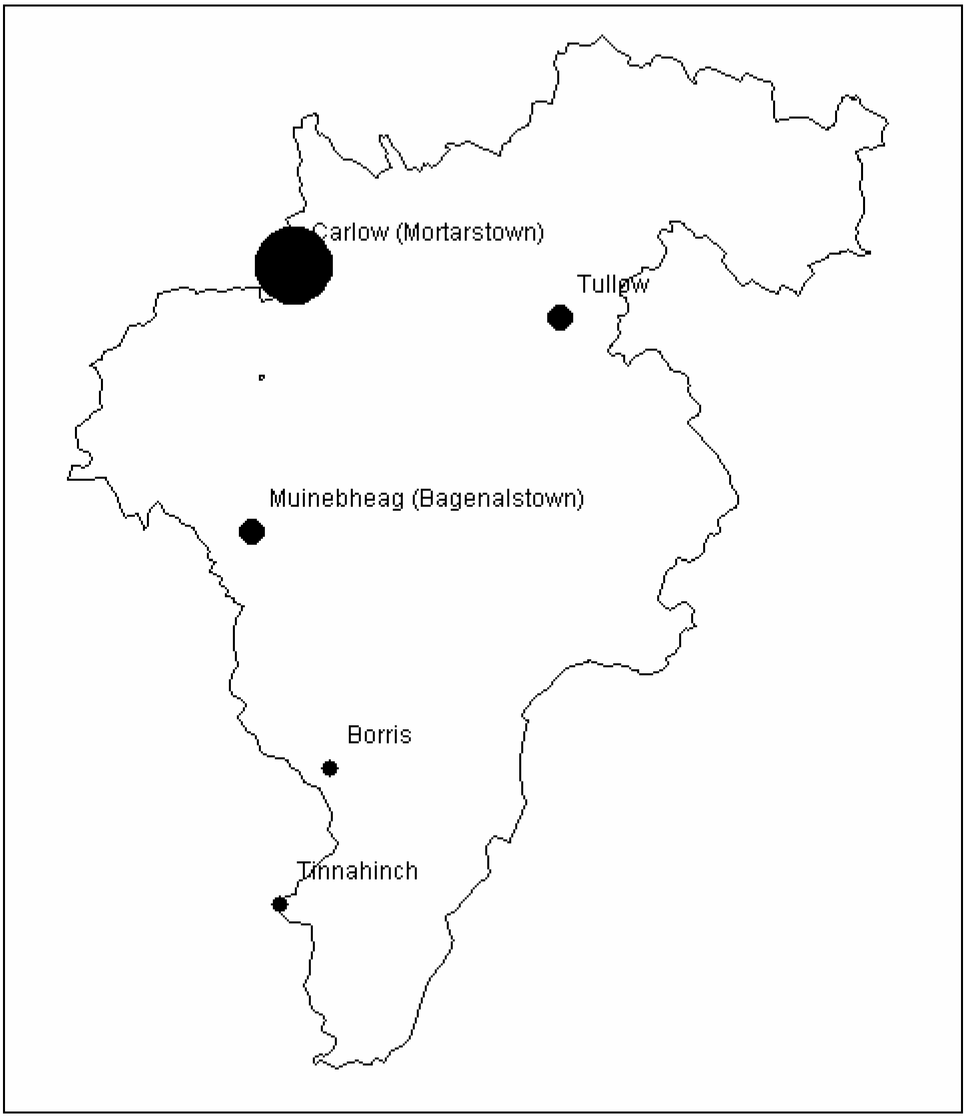
Accessible energy resource
Given that this resource refers only to waste water treatment plants with operating population equivalents greater than 500 persons, and that current disposal routes are to landfill or to agriculture, all of this resource is potentially available for energy use.

Potential useful energy
Based on this accessible resource, the annual potential useful energy from electricity only, and heat only generation is given in the table below for various conversion efficiencies of anaerobic digestion technologies.

The potential installed capacity is:
- 0.02-0.04MW electrical with plant operating at 85% uptime
- 0.1-0.14MW installed heating capacity with a seasonal efficiency of 50%

Electricity only		**Heat only**	
Efficiency	*MWH/Year*	*Efficiency*	*MWH/Year*
20%	149	60%	447
30%	224	70%	522
40%	298	80%	596

Resource distribution
The map below illustrates the distribution of the 5 largest waste water treatment plants in Co. Carlow. By far the largest, and the only one considered in this assessment, is the Mortarstown plant near Carlow Town. A likely energy use at this plant is to use heat to dry the sludge.



2.3.2. Landfill gas

Definition
Landfill gas is generated by the natural decomposition of the biodegradable or organic portion of Municipal Solid Waste in landfill.

Considerations for development
For environmental reasons, landfill gas is generally collected using a series of gas wells and flared off. Collecting and burning LFG reduces methane emissions to the atmosphere and reduces local safety hazards from the potential build up and explosion of methane. It also reduces odours associated with landfill sites.
Pumping trials and modelling of gas resource may not necessarily guarantee future availability of biogas from a particular landfill site. Moves to reduce, reuse, recycle and pre-treat MSW, especially biodegradable waste, will reduce the long-term availability of the resource.

Total energy resource
Landfill gas can be produced within 3 - 6 months of the waste being landfilled. A number of factors affect the rate at which landfill gas is generated - such as moisture content of the waste, temperature, acidity, and depth of the landfill. The following estimate for landfill gas production in Co. Carlow is based on data provided by the National Waste Database Interim Report 2003 (EPA, 2004) in the tables below:

Table 3 - *Municipal waste generation, as reported by local authorities*, compiles figures for the total volume of household and commercial waste generated per county in 2003. The total volume for Co. Carlow is 20,721 tonnes (household) and 6,188 tonnes (commercial), a total of 26,909 tonnes in 2003.

Table 4 *Composition of household and commercial waste - 2003* in the same report shows that of the total waste generated in Ireland, 72% is sent to landfill. Of this landfilled volume, 63% is in the form of biodegradable or organic waste (i.e. paper, textiles, organics and wood). Applying these figures to the total volume of waste generated in Co. Carlow, 19,375 tonnes of waste is landfilled and of this 12,200 tonnes is in the form of biodegradable or organic waste.

Given a landfill gas yield of $150m^3$ per tonne of biodegradable and organic waste, the total resource is $1,830,000m^3$ of biogas per annum containing on average 55% methane.
This methane gives the biogas an energy content of $5.1kWh/m^3$. Therefore the total energy resource is 9,300Megawatt hours per annum

Accessible energy resource
The accessible energy resource is determined by the collection efficiency of the gas wells, assumed here to be 50%. This results in an accessible energy resource of 4,730Megawatt hours per annum

Potential useful energy

Based on this accessible resource, the annual potential useful energy from electricity only is given in the table below for various conversion efficiencies. The table also gives the potential for heat only generation if a suitable heat use can be found.

The potential installed capacity is:

- 0.13-0.25MW electrical with plant operating at 85% uptime
- 0.64-0.86MW installed heating capacity with a seasonal efficiency of 50%

Electricity only		**Heat only**	
Efficiency	*MWH/Year*	*Efficiency*	*MWH/Year*
20%	940	60%	2,820
30%	1,410	70%	3,290
40%	1,880	80%	3,760

Resource distribution

The entire landfill gas resource in Co. Carlow is located in Powerstown Landfill in the Northwest of the county.

2.4. Solar Energy

2.4.1. Solar Thermal and Photovoltaic panels

Definition
Active solar systems derive their energy from direct, diffuse and to a lesser extent reflected solar radiation.
Solar thermal systems concentrate light from the sun to generate warm water or air.
Solar photovoltaic systems convert sunlight into direct current (DC) electricity.

Considerations for development
For both total Thermal and Photovoltaic systems the energy resource is the same, as they both use sunlight to generate heat or electricity.
Energy storage (hot water tank or battery) is required for night-time use. The energy resource varies by up to a factor of 5 between summer and winter.
Space availability may be an important consideration especially in urban applications.

Total energy resource
As an assessment of the total solar resource in the county is of limited use, the following will describe the total solar resource per square metre.

- The amount of solar energy received by a surface at ground level depends on the following factors: latitude, atmospheric conditions, orientation in relation to the sun, tilt angle of the solar modules, day of the year, and hour of the day.
- The solar energy received on a horizontal surface in Co. Carlow is almost 1,000kWh/square metre/year based on an average proportion of diffuse to global irradiation of 60%. Equal to ~900TWH/year for the County.
- The optimum orientation of a solar panel is within 20deg of South.
- The table below illustrates the variations in daily solar radiation received per square metre for different tilt angles of a solar panel over a typical year.
- This becomes relevant when optimising the system for a particular use. Even though 37deg tilt angle receives the greatest total radiation over the year, other factors may need to be considered, For example:
  - A lower tilt is beneficial when the energy is used mostly in the summer.
  - A steeper tilt may be preferable when the energy requirement is more evenly distributed throughout the year

Solar Radiation	Tilt Angle (southern orientation)						
(kWh/m^2/day)	South Vertical	Horizontal	15 deg.	30 deg.	37 deg.	45 deg.	60 deg.
Jan	1.30	0.64	0.90	1.11	1.19	1.27	1.36
Feb	1.74	1.18	1.49	1.73	1.81	1.88	1.94
Mar	2.34	2.21	2.55	2.79	2.85	2.89	2.84
Apr	2.83	3.61	3.95	4.11	4.12	4.08	3.84
May	2.86	4.79	4.99	4.98	4.90	4.75	4.30
Jun	2.55	4.81	4.89	4.79	4.67	4.48	3.99
Jul	2.69	4.80	4.93	4.87	4.77	4.60	4.13
Aug	2.53	3.70	3.92	3.99	3.95	3.87	3.58
Sep	2.65	2.74	3.12	3.36	3.42	3.44	3.34
Oct	2.08	1.56	1.92	2.19	2.27	2.35	2.38
Nov	1.49	0.80	1.08	1.32	1.41	1.49	1.58
Dec	0.98	0.46	0.66	0.82	0.88	0.94	1.01
Daily average	**2.17**	**2.62**	**2.87**	**3.00**	**3.03**	**3.00**	**2.86**
Total annual	**792**	**954**	**1049**	**1096**	**1104**	**1096**	**1043**

The following table gives typical hourly solar radiation in *Watt-hours per Square Metre* on a surface which is at a tilt of 45deg facing south. The data in this table can be used to compare how daily instantaneous energy requirement distribution throughout the year will compare to the distribution of energy provided by a solar system of any given size at a tilt of 45deg facing south.

Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4am - 5am					15	39	26					
5am - 6am				19	64	81	73	34				
6am - 7am			19	82	132	146	139	96	40			
7am - 8am		21	105	185	239	235	236	186	132	51		
8am - 9am	41	110	201	293	342	320	330	279	239	147	65	20
9am - 10am	127	192	286	386	430	390	408	358	335	237	151	91
10am - 11am	188	253	349	455	493	441	466	417	408	305	215	143
11am - 12pm	223	289	385	494	529	469	498	451	450	345	251	172
12pm - 1pm	229	296	393	502	536	475	504	457	458	353	258	178
1pm - pm	209	275	371	478	514	458	485	437	433	329	237	160
2pm - 3pm	161	226	321	424	464	418	440	390	375	275	186	121
3pm - 4pm	87	154	246	342	389	357	371	321	289	194	110	52
4pm - 5pm	4	65	154	240	292	279	284	233	186	98	17	
5pm - 6pm			59	132	185	190	187	140	82	13		
6pm - 7pm				45	90	108	99	61	11			
7pm - 8pm				3	42	61	51	11				
8pm - 9pm						14	6					
Daily	1270	1880	2890	4080	4750	4480	4600	3870	3440	2350	1490	940

Accessible energy resource

To give an approximation of the accessible solar energy resource, it is assumed that any new domestic dwelling in the County can incorporate a solar energy system. Therefore, the accessible energy resource is calculated here as being a product of the number of new houses built in Carlow by an installed solar panel area per house of $4m^2$ (to provide 60% - 80% of annual Domestic Hot Water requirements for a 4 person household). This size of solar panel would be applicable on both urban and rural houses.

Note: This assessment ignores the potential for non-domestic buildings and retrofit to existing buildings although these also offer significant potential.

Based on the Annual Housing Statistics Bulletin 2002 - (Part I - Housing Activity - House Completions by Area) (DOE, 2003), total house completions over the years 1998 - 2002 averaged almost 700 houses per year. Taking the average of $4m^2$ of solar collector per dwelling this equates to a total area of $2,800m^2$.

Using the solar radiation data from the table above, this would result in an ***additional*** 3,000MWH of solar energy becoming accessible ***every*** year.

Potential useful energy

The table below outlines the ***additional*** potential useful energy which could be accrued ***every year*** by solar photovoltaic and solar thermal panels for a total additional collector area of $2,800m^2$ per year in the County.

Photovoltaic		**Solar thermal**	
Efficiency	*MWH/Year*	*Efficiency*	*MWH/Year*
5%	150	25%	750
10%	300	35%	1,050
15%	450	50%	1,500

This is equivalent to 200-600kWh/year of electricity or 1,100 - 2,200kWh/year of water heating for each household using $4m^2$ photovoltaic panel and $4m^2$ solar thermal panel.

2.4.2. Ground source geothermal

Definition

Geothermal heat is in effect solar energy stored in the surface soil/water.
Geothermal heat in the soil can be upgraded to that needed for space heating and industrial processes using heat pumps.
This heat is generally extracted from the ground through a series or Horizontal or Vertical pipes.
While heat pumps use electricity, they generate up to 4 times as much heat. i.e. for every kWh of electricity used, 4kWh of useful heat is generated.

Considerations for development

Geothermal heat-pumps can be used in almost any location although soils with a higher moisture content conduct heat more effectively than dry or stony soils.
Space availability is the most important consideration for a geothermal heat pump system especially in urban applications. While horizontal pipe systems are cheaper to install, vertical systems are more space efficient.

Total energy resource

As with solar energy, an assessment of the total geothermal heat resource in the County is of limited use. Therefore the following will outline the length of collector pipes and ground area needed for typically sized domestic and commercial applications[2].

Horizontal closed-loop piping

The length of collector pipe depends on the size of the heat pump, seasonal performance factor, and the moisture content of the soil as well as overshading. Taking a typical seasonal performance factor of 3 and collector piping buried 1.5 - 2.5m deep, the table below gives typical collector pipe length(m) and area needed(m^2) for horizontal closed-loop piping systems of 10kW, 15kW, and 20kW.

	10kW	15kW	20kW
Ground class 1	400m (150m^2)	650m (250m^2)	900m (350m^2)
Ground class 2	600m (225m^2)	850m (350m^2)	1,100m (450m^2)
Ground class 3	750m (450m^2)	1,100m (650m^2)	1,400m (900m^2)

Notes on ground class soil conductivity

- Ground class 1 - Favourable conditions: Sandy ground, water saturated with high solar radiation exposure
- Ground class 2 - Regular conditions: Humid, silty-sandy ground with regular solar radiation exposure
- Ground class 3 - Unfavourable conditions: Stony ground, dry and shady
- The area of the collector pipe can be reduced by laying it as a spiral although a longer pipe length would be necessary.

[2] note: The areas and lengths shown are indicative only, and are not intended as design guidelines. It is important that each potential geothermal heating system be assessed independently.

Vertical closed-loop piping
The length of vertical collector pipe depends on much the same factors as horizontal systems. The length of each vertical borehole should be between 40 - 100m with a minimum distance between each borehole of 5m - 6m. The table below gives typical *total* pipe lengths and areas (for 75m long pipes) needed for a number of system sizes in ground classes as listed above.

	20kW	30kW	40kW
Ground class 1	300m (36m^2)	450m (70m^2)	600m (100m^2)
Ground class 2	450m (70m^2)	650m (150m^2)	850m (200m^2)
Ground class 3	800m (200m^2)	1,200m (320m^2)	1,600m (450m^2)

Note: based on a usage factor of ~2,000 hours per year

Accessible energy resource
To give an approximation of the accessible geothermal energy resource using heat-pumps, it is assumed that any *new rural* domestic dwelling in the County would have sufficient space available for a geothermal heat-pump collector pipe system. Therefore, the accessible energy resource is calculated here as being a product of the number of new bungalows and detached houses built in Carlow by an installed geothermal heat-pump capacity of 15kW, each producing 15,000kWh of heat per year.
Note: This assessment ignores the potential for urban dwellings, non-domestic buildings and retrofit to existing buildings although these also offer some potential.

Based on the Annual Housing Statistics Bulletin 2002 - (Part I - Housing Activity - New houses completed - by type) (DOE, 2003), total dwelling completions over the years 1998 - 2002 averaged almost 700 houses per year with about 45% of these bungalows and detached houses, equivalent to 315 rural houses per year.
Based on these figures, this would result in an ***additional*** 4,725MWH of geothermal heat-pump energy being generated ***every*** year.

Potential useful energy
Given that geothermal heat-pumps consume a certain amount of electricity to produce heat, the table below outlines the potential useful energy produced less the energy consumed for a number of COPs[3] based on a total 4,725MWH of heat generated. This amount of renewable heat could be accrued ***every year***.
The table also illustrates carbon dioxide emissions per kWh of total heat generated (based on an electricity generation emission factor of 0.47kg CO_2/kWh). This figure would be near zero for other renewable energy sources and between 0.30 - 0.35kg CO_2/kWh for LPG and oil fired boilers.

COP	*Renewable Heat generated MWH/Year*	*Electricity Used MWH/Year*	*Carbon dioxide emissions kg /kWh*
3.0	3,150	1,575	0.16
3.5	3,375	1,350	0.13
4.0	3,544	1,181	0.12

[3] COP - The efficiency of a heat pump is measured as coefficient of performance, COP. The COP is affected mainly by the quality of the equipment used and the temperature difference between the geothermal heat source and the temperature required for heating.

2.5. Wind

Definition	***Considerations for development***
Wind turbines harness the power of the wind by using the force of the wind to turn rotor blades which in turn power a generator or other mechanical drive. The amount of energy which the wind transfers to the rotor depends on the density of the air, the rotor area, and the wind speed.	Wind energy is intermittent and as such requires some form of energy storage or back-up power such as batteries, generator or the electricity grid. While wind is available everywhere, its power is greatly influenced by distance from the coast, exposure above the surrounding terrain, and surrounding land cover. Depending on the scale of the installation, planning considerations can also be a significant factor in the suitability of wind energy applications.

Total energy resource
As with solar and geothermal energy, an assessment of the total wind energy resource of the county is of limited use. As such, this study attempts to give a broad indication of the scope for electricity generation from wind in the County using data from the recently produced Irish Wind Atlas (ESBI, 2003). This atlas provides wind speed and wind power data for the entire country for heights of 50m, 75m and 100m ASL.
The data is available in 2 formats:

- unconstrained resource - the resource over the entire country
- constrained resource - the remaining resource after certain areas have been excluded:
    - 500m buffer around settlements
    - 100m buffer along main roads, railways, high voltage power lines
    - rivers, lakes, canals, reservoirs
    - Areas with mean wind speed < 7.0m/sec.

The Wind Atlas did not make any recommendations regarding local planning policies.

1. Small turbines are designed to operate at lower wind speeds, and may be useful at mean speeds as low as 5-6 m/s at 30m - 50m height. These smaller turbines are therefore suitable for any part of the county and are not as restricted by planning considerations as large turbines.
   Landowners in rural areas would be able to harness wind energy for private use. Therefore, for the purpose of this assessment, the total energy resource for small scale turbines is calculated as a product of the number of farms in the county by a 10kW wind turbine.
   This size of turbine would be suitable for large homes, farms and small businesses and would produce in the region of 15,000kWh - 25,000kWh per year depending on the quality of the local wind resource. (A system of this scale with batteries or for distribution grid connection would cost approximately €35,000 - €50,000)

   According to the Census of Agriculture, June 2000, Table 1 (CSO, 2001), there are 1,844 farms of a size greater than 1 hectare in Co. Carlow.

This would result in a total small-scale wind energy resource of 18.44MW installed capacity generating between 27,660MWH - 46,100MWH of electricity per year (Average: 36,880MWH per year).

2. Commercial wind power projects using large turbines (>1,000kW) require a mean wind speed of at least 7m/s at hub height.

In order to assess the total energy resource for large scale wind turbines, the following assumptions are made:

- The constrained resource from the Wind Atlas as described above is used to identify areas with a suitable wind resource
- SAC and NHAs have been excluded
- 1,000kW turbines sited at a density of ten turbines per square kilometre
- An average wind speed of 7m/s at 75m ASL.

The total area in the County with average wind power of 7m/s or more at 75m ASL is approximately 150 square kilometres. This is sufficient for 1,500 turbines.
These 1,500 turbines - 1,500MW installed capacity - would generate an energy output of approximately 3,000,000MWH per year.

Accessible energy resource

For small-scale wind turbines, this study assumes a realistic potential uptake on the accessible energy resource of as little as 1%. This would result in a potential useful energy production of 369MWH per year from an installed capacity of 184kW.

For large-scale commercial developments, this study assumes that potentially realistic developments will be:

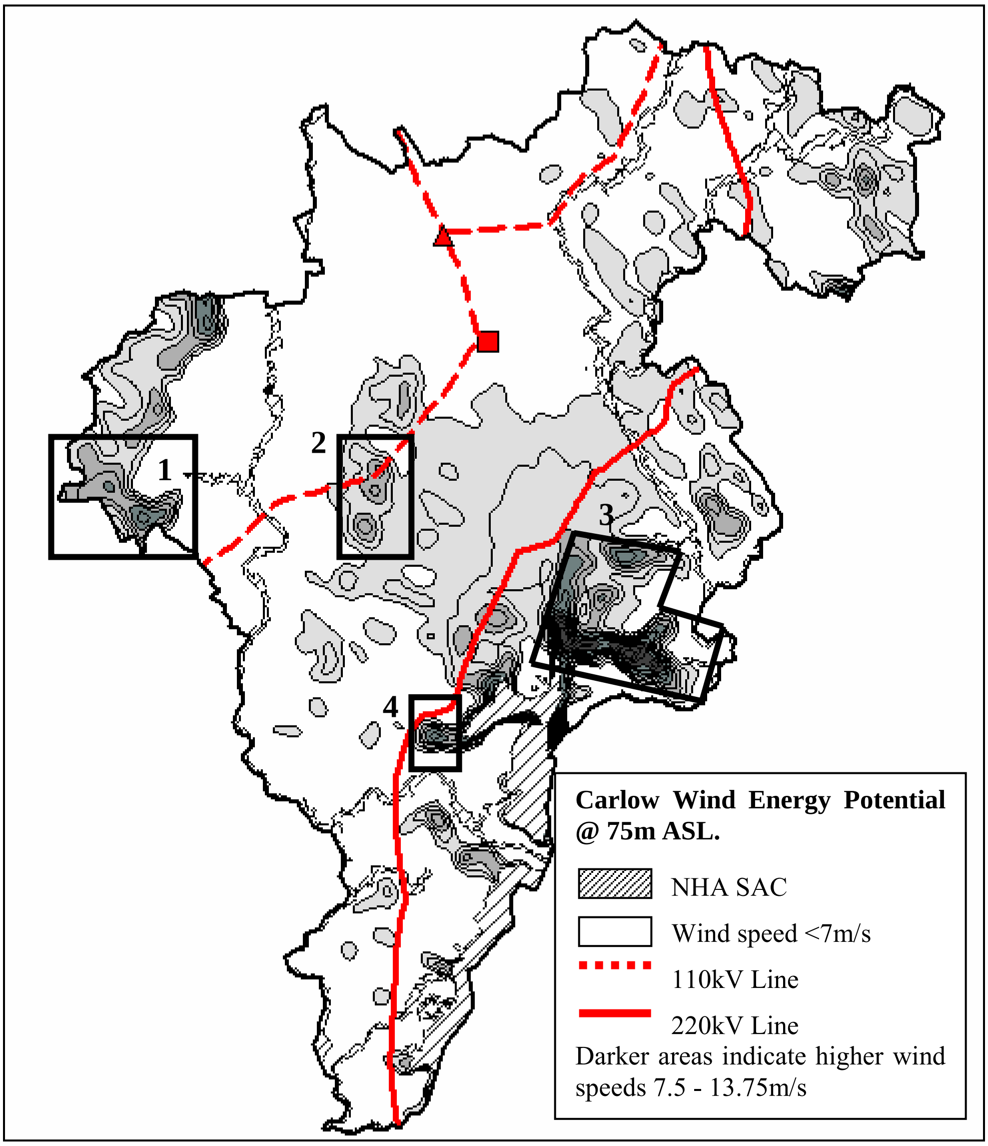
- limited to wind speeds of at least 8m/s at 75m ASL
- subject to a minimum size of 5 turbines within 2.5km of the grid
- subject to a minimum size of 10 turbines within 10km of the grid
- excluded from areas within 1kilometer of NHA or SAC boundaries

The accessible energy resource of the 4 areas with the best potential are detailed in the table below and highlighted in the map - Carlow Wind Energy Potential @ 75m ASL.

Area	Suitable area available (Sq. km)	No. of Turbines	Installed Capacity (MW)	Energy Output (MWH/Yr)
1	7	70	70	175,000
2	3.5	35	35	87,500
3	15	150	150	375,000
4	1.5	15	15	37,500
Total	27	270	270	675,000

Resource distribution

The map below illustrates the wind energy resources above 7m/s available in Co. Carlow. The best wind resource is based around the Castlecomer plateau and the Blackstairs Mountains. The centre of the county also offers some potential especially for small scale turbines.



2.6. Hydropower

Definition
Hydropower systems use the energy in flowing water to produce electricity or mechanical power.
Hydro schemes offer a continuous renewable energy supply and can respond rapidly to changes in load demand if required.

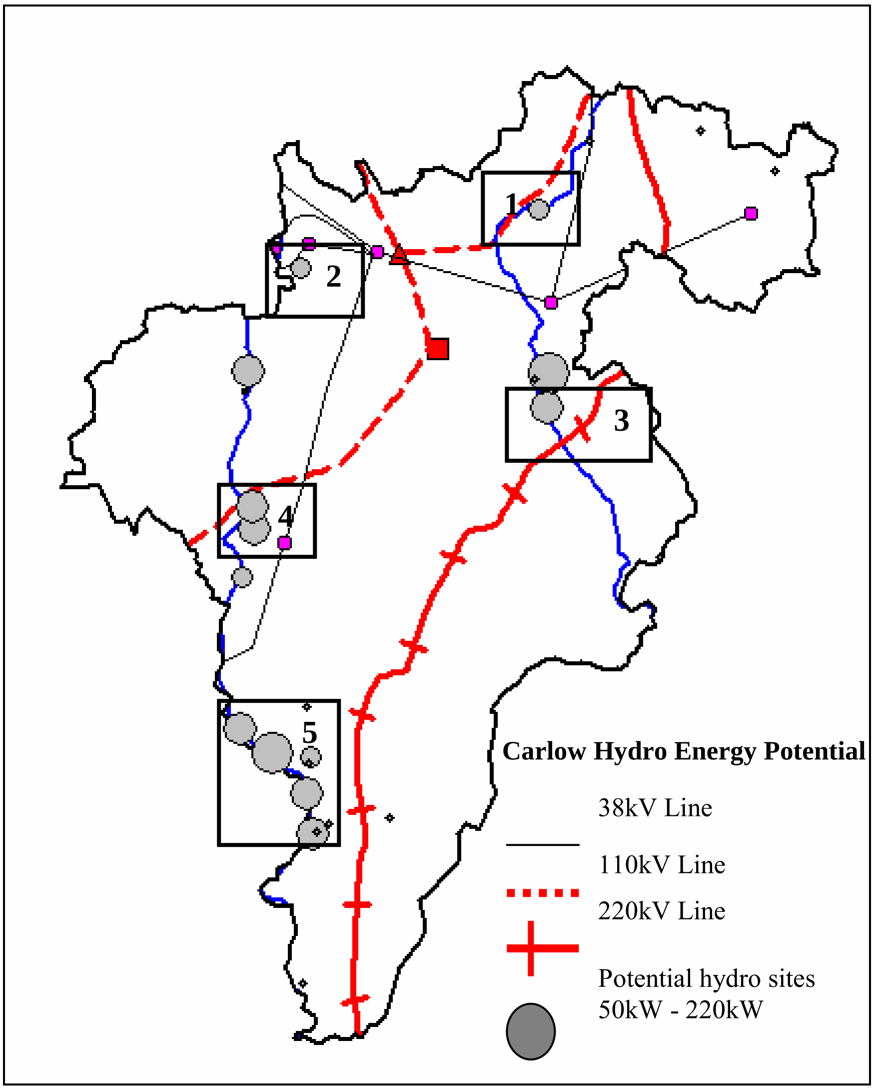
Considerations for development
A small scale hydroelectric facility requires that a sizable flow and height of fall of water is obtained without having to build elaborate facilities.
It is most economic to develop schemes where existing dams have been constructed for lake and river water-level control, and redevelopment of old mill water wheels.
Care must be taken to ensure that fish stocks are not impacted.

Total potential resource
A resource study carried out in 1997 (ESBI/ETSU, 1997) estimated the total feasible small scale hydro resource in the County. The list below represents potential hydroelectric sites in the County showing installed capacity and annual energy output.

River Name	Catchment	Easting	Northing	Potential Capacity (kW)	Annual Energy (MWH/yr)
Aughanaul	Barrow	272800	138300	23	103
Barrow	Barrow	270300	162000	101	340
Barrow	Barrow	269700	159500	97	669
Barrow	Barrow	269600	151600	135	943
Barrow	Barrow	273400	146100	122	872
Barrow'	Barrow	270000	170200	110	650
Barrow	Barrow	270200	163200	133	915
Barrow	Barrow	271300	150300	174	1209
Barrow Trib.	Barrow	274200	146700	37	168
Barrow Trib.	Barrow	273600	146200	40	183
Barrow	Barrow	273100	148200	126	899
Black	Barrow	273100	152800	28	164
Burren	Barrow	272700	175600	54	279
Dinin	Barrow	273300	150100	51	231
Dinin	Barrow	273200	149800	19	150
Pollmounty	Barrow	274200	127000	20	100
Un-named	Barrow	277400	147000	20	88
Dereen	Slaney	297500	180700	34	243
Dereen	Slaney	285700	170100	220	1475
Derry	Slaney	291500	160500	24	167
Douglas	Slaney	293600	182800	18	79
Slaney	Slaney	285200	178700	70	407
Slaney	Slaney	284900	169800	46	320
Slaney	Slaney	285600	168300	110	756
Slaney	Slaney	287800	182200	32	226
TOTAL				1,844	11,636

Resource distribution

The map below illustrates these sites and their proximity to the electricity grid. The majority of the sites are based along the Barrow and Slaney Rivers. The largest cluster of potential sites is located between Borris and Graiguenamnagh on the Kilkenny Border (Area 4 on map).



Accessible energy resource

To determine the accessible energy resource, sites with the following credentials have been included[4]:

- sites within 2.5km of the electricity grid
- sites with greater than 50kW installed capacity potential

There are six potential sites in the county which meet these criteria. These are marked on the map above and detailed in the table below:

[4] The majority of the sites are within an SAC or NHA. If the development of a site is prohibited in these areas, then the accessible energy resource is reduced to zero.

Area	River Name	Catchment	Easting	Northing	Potential Capacity (kW)	Annual Energy (MWH/yr)
1	Slaney	Slaney	285200	178700	70	407
2	Burren	Barrow	272700	175600	54	279
3	Slaney	Slaney	285600	168300	110	756
4	Barrow	Barrow	270300	162000	101	340
4	Barrow	Barrow	269700	159500	97	669
5	Barrow	Barrow	269600	151600	135	943
5	Barrow'	Barrow	271300	150300	174	1209
5	Dinin	Barrow	273300	150100	51	231
5	Barrow;	Barrow	273100	148200	126	899
5	Barrow	Barrow	273400	146100	122	872
	TOTAL				1,040	6,605

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