Contents

Devon Association for Renewable Energy **12a, The Square, North Tawton, Devon EX20 2EP**
Tel. 01837 89200 **Web. www.devondare.org** **E mail. admin@devondare.org**

Glossary

Term	Meaning
kW	Kilowatts – a measure of power
kWh	Kilowatt hour – power x time giving a measure of energy
KW_e	Kilowatts $_{(electricity)}$ – the same as kW above but with additional indication it relates to electrical output. Similarly kW_h means Kilowatts $_{(heat)}$
$KWh/kW_p/y$	Kilowatthours per kilowatts per year
PV	Photovoltaics
SHW	Solar Hot Water
dt	Dried tonnes
ha	Hectare (approx. 2.5 acres)
Peak Oil	The time when demand for oil exceeds the capacity of the oil industry to supply that demand and after which oil supplies start to go into permanent decline.
OSR	Oil Seed Rape – a plant whose seeds can be used as oil.
GJ	Giga Joule - a measure of energy 1GJ = 277.8 kWh
GVA	Gross Value Added – a measure of economic activity
PSG	Passive solar gain – passive systems incorporated into house design to absorb solar energy.
LCBP	Low Carbon Buildings Programme – the new grant-funding scheme for renewable energy projects.

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South Devon Renewable Energy Scoping Study

1. Summary

Energy, both in terms of how we use it and where it comes from, will be the single major issue to address in the 21st century. The two principal challenges converging on us are climate change and 'peak oil'. Climate change is now established as a scientific fact, the pace and nature of its onset surprising even climate scientists. The less-often heard term 'peak oil' refers to the point when we will no longer have an increasing supply of oil. It is not that we are running out of oil *per se,* rather that the age of cheap oil, and all that it has made possible, is rapidly drawing to a close. Thus, the pressure from two directions is to learn to live within the limits of a constricting supply, and to seek energy independence from an increasingly fragile supply system.

This study by the Devon Association for Renewable Energy (DARE) was commissioned by the Totnes Sustainability Group and funded by the South Devon AONB Sustainable Development Fund. It has sought to quantify the available renewable energy resources within South Devon, to identify the constraints and opportunities for their implementation, to provide policy makers with the information they need in order to be able to develop policies in this area, and specifically to look at the town of Totnes as a case study. The study focused on technologies that are already available or under development, and linked up landscape considerations to the various technologies, so as to enable a realistic identification of the most suitable ones.

Key Findings

- Were all the renewable energy options for South Devon to be harnessed, they would only have the potential to meet one-third of current demand.
- The authors argue that the remaining two thirds would need to either come from off-shore technologies (felt to be too expensive to be feasible) or from demand reduction through a radical programme of energy conservation.
- This conservation would best be achieved through a combination of domestic insulation and increased overall energy efficiency.
- The town of Totnes could, were it to maximise energy conservation, achieve 80% of its domestic energy needs through a diverse 'energy portfolio' of photovoltaics, solar hot water heating, microhydro, windpower, anaerobic digestion, energy from waste and heat pumps.
- Energy conservation emerges as the single most cost-effective method of meeting energy demand.
- Solar water heating emerges from this study as the most cost effective domestic renewable energy technology at this time.

Key Recommendations

- Energy conservation and renewable energy should be at the heart of all local authority policy making.
- All new buildings, domestic, commercial and public sector, should be built to the highest possible standards of energy efficiency, incorporating renewables as standard.
- Further research should be undertaken to identify practical and imaginative ways forward in terms of implementing the findings of this study.
- Certain technologies, such as micro wind and biomass CHP, should receive 'permitted development' rights under planning law to facilitate their rapid and widespread adoption. (at present ground sourced heat pumps, PV and solar hot water – except in special circumstances – do not require planning permission.)
- The training of installers of renewable technologies should be offered as part of a progressive programme of renewable energy adoption.
- The move to a lower-energy future should be seen as an opportunity rather than a challenge; making South Devon more self reliant and resilient in the face of world energy insecurity should be addressed with creativity and imagination.

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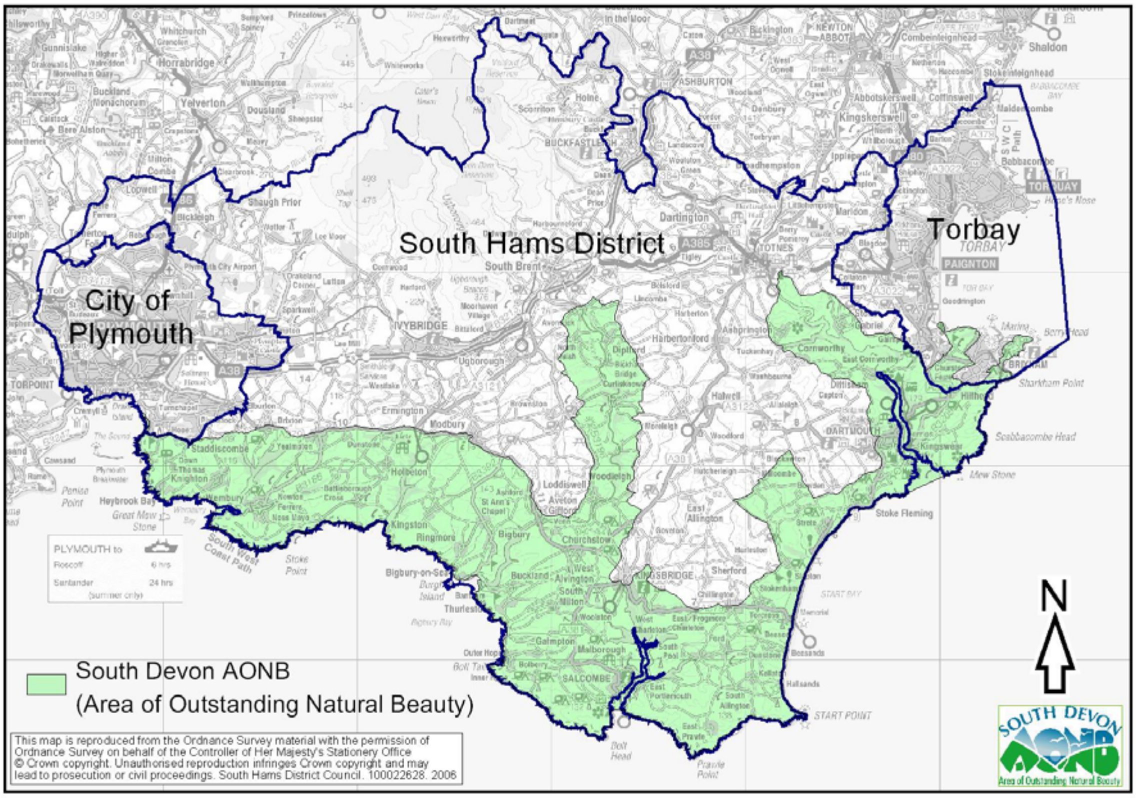
2. Scope of study

The study area is confined to the geographical area of South Hams District Council but excludes that portion within the Dartmoor National Park. The study area includes The South Devon Area of Outstanding Natural Beauty, which extends along the entire South Devon coastline and includes, on the western boundary, a strip of coastline within the Unitary Authority of Plymouth and to the east, Berry Head and Churston Ferrers both within Torbay Unitary Authority.

The area is characterised by a plateau of gently undulating farmland about 125 metres above sea level incised by five river catchments: the Dart, Avon, Erme, Yealm and Plym. All the rivers rise on the high ground of Dartmoor to the north and run southward to the coast. The 60 mile coastline has areas of high ground with steep cliffs, a number of excellent beaches and several significant headlands with rock outcrops.

The primary economic activity in the area is farming and tourism, although marine sector industries are increasingly important. Farming practice is characterised by a large number of smaller holdings with sheep and dairy predominating and with some arable. Tourism is represented by a number of hotels, holiday cottages, bed & breakfast accommodation and touring campsites. The marine sector is particularly strong in Totnes, Dartmouth and Salcombe.



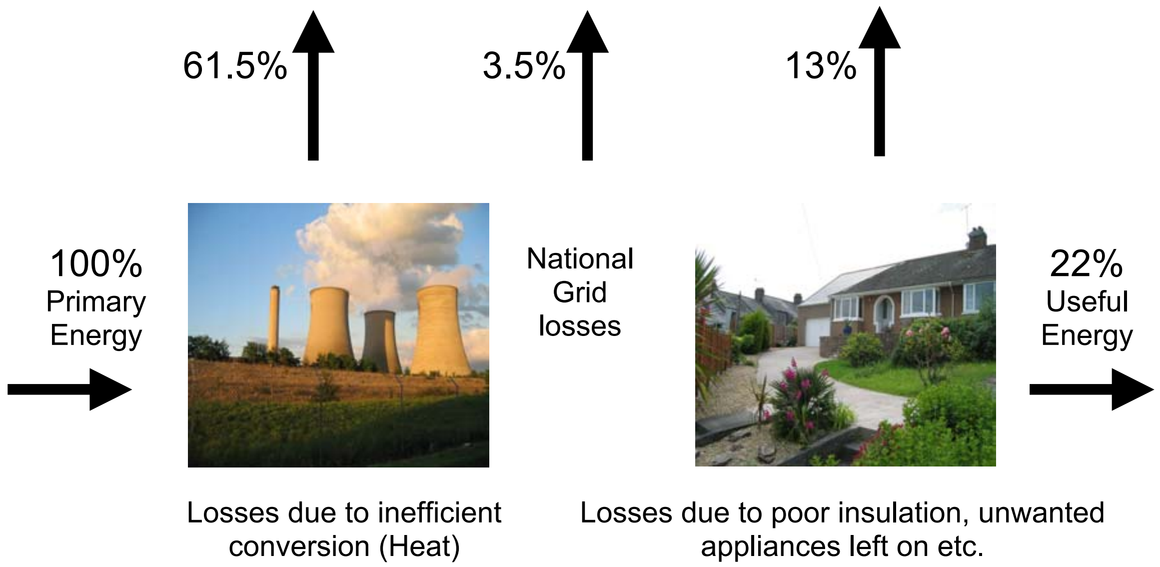
Road communications are served by the A38 Devon Expressway, running between Plymouth and Exeter, and the A379 running east-west. There are a number of north south links and numerous smaller roads. The Plymouth–Paddington railway runs through the area with a main station at Totnes. Exeter has a regional airport with some international connections and Plymouth a local airport with internal connections to London and the North.

The main settlements are Totnes, Ivybridge, Dartmouth and Kingsbridge. There are scores of smaller settlements and hundreds of individual isolated dwellings and farms. Having an attractive coastline and being close to the Dartmoor National Park, a significant proportion of dwellings are second homes; in some settlements such as Salcombe about 50% of homes are holiday homes.

All the larger settlements have associated light industrial and small business estates. There is no heavy industry although the Ministry of Defence has a large establishment at Britannia Royal Naval College, Dartmouth. Apart from a small number of very small energy generation systems, most of the energy used in South Devon is imported by way of the National Electricity Grid. The National Gas grid only serves the main population centres (see appendix 3). The majority of the rural parts of the area rely upon grid electricity, oil and liquid petroleum gas (LPG).

3. Background
3.1 Environmental context

There is clear evidence that the global climate is changing - temperatures are rising and with them sea levels. The relationship between the temperature of the atmosphere and the level of carbon dioxide (CO_2) has been scientifically proven since 1894. [1][2] Since the Industrial Revolution most of our energy needs have been met by burning carbon based primary fuels in centralised power stations, but the process of converting primary fuels into electricity not only releases large quantities of CO_2 [3], the process of combustion is inherently inefficient as illustrated below.



Source – Green Peace Decentralised power [4]

More than 75% of the energy embodied in the primary fuel is lost (eg not put to useful purpose) one way or another. The biggest single loss is due to the inefficient conversion of energy at the power station, where, unless there is a nearby demand, most of the heat is vented to atmosphere through large cooling towers. Although a number of other gases contribute to climate change, it is CO_2 emissions that cause the greatest concern. The aim is to reduce CO_2 emissions as soon as possible.

3.2 Local Economic and Community Context

The GVA (Gross Value Added) index[5] of the South Hams economy is 84.2% of the UK national GVA index. This compares with a GVA of 77.9% for Devon as a whole. In 1993 South Devon's GVA was 69.0% implying that the South Devon economy has much improved in the last ten years but is still lower than the UK average, so if energy shortages come about South Devon will need

1 – Prof. Svante Arrenhuis, Swedish Nobel Prize winner 1894, first described the CO_2 greenhouse gas effect.
2 – Source – www.bbc.co.uk/ 13.03.06 - CO_2 concentration passed through 380ppm – highest since 100 million years ago.
3 - Source – www.defra.gov.uk/emissions grid electricity CO_2 emission for present primary fuel mix = 0.43kg/kWh
4 – Source – www.greenpeace.org.uk/DecentralisingPower
5 – Source - www.devon.gov.uk/dris/ - state of the Devon economy 2003 Gross value added is an indicator of economic activity
6 – Source – www.devon.gov.uk/dris/ Annual survey of hours and Earnings (ASHE) 2005

to work harder to maintain its position. The Median Gross annual pay for the South Hams is £23,154[6] compared with £20,261[6] for Devon as a whole and £22,901[6] for the UK. This is reflection of the fact that Devon as a whole has a higher than average percentage of people over pension age and this also applies to South Devon. South Devon multiple deprivation indices[7] show a wide range, Totnes ward being 1832/8414 and Ivybridge Ward being 6472/8414.

Devon has a higher than average skills level, South Devon having the highest percentage in Devon of people qualified with NVQ level 4 and above. Against this South Devon has the lowest level of trade apprenticeships[5]. South Devon can be characterised at as an area of contrasts: areas of wealth with higher than average salaries and areas with deprivation. Child poverty and health indicators follow the same pattern as the multiple deprivation indices.

3.3 Local Energy demand and supply

The 2001 census states that South Devon has 34,831 households[8]. It is beyond the scope of this study to visit every household and business to enquire as to their individual energy use so we reply upon National average energy consumption statistics.

Annual domestic energy consumption by end use for an average 3 bed semi-detached house[9]

All energy use	80.8 GJ	x 277.8	22,446 kWh
Space heating	50.0 GJ	x 277.8	13,890 kWh
(1 GJ = 277.8 kWh)			
34,831 households		x 22,446	781,345,260 kWh
			781.3 GWH

UK energy consumption statistics are divided into four categories[10]: Industry, Domestic, Transport and Services (includes agriculture). The Dti Digest of UK Energy Statistics states that the distribution of energy use by sector is: Industry 21%, Domestic 30%, Transport 36%, Services 13%.

Sector	%	GWH
Industry	21	546.9
Domestic	30	781.3
Transport	36	937.6
Services	13	338.6
total	100	**2604.4**

If the South Devon domestic energy consumption is 781.3 GWH and this represents 30% of the overall consumption, then South Devon's total energy consumption is **2604.4 GWH**. This method of estimating the total energy consumption is subject to some errors so the results should be regarded as indicative rather than definitive. However, for the purposes of this study the methodology gives a reasonable estimate of the target to be aimed at.

4. Policy Context

It is not proposed to examine the various policy documents in detail, but rather to give a brief overview and references where the reader can find out more if needed.

7 – Source – www.devon.gov.uk/dris/commstat/dv_mdip.html low number most deprived - high number least deprived
8 – Source – www.devon.gov.uk/dris/census/
9 – Source – Domestic Energy fact File 2003 http://projects.bre.co.uk/factfile/BR457prtnew.pdf
10 – Source – Dti UK Energy in Brief July 2005 www.dti.gov.uk/energy/inform/dukes/index.shtml

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4.1 National

UK - Energy White Paper

In 2003 the UK government issued its Energy White Paper setting out its objectives

- To reduce CO_2 emissions by around 60% by 2050
- To maintain security of energy supplies
- To sustain industrial and business competitiveness
- To ensure that every home is adequately and affordably heated.

For further information go to http://www.dti.gov.uk/energy/

4.2 Regional

Regional, County and Local Policies

The South West renewable energy policy can be found at

www.regensw.co.uk/sw/strategy.asp

www.southwest-ra.gov.uk/swra/ourwork/energy_index.shtml

or by putting the words "**South West Renewable Energy Strategy"** into an internet search engine.

The Devon County renewable energy policy and action plan can be found at

www.devon.gov.uk/index/business/regeneration/renewable_energy.htm

or by putting the words "**Devon Renewable Energy Strategy"** into an internet search engine.

The **Devon Strategic Partnership (Renewable Energy Task Group report)** can be found at www.devonsp.org.uk/partnership/energy.html

The Revision 2010 Renewable Energy targets can be found at

www.oursouthwest.com/revision2010/1-

4.3 South Devon

South Hams District Council's (SHDC) sustainable development policy can be found at (11)

www.southdevon.gov.uk/

SHDC's core policies include:

- CS12 Climate Change Policy - climate change strategy due for completion in autumn 2006. The SPD on Sustainable Development (due 2007) will contain a section renewable energy.
- CP1 Affordable Housing – with links to fuel poverty and affordable warmth
- CP2 Economic Development and Prosperity Strategy – which at present makes no mention of energy use and the potential for renewable energy at all.

4.4 South Devon AONB

The designation, Area of Outstanding Natural Beauty (AONB), was created to conserve and enhance the natural beauty of Britain's finest landscapes. South Devon received its designation in 1960. The area is administered by a management partnership through a mechanism of Policies and Action Plans. The relevant policies are:

Policies for Planning and Development - Policy P/PD5:

"To adopt a supportive approach to the development of sensitively sited, small scale or innovative renewable energy projects, having regard for their appropriateness in an AONB location, the need for environmental impact assessments, the benefits to the community and emerging energy policy".

11 – Source – www.southdevon.gov.uk/

12 – Source – South Devon Area of Outstanding Natural Beauty, Management Plan 2004 – 2009

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This is accompanied by a corresponding action, Action A/PD4:

<table>
<tr><td>Project A/PD4a</td><td colspan="2">Investigate and adopt an agreed position on renewable energy developments, and work through the Devon Renewable Energy Partnership to support any technologies that may be appropriate to the AONB, especially where these bring benefits to local communities and the landscape.</td><td rowspan="6">Cross reference to Policies

P/PD5</td></tr>
<tr><td>Lead</td><td>1. AONB Staff Unit
2. Devon Renewable Energy Partnership</td><td rowspan="5">Project target
1. Publish a South Devon AONB Partnership position statement on renewable energy.
2. Work with Devon Renewable Energy Partnership to identify appropriate opportunities for renewable energy for the AONB</td></tr>
<tr><td>Partners</td><td>National Association of AONB's, local Planning authorities, other stakeholders</td></tr>
<tr><td>Costs</td><td>Staff costs</td></tr>
<tr><td>Funding</td><td>Staff costs already covered</td></tr>
<tr><td>Timescale</td><td>By 2006</td></tr>
</table>

Other policies include:
Policy for rural economy and regeneration
P/ER2 "To support sustainable rural and farm diversification initiatives, where these maintain or enhance the distinctive character of the area and contribute to employment and prosperity"
P/ER3 "To support the establishment of 'clean' technologies which create prosperity and employment with minimum impact on the local environment"

The purpose of this study is to further the actions identified in the South Devon AONB Partnership Management Plan, namely to

- Support community engagement in physical, cultural and natural heritage of the AONB
- Inform on appropriate use of landscape assets
- Strengthen community resources
- Deliver environmental schemes
- Help with economic regeneration

5. Methodology

The original terms of reference for the scoping study were to simply identify which renewable energy technologies are available in South Devon and quantify the available resource. It would be a relatively straightforward matter to consider each technology in turn, identify the physical constraints for that technology then multiply up to get an indicative output figure. The summation of all the technologies would offer an overall indicative output figure for the geographical area under consideration. But in isolation, such a number is of little value.

Some technologies are more cost effective than others. Political acceptability varies and some offer more consistent output than others, so consideration needs to be given to the objectives of the study. If the purpose of the study is to help inform a strategy to reduce carbon emissions then emphasis will need to be directed at those technologies where maximum energy output can be achieved with minimum carbon emission. If the purpose is to develop a strategy to allow South Devon to become self-sufficient in energy, without regard to the economics, then there will be a need to maximise the overall output. If economics is a consideration (and it is likely it will be) then the value of energy reduction will also need to be taken account of. If the study attempts to address too many objectives there is a risk competing objectives will produce a confused outcome.

This study therefore ignores political issues - it is recognised that public opinion is divided over large-scale wind turbines, yet they are the one mature technology that can deliver large amounts of cost effective carbon free energy. The study ignores economic factors - an indicative cost, at today's prices (2006), is offered for each technology to allow the reader to gain some idea of costs. But costs can change, research and development can bring costs down and the costs of conventional energy can go up, therefore economic considerations can change over time. Output figures are offered regardless of the cost.

This study therefore adopts a hybrid approach:
Each technology is considered in turn, a brief non-technical description is offered together with a description of the requirements. A similar format is adopted for each. A calculation is undertaken for each technology to offer an indicative output figure; in each case the assumptions used are described. In some cases obtaining robust evidence to validate the assumptions has been difficult. Where confidence is low this is highlighted. Where outputs figures rely on data within a range, the lower end of the range is assumed to increase confidence, again this is highlighted in the text. Where more than one technology competes for the same space (e.g. where different energy crops could be grown) each is considered on a like basis and a conclusion is drawn.

The starting point was to calculate the existing energy demand (shown at 3.3 above). In a study at this level it is not possible to visit every property to take meter readings of energy used. Use was made of national statistics (Dti Digest of UK Energy Statistics and the Domestic Energy Factfile) and Local Authority statistics for numbers of properties and population. The resultant figure for consumption gives a first order approximation with a reasonable degree of confidence in its accuracy.

At the end of the technology section a table is presented showing the potential levels of output for each technology and the cumulative total.

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6. Technologies

Each technology is treated similarly by offering a non-technical description of the technology, installation requirements, landscape impact, environmental impact, planning permission, indicative installation costs and expected pay back times. Consideration is given to the available resource; assumptions and constraints are discussed to arrive at a figure for the potential energy output.

6.1 Photovoltaics

Photovoltaic cells are made of very pure silicon cut into thin wafers that produce a small current of electricity when sunlight falls on the cell. A large number of cells are connected together to produce a usable current. There are three types of cell

Amorphous silicon cells convert between 8–12% of ambient daylight into electricity but rely on diffuse light so are shadow tolerant.

Polycrystalline cells convert between 12–18%

Monocrystalline cells convert between 18–25% efficient but are not shade tolerant.

Monocrystalline cells cost about twice as much as amorphous cells.

Installation requirements	Mono and Polycrystalline PV cells need to be exposed to direct sunlight. Shadows cast by clouds, trees or buildings falling across the cells can significantly reduce their output so should be avoided. Ideally cells should be installed facing due south, inclined at an angle of about 40^o to the horizontal; any departure from this angle will reduce the output. (See Solar Sundial in Appendix 2)
Landscape impact	PV cells are normally installed lying flush with the roof surface or façade of the building and have no moving parts. The natural colour of silicon is a blue/grey although it is possible to get a range of colours to match the building fabric. If the roof orientation is not suitable, cells can be installed on a separate frame at ground level provided no shadows fall across the cells.
Environmental impact	Silicon (sand) is abundant in the Earth's crust so there is no significant issue with resource depletion. However a lot of energy is needed to purify the silicon to the high standard needed. PV cells therefore have a lot of embodied energy and it will take about 2 years of use for the cells to repay the energy used in manufacture. Some exotic chemicals are used during the course of fabrication but the industry is sufficiently well regulated to avoid issues around these.
Planning permission	If installed flush with the building or roof structure, planning permission may not be necessary and installation may be regarded as 'permitted development'. However planning permission will be required if • The building is listed • Located in a Conservation Area, National Park or Area of Outstanding Natural Beauty.
Scale	PV panels come in a range of sizes so are modular. Multiple numbers may be installed, limited only by the area available and the cost of the installation.
Installation costs	Approximately £6,000 per kW_p installed. (The PV industry recognises that costs are a serious barrier to uptake

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	and new production facilities are being built. The aim is to reduce costs to 1€/watt within 5 years.) It requires about $6m^2$ of monocrystalline PV to produce $1kW_p$ in good sunlight. It requires about $12m^2$ of amorphous silicon to produce $1kW_p$ in average daylight.
Pay-back period	In UK latitudes 1 kW_p of PV will produce about 750 kWh/y. The value of the energy captured will depend on how it is used. If used on site to displace grid electricity it may be valued at the retail price the consumer otherwise pays, which may be 12p/kWhy or more depending on tariff. In this case the value will be about £90. If sold to grid the value will depend on the negotiated rate with an energy supply company. This could be as low as 4.5p/kWh. Pay-back times will vary but are likely to be long.

PV will only supply energy during daylight hours, which is out of sync with domestic needs but is in line with commercial and industrial needs.

In many ways PV appears to be the ideal renewable energy technology. Cells can be manufactured in a wide range of styles and colours and can simulate the appearance of roofing tiles. If integrated into the roof they can all but disappear. They sit there silently collecting sunlight and converting it into electricity. Technically every roof of every building could be covered with PV but this unrealistic because: 1) at present day prices the cost will be prohibitive and 2) Solar Hot Water (considered at 8.2) competes for the same roof space.

Calculating a potential power output for PV involves making a number of assumptions – which PV will be used, Mono or Polycrystalline or Amorphous? Mono and Poly are more efficient but are not shade tolerant. Amorphous is shade tolerant but only half as efficient. Can the cells be orientated to the best angle? (See the Solar Sundial at Appendix 2 to show how less favourable orientation reduces power output.)

Available Resource

Assumptions:

1. Monocrystalline PV will be used (1 $kW_p = 6m^2$)
2. 1 kW_p will produce 750 kWh/y[(13)]
3. The cells are orientated between South East through South to South West at an angle of 35^0 (standard roof pitch) to the horizontal. This implies >96% of the maximum available solar energy will be collected, i.e. for all practical purposes 100%.
4. Number of dwellings 34,831 of which half will have roof area orientated between South West and South East (= 17,415).
5. Available roof area - assumes average roof area of 9m x 7m = $63m^2$. Assumes a normal straight ridge roof with half facing one way and half the other. 63 ÷ 2 = $31m^2$ less $4m^2$ for solar hot water leaves $27m^2$ available for PV. 17,415 x 27 = 470,205 m^2
6. Installed capacity @ $6m^2$/kW = 470,205 ÷ 6 = 78,368 kW_p
7. Annual energy capture @ 750 kWh/kW_p/y = 58,775,625 kWh/y = **58,776 MWH/y**
   This figure is for dwellings only.

Installation costs at 2006 prices (costs are mentioned here for completeness but cost has not been used as a factor to determine the amount of installed capacity): 78,368 kW_p x £6000/kW_p = £470,220,000. This is expensive and highlights the cost barrier of PV at the time of report unless support is available from grants. If the industry can get costs down to their target figure of 1€/w (≈ £660/kW_p) in five years then the costs of 78,368 kW_p will come down to £51,724,200.

13 – Source – www.pv-uk.org British Photovoltaics association.

The output from PV is directly related to the area of collector. The constraint on PV is therefore the amount of available space upon which to mount PV panels. Once all suitable roofs are saturated with PV it will be difficult to add more unless purpose built arrays are constructed. (e.g. installing PV canopies over car parks)
The roofs of all commercial/business premises, such as village halls, hospitals, leisure centres could be included to increase the amount of PV installed.

Note. Referring to the solar sundial (see appendix 2) roofs facing due east or due west at a pitch of 35^0 receive 86% of the available solar radiation. If this is deemed economically viable, PV could be installed on all roofs facing between west through south to east. But due to cost of PV it is thought only the higher solar insolation values are worth harnessing.

6.2 Solar Hot Water (SHW)

SHW collectors are either 'flat plate' (as shown to the left) or 'evacuated tubes'. Flat plate collectors consist of a black surface with water pipes enclosed within an insulated glazed box. They are 'low tech', relatively cheap, can be home made and have an efficiency of about 50–60%. Evacuated tube collectors comprise a series of twin walled glass tubes enclosing a black collector tube. The glass tubes have a vacuum so as to reduce heat losses. They can reach efficiencies of 90% but are 'high tech' and cannot be home made.
The hot water collected is transferred to the domestic hot water system by an additional coil in the hot water tank.

Installation requirements	Solar hot water collectors need to be exposed to direct sunlight. Ideally collectors should be installed facing due south inclined at an angle of about 40^o to the horizontal; any departure from this angle will reduce the output. (See Solar Sundial in Appendix 2)
Landscape impact	Solar hot water collectors are normally installed lying flush with the roof surface or façade of the building and have no moving parts. If the roof orientation is not suitable, collectors can be installed on a separate frame at ground level.
Environmental impact	Construction materials may include glass, copper, aluminium, stainless steel, plastic. The heat transfer fluid may well contain anti-freeze.
Planning permission	If installed flush with the building or roof structure, planning permission may not be necessary and installation may be regarded as 'permitted development'. However planning permission will be required if • The building is listed or is • Located in a Conservation Area, National Park or Area of Outstanding Natural Beauty.
Scale	SHW are factory fabricated so will be available in a range of fixed sizes. However being modular, multiple numbers could be installed. The limiting factor will be the space available and the energy demand. (There is no point in installing a larger than needed SHW collector.)
Installation costs	Costs vary considerably. One installer is known to charge over £7,000 for an evacuated tube system. Another installer charges under £3,000 for a flat plate system. It is possible to purchase the

	components for a DIY installation for under £1,000. CAUTION: SHW could become the new 'double glazing'; always get several quotes from an accredited installer. A guideline price is between £3,000 - £4,000.
Pay-back period	In South Devon solar insolation is between 900–1300kWh/m^2/y. Solar insolation varies by a factor of 10 between mid-winter and mid-summer (see Solar Insolation chart in Appendix 1). A system optimised for winter use will provide too much heat in the summer, a system optimised for summer use will not provide enough heat in the winter. Generally the most economic size is suitable for spring and autumn and will offer about 70% of the annual hot water need. A 3m^2 system will be suitable for a 2-person household and will capture between 1800–3000 kWh/y (average 2400 kWh/y) depending upon system type. Pay-back periods will depend on system type, who installed it and what your existing hot water heating is. If you currently use an electric immersion heater, pay-back could be just a few years. If you currently use a wood fuel boiler and harvest your own logs pay-back may be longer. Generally it is true to say SHW is the most cost effective of all renewable energy technologies and therefore should be the first RE option to consider.

Solar hot water is already establishing itself as a good investment and increasing numbers of installations can be seen. The choice is between flat plate and evacuated tube collectors. Flat plate collectors are cheaper but less efficient so a larger collector area is needed. Evacuated tubes can collect energy even on overcast days and suffer fewer losses but are more expensive. Both types of SHW collector are significantly more efficient than PV and much cheaper. Using SHW to replace electric water heating is very good value.

Available Resource

Assumptions:

1. A 3m^2 evacuated tube collector will be used. Whilst more expensive they have fewer losses and work in overcast weather. Typically an evacuated tube collector is about 90% efficient.
2. SHW will take priority on the roof space because: a) SHW is more efficient so will collect more energy per unit area and is a cheaper technology and b) plumbing runs are more difficult to install and to minimise losses the panel needs to be as close as possible to the hot water tank (PV can be installed around the SHW more easily.)
3. Even an East-West facing roof can collect 84% of the available heat energy (see Solar Sundial – Appendix 2), so most dwellings will have access to a roof pitch or vertical surface that could accommodate a viable SHW heater. Although a SHW panel orientated between South East through South to South West at an angle of 35^0 (standard roof pitch) to the horizontal, will, for all practical purposes, work close to its maximum efficiency.
4. Number of dwellings = 34,810. Dwellings located in Conservation Areas may be subject to restrictions. But it is assumed that the majority of dwellings will be able to find space somewhere to install a panel.

Calculations: Average Solar Insolation = 940 kWh/y per m^2 (see Appendix 1). 3m^2 = 2,820 kWh/y x 90% = 2,500 kWh/y x (say) 34,831 dwellings = 87,077,500 kWh/y = **(87,078 MWH/y)**

These figures are for dwellings only. All industrial and commercial premises could use SHW as could all the touring campsites and holiday parks.

The output from SHW is directly proportional to the area of collector. The constraint is therefore the area of collector that can be accommodated, but unlike electricity in PV above, hot water is more difficult to move from place to place. The practical constraint is therefore the size of the hot water storage tank and the demand on it.

There are 29 touring campsites in South Devon and these offer a particularly attractive opportunity because the demand for hot water coincides with the summer sun. Campsites are likely to have heavy demand in the morning and again in the evening for showering. To cope with this peak demand, shower facilities will need to be fitted with larger hot water tanks. To offer a figure for the potential output from campsites will need each site to be surveyed to consider to size of system needed. This is beyond the scope of this study.

6.3 Hydropower

Hydropower is the capture of the energy in flowing water. Here we consider micro-hydro – the capture of energy from rainwater runoff flowing in rivers, tidal lagoons – the capture of energy by the release of water impounded at high tide, marine current turbines – the capture of energy from the tidal streams in the open sea and wave power – the capture of energy from the movement of water on the surface of the open sea.
Under EU rules, energy generated from offshore resources such as wave and tidal current cannot count towards local RE targets.

6.3.1 Micro-hydro

Hydropower output is the product of 'head' (the vertical distance through which the water falls, measured in metres) and the 'flow' (the volume of water flowing through the turbine, measured in cubic metres of water per second):

Power (kW) = 5 x Head (m) x Flow (m^3/s)

At a given point on a river there will be an area of catchment above it where rainwater runoff is collected. Some of the water will be taken up by plants, trees etc. so will evaporate again. The flow available for hydropower will be the net flow less a residual flow that must be left in the main river to ensure the health of aquatic life. Fish protection screens will be needed both above and below the turbine.

Installation requirements	An adequate head and flow.The head is determined by the topography of the surrounding land; the flow is a function of the size of the rainwater catchment less any abstractions for public drinking water supply or industrial or agricultural use. Where the gradient of the river is very shallow, the head can be increased by diverting a percentage of the river flow along a leat following a contour. As the river continues to fall a head is built up. The turbine (waterwheel) is located where the water flow is allowed to fall back to river level. If the installation is large enough to grid connect, a nearby connection is needed.
Landscape impact	In the case of micro-hydro there is no need to construct large dams across rivers. A small weir may be necessary to capture part of the flow to direct it into the leat. Generally weirs, leats, turbine houses are all small scale and can be integrated into the landscape. Landscape impact is therefore minimal.
Environmental impact	Micro-hydro does have an environmental impact but those impacts can be mitigated;

	Weirs – can incorporate a fish pass to allow migratory fish to get up river. Leats – can become a habitat in their own right. Penstocks – can be buried. Turbines – can be fitted with screens to prevent fish getting into the turbine and some turbines can aerate the water thus improving oxygen levels. A well-designed leat can become a bio-diverse environment in its own right and can help to alleviate flood risks.
Planning permission	Planning permission will be required. Planners may require an Environmental Impact Assessment and a Flood Risk Assessment. It will be necessary to apply for an Abstraction Licence and Land Drainage Consent from the Environment Agency. (see useful contacts in Appendix 6)
Scale	Scale will be site specific and match the available resource.
Installation costs	Costs vary considerably and are site specific. Abstraction Licence and grid connection costs are similar irrespective of size of scheme so smaller sites suffer disproportionately. e.g.A 90kW site on Dartmoor cost £80,000(1997) (less than £1,000/kW) A 3kW site on Dartmoor has been quoted £40,000 (more than £13,000/kW)
Pay-back period	Because development costs vary so widely pay-back periods can also vary. The 90kW site mentioned above paid back in just over 4 years. The 3kW site has not been developed at the time of report (February 2006). Because of the costs of grid connection it may never be economic to grid connect the smaller site. But any energy produced can still have a value ascribed to it because it will displace mains electricity that would otherwise have to be paid for. Smaller schemes should not be discouraged if a use can be found for the energy on site.

It has not been possible to visit all the old mill sites within the area of study (Rattery Mill has been used as a case study - see Appendix 4). Existing research is available in the form of the Salford Study.

The Salford Study

In the mid 1980's, the then Department of Energy commissioned Salford Civil Engineering Ltd., a trading arm of Salford University, to carry out a resource assessment for micro-hydro across the UK. The results were made public in a document entitled 'Small-scale hydro-electric generation potential in the UK'. The document was published by the Energy Technical Support Unit (ETSU) as report ETSU SSH 4063, Parts 1,2 & 3 (no longer in print).
Part 1 describes the methodology used, Part 2 is a list of all sites identified as having a potential with an installed capacity of 25 kW or greater (at the time of the report 25kW was deemed to be the smallest size of hydro that would be economic to develop). Part 3 lists the rejected sites (i.e. those under 25kW). As part of the South Devon Study, ETSU parts 2 and 3 have been researched and the following sites identified.

ETSU Part 2
This table lists the sites considered suitable for development with the projected power output.

ETSU No.	River	Site	Head (metres)	Installed capacity KW	Annual Energy capture MWH
046004	Dart	Staverton Mills	2.5	68	441
046005	Dart	Town Mills	2.4	90	430
046006	Dart	Swallowfields Weir	2.9	196	887
046007	Avon	Diptford Manor	3.2	43	221
046008	Erme	Ivybridge Aqueduct	6.8	54	280
046009	Avon	Lydia Bridge	6	49	247
046010	Erme	Stowford Mill	20	110	666
047004	Plym	Cann Woods Weir	9	136	712
		Totals		**746**	**3884**

ETSU Part 3
This table lists the sites considered but rejected by the Salford study and the reason.

River	Site	Reason for rejection
Erme	Sequers Bridge	No potential
Erme	Yealmpton	No potential
Erme	Ermington Mills	May be suitable for small scheme
Erme	Harford moor	Access difficult
Erme	Harford Manor	Access difficult
Harbourne	Bow Mill	May be suitable for small scheme
Harbourne	Beenleigh manor	Operational
Harbourne	Crowdy Mill	Operational
Harbourne	Old Mill	May be suitable for small scheme
Harbourne	Harbertonford	May be suitable for small scheme
Avon	Curtisknowle	Prior use
Garra	Garra Mill	Power under 50 kW
Avon	Aveton Giffard	No potential
Avon (trib.)	Knap Mill	Power under 25 kW
Avon	Loddiswell Mill	May be suitable for small scheme
Yealm	Lee Mill	Power under 25 kW
Dart (trib.)	Stoke Gabriel	No potential

Because the power output is site specific it has not been possible, within the scope of this study, to visit each site and calculate the site flow data for each location. However it would appear there could be merit in a further study of micro-hydro power at a number of sites in South Devon.

Available Resource
Assumptions:

1. The ETSU report includes all the larger sites within the South Devon area.
2. There will a number of smaller mill sites, such as Rattery Mill, where power could be generated. Experience shows that many old mill sites have fallen into disrepair, many have lost their water supply and those that do still operate rarely produce more than 10 kW. It is unlikely that old mill sites will make a significant contribution to South Devon's total energy demand, however old mill sites may be able to produce power for on site use.
3. The ETSU report figure of **3884 MWH/y** is taken as the output for micro-hydro.

The energy output from micro-hydro is the product of head and flow so the constraint relates to the gross volume of water available, which in turn is dependent upon the area of catchment and the level of rainfall and evaporation within the catchment. The other factor is the head available at a site and this relates to the topography of the land. There may be a number of old watermill sites within South Devon that could be restored but rainfall levels across South Devon are lower than on Dartmoor and catchment areas smaller so the cumulative totals from old watermill sites is unlikely to contribute much more than the figure above.

This is highly speculative, but there may be some long-term additional micro-hydro potential if, as a consequence of climate change, we need to construct additional reservoirs to retain excess winter rains to supply summer time water needs. No assumptions and therefore no allowance have been made for long-term changes of this nature.

6.3.2 Tidal Lagoons

The River Dart below Totnes.

Many years ago the riverbank was canalised in order to create a narrow but deep stream suitable for boats to navigate up to Totnes. Recently the bank has breached and with each high tide water is inundating the reed beds to the side of the main river channel. There is concern that unless the breach is regulated the entire length of riverbank will fail and river channel may silt up. However the flow in and out of the reed bed could offer an opportunity to generate power.

Installation requirements	To ensure the entire riverbank is stabilised, the breach needs to be filled in. However, a sluice could be incorporated in the new wall to allow the continued inward and outward flow of water. A turbine could be installed in the sluice to generate power form the water flow.
Landscape impact	The structure to close the breach will essentially be a wall in line with the existing riverbank. At some state of the tides this will be more visible than others. However, it will be a matter for Planning to ensure the structure is as unobtrusive as possible. Marine growth will soon cause the structure to blend in.
Environmental impact	Construction materials may include concrete, steel, and plastic.
Planning permission	Almost certainly required. Likewise an Abstraction Licence and Land Drainage Consent. Where navigable waters are concerned the local Navigation Authority as well
Scale	Scale will be site specific and match the available resource.
Installation costs	Very difficult to estimate as this type of construction is unusual with no recent examples to draw on for comparison.
Pay-back period	Again very site specific so difficult to assess.

Close scrutiny of Ordnance Survey maps suggests there may have been several old tidal mill sites in South Devon. However none still operate and all would only generate small amounts of power. The only site currently under investigation in South Devon is on the River Dart at Sharpham. At this location the riverbank has collapsed and there is a risk that silt may compromise the navigable channel to Totnes. Whilst repairs to the riverbank are necessary, consideration is being given to install a turbine to exploit the flow. Tidal lagoons are a specialist field and a Hydro engineering company has been employed to assess the potential energy capture at the site. Early indications show that it may be possible to install a 64 kW turbine that could produce up to 64,000 kWh of energy per annum. **(64 MWH)**

<u>Available Resource</u>
It is believed the lagoon at Sharpham is the only site under investigation in South Devon.
So **64 MWH** is taken as the available resource. No costings are available for this development.

The constraint for tidal lagoons is the availability of possible sites and the volume of water a lagoon may hold. A review of Ordnance Survey maps indicates there may be opportunities for additional tidal lagoons on the River Dart at Stoke Gabriel, River Erme at Clyng Mill and the River Yealm below Kitley. It has not been possible investigate these sites so no assumptions and therefore no allowance has been made for them.

There may be scope to consider energy generation from tidal barrages across all the major rivers. If climate change means rising sea levels, there may be merit in a Thames Barrier style device to hold back high tides to prevent flooding of low lying areas and to allow energy generation on falling tides. No assumptions and therefore no allowance have been made for this highly speculative and therefore uncertain long-term possibility.

6.3.3 Marine Current Turbines

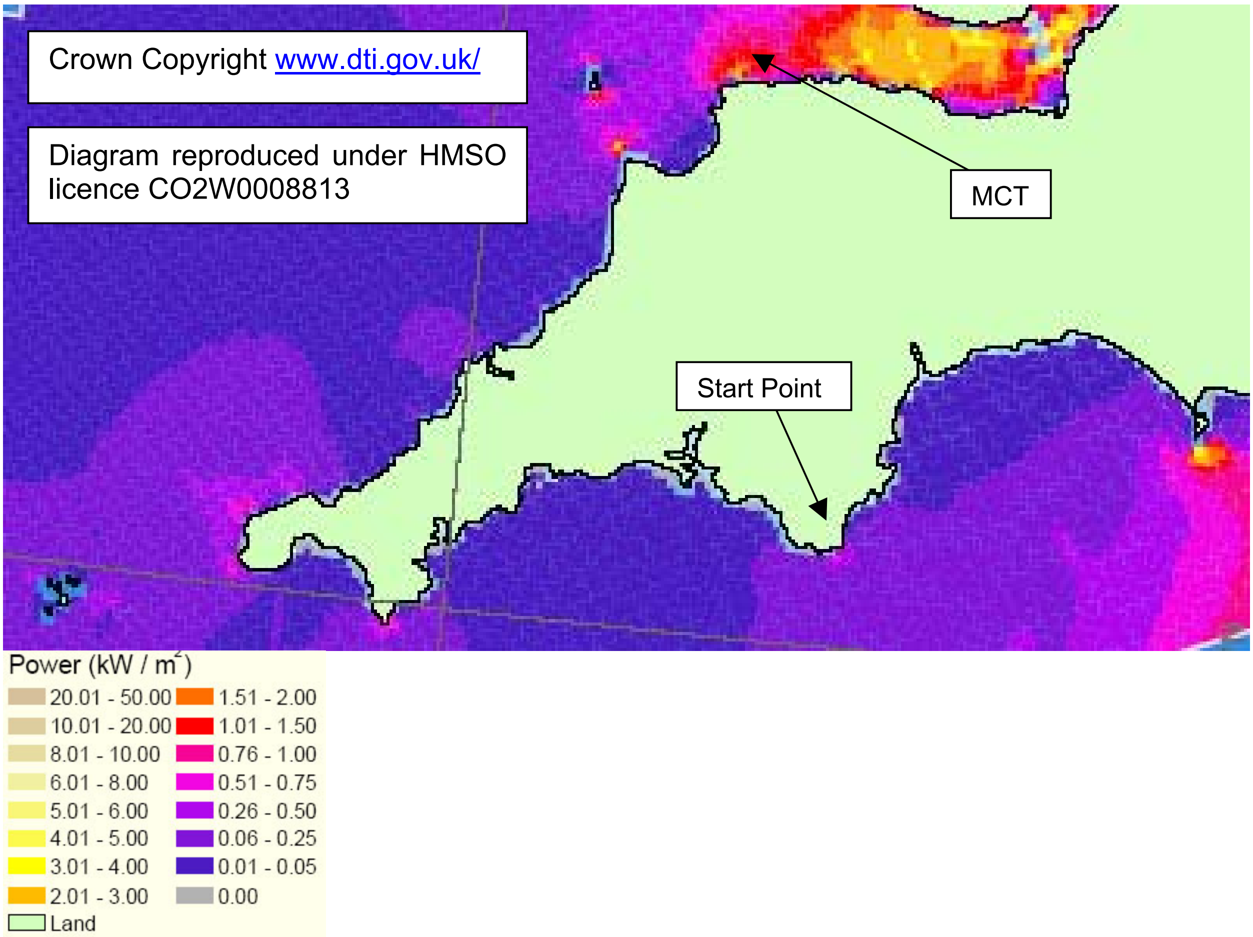
For all practical purposes marine current turbines are similar to wind turbines but function underwater. Water is 700 times denser than air so the energy contained in a moving body of water is far greater than air, against this tidal currents move more slowly. The turbine blades need to withstand the pressure of water and marine growths.

(See map below for location of this prototype turbine off the North Devon coast)

Installation requirements	An area of seabed with regular tidal flows with sufficient speed to ensure a good energy stream. The depth of water needs to be sufficient to allow the turbine blades to be adequately covered. An underwater cable needs to be installed to bring the energy back to shore and a nearby grid connection point.
Landscape impact	This is a technology that is likely to be installed at sea some distance from land and therefore be barely discernable to the eye. Most of the structure will be below the sea level with only the top of the pile visible.
Environmental impact	There may be some concern that the rotating blades may set up underwater noise that could disturb some fish species such as dolphins. Where many offshore wind turbines have been installed early indications suggest that because fishing is obstructed, the ‘no go’ area allows fish stocks to recover. Further research is necessary to validate this in the longer term. Turbines need to be anchored to the seabed and a cable laid to bring the power ashore.
Planning permission	The seabed is Crown Estates and almost certainly permission will be needed and probably a licence fee will be payable. It is thought each installation will be subject to negotiation. Consideration will need to be given to ensuring shipping channels are left clear and consultation with local fishermen.
Scale	It is likely that offshore appliances will be fabricated on shore to an approved design and be shipped to the installation site. In effect the appliances will be modular and therefore multiple numbers could be installed and only limited by the area of seabed suitable for anchoring

	the devices and the available wave resource.
Installation costs	This is a new technology still under development. There is no data currently available to offer a figure for costs. However due to the difficult nature of working at sea in depths of water, costs are high.
Pay-back period	Again, being a new technology experience is limited. However tidal currents flow with great predictability and experience of the MCT installed off the North Devon coast suggest that outputs were higher than anticipated. This is likely to be a high cost technology but will pay back over time.

The map below shows part of the UK tidal atlas for the South West.



<u>Tide energy density along the South Devon coast</u>
Most of the South Devon coast (the blue area) equates to 0.01 – 0.05 kW/m^2.
Between Bolt Tail to Dartmouth (the mauve area) energy density equates to 0.06 – 0.25 kW/m^2.
Around Start Point (the lilac area) energy density equates to 0.26 – 0.50 kW/m^2
Just off Start Point (the pink area) there is a very small area with 0.51 – 0.75 kW/m^2.
For the greater part of the coastline the energy density is so low it is unlikely marine current turbines will ever be viable. Given that marine current turbines are still in an early stage of development it is possible that at some time in the future costs may make it viable to install turbines at Start Point.

A marine current turbine located in the pink area (just off Start Point) with a swept area of say 100 m^2 would have a capacity of 51 kW (taking the lower figure for added confidence). Allowing for the fact that the tides change direction twice each day there will be four periods of slack water. If each period of slack water is 1 hour the turbine may be expected to operate 20 hours each day = 7,300 hours each year. (say 7,000 hours a year for added confidence) 51 kW x 7000 hrs = 357,000

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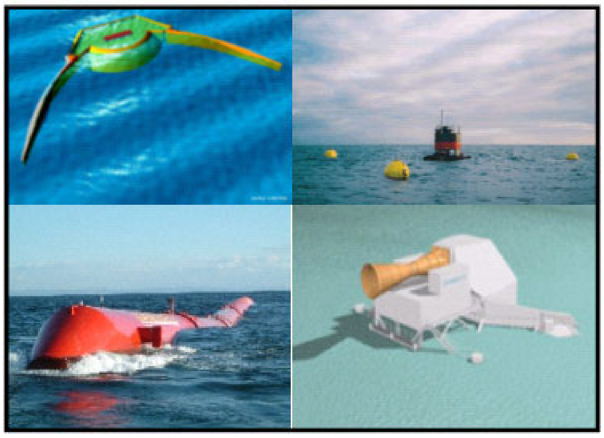
kWh/y = 357 MWH/y. If the seabed can accommodate 10 such turbines a total of **3,570 MWH/y** might be generated. (It is useful to compare these figures with the results from the Marine Current Turbine being tested off Lynton, North Devon (pictured at 6.3.3 above). The North Devon turbine is 11m in diameter (95.0 m^2 swept area) and was rated at 300 kW because the average current flow was that much higher in the Bristol Channel.)

The area of seabed off Start Point does have some energy resource but clearly the energy density is not has high as other areas such as the Bristol Channel or off Portland Bill. In the short term it is thought that the economics of marine current turbines off South Devon will not be viable. However it is possible that once the technology is fully established unit costs may come down, though in the first instance other areas with a better energy density are likely to be developed. Once the infrastructure has been put in place South Devon may benefit as installers seek further installations to recover their costs.

Because this is an offshore technology any energy capture will not be countable towards South Devon's RE targets. That said, any energy capture coming ashore in South Devon will be fed into the grid so will be accessible by all. The constraints on marine current turbines is the availability of seabed with a high enough current flow to make it worth while to install turbines and crucially located close enough to land to allow a shore connection to the national grid.

6.3.4 Wave Power

Example wave energy devices



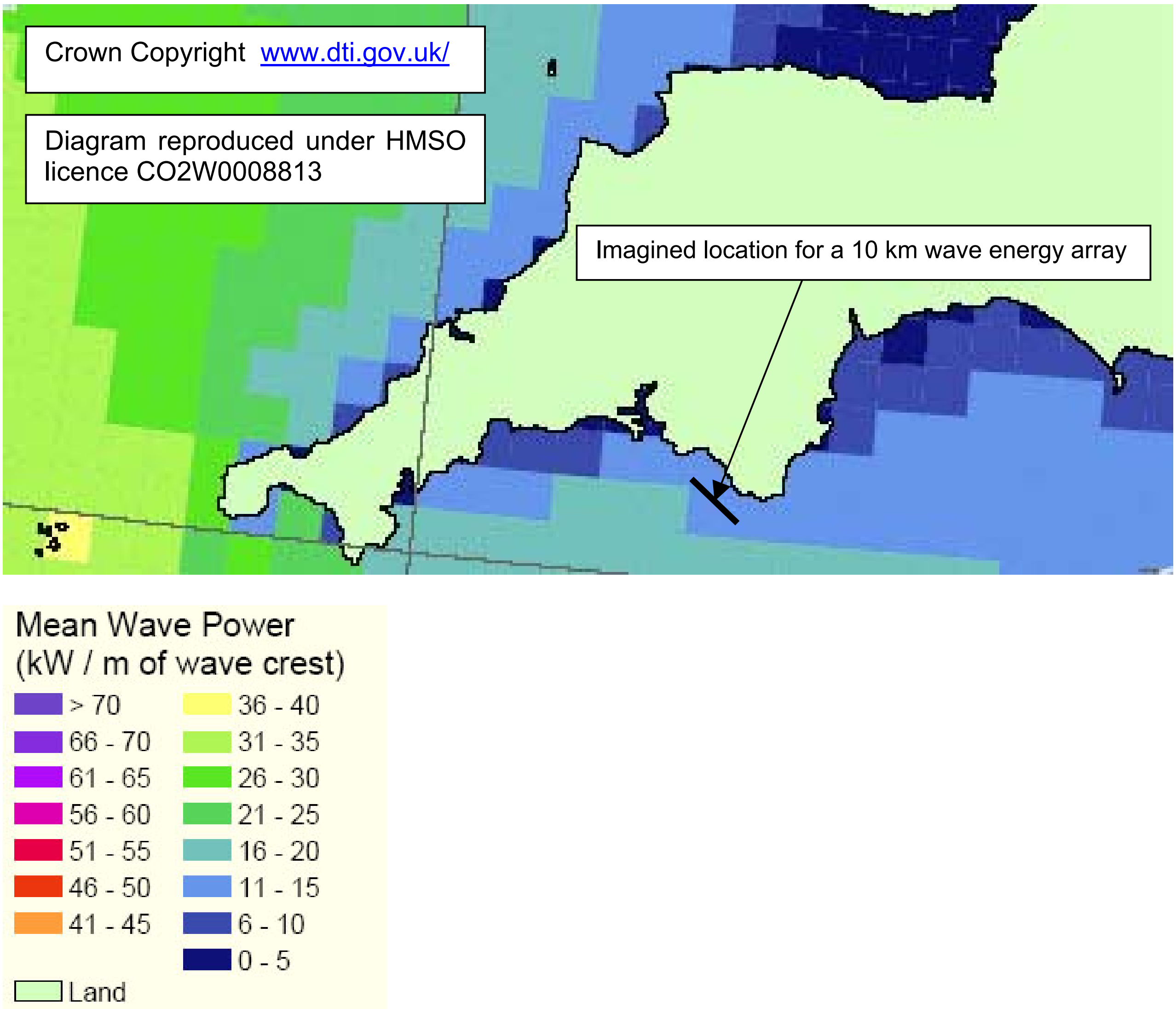
There are 22 different wave energy designs currently being tested. The 'Pelamis' (bottom left) comprises a string of sealed floating tubes with a pump at each joint. As waves pass the device the joints flex and operate the pumps that drive a generator.

Other devices include the oscillating column (top right) where water enters the bottom of the vertical tube and compresses air trapped above to drive a turbine. Research will show which device is rugged enough to cope with extreme weather and also demonstrate an economic return.

Installation requirements	An area of open sea exposed to regular wave patterns with sufficient energy per length of wave front.
Landscape impact	This is a technology that is likely to be installed at sea some distance from land and therefore be barely discernable to the eye.
Environmental impact	Devices will need to be anchored to the seabed and a cable will have to be laid to bring the power ashore.
Planning permission	The seabed is owned by the Crown Estates and almost certainly permission will be needed and probably a licence fee payable. It is thought each installation will be subject to negotiation. Consideration will need to be given to ensuring shipping channels are left clear and consultation with local fishermen.
Scale	It is likely that offshore appliances will be fabricated on shore to an approved design and be shipped to the installation site. In effect the appliances will be modular and therefore multiple numbers could be installed and only limited by the area of seabed suitable for anchoring the devices and the available wave resource.
Installation costs	This is a new technology still under development. There is no data

	currently available to offer a figure for costs. However due to the difficult nature of working at sea in depths of water, costs are high.
Pay-back period	Again, being a new technology experience is limited. This is likely to be a high cost technology but will pay back over time.

The map below shows the UK wave energy atlas for the South West.



Wave energy density along the South Devon coast.
Most of the South Devon coastline lies within an area (the mid blue area) with an average wave energy density of 11 –15 kW/m.

If a 10 km wave energy array were installed 2km off the coast, say from south of the mouth of the River Erme in a south-easterly direction to a point 2km off Bolt Tail, (that is, facing the Western Approaches and the Atlantic Ocean), using the lower figure of 11 kW/m (for added confidence) and assuming this average figure is available for 8760 hours per annum, a total of **963,600 MWH** could be generated.

Wave energy devices are still under development and costs remain high. There may come a point in the future when costs come down but that is not anticipated in the near future. Therefore it is not foreseen that wave energy devices will contribute to South Devon's renewable energy mix in the short term. Because this is an offshore technology any energy capture will not be countable towards South Devon's RE targets. That said, any energy capture coming ashore in South Devon will be fed into the grid so will be accessible by all.

The constraints for wave energy are the availability of suitable locations to site devices and bringing a power connection ashore to the national grid. If wave energy devices can be constructed to withstand to the rigours of the sea it may be possible to install a second 10km array off Start Point. In a national context there is scope for many devices off the North Cornish coast.

6.4 Wind Power

Exploiting the power in the wind is an ancient technology and old windmills form part of a picturesque landscape in parts of the country where the absence of high ground means there is no scope for hydropower. Modern materials and research has improved the design and efficiency of wind turbines offering scope for significant amounts of renewable energy generation. The technical resource is only limited by the size and number of turbines installed. Turbines work by slowing down the wind that passes through the swept area of the blades but the wind soon recombines and a second turbine can be installed at a distance of about 20 rotor diameters. Wind energy can only be farmed where average wind speeds are high enough. Wind power therefore has a practical constraint and will be confined to those areas with an average speed of over 7 m/s.

6.4.1 Small scale wind

Air contains energy by virtue of its movement and the available power is proportional to the cube of the wind speed (double the wind speed gives 8 times the power) and the swept area of the turbine blades.

Modern, near silent, wind turbines have been developed to be mounted like a TV aerial on the rooftops of dwellings.

Installation requirements	An adequate average wind speed and a roof ridge with a clean flow of air over it.
Landscape impact	Like TV aerials and satellite dishes, small-scale wind turbines will have a visual impact. But all things are relative and at 1.5 m in diameter these turbines should not attract the same controversy as large turbines.
Environmental impact	Construction materials may include copper, aluminium, stainless steel and plastic. Given that small-scale turbines are intended to be roof-mounted, there may be an issue with garden birds accustomed to perching on ridge tiles close by. At the present time there is no data available. (It should not be assumed that data from large scale wind turbines is automatically transferable to this scale.)
Planning permission	Planning permission will be required.
Scale	By definition these are smaller size turbines. As power output is related to the swept area of the blades its seems unlikely sizes will get smaller as the amount of usable power will reduce to the point there is no purpose in having such a turbine.
Installation costs	Small-scale turbines have been available for marine use for many

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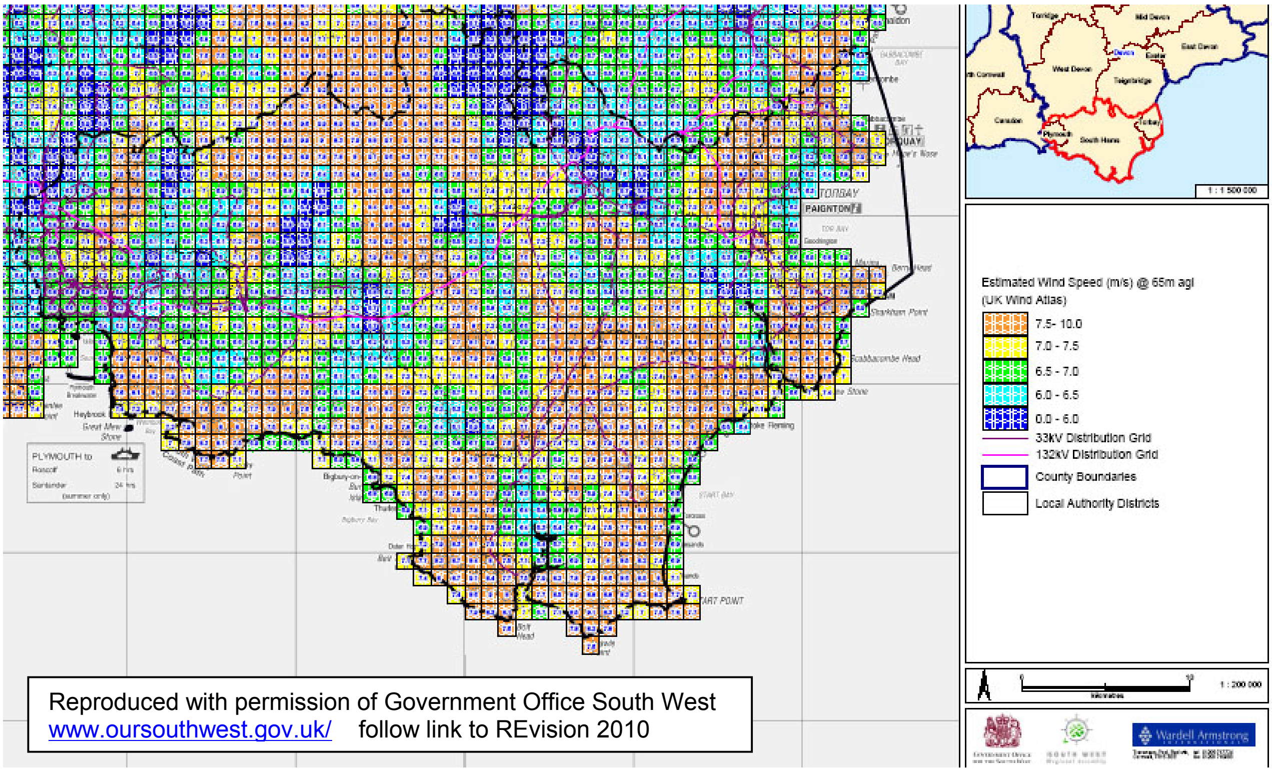
	years and can be used in a domestic situation for battery charging. An extensive range of intermediate sized turbines is available for farm use. Two companies are marketing a domestic scale wind turbine. Costs vary between £1,000 for a 1kW machine to £2,000 for 1.5 kW machine. As this is a very new market costs are likely to change as the market develops. So, get more than one quote.
Pay-back period	This is crucial! One supplier is quoting their 1.5 kW machine will supply 4,000 kWh/y in an average wind speed of 12 m/s. This may well be so but the reality is the average wind speed across much of South Devon is significantly less than this. Some areas, such as Totnes town, lying as it does in the Dart valley, has an average wind speed of 4 m/s. Because the energy in the wind is the cube of the average wind speed the annual energy capture will only be 1/27th of that collected at 12 m/s, i.e. 148 kWh/y. If this energy is used to displace mains electricity valued at say, 12p/kW, the value of the electricity collected is £18.00 per annum! If the turbine cost £2,000 it will take 111 years to pay back. Small wind turbines are economic in 'off grid' situations or places with a higher wind speed.



South Devon Wind Resource map

The map of South Devon is overlaid with the Ordnance Survey grid and each square is colour coded by wind speed at 65 m above ground level.

For large-scale wind turbines 7.5 m/s is generally regarded as the lowest viable wind speed for economic development. It is apparent is that most of the red areas coincide with the outline of the South Devon Area of Outstanding Natural Beauty and the Dartmoor National Park.

South Devon falls within the Countryside Character Area 151: South Devon. That study concludes that South Devon has a moderate sensitivity to large-scale wind turbines and suggests that "For the purposes of this strategic target setting exercise, large clusters of turbines have been discounted for reasons of landform scale. Because of the wide views across this incised plateau, consideration should be given to the spacing of turbine clusters to avoid inter-visibility or 'visual clutter'."

Given that Dartmoor rises above the South Devon plateau, any large wind turbine in South Devon is likely to be visible from the southern flanks of Dartmoor. To reduce the visual impact any turbine will need to be some distance away from the National Park boundary. This leaves very few locations with a viable wind regime to exploit. Technically there is a significant wind resource across South Devon and the energy available is only limited by the number of turbines installed. But the landscape designations suggest it will be politically unacceptable to exploit this. However, it may be possible to install a small number of clusters of say no more than three turbines. (See 8.4.2 below.)

Small-scale wind turbines may be more politically acceptable than large-scale turbines. However the cost per kW installed is greater. The wind resource map shown at 8.4 above illustrates the wind speed at 65m above ground level. Small-scale wind turbines are designed to be mounted at roof level, i.e. about 10 m above ground level. At this height the average wind speed will be correspondingly lower. Given that wind energy is related to the cube of the average wind speed, any reduction in average wind speed will greatly reduce the available energy. Specific site location will be crucial. E.g. take two identical turbines, one installed on a roof in Totnes town centre (average wind speed 4 m/s), the other on the roof of a building at East Prawle (average wind speed 7 m/s). The turbine at East Prawle will produce nearly 8 times as much energy; it will be difficult to make an economic case to support the Totnes turbine.

Available Resource

Assumptions:

- If 1000 x 1.5 kW wind turbines are installed on dwellings randomly distributed across the area coloured red (average wind speed 7.5 m/s) in the wind resource map shown at 8.4 above, then
- each turbine will generate between 2000 – 3000 kWh/y (manufacturers' figures). Taking the lower figure for increased confidence, 1000 x 2000 = 2,000,000 kWh/y = **2000 MWH/y**

The only constraint is the number of turbines installed. Whilst it is suggested 1000 x 1.5 kW wind turbines could be installed in South Devon, in fact every building within an area with an adequate average wind speed could have a small wind turbine. Within this study it has not been possible to determine how many buildings fall within a suitable area.

6.4.2 Large scale wind

Opinions are polarised about the appropriateness of large-scale wind turbines. There is no doubt these tall structures do have a visual impact on the landscape but they are the one technology that has been developed to the point where they can deliver energy at a cost comparable with fossil fuel derived energy. The UK has a good wind regime and South Devon has a number of areas where, Landscape designations apart, a significant wind resource could be harnessed.

Installation requirements	A high average wind speed. A clean air stream and a grid connection.
Environmental impact	Construction materials may include steel, copper, fibreglass. The foundation will require concrete. It may be necessary to construct a temporary access. Noise – can be produced from gearboxes, blade tips scything through the air and the interaction between the blade and the tower. With second generation turbines these problems have been solved. Direct drive turbines have no gearbox. Rotor speeds have been slowed down so tip speed noise has been eliminated. Little can be done to reduce the interaction between tower and blades but the noise level is very low and generally inaudible at more than a couple of hundred metres from the machine. Rotor flicker – may be an issue in the early morning or late evening when the sun is low in the sky. If there is a risk of shadows passing over nearby dwellings the turbine can be programmed to stop temporarily. Bird strikes – Many years ago a wind farm sited directly in the path of a bird migration route was responsible for many bird deaths. Today a better understanding of migration routes and the use of much slower rotating blades have significantly reduced bird strikes to the point where it is unlikely to be a serious problem. TV and radar interference – In an age of mobile phones there are numerous micro-wave links between aerials. All the links are mapped so turbines can be sited to avoid this interference. There may be some interference to TV signals but this will be very localised.
Planning permission	Planning permission and an Environmental Impact Assessment will be needed. Renewable energy installations are subject to Planning Policy Statement 22 (PPS22). In the accompanying guidelines to PPS22 it clearly states that buffer zones (that is areas of exclusion around sensitive sites) will not be acceptable.
Scale	With the advance of technology it is now possible to construct large wind turbines up to 5MW installed capacity. This is currently the largest size machine being developed and is thought to be close to the maximum size possible with presently available composite construction materials.
Installation costs	The economics of large-scale wind turbines is very different from small-scale. Typical capital costs will be in the order of £800,000 per MW installed capacity. In addition there will be one off costs of Planning Permission (£50,000+) and annual ongoing costs of Business Rates (£10,000), insurance (£10,000), maintenance (£40,000). Third generation turbines of 3MW plus may well be cheaper per MW. NOTE: these figures will change over time and need to be checked against up-to-date figures.
Pay-back period	A 1.3 MW wind turbine will typically produce a minimum of 2,000 MWH/y of electricity. Quite simply, if the average wind speed is not sufficient to supply this level of output, a wind power developer will not develop the site. Sales of electricity will give an annual income of £170,000. After annual costs (rates, insurance & maintenance) are meet there is a balance of £110,000 from which the cost of servicing the debt has to be met. Depending on the original debt/equity ratio, a turbine may pay its cost off in up to ten years. Given that this size of turbine is expected to have a 25-year design life, once the debt is paid off there is a handsome income over the remaining life. (Energy prices are likely to rise as oil supplies become scarcer so the income may well exceed these figures.)

The economics of large-scale wind turbines is well established; hence the continual rise in numbers of planning applications. Quite simply, because of the costs of development a great deal of research goes into planning where to site them. From a purely wind resource perspective any site that has an average wind speed in excess of 7.5 m/s will offer an economically viable site. From the wind resource map shown above the red areas represent locations with high average wind speed.

If the average wind speed is known for a site, the annual energy production can be estimated by the formula

$$P\ (\text{kWh}) = 3.2 \times V_a^3 \times A \quad ^{(14)}$$

Where V_a - is the average wind speed in metres/sec
A - is the swept area of the turbine blades.
NOTE: this formula should be applied with caution as local conditions may adversely influence average wind speeds.
Source – EWEA, 1991; Anderson, 1992; Beurskens and Jensen, 2001; Open University RE Report, G. Boyle, page 267

If the average wind speed, at hub height, is 7.5 m/s then $P = 3.2 \times 7.5^3 = 3.2 \times 421.875 = 1{,}350$ kWh/y/m^2.
A typical 1.3 MW wind turbine will have a hub height of 50m with 26m blades (52m diameter) giving 76m to blade tip at the top of the blade arc.
If the turbine blades are 26m long the swept area will be ($A = \pi r^2$) = 3.142 x26 x 26 = 2,124 m^2.
The total energy capture will be 1,350 x 2,124 = 2,867,400 kWh/y (2,867 MWH)

Available Resource
Assumptions:
If three clusters of three 1.3 MW wind turbines were installed the combined output will be
3 x 3 x 2,867 = **25,803 MWH/y**

The only constraint will be the number of turbines installed and this depends upon the land area with adequate average wind speed. Turbines extract energy from the wind by slowing the wind speed down. Wind that passes through the swept area will be slowed, wind that just misses the blades will continue at the original speed. The two airstreams mix and rejoin over a distance of about 20 blade diameters. In the case of a 52 metre swept diameter, the air will re-unite in about 1 kilometre where a second turbine could be installed. In practice the wind tends to arrive from a prevailing direction and turbines can be located much closer when placed across the direction of the prevailing wind. Up to 5 turbines could be installed per kilometre wind front.

14 - Source – EWEA, 1991: Anderson, 1992; Beurskens and Jensen 2001. – Open University RE G. Boyle page 267

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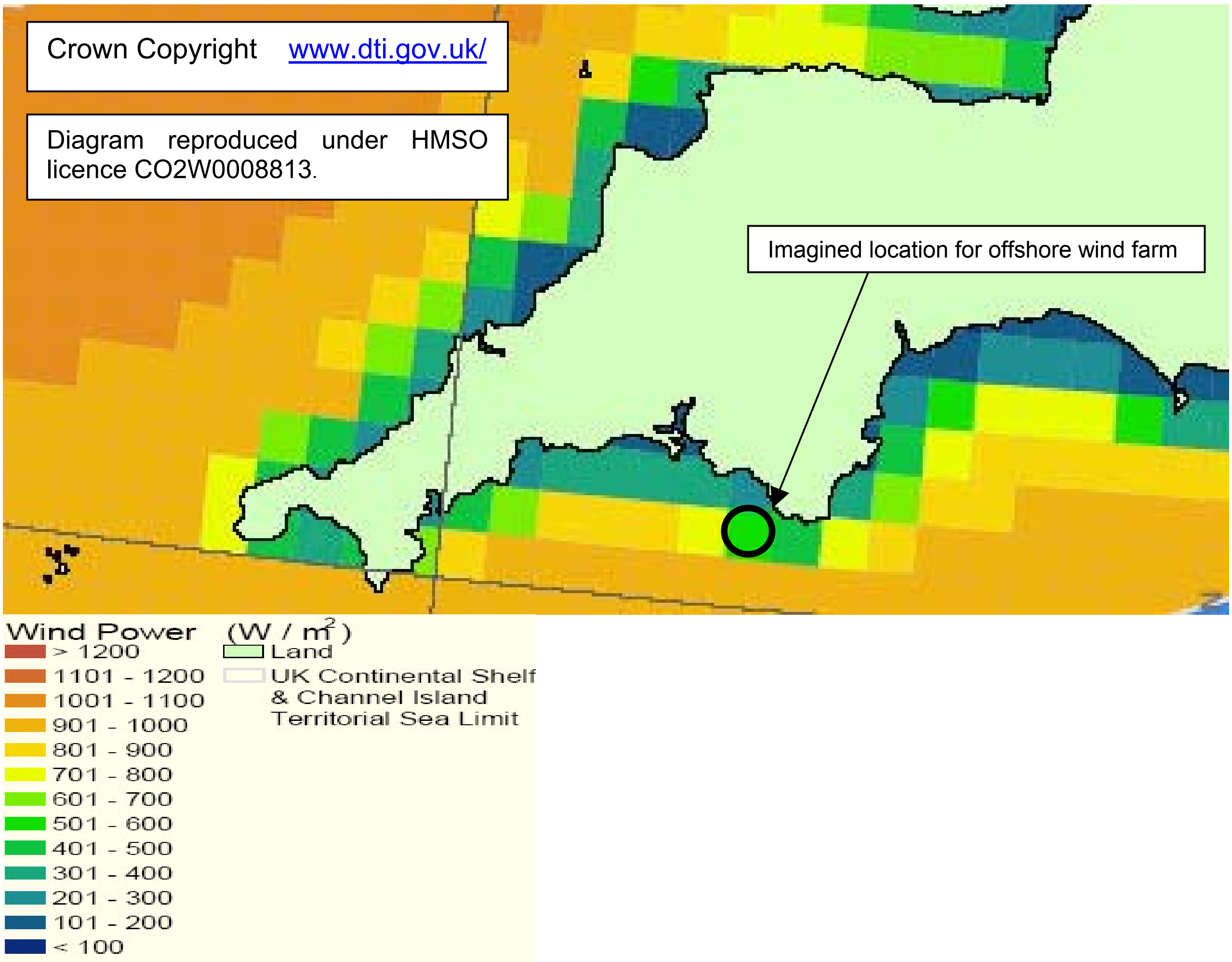
Offshore wind resource

There is no plan to install offshore wind farms around the South Devon coast but for the sake of completeness and to facilitate informed debate it is necessary to draw attention to the possibilities.

UK atlas of Offshore wind resource



In the coastal waters off South Devon, to the South-West of Bolt Tail (green square indicated on map above), the wind energy density is 501 – 600 W/m^2. Given that the costs of the foundations for offshore wind turbines are large it makes sense to install the largest size of blades. (As they will be offshore and therefore seen at a distance, the visual impact will be small).
If marine current turbines were installed off Start Point, it might be possible to install offshore wind turbines on the top of the same piles. This would make sense as it will utilise the same cable to bring the energy ashore. Off Start Point (yellow square) the wind energy density is 701 – 800 W/m^2.

Available Resource
The resource will be constrained by the number of turbines installed, which in turn will depend on the seabed conditions for installing the foundations. It is beyond the scope of this study to investigate offshore wind further. A 2MW wind turbine installed offshore could generate up to 8,000 MWh/y.

Because this is an offshore technology any energy capture will not be countable towards South Devon's RE targets. That said any energy capture coming ashore in South Devon will be fed into the grid so will be accessible by all.

6.5 Biomass

The term biomass refers to a wide range of organic material such as timber, straw and energy crops. However, before looking at the various forms of biomass we need to consider how much land is available for energy crops.

Land use issues
As with any other crop, energy crops need space to grow. There is only a finite amount of land available so priorities will need to be identified. At the time of report (2006) there are 1993 hectares of set-aside land available in South Devon(15), however it would be unwise to assume that set-aside land will always be available for energy crops.

Improved farming methods and scientific application of fertilisers have increased crop yields which means less land is needed to grow our food needs. But it may not be possible to maintain increased yields if petrochemical-based fertilisers are no longer available as oil supplies dwindle. It may become necessary to take set-aside land back into food production use so that land dedicated solely for energy crop use is not possible. For the purposes of this scoping study it is assumed that set-aside land is and will continue to be available for the immediate future. It is also assumed that once Peak Oil is passed and oil begins to be in short supply, the laws of supply and demand will drive up the price of fertilisers progressively so there will be warning of any impending need to reduce set-aside.

The South Hams District had a total of 1548 holdings covering 64,747 hectares recorded in the 2004 agricultural census, of which set aside (15)

Year	Output area	Category	No. of holdings	Area (ha)	Confidence
2004	South Hams	Set aside	218	1,993	V. good

The South Devon AONB had a total of 615 holdings covering 27,245 hectares recorded in the 2004 agricultural census, of which set aside (16)

Year	AONB	Category	No. of Holdings	Area (ha)	Confidence
2004	South Devon	Set aside	115	1,078	V. good

South Devon AONB Woodland Cover
Roughly calculated, total woodland cover including small woodlands of less than 2 ha equals 3144 ha (of which 753 ha is ancient woodland). 704 ha of the 3144 are coniferous and 2440 ha are deciduous. (Based on GIS analysis of aerial photography and the England inventory of woodland and trees.)

15 - Source: http://farmstats.defra.gov.uk/cs/farmstats_data/DATA/soa_data/repop_results.asp this may include some land within the Dartmoor National Park.
16 - Source:
http://farmstats.defra.gov.uk/cs/farmstats_data/MAPS/interactive_maps/anob_results.asp?aonb_id=31&year=2004&ord=year&submit=Get+Census+Data&c_id=24

6.5.1. Woodlands

Wood fuel is perhaps the oldest known fuel to man and is usually derived as a secondary product from other timber production processes.

Here cordwood is stacked for air drying preparatory to chipping for use in an automatic woodchip boiler used to heat a complex of farm buildings, holiday cottages and a swimming pool all served by a mini district heating system.

Installation requirements	Available land
Landscape impact	Natural woodland is generally regarded as an asset to the countryside although large areas of single species plantation may not be seen as desirable.
Environmental impact	Generally trees are regarded at having a positive benefit on the environment.
Planning permission	Not required
Scale	Dependant on the size of woodland available.
Installation costs	Grants are available to establish new woodlands.
Pay back period	As woodlands have an amenity value it is difficult to put a monetary value on

Anecdotal evidence from experienced foresters is that on first clearance, previously un-maintained mixed woodland can give 15 tonnes of timber per ha. and thereafter a sustainable yield of 2.5 tonnes per ha. per year. This implies the 2440 ha of deciduous woodland could sustainably supply (2440 x 2.5) 6,100 tonnes of timber year on year. However the energy value of this yield will depend upon how the timber is processed. The more handling that is involved the higher the cost of the resource and the lower the energy balance. To maximise the benefit of harvesting existing woodlands it will be necessary to develop local markets and timber handling processes that minimise the energy involved in getting the timber to market. There are four primary ways of using timber: as slab wood, logs, woodchip and pellets.
A standing tree can be assessed for its timber value and once felled can be cleared of the brash and transported to a sawmill for use as construction timber. The sawdust from the milling process can be used to form pellets and slab wood can be chipped. Timber deemed unsuitable for milling can be used as logs or chipped. Generally chipping does not take place until the moisture content is between 25 to 35%. (Below 25% the timber is so hard it causes excessive wear on the chipper blades, above 35% it will start to compost.) Felled timber is taken to the ride-side of the woodland and stacked so it can air dry for a period of time. The brash left in the forest (forestry residues) may be of value or may be left in situ to rot and give nutrients back to the soil and support other forms of wildlife.

The energy content of timber is directly related to the moisture content: the drier it is the higher the energy. Timber with 60% moisture content only has 6 GJ/t. energy, whereas timber with 20% moisture content has 15 GJ/t[(17)]. energy. It is assumed that the drying process will be natural air drying so will not consume further energy. 1 tonne of dry timber will replace about 400 litres of oil with a net saving of 1072 kg of CO_2 [(17)]

17 – Source - South West Wood Fuels. www.swwf.info
18 – Source - Working Woodlands, Dartington.

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Although 6,100 tonnes of timber per annum is a significant amount of timber it is still a finite resource and consideration will need to be given as to how best to use it. Should individuals be encouraged to install their own log stoves or boilers (typically 70 –90% efficient) or is it better to encourage communities to work together to install a community CHP scheme with a district heat main? In the former case the individual bears the cost and has control over when they need the heat. In the latter case a community CHP scheme will need financing and although it may utilise the fuel more efficiently by producing both heat and power, will need to be operational all the time to ensure continuity of supply for all. There is no easy answer except to say whatever schemes emerge it is better to have flexibility.

Turning to the 704 ha of conifer, a mature stand of Douglas fir can yield up to 20 dt/ha/y. [18] Much of this timber will be used for construction so the available resource for energy will depend upon how efficiently the timber is milled and waste is reduced. It is assumed that 80% of the timber can be converted into useable timber and 20% can be used as energy, i.e. 4 dt/ha/y is available for energy. (704 x 4) = 2816 dt/y

Increasing woodland cover

Given that it is possible that much of the existing set-aside land will need to be taken back into food production at some point, it seems probable that very little set-aside will be available to create new woodlands. That said, there might be areas within the region where woodland is sparse and it is desirable to plant new woodland for amenity benefit. Likewise there may be opportunities to add to existing small woodlands to either join two nearby blocks of woodland to create wildlife corridors or to fill in awkward corners or steep land that tractors cannot reach. It is assumed any new woodland planting will be primarily native deciduous species.

Available Resource

Assumptions:

1. Some form of cooperative or machinery ring can be established, or a company be established, that all woodland owners will contract with and agree to maintain all the woodland in South Devon.
2. That the market can be developed and numerous local applications can be found for wood energy.
3. That all woodland can be exploited on a sustainable basis and provide:
   - 6,100 dt/y of hardwood
   - 2,816 dt/y of softwood
   - = 8,900 dt/y
   - 8,900 dt/y x 15 GJ/t = 133,500 GJ/y (1GJ = 277.8 kWh) = 36,979,500 kWh = **36,980 MWH**
   - which will replace 3,560,000 litres of oil
   - and save 9,540,800 kg of CO_2/year = 9,540 tonnes

6.5.2. Short Rotation Coppice

Short Rotation Coppice (SRC) is the term used to describe a system of harvesting a timber crop. Some tree species, when cut back to ground level, re-grow from the cut root with a large number of thin stems. Coppicing is a well-known method of tree management, historically used to produce charcoal. Several species can be used but Willow (Salix spp.) is the most commonly used as an energy crop. Once the crop is established, stems are cut on a three-year rotation.

Installation requirements	SRC will grow on most soils with a reasonable nutrient level and

	moisture retention. Ground needs to be reasonably level for machinery to access.
Landscape impact	Once established a crop is likely to be in place for 30 or more years, if planted in large blocks there will be visual impact.
Environmental impact	There are mixed impacts; some cultivars are susceptible to rust and attack by Willow beetle so will need pesticides. There is evidence that some species of SRC cross hybridise with naturally occurring local willow species. On the other hand the semi- permanent ground cover (the crop is harvested every third year) offers shelter to many species of small mammals and birds.
Planning permission	Not required
Scale	Dependent on the land area available for crops.
Installation costs	Planting grants are available but the crop will need specialist-harvesting equipment. SRC is normally used as wood fuel crop and is chipped with moisture content between 25 –35%.
Pay back period	Comparative costs with other bio-mass fuels suggests that SRC may not be the most competitive crop to grow. However some soils may be better suited to SRC and there may be ecological and landscape benefits. With more than one factor to account for pay back periods are difficult to estimate.

Available Resource
Experience in the South West indicates that an average yield is 8 – 9 dt/ha/y
Assumes

- All 1993 ha of set aside is used for SRC.
- 1993ha x 8 dt/ha/y = 15,944 dt/y
- 15,944 dt/y x 15 GJ/t = 239,160 GJ x 277.8 kWh/GJ = 66,438,648 kWh = **66,439 MWH**

SRC is normally harvested in the winter when the sap is low so the moisture content is naturally low. Willow can either be stored as long stems or be chipped and dried further. The resultant fuel can be used in three ways: 1) combustion to provide heat. The heat can boil water to produce steam for a steam turbine to generate electricity. 2) gasification (see 6.7.2 later) to produce a combustible gas that may be burned in an engine or turbine. 3) pyrolysis (see 6.7.2 latter) to produce gas, oil or charcoal fuels.
See http://www1.sac.ac.uk/envsci/External/WillowPower/

6.5.3 Miscanthus

Miscanthus is a C4 (see box below) perennial grass originating from the tropics but grows well in our climate. The crop is established by planting rhizomes and once established, the crop requires minimal inputs and typically grows to 3 metres high in a season. At the end of the growing season the chlorophyll retracts into the roots leaving just the cellulose stem above ground, this has two advantages: most of the soil nutrients stay in the ground and the stems have very low moisture content at the time of harvesting (February/March) is typically between 25 –30%.

C3 and C4 plants
Photosynthesis needs both sunlight and carbon dioxide in the correct proportions, however sunlight can be variable and if the proportions get out of balance plant growth can suffer. Growth in C3 plants, normally found in temperate latitudes, can slow down if the sunlight – CO_2 balance is wrong.
C4 plants, normally found in tropical latitudes, have evolved to store CO_2 in their cells, are more draught tolerant and better able to cope with sunlight variation, so potentially produce better yields of biomass than C3 plants. [19]

A Miscanthus crop in late February.

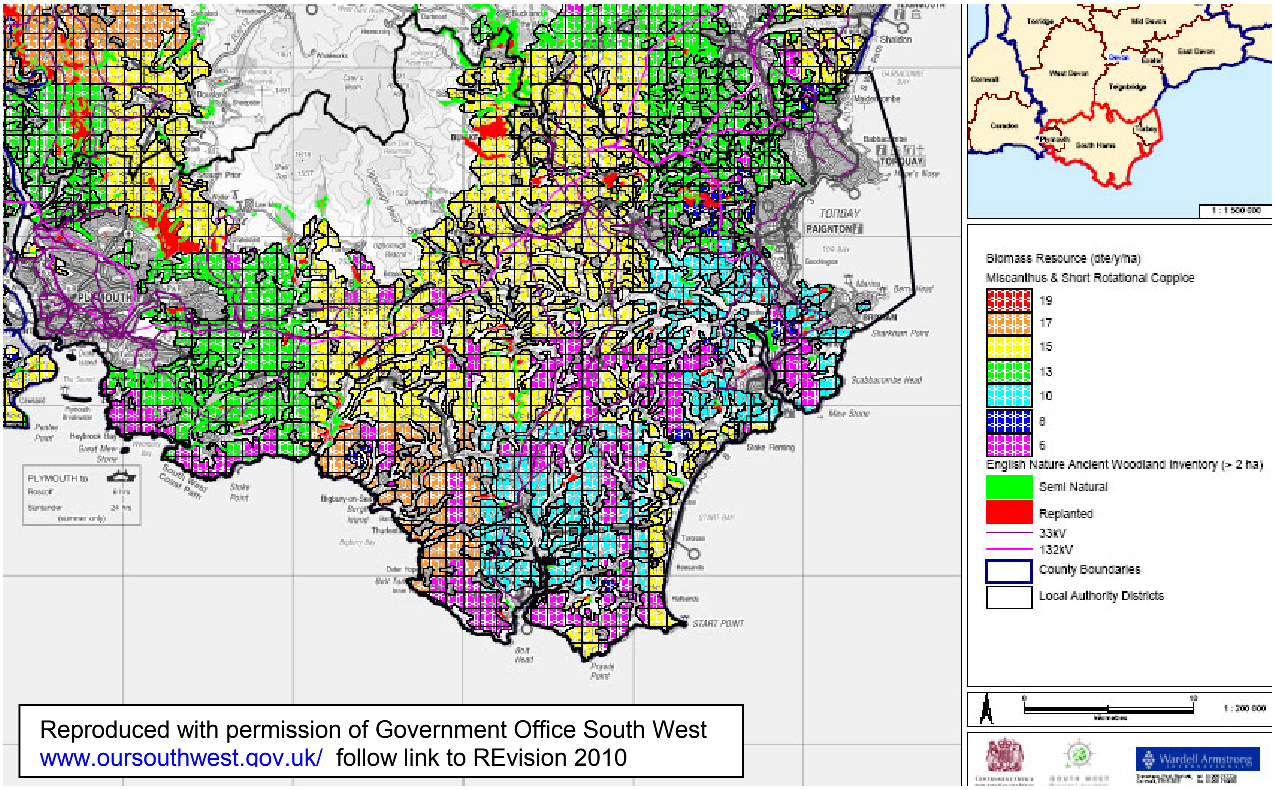
The chlorophyll has retracted into the roots and the crop appears a pale straw yellow. It can be harvested with conventional forage harvesting machinery in March. In the spring fresh green stems start to shoot. Because the chlorophyll stays in the plant nutrient depletion is low so the application of fertiliser is minimal. The extensive rhizome root structure allows tractors to pass over the ground without sinking or damaging the soil structure.

Installation requirements	Basically any field that can be accessed by farm machinery is suitable. Generally the remains of any previous crop need to be cleared from the ground and any weeds need to be suppressed (usually by herbicide) to prevent competition whilst the crop is establishing itself. Once established, the density of the crop itself will effectively smother new weeds. Miscanthus is a rhizome and propagation is by root division.
Landscape impact	As with any monoculture crop, a large block of Miscanthus will be visible in the landscape. However it is essentially a grass so is green in the growing season turning to a straw colour in the winter. The crop is harvested once a year, usually in March/April.
Environmental impact	Miscanthus requires sunshine and water and little else. However the water requirements could reduce the rainwater run off into rivers which could be a problem in some areas, but on the other hand could help to reduce the erosion of soils following heavy rains. Because Miscanthus is a rhizome its roots help bind the soil and if planted along river margins it would act as a buffer crop to help the management of rainwater. Once established, the crop only needs to be accessed once a year for harvesting. Depending on the equipment used this may be with a single pass that cuts and chops the crop or several passes; once to cut, once to turn and once to bail. Because the roots form a dense mat tractors can access the crop without sinking in.
Planning permission	Not required for the crop. Where existing farm buildings are used for storage then planning will not be needed. However if a farm building were converted to house a small local power generation plant then planning would be needed.
Scale	Dependent on the land area available for crops.
Installation costs	Installation consists of sourcing the rhizomes and planting them. This can be done with a potato planter but it may be more cost effective to employ the company that supplies the rhizomes to use a dedicated planter. Costs in 2005 equated to about £1,800 per hectare.
Pay-back period	Initial planting costs are high and yields in the first couple of years low but increase over the following years. Once the crop is established inputs are low so pay-back improves. Break-even will depend on soil fertility but should be within a couple of years. Being a grass, Miscanthus can be cut with normal grass harvesting equipment and can be bailed for transport. [20]

19 - Source – Hall and Rao, 1999; Open University RE, G Boyle

20 - Source - www.defra.gov.uk/erdp/schemes/energy/crops.htm Defra research and development report CSG15.

Miscanthus and Short Rotation Coppice resource map



The map shown above depicts the expected levels of yield for Miscanthus in South Devon. From the colour coded legend it is clear that potential yields vary considerably from area to area. Since set-aside land can change from year to year it is impossible to produce a detailed map of potential growing sites. It is evident there are no areas of red (19 dt/ha/y) but some areas of mauve (6 dt/ha/y). Growing to 3m in height Miscanthus is susceptible to wind damage and is not suitable for areas with an average wind speed over 7 m/s. The more favourable areas are the yellow and green on the above map. It therefore appears reasonable to assume that South Devon could sustainably support an average yield of 15 dt/ha/y.

Comparing Short Rotation Coppice and Miscanthus, Miscanthus appears to be the better choice. Although planting costs are higher, the crop needs fewer inputs and converts solar energy more efficiently. Existing farm machinery can be used to harvest and it is not necessary to oven dry the crop to reduce its moisture content. Miscanthus can be left as long stalks, chopped or pelleted and has other uses such as animal bedding, so in some circumstances could be used twice thereby adding value.

<u>Available Resource</u>

Assumptions:

- All 1993 ha of set aside will be planted to Miscanthus
- Crop yield 15 dt/ha/y
- Energy conversion rate = 15 GJ/dt[21 & 22] gives 225 GJ/ha/y (1GJ = 277.8 kWh) = (62,505 kWh/ha/y)
- Energy input to establish the crop is a 'one off' cost and is discounted.
- Energy to harvest crop is 630MJ/ha (1MJ = 0.2778 kWh) = 175 kWh/ha [27]
- Energy to transport crop is dependant on distance (say 330 kWh/ha/y).
- Net energy output; 62,505 less 175 less (say 330) = 62,000 kWh/ha/y.
- 1993 x 62,000 = 123,566,000 kWH/y = **123,566 MWH/y**

21 – Source – Open University RE, G Boyle page 110
22 – Source - www.defra.gov.uk/erdp/schemes/energy/crops.htm

Note – it will not be possible to grow both SRC and Miscanthus, but when comparing the relative outputs, it is clear Miscanthus offers far better energy supply per hectare. Given that Miscanthus does not need specialist machinery to harvest, only needs few inputs once established and has naturally has low moisture content when harvested, it offers a much better energy balance. Miscanthus appears the better choice of energy crop. It is possible to split the area of set-aside between the two crops if soil conditions dictate that one crop is better suited to a particular soil type.

6.6 Biofuels

The term biofuels applies to a wide range of products derived from organic material, but generally has come to mean liquid fuels intended for transport use. Bio-ethanol is the main replacement for petrol, whilst a variety of animal fats and vegetable oils can be processed into diesel replacement. Bio-ethanol can be produced by fermenting sugar or starch-based material such as wheat and sugar beet. Latterly enzymes and other chemical processes have been used to break down cellulose found in plant material to produce alcohol. This opens up the possibility that a wide range of waste stalks and stems, and farming and forestry residues could become the feedstock for petrol replacements.

Bio-diesel can be produced by the trans-esterification of fatty acids from a wide range of plant oils and animal fats. This process is straightforward and the equipment can be purchased to allow small-scale local production. Some diesel engines can burn plant oil direct.

6.6.1 Oil seed rape

The bright yellow of oil seed rape in flower is now a common site in the springtime; the crop is normally grown for cooking oil. After the oil has been used for some time it degrades and is replaced with new oil. The old oil is collected and transported for re-processing into bio-diesel.

There is a move to include 5% of bio-diesel in all mineral diesel sold at petrol stations. All diesel engines can accommodate this low level of bio-diesel without any modification. Some engines can accommodate higher levels of bio-diesel some can run on 100% recovered vegetable oil.

Take advice from your garage before using bio-fuel.

Installation requirements	Basically any field that can be accessed by machinery is suitable. The crop is planted and harvested by standard farm machinery
Landscape impact	Oil Seed Rape (OSR) is an annual crop and occupies the ground for about 10 months. Apart from the vivid acid yellow colour of the crop when in flower, any visual impact is temporary.
Environmental impact	A number of tractor passes are required to plough, harrow, sow and fertilise the crop and then to harvest. OSR is very free seeding and crop can 'escape', unless controlled it may become a problem. There is a suggestion that pollen from OSR can adversely affect respiratory illnesses. There is concern that some OSR may be genetically modified.
Planning permission	No planning permission needed to plant and grow the crop. However if the bio-diesel trans-esterification plant is installed planning may well be needed. Also the Environment Agency and H.M. Custom and Excise will need to be notified.

Scale	Dependant on the land area available for crops.
Installation costs	The crop needs a number of inputs such as tractor passes to plough, harrow, sow and fertilise the crop. Fertiliser itself has energy content; where OSR is grown as an energy crop the energy balance needs to be carefully analysed. There is a strain of OSR that produces a higher yield but it is not suitable for human consumption.
Pay-back period	OSR is already grown as a commercial crop so will pay back within the season.

OSR is already grown in South Devon as a commercial crop for use as cooking oil. It requires a number of inputs in terms of a number of tractor operations to prepare the ground and fertiliser applications. The balance between the energy output and energy inputs is about 2 to 1. Although there is a positive energy balance, the question needs to be asked whether such a marginal benefit is the best use of land. It therefore seems likely that OSR will continue to be grown in South Devon primarily as a food crop and not as an energy crop. The crop once harvested will be collected and processed into cooking oil. After use as cooking oil, the waste vegetable oil (WVO) will be available for trans-esterification into bio-diesel. There is no data available as to how much WVO is collected in South Devon.

Europe's largest Biodiesel plant has just come on stream near Newcastle. (See http://www.biofuelscorp.com) This will kick start the production of biodiesel in the UK. Farmers are currently being approached to grow under contract for this plant.

Available Resource

Assumptions:

- All 1993ha is used for OSR
- Yields vary but average 2.9 t/ha [(23)]
- 1993 x 2.9 = 5779.7 t
- Energy value 37 – 39 GJ/t (say 38 GJ/t) [(24)]
- Energy yield 5780 x 38 = 219,640 GJ (1GJ = 277.8 kWh) = 61,015,992 kWh = 61,016 MWH

Energy inputs to grow and harvest the crop = 16,269 ± 896 MJ/t (say 16.25 GJ/t) [(25)]

Therefore the net energy output = 38 – 16.25 = 21.75 GJ/t

- Net energy yield 5780 x 21.75 = 125,715 GJ (1GJ = 277.8 kWh) = 34,923,627 kWh = **34,924 MWH**

23 - Source – www.ukagriculture.com/frame_set.cfm?page

24 - Source - Open University RE, G Boyle, page 136

25 - Source - Sheffield Hallam University, Evaluation of the comparative energy, Global warming and Socio-economic costs and benefits of bio-diesel.

6.6.2 Bio-ethanol

Bio-ethanol is derived from fermenting either grain (wheat) or sugar beet into alcohol. This is a tried and tested technology in other parts of the world, particularly Brazil and the USA.

Installation requirements	Crop – none Processing – requirements of an industrial plant.
Landscape impact	Both wheat and sugar beet are annual crops and part of the normal rotation of crops. Any landscape impact will be minimal
Environmental impact	Neither crop has any detrimental effect on the environment.
Planning permission	None required for growing the crop although a processing plant will need planning permission.
Scale	Dependent on the land area available for crops. Processing – depends on catchment area from which crops are imported.
Installation costs	The first UK bio-ethanol plant is under construction in Somerset at the time of report. Costs are therefore uncertain at this time due to lack of experience.
Pay-back period	It is too early to predict until more operating experience is to hand.

<u>Available Resource</u> (Wheat)
Assumptions:
- All 1993 ha of set aside are available for growing wheat as an energy crop
- Yields 7.74 t/ha [26]
- 1993 x 7.74 = 15,425 t
- 1 tonne of wheat gives 0.336m^3 of bio-ethanol (336 litres)[26]
- 15,425 x 0.336 = 5183.07552 m^3 = 5,183,075 litres
- Bioethanol has an energy content by volume of 21.1 MJ/L
- 5,183,075 x 21.1 = 109,362,882.5 MJ (1MJ = 0.2778 kWh) = 30,381,008 kWh = **30,381 MWH**

<u>Available Resource</u> (Sugar beet)
Assumptions:
- All 1993ha of set aside are used for growing sugar beet as an energy crop
- Yields 57.5 t/ha [26]
- 1993 x 57.5 = 114,597.5 t
- 1 tonne of Sugar beet gives 0.108m^3 of bio-ethanol (108 litres) [26]
- 114,597.5 x 0.108 = 12376.53 m^3 = 12,376,530 litres
- Bioethanol has an energy content by volume of 21.1 MJ/L [26]
- 12,376,530 x 21.1 = 261,144,783 MJ (1MJ = 0.2778 kWh) = 72,546,020 kWh = **72,546 MWH**

It appears that Sugar beet will produce more than twice the energy of wheat per hectare.
NOTE – Internet research indicates there is some debate about the energy balance of these crops.

26 - Source - Bioethanol Production - www.esru.strath.ac.uk/
27 – Energy balance - wheat – http://www.cropgen.soton.ac.uk/Agro-%20energetic.htm

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All annual crops need multiple tractor operations to plough, cultivate, sow, fertilise and harvest the crop. Go to http://www.cropgen.soton.ac.uk/Agro-%20energetic.htm for a detailed breakdown of energy inputs and outputs for wheat produced as an energy crop(27).

Summarising energy crops
A straightforward comparison of the four annual crops is difficult, whilst energy balance data is available for some crops it is not for all. It seems reasonable to assume that all annual energy crops will need multiple tractor operations to cultivate the crop so the energy balance for annual crops with a low yield may be marginal at best or even negative.

The efficacy of growing energy crops is far from clear. How is success to be measured – by the financial profit the crop may make, the ratio of energy output to energy input or by the amount of carbon released per kWh generated? Subsidies/grants may be necessary initially to establish a market but for a crop to be sustainable it must be financially profitable in its own right. A crop must have a positive energy balance otherwise it is better to use the energy inputs directly for another purpose. However it is the carbon balance that is crucially important, if climate change is to be averted the need is for energy that doesn't add to the carbon already in the atmosphere.

Purely from an energy balance perspective, Miscanthus appears to be the crop of choice. There will be multiple tractor operations in the first year to cultivate the ground, plant the crop and spraying to prevent weeds until the crop is established. But being a perennial crop, in subsequent years the only input will be the single tractor operation to harvest the crop. Anecdotal evidence suggests Miscanthus can survive in the same plot of ground for 20+ years.

Energy crops are generally regarded as 'carbon neutral', that is, they only release the carbon they absorbed when growing and therefore do not contribute new carbon to the atmosphere, but the energy capture per hectare is low.
Comparing the energy capture from energy crops with other renewable energy technologies: one hectare of Miscanthus (6.5.3 above) could produce 62,000 kWh/y, whereas one hectare of PV (6.1 above) could produce 1,250,000 kWh/y and a single 1.3MW wind turbine (6.4.2 above) could produce 2,867,400 kWh/y (and most of the land would remain available for planting).

6.7 Energy from Waste

The term 'waste' needs to be used with caution as nothing is wasted in nature. The by-products from one process are used as the raw material for the next. In this context waste is the collective name we call the organic material we no longer have a use for. It comprises the contents of our dustbins (after re-cycling), kitchen waste, human faeces, animal slurries, animal by-products and food processing wastes.

All organic material degrades quite naturally if oxygen is present, by what is known as an aerobic process, and is familiar to us as composting. If oxygen is excluded, by enclosing the process in a sealed chamber, the process is known as anaerobic. The advantage of using an enclosed chamber is that the by-products of organic breakdown (methane) can be captured easily. The methane can then be used as a fuel. If the source material is predominantly wet, a process of anaerobic digestion can be used. If the source material is predominantly dry a process of gasification can be used.

The waste streams considered here are
- Municipal solid waste (incl. commercial waste arisings)
- Animal slurries
- Sewage sludge

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6.7.1 Anaerobic Digestion (AD)

All Anaerobic Digestion processes rely upon naturally occurring bacteria and enzymes to break the source material down. Some bacteria work better at 35^0C and others better at 56^0C. The lower temperature bacteria take about 7 weeks to work, the higher temperature bacteria about 2 weeks but are fussier about the consistency of the feedstock.

There are a number of different proprietary solutions available each with advantages and disadvantages. AD works best with wet materials. Shown to the left is a system based on farm trailers adapted with pumps and a heater system.

Installation requirements	The basic requirements are the same for all anaerobic processes. You need a source of organic material. That material needs to be enclosed within an airtight chamber with oxygen excluded. The chamber must be heated and maintained at the chosen temperature for the required time. Feedstock that may contain harmful bacteria should be pre-treated by heating to 70^0C for an hour to pasteurise it. The residual heat can be used to start the digestion process. It is crucially important to ensure new feedstock added to the process does not contaminate feedstock already in the process to prevent untreated pathogens passing through the system.
Landscape impact	Although there are a number of different proprietary processes, they all need to have mechanisms for handling the material, chambers for the digestion process and chambers to hold the spent material before it is distributed. It is in effect an industrial process. Any impact on the landscape will be directly related to the size of the processing plant. One of the benefits of AD is that it can happen at a really small scale. Since organic waste is produced anywhere there is human activity and since energy is needed wherever we are it seems logical to consider a large number of really small AD plants in every community. This will have the effect that transporting waste materials from where they are created to a centralised processing plant can be avoided with a saving of the pollution caused by road fuel. The resultant methane produced by the process can be used locally.
Environmental impact	Methane gas is known to be about 21 times more damaging to the environment than CO_2. Therefore if all natural rotting process could be contained much of the methane that currently escapes to the atmosphere could be eliminated with enormous environmental benefit. When methane is burned as a fuel CO_2 is released but on a one-for-one molecule basis. Therefore although the CO_2 will cause some damage to the environment it will be significantly less than if the methane were simply allowed to escape. AD involves handling deleterious materials which could cause pollution so all AD processes need to be carefully managed and monitored to ensure safe operation. The Environment Agency (EA) will need to licence all AD plants
Planning permission	Being an industrial process, planning permission will be needed. It must be remembered that even at small scale, the gas that is being produced, methane, is highly explosive so it will be imperative that

	plant operation is carried out to the highest safety standards. It will be part of the planning process to ensure safety is built in to the process.
Scale	One company produces a small AD based on a wheelbarrow with $0.75m^3$ capacity. The photo above shows a 10 tonne farm trailer being used. The photo below shows the Holsworthy Biogas plant, which is much larger scale. Size needs to be related to the volume of material being processed as the digester will need to retain the material for up to 5 weeks. The volume of the digester will need to be about 40 times the volume of the daily supply of raw material.
Installation costs	These will depend upon the scale of the plant being considered. Much research and development is still in progress and as yet AD plant is being built on a site by site need. It is very difficult to offer a single figure as a representative cost of AD development.
Pay-back period	Anecdotal information suggests that at present AD is not cost effective as a process to produce energy. Disposing of animal by-products is currently a costly process as rendering plants charge a fee for their services. (Likewise the cost of disposing of municipal waste by landfill has a cost attached to it.) If AD were the preferred process it is thought that the value of the methane produced would not pay for the process so there would still be a need to charge a gate fee to dispose of unwanted organic waste. Using existing financial models AD seems more appropriate as a mechanism to dispose of waste rather than produce energy. However, organic waste is a fact of life, methane release from rotting matter is a fact of life, and our need for energy is a fact of life. It seems totally illogical to use energy to collect a potential energy source only to dispose of it centrally in a way that uses more energy than it saves.

Available Resource   Municipal waste
Statistics show 70% of waste arisings go to landfill and 30% is recycled or composted.(28)

Assumptions:

- South Hams domestic waste 44,802t less 11,281t recycled = 33,521t (29)
- Energy value = 9.5GJ/t (30)
- 33,521 tonnes x 9.5 GJ/t = 318,450 GJ
- 318,450 GJ (1GJ = 277.8 kWh) = 88,465,271 kWh = 88,465 MWH

However this is the value for raw Municipal Solid Waste (MSW) which is made up of kitchen waste and other dry waste such as paper. Historically MSW has gone to landfill where the organic matter breaks down in a natural process of anaerobic digestion to give landfill gas. However as landfill sites become full this is no longer an option. There is limited experience of using Anaerobic Digestion for MSW but an experimental AD pilot plant has recently been commissioned in Ludlow, Shropshire. AD is feedstock sensitive so kitchen waste is collected separately from other MSW.

The Ludlow experience suggests 4.2 kg of kitchen waste is collected per household per week. This had 77% moisture content and 23% dry matter. $140m^3/t$ of bio-gas was generated with a calorific value of $22MJ/m^3$. (31)
Source – www.greenfinch.co.uk/ludlow

28 – Source – www.defra.gov.uk/environment/statistics/wastats/index.htm
29 – Source – Devon County Council, Waste Management Strategy
30 - Source – www.defra.gov.uk/energy/inform/energy_prices/annex_b_mar04.shtml
31 – Source – www.greenfinch.co.uk/ludlow

As the Ludlow experience is the best available knowledge at this time, translating it to South Devon -
Assumptions:

- 34,810 households
- 4.2 kg/household/week
- feedstock = 34,831 x 4.2 x 52 = 7,607,090 kg/y = 7,607 tonnes.
- Energy value 7,607 x 140 m^3/t (bio-gas) = 1,064,980m^3 x 22MJ/m^3 = 23,429,560MJ (1MJ = 0.2778 kWh) 23,429,560 x 0.2778 = 6,508,731 kWh = **6,508 MWH**

Animal slurries
It is very difficult to assess accurately the available resource. The 2004 farm statistics [32] suggests South Devon has 56 Dairy holdings, 5 pig holdings and 16 poultry holdings. But whilst a figure of 68,000+ cattle is recorded for Devon as a whole, there is no breakdown of figures for the number of cattle in South Devon. Also no figures are available to describe how animals are housed and therefore how much slurry may be collected. It is therefore not possible to quantify how much animal slurry is available for digestion. The best guide available is to draw parallels with the Holsworthy Biogas plant.

Holsworthy Biogas Ltd. collects cattle slurry from 30 farms within a 20 km radius and food waste from food processing plants. South Devon has 56 dairy holdings so it should be possible to replicate the Holsworthy concept.

Holsworthy Biogas Plant [33] has two x 0.9 MW generators fuelled by the methane gas collected from the digesters. There is sufficient gas to maintain one engine working full time and the second engine part time.

The AD process is very effective in killing pathogens and weed seeds; the liquid digestate is available to be returned to the farm as a liquid fertiliser.

When the Holsworthy plant was originally constructed no heat distribution main was installed to transport the heat to the nearby town. Some of the heat produced was used on site to maintain the temperature of the digesters but the remainder was wasted. The economics of the plant relied solely on the sale of electricity to grid and the plant did experience financial difficulty and is now under new ownership. The lesson learned is that a load for the heat is needed for financial viability.

With hindsight it might have been better to physically separate the digestion process from the generation process. Slurry is collected from farms by road tanker, so to avoid traffic congestion close to habitation, the digestion part of the process is better located out of town but close to good road connections. The heat and power is needed in town so the CHP generating sets could be located in the midst of the community. The gas produced would be piped to the generators, it being easier and cheaper to pipe gas than heat.

The Holsworthy biogas plant is capable of producing up to **14,400 MWH/y**. It seems reasonable to assume a similar size plant could be installed in South Devon.

32 - Source – http://farmstats.defra.gov.uk/cs/farmstats/
33 – http://www.holsworthy-biogas.co.uk/ with animated graphics to explain process.

Sewage sludge
South West Water (SWW) is the authority responsible for disposing of human sewage. SWW already has in place a number of AD plants operating in South Devon. Pictured below are the digester tanks and CHP turbine at the Kilmington (East Devon) sewage treatment works but a similar plant is installed at Totnes sewage treatment works. Sewage sludge is collected from numerous small treatment works for processing at the larger sites.

Kilmington sewage treatment works – showing anaerobic digester tanks.

Kilmington sewage treatment works – showing gas turbine CHP. To give scale, the cabinet shown above is 2 m high x 3.5 m long x 0.75 m deep.

SWW sell the electricity to grid but due to the remote location of the sites, the heat is used on site to maintain the temperature of the digester. Overall SWW is a net consumer of energy across its many operations throughout the area.

Due to the possible risks of pathogen escape, it is suggested this is a technology best left in the hands of professionals so it is assumed there is little scope to develop energy generation from sewage sludge.

6.7.2. Gasification

Gasification and pyrolysis are advanced thermal processes for the disposal of any combustible material. Historically incineration has been used to dispose of waste however there have been concerns that combustion at normal burning temperatures releases dioxins as well as not making best use of the heat generated. Feedstocks include: municipal solid waste, refuse derived fuel, miscanthus, clinical waste, old tyres, sewage sludge cake, animal litter, animal by-products (rendered) and various plant residues such as palm oil husks.

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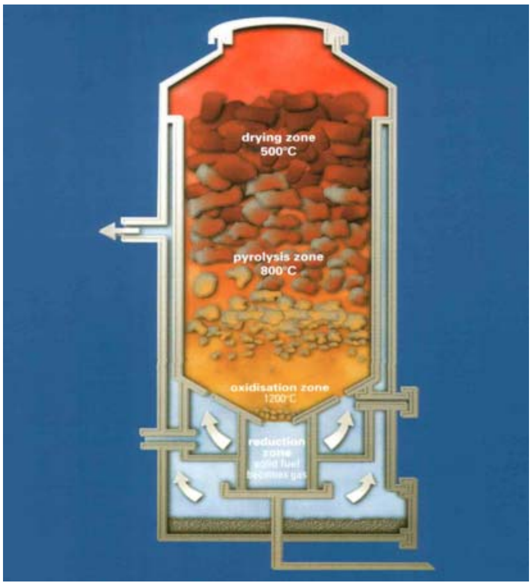


Gasification and Pyrolysis:

Gasification takes place where combustible material is heated up within a sealed chamber where most of the oxygen has been excluded. Incomplete combustion takes place so the gases given off still retain the ability to burn when they come into contact with a further supply of oxygen. The gases are piped away to be used as a fuel.

Pyrolysis takes place where combustible material is heated up in the complete absence of oxygen. The heating breaks down the material into its basic components some of which form the basis of a fuel.
Gasification and pyrolysis work best with dry materials. If wet material is used some of the energy is used to burn off the moisture before the process can start.

Installation requirements	This is in effect an industrial process and needs to be located where the feedstock can be stored and handled, implying access to transport. The process can be any scale and at least one company produces a complete processing plant in a standard shipping container. The module contains the hopper to accept the feedstock, gasifier, generator and grid connection controls.
Landscape impact	Any landscape impact will be directly related to the scale of the plant. A shipping container sized plant could easily be placed in amongst existing farm or commercial buildings, or the container could be installed inside an existing building thereby giving no visual impact at all. The only remaining issue will be how many vehicle movements may be necessary to deliver the feedstock to the plant
Environmental impact	This is more difficult to state as it depends on the feedstock used. It is perfectly possible to use clean organic material such as miscanthus, although it may be more economical to burn miscanthus like straw. If the feedstock is derived from Municipal Waste it could in theory contain any number of unpleasant things such as old batteries, which if heated to the temperatures required could release toxins. Quality control of the feedstock will need to be tightly monitored.
Planning permission	Planning permission will be needed. If small scale and a shipping container can be 'lost' amongst other buildings this is unlikely to be a problem. Large-scale plant is likely to be developed by the larger waste disposal companies and will form part of a wider waste management strategy. The Environment Agency will have an interest as in AD above.
Scale	In theory a gasifier can be constructed to any size but in reality economics dictate that certain sizes are viable and others not. Because gasification is an advanced technology there has been no demand for small-scale plant so none exists. One company does produce a turnkey gasifier complete with generator and grid connection all installed inside a standard size shipping container. Economies of scale could be achieved by replication if the concept of many small-scale plants were to become the accepted norm.
Installation costs	There is no small-scale 'off the shelf' gasifier unit available at the time of report. One company sells a standard 40' shipping container with 1MW generating capacity for £150,000

Pay-back period	Current experience suggests the economics are marginal. This is because waste is seen as something that has to be disposed of instead of being valued as a resource for its energy content.

Statistics show 70% of waste arisings go to landfill and 30% is recycled or composted[29].

Available Resource   Municipal waste
Assumptions:

- Referring to 6.7.1. above, the total amount of MSW collected (less recycled) is 33,521 tonnes. Of this 7,607 tonnes is kitchen waste and will be used in the Anaerobic Digestion process as described above leaving 25,914 tonnes available for gasification.
- Energy value = 9.5GJ/t [30]
- 25,914 x 9.5 = 246,183GJ (1GJ = 277.8 kWh) = 68,389,637 kWh = **68,390 MWH**

Available Resource   Commercial waste
Assumptions:

- 10,000 tonnes of mixed waste is collected from all commercial properties in South Devon. (Source – South Hams District Council – Waste management.)
- It is not known what proportion is recycled but assumed the same proportion of commercial waste is recycled/composted.
- Available 7,000 tonnes
- Energy value = 9.5 GJ/t [30]
- 7,000 x 9.5 = 66,500 GJ (1GJ = 277.8 kWH) = 18,473,700 kWh = **18,473 MWH**

There will be other feedstocks available such as construction industry waste, abattoir waste (animal by-products) but data is not available.

6.8 Combined Heat and Power

Combined heat and power (CHP) is a generic term used to describe a process that produces energy in a more efficient way. CHP is not a renewable energy technology. When any combustible fuel is burned the primary energy given off is heat. The heat can either be used to drive a diesel generator or to heat water to make steam to drive a steam turbine. Without going into the theory of thermodynamics, approximately ⅓ of the energy in the primary fuel is converted into power whilst ⅔ remains as heat. Heat can be transmitted in the form of hot water in pipes as in a central heating system, but the water eventually loses its heat even when the pipes are insulated. The power can be transmitted many miles in the form of electricity along power lines. The further electricity is required to travel, the more power is lost. Unless there is a use for the heat close to the power station, the heat is frequently wasted as is seen by the large cooling towers (see diagram at section 3.1 above).

CHP seeks to overcome the inefficiencies inherent with centralised power generation by installing a smaller scale generating plant close to where both heat and power are needed. Any combustible fuel source can be used, so it is perfectly possible to have a logwood, wood chip or pellet boiler to heat water to drive a generator, and the residual heat used in nearby properties. Likewise, oil or gas can be used to power an engine to drive the generator and the heat can be piped to nearby properties.

New CHP gas boilers are becoming available for domestic properties and may be worth considering if a property is on the gas grid and the old boiler needs replacing. However grid gas fuelled CHP is not renewable energy, simply a more efficient way of using fossil fuel.

34 – Source - www.bedzed.org.uk/main.html

The photo shows the CHP plant at Bedzed in South London. The fuel is waste timber from the construction trade and arboreal waste from maintaining London's trees. The plant has been sized to supply all the electricity needs so when demand is low the surplus is sold to grid.

See www.bedzed.org.uk/main.html [34]
Go to Google images for photo.

Installation requirements	This depends on the fuel source being used and the scale of the plant. If a mains gas domestic CHP boiler is being installed, the requirements are the same as the old boiler it replaces. If a district heating system is under consideration, then a boiler-house will need to be built and its size will be commensurate with the size of the boiler. If a wood fuel system is being considered then there will be a need to store a supply of logs or wood chips/pellets. Most modern wood chip/pellet boilers are now fully automated.
Landscape impact	A mains gas domestic CHP boiler is unlikely to have any landscape impact. A wood fuelled system will by implication need a source of wood and this may have an indirect landscape impact in that the timber crop may have to be grown to ensure a sustainable supply of fuel.
Environmental impact	Because CHP uses fuel more effectively it is almost certainly the case, no matter which fuel source is used, that greenhouse gas emissions will be reduced. If wood fuel is used then a further benefit is enjoyed because the carbon emissions will be only those that the timber crop absorbed whilst growing. If more woodland is planted to cater for any increase in demand for wood fuel, there could be further environmental benefit.
Planning permission	Not likely to be required to replace an existing domestic boiler with a CHP boiler. Where a new CHP boiler-house and/or wood fuel store is needed such as for a district heating system then almost undoubtedly – yes.
Scale	CHP plant can be individual dwelling size or community size serving hundreds of homes through the grid and a district heating system.
Installation costs	Costs vary depending on the type of system installed. A domestic CHP boiler may cost £2500. A large district heating system CHP boiler may cost tens of thousands. No general figure can be quoted as costs will be site specific.
Pay-back	Pay-back periods will depend on circumstances. At a domestic level micro-CHP boilers will be a direct 'drop in' replacement for conventional boilers. At community level CHP could prove very economical in urban areas where the housing density is sufficient to make good use of all the heat and power generated. However in rural areas, where housing density is lower the economics may be more marginal. If de-centralised AD or gasification is adopted it may be more economical to pipe the bio-gas (methane) produced back to the nearest large habitation for use in a community CHP system and district heating scheme. (See schematic at 8.2)

Available Resource
CHP is not a renewable energy technology. That is, it doesn't harness *new* energy from the environment. Rather CHP is a conversion technology able to make better efficient use of other renewable energy sources.

Technology	para	MWH	Fuel type	Use
Wood fuel	6.5.1	36,980	woodchip	Biomass CHP boiler
Miscanthus*	6.5.3	123,566	straw	Biomass CHP boiler
AD (MSW)	6.7.1	6,505	Methane	Co-firing
AD (animal slurry)	6.7.1	14,400	Methane	CHP engine
Gasification (MSW)	6.7.2	68,400	Methane	CHP engine
Gasification (Comm.)	6.7.2	18,473	Methane	CHP engine
Total		268,330		

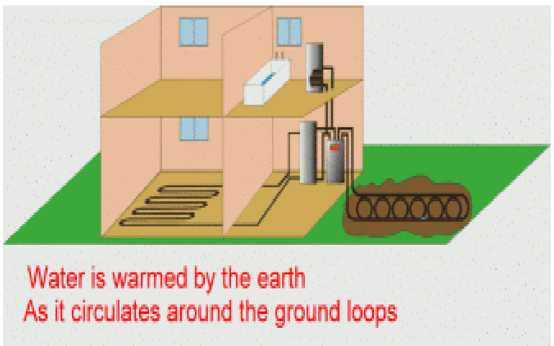
* NOTE it is assumed that Miscanthus is the preferred energy crop.

Assuming the CHP plant is 90% efficient, 242,397 MWH of energy will be delivered. Of this 161,598 MWH will be delivered as heat and 80,799 MWH will be delivered as electricity. (This is not new energy so is not counted towards the available renewable energy resource.)

6.9 Heat Pumps

A heat pump can be likened to a refrigerator working in reverse. A closed loop of pipe contains a liquid that evaporates and condenses at low temperature. One side of the loop may be buried in the ground (ground sourced heat pump – GSHP), placed in a stream of flowing water (water sourced heat pump – WSHP) or be placed in a stream of moving air (air sourced heat pump – ASHP), where it collects a large quantity of low temperature energy from its surrounding. The pump that circulates the liquid around the loop compresses the liquid and delivers a smaller quantity of high temperature liquid where the heat is needed. The cycle is then repeated.

Depending on the level of temperature rise needed, it is possible for a 1 kW pump to absorb and deliver up to 4 kW of heat from a low grade temperature source to a heating system. Heat pumps are a renewable energy technology because, although they need an external source of energy to power them, they collect solar energy from the ground, water or air.



The illustration shows a schematic of a ground-sourced heat pump. A coil of plastic pipe is buried about 1-2 metres below the surface of the ground. It requires about 100 metres of trench to collect enough heat. If insufficient space is available the loop can be installed in a vertical borehole about 150 metres deep. The other side of the loop, in this case, is seen as loops of underfloor heating pipe. The energy can also be used to heat the hot water tank.

Installation requirements	An independent power source is needed to operate the heat pump and a supply of low-grade heat which may be from underground, flowing water or from the air.
Landscape impact	Generally there will no landscape impact at all because everything is

	hidden from view. If horizontal ground loops are used then it will be necessary to dig trenches to bury the coils. However the soil soon recovers when re-seeded; within six months it will not be possible to know there is a heat pump installation nearby at all.
Environmental impact	Because heat pumps collect low-grade heat from the surroundings there may be some concerns that soil temperatures are being lowered. If a system is well designed and the heating coils are large enough the collection takes place over a wide area, so this should not be a problem. It is possible in the summer to use a heat pump in reverse, i.e. house cooling can be achieved by pumping heat back underground and heating the ground back up ready for winter. (However it may be more eco-friendly simply to open the windows on a hot day.) With a water-sourced heat pump care is needed to ensure that coils in a lake or stream cannot get damaged as leaking refrigerant liquid could damage the environment.
Planning permission	For most domestic situation where coils will be underground and hidden, it is unlikely planning will be needed. If you need to build a separate compartment to house a heat pump then maybe.
Scale	The system can be any size necessary. In the case of a very large system it may be necessary to drill a number of boreholes
Installation costs	Costs vary depending on the type of system installed. A domestic heat pump system may cost between £4,000 to £12,000 depending on the size of system required. NOTE – It will pay dividends to insulate a property thoroughly before installing a heat pump. More money spent on extra insulation could mean a huge saving on a smaller heat pump. Perversely if a building is very well insulated it may be cheaper simply to install a small electric fan heater at much greater saving again. *Heat pumps are best suited to 'difficult to heat' buildings where after insulating to the highest standard possible there is still a large heat load*.
Pay-back	This will need to be calculated by careful understanding of the heating load of the building and depends upon the existing heating method. A building that relies on grid electricity for its heating will pay back sooner than one using mains gas.

In theory every property could be equipped with a heat pump, but it makes sense to insulate a property first so as to reduce the heat demand. Heat pumps need a significant amount of supporting infrastructure and an external energy source. If a building is sufficiently well insulated its heat load may be so low that a simple electric fan heater may be the best economic solution, particularly if the electricity comes from renewable sources. Alternatively, if a property has a sustainable source of wood fuel it might be more economic to heat with a log stove or boiler. In practice heat pump technology is better suited to modern new build with high-energy efficiency and 'hard to heat' buildings or buildings which only have grid electricity available. In this instance a heat pump could provide up to four times more heat energy than by conventional electric heating.

Heat pumps could be fitted to most buildings but may be better suited as an option for all new build dwellings and commercial/industrial properties and those properties where due to the nature of construction it is impossible to achieve a high degree of insulation, so there will always be a

35 – Source – www.dunsterwoodfuels.co.uk Calculation sheet for heat loads: 3 bed semi uninsulated = 11 kW. 3 bed semi insulated = 6 kW See section 7 below for benefit of insulation.
36 – Source www.defra.gov.uk/environment/business/envrp/gas_05.html

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significant heat load. It is impossible in a survey at this level to assess how many properties fall into the latter category.

Available Resource

Assumptions:

- Half of all properties are suitable for heat pump installations = 34,831 ÷ 2 = 17,415
- All properties are fully insulated so heat load is reduced to an average of 6kW per home(35)
- Heat load = 17,415 x 6 = 104,490kW
- Heating will be needed for 6 months per year (8760 ÷ 2 = 4380 hours)
- Using a Coefficient of Performance (COP) of 4 the 104,490 kW could be supplied by 26,122 kW power.
- Energy use = 26,122kW x 4380h = 114,414,360 kWh = 114,414 MWH (114.4 GWH)
- Renewable Energy gain (energy saving) = 104,490 – 26,122 = 78,368 kW x 4380h = 343,251,840kWh = **343,252 MWH**

Costs – assuming a bulk contract can be negotiated for a number of systems @ £6,000 per installation - 17,405 x £6,000 = £104,700,000

6.10 Summary of outputs

This section summarises the outputs from 6.1 to 6.9 above.

Technology	Para	Energy capture MWH/y	Energy capture MWH/y (not countable)	CO_2 Saved * @ 0.43 kg/kWh
Photovoltaics	6.1	58,776		25,274 t
Solar Hot water	6.2	87,078		37,444 t
Micro-hydro	6.3.1	3,884		1,670 t
Tidal lagoons	6.3.2	64		28 t
Marine current	6.3.3		3,570	
Wave energy	6.3.4		963,000	
Small wind	6.4.1	2,000		860 t
Large wind	6.4.2	25,803		11,095 t
Offshore wind	6.4.3		Not calculated	
Woodlands	6.5.1	36,980		15,901 t
Short RC	6.5.2	66,439		
Miscanthus	6.5.3	123,566		53,133 t
Oil seed rape	6.6.1	30,508		
Bio-ethanol (wheat)	6.6.2	30,381		
Bio-ethanol (beet)	6.6.2	72,546		
AD kitchen waste	6.7.1	6,505		2,797 t
AD slurry	6.7.1	14,400		6,192 t
Gasification (MSW)	6.7.2	68,400		29,412 t
Gasification (Comm)	6.7.2	18,473		7,943 t
CHP	6.8		Not calculated	
Heat pumps	6.9	343,050		191,749 t
Sub total (MWH)		788,979	966,570	
Sub total (GWH)		789 GWH	967 GWH	
Total (GWH)		**1,756 GWH**		

NOTE – figures in red are alternatives. It is assumed that Miscanthus will be the preferred energy crop because of its better energy balance and ease of cultivation/harvesting.

*The amount of CO_2 saved depends on which primary fuel is being replaced. Coal, gas and oil each give off differing amounts of pollutant per kWh generated. The figure 0.43 kg/kWh is the figure used by DEFRA for grid electricity(36) and reflects the present % mix of primary fuels used.

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If the balance of primary fuels changes appreciably in the future this figure may need to be revised.

If all shore-based technologies are developed as indicated above 789 GWH of energy might be generated. From 3.3 the energy demand is determined to be 2,604 GWH. It therefore appears about 30% of South Devon's energy demand could be generated by renewable energy within the constraints described in the text, with a saving of 191,749 tonnes of CO_2 emissions per year.

7. Energy Efficiency

It is clear from section 6.10 above that to generate enough energy to meet current energy use will require a huge investment over many years. Reducing our energy demand by investing in energy efficiency is an essential prerequisite to introducing renewable energy, and will have a double benefit:

1. A 'one-off' investment in energy efficiency will continue to save energy indefinitely
2. This will then reduce the capital investment needed for renewable energy infrastructure, due to the reduced energy demand to be met.

'Energy efficiency' covers a wide range of measures, from switching to a condensing boiler to switching off a light. The availability of grants for cavity wall and loft insulation has seen many Devon home owners take up this option, reducing space heating demands. Low energy lighting options are essential to cut our energy use for lighting from 2% to 0.4% - very worth while and resulting in a saving for the householder of £7 per year per lamp, for an outlay of as little as £2. Other energy efficiency measures include double-glazing, draught-proofing and changing to energy 'A' rated appliances. However, it should not be forgotten that simple things like switching off appliances as soon as they are no longer required can save energy and costs nothing. Approximately 10% of all energy could be saved simply by changing people's behaviour and switching off unwanted appliances.

To what extent can energy efficiency reduce our energy demand?
Referring back to para 3.3 above (on local energy demand and supply)

Annual domestic energy consumption by end use for an average 3 bed semi-detached house -

All energy use	80.8. GJ	x 277.8	22,446 kWh
Space heating	50.0. GJ	x 277.8	13,890 kWh
(1 GJ = 277.8 kWh)			
34,810 households		x 22,446	781,345,260 kWh
		total energy use -	**781.3 GWH**
For space heating			
34,810 households		x 13,890	483,510,900 kWh
		space heating load -	**484 GHW**

(Note 9 – Source: Domestic Energy Fact File 2003)

It is immediately apparent the largest single use of energy is in space heating and this is where the best possibilities for energy efficiency occur.

There are a number of internet-based worksheets to calculate space-heating demand. The worksheets take the reader through a number of steps to give the size of boiler needed for a specific property. If the process is undertaken for two identical properties, one with no cavity or

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loft insulation and the second with full insulation, a comparison can be made to show the savings resulting from insulation.

Example:
Using a three-bedroom semi-detached house measuring 8m x 7 m, UPVC double-glazed and maintaining an indoor temperature at 21^0 C whilst the outside temperature is 0^0C -

An uninsulated property will need an 11.5 kW boiler
An insulated property (cavity wall insulation and >75mm loft insulation) will need a 6.1 kW boiler. A saving of 5.4 kW or 53%

Note: these figures are based on the heat load for the property and are independent of the method of heating. Different types of fuel and the associated heating appliance will give rise to different heating costs and different levels of carbon emissions, but the heat load will depend on the size of the building and its construction.

Source: www.dunsterwoodfuels.co.uk/energy/boilersizewpdf.pdf

Available energy savings assumes:

- 90% of all dwellings are capable of being fully insulated
  (34,810 x 90% = 31,329)
- Space heating energy consumed by 31,329 dwellings x 13,890 kWh =
  435,159,810 kWh x 53% saving = 230,634,699 kWh **=**
  230.7 GWH energy reduction through maximising insulation

To answer our initial question, "to what extent can energy efficiency reduce our energy demand?" we can calculate the energy efficiency measures as follows:

▪ **Total energy demand**	**781.3GWH**
▪ minus behaviour changes (10% of total consumption)	78.1GWH
▪ minus lighting saving (80% of 2% of total consumption)	12.5GWH
▪ minus insulation measures saving	230.7GWH
▪ **Remaining total energy demand:**	**460GWH**

……….a considerable reduction from our initial energy loads.

This calculation highlights the significant savings in energy consumption to be achieved through energy efficiency. Once energy efficiency has been maximised and our energy demand has been reduced as far as possible, there remains a need to generate energy without creating carbon emissions. *Energy efficiency is vital to maximise the value, and therefore the viability, of renewable energy.*

Details of grants and discount schemes for lofts and cavity wall insulations and all other aspects of energy efficiency can be found at the Devon Energy Efficiency Advice Centre. Householders can phone 0800512012, email info@devon-energy-advice.co.uk, or go to http://www.devon-energy-advice.co.uk

7.1 Existing housing stock

The 2001 census indicates there are 34,831 houses in South Devon. National statistics suggest that less than 0.5% of our housing stock is being replaced each year. On this basis it will take over 200 years to replace our housing stock with properties built to the most recent insulation standards. In other words our future housing is already here. It is impractical and unsustainable to re-build otherwise sound houses, so a 'sustainable refurbishment' programme is needed to improve the energy efficiency of existing houses. (*Housing consumes 52% of UK energy demand and provides a quarter of CO_2 emissions.)*

Whilst there has been a steady improvement, requiring higher standards of insulation, even Part L of the most recent Building Regulation updates could be further improved. It seems very short-sighted to continue to allow the construction of new dwellings that consume more energy than they need. At the design stage it is an easy matter to incorporate features such as high insulation, passive solar gain and heat recovery ventilation and should be considered in every case as a matter of course rather than as something special.

7.2 New Build - Sherford New Town

Sherford is a major urban extension to be built in the South Hams, east of Plymouth, which is being designed to function as a sustainable new community. The development is the size of a small market town and will be built over a period of 10-15 years. On completion it will provide for a population of some 13,000 people in a mixed use development containing community services, infrastructure, housing, employment, retail, education, health and leisure needs required by a town of this size.

The Local Authority's aspirations for the new community are to achieve high social, economic and environmental sustainability in a high quality design standard. This will include low energy demand and CO_2 production and a high proportion of energy demand supplied from on-site renewable sources.

The developers, Red Tree, (working in collaboration with the Prince's Foundation - designers involved with Poundbury, Dorset and Upton, Northamptonshire) share these aspirations and have engaged a sustainability consultant to advise on methods of minimising energy requirements and maximising the use of renewable energy. A number of workshops have been held with stakeholders and experts in the field and some study work has been commissioned. A report of findings is awaited but initial indications suggest that reducing energy demand (in line with new Building Regulations and further aspirations of the developer) actually works against the aspiration to achieve a district heating scheme. Further work continues to assess the most effective ways in which renewable energy can be generated to minimise the carbon footprint of the development.

The energy demand and CO_2 generation from construction of the town is also being carefully examined and it is intended that design life standard of 300 years will be applied to all buildings. The Buildings Research Establishment's EcoHomes standard of 'Excellent' is being required for all dwellings and BRE are also carrying out a town wide assessment of the proposal.

The design also seeks to reduce transport generated CO_2 by making Sherford as self contained as possible. It will incorporate permeable walkable neighbourhoods (with centres providing daily needs), employment uses mixed in with housing to reduce commuting and the provision of a high quality high capacity public transport service from Sherford to Plymouth city centre to reduce the need to use private transport.

37 –Source – World health Organisation
38 –Source - http://www.devon-energy-advice.co.uk/
39 - Source – http://www.jrf.org.uk/knowledge/findings/housing.n11.asp

7.3 Affordable Warmth - Fuel poverty alleviation

Fuel poverty is defined as a household needing to spend more than 10% of its disposable income on energy requirements. After the energy sector de-regulation in the late 1990's energy prices dropped and the numbers of peopled deemed to be in fuel poverty fell steadily. Latterly energy prises have started to rise steeply, at a rate far steeper than any cost of living rises. It is likely that the numbers of households experiencing fuel poverty will be increasing. (Because the most recent large rises in fuel costs are so recent, no statistics are yet available.)

Affordable warmth is essential for healthy living. There is a clear and well-established correlation between health and temperature. The ideal healthy temperature for a sitting room is accepted to be 20 – 21^{0}C. Between 16 – 19^{0}C there is an increased risk of respiratory disease. Between 10 – 15^{0}C there is an increased risk of heart illness. At temperatures of 9^{0}C or below there is a risk of death by hypothermia.[37] Winter mortality rates are known to rise by 2% per degree centigrade below temperatures of 19^{o}C.[39] Those most at risk are children, the elderly, the disabled and the chronically sick. Various programmes exist to help those experiencing fuel poverty[39].

7.4 Grant funding

Grant funding

The 'Clear Skies' funding stream for renewable energy projects closed in March 2006. As of April 2006, Clear Skies has been replaced with the **'Low Carbon Building Programme'** (LCBP). The LCBP has funding streams for large commercial developments, new build and private individuals; grants are available for all the renewable energy technologies. For private dwellings to qualify a house MUST have first reduced it energy demand by having;

- A minimum of 270mm of loft insulation
- Be cavity wall insulated
- ALL lights must be low energy
- Heating systems must have temperature controls

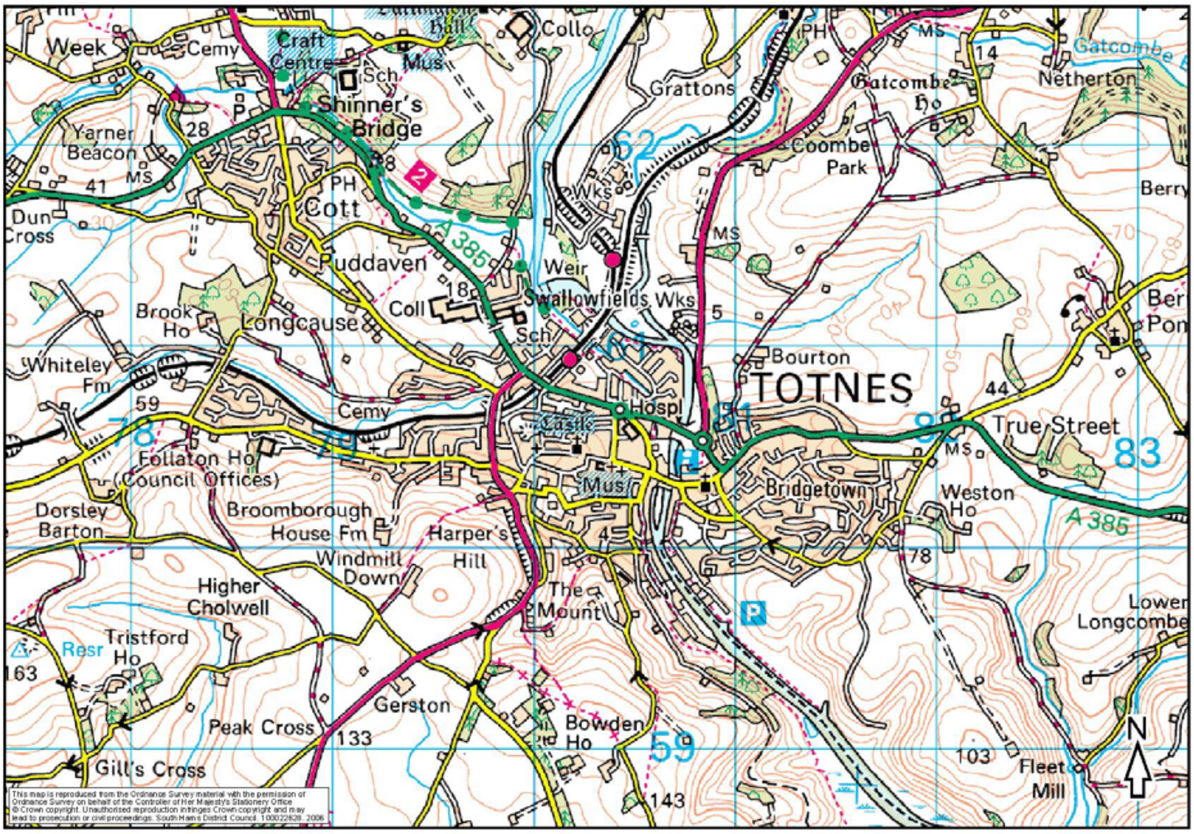
Renewable energy installations must be undertaken by accredited installers and the LCBP will only fund a % of the cost up to a maximum amount. For further details go to; http://www.est.org.uk/housingbuildings/funding/lowcarbonbuildings/

Devon Association for Renewable Energy 12a, The Square, North Tawton, Devon EX20 2EP
Tel. 01837 89200 Web. www.devondare.org E mail. admin@devondare.org

8 Local Application of technologies

8.1 Totnes and District

Considering Totnes and the immediate surrounding area, which renewable energy technologies could have direct application?



Totnes occupies a site where the River Dart has eroded a narrow gap through a range of low hills. Coincidentally this is the upper tidal limit of the river and the hills either side of the gap made an easily defendable place. A castle was built overlooking the river on the west bank and the town grew up below the castle. Totnes became a thriving commercial centre.

Today the topography effectively divides the town into three areas.

1. The town centre occupies land to the west of the River Dart. Most of it is at low level adjoining the flood plain. The old part of the town rises to the west on a hill that is for the most part east or north east facing. Although this part of town does receive sunshine the northeasterly aspect means the sun strikes at an oblique angle during most of the winter creating deep shadows.
2. Bridgetown occupies land to the east of the River Dart. Again on a steeply rising hill but with a south westerly facing aspect. This part of Totnes receives good exposure to solar radiation.
3. A long strip of development extends to the west from the town centre towards Follaton. There is high ground to the south so this entire area is at the bottom of a north-facing slope. The area does receive sunshine but in the winter the sun strikes at an oblique angle and shadows will be deep.

The steepness of the valley sides means that there will be some properties that get good exposure to the sun and others that experience deep shadows. From a solar radiation point of view most of the properties in Bridgetown will receive a good solar income whilst in the town centre and the Follaton areas individual properties may be well placed whilst others may not.

Each property will need to be assessed individually. Part of the town centre is a Conservation Area so the fact that many properties may not be able to access solar radiation may minimise the disadvantage.

Totnes domestic energy demand
Totnes parish households = 3831 [(40)]
Assume all are fully insulated

All energy use	80.8 GJ	x 277.8	22,446 kWh
Space heating	50.0 GJ	x 277.8	13,890 kWh

Source – Domestic Energy fact File 2003

(1 GJ = 277.8 kWh)

All energy use less space heating	30.8 GJ	X 277.8	8,556 kWh
Assume fully insulated (53% reduction in space heating) 50.0 GJ x 53% =	26.5 GJ	X 277.8	7,361 kWh
All energy use (fully insulated)			15,917 kWh
Totnes domestic energy use = 3831 x 15917 =			60,978,027 kWh
			60,978 MWH

Photovoltaics and solar hot water have similar siting requirements so individual properties will be able to benefit but not all. It will be necessary to carry out a more detailed study of all the buildings in the town to accurately assess the potential for either technology. Given that even buildings with a less than ideal orientation to the sun can benefit from some solar gain (see solar sundial – appendix 2) most properties should be able to install some PV and SHW.
PV assume 3000 properties can install 2kW$_p$ (see 6.1 above) = 3000 x 2 x 750 = 4,500,000kWh = **4,500 MWH** SHW assume 3000 properties can install 3m^2 each producing 2,820 kWh/y (see 6.2 above) = 3000 x 2,820 = 8,460,000kWh/y = **8,460 MWH**
Micro-hydro – Just above the town a large weir at Swallowfields marks the upper limit of the tidal section of the River Dart. The weir feeds a large leat that leads into the town centre. There is an old mill site close to a supermarket car park but the leat is far too large to serve that mill alone. According to the Salford Study (see 6.3.1. above) Swallowfields weir could support a micro-hydro scheme with an installed capacity of 196 kW producing an annual energy capture of **887 MWH**.
Windpower - In the town (bottom of the valley) the average wind speed is 4 m/s. This is too low for the economic use of wind power at either small or large scale. However the town is surrounded by hills that would afford suitable sites for large-scale wind turbines. To the south west of the town centre is 'Windmill Down', a name that may give an indication of its former designation. Windmill Down enjoys an average wind speed of 7 m/s at 45 m above ground level; this is an economic wind speed so it would be possible to install a number of large wind turbines around Totnes. Say a cluster of three 1.3 MW turbines (see 6.4.2) 3 x 2,867 = **8,601 MWH**.
Woodlands - Within the limits of the town there is little space for growing energy crops so the town will need to rely on woodfuel brought in from the surrounding countryside.

Energy from waste the town has 3831 dwellings. Using data from 6.7.1 above kitchen waste for use in an AD plant: 3831 x 4.2kg/week x 52 = 836.6 tonnes of kitchen waste/year x 140m^3/t =117,124m^3 methane x 22MJ/m^3 = 2,576,728 MJ (1MJ = 0.2778 kWh) = 715,815 kWh = **715.8 MWH**.
Commercial waste arisings: it has not been possible to get a breakdown of commercial waste from Totnes town but on a per capita basis it is estimated about 1375 tonnes are available.
1375 x 9.5 GJ/t = 13062.5 GJ (1GJ = 277.8 kWh) = 3,628,762 kWh = **3,629 MWH**
There is no data on how much waste vegetable oil (WVO) is available.
Sewage sludge – SWW already digests sewage sludge and use a CHP unit, there are unlikely to be any further gains here.

40 – Source - www.devon.co.uk/dris/houses/sh_hsebp.html

CHP – The methane produced by domestic kitchen waste and commercial waste could be piped to a CHP unit close by the town. The CHP unit will to some extent conflict with the heat pump technology (see next paragraph below) as both will produce heat. It will be a matter for a detailed technical study to determine the optimum mix of technologies. It may be that both technologies can co-exist, as the heat load will vary across the seasons and use of two technologies will offer flexibility in meeting the demand.
Heat pumps – buildings in the centre of Totnes are densely packed so there is little scope for ground sourced heat pumps using horizontal collector coils. However many properties could accommodate boreholes within their curtilage. Where an individual property does not have enough land to install a bore hole it may be possible to get a way-leave to drill a borehole on land adjoining (even in the road). Where this proves impossible it will still be possible to install an air sourced heat pump. It is therefore assumed that most properties could access heat pump technology in one form or another. For those properties within the Conservation Area this could be the ideal solution as the equipment will not be visible. If all properties are fully insulated the heat load could be reduced. 3831 fully insulated dwellings will use 53% of the energy of otherwise uninsulated properties (= 7361 kWh/household) If the heat pump operates with a COP of 4 this could reduce the energy demand to 7361 ÷ 4 = 1840 kWh/household) for 3831 households = 7,049,040kWh = 7,049 MWH So for 7,049 MWH of energy consumed to power the heat pumps, 28,196 MWH of heat could be delivered. i.e. a gain of (28,196 – 7,049) = **21,147 MWH**

Totnes domestic energy consumption =	60,978 MWH
PV	4,500 MWH
SHW	8,460 MWH
Micro-hydro	887 MWH
Wind Power	8,601 MWH
Energy from waste AD	716 MWH
Energy from waste (commercial)	3,629 MWH
CHP	
Heat Pumps – solar gain	21,147 MWH
	47,940 MWH

It appears that if all properties were fully insulated thus reducing the energy demand, all properties were installed with PV and SHW, micro-hydro at Swallowfields weir were to be fully developed, all kitchen and commercial waste were converted to energy, and the heating load supplied by heat pumps, then about 80% of the town's domestic energy needs could be met from within its own boundaries. Further energy saving measures - woodfuel from surrounding areas and possibly energy from wind turbines - will be needed to supply the needs of commerce and transport.

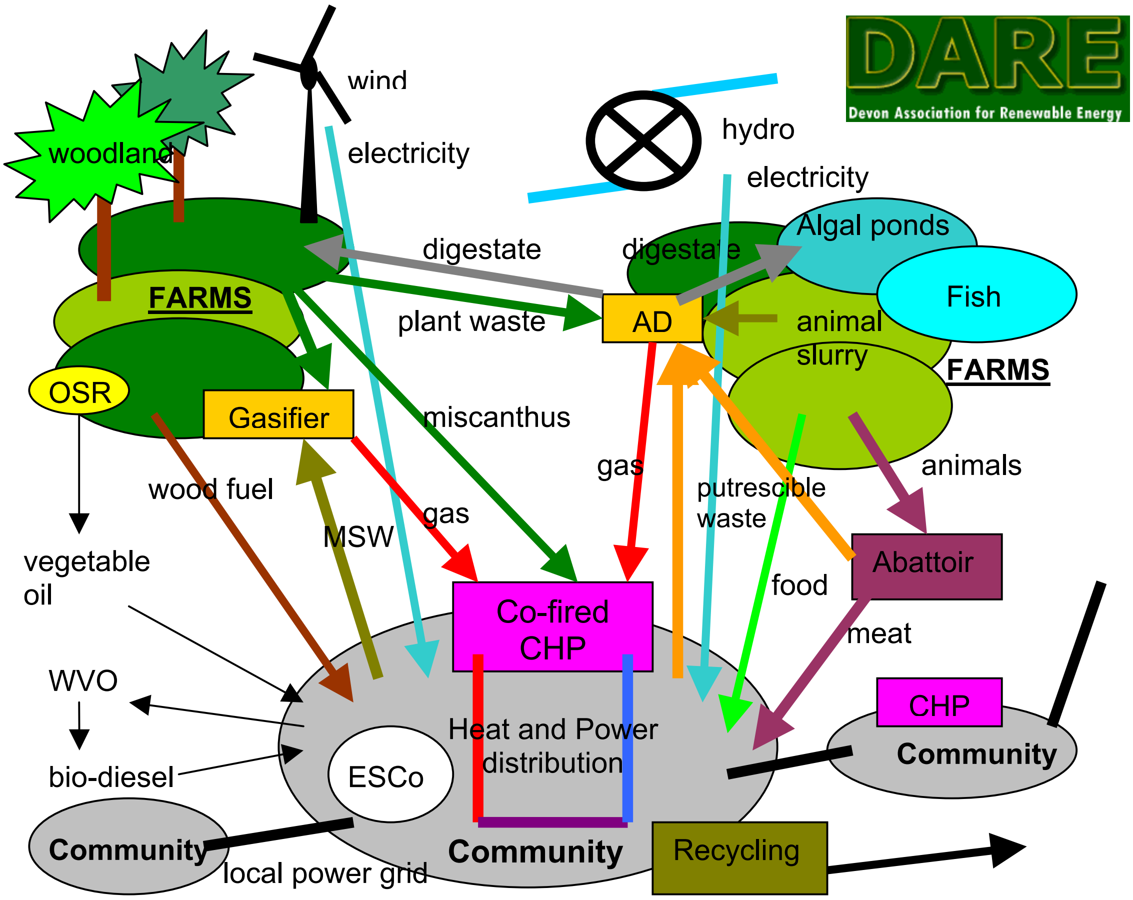
8.2 Farming

Farming, the primary industry throughout South Devon, has undergone major changes over recent years. It is not the purpose of this report to recommend a strategy for farming but it is evident that a number of renewable energy activities are compatible with farming practice.

The schematic below shows a possible future scenario. Farms, Market gardens and Smallholdings are widespread throughout the area so are always close by habitation. They produce food, energy and waste; humans need food, energy and also produce waste so this allows a number of virtuous circles to be formed. Dairy, pig and poultry units have the capacity to generate quantities of animal wastes that could become the feedstock for AD systems. A network of small AD plants could be established on farms to deal with the 'on farm' waste and the organic waste from the local community. The gas produced could be used to power a small community

CHP plant to supply heat and power to the local community via a heat distribution main. This would create local jobs and the additional benefit that waste would not need to be transported to centralised processing plants. The digestate from AD plants will act as a valuable fertiliser and or could be used as nutrients for algal ponds. The water, once cleaned, could support fish farms.

Farms could use set-aside land to grow energy crops. OSR could be processed on farm to produce cooking oil for farm gate sales. The used coil could then be re-processed into bio-diesel. Miscanthus could be used as feedstock for biomass fuelled CHP. Woodlands could be managed to produce sustainable wood fuel either as logs, wood chips or pellets.



Local energy flow between community and farms

Dry MSW could be used as a feedstock for a gasifier. Again because the population is dispersed throughout the area and farms are widespread, farms offer the ideal venue to accommodate a small-containerised gasifier to deal with local waste. The gas formed could be used to power the community CHP plants already referred to above. Adjoining communities could be linked by a local power grid so that temporary shortages or surpluses can be exchanged. The schematic diagram is not intended to be prescriptive but illustrates a multi-facetted approach to using recycled resources.

The word 'waste' becomes redundant; there is no such thing in nature, everything is recycled. No doubt changing prices for primary fuels will impact on the economics of such a de-centralised concept. It will need further research to prove the technical feasibility and it will take time for confidence to grow to accept this as an economic and safe method of disposing of a range of wastes. The Environment Agency will have an interest to ensure safety. Farms will become central to local 'sustainability'. Locally owned energy service companies (ESCo) could play a crucial role in developing local renewables and help retain the wealth within the community.

8.3 Tourism – campsites

Tourism is another important industry across South Devon (South Hams has Green Tourism Beacon Council status) and tourist numbers reach a peak in the summer when solar energy is at its highest. The provision of hot water is the largest energy consumption for campsites and SHW could make a valuable contribution to reduce costs and energy use.

8.4 Community – Totnes & District Sustainability Group and Totnes Energy Descent

Totnes has a number of community groups actively looking for alternative solutions to deliver a sustainable society. The Totnes and District Sustainability Group is a working group under the Market & Coastal Towns Initiative, and this report is their first project. TDSG strongly supports all local sustainability initiatives and looks forward to the new South Hams Sustainable Community Strategy.

TDSG is giving its full backing to the forthcoming Totnes Energy Descent project, evolved from a pilot first developed in Kinsale, West Cork, Ireland. The "Kinsale Energy Descent Action Plan" was the world's first attempt at designing a timetabled pathway down from the 'peak' of oil consumption where we find ourselves now, to a more energy-scarce future, in such a way that the change is seen as a positive transition. The Plan utilised innovative community participation tools and visioning work and the model demonstrated in the final plan has been adopted by communities around the world.

The Totnes process, beginning in Autumn 2006, will build on the lessons learnt in Kinsale and will urge that a process of relocalisation will be the only feasible response to the current dependence on fossil fuels. Food, energy, waste, livelihoods, housing, economy and more will be explored and solutions and mechanisms set out, the whole grounded in extensive community consultation. For more information and to download the Kinsale Energy Descent Action Plan, visit www.transitionculture.org.

9 Barriers and Opportunities

Barriers

- Public apathy/attitudes – There is increasing evidence that public attitudes are changing. DARE has experienced an increased number of enquires across all technologies. Indeed this report has been commissioned by a community group concerned about energy issues.
- Local Authority policies – The lack of any strategy to deal with energy provision in the future is a serious issue that needs to be addressed
- Costs – Costs continue to be a major disincentive to the uptake of renewable energy technologies but it is no coincidence that the upsurge in enquiries closely follows the recent increases in the price of energy. Regrettable though this may be, it may be the financial implications of increased energy prices that act as the driver to stimulate interest in renewables.
- Resource limitations – Energy exists in abundance in nature, it is simply that it is very diffuse, intermittent and available in different forms so many technologies are needed to harness the available energy.
- Planning issues – Planning laws are changing and there is increasing acceptance of renewable energy technologies. It will always be the case that some technologies will need to be subject to planning to ensure safe operation for all.
- Environmental issues – Most renewable energy technologies will have some form of environmental impact. Any adverse environmental impact from renewable energy

technologies needs to be balanced against the potential adverse impacts of climate change.

Opportunities

- Jobs – Increased activity to generate energy locally will inevitably lead to more local jobs. Plumbers will be needed to install solar hot water, electricians to install PV, wind turbine and hydro engineers, etc.
- Wealth creation – Energy is vital to every human activity. Energy used in industry helps add value to the raw ingredients of whatever process. At present most of the energy used in South Devon is imported via the national grid so the money to pay for it migrates out of the area. Energy generated in the area can displace imported energy and so help retain wealth in the community. (The Local Multiplier effect)
- Fuel poverty alleviation – Affordable warmth is vital for the health of the community. Locally generated energy can help maintain the well-being of the local community.
- Reduced dependence on oil – As North Sea oil and gas reserves run out, the UK will become increasingly dependent upon supplies imported from abroad. Initially this may not be too much of a problem but as supplies get increasingly short, suppliers may decide their own need is more important than the revenues earned from selling oil.
- Reduced dependence on corporate control – At present most energy is supplied by a small number of large corporate companies. Historically it has not been possible for communities to own their own generating capacity. Because renewable energy technologies can be scaled down to community size, the opportunity now exists for communities to develop their own schemes and enjoy all the benefits of the added value.
- Innovation – The challenge to live within our energy income will need imagination and creativity.
- Community Coherence – A community that pulls together to face the new possibilities and challenges will be a stronger community.

10 General Conclusions and Recommendations

The UK government's Chief Scientific Adviser, Sir David King, is reported as saying, "Climate Change is the single most serious threat mankind will face in the 21st century." Scientists generally are agreed that whilst there are a number of causes of global warming, one of the more significant is the emission of carbon dioxide gas from the burning of fossil fuels to generate energy. The provision of a sufficient and affordable energy supply is as essential to life as; air, water, food and shelter. Energy is essential for life – without energy there is no life.

Since the Industrial Revolution, most of our energy has been generated by burning carbon-based fuels such as coal, gas and oil. Primary energy supplies are finite and are being consumed faster than nature can replenish them and will eventually run out. However at current rates of consumption, the world's known reserves of primary energy will last long enough to allow us to develop alternative energy sources, provided we act soon. So whilst resource depletion is of concern the principle issue is that of climate change and reducing our carbon emissions. At the present time there are two technologies that can supply carbon free energy; nuclear and renewable energy.

This study shows that South Devon has a significant renewable energy resource but even if all on-shore based renewable sources (other than large scale wind turbines) were fully developed it would only meet about 30% of the current energy demand. This implies that either energy demand has to be substantially reduced or we go nuclear, or additional sources of renewable energy need to be found.

Energy reduction through increased uptake of energy efficiency measures is an obvious starting point. Energy efficiency has a double bonus: for a one-off investment in more efficient technology there is a permanent ongoing saving in reduced energy use, but a reduced energy demand also allows for savings to be made in reduced generating capacity. But energy efficiency measures also have an associated cost. Replacing tungsten light bulbs with low energy bulbs is a move in the right direction and cost effective, but lighting only accounts for about 2% of our total energy demand so the savings to be made is limited. If energy saving is to make a significant impact on reducing carbon emissions, the need will be to reduce the energy demand for one of the major energy uses such as space heating. Space heating accounts for about 60% of all domestic energy use. In the case of South Devon, large areas are off gas grid, so rely on solid fuels, oil, LPG or mains electricity, all of which emit more pollution than mains gas. Loft and cavity wall insulation must be considered essential for every dwelling and should be encouraged. It is worth noting that in order to be eligible for grant funding from the Low Carbon Building Programme, applicants MUST have loft and cavity wall insulation before they apply. There must be a radical increase in the uptake of energy efficiency measures as soon as possible. However once all reasonable energy efficiency measures have been adopted there will still be a need to meet the remaining energy demand.

Going nuclear is an option and it is recognised that the conclusion of this report, namely that renewable energy alone cannot meet current energy demand, will give the pro-nuclear lobby encouragement to promote their view. However the primary fuel source for nuclear, uranium oxide, is also a finite resource and at current consumption rates the world's known reserves will last about 60 years. If there is a large increase in the numbers of reactors, even if fast breeder reactors become the standard, uranium could be exhausted earlier. Given that we are already committed to clean up the existing nuclear sites at huge cost, the wisdom of creating new nuclear power stations needs to be questioned.

Energy efficiency can only take us so far towards sustainability; nuclear is not sustainable in the long term. Unless nuclear fusion becomes available, and there is little sign of that at present, sooner or later we will need to embrace renewable energy despite the huge cost implications. Human society has developed this far by exploiting our solar inheritance; the challenge now is to learn to live within our solar income. The longer we leave it the more of a challenge it will be. *Energy efficiency and renewable energy should be foremost in all our minds.*

Key findings

- Excluding large-scale wind turbines and with no energy efficiency measures, if all other renewable energy options in South Devon were fully developed, about one-third of the energy demand could be met.
- To meet the other two thirds of energy demand either
  - large-scale wind turbines will need to be constructed in large numbers, or
  - offshore technologies will need to be developed, or
  - energy demand must be reduced through a radical programme of energy conservation, or
  - a combination of the three above.
- Energy reduction through energy efficiency is the single most cost-effective method of meeting energy demand.
- Solar hot water emerges as the most cost-effective domestic renewable energy technology at present, closely followed by woodfuel heating.

Key recommendations

- Energy reduction through the uptake of energy efficiency measures should be at the forefront of all local authority policy making.
- Industry needs competitively priced energy; the local authority should as a matter of urgency consider the provision of energy as part of its Economic Development and Prosperity Strategy.
- Planning policies should ensure all new build - domestic, commercial and public sector - are built to the highest standards. Developers should be encouraged to exceed the latest

Devon Association for Renewable Energy 12a, The Square, North Tawton, Devon EX20 2EP
Tel. 01837 89200 Web. www.devondare.org E mail. admin@devondare.org

Building Regulations insulation standards (Part L) and the 10% target for renewable energy be enforced.

- There should be a presumption in favour of planning permission for domestic scale renewable energy technologies. The publication of clear guidelines for permitted development rights would be helpful.
- Training for installers of renewable technologies should be offered as part of a progressive programme of renewable energy adoption and business development.
- The challenge of moving towards living within our solar income should be seen as an opportunity to innovate.

Final thoughts

- The health and well being of society is dependent upon the sufficient supply of affordable energy.
- Industry and commerce needs competitively priced energy.
- Locally owned local energy generation will add to local prosperity by reducing the outward migration of wealth.

Devon Association for Renewable Energy 12a, The Square, North Tawton, Devon EX20 2EP
Tel. 01837 89200 Web. www.devondare.org E mail. admin@devondare.org

References

1 – Prof. Svante Arrenhuis, Swedish Nobel Prize winner 1894, first described the CO_2 greenhouse gas effect.
2 – Source – www.bbc.co.uk/ 13.03.06 - CO_2 concentration passed through 380ppm – highest since 100 million years ago.
3 - Source – www.defra.gov.uk/emissions grid electricity CO_2 emission for present primary fuel mix = 0.43kg/kWh
4 – Source – www.greenpeace.org.uk/DecentralisingPower
5 – Source - www.devon.gov.uk/dris/ State of the Devon economy 2003
6 – Source – www.devon.gov.uk/dris/ Annual survey of hours and Earnings (ASHE) 2005
7 – Source – www.devon.gov.uk/dris/commstat/dv_mdip.html low number most deprived - high number least deprived
8 – Source – www.devon.gov.uk/dris/census/
9 – Source – Domestic Energy fact File 2003 http://projects.bre.co.uk/factfile/BR457prtnew.pdf
10 – Source – Dti UK Energy in Brief July 2005 www.dti.gov.uk/energy/inform/dukes/index.shtml.
11 – Source – www.southdevon.gov.uk/
12 – Source – South Devon Area of Outstanding Natural Beauty, Management Plan 2004 – 2009
13 – Source – www.pv-uk.org British Photovoltaics Association
14 - Source – EWEA, 1991, Anderson, 1992; Beurskens and Jensen 2001; Open University RE Report, G. Boyle, page 267
15 – Source- http://farmstats.defra.gov.uk/cs/farmstats_data/DATA/soa_data/repop_results.asp
16 – Source - http://farmstats.defra.gov.uk/cs/farmstats_data/MAPS/interactive_maps/anob_results.asp?aonb_id=31&year=2004&ord=year&submit=Get+Census+Data&c_id=24
17 -Source: South West Wood Fuels www.swwf.info
18 - Source: Working Woodlands, Dartington.
19 – Source – Open University – Renewable Energy G Boyle page 113.
20 - See: www.defra.gov.uk/erdp/schemes/energy/crops.htm Defra research and development report CSG15.
21 – Source – Open University RE G Boyle page 110
22 – Source - www.defra.gov.uk/erdp/schemes/energy/crops.htm
23 - Source – www.ukagriculture.com/frame_set.cfm?page
24 - Source – Open University RE G Boyle page 136
25 - Source – Sheffield Hallam University, Evaluation of the comparative energy, Global warming and Socio-economic costs and benefits of bio-diesel.
26 -Source - Bioethanol Production www.esru.strath.ac.uk/
27 – Source – www.defra.gov.uk/environment/statistics/wastats/index.htm
28 - Source – www.defra.gov.uk/energy/inform/energy_prices/annex_b_mar04.shtml
29 - Source – www.greenfinch.co.uk/ludlow
30 - Source – http://farmstats.defra.gov.uk/cs/farmstats/
31 – Source – www.defra.gov.uk/environment/statistics/wastats/index.htm
32 - Source – www.defra.gov.uk/energy/inform/energy_prices/annex_b_mar04.shtml
33 – Source - www.bedzed.org.uk/main.html
34 – Source – www.dunsterwoodfuels.co.uk/energy/boilersizewpdf.pdf Calculation sheet for heat loads – 3 bed semi uninsulated = 11 kW. 3 bed semi insulated = 6 kW
35 – Source- www.defra.gov.uk/environmnet/business/envrp/gas_05.html
36 – Source - http://www.devon-energy-advice.co.uk/grants
37 –Source – World Health Organisation
38 –Source - http://www.devon-energy-advice.co.uk/
39 - Source – http://www.jrf.org.uk/knowledge/findings/housing.n11.asp
40 – Source - www.devon.co.uk/dris/houses/sh_hsebp.html
41 – Source - http://www.fromthewilderness.com/free/ww3/dec2001.files/peakall.gif
42 – Source - www.uic.com.au/

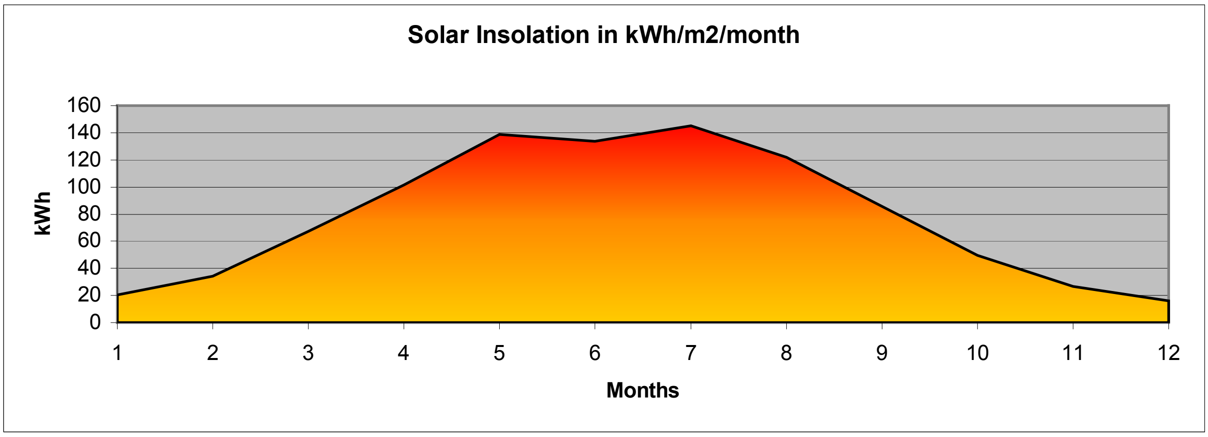
Appendices

1) Solar Insolation

South Devon is located 51° North of the Equator and the level of incoming solar radiation varies according to the angle of the sun above the horizon. These figures assume average weather conditions.

Solar Insolation on a horizontal surface (kWh/m^2/month) at Latitude 51^0 N													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
10 y ave.	20.46	34.16	67.27	101.4	138.6	133.5	145.1	121.8	85.8	49.6	26.7	16.12	940.5

Source: NASA



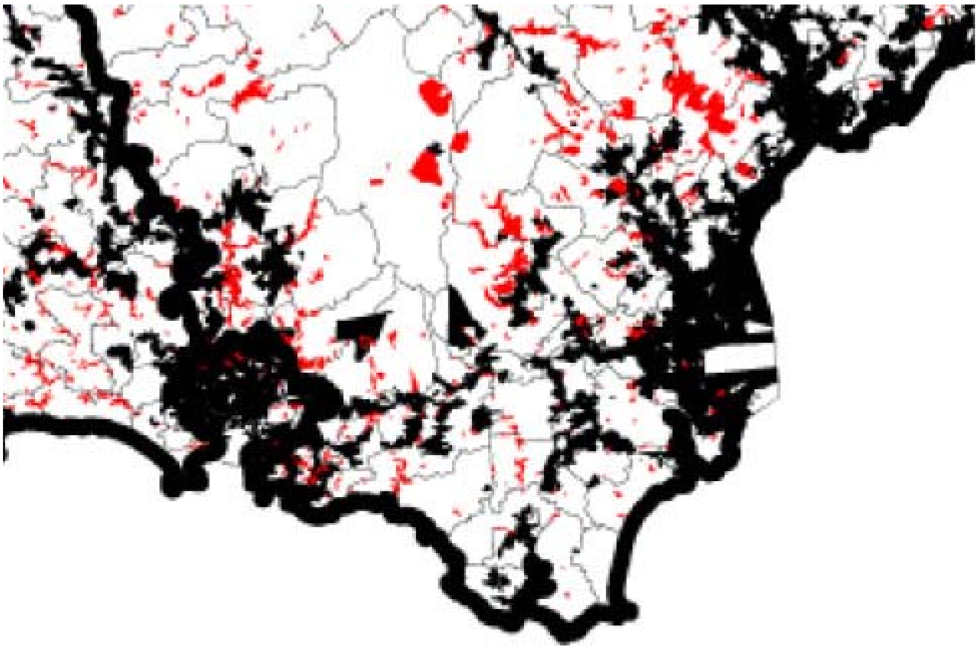
The annual energy available per horizontal square metre in the South West approximates to 0.94MWh. However the annual variation across the year varies by a factor of 10 from mid-winter to mid-summer.

2) Solar Sundial

		West						South						East	
		-90	-75	-60	-45	-30	-15	0	15	30	45	60	75	90	
vertical	90°	56	60	64	67	69	71	71	71	71	69	65	62	58	vertical
	80°	63	68	72	75	77	79	80	80	79	77	74	69	65	
	70°	69	74	78	82	85	86	87	87	86	84	80	76	70	
	60°	74	79	84	87	90	91	93	93	92	89	86	81	76	
Inclination	50°	78	84	88	92	95	96	97	97	95	93	89	85	80	
to horizontal	40°	82	86	90	95	97	99	100	99	98	96	92	88	84	
	30°	86	89	93	96	98	99	100	99	98	96	94	90	86	
	20°	87	90	93	96	97	98	98	98	97	96	94	91	88	
	10°	89	91	92	94	95	95	96	95	95	94	93	91	90	
horizontal	0°	90	90	90	90	90	90	90	90	90	90	90	90	90	horizontal

A solar panel facing due south at an angle of 30° - 40° to the horizontal collects the maximum (100%) of available solar energy. A solar panel installed at an angle other than due south or other inclination to the horizontal will collect proportionately less energy.
To use the solar sundial – first use a compass to find out the direction of the roof slope. Use the vertical column corresponding to the roof slope direction. Estimate the angle of pitch of the roof and use the corresponding horizontal row. Where the two intersect will give the % of solar energy available.
e.g. A roof facing due southwest (-45) with a 30° pitch will give 96% of the available solar energy.

3) South Devon Gas grid



The black areas represent the postcode areas that are on the national gas grid. The A38 corridor, Totnes, Dartmouth and Kingsbridge areas and linking corridors are on mains gas but the greater bulk of South Devon is not. This implies most of that area relies on oil, LPG, electricity or solid fuel and means the carbon emissions for dwellings will be higher that the national average

4) Peak Oil

'Peak Oil' is the term used to describe the time when the demand for oil equals the ability of the world's oil wells to supply that demand. When a new oil field is tapped, oil can be extracted freely. As the underground oil reserve reduces, the flow rate slows down, giving notice that the reserve is beginning to run dry. If an oil company has a number of oil wells it may well decide to shut down a particular oil production well because it can obtain all the oil it needs to meet its obligations more cheaply from another well. Rarely is an individual oil well totally exhausted.

There have been no discoveries of major new oil fields since the early 1970's. New extraction techniques have been developed to enable oil companies to reopen previously closed wells to allow them to recover more oil, but even allowing for improved extraction methods, the global demand for oil continues to grow and a number of commentators within the oil industry are suggesting that demand is about to exceed the ability of the world's oil fields to supply.

The graph below is commonly referred to as 'Hubbert's Curve'. Hubbert was an American mining engineer, who, as part of his degree dissertation researched the production output from the oil fields in Texas in the 1950's. He noticed that the rate of growth in car ownership in America appeared to be exceeding the rate at which new oil fields were being discovered. He was the first person to apply scientific methods to predict the future of oil supplies; his research concluded that the Texas oil fields would reach their production peak in the late 1970's and then go into permanent decline. When he published his results in 1957, the oil barons of Texas ridiculed his findings, stating they had enough oil to last for centuries. In fact oil production in Texas peaked in 1977 and has been in decline ever since. Undeterred, Hubbert went on to look at global oil production and the graph below summarises his findings and the findings of others.

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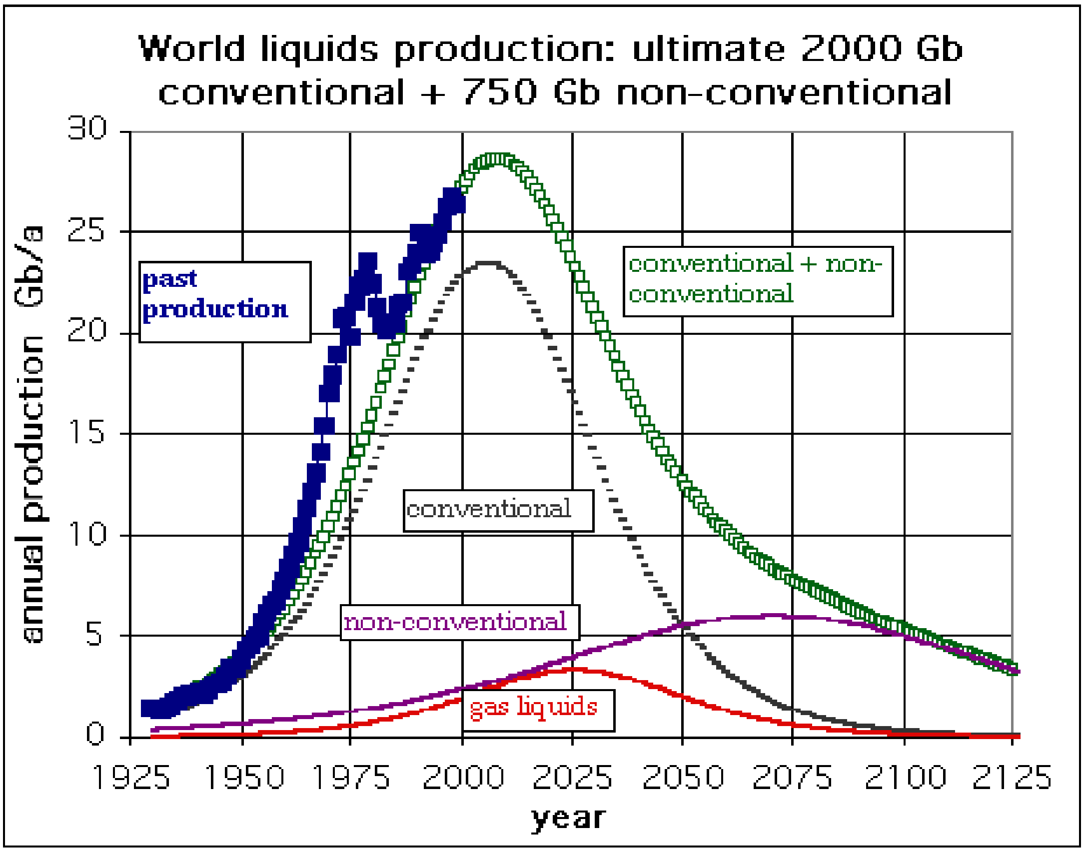

(41) Source http://www.fromthewilderness.com/free/ww3/dec2001.files/peakall.gif

The graph above shows annual production in Gb/a (Giga barrels/year) on the vertical axis and time on the horizontal axis. The black 'bell-shaped' peak in the centre represents convention oil production. The purple curve represents the production of non-conventional oil, that is oil extracted from tar sands. The red curve represents the production of natural gas. The curve comprising numerous small green boxes is the result of adding the three previous production curves together (i.e. it represents the total output of all oil and gas). The curve comprising solid blue squares represents past production and is based on real production figures. It can be seen that apart from an anomaly in the late 1970's, past production very closely matches Hubbert's predicted curves.

Considering the curve for conventional oil production (black curve in centre of graph) it can be seen that the peak occurs around 2005 (about now) and is symmetrical about an axis through the peak. This suggests we have consumed about half of all the world's known oil supplies. The implications are, from hereon oil production is likely to go into permanent decline, initially at a rate of about 2% per year but then more rapidly.

Hubbert's curve implies we are not about to run out of oil, however supplies will start to become in short supply. It is worth considering a scenario 19 years hence, in 2025. Referring to the curve above, by 2025 world oil supplies will be well in decline. Also, if Hubbert is right, the world will be at 'peak gas' and gas supplies will also start to decline. The laws of supply and demand suggest that fossil fuel prices will be much higher than today.

Since the Industrial Revolution we have been spending our solar inheritance; the challenge now is to learn to live within our solar income. One thing is certain; the era of plentiful cheap energy is over and we are at the start of a transition period to a new way of generating our energy needs.

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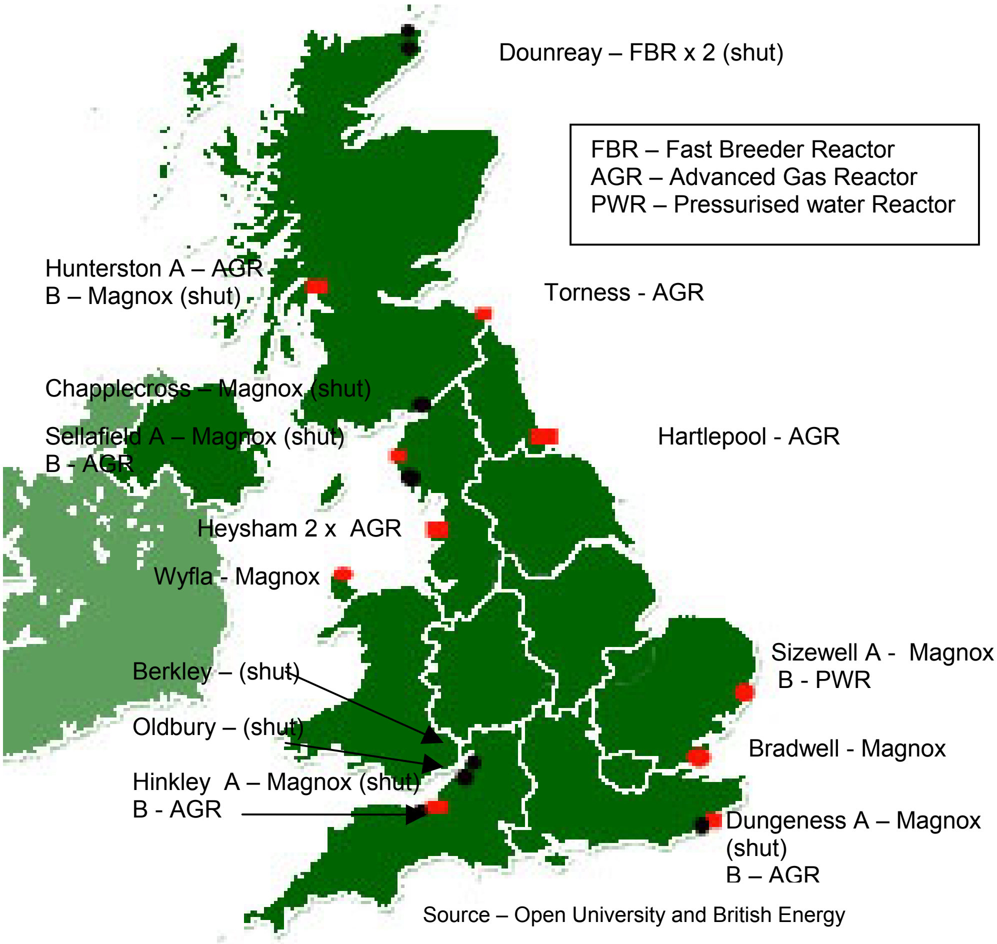
5) The Nuclear Option

The clear result of the RE scoping study is that renewable energy alone cannot meet South Devon's energy need. South Devon will need to invest in the whole range of RE technologies and energy reduction methods. At first sight this may suggest there is an argument for going nuclear. But just as the reserves of coal, gas and oil are finite, so are the reserves of uranium oxide. Uranium oxide is ubiquitous, it can be found almost everywhere on the Earth's surface but at a very low density of about 2.7 ppm (parts per million). Uranium oxide is present in seawater but at an even lower density of about 0.003 ppm. (Source – World Nuclear Association.)

The problem with such low densities is more energy is used to locate and collect the uranium than it contains. There are a number of locations where uranium oxide has collected in sufficient concentration to justify mining. The world's known reserves of economically recoverable uranium oxide are believed to be just less than 4 million tonnes[42].
Currently there are about 440 nuclear power stations worldwide that, collectively, use about 66,000 tonnes of uranium oxide per annum[42]. On this basis there is about 60 years worth of supply assuming no additional nuclear power stations are built.



Source – Open University and British Energy

The UK currently has 22 operational nuclear power stations (red dots), collectively producing about 22% of our electricity needs (equating to about 9% of our total energy needs). All the Magnox stations are overdue to close and all but one of the remaining stations is due to close by 2016. However if nuclear were to become the preferred choice of non-carbon energy to replace fossil fuel generation, we would need to build 200+ nuclear power stations. If the purpose of going nuclear is to reduce carbon emissions then the whole world will need to go nuclear, implying a massive number of new nuclear power stations, in which event the uranium will not last long.
The nuclear industry suggests that the next generation of nuclear power stations will be of the fast breeder type which produces 50 – 60 times as much energy for the same amount of uranium and produce plutonium as a by-product. Plutonium can also be used as a fuel for nuclear power. At

first sight it appears that as energy is generated so more fuel is produced, but in fact the rate at which plutonium is made is too slow to allow for a significant expansion of nuclear power.

All our nuclear power stations (past and present) are on the coast at sea level. If the Climate Change scientists are right and sea levels are set to rise in the future, all could become inundated and eventually leak radiation into our seas. We are already committed to de-commissioning costs of £56 billion, without building any new nuclear power stations. Uranium is a finite resource - nuclear power is simply not sustainable.

6) Case Studies

The case studies are not exhaustive but illustrate some local applications.

PV

One of six properties at Hunter's Moon, Dartington with PV installations. This was one of the earliest schemes in the country.

PV panels installed on the roof the Batham Surf Lifeguards beach hut.
The hut demonstrates several energy saving features;

- The building is constructed into the hillside so is partially earth sheltered.
- There are two large skylights allowing light into the interior of the building reducing the need for electric lights.
- The PV panels are mounted on inclined pedestals to maximise the energy gain.

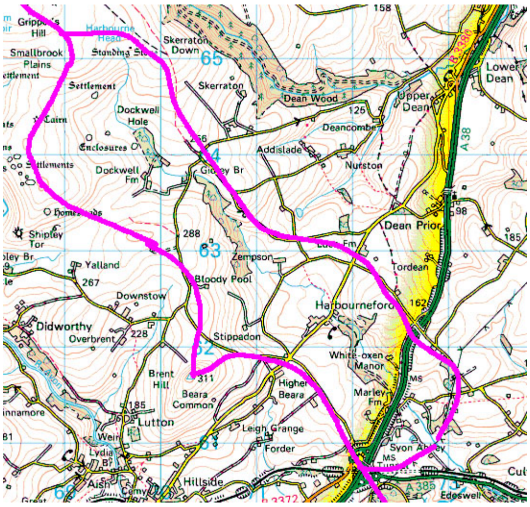
SHW

An array of flat plate solar hot water panels on a property near Dartington. The system produces all the hot water needs in summer and pre-heats the water in winter.

Micro-hydro

<u>Rattery Mill</u>
Rattery Mill lies on the Harbourne River.

Rattery Mill showing the wheel in a state of disrepair in April 2004



Rattery Mill catchment area, outlined in purple extends up onto Dartmoor

Rattery Mill site flow data

Catchment area	A	= 8.3 km^2
Average rainfall across catchment	R	= 1698 mm
Average evaporation rate	E	= 528 mm
Gross annual flow [A x (R – E)] Q_{gross}		= 9,710,000 m^3
Mean annual flow $Q_{gross} \div (8760 \times 60 \times 60)$		= 0.31 m^3/s (Q_{mean})
Residual flow Q^{90}		= 0.04 m^3/s
Provisional design flow $Q_{rated} = Q_{mean} - Q^{90}$		= 0.27 m^3/s (Q_{rated})

<u>Head</u>
The net hydraulic head (usable water drop) is estimated as 3.6 m
<u>Power output</u>
The amount of power a river can supply is a function of both the vertical distance the water falls (this is called the 'head' and is measured in metres) and the volume of water flowing through the

turbine (this is measured in cubic metres per second [m^3/s]). It is not appropriate here to explain hydropower theory in greater detail (for more information go to the British Hydropower web site at http://www.british-hydro.org/)
Suffice it to state here the water to wire power output: P (kW) = 5 x Head x Flow
So for Rattery Mill the power output will be in the order of

Maximum electrical power output = 5 x H x Q_{rated}
= 5 x 3.6 x 0.27 = **4.86 kW**

Annual energy capture
Annual energy capture = electrical output x no. hours in year x load factor. (The load factor represents that proportion of time the resource is available)
HydrA calculates the output for a Crossflow turbine:

Turbine type	Annual gross MWH	Annual net MWH	Max power kW	Rated power kW	Minimum flow m^3/s
Crossflow	20	16	5	4	0.08

Comment

Rattery Mill is a traditional corn mill with a leat drawing water off the Harbourne River further upstream which is delivered to an overshot wheel to operate machinery. The mill ceased to function many years ago, the water wheel has since fallen into disrepair and the leat has dried up. To get this mill back into production the water supply will need to be restored and either the water wheel repaired or replaced with a modern turbine.

The flow data above is arrived at by taking a theoretical approach; the rainfall catchment area is defined by examining maps and applying Met Office historic rainfall records to calculate how much water flows in the river at the weir above the mill. A minimum residual (Q^{90}) flow must be left in the main stream to protect the ecology of the river. The Environment Agency (EA) has a statutory duty to protect rivers so an Abstraction Licence will be needed before water can be diverted. The EA will state how much water can be diverted to the mill. (Here it is assumed the EA will agree to licence a flow up to 90% of the average annual flow.)

A power output of 4 kW is fairly typical for traditional mill sites and the 20 MWH annual energy capture is about equivalent to the annual energy demand for four homes.

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One man's commitment to reducing carbon emissions.

A solar power station. A purpose built shed with PV panels on the roof and a small wind generator.

Inside the power station with the battery storage, charge controllers and sine wave inverter. The inverter changes 12 volts dc into 230 volts ac to run normal mains powered appliances.

A professionally installed evacuated tube solar hot water heater that provides excess domestic hot water in the summer. The system is oversized so supplies most of the winter demand as well.

A homemade flat plate hot water collector using a design supplied by the Centre for Alternative Technology (CAT). The hot water is used to run the central heating system.

The house is grid connected but has a change-over switch at the meter. In the summer the entire house (including the deep freezer) is run on solar energy. In the winter some grid electricity is used to supplement the solar.

7) Useful Contacts

South Hams District Council
Follaton House, Plymouth Road, Totnes TQ9 5NE
web www.southhams.gov.uk/ Tel. 01803 861234

British Wind Energy Association
Renewable Energy House, 1, Aztec Row, Berners Road, London N1 0PW
web www.bwea.com/ Tel. 020 7689 1960

British Hydropower Association
The British Hydropower Association is the professional association for the hydropower industry.
British Hydropower Association, Unit 12 Riverside Park, Station Rd, Wimborne, Dorset, BH211QU
web http://www.british-hydro.org Tel. 01202 886622

British Photovoltaic Association
The National Energy Centre, Davy Ave, Knowlhill, Milton Keynes MK5 8NG
web www.pv-uk.org.uk/

Solar Trade Association
The National Energy Centre, Davy Ave, Knowlhill, Milton Keynes. MK5 8NG
web www.solartradeassociation.org.uk/ Tel. 01908 442290

Environment Agency
Devon Area Office, Exminster House, Miller Way, Exminster, Exeter EX6 8AS
web www.environment-agency.gov.uk Tel. 08708 506506

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