CLIMATE ACTION WEST

Renewable Energy Resource For Exmoor

Interim Report

CAW
11/5/2008

For Forum 21

Please note that this report is a working document in support of the overall Exmoor Carbon Neutral Strategy. The figures presented here were based on an initial assessment. Since first draft, peer review was sought and the figures were revised during the drafting of the strategy document. Comments have been kept in the document in the form of footnotes so that future assessments can use this as a basis for further and more accurate work.

Contents

Section 1 Background and Introduction

1 Introduction to the Project

Please note that figures and comments in this report may have been modified during the final modeling and compilation of the Exmoor Carbon Neutral Strategy. This assessment was used as a basis only.

This is an interim report which is intended to feed into the wider carbon neutral strategy for Exmoor National Park. It is not meant to be read in isolation of any recommendations for deployment rates and targets which will only be published in the wider strategy. However, it is intended to provide background to how those recommendations will be derived.

1.1 SCOPE

Key objectives: To identify on a macro level the renewable energy (RE) resource potential across the park area.

The development of the carbon neutral strategy depends upon an understanding of the possibilities to reduce CO_2 across the park area including an understanding of the renewable energy potential, the associated costs and the technical viability.

The geographical scope of the project is the Exmoor National Park, in Somerset and Devon, including its Bristol Channel coastal waters.

1.2 METHODOLOGY

This RE assessment is a desk top study and has included:

- A review of relevant studies and papers relevant to this assessment including those that have been undertaken to date for the Exmoor area. This includes internet based research. Please refer to the bibliography.
- Data analysis to understand the potential demand for energy against the potential RE resource of the Park detailing
    - Deployment – geographical location
    - Quantity and generation capacity
    - Potential CO_2 savings/ technology
    - Costs and benefits of the different technology options
    - And technology descriptions

GIS maps of the RE potential have been produced wherever it was useful to do so and possible, subject to access to relevant data sources.

Section 1 Background and Introduction

The methodology for assessing the baseline energy profile, the LULUCF, the GHG emissions arising and the costs and benefits of each technology deployed has been detailed in appendix (??). The methodology for assessing the renewable energy potential for each technology is detailed in the relevant technology sections.

The summary in section 2 of the report has presented the 'theoretical' and the 'likely' renewable energy resource for the different heat and electricity technologies.

The **'theoretical'** limit is based on the 100% deployment of a technology where it is practical to do so. For example, if it is practical to deploy ground source heat pumps (GSHP) to only 16% of all households, then 100% deployment rate is 100% of the 16% of all households.

The **'likely'** limit is based on 40% of the practical deployment. In other words 40% of the 100% as outlined in the theoretical limit above.

1.3 OUTPUTS

The output is this interim report. It details the potential RE resource of the Park against demand, the CO_2 reduction potential and the potential costs and benefits. The findings and recommendations arising from this assessment feed into the overall recommendations for the carbon neutral strategy.

1.4 FORMAT OF THIS REPORT

Section 2 'summary of assessment findings' summarises the results of the renewable energy assessment and draws a comparison between the different technology options in terms of the costs and benefits.

Section 3 'the current baseline' presents the baseline assessment of the energy profile of the National Park. It provides an understanding of the current demands of both electricity and heat demand from the residents of the National Park. The CO_2 emissions have then been estimated based on the current demand.

Section 4 'RE assessment by technology' is divided into subsections by technology. A detailed assessment of the potential to deploy the technology has been undertaken and the methodology and results are presented here. It also details the costs and benefits of each technology and how these were derived.

2 Summary of the Renewable Energy Resource Assessment for Exmoor National Park

This section is subdivided into two main summary sections;

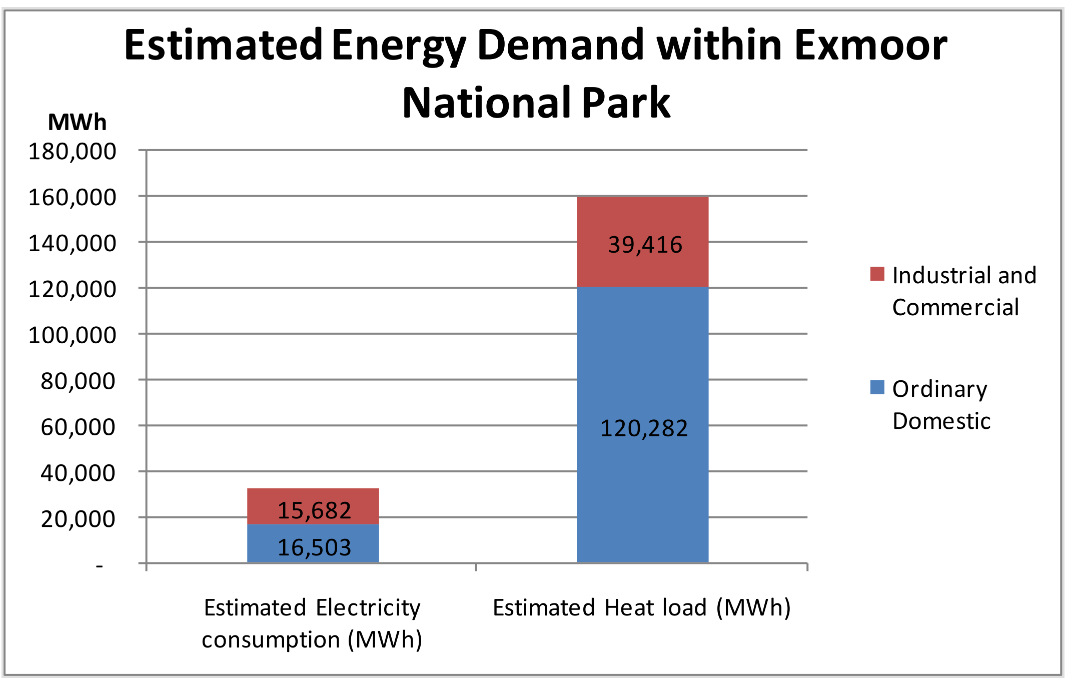
2.1 and 2.2 summarises the energy demand of the National Park area in terms of heat and electricity and presents the associated CO_2 profile.

2.3 – 2.6 presents a summary of the renewable energy resource potential of the park area. It draws comparisons between the different technology options in terms of their 'theoretical' and 'likely' deployment potential in kWh, the CO_2 reductions arising and the associated costs and benefits.

2.1 ENERGY PROFILE OF EXMOOR NATIONAL PARK

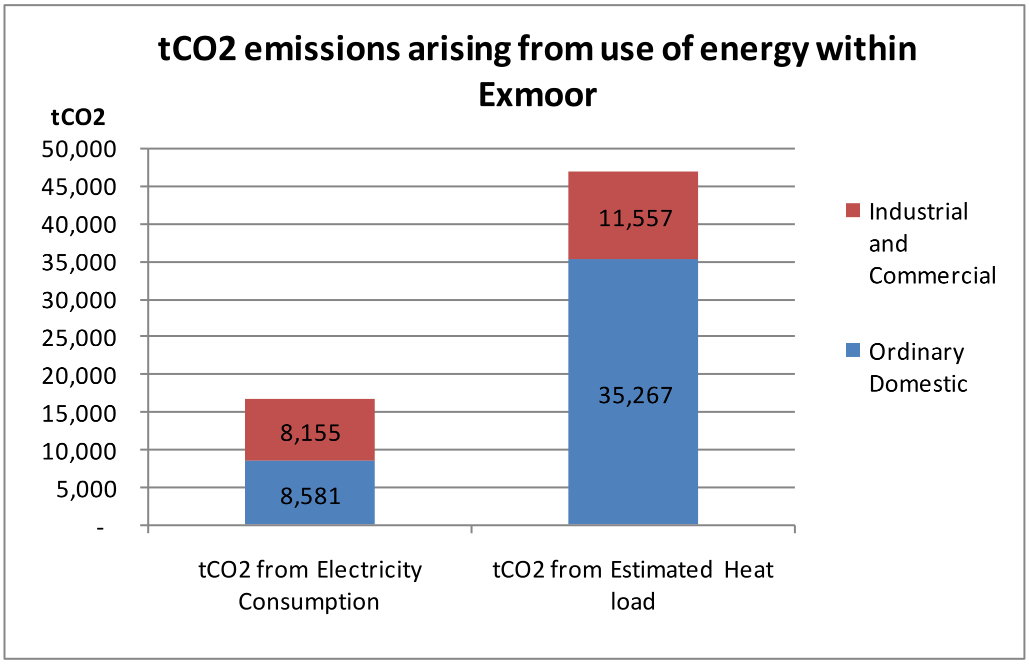
It is important to understand the energy demand (or profile) for the park area for two primary reasons. The first is so that we can calculate the CO_2 attributable to that demand. The second reason is so that we can understand the use of energy (split into heat and electricity demand by sector) so that we can compare how this demand will be met with renewable energy.

The assessment estimated that the total heat demand for Exmoor National Park is 159,698 MWh/year. The electricity demand is an estimated 32,185 MWh/year. A breakdown of this is presented in the following chart (please read Mwh/y).



2.2 CO_2 PROFILE ATTRIBUTABLE TO ENERGY FOR EXMOOR NATIONAL PARK

The associated CO_2 emissions attributable to the energy use above has been calculated to be 63,560 tCO_2/year and is reflected in the following chart by heat and electricity and by sector.



2.3 RENEWABLE ENERGY RESOURCE POTENTIAL OF EXMOOR AND ASSOCIATED CO_2 REDUCTION POTENTIAL

Summary

This subsection presents a summary of the key findings of the assessment. It is divided into **'heat'** resource and **'electricity'** resource. Each of these sections presents the potential CO_2 reductions associated with the renewable heat and electricity resource.

The resource assessment findings have been presented as 'theoretical' limit and 'likely' implementation.

The theoretical limit represents the absolute **practical** limit in renewable resource capacity. So for example if half the properties across Exmoor are assessed as suitable for solar technology (because their orientation lies between south west and south east) then it will only be half the properties that will be used to calculate the theoretical limit. More detail is provided about how the theoretical limit has been derived for each of the technologies in the individual technology sections.

The **likely** limit is in some instances 40% of the theoretical limit or has been adjusted to reflect other reasons like how commercially available is the technology to exploit the resource potential. The 'likely' limit for each technology and how it has been derived is explained in the respective technology sections.

It is important to note that this exercise has been a desk top study and the findings of the assessment are subject to range of other activities including, site specific surveys, ownership of projects, funding and planning permission to but a few. These limits need to be treated with extreme caution and have been used only as a method for comparison.

2.3.1 Theoretical renewable heat resource

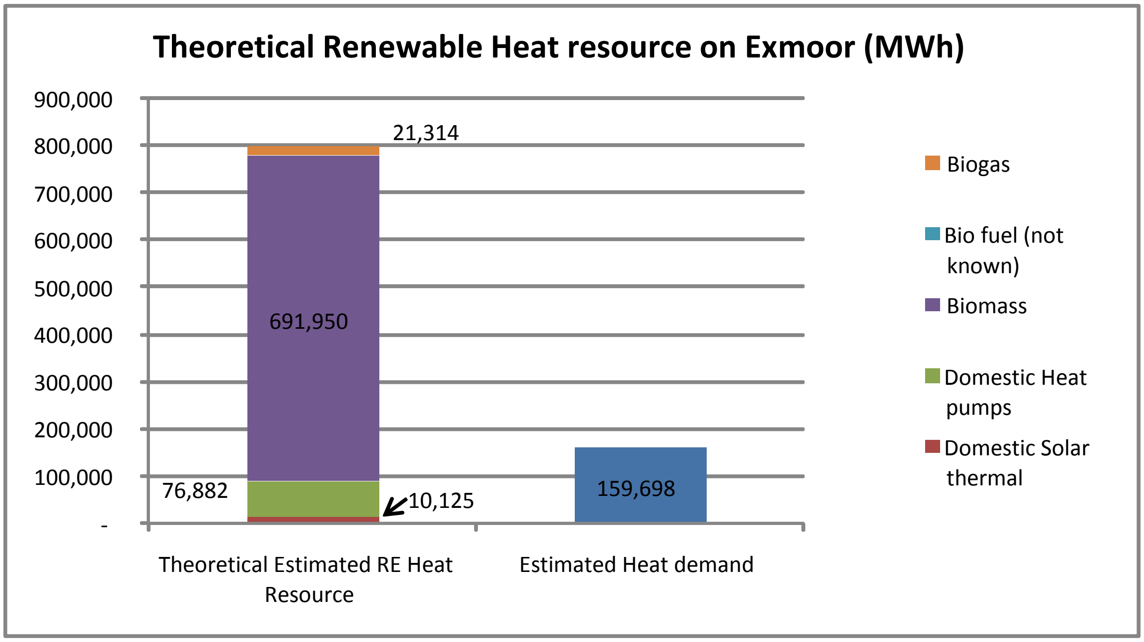
The theoretical renewable heat resource of Exmoor would appear to exceed that of demand. According to this assessment the most available renewable heat resource within Exmoor is biomass in the form of wood-fuel[1].

Section 2.1 above reported that the heat demand across the national park was calculated to be 159,168 MWh. The assessment has estimated that the theoretical renewable heat resource available within Exmoor Park is **800,271 MWh**. This is a significant difference of 640,173 MWh that would be available as export if the renewable resource could be realized.

The graph below shows that biomass is the most available renewable heat resource available to the park. All of the biomass here represents the potential in the form of wood fuel and is based on one report[2].The respective contribution of each renewable heat resource or technology is reflected in the bar chart below.

1 It should be noted that the deployment of heat pump and solar technologies was not assessed against commercial and industrial premises. If accounted for the likely implementation could be higher than presented here.

2 SWWF.



Notes to accompany the above chart:

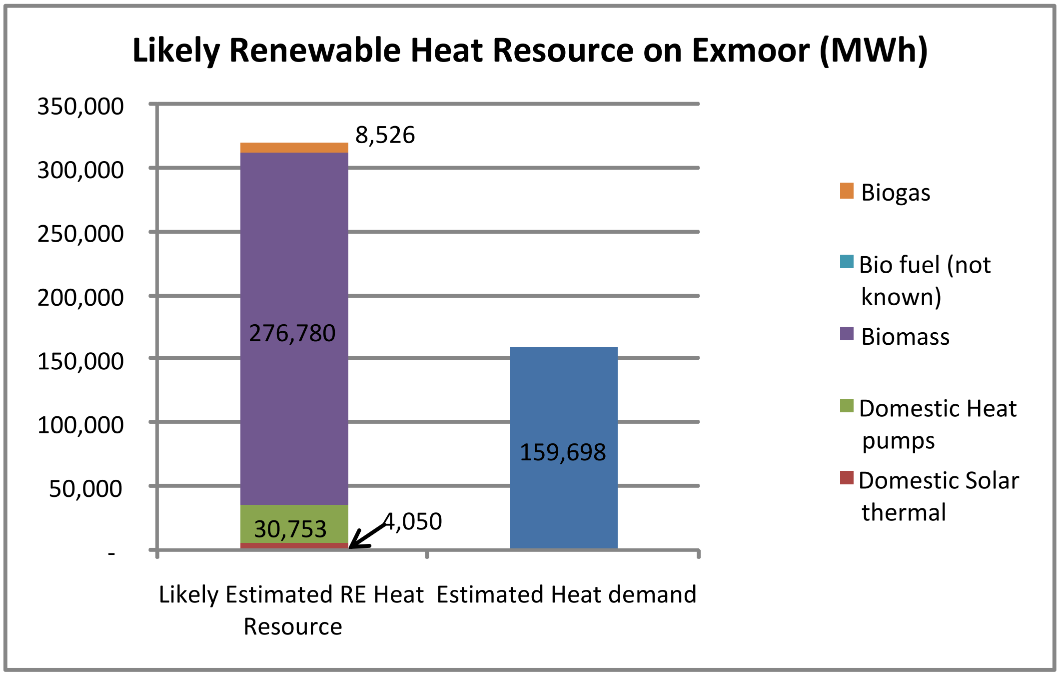
- Biogas is based on the total available manure from cow population (2004 figures)
- Biomass is based on the SWWF report and potential of 197,000 tonnes of dry wood being made available
- Domestic heat pumps reflects 100% deployment of heat pumps with a coefficient of performance of 4 (CoP 4) and above because on the whole less than this is not effective.
- Domestic solar thermal is based on every domestic property installing a 4m^2 evacuated tube system with an efficiency of 55%. The efficiency has room for positive growth but the deployment rate is at its absolute limit.

2.3.2 Likely renewable heat resource

According to this assessment and its methodology the 'likely' renewable heat resource of Exmoor would still exceed the heat demand. The **likely** renewable heat resource is estimated to be **320,109MWh/year.** This estimation still exceeds the heat demand with an excess difference of **160,411MWh/year** potentially available for export.

Once again this is because of the significant potential in wood fuel resource. The methodology for assessing the 'likely' wood fuel resource was discussed with the ENPA woodland officer who thought that the methodology employed was 'reasonable' in the absence of more data being made available for the assessment.

One aspect of woodfuel resource potential that hasn't been assessed is the amount of accessible woodland that is available for managing the potential resource. It is recommended that this is assessed for both current and future accessibility and factored into the results.



Notes to accompany the above chart:

- Biogas has been calculated based on 40% of the total available resource in the Park (cow manure).
- Biomass has been calculated as 40% of the theoretical limit as reported by SWWF.
- Domestic heat pumps have been estimated as 40% deployment of pumps with a CoP of 4 only.
- Domestic Solar thermal has been calculated as 40% of theoretical limit. Other applications of this technology should also be considered such as swimming pools and dairies.

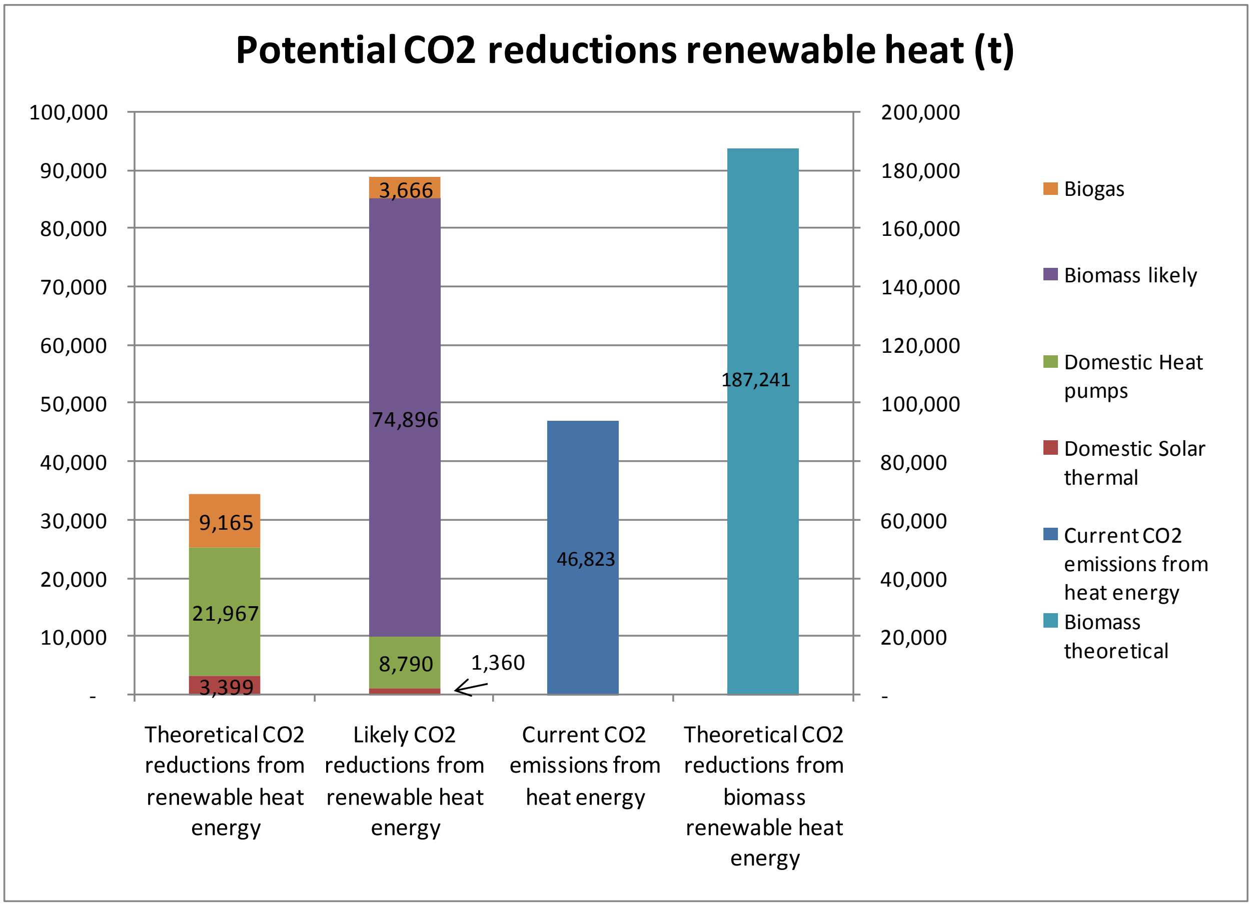
2.3.3 Potential tCO_2 reductions from the potential renewable heat resource on Exmoor

Section 2.2 above reported that the CO_2 emissions attributable to the energy used across Exmoor was an estimated **63,560 t/year**.

Based on the **theoretical** limit of each of the technologies assessed that would supply renewable heat, Exmoor could effectively reduce CO_2 emissions by **221,772 t/year**. This exceeds its current emissions by 174,949 tonnes/year. This is due largely to the theoretical limit of wood fuel being realized and would include claiming the CO_2 benefits of the exported wood-fuel. Claiming the exported CO_2 benefit of wood fuel runs the risk of double counting and this should be discussed a policy recommended in the Carbon Neutral Strategy.

The likely limits also exceed the current CO_2 emissions of Exmoor's current heat demand for the same reasons stated above. The total CO_2 reduction potential is 88,712 tCO_2/year compared to current estimated emissions of 46,823tonnes/year.

The bar chart below reflects the respective contribution of each technology both in terms of the theoretical and likely limits of deployment. For CO_2 reduction of theoretical biomass read the secondary axis.

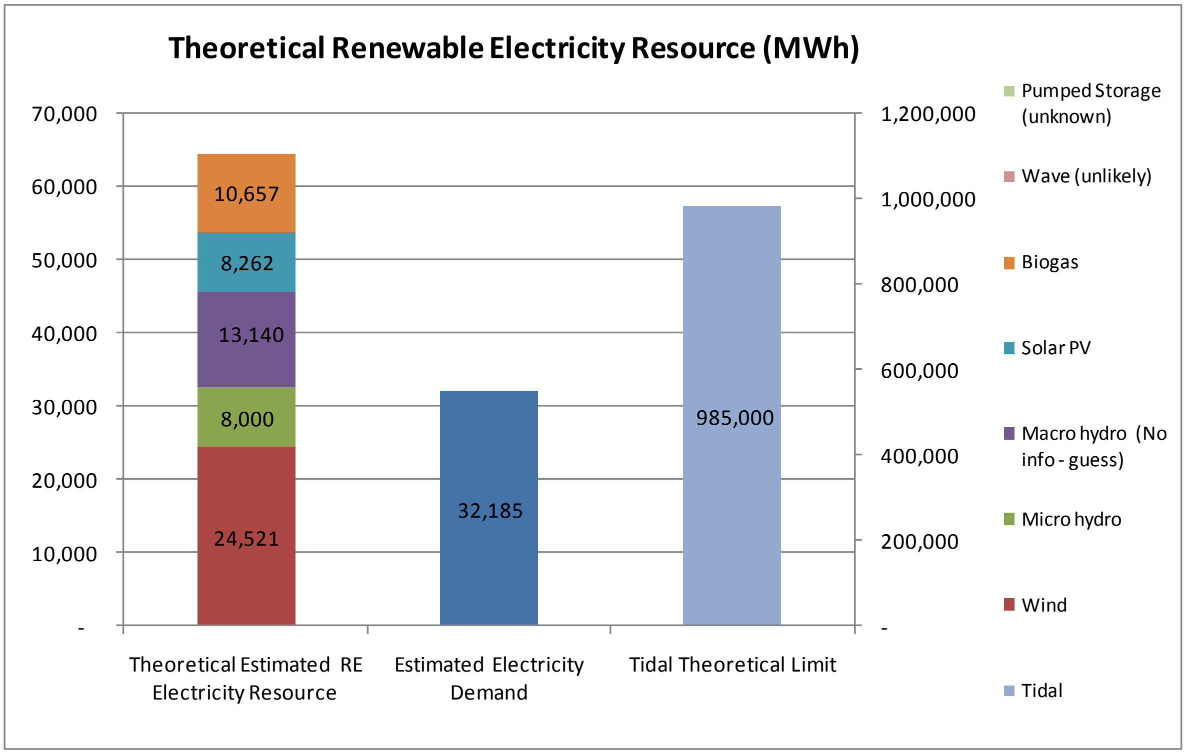


2.4 SUMMARY OF RENEWABLE ELECTRICITY RESOURCE FOR EXMOOR NATIONAL PARK

2.4.1 Theoretical renewable electricity resource

The potential renewable electricity resource of Exmoor exceeds the electricity demands. According to this assessment the electricity demand for Exmoor is an estimated 32,185 MWh/year. The total theoretical renewable electricity resource is estimated to be 64,580MWh without exploiting the tidal

resource and 1 TWh with tidal resource. 32,185 Mwh/year is around 12MW installed large scale wind turbines
Without wind (and tidal) the electricity demand of the national park area is unlikely to be met unless further research shows that macro hydro is a greater resource than estimated here. Deploying larger wind turbines will mean that the electricity demand can be met (and therefore CO_2 emissions reduced or even neutralised) with far fewer turbines though they will be much larger.



Notes to accompany the above chart:

- Pumped storage has not yet been investigated enough to provide this assessment with a potential capacity. This technology could only be economically deployed at reservoirs.
- Wave is a technology that is still under development and though reports say it is only 2-3 years away this has been the case for the last 15 years. In addition to this the wave profile off the Exmoor coast does not lend itself easily to the deployment of this technology. For these reasons it has not been included but if further evidence to the contrary should come to light then this should be reviewed.
- Biogas is based on 100% utilisation of the estimated manures available from the cows on Exmoor (2004 figures).
- Solar pv assumes 50% of domestic properties on Exmoor deploy the technology

- There is no information available for macro hydro to date (but will keep trying) and so the information here is purely a professional estimate. This could increase considerably
- Micro-hydro is based on the research done by a number of studies – this is awaiting further analysis and could increase or decrease depending on the outcome
- The wind resource on Exmoor is based on the deployment of 15kW turbines across a range of 'very high' to 'low' potential areas of wind speed. Note to this assessment all 15kW horizontal axis machines have hub height over 10m and tip height over 14m.
- Tidal has been tested off the coast of Lynmouth with apparent success. A proposed scheme by a community further up the north Devon coast (outside of Exmoor) is assessing the feasibility of deploying enough tidal turbines to generate 985,000MWh. The technology has not yet been successfully deployed commercially and so is still theoretical.

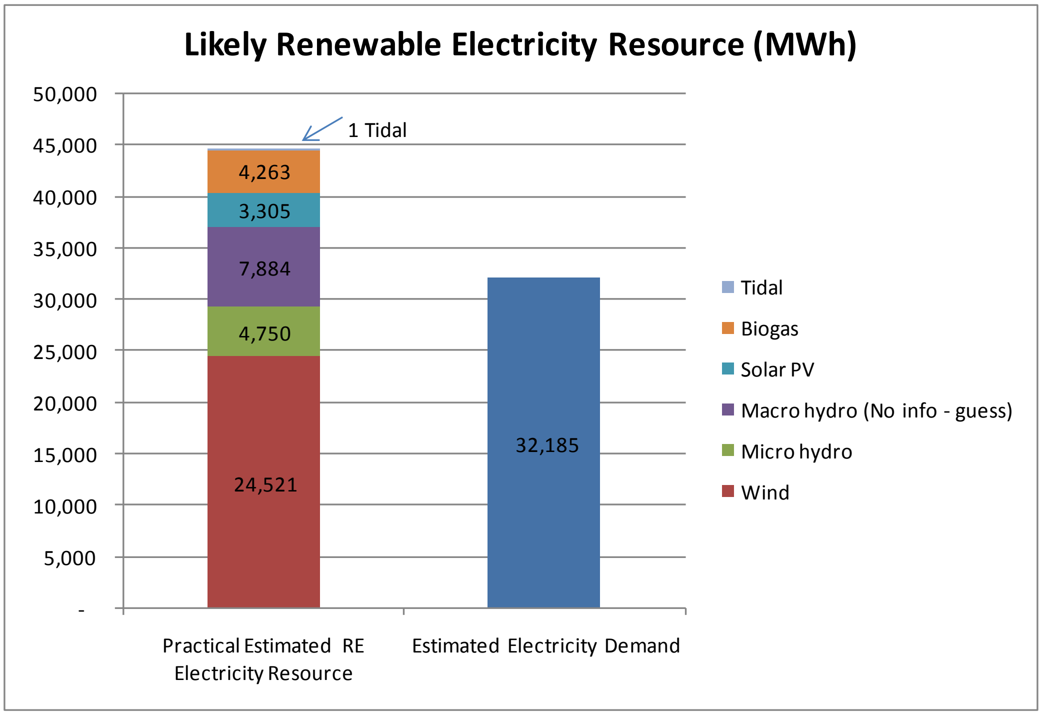
2.4.2 Likely renewable electricity resource

The likely renewable electricity resource within the Park is estimated to be 44,723MWh which is still in excess of the demand of 32,185MWh/year.

If wind is not deployed and tidal cannot be deployed because it is not yet commercially accessible then the likely renewable electricity resource will rely heavily on micro and micro hydro, solar pv and biogas. Using these technologies only would potentially provide 20,202 kWh of renewable electricity, a shortfall of 11,983 kWh's. The potential for the use of macro hydro is the least researched in this assessment and could be greater or less than the proposed kWh's presented here.

The contribution of the respective technologies and renewable resource is presented in the bar chart below.

Section 2 Summary of Assessment Findings



Notes to accompany the above chart:

- Tidal has been reduced to 1MW based on the deployment of 1 tidal turbine similar to that test off the coast of Lynmouth.
- Biogas is based on 40% of the theoretical limit
- Solar PV is based on 40% of the theoretical limit
- Macro –hydro is based on professional guess and reduced against the proposed guess for the theoretical limit – awaiting more information to improve on these figures
- Micro-hydro is based on the 51 schemes identified and assessed by Loughborough university as those that are viable
- Wind has taken the theoretical limit of installing 15kW turbines across the Park in all areas from 'very high' to 'low' wind speed areas. However this would mean deploying 685 turbines across the Park and is unlikely to be acceptable by local residents and planning. But if larger turbines were to be deployed (even on the edge of the Park) then to achieve the theoretical limit of 24,521MWh would mean installing five 1MW turbines, or three 1.5MW turbines. Deploying just three 2 MW turbines would exceed the theoretical limit of the combined deployment of 685 turbines across the park. More detailed information is provided in the section of wind[3].

- [3] 3 turbines of 2MW would yield around 20,000MWh, depending on the wind speed and turbine model. At the time of writing new turbines in the range 0.5MW to 1.0MW are becoming hard to obtain commercially

However, unless the renewable electricity is first used locally then exported It should also be noted that most of the electricity generated through renewable technologies is likely to be exported unless distributed locally first. In some instances this is easier than others. For example solar pv can benefit the property directly before any excess is exported – where as larger scale wind is usually grid connected unless accompanied by a distributed generation system or private wire.

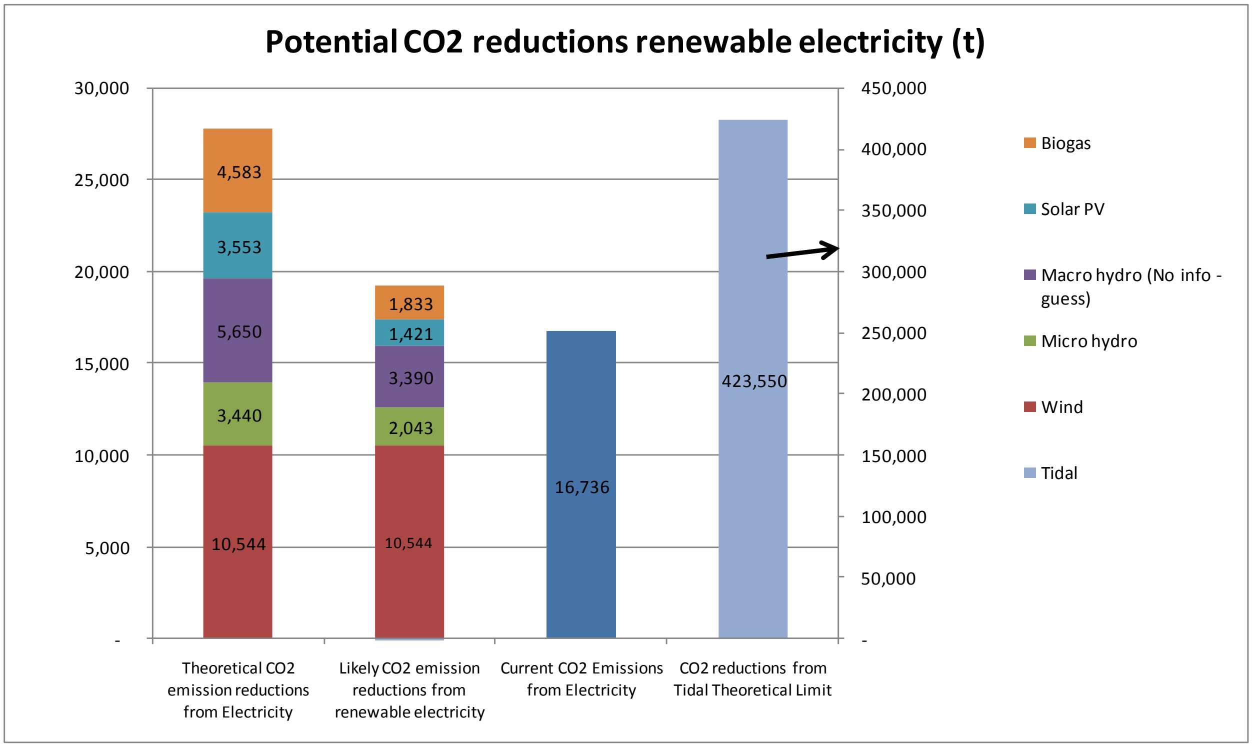
2.5 SUMMARY OF CO_2 REDUCTION POTENTIAL FROM EXMOOR'S RENEWABLE ENERGY RESOURCE

2.5.1 Potential tCO_2 reductions from renewable electricity resource on Exmoor

Based on the theoretical limit of the electricity technology (and on the whole due to the potential tidal power) then CO_2 emissions could be reduced by 451,319 tonnes. See chart below. This is almost all due to the potential to harness tidal power which is currently being commercially tested and is expected on stream within the next 3-5 years. Without tidal power the CO_2 emissions reductions based on the theoretical limits will be an estimated 27,769 per year. And without wind these will be further reduced to 17,225 tonnes per year which is a difference of only 469 tonnes when compared with the current emissions of Exmoor from the use of electricity.

The assessment has shown that for the 'likely' scenario CO_2 reductions could potentially be reduced by 19,231t/year including tidal and wind. Without tidal the figure would be 19,230 t/year and without wind this would be reduced to only 8686 t/year. This would not be enough to match the CO_2 emissions attributed to the use of electricity which is 16,763 t/year.

The likely scenario is also potentially able to reduce emissions beyond the current emissions attributed to electricity demand within the National Park. The bar chart below shows that likely CO_2 reductions from renewable electricity. This exceeds current emissions by 2495tCO2/year.



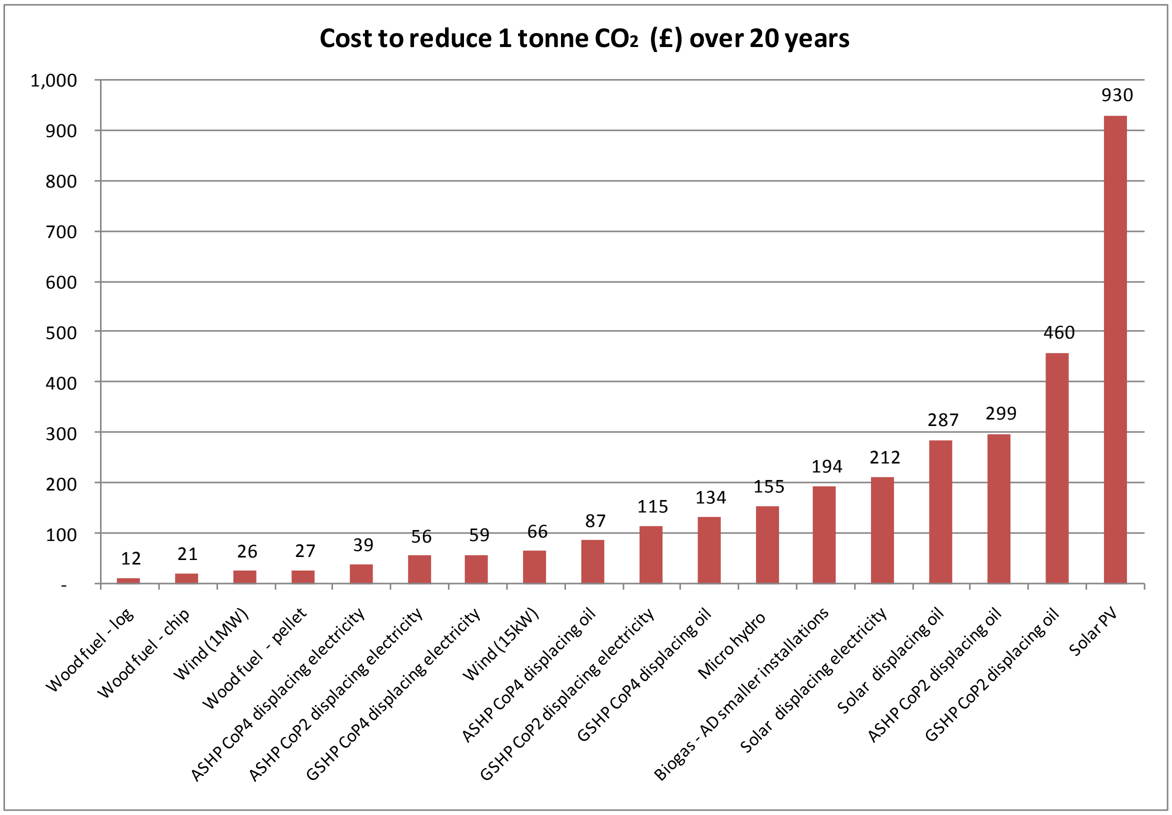
2.6 SUMMARY OF COSTS TO REDUCE CO_2 REDUCTION POTENTIAL FROM EXMOOR'S RENEWABLE ENERGY RESOURCE

This assessment has considered the installation costs for each technology and then reviewed against the emission reduction potential of the technology if deployed within the park. This has given a rudimentary benchmark which will provide an initial screening of the most cost effective technology. The results have been ranked in order of cost effectiveness and presented in the following bar chart.

It must be noted that this is purely based on researched costs to install the technology and is subject to change. It also does not take account of any local benefits to the economy from the revenues received through the displacement of imported electricity or other fossil fuels in favour of export of energy generated from the Park. This and the gross value added, net present value and internal rate of return will provide a much more holistic and realistic assessment of the benefits of any technology deployment to the economy.

These latter elements will be undertaken as part of the wider carbon neutral strategy if time and budget permits. Nevertheless, the cost per tCO_2 reduced is useful as an initial appreciation of the cost benefit of installation costs versus reduction potential of different technology and will help to screen where focus should initially be directed.

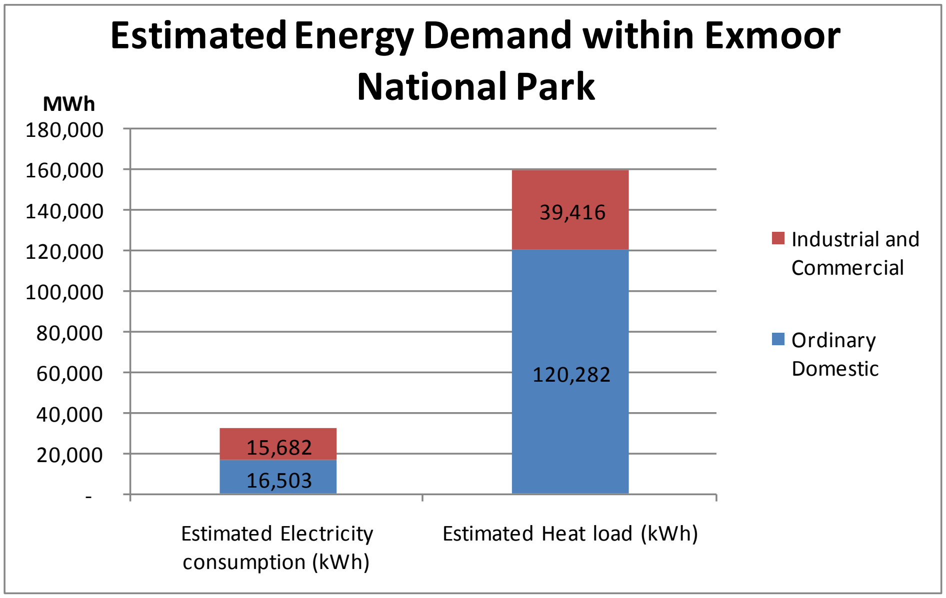
Section 2 Summary of Assessment Findings



3 The current Baseline

3.1 ENERGY PROFILE OF EXMOOR NATIONAL PARK

All estimations are based using 2005 published data from central government.
The estimated heat and electricity demand for properties across Exmoor National Park has been estimated as follows:



Note that the estimated heat load includes electricity delivered as heat. This is explained in more detail in what follows. The heat and electricity demand for the Park has been estimated using a combination of two methodologies.

Methodology One

Methodology one has used the information presented by South West Wood Fuels (SWWF) in their 2004 report.[4] Based on ENPA's statistics the Park had at that time, 4896 households. 84% (4113) of the properties had some form of central heating. It can be deduced from this that the remaining 16% (783) were using some form of solid fuel and/or electricity for heating.

Of the 84% that have central heating, 734 were farms. The energy profile of a farm will be different to that of a household and this is reflected in the estimated energy profile.

[4] Fuel supply and handling for the expansion of automated wood heating on Exmoor

The SWWF report estimates the average heat load of the properties with central heating to be 30kW for households and 50kW for the 734 farms. This gives and estimated heat load of 138,000kW for 84% of the properties.

What the report doesn't supply is an estimation of the heat load for the remaining properties without central heating. For consistency, applying 30kW to each of the 783 properties would add another 23,490kW heat load to the above figure. However, estimations derived from the super output data (see below) give the heat load from electricity use for heat (economy 7) at 16,769MWh which would give an average energy consumption per property of 21,417kWh. The two approaches give similar results and this assessment has chosen to use the higher figure which is more likely given the nature of the housing stock on Exmoor.

Using this methodology the total heat demand for the households across the Park can be estimated to be **161,490 kW**.

If it assumed that heating is required for an average of four months per year, six hours a day then the total kWh delivered is an estimated **120,282 MWh**.

The SWWF report does not take into account other properties that might be classified as industrial and commercial premises including public sector buildings such as schools.

Using ENPA statistics we know that there are 19 schools across Exmoor (including nurseries) and have applied an estimated average energy profile of 70kW per school..

In the absence of any data this assessment has assume that business and other organisations are in the region of 400. The energy profile of these organisations will vary dramatically but using this methodology an average figure of 35kW has been applied.

The electricity demand for the park (for use other than for heat) can be estimated using the super output data for 2005 which is given below.

Methodology Two

The second methodology uses the 2005 electricity and gas consumption super output data for 2005[5]. This presents data geographically for each local authority area in the country. Because Exmoor National Park resides in two LA areas the data must first be filtered using GIS to assess the electricity and gas consumption.

The super output data presents average electricity and gas consumption per meter for domestic and industrial & commercial use. The electricity data is useful because the average will be broadly applicable to the Parks energy profile for domestic and Industrial & commercial users.

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Using the super output data the electricity consumption has been pro-rated according to the % population of the Park. This has produced the following estimations for electricity use per annum in the Park.

Elec allocated to ENP (kwh)				
Ordinary Dom	Economy 7 Dom	Domestic	Ind & Com	Total
16,502,715	16,769,214	33,271,929	15,682,016	48,294,351

Therefore for domestic properties the electricity demand is estimated to be **33,272 MWh** of which a large proportion of the 16,769MWh economy 7 will be used as heat.

The gas profile presented in the super output data is less relevant to understanding the heat demand of the Park. This is because a large proportion of the properties within the park are off-grid and will rely on a combination of oil, lpg, solid fuel and electricity to heat them.

It can be argued that the average gas consumption for the area will equal the average heat demand but this does not take into account the efficiency of different fuels and systems to deliver the same amount of heat. For example a modern gas boiler is expected to operate at efficiencies greater than 90% whereas older oil and LPG systems may only be reaching efficiencies between 65% and 80%. This means that each system will use different amounts of fuel (kWh) to achieve the same indoor temperature.

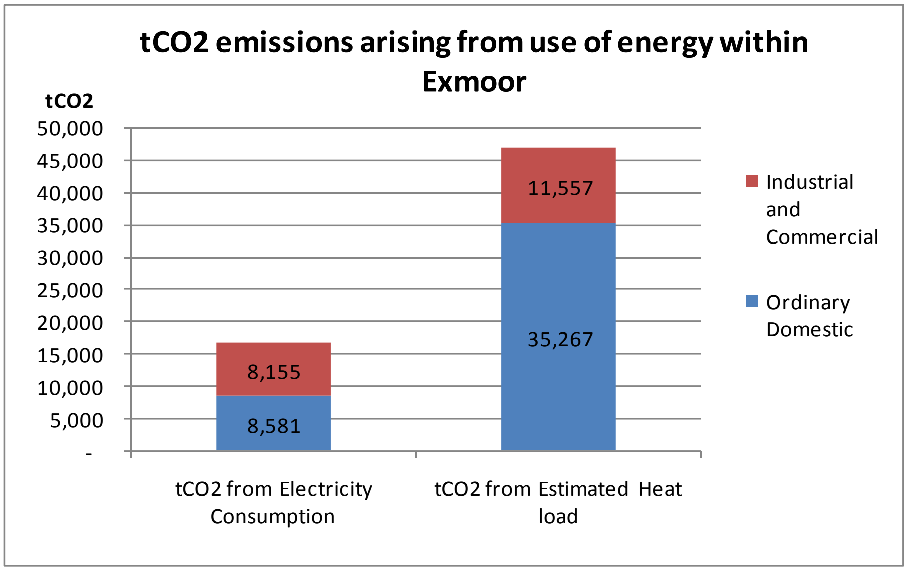
In addition to this the efficiency of the building will also influence the amount of kWh delivered to reach the same indoor temperature. Properties in and around Exmoor vary considerably with many hard to treat in terms of reducing heat loss from the building. Both of these factors together will most likely increase the average heat load per property in the National Park compared with that presented in the super output data for gas in the local areas.

The super output data presents the average gas consumption per domestic meter point as 17,042 kWh for West Somerset and 17,069 kWh for North Devon providing an average of 17,066 kWh per domestic meter point. The total heat load for the Park domestic properties using these figures is **83,553MWh**.

If methodology one above is applied the average kWh is 24,024 per domestic property (including those classified as farms above) or 19,656 for domestic properties and 32,760 for farms. This is higher than the local average presented in the super output data and probably more realistic given the facts stated above. For this reason this assessment has adopted this latter method for estimating the total heat requirement for the National Parks domestic sector which stands at **120,282MWh**.

3.2 THE CO_2 PROFILE FROM THE USE OF ENERGY

The CO_2 profile from the use of energy in the Park is 63,560t/year and has been estimated as follows:



Emissions attributable to heat for both sectors are split on an 84%/16% oil & LPG/electricity for consistency as discussed above. For the purposes of this assessment LPG and oil have been grouped because the exact consumption for the two fuels is unknown. This shouldn't affect the results too much since LPG and oil have similar emission conversion factors of 0.24 and 0.26kgCO_2/kWh. This assessment has used an average conversion factor of 0.25kgCO_2/kWh.

0.52kgCO_2/kWh has been used for electricity –this is the DEFRA recommended conversion factor for past emissions based on the national grid average. However, for future projections of emissions reductions 0.43kgCO_2/kWh has been used, this is recommended by DEFRA based on anticipated national grid average in the future.

4 Detailed Assessment of the Renewable Energy Resource for Exmoor National Park

4.1 WIND RESOURCE IN EXMOOR

4.1.1 Methodology for Assessment

Average wind speed estimates data was mapped within Exmoor using 1km grid wind speed database sourced from The Department for Business, Enterprise & Regulatory Reform's[6]. Data was mapped at three elevations: 10 meters, 25 meters and 45 meters.

Wind resource potential in Exmoor is likely to be limited by the constraints upon development imposed by its designation status. Therefore small scale wind resource potential at 10m elevation has formed the focus of this study. However, the assessment has then compared this with deployment of larger turbines to achieve the same results.

Using the 10m elevation wind speed grid the following output area selections were derived through querying the data:

- Low Potential: All cells below 5 m/s selected.
- Medium Potential: All cells 5 m/s or above and below 6 m/s selected.
- Medium/High Potential: All cells 6 m/s or above and below 7 m/s selected
- High Potential: All cells 7 m/s or above and below 8 m/s selected
- Very High Potential: All cells 8 m/s or above selected.

Wind speed bandings were chosen in accordance with published power ratings for four classes of wind turbines. The potential wind energy resource per turbine was calculated and multiplied by the number of turbines deployed based on 1 turbine per sq km to give us the potential wind energy resource for Exmoor.

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[6] www.berr.gov.uk/energy/sources/renewables/explained/wind/windspeed-database/page27708.html

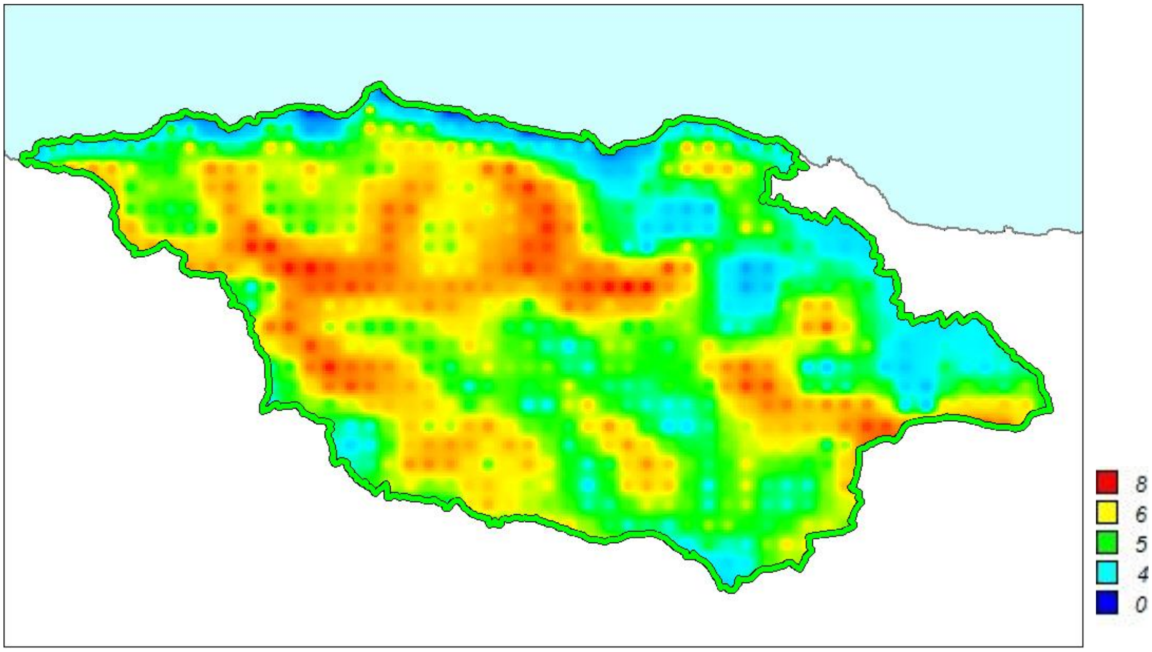
Yearly output for different rated turbines					
Yearly output in kWh for turbines rated at:	4.0	5.0	6.0	7.0	8.0
600W	794	1354	1,948	2,504	2,969
2.5kW	2,473	4,282	6,333	8,403	10,251
6kW	6,675	11,622	16,900	21,216	22,216
15kW	16,912	29054	42,250	54,860	65,541

There are numerous combinations of different rated turbines, but for the purposes of this report we have taken the maximum (15kW) and the minimum (0.6 kW) and plotted them against the potential wind speed to derive the potential wind resource, the potential CO_2 displacement and the average cost to reduce a tonne of CO_2 using this technology[7].

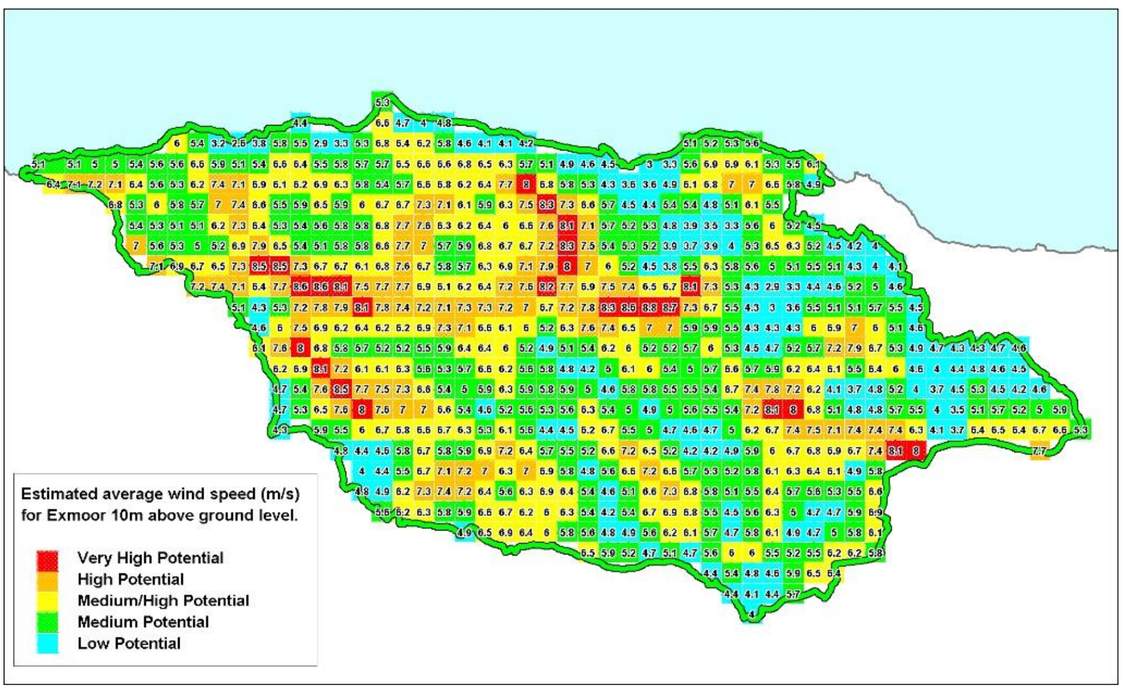
4.1.2 Resource Potential

Exmoor is well placed nationally in terms of its potential for renewable energy derived from wind power. Average UK wind speed is 5.48 m/s. The highest wind speed in the UK is 16.5 m/s, the lowest is 0.3 m/s. Wind speed in Exmoor varies from 2.6 - 8.8 m/s. The average wind speed was found to be 5.8 m/s.
The following interpolated map shows average annual wind speed estimates at 10m for Exmoor National Park:

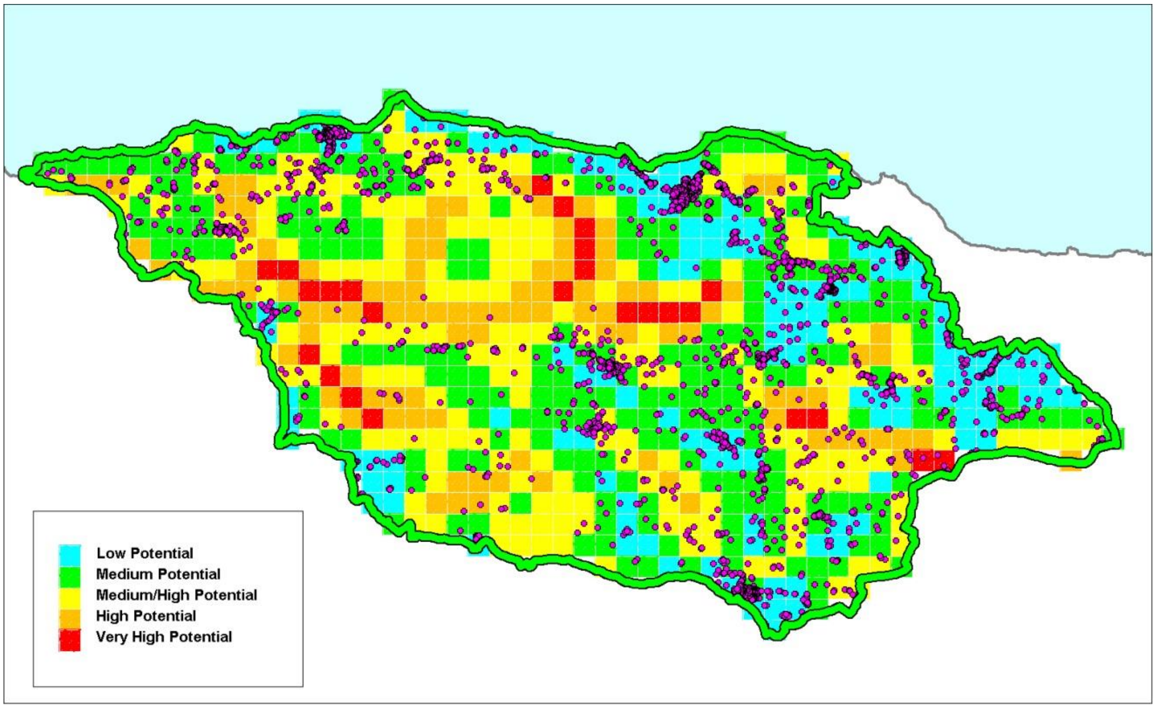
[7] These numbers appear to be too high. For example a load factor of 15% at average wind speed of 15kW 8m/sec is too optimistic. 15KW turbine will need 3 phase electrical supply for exporting most cases. Amend in the figures when drafting the strategy.



10m elevation wind speed grid are represented on the following map



The following map shows the locations of properties within Exmoor that were queried and their situation in relation to the wind speed map of Exmoor:



The theoretical limit of wind resource in the park using 15kW turbines is 24,521MWh.

25 sq km has been identified as 'very high potential' and eight properties within that area exist where 10 meter turbines could be deployed. Based on the uptake by properties 524 MWh could be generated using eight 15kW turbines. If twenty five 15 kW turbines were deployed in this area then 1639 MWh could be generated.

102 sq km has been identified as having 'high potential' for wind resource and 130 properties fall within these zones. If all properties were to deploy the technology then 7,132 MWh could be generated. If 102 turbines were deployed then the amount of wind resource captured could generate 5,596 Mwh[8].

However the data detailing other planning restrictions such as SSSI, Section 3 Landscape are yet to be layered - once queried this is likely to drop the potential deployment of turbines. Clustering the turbines would allow for more than 1 turbine/ sq km but until site specific assessments are undertaken it is not possible to say what the actual numbers will be. (A sensible approach would be clusters of 50kW installation to achieve double ROCs).

4.1.3 Assessment

Given the planning restrictions of national parks this assessment has considered in detail the deployment of wind where the turbine is less than 10m high. In addition to this it has then compared this with the deployment of a larger turbine to achieve the same results.

[8] Wind turbines do not have to be installed at properties. Landscape considerations may "trump" wind speed in terms of site selection. There may also be ecological, aviation and other constraints.

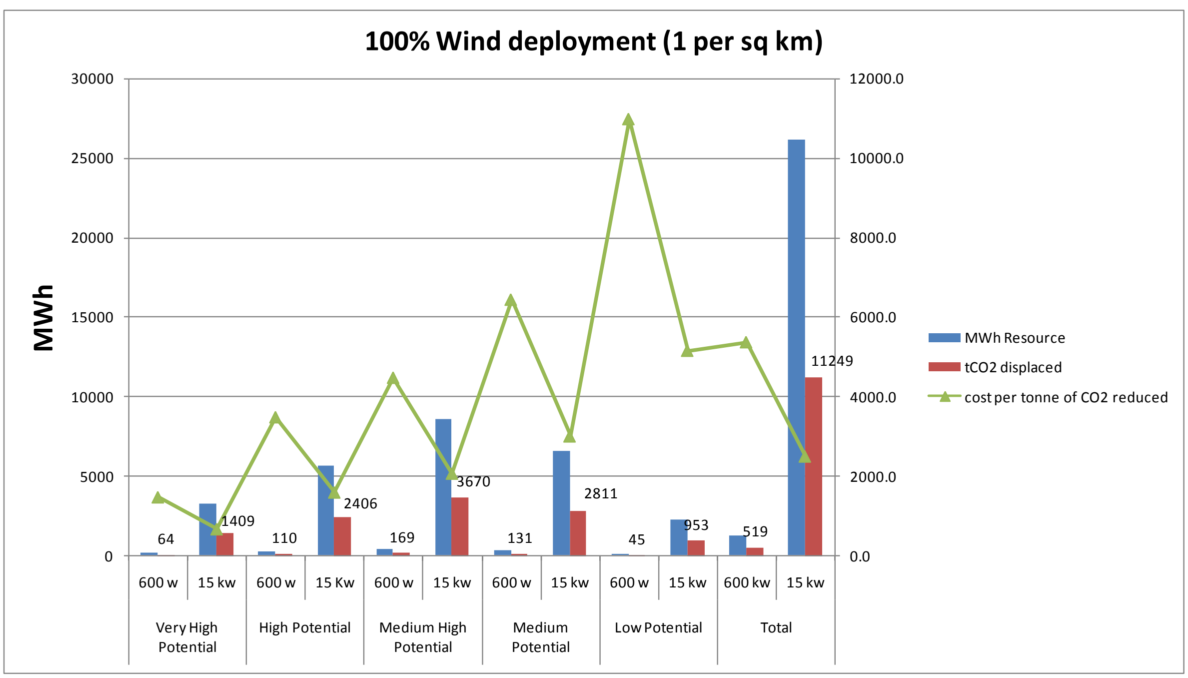
As noted above the theoretical limit of wind resource in the park using 15kW turbines is 24,521MWh. However this would mean installing 685 turbines across areas with 'very high potential' wind speeds through to 'low potential'. Practically only areas identified as 'very high potential' and 'high potential' would be utilised.

The visual impact of deploying so many turbines across the Park is likely to be significant. In reality only site specific surveys and a combination of spatial mapping to best understand where the most effective deployment is to be achieved will provide some understanding of the level of uptake that is likely to be possible. This will undoubtedly be a combination of the above and include turbines with different power outputs to those presented here.

When comparing the deployment of smaller turbines to that of a larger turbine it can be shown that a one 1MW turbine in an area of 'high potential' could generate 4,543 MWh and a 1.5 MW and a 2MW turbine could generate 7,731MWh and 9,435MWh respectively. As expected because of efficiencies of scale the latter two exceed the combined capacity of deploying a 137 turbines across the park in 'very high' and 'high' potential areas of wind resource.

To achieve the theoretical limit of 24,521MWh would mean installing five 1MW turbines, or three 1.5MW turbines. Deploying just three 2 MW turbines would exceed the theoretical limit of the combined deployment of 685 turbines across the park.

The following plot reflects the 100% deployment of 600W and 15kW turbines across all areas with potential wind speed from 'very high' through to 'low' potential. The potential MWh generated and the tonnes of CO_2 displaced are also reflected.



Other points to note:

The CO_2 reduction potential from the deployment of wind technology

Because wind is displacing grid electricity the CO_2 savings have been estimated using the national average of 0.43kg of CO_2 per kWh and based on the above estimated wind resource.

The potential CO_2 reduction from achieving the theoretical limit of wind resource in the park is estimated to be 10,544 tonnes per annum. If three 2MW turbines were deployed then this would reach 12,171 tonnes per annum.

The average cost of a 15kW turbine is £37,500. One 15kW turbine could reduce CO_2 by 28tCO_2 per annum and 560tCO_2 over 20 years. The average cost to reduce a tonne of CO_2 is £66.5 based on the reduction potential across 20 years for the deployment of 15kW turbines. The cost to reduce 1 tonne of CO_2 with a 1MW turbine is estimated to be £26

Investment costs (2007/8)

Costs to deploy wind technology will vary considerably from site to site. Based on discussions with project developers and web based research this assessment has used a range of lower and upper costs to derive an average cost for the size of turbine used.

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Of the range of turbines modeled (less than 10m high), not surprisingly, the most cost effective is the 15kw in areas of very high potential. However, this is not the case when compared to the deployment of a single larger turbine where the cost of a 1MW turbine is around £1million

To achieve 100% of the resource potential of wind using 15kw turbines would mean installing 685 turbines across the Park. This would cost an estimated £26M for a total reduction of just over 10,000tCO_2 per annum generating a potential 24,521 MWh. Over 20 years this would deliver an estimated 211,000tCO_2 and 490,427MWh.

In summary, if just the 15kW turbines were deployed in areas of very high potential the cost would be - around £930,000. If the additional turbines in areas of 'high potential' were deployed the cost would be another £3.8M for 102 turbines.

By comparison deploying a 1MW turbine will cost in the region of £1 million for an output of 4,543MWh per annum about a fifth of the total theoretical limit deploying turbines less than 10m high[9].

Energy cost saving to the economy and example of saving to the householder

The Parks current electricity demand (including that used for heat) is estimated to be 26,730 MWh which at 12p per kWh costs the economy around £3.1 million per annum.

If the deployment of a wind turbine is undertaken by a private individual or small community then there is a net gain to them because they will receive revenue for any exported electricity to the grid. If the wind is deployed using private wire or for use in the immediate vicinity then there is a cost saving because it will displace the use of imported grid electricity. In both of these instances where the individual or community is based in the national park there will be a net gain for the Park's economy.

Based on the above calculations if wind is deployed on a larger scale to achieve the Parks electricity demand, three 2MW turbines will be needed at an estimated cost of £5million-£6million. This could potentially pay for itself within 2-3 years[10].

If one 15kW turbine was deployed by a private individual then the average cost would be around £37,500 to deliver around 65,000kWh per year. If the householder used around 7000kWh of electricity per year then the cost saving through displaced electricity would be in the region of £840. If the excess electricity is sold back to the grid then this would realise and annual income of a maximum £5800[11] including the ROCs. On this basis the turbine would pay for itself within about 5 years[12].

Planning Constraints

Ideally, the turbine should be sited as far away as possible from buildings or trees, which may block the wind and cause turbulence. See the figure illustrating where a wind turbine should ideally be located.

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[9] . Deploying three 2MW turbines will cost around £5m and will exceed the theoretical limit compared with £26m for 685 15kW turbines. Additional Note: 3 x Enercon 2.3 MW E70s at wind speed 8.4m/s at 65m hub generate 23,500MWh per annum and cost £7 million (increased because of fall of sterling)

[10] Payback is a little short and ignores planning cost and risk. Cost going forward should really be around £7m not £5m

[11] This has been calculated selling 58,000 kWh back to the grid for a price of 10p/kwh which is the best price on the market at the time of writing offered by good energy.

[12] Yield in this calculation is likely to be too high.

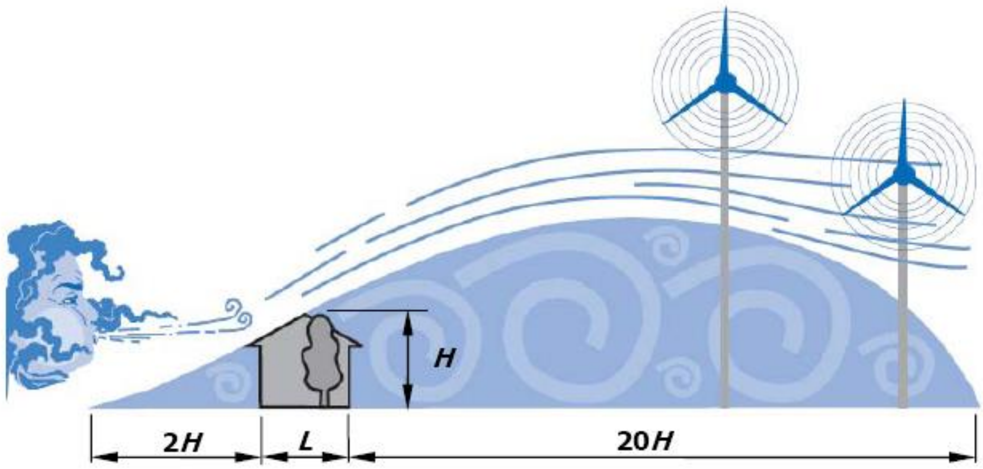


Figure 4 Rule of thumb for assessing impact of obstacles of height H on wind turbine performance.

Turbine location needs to consider the following:

- **Military installations**. A small wind turbine will not be allowed in close proximity to a military airfield or radar installation.
- **Proximity to neighbours**. A small wind turbine should be located at least 50m from the nearest neighbours, and ideally at least 75m - 100m to avoid noise being an issue.
- **Designated areas**. Whilst there is not an absolute ban on small wind turbines in National Parks or Areas of Outstanding Natural Beauty the visual impact will need to be taken into account.
- Access to the site will be needed for a lorry or crane in order to deliver and install the turbine pole. Not usually an issue with small turbines.

To take into account these potential restrictions the wind energy potential grid layer was queried against the geospatial point databases of properties and sites within Exmoor and designated areas that may pose a challenge to planners. This GIS investigation will reveal a more complete estimation of wind resource potential.

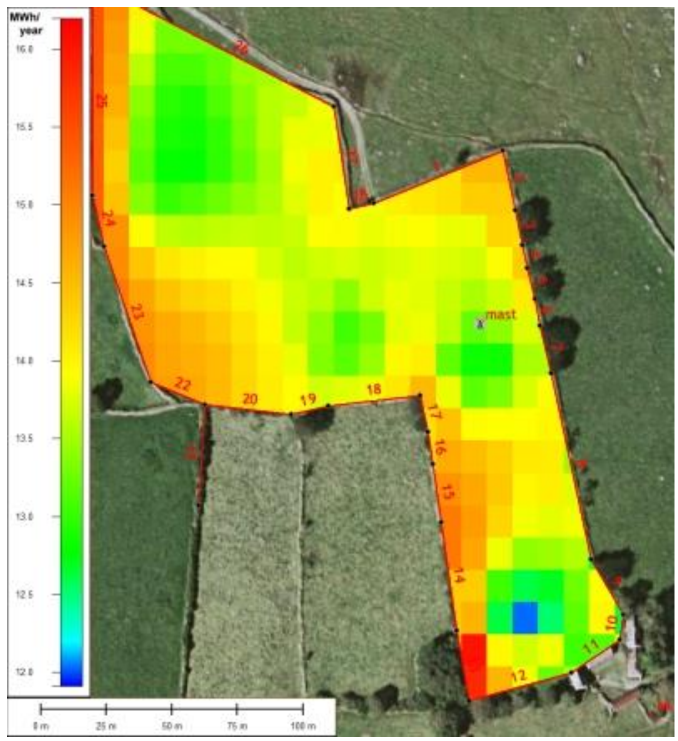
4.1.4 Technology Description

Wind measurement

To assess a site successfully an anemometer should be erected to find possible energy capture companies such as WindMeasurement.co.uk based in Devon provide a low-cost wind monitoring service aimed at the small scale wind turbine market (5-20 kW). The standard service includes site assessment, wind monitoring, average annual energy yield prediction and turbine optimisation.

The assessment leads to a local wind map with potential energy capture in different areas around the particular site.

The result (see figure) is an energy map across your site, at a range of heights, of the 10 year average annual energy production of your preferred turbines. The results quantify discussions with planning authorities and allow a balanced view to be taken on energy yield versus visual impact.



Turbine types

Wind turbines come in many shapes and sizes and vary in output and price. Small systems can be utilised to charge battery on boats, road signs and remote sensing systems, 1KW system can be used to power building that only require a small amount of power say to drive a water pump for example.
Household systems of around 2.5KW, supply to a farm or multiple buildings then move into the 5-6KW range, still in the small wind turbine range are the 15kw systems, after this size its more efficient for a turbine to be sited on a larger pole and begin to move into the +20kw system.

100 Watt system

- Generates up to 100 watts for 12 volt or 24 volt battery systems.
- Designed to survive the severe marine environment. ·
- Heavy duty, all-weather generator, sealed to keep corrosion out.

- Permanent installation as a fit & forget unit.
- Found in many other applications such as weekend chalets, radio repeaters, navigation equipment or anywhere that requires 12v/24v battery charging.
- Save cost of fuel and the need to run noisy engines. Reduce engine running under light loads · Supplement solar charger output with energy that is potentially available day and night; winter and summer.
- Improve battery condition and extend battery lifetime. Increase battery charging out of summer season when electrical demand increases but sunlight reduces.

Rated Output: - 200W (6kW)
Voltages available: - 48V / 12V /
Annual Output - 200-400 kWh*
Rotor Diameter: - 0.5m
Hub Height: - various

2.5 KW system

- The Proven 2.5 produces 2.5kW of electricity. This can meet the power needs of a standard three-bedroom home, excluding heating.
- Any excess energy production can be stored or exported to the grid, depending on local regulations. The turbine is approximately the same size as a standard telegraph pole.
- The 2.5 can be used to power small lighting systems in commercial premises. The Proven 2.5EX is widely used on off-shore oil platforms, as it is the only turbine in the world that is totally explosion-proof.

Rated Output: - 2500W (2.5kW)
Voltages available: - 12V / 24V / 48V / 120V / 240V / 300V
Annual Output - 2,500-5,000 kWh*
Rotor Diameter: - 3.5m
Hub Height: - 6.5m / 11m

6KW system

- The Proven 6 produces 6kW of electricity. It is able to meet the power needs of a standard house with four to six bedrooms, excluding heating.
- Any excess energy production can be stored or exported to the grid, depending on local regulations.

- The Proven 6 is suited to a broad range of applications. It has been installed in schools, local authority buildings, agricultural small holdings, business and retail premises.

Rated Output: - 6000W (6kW)
Voltages available: - 48V / 120V / 240V / 300V
Annual Output - 6,000-12,000 kWh*
Rotor Diameter: - 5.5m
Hub Height: - 9m / 15m

15kw System

- The Proven 15 is the largest Proven wind turbine.
- It is able to meet the energy needs of six houses, each with three bedrooms, excluding heating.
- Excess energy production can be stored or exported to the grid, depending on local regulations. Please contact your local installer or reseller for a delivery date as demand is high.
- The Proven 15 is ideal for commercial applications, including agriculture, telecoms applications, small industrial units and mini wind farms see Windcrofting™ proposition.

Rated Output: - 15000W (15kW)
Voltages available: - 48V / 300V
Annual Output - 15,000-30,000 kWh*
Rotor Diameter: - 9m
Hub Height: - 15m

4.2 SOLAR THERMAL RESOURCE

4.2.1 Methodology for assessment

Solar thermal is usually deployed on an individual household basis and the resource potential is determined by a number of factors including;

- The solar insolation (or gain) (kWh/m^2/day)
- [13]The energy requirements of the household – this will include the volume of water to be heated and the rise in temperature needed.

A solar system orientated between south east through south to south west at an angle of 350 (standard roof pitch) to the horizontal, will, for all practical purposes, work close to its maximum efficiency. However, even an east-west facing roof can collect 84% of the available heat energy, so most dwellings will have access to a roof pitch or vertical surface that could accommodate a viable solar system.

This assessment does not have access to information that gives the number of properties that have a south or east-west facing surface and that would lend themselves to the deployment of an effective solar system. So for the purposes of this assessment, assumptions have been made to arrive at an average energy requirement of two types of households in the Exmoor Park and then presented as a collective resource with potential outlined across 10%, 40% and 100% deployment bands.

Assumptions:

1. Based on evacuated tube systems with a 55% efficiency.
2. The number of domestic properties across Exmoor is 4896, though it should be noted that not all will be suitable for solar thermal.
3. 16% of properties use electricity to heat their homes and 84% use LPG or Oil – a small amount of gas is used but in terms of calculating the CO_2 benefits the amount is negligible. Most properties LPG and Oil have a similar CO_2 conversion factor and so have been collectivised and accounted for with the 84%.

4.2.2 Resource Potential

The resource potential has been estimated[14] as follows:

Average Solar insolation = 940 kWh/y per m2.

4m^2 evacuated tube= 940 x 4 = 3,760 kWh/y x 55% = 2,068 kWh/y

2,068 kWh/y x 4,896 dwellings = **10,124,928** kWh/y

Or **10,125 MWh/year**

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[13] http://www.apricus.com/html/solar_collector_size.htm

[14] Note that an alternative way to calculate this is to take the figures assumed by the Energy Efficiency Commitment Scheme of 454kWh/year saving per m_2 of flat plate collector or 582kWh/yr per m^2 for an evacuated tube system. Assuming a 4m^2 system this would provide a saving in energy use of 1,816kWh/year and 2,328kWh/year respectively for the two systems.

4.2.3 Assessment

The estimated heat demand for Exmoor's domestic sector is 120,2820MWh/year. Based on the above calculations the maximum contribution that solar thermal would make is about 9% of total domestic heat demand at a capital investment of around £20 million.

This is the theoretical limit and in reality it will be considerably less than this.

Some sources[15] claim that a 4m^2 collection area will provide between 50% and 70% of a typical home's hot water requirements. However based on our assumptions the average consumption of a domestic property is 19,656 kWh per year (not including farms). If hot water heating requirements are 40% of the overall heating bill[16] (7862) and projected savings are 2068kWh/y (as calculated above) then the overall savings will only be around a 26%.

The CO_2 reduction potential from the deployment solar thermal technology

The maximum amount of CO_2 that will be saved is 3,399 tonnes per annum where solar thermal displaces oil/LPG and electrically heated systems for a 100% deployment. In reality this is unlikely and for the purposes of this assessment this will be referred to as the theoretical limit. 40% deployment is more practical and this would achieve savings of 1,269 tCO_2 per year. This would also allow for uptake by the commercial and industrial sector where larger solar thermal units may be installed.

The cost to reduce a tonne of CO_2 varies depending on the fuel it is replacing, this is because the CO_2 benefit is a factor of the type of fuel consumed. The costs per fuel type are outlined in the following table;

	Cost to reduce 1 tCO2		
	Electricity	Oil	LPG
Over 20 years (life time of technology)	£4,246	£5,747	£6,207
	£212	£287	£310

Investment costs

15 The current status and prospects for micro-generation technologies; EST; http://www.berr.gov.uk/files/file27578.pdf

16 According to the Energy Savings Trust

The cost to install a $4m^2$ solar thermal unit with evacuated tubes varies and research has shown that the lower cost is around £3,500 and the upper cost around £5000. This assessment has taken an average of £4,250 as an estimate for the installed cost per unit.

The following tables reflect the CO_2 and financial savings to the economy against the displacement of oil and electricity for 100%, 40% and 10% deployment. Based on earlier estimations using the SWWF report as a basis for calculating the heat demand in the Park for consistency, this assessment has applied the assumption that 84% of domestic properties will have some form of central heating and 16% will rely on electricity and solid fuel for heating.

	84% of properties	16% of properties	
100%	OIL	ELECTRICITY	TOTAL COST
tCO2 Savings	2,702	697	
Financial Savings (£)	425,247	194,399	20,808,000

40%			
tCO2 Savings	1,081	279	
Financial Savings (£)	170,099	77,759	8,323,200

10%			
tCO2 Savings	270	70	
Financial Savings (£)	42,525	19,440	2,080,800

Energy cost saving to the economy

Using the figures in the table below the above table also reflects the potential financial savings per year depending on the fuel replaced for different deployment rates.

CONSTANTS	Efficiencies	Cost
gas	95.00%	0.04
LPG	85.00%	0.07
oil	85.00%	0.05
electricity		0.12

So for a 40% deployment of solar thermal across the Park the cost will be in the region of £8 million with an estimated payback of 17 years for electricity heat displacement and 41 years for oil displacement.

4.2.4 Technology description[17]

[17] http://www.optimumenergysolutions.co.uk/solar-thermal.asp

Solar water heating systems use the energy from the sun to heat water, most commonly in the UK for hot water needs. The systems use a heat collector, generally mounted on the roof in which a fluid is heated by the sun. This fluid is used to heat up water that is stored in either a separate hot water cylinder or a twin coil hot water cylinder inside the building. The systems work very successfully in all parts of the UK, as they can work in diffuse light conditions.

There are two types of collectors used for solar water heating applications: Flat plate collectors and evacuated tube collectors.

- The flat plate collector is the predominant type used in domestic systems as they tend to be cheaper.
- Evacuated tube collectors are generally more expensive due to a more complex manufacturing process (to achieve the vacuum) but manufacturers generally claim better winter performance[18].

Where can solar water heating systems be used?

Ideally the collectors should be mounted on a south-facing roof, although south-east/south-west will also function successfully, at an elevation of between 10 and 60°. The panels can be bolted onto the roof or integrated into the roof with lead flashings. They look similar to roof lights. Solar water heating systems are suitable for any building type that has sufficient year round hot water needs (ideally during the day) and a suitable south-facing roof of sufficient size. This technology is particularly suitable for low-density housing developments. Retail units or offices with canteens and washrooms and/or showers may also have a Suitable demand for hot water. Where possible, solar water heating systems should be placed on roof areas not visible to the road or sight line of other buildings. Some systems can be integrated flush to the roof. The systems are no more intrusive than a roof light (window in the roof) when roof integrated.

Domestic systems

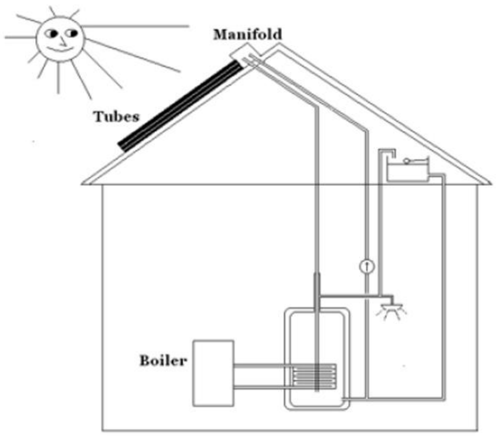
Some source claim that a $4m_2$ collection area will provide between 50% and 70% of a typical home's hot water requirements depending on the quantity of hot water required and the timing of that requirement. This assessment has estimated that a figure of 26% is more realistic against the energy profile of the Park domestic stock. The percentage can be increased if:

- Hot water is drawn off during the day, allowing more water to be heated up in the afternoon.
- Low flow showers and spray taps are fitted so that less hot water is required
- Showers are taken instead of baths.

The system is particularly beneficial for dwellings where residents are at home using hot water during the day, for example, young families or the elderly. Savings from solar water heating are difficult to predict and will in practice depend on how much water the occupants use and at what times they use it.

[18] Note 2010: Not any more – maintenance is more the issue

Flat plate collectors



DIY Thermal Kit

If an existing house would like to retrofit a solar thermal system one solution is a direct feed system. This will only work with conventional hot water tanks systems with a header tank.

Advantages of this system:

1) There is no requirement for a new hot water cylinder
2) It can be installed by the home owner

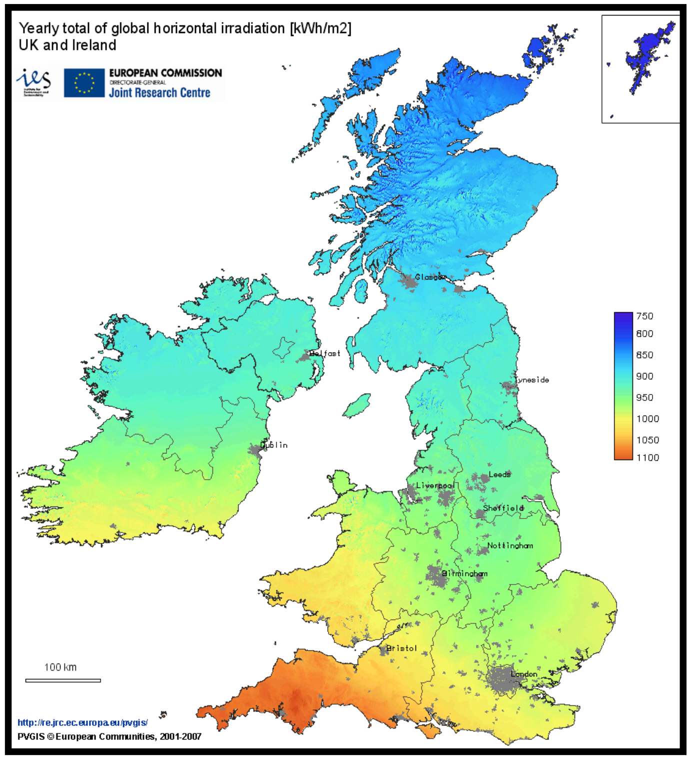
4.3 SOLAR PV RESOURCE

4.3.1 Methodology for Assessment

As with solar thermal systems a solar photovoltaic system orientated between south east through south to south west at an angle of 350 (standard roof pitch) to the horizontal, will, for all practical purposes, work close to its maximum efficiency . This implies >96% of the maximum available solar energy will be collected, i.e. for all practical purposes 100%.

The assessment does not have access to the number of properties that provide a south or east-west facing surfaces and that would lend themselves to the deployment of an effective solar system. So for the purposes of this assessment, it is assumed that all properties identified within this study could potentially gain benefits from either a solar water heating and/or photovoltaic system. In the UK the south west easily has the highest solar irradiation in the country and although Exmoor's levels are not the highest in the region there is substantial solar energy to be utilised. Exmoor's annual levels of solar irradiation will be in the region of 1000 – 1100 per kWh/m2.

Source: UK Solar Irradiation levels, copyright EU Joint Research Centre.



The potential collective resource has been presented across deployment bands of 10%, 40% and 100% to provide a range of the potential resource.

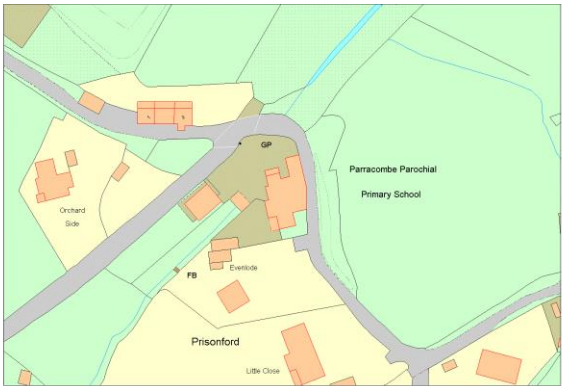
A study of the typography and surface roughness of Exmoor is beyond the scope of this investigation but could yield sites which are optimally located geographically to harness solar power.

Additionally, future studies could assess sites based on their potential for solar power by looking at mapping and aerial photography to determine roof type (flat or pitched, pitch orientation, site aspect, building orientation and available roof surface area).

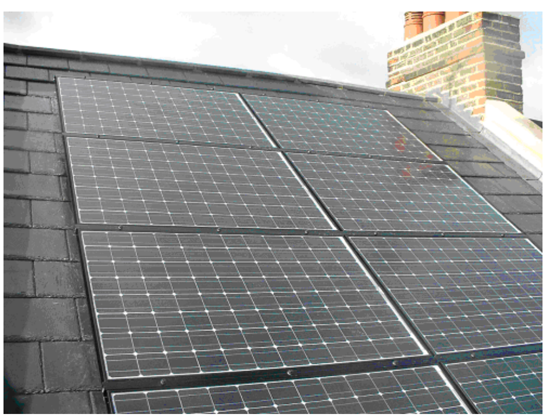
An example of this methodology is shown below.

Parracombe Primary School:

Primary School Name	Grid Ref	South Shading	Facing Side	Roof Type	Roof Area	Available Area	Solar Potential
Parracombe Church of England Primary School	267098, 144877	Shaded by trees	South South East	Pitched	Total: 227.3 m2	Area halved to factor in roof pitch: 113.65 m2	Low



Panel Type	Efficiency	m2 required to mount 1kWp	Potential Power Available
Mono-crystalline silicon	15%	8m2	14.125 kWp
Poly-crystalline silicon	8-12%	10m2	11.3 kWp
Amorphous silicon	4-6%	20m2	5.65 kWp



4.3.2 Resource Potential

The resource potential through the deployment of Solar PV is estimated to be 11,016 kW per year. This has been calculated as follows:
Number of dwellings **4896** of which half (**2448)** will have roof area orientated between South West and South East. The available roof area[19] is estimated to be 66,096m^2. Installing monocrystalline PV of 6m^2 which delivers 1kW$_p$ gives a potential installed capacity of 66,096÷ 6 = 11,016 kW$_p$

1 kW$_p$ will produce 750 kWh/y, therefore, the annual energy capture can be calculated as:

750 kWh/kWp/y = 8,262,000 kWh/y = **8,262 MWh** of electricity per year.

Assumptions:

The cells are orientated between South East through South to South West at an angle of 350 (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%.

4.3.3 Assessment

The above resource potential is the theoretical limit. In reality the cost and the practicality of covering almost 50% of half the properties in the National Park with solar pv of this type is unlikely in the near future. As technology advances both the visual impact and the cost of solar pv will be addressed for a more positive outcome.

The CO_2 reduction potential from the deployment solar pv technology

The CO_2 emissions reductions for 8,262 MWh per year is 3,553 tonnes. Based on the cost of the investment alone the cost per tonne of CO_2 reduced is £930.

Investment costs

At a cost of £6000/kW$_p$ installing the solar pv to the theoretical limit will cost in the region of £66 million.

The following table gives an outline of the costs and financial returns for the deployment of solar pv.

---

19 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.
2448 x 27 = 66,096m^2

% uptake	100.00%	40.00%	10.00%
Mwh	8,262	3,305	826
tCO2 Savings	3,553	1,421	355
Financial Savings (£)	991,440	396,576	99,144
ROC value	371,790	148,716	37,179
Export value/kWh	495,720	198,288	49,572
Cost	66,096,000	26,438,400	6,609,600
Payback time for export	76		
Payback time local use	67		

Energy cost saving to the economy

The above table reflects that through the displacement of grid imported electricity the savings to the economy will be nearly £1 million[20] per year if the energy is used locally. If the energy is exported then the ROC value can be realised and revenue received for the exported energy. This will add further benefit to the economy of £800k.

4.3.4 Description of the technology

Photovoltaic systems convert energy from the sun into electricity through Semi conductor cells. Systems consist of semi-conductor cells connected together and mounted into modules. Modules are connected to an inverter to turn their direct current (DC) output into alternating current (AC) electricity for use in buildings. Photovoltaics supply electricity to the building they are attached to or to any other load connected to the electricity grid. Excess electricity can be sold to the National Grid when the generated power exceeds the local need. PV systems require only daylight, not sunlight to generate electricity (although more electricity is produced with more sunlight), so energy can still be produced in overcast or cloudy conditions. Photovoltaics are generally blue/grey in colour and can be used successfully in all parts of the UK.

Output Ranges

The size of a photovoltaic installation is expressed by its kilowatt peak (kWp) potential, which is an indication of how much electricity the system could generate at peak or optimum conditions. As a rough rule of thumb the Department of Trade and Industry estimates that a typical 1kWp system in the UK could be expected to produce between 700-750 kWh/yr of electricity (new data is pending), although some technologies will generate considerably more than that. A high performance system in London might be expected to produce a maximum of 850kWh/yr. The performance depends more on location, orientation and whole system design than it does on cell type. Photovoltaic cells come in a number of types with varying operating efficiencies and therefore different areas of panel are required to produce the same output:

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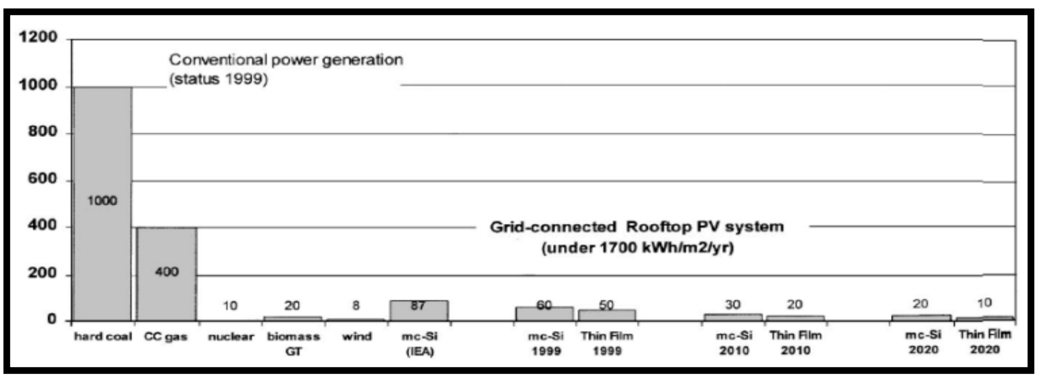
[20] Based on 12p/kWh

Panel Type	Efficiency	m_2 required to mount 1kWp
Mono-crystalline silicon	15%	8m2
Poly-crystalline silicon	8-12%	10m2
Amorphous silicon	4-6%	20m2

CO2 emissions [g/kWh] for grid-connected roof-top PV systems now and expected in the future.



For the sake of comparison emission data is shown for a number of competing energy systems (coal, gas, nuclear; data from Suter and Frischknecht (1996); wind and biomass energy estimates from IEA (1998)). The PV technology estimate from the same IEA study is also shown. Actual CO_2 emissions for PV will vary with irradiation and system performance.

Where Can Photovoltaics Be Used?

Photovoltaic panels come in modular panels which can be fitted to the top of roofs (looking similar to a roof light) and in slates or shingles which are an integral part of the roof covering (looking similar to normal roof tiles). Photovoltaic cells can be incorporated into glass for atria walls and roofs or used as cladding or rain screen on a building wall - this is particularly suitable for prestige offices. They can also be attached to individual items such as street lights, parking meters, motorway noise barriers or the sides of bridges.

Technological state of the art and anticipated developments

Photovoltaic (PV) systems are currently based predominantly on crystalline silicon technology and are mature for a wide range of applications. Today the average turn-key price of a small to medium size (3 to 20 kWp) PV system is £4/Wp and for large systems in the multi MWp range about 2 - 3 £/Wp. The efficiency of commercial flat-plate modules and of commercial concentrator modules is up to 15% and 25%, respectively. The typical system energy pay-back time depends on the location of the installation. In southern Europe this is approximately 1 to 2 years and increases at higher latitudes. Finally, the average generation cost of electricity today is about 2.6p/kWh, ranging between 20 and 30 /kWh depending on the location of the system. Crystalline silicon-based systems are expected to remain the dominant PV technology in the short term. In the medium term, thin films will be introduced as integral parts of new and retrofitted buildings. Finally, in the long term, new and emerging technologies will come to the market, such as high concentration devices that are better suited for large grid-connected multi-MW systems, and, compact concentrating PV systems for integration in buildings. It is expected that crystalline silicon, thin films and other technologies will have equal shares in the installed PV capacity in 2030. The cost of a typical turn-key system is expected to be halved to £2/Wp in 2015, and reach £1/Wp in 2030 and £0.5/Wp in the longer term.

Simultaneously, module efficiencies will also increase. Flat-panel module efficiencies will reach 20% in 2015 and up to 40% in the long term, while concentrator module efficiencies will reach 30% and 60% in 2015 and in the long term respectively. It is expected that if these technology developments are realised, the cost of electricity from PV systems will be comparable to the retail price of electricity in 2015, and to the wholesale price of electricity in 2030.

4.4 HEAT PUMPS

4.4.1 Methodology for Assessment

The deployment of a heat pump and its ability to reduce CO_2 and cost is dependent on its performance. This in turn depends on the application of the technology which will vary from site to site. For these reasons the methodology to assess the potential uptake of heat pumps across the park, as with other micro technologies, cannot produce exact figures for the potential deployment but has taken a macro approach to produce a range of potential costs and benefits.

For the purposes of this assessment the potential benefits of using heat pumps to deliver the heat energy requirements across the Park has been considered against other fuels used such as oil, LPG and electricity. This comparison presents the potential cost and CO_2 benefits of the technology against the fuel they would be replacing as well as the potential energy savings.

The potential to deliver the heat requirements will be determined by the efficiency of the heat pump system and is measured by the coefficient of performance (CoP). This is the ratio of units of heat output for each unit of electricity used to drive the compressor and pump for the system. Typical CoPs range from 2.5 to 4. The higher end of this range is for under-floor heating, because it works at a lower temperature (30-35 °C) than radiators. Understanding the impact of the CoP is essential to understand the potential CO_2 reduction potential as well as the cost implications. For this reason the resource potential has taken into account the energy requirements to deliver the heat load for a CoP of 2 and a CoP of 4 where CoP 2 is a lower performing application of the technology. (See later section 'description of technology' for more detail).

The assessment has worked out the energy and carbon benefit of a heat pump with a coefficient of performance (CoP) of 2 and 4 against the fuel type it is likely to replace to provide a range. It has then applied this to a potential deployment of 100%, 40% and 10% and worked out the capital cost and therefore the cost to reduce a tonne of CO_2 using this technology. The final report will also work out the economic impact taking account of the IRR and NPV to the economy.

Note that heat pumps only work effectively where there is good insulation and draught proofing already. Or the application is occasional heating of areas with low occupancy rates, where air to air heat pumps may displace direct electrical heating.

4.4.2 Resource Potential

The residents of Exmoor National Park require an estimated heat load of 120,282 MWh . This is currently met through a combination of oil, LPG, coal, electricity, biomass and a small amount of gas. The exact split between the different fuel types has not yet been calculated but according to one report 84% of the domestic properties have central heating[21]. This could indicate that the remaining 16% are using a combination of electricity and solid fuel to heat their homes where the benefits of using a heat pump be increased because the performance of a heat pump is better when used to provide under-floor heating rather than delivered through radiators. In addition to this the CO_2 displacement is greater when replacing these electricity and coal. (See later section on description of technology).

Theoretically every property in the Park could have a heat pump installed to meet the heat demand of 120,282 MWh.

Based on this assumption the following graph models the implications of this approach by assessing the deployment across 100%, 40% and 10% bands to provide a more realistic assessment of what is practical.

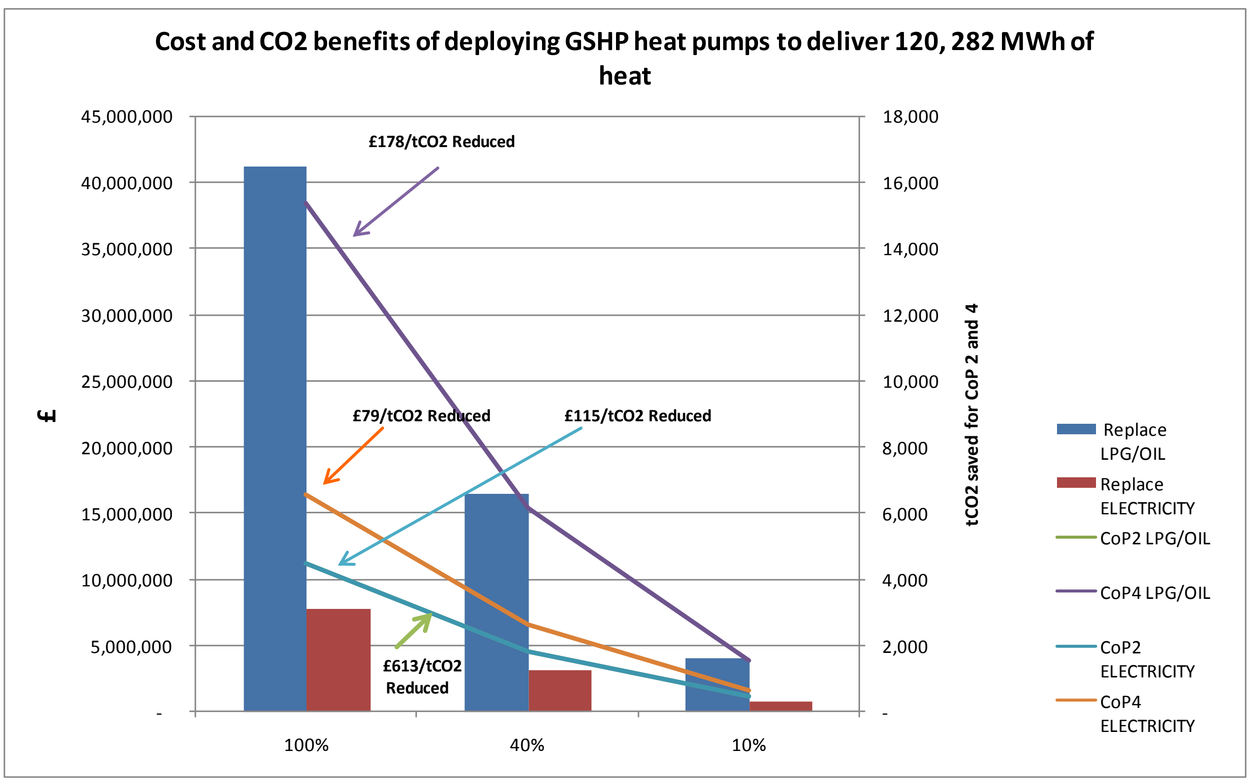
21 The woodfuel report – no reference or explanation is given about how this figure was arrived at

4.4.3 Assessment

Assumptions:

To supply the heat load requirements of residents of the National Park this assessment been based on the following assumptions:

- Deploying heat pump technology with an average power rating of 10kW.
- A cost of £1000/kW has been used for GSHP and £650/kW for ASHP but it should be noted that although the capital costs will be reduced the maintenance cost of ASHP will bring the cost back up in line with GSHP. However, if serviced locally then this is revenue that will circulate around the local economy.
- The use of mains gas in the Park is minimal and has not been included in the model because the impact would be extremely low. However it should be noted that the use of heat pumps in a gas centrally heated house would be less effective than those fuels modelled here.
- The costs have been modelled over 15 years to coincide with expected manufacturer's warranty.



The CO_2 reduction potential from the deployment heat pump technology

The line graph on the above chart reflects the different CO_2 savings for heat pumps with different CoPs and taking into account the fuel it is replacing. In addition to this the following bar chart provides an overview of the CO_2 reduction potential per annum for the deployment of heat pumps with a CoP of 4 and 2.

From this assessment it can be shown that the maximum potential carbon dioxide savings from deploying heat pump technology is estimated to be 15,394tCO_2 and to achieve these savings 84% (4113) of properties would need to have heat pumps installed.

The most cost effective deployment of GSHP technology is when it is used to supply heat that would otherwise be supplied using electricity (economy 7 or bar heaters for example).

The graph shows that this would cost around £79 per tonne of CO_2 reduced where a CoP of 4 and above is achieved.

However, even with a 100% deployment to all those properties (783) using electricity and solid fuel to heat their homes the maximum annual savings of CO_2 will only amount to 6800tCO_2 for an investment of nearly £8m

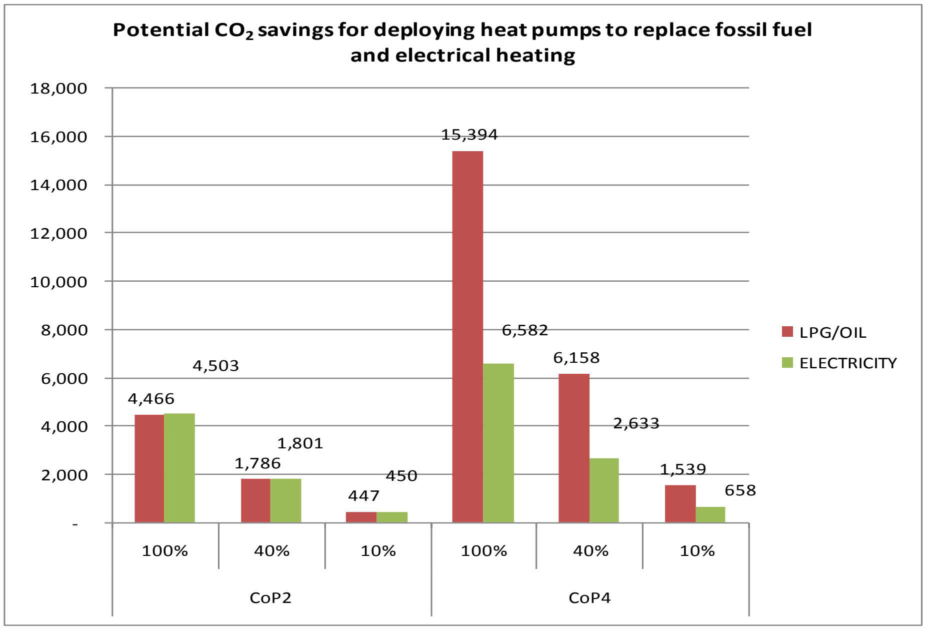
In detail: Replacing ELECTRICITY

- To replace electricity with a GSHP heat pump for 100%, 40% and 10% of properties will cost an estimated £7.8M, £3M and £0.8M respectively (the bar diagram).
- If heat pumps with a CoP of 4 is used then this will achieve emissions reductions of 6,500tCO_2, 2600tCO_2 and 650tCO_2 respectively for a CoP of 4 (the orange line and bar graph below).
- If heat pumps with a CoP of 2 is deployed and emission reduction levels of 4,500 tCO_2, 1,800tCO_2 and 450 tCO_2 might be achieved (blue line and bar chart below).
- This equates to a cost of around £77/tCO_2 reduced when replacing electricity with a GSHP where a CoP of 4 is achieved and £112/tCO_2 where a CoP of 2 is achieved.

In detail: Replacing LPG/OIL

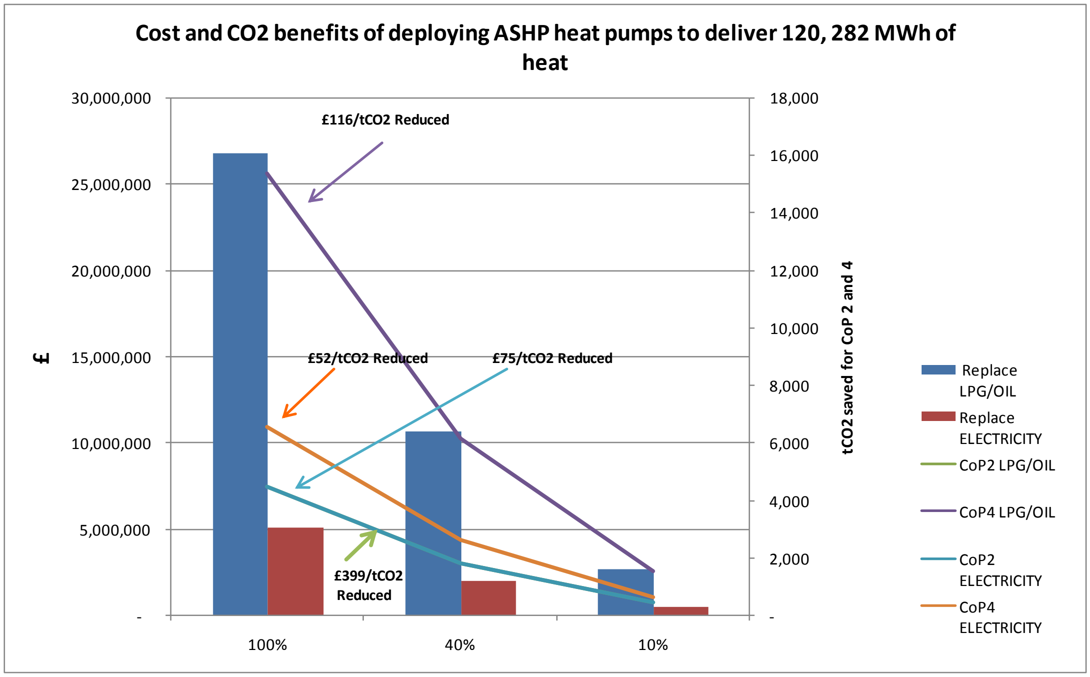
- To replace LPG/OIL with a GSHP heat pump for 100%, 40% and 10% of properties will cost an estimated £41M, £16 and £4m respectively (the bar diagram).
- If a heat pump with a CoP of 4 is used, this will achieve emissions reductions of 1,394tCO_2, 6152tCO_2 and 1539tCO_2 (the purple line on the above and the bar graph below)
- If a heat pump achieving a CoP 2 is used then emission reduction levels of 4,600 tCO_2, 1,839tCO_2 and 460tCO_2 could be expected(green line hidden behind the blue line and bar chart below).

- This equates to a cost of around £178/tCO_2 reduced when replacing LPG/OIL with a GSHP where a CoP of 4 is achieved and £613/tCO_2 where a CoP of 2 is achieved.



The following graph shows the same information but for the deployment of ASHP which are cheaper to install hence the capital and CO_2 reduction costs are reduced. It should be noted however that ASHP need more maintenance but this could be revenue that is circulated within the economy and could help to increase jobs in the environmental technology sector.

Note also that the CO_2 savings are the same as for GSHP for less upfront investment hence the lower cost per tonne of CO_2 reduced.



Energy cost savings to the economy

The following table shows the potential macro energy cost savings to the economy for the deployment of heat pumps with CoP2 and CoP4. The fuel type that the heat pump is replacing has also been reflected in the potential cost savings across different rates of deployment.

		kw per property	kW						
	average heat req., for a domestic property on Exmoor	24024	120,282,000	47,048,602	11,762,150				
	number of properties	4896	4896	1958.4	489.6				
	%Uptake		100%	40%	10%	cost benefit to economy for HP with CoP4 (100%)	cost benefit to economy for HP with CoP2 (100%)	cost benefit to economy for HP with CoP4 (16%)	cost benefit to economy for HP with CoP4 (84%)
CoP2	cost to run the pumps £		**7,216,920**	**2,886,768**	**721,692**			**Electricity**	**Oil/LPG (avrge)**
CoP4	cost to run the pumps £		**3,608,460**	**1,443,384**	**360,846**				
Oil	**Cost to import required heat load for Park by fuel type£**		**6,014,100**	**2,352,430**	**588,108**	2,405,640	-1,202,820		
LPG			**8,419,740**	**3,293,402**	**823,351**	4,811,280	1,202,820		3,031,106
Gas			**4,811,280**	**1,881,944**	**470,486**	1,202,820	-2,405,640		
Electricity			**14,433,840**	**5,645,832**	**1,411,458**	10,825,380	7,216,920	1,732,061	

In summary what the table reflects is that:

- If all households currently using electricity for heating (16% of total properties) installed a heat pump with a CoP of 4, then estimated electricity cost savings will be £1.7 million. This is the most cost effective application of this technology
- For the remaining(84%) of households with central heating this would realise energy cost savings of an estimated £3million

- If heat pumps with a CoP 2 are implemented then they only really bring an economic net benefit if they are replacing LPG and more significantly so with electricity.
- Replacing any fuel types with a heat pump that has a CoP of 4 will bring about some economic benefit

The table below reflects the estimated payback for the deployment of a 10kW heat pump with a CoP 4 to replace grid imported electricity or OIL/LPG.

Payback for a 10kw GSHP	£	Payback years
Cost to install GSHP	10,000	
Cost to run the pump	737	
Oil/LPG imported energy costs	1,474	
Electricity imported costs	2,948	
Electricity (Cost benefit)	2,211	4.5
OIL/LPG (Cost benefit)	737	13.6

In conclusion:

- ASHP are a more cost effective technology to install but the maintenance costs over the lifetime of the equipment need to be accounted for which may show that there is little overall difference across the expected lifetime of the equipment compared to that of GSHP
- The most cost effective deployment of HP technology is when it is used to supply heat that would otherwise be supplied using electricity (economy 7 or bar heaters for example).
- The graph shows that this would cost around £79 per tonne of CO_2 reduced where a CoP of 4 and above is achieved.
- However, even with a 100% deployment to all those properties (783) using electricity and solid fuel to heat their homes the maximum annual savings of CO_2 will only amount to 6800tCO_2 for an investment of nearly £8m

4.4.4 Description of the Technology

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.

Where Are Heat Pumps Used?

Heat pumps can be used on any building requiring space heating. They only deliver low grade heat (30-40 degree heating) therefore the building requires good levels of energy saving measures (double glazing, good insulation cavity wall insulation floor insulation) it also requires underfloor heating as the heat pump cannot deliver 60 degree heat as required by a conventional wet system.

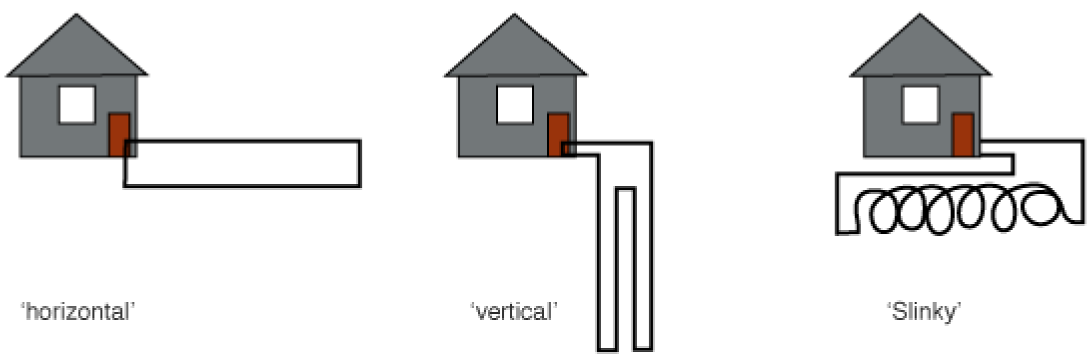
Ground Source Heat Pumps

A ground source heat pump takes the heat from the ground using a slinky system or a borehole

For every unit of electricity used to power the heat pump system, approximately 3-4 units of heat are captured and distributed. In effect this means a Ground Source Heat Pump is 300-400% efficient in terms of its use of electricity. At this efficiency level there will be less carbon dioxide emissions than for a gas boiler heating system.

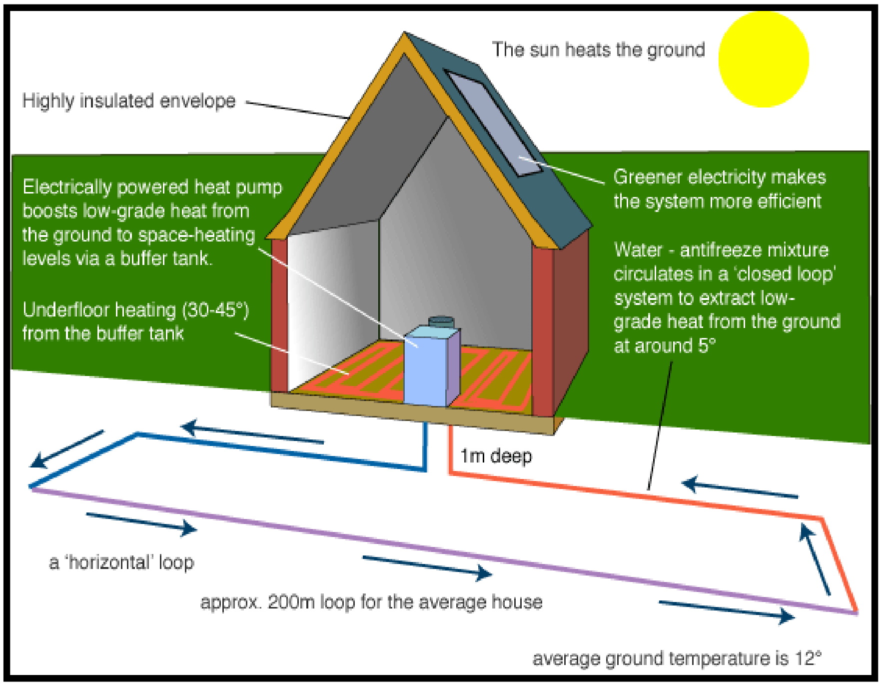
In many cases it may also be possible to provide the required electricity by means of renewable energy, thus virtually doing away with any use of fossil fuels and reducing carbon emissions to zero.

Closed loop systems- Ground Source Heat Pumps



Horizontal loops

Piping is installed horizontally in trenches. The depth of the trenches will vary according to the design and soil characteristics, but is generally 1.5 – 2m deep. Horizontal loops require much more surface area than vertical loops. Around 200m of pipework is generally required for a single dwelling.



Vertical loops

Most commercial and institutional projects using GSHPs use 'Vertical loop' systems. The advantage of a vertical loop system, which consists of pipe inserted into vertical bore holes, is less space is required. Holes are spaced at around 5m intervals and can vary between 15m and 60m according to the design and soil characteristics.

Slinky coils

The 'Slinky' is a variation of the 'Horizontal loop'. Slinky coils are flattened coils of overlapping piping, which are spread out and laid either horizontally or vertically. Their ability to focus the area of heat transfer into small volume reduces the length of the trenches and hence the quantity of land needed. A 10m long trench laid with a 'Slinky' coil will typically supply 1kW of heating load.

Air-source heat pumps

An air-source heat pump can provide efficient heating and cooling for your home, especially if you live in a warm climate. When properly installed, an air-source heat pump can deliver one-and-a-half to three times more heat energy to a home than the electrical energy it consumes. This is possible because a heat pump moves heat rather than converting it from a fuel, like in combustion heating systems.

Although air-source heat pumps can be used in nearly all parts of the UK, they do not generally perform well over extended periods of sub-freezing temperatures. In regions with sub-freezing winter temperatures, it may not be cost effective to meet all your heating needs with a standard air-source heat pump.

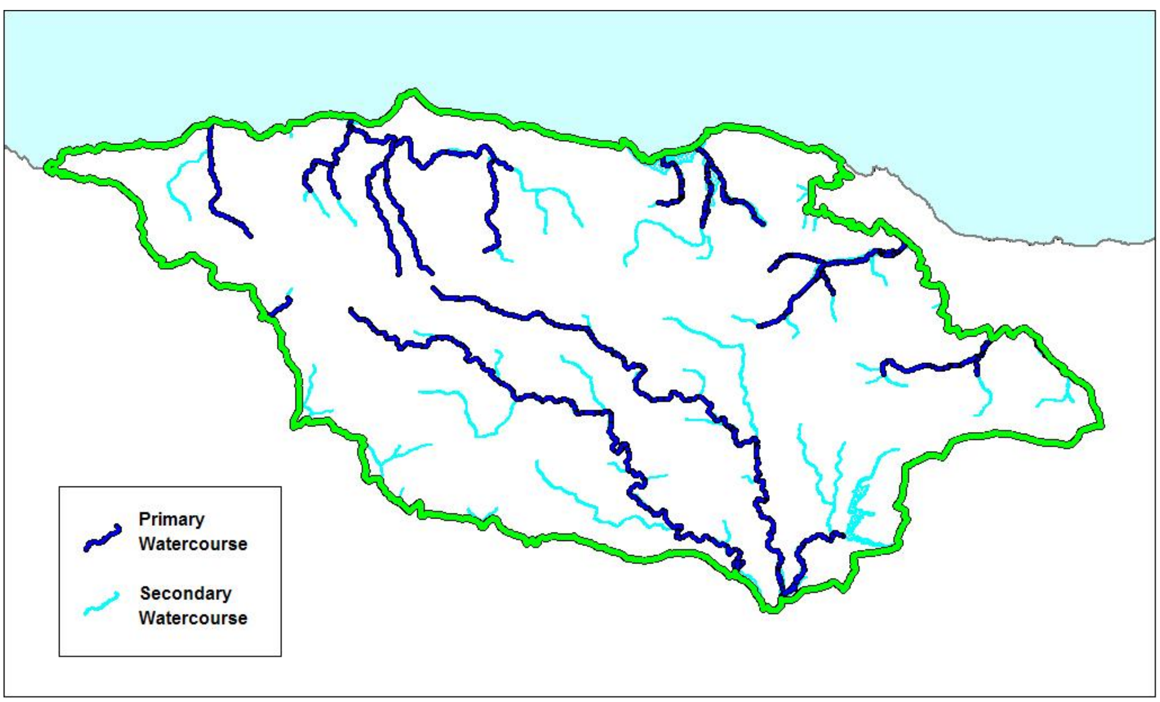
water source heat pumps - **Open loop systems**

Open loop systems take heat from an existing source such as a river or bore hole and utilise the energy then return the source back to where it came from originally. These are otherwise known as a water source heat pump. Mill sites tend to work especially well as they have the possibility of hydro power to power the heat pump.

4.5 MICRO HYDRO

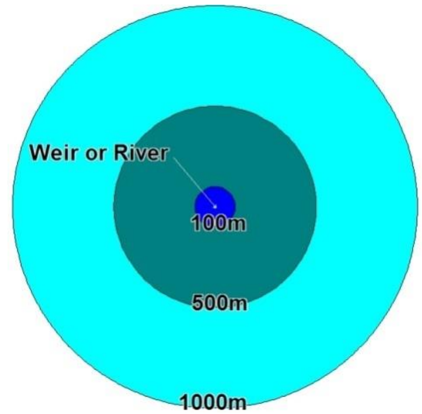
4.5.1 Methodology for Assessment

In the first instance the primary watercourses and weir locations (92) were identified and mapped in GIS. The following map shows the principal watercourses which drain Exmoor:

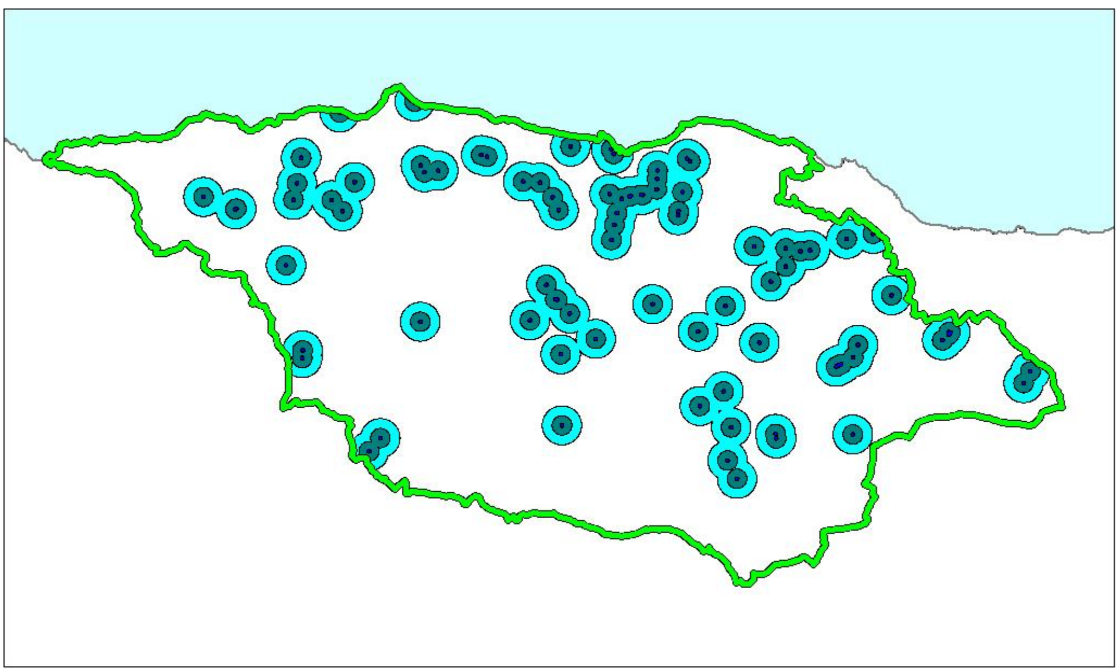


Then buffers (see diagram opposite) were created around each weir feature-centre-point and along the river centre lines.

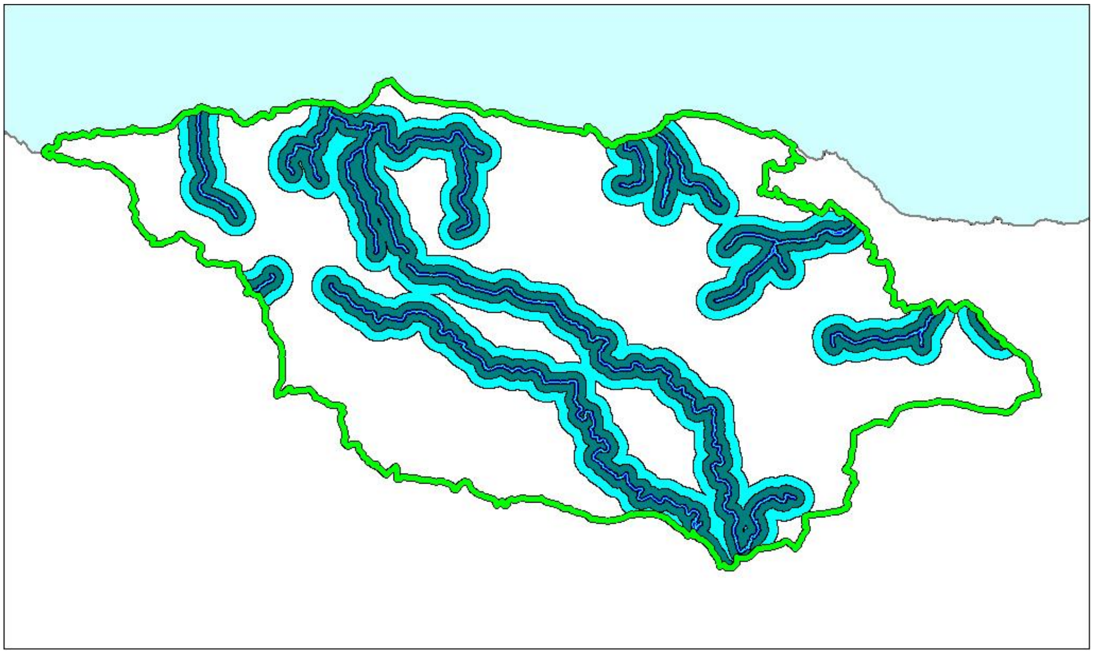
- A 100 meter buffer was used to identify any sites situated directly next to a weir or a river.
- A second buffer was created to identify sites within 500 meters of a weir or a river.
- And a third buffer was created to identify sites within 1000 meters of a weir or a river.



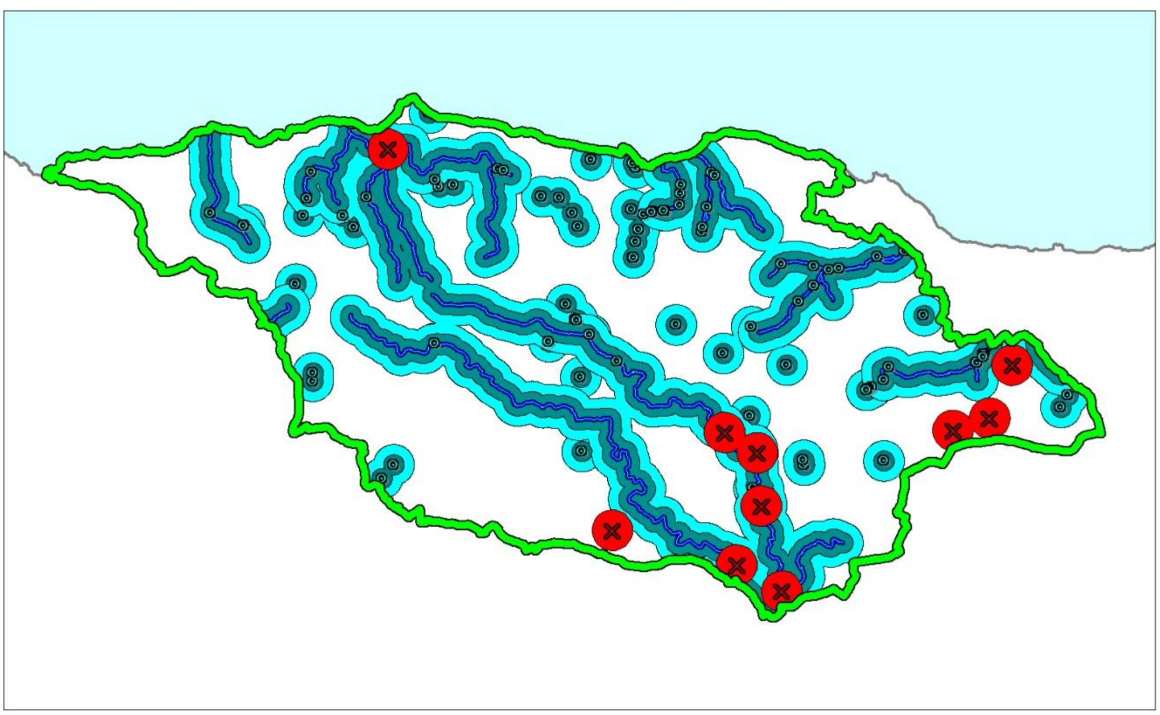
The following map shows the hydro power potential areas created by buffering all **weir features** identified within Exmoor:



The map below shows the hydro power potential areas created by buffering all **primary watercourse** features identified within Exmoor:



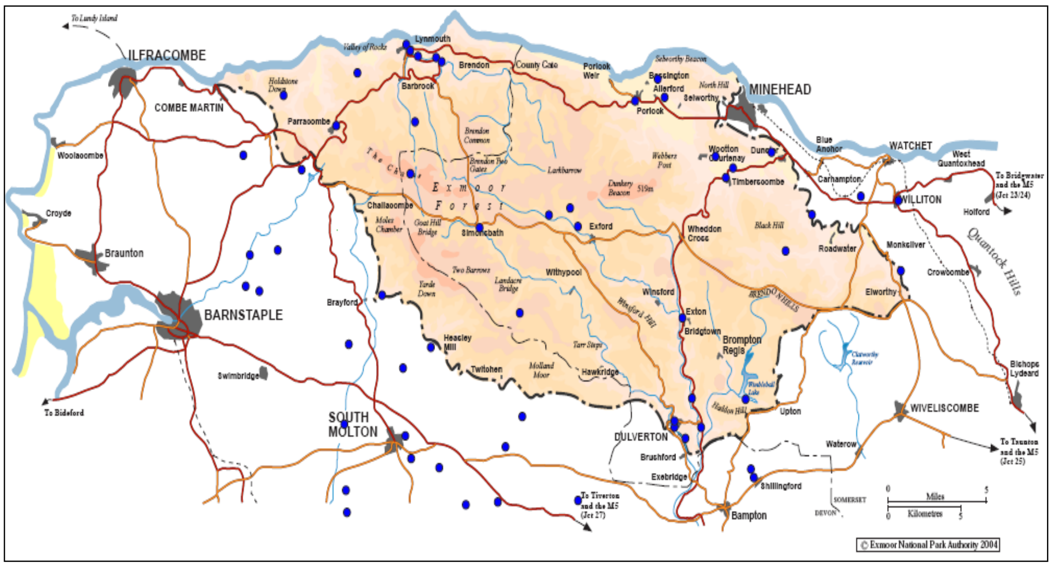
Next the potential sites identified in previous studies was queried through GIS to further identify which of those sites fall within the hydro power buffer zones mapped above. The results have been mapped (see below) and rated according to their proximity to the rivers and weirs. Sites unsuitable for hydro power generation are shown below by red crosses and 1km query buffers:



4.5.2 Resource Potential

Exmoor National Park currently has one 300 kW_e hydro scheme operational at Lynmouth. According to the Loughborough University study[22], of the 111 sites identified, 51 were deemed suitable for development providing a potential power output (total energy available) of 1809.5 kW[23].

A study of stream sites suitable for hydro power was produced by Exmoor National Park Authority in 2004. It was not possible to query these sites as above because the information was not available in GIS format. Ideally these sites should be compared with the above to identify any additional potential to that in the Loughborough University study but time has prevented that being undertaken as part of this assessment. The sites identified in the 2004 study are shown as blue points on the map below:



Another study was undertaken by HydroGeneration Ltd., and identified four sites around Barbrook and Lynbridge as having potential for small scale hydro development which could provide a further 113 kW_e. These comprised:

- Stockwater Farm (4.1 kW_e)
- West Lyn River – Barbrook to Lynbridge (10.4 kW_e)
- West Lyn River – Lynbridge to Lynmouth (10.4 kW_e)
- East Lyn River – reconstruction of original scheme (88 kW_e)

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22 *'A previous study of 111 hydro power studies on Exmoor was produced in 1998; as part of the Greater Exmoor LEADER renewable energy survey produced by the south west energy group June 1998 was used to show all possible sites on Exmoor, as rivers and mills sites have not increased in number and the report was very thorough'*

23 IB's Lynmouth study identified 1,364kW. – ensure this has been taken into account in future assessments

NOTE 2009: It is believed that these are under-estimates. This study was revised in a report by Ian Beath showed 1362kW additional potential in Lynmouth not 105kW. There is an additional 15kW-20kW in Lynmouth soon to be looked at. On basis of this, the estimate should be revised upwards by around 1200kW. Going forward future assessments need to identify if these are additional to those presented in the Loughborough University study and have they been included in the potential resource 1809kW.

4.5.3 Assessment

This assessment has considered only those sites identified in the Loughborough University study as queried through GIS and found to be within the hydro power potential zones as presented in the GIS map above. This potential power output associated with these sites is estimated to be 1809.5 kW

However, a comparison of the sites identified in the other studies may reveal more potential when this is undertaken. The Loughborough University study also identified another 60 sites including mills and it is not clear why they were not considered to be feasible. If it was previously assessed that some of these sites were not feasible for economic reasons then it should be noted that as electricity prices increase year on year then some of these sites may become more feasible and be deemed suitable for further investigation and feasibility work.

Taking the potential power output of 1809.5 kW we can calculate the estimated annual energy capture that will be available for use.

Annual energy capture = electrical output x no. hours operational per x load factor of 0.3

1809 KW x 365 x 24 x 0.3 = 4,754,052 kWh

4,754 MWh

The CO_2 reduction potential from the developing the hydro scheme

A maximum of around 2,045tCO_2 per annum could potentially be reduced based on the above assumptions and assessment if all 51 sites identified were developed.

The table below shows a range of costs for reducing a tonne of CO_2 depending on the cost/kW installed. It also reflects the cost of the potential lifetime of the hydro scheme which often carry longer warranties than other RE technologies hence the calculation of 40 years.

kw	£ lower	£ mid	£ upper
1809.5	2500	3500	4000

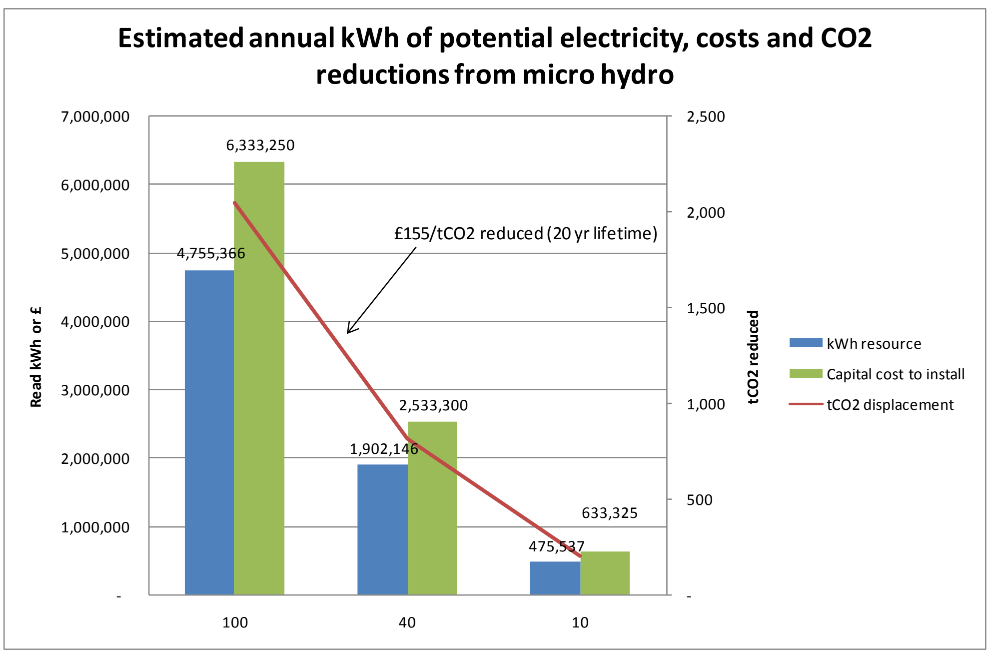
Cost per tCO2 reduced (£)	2,212	3,097	3,540
Cost per tCO2 reduced/20 years (£)	111	155	177
Cost per tCO2 reduced/40 years (£)	55	77	88

Investment Costs

The capital cost to develop the potential 51 schemes is in the range of £4.5m to £7.2m. (Based on costs/kW between £2500 and £4000 see table above).

Until site specific assessments and surveys have been undertaken we cannot be certain what the power potential is and what the costs of deploying the technology will amount to. A number of factors affect the installed cost of a hydro power scheme, and can vary substantially from one site to another. This includes the extent of civil works needed, accessibility to the site and other environmental factors needing to be addressed. For a low head system (less than 20 metres), where a pond or weir already exists, installed costs could be between £3,000 and £4,000 per kW up to 10kW. Larger schemes tend to cost less per kW. A medium head system (20-100 metres) will require a different and possibly smaller turbine for a given output reducing costs per kW to around £2,500. However, civil works could be more involved, increasing its associated cost.[24]

For the purpose of this assessment the graph below assumes a cost of £3500 per kW (the mid cost) but stress that this is a very broad approach and actual costs will vary considerably from site to site for all the reasons stated.



What this reflects is that for an investment of just over £6million, the Park economy will generate 4,754 MWh.

24 www.ecocentre.org.uk

Energy cost savings to the economy

If this energy was used locally then the displacement of grid imported electricity will save the economy £570,644/year at 12p/kWh. This would provide a payback of 8.3 years.

If the energy was delivered to the grid then ROC's would be available. At today's price of £45/MWh this would provide revenue of £213,991 per year and if double ROC's are available this could be as much as £427,982 per year. This would provide a payback of 22 and 11 years respectively. [At the time of writing the ROC's system is under review and it is uncertain what revenue will be available for the delivery of RE into the national grid.

It should also be noted that there will be certain ongoing costs that need to be taken into account. Machine consumables, overhaul and servicing costs will be of the order of £1,000 per annum. Other costs which need to be considered are meter reading and insurance, which may amount to £1,000. In total a £2,000 budget is suggested per annum.

This assessment has not taken running and maintenance costs into account for other technologies and for consistency will not do so for micro-hydro. However, policy makers need to be mindful that a more detailed study would reveal the true benefit to the economy if these are accounted for. NPV and GVA would also identify where value remained in the economy of the maintenance and servicing was provided locally.

Planning

When considering a hydro power scheme, 3 types of consent must be required before the scheme can be deployed, these are;

- Planning permission
- Abstraction license and
- Land drainage consent

Planning permission will probably not be granted until the EA has settled the licensing issue which will be dependent on an assessment of the environmental impacts of the scheme.
The Environment Agency is the regulating authority on matters of water abstraction; whilst essentially in favour of renewable energy generation they also have to consider the EU Water Framework Directive and more particularly the Exmoor Habitat Directive.

The Exmoor Habitat Directive applies to the seven main rivers having their headwaters on Exmoor.

A number of Exmoor's rivers have their source in the area of bog in the centre of the north moor. This area contains the spawning grounds for the Atlantic salmon and is designated a 'Special Area of Conservation' (SAC) and a 'Special Protected Area' (SPA). There are many factors that adversely influence the life cycle of the salmon, one such factor is the abstraction of water from rivers for public drinking water supplies and micro-hydro. Abstraction for drinking water removes water volume from the catchment whilst micro-hydro only 'borrows' the water for a defined stretch. However where, within that defined stretch, the flow in the main river is lowered to the extent that Salmon cannot pass or if there is a riffle suitable for spawning but the flow is too low to cover the redd, then micro-hydro may well have an adverse effect[25].

A second factor cited in academic papers is the physical barrier created by weirs. Salmon are noted for their ability to 'jump' over obstacles such a weirs and waterfalls but do need an area of deep water immediately in front of the obstacle in which to develop the speed to make the jump.

There are a number of quite different types of machinery that can be used to generate hydroelectricity, each having advantages and disadvantages for a particular location. All systems have some kind of gearing mechanism that drives the generator, but where they differ is in the method used to convert the power of falling water to mechanical rotation. All machinery will also require a trash screen with a wide bar spacing to keep out large debris that could potentially damage the machinery. A failsafe means of stopping the flow of water to shutdown the equipment is also required which would normally consist of an inlet sluice gate that can fall by gravity to stop the flow

4.5.4 Description of Technology

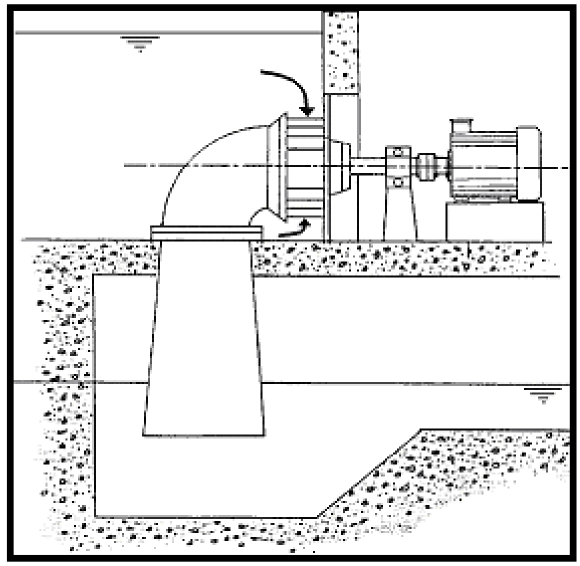
Archimedean screw

This consists of an Archimedean screw pump operating in reverse, so that the falling water turns the screw, which in turn drives a generator.

Advantages

- Leaves and debris can simply pass through the screw reducing the need to clear the trash screen
- The screw turns quite slowly (20 rpm) thus preventing injury to fish caused by contact with moving blades
- Large chambers of water are maintained at all times, allowing fish and debris to simply pass slowly down through the machine
- The water pressure is not affected thus preventing damage to fish swim bladders
- No draft tube is required, reducing the civil costs of excavation
- High efficiency is maintained over a wide variation of flows, in particular for low flows

25 The Atlantic salmon has been the subject of much research. Whilst not law, the paper cited by the Environment Agency is: Hendry K & Cragg-Hine D (2003). *Ecology of the Atlantic Salmon*. Conserving Natura 2000 Rivers Ecology Series No.7. English Nature, Peterborough. A web link can be found at; www.riverlife.org.uk or via the Environment Agency web site.



- No fine screening is required reducing installation and maintenance costs
- High education and community interest value

Disadvantages

- Overall efficiency is slightly worse than for a Kaplan at design flow

A German Instillation of an Archimedes turbine (above)

Vertical or horizontal Kaplan turbine

This consists of a rotating blade, rather like those used for aero plane propellers located within a sealed tube. It is a reaction turbine relying on pressure differences to turn the blades. This machine operates most efficiently at a fixed design flow, so for sites with varying flows a Kaplan type is used permitting the angle of the blades to be changed to match the flow conditions.

Advantages

- Delivers the highest efficiency at design flow

Disadvantages

- Fine fish screening is required which will increase the maintenance overhead and reduce the effective head
- Efficiency at low flows is worse than for hydrodynamic screw
- Complex control system requires either manual adjustment with varying flow or expensive automation
- High capital cost

4.6 MACRO HYDRO

4.6.1 Methodology

Hydraulic power can be captured wherever a flow of water falls from a higher level to a lower level. This may occur where a stream runs down a hillside, or a river passes over a waterfall or man-made weir, or where a reservoir discharges water back into the main river.

The vertical fall of the water, known as the "head", is essential for hydropower generation; fast-flowing water on its own does not contain sufficient energy for useful power production except on a very large scale, such as offshore marine currents. Hence two quantities are required: a Flow Rate of water **Q**, and a Head **H**. It is generally better to have more head than more flow, since this keeps the equipment smaller.

The Gross Head (H) is the maximum available vertical fall in the water, from the upstream level to the downstream level. The actual head seen by a turbine will be slightly less than the gross head due to losses incurred when transferring the water into and away from the machine. This reduced head is known as the Net Head.

Sites where the gross head is less than 10 m would normally be classed as "low head". From 10-50 m would typically be called "medium head". Above 50 m would be classed as "high head".
The **Flow Rate (Q)** in the river, is the volume of water passing per second, measured in m^3/sec. For small schemes, the flow rate may also be expressed in litres/second where 1000 litres/sec is equal to 1 m^3/sec.

To assess each site yearly flow and head measurements have to be taken in order to give an accurate picture for each site. This kind of detail is not able to be found in this document as resources were not available for this type of detail.

4.6.2 Resource Potential

For the larger macro hydro schemes 20MW and above there are no options on Exmoor national park. The largest possible schemes where macro hydro could be deployed appear to be at the 5 potential reservoir sites.

There are three main impounding reservoirs in the National Park: Challacombe, Nutscale and Wimbleball, with two others, Clatworthy Reservoir and Wistlandpound, just over the border. They are managed by Wessex Water (WW) and South West Water (SWW).

Each of these sites has possibility for power generation and to understand the potential power that would be available at these sites a flow analysis would have to be undertaken. This assessment does not have access to the data required to provide a value for the potential energy capture from the reservoirs.

The reservoirs are privately owned by the water companies Wessex and South West Water and although the decision to develop macro hydro schemes at these sites will ultimately rest with the water companies, the Exmoor community could seek to work with them to progress these projects.

Assessment

Because of the lack of access to information this assessment will not be able to provide any meaningful data upon which project potential resource. However for the purposes of this exercise it would be reasonable to assume that up to 5MW of installed capacity could be potentially available delivering an estimated 13GWh (assuming a load factor of 0.3).

Wimbleball Lake

The Lake lies in an upland valley at a height of 236m (775ft) and is surrounded by farmland, woodland and some heathland. The reservoir was formed by damming the River Haddeo, a tributary of the Exe. The water from Wimbleball Lake is used to supply Exeter, Mid Devon, East Devon, a small part of North Devon and West Somerset. Under the Lake and most of Exmoor lie sedimentary rocks of the Devonian system. The dam was constructed between 1974 and 1979 using aggregate and sand from local quarries to maintain the pinkish colouring of the local soils. The dam is approximately 300m in length and 50m in height.

Head	50M
Flow	Unknown
Possible energy capture	Unknown

Challacombe

Head Unknown
Flow Unknown
Possible energy capture Unknown

Nutscale Reservoir

Os reference SS8643

Head Unknown

Flow Unknown

Possible energy capture Unknown

Clatworthy

Clatworthy reservoir is situated in the Brendon Hills on the edge of the Exmoor National Park in west Somerset. It impounds the head waters of the River Tone and the surrounding rolling hills.

Head Unknown

Flow Unknown

Possible energy capture Unknown

Wistlandpound Reservoir

Located at grid reference SS642417

Head Unknown

Flow Unknown

Possible energy capture
Unknown

4.6.3 Assessment

The economics of installing hydro power on any of these sites are unknown without developing the project through the stages of pre feasibility, feasibility studies, engineering studies and ownership issues.

However there is potential at each of these sites and they could be developed. The benefit of having a high head site with existing infrastructure means the civil costs are severely reduced.

Because of the scale of these projects a three phase connection would be a minimum requirement, it would be expected that an upgrade for the grid connection would be required which could be a major cost to any of the potential schemes.

4.6.4 Resource Potential

This is unknown at this time without further investigation.

Description of Technology

Hydropower is the generating of electricity by harnessing the energy in water as it falls. The key factors in determining the amount of electricity are the amount of water falling during a given second ("Flow") and how far it falls (the vertical distance, "Head"). Consequently, a site on a large river with water falling 5 meters at a weir might produce as much electricity as a site on a small river where the fall is 100m. In either case, a water turbine is used to extract the energy from the water. The turbine drives a generator that converts the mechanical power into electrical power. This electricity can be used on site (whether or not the system is connected to a national electricity network) or it can be "exported" through a network to consumers in other locations.

Hydropower is one of the most cost-effective and reliable energy technologies for providing clean electricity generation. In particular, the key advantages that hydro has over wind, wave and solar power are:

- A high efficiency (70 - 90%), by far the best of all energy technologies.
- A high capacity factor (typically >50%), compared with 10% for solar and 30% for wind.
- A high level of predictability, varying with annual rainfall patterns.
- Slow rate of change; the output power varies only gradually from day to day (not from minute to minute).
- It is a long-lasting and robust technology; systems can readily be engineered to last for 50 years or more.

There are three main categories used to define the output from hydroelectric power:

- Large-scale capacity (systems producing more than 20 megawatts) in the UK is currently 907 megawatts.
- Small-scale capacity (systems producing less than 20 megawatts) in the UK is currently 503 megawatts.
- Micro-scale capacity (systems producing less than 50 kilowatts) in the UK is currently 46 megawatts.

Total hydroelectric capacity in the UK is approximately 4,244 megawatts (including 2,788 megawatts of pumped storage capacity).[26]

[26] Data taken from the BERR website.

4.7 BIOMASS

Please note that figures presented here were the result of an initial assessment which were then revised along with the rest of the figures as part of the development of the strategy document.

4.7.1 Methodology for Assessment

A desk top review of recent studies has been undertaken to assess the potential biomass resource within the park. The potential resource has then been compared with other forms of fuel used for heat and the cost and CO_2 benefits derived.

Biomass is a generic term for organic matter used as fuel and includes wood, crops such as miscanthus and sugar beet and agricultural residues such as straw, poultry manure, olive pits, rice husks and nutshells. This assessment has considered miscanthus, wood fuels and the potential for biogas from manure.

Miscanthus and Short Rotation Coppice

In 2007, Devon Wildlife Trust commissioned CSE to produce the Devon miscanthus and woodfuel Statement. The assessment considered to what extent miscanthus and short rotation coppice could be integrated into the landscape without change to landscape character. 17 landscape types were ranked according to their sensitivity and then mapped in GIS to show areas unsuitable for crop cultivation and where crops could be cultivated, the report modelled the yields.

The bioenergy assessment in the above statement is not directly applicable for Exmoor because it was undertaken for the County of Devon which only includes about one third of Exmoor.

Wood Fuel Resource

The Exmoor Wood Fuel report by South West Wood Fuels (May 2004) considered the quantities of available wood fuel resource from the following sources:

- Forestry
- Hedgerows
- Saw mill residue
- Other – including waste wood, Rhododendron and grown crops

A summary the report's findings in terms of the potential wood fuel resource is presented in the next section, for a more detailed report refer to the Exmoor Wood Fuel report by South West Wood Fuels, May 2004.

4.7.2 Resource Potential

"In the South West, energy crops and forestry residues are identified as significant contributors to the overall regional [RE] targets. For example, REvision 2020 identifies targets for up to 100MW of biomass fired electricity by 2020, along with 247MW of heating, 42MW of CHP, and 39MW of community heating on site in new developments." *CSE Devon Miscanthus and Woodfuels Opportunities Statement*

Exmoor is well placed to develop this opportunity not least because it has a greater forest cover than the national average, with a distribution of some larger holdings to the east of the park and a wide scattering of isolated blocks and wooded valley sides. There are approximately 8,400 ha of woodland on Exmoor covering 12% of the park's area, this compares favourably with the total for the South West being 8.9% (212,022 ha)[15].

The potential sources of wood-fuel have been examined in the Exmoor Woodfuel report and include;

- Forestry products and residue
- Land management residues – hedge restoration and Rhododendron clearance
- Sawmilling residues
- Waste wood
- Energy crops

The report[27] concludes that Exmoor has sufficient wood fuel to heat all households if there were no competition from other uses and all timber could be accessed. It goes on to argue that the realistic quantity of wood fuel available now, on a sustainable basis and taking into account limitations for access is approximately 8,000 t. If the figures presented in the report are correct this is less than 5% of the total available resource in the Park and this does not take into account energy crops.

The following table breaks down the resource potential according to the source of the wood fuel reported by SWWF:

Type		100%	40%	10%
Forestry	Thinning of unmanaged stands	160,000	64,000	16,000
	sustainable annual growth of woodland	29,000	11,600	2,900
Hedgerows		7,500	3,000	750
Saw mill residue		1,200	480	120
Other Sources	not quantified			
Miscanthus	not quantified			
Total		**197,700**	**79,080**	**19,770**

Based on the report's figures, 8000 dry tonnes of biomass would deliver **28,000 MWh** of energy. This is currently accessible and an implementation programme could begin almost immediately. In real terms

27 Exmoor Wood Fuel report by South West Wood Fuels; May 2004

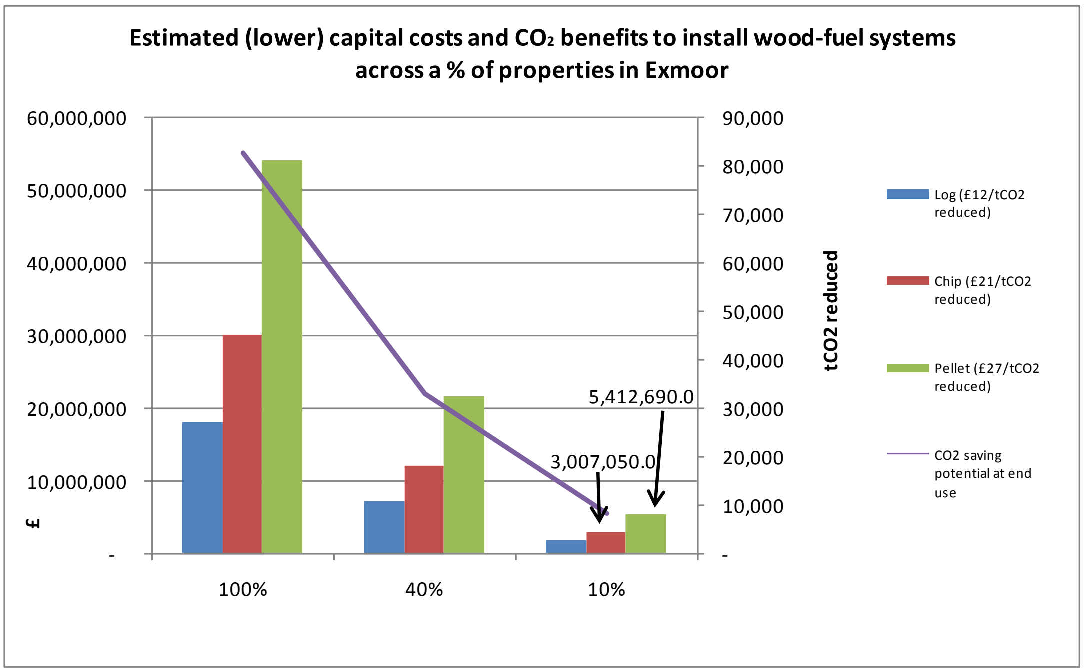
this could supply the heating needs of 23% (1166) of domestic properties (including farms) where there is an average demand of 24,024kWh.

However, according to the report the estimated annual wood fuel resource is nearly 200,000t which could deliver **691,950 MWh**, more than 5.5 times the amount need to supply the Parks domestic heat demand)

4.7.3 Assessment

This assessment has considered the benefits of the biomass resource for chip, log and pellet.
It has also estimated[28] that around 34,000dt of wood fuel would be needed to provide for the heat load requirements of the Parks domestic sector.

The following graph highlights the key findings from this assessment:



The graph reflects:

- The level of investment required to deliver 100%, 40% and 10% of the Parks heat load requirements for the domestic sector.
- The associated CO_2 reduction in tonnes and the key also provides the cost per tonne of CO_2 reduced.

Assumptions:

- Heat demand for the properties within the National Park is 120 282 kWh (100% on the graph)
- Cost per tCO_2 reduced has been derived using a 20 year lifetime of the wood-fuel boiler. However it must be noted that this has not taken into account the relevant efficiency of different technology types or the life cycle of processing and transporting the different fuel types. These

28 Based on 3500kWh/dt of fuel

and other costs (capital, maintenance and NPV) need to be taken account of to derive the true cost to reduce CO_2.

CO_2 reduction potential of the biomass resource

A very simple assessment shows that:

- If the current accessible wood fuel was fully utilised the potential CO_2 savings would be about 7,577tCO_2 per annum. This would mean installing wood fuel systems in 1107 properties. with an estimated capital cost ranging from just over £2M for log boilers to more than £6M for pellet boilers.
- The maximum CO_2 savings that can be achieved from the deployment of wood fuel systems within the Park is about 32,548 tCO_2. (Based on 34,366dt wood fuel resource per annum to supply the heat load requirements of the properties within the National Park).
- This would allow for the export of around 163,334t of wood fuel and a further reduction of 151,000tCO_2 achieved through export. (However, would need to consider the wider implications of accounting for this – double counting issues).
- The cost to reduce a tCO_2 using wood fuel systems ranges from about £12/tCO_2 -£27/tCO_2 depending on the technology used.
- According to the Exmoor Wood Fuel report each hectare of wood can store approximately 53 tonnes of carbon, suggesting that Exmoor's woodland alone could hold 445,200 tonnes of carbon with a capacity to capture 11,760 tonnes per year if they are managed.

Investment Costs

To utilise the current accessible resource of about 8000dt fuel around 1000 properties could be installed with wood fuel systems with an estimated capital cost ranging from just over £2M for log boilers to more than £6M for pellet boilers. The table below provides the range of costs depending on the system installed and the deployment rate. This is also reflected in the above graph.

installation (capital costs)/(kW)			Lower Cost of installation		
	lower	upper	100%	40%	10%
Log (£	150	300	18,042,300	7,216,920.0	1,804,230.0
Chip (£	250	450	30,070,500	12,028,200.0	3,007,050.0
Pellet (£	450	700	54,126,900	21,650,760.0	5,412,690.0

If commercial organisations installed wood fuel systems then economy of scale would bring the cost down. Due to the inaccessibility of data for oganisations in the Park this assessment cannot estimate what the costs or demands might be.

Energy cost savings to the economy

Assuming that Exmoor's heating is met by 84% oil and 16% electricity, an annual saving to consumers of £1,153,600[29] can be achieved where chip is utilised for example. [Refer to table below].

100% (of assumed 8000 tonnes)			
Financial Savings	Oil	Electricity	84%/16%
Logs	£1,064,000	£3,024,000	£1,377,600
Chip	£840,000	£2,800,000	£1,153,600
Pellet	£420,000	£2,380,000	£733,600

If the total heat demand for the Park's domestic sector was met through biomass then the cost savings would range from £3m to nearly 6m per annum through the displacement of electricity (16%) and oil (84%).

100.00% (of assumed 34,366 dry tonnes)			
Financial Savings	Oil	Electricity	84%/16%
Logs	£4,570,716	£12,990,456	£5,917,874
Chip	£3,608,460	£12,028,200	£4,955,618
Pellet	£1,804,230	£10,223,970	£3,151,388

The payback has been estimated for the different fuel types. However it must be noted that the payback has not factored in the efficiency of the different fuel type which will probably have the effect of reducing the payback for pellet and chip and increasing the payback for log. Pellet also has many other associated costs that are greater than chip. Chip is likely to be the most cost effective for the local economy. However, pellets and logs are more suitable for single domestic dwellings.

Fuel type	payback (lower cost)	payback (upper cost)
Log	3.0	6.1
Chip	6.1	10.9
Pellet	17.2	26.7

According to the Exmoor wood-fuel report if the available (8000dt) wood fuel resource is used to make wood chip, it would contribute a further £360,000 - £440,000 per year to Exmoor's economy, assuming

29 Figures based on the following costs per kWh for different types of wood-fuel

Cost per kWh£Logs0.012Chip0.020Pellet0.035

£45-£55 per tonne.

In addition to the economic and social benefits of the market for wood fuel, there would also be a larger market for companies involved in the sale and maintenance of wood-fuel boilers.

A full economic assessment including NPV and GVA would probably reflect that biomass, particularly chip, would bring about many economic benefits for the local economy as well as contributing significantly to reducing the Park's carbon emissions.

3.1.1 Description of the Technology

The boxes below have been taken from the Exmoor wood-fuel report which provides an excellent description of the technologies.

Wood chip boilers

These are available in sizes ranging from 20 to 3,000 kW. A typical boiler for a larger domestic building possibly with outbuildings or commercial space would fall in the 50-500 kW bracket. Utilising around 25-250 tonnes of wood chip fuel per annum. A break-even price for wood chip heating compared to oil is £90.00 per dry tonne. It is therefore attractive if fuel can be delivered at £45-50 per dry tonne as this gives an annual saving which can cover the initial greater capital cost of installation associated with wood chip boilers. Pay back periods vary between 5 and15 years depending on the heat load and plant specifications. The systems are fully automated with fuel store, feed auger and electronic capacity controls. The boilers have an independently certified efficiency of >90% making them comparable with any other form of heating. Fuel delivery to the chip store is normally only required every 1-3 months depending on chip store size. Minimal maintenance is required weekly or monthly depending on plant type. Cleaning of heat exchangers may be required manually on a monthly basis depending on heat load however this can be done automatically with some plant and ash removal can also be done either manually on a monthly basis or automatically.


Boiler


Underground store


Feed auger


Wood chip fuel

Log boilers

Traditional log heating has been modernised and semi-automated with these units. Loaded with a charge of logs they burn for 4-6 hours providing hot water and central heating. Utilising an accumulator tank to store hot water increases the efficiency of these units allowing extended periods between burns. Sizes of 15 kW – 40 kW would typically have accumulator tanks ranging from 750-2,000 litres of water as a heat sink. Much used in Scandinavia as an extension of their traditional log heating there are only a few currently installed in the UK at present. This is despite them being very suitable for our small heat load requirements and also for our readily available supply of logs.

Typically logs (at 25% moisture content) have a value between £50-90 per tonne.

15-25kW KOB log boiler with 1 metre loading chamber

Prepared firewood billets suitable for log boiler

Traditional log burners

The traditional firewood market for stoves, boilers, Agas and open fires, although not automated, should not be discounted as it makes an important contribution to forestry management and the forest industry and displaces fossil fuel. On Exmoor many thousands of tonnes of logs are burnt each year replacing considerable amounts of oil and LPG

Esse 15kW combination cooker and space heater

Pellet stoves and boilers

Pellet stoves offer clean efficient heat at the flick of a switch, they are especially suitable for smaller properties within the domestic market that have small heat loads, rapid space heating needs and for sites with limited storage space. The outputs of pellet stoves range from 5-25kW with larger models with back boilers able to provide central heating as well as hot water. Pellet boilers range in size from 15kW up to commercial units of 500+kW. Pellet supply is currently mostly imported with bagged prices of £180 per tonne. National production in Wales and Durham is likely to reduce this price in the future, as is small scale localised production coming online in Shepton Mallet and Winkleigh. Even at £80 per tonne bulk price they are more expensive than wood chip fuels but less expensive than oil.


15-25kW pellet boiler


5kW pellet stove


Wood fuel pellets

4.8 BIOFUELS

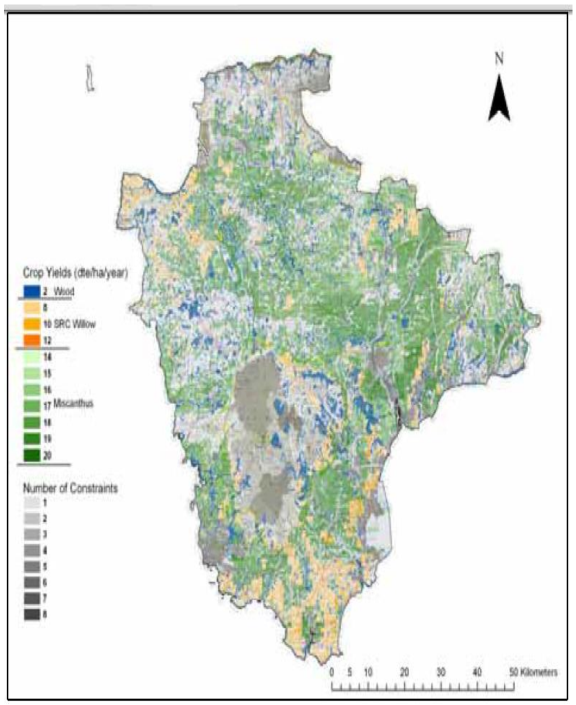
Biofuels include bio-ethanol (derived from crops such as sugar beet and grain and miscanthus) and bio-diesel which is mostly derived from vegetable oil, either as a by-product of food crops or from waste oils used in kitchens and restaurants.

4.8.1 Methodology for Assessment

The methodology taken by CSE in the *Devon Miscanthus and Woodfuels Opportunities Statement* can equally be applied to determine the resource potential for biofuel crops across Exmoor taking into account the sensitivity of the landscape.

What the report identified were the number of constraints that would prevent the growth of SRC willow and miscanthus for the area of Devon. It then layered this in GIS with the crop yield/HA/yr. (See the example below).

Example of the map for Devon from the above report:



What the assessment was then able to do was calculate the potential CO_2 emissions where the crops were used to displace fossil fuel. The following tables from the report show the potential yields and CO_2 savings:

Table B: Miscanthus yields at different landscape sensitivities

Landscape Sensitivity	Yield (dte/year)	Total Area (ha)	Energy content (GWh)	CO_2 reduction (tonnes)
Low-moderate	300,000	17,000	1,500	300,000
Moderate	1,800,000	100,000	8,600	1,800,000
Moderate-high	1,900,000	110,000	9,200	1,900,000
Total	**4,000,000**	**230,000**	**19,000**	**4,000,000**

Table C: SRC willow yields at different landscape sensitivities

Landscape Sensitivity	Yield (dte/year)	Total Area (ha)	Energy content (GWh)	CO_2 reduction (tonnes)
Low-moderate	80	8	0	85
Moderate	4,300	512	22	4,580
Moderate-high	499,000	61,100	2,580	531,000
Total	**503,000**	**61,600**	**2,600**	**535,000**

Table D: Existing Woodland Arisings

	Yield (dte/year)	Total Area (ha)	Energy content (GWh)	CO_2 reduction (tonnes)
Existing Woodland	146,000	73,000	771	159,000

4.9 BIOGAS

Biogas can be produced from the process of anaerobic digestion where organic matter is broken down by bacteria in an environment with little or no oxygen.

4.9.1 Methodology for Assessment

The resource assessment for biogas has been based on reviewing a number of related studies[30] for relevant information that can be extrapolated and applied in the context of Exmoor. For the purposes of this assessment only cattle slurry has been considered for use in AD.

4.9.2 Resource potential

The resource potential for bio-gas has been calculated based on the following assumptions:

- One tonne of cattle slurry gives around $20m^3$ of biogas which equates to 60kWh
- There are 32,442 cattle on Exmoor (2004 figures).

30 A detailed economic assessment of anaerobic digestion technology and its suitability to UK farming and waste systems;The Andersons Centre for the National Non-Food Crops Centre; April 2008
The state of farming on Exmoor; Exeter university, 2004
Defra website

- Each produces an estimated 30kg of manure per day (lower end of range some figures are as high as 60kg/day)

Based on these assumptions Exmoor could produce 355,239 tonnes of cattle manure per year producing **21,314MWh** of biogas per annum.

Assuming this is used primarily for electricity generation the biogas will deliver **10,657MWh** of power, (assuming 25% efficiency).

If the waste heat could be usefully harnessed, then an additional **21,314MWh**[31] of heat would be available, (75% combined efficiency).

4.9.3 Assessment

It must be stressed that all the calculations provided in this assessment are based on the theoretical limit of the energy resource for menu available within the Park.

Based on the above and the assumption that Exmoor's electricity demand is in the region of 30,000MWh then biogas could potentially deliver 30% of the Parks electricity demand. In addition to this the biogas could deliver just under 10% of the heat demand but this would require optimal utilisation of CHP plant in populated areas. For practical reasons it is unlikely to reach a 10% supply of heat demand based on these figures but should not be discounted as a serious contributor to the RE heat supply.

	Estimated annual resource cattle manure (t)	1t = 20m^3	kWh per m3	Efficiency	kWh available	MWh available	CO2 savings against oil (tonnes)	CO2 savings against electricity
kWhe	355,239	7,104,780	6	0.25	10,657,170	10,657	2,877	4,583
kWhheat	355,239	7,104,780	6	0.50	21,314,340	21,314	5,755	9,165
	total					**31,972**	**8,632**	**13,748**

CO_2 reduction potential of the biomass resource

As the above table reflect and based upon the above calculated estimations the use of biogas for electricity could displace around 4,500tCO_2.

Where heat is utilised and displaces oil as a fuel then a further 5,700tCO_2 could be displaced and where electricity is displaced as the fuel for heating then the CO_2 emissions reduced are higher at around 9,000 tonnes.

The cost to reduce a tonne of CO_2 will vary considerably because the cost of installing AD seem to vary considerably. Based on just the capital investment and a 20 year lifetime and using the figures below

[31] About 0.5% of the energy of the biomass generated goes back into heating the digester so this would need to be accounted for (deducted or otherwise).

this assessment has estimated that it will cost an average of £194/tCO_2 reduced for installing smaller units.

What also needs to be considered is the affect of methane from cows on the overall National Park CO_2 equivalent profile and a comparison drawn between that and the perceived benefits of using manure as a renewable energy resource.

Investment Costs

According to one report the cost of installation ranges from £2,500 - £7,000 per kW and where cattle slurry is used then the cost per kW is likely to be at the upper end of this range – this is because a larger digester is needed. Other figures suggest that a small plant of 10kWe capacity using residues from 100 cows would be a digester of 150m^3 costing £60,000 to £70,000. Whereas a complex 1MWe plant (with a 10,000m3 digester) will cost £3m to £4 million suggesting efficiencies of scale.

Assuming a load factor of about 50% then to deliver the theoretical limit 10,687 MWh of electricity (see table above) then installed capacity would need to be in the region of 2.5MW.

If this was achieved through deploying a number of smaller plants then the capital cost would be in the region of £17.5 million (based on the above figures of £7k/kW).

Energy cost savings to the economy

Based on achieving the theoretical limit for both heat and electricity the table below reflects the potential revenue to the economy for exporting the energy of using it locally in the case of heat.

If electricity is generated and sold back to the gird then the revenue back to the economy will be in the region of £1.1million or £1.6million per year depending on whether or not single ROC[32]s or Double Rocs would be available.

Where the heat energy is utilise and displace electricity for heating then the cost saving to the economy is £2.6million and where oil imports are displaced then the cost saving is just over 1million.

[32] Based on £45/MWh

Biogas	electricity	heat enery
Costs of installation	£17,500,000	£17,500,000
kWhe delivered	10,657,170	21,314,340
Single ROC value	£479,573	
Double ROC value	£959,145	-
Grid export value 6p/kWh	£639,430	
Grid import displacement (£)		2,557,721
Imported oil displacement (£)		1,065,717
Payback (dbl roc or elec displacement for heat)	11	7
Payback (single roc or elec displacement for heat)	16	16
Payback (dbl roc and elec displacement for heat)	4	
Payback (single roc and oil)	8	

The table also provides payback for the different uses of the energy generated. The best payback would be 4 years based on the theoretical limit achieved, and exporting to the grid any electricity generated, receiving double ROCs and 6p/kWh for exporting and using the heat in homes that would have used electricity for heating.

Planning constraints

From an ecological point of view it is quite a sound process. Impacts related to visual intrusion, pests and noise will be similar to other waste management options and with proper planning can be minimise to acceptable levels. The input of waste, seen as a liability, can be reduced to a saleable soil conditioner. All the greenhouse gas generated is burnt for energy recovery rather than letting some of it escape to the atmosphere as would occur in landfill. CO_2 is emitted but as it comes from organic material this has a short carbon cycle and so has no overall environmental impact.

A secondary environmental impact from this system is that it also help reduce the impact of cattle delivering high levels of nitrates onto farmland and then into river courses. This will also help part of the Exmoor national parks habitats directives.

4.9.4 Description of technology

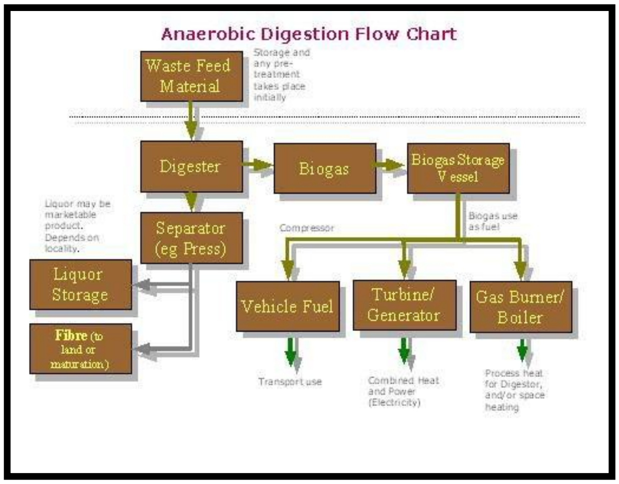
AD produces a biogas made up of around 60 per cent methane and 40 per cent carbon dioxide (CO2). This can be burnt to generate heat or electricity or can be used as a vehicle fuel. If used to generate electricity the biogas needs to be scrubbed. It can then power the AD process or be added to the national grid and heat for homes.
As well as biogas, AD produces a solid and liquid residue called digestate which can be used as a soil conditioner to fertilise land. The amount of biogas and the quality of digestates obtained will vary according to the feedstock used. More gas will be produced if the feedstock is putrescible, which means it is more liable to decompose. Sewage and manure yield less biogas as the animal which produced it has already taken out some of the energy content.

The waste and water slurry is pumped into a sealed vessel where it is heated and stirred where it stays for up to about 3 weeks. This is known as the digestion or fermentation stage.

During this period the bacteria digest the waste and create a gas comprising of about sixty percent methane with the remainder being mostly carbon dioxide. This can be used as the source of the heat energy to warm the digester(s), and there is usually sufficient methane left over to power an electricity generation set.

The process is normally continuous and filling and removal of the treated material takes place simultaneously. The output takes two forms. There is a solid digested material (digestate) which is often pressed to reduce the water content. The solid digestate is fibrous and can be used as a soil improver once it has been further matured usually by being placed in piles to aerobically compost, further reducing its weight, for about two weeks.

The digestate is very similar to compost once it has stood in the air for this period.



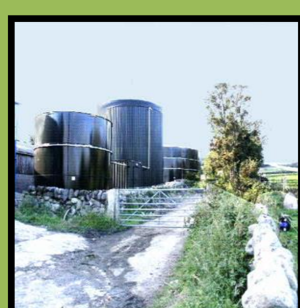
CASE STUDY: South Shropshire Biowaste Digester

Greenfinch Ltd designed and installed an AD plant in South Shropshire in partnership with the South Shropshire District Council. It was constructed under Defra's New Technologies Demonstrator Programme and can be visited by anyone interested in finding out.

The process starts in an enclosed waste reception hall in which a biofilter controls emissions. After shredding, the waste is heated in tanks to 37 degrees centigrade. After it has broken down, the material is pasteurised for an hour at 70 degrees so that it complies with the animal by-products regulations.

The plant has a capacity of 5000 tonnes each year at a cost of between £40 and £50 per tonne. The biogas is converted into electricity and 800,000 kilowatts per hour is used to heat the plant. The pasteurised bio-fertiliser is offered to local farmers. The plant could produce around 4,320 tonnes of biofertiliser and 880 tonnes of biogas each year. In the future, biogas may be used in a local district heating system.

The plant began full operation in the first quarter of 2006 and initially processed source-separated kitchen waste and garden waste collected from households in South Shropshire. It was found there was too much garden waste in the mix to produce the most biogas possible, so the plant is now focusing on processing food waste.

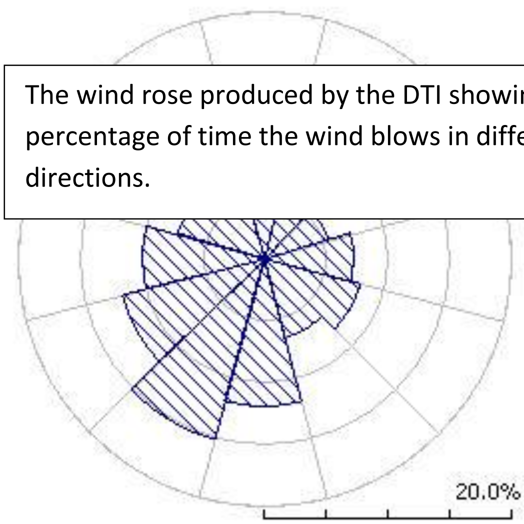


4.10 WAVE POWER[33]

4.10.1 Methodology for Assessment

There are three main factors that affect the size of a wave in open sea.

- **Wind Speed** - The greater the wind speed the larger the wave.
- **Wind Duration -**The longer the wind blows the larger the wave.
- **Fetch -** The greater the area the wind affects the wave the larger the wave



The wind rose produced by the DTI showing the percentage of time the wind blows in different directions.

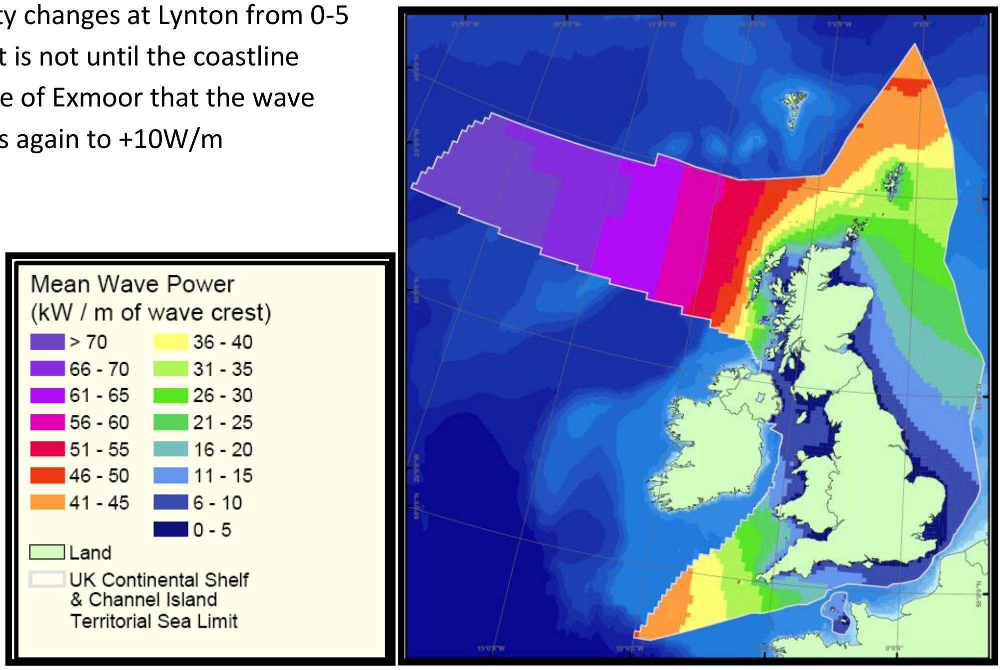
4.10.2 Resource Potential

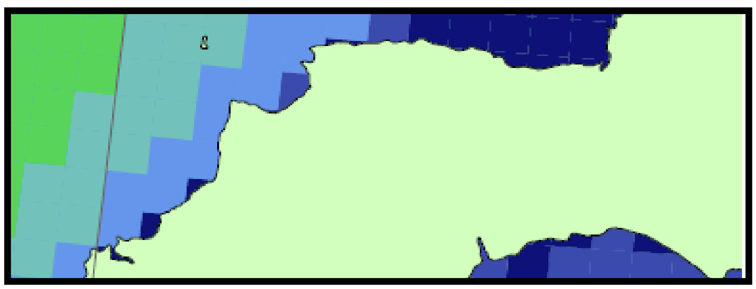
The swell in the Exmoor park area is limited. This is due to the prevailing wind which as the above wind rose reflects is predominantly from the south west and therefore the swell is from the south west. The coast is also sheltered by Ireland and Wales from any potential North West swells.

The wave energy density maps show that most of the Exmoor coastline has an average wave energy density of 0-5 kW/m

33 NEED TO GET A SECOND OPINION FROM A WAVE POWER DEVELOPER

The wave density changes at Lynton from 0-5 to 6-10 kW/m; it is not until the coastline reaches the edge of Exmoor that the wave energy increases again to +10W/m





Data source Atlas of UK marine renewable energy resources: Atlas pages Annual Mean Wave Power South West Area of UK.

4.10.3 Assessment[34]

From this information it is difficult to see how any power could be generated through wave power that would be economically viable in the short term.

Wave energy devices are still under development and costs remain high. Various types of technology are currently being tested; none are commercially available or provide any real energy curves. This technology is in its infancy however it is expected to be commercially available within the next 3-5 years. The wave hub an SWRDA developed programme, will give the UK a testing site for the four leaders of this developing technology.

[34] Needs an explanation of how the potential wind power resource is derived?

However the conditions off the coast of Exmoor do not lend themselves to deploying this technology effectively.

4.10.4 Description of technology

Wave energy is produced when electricity generators are placed on the surface of the ocean. The energy provided is most often used in desalination plants, power plants and water pumps. Energy output is determined by wave height, wave speed, wavelength, and water density. To date there are only a handful of experimental wave generator plants in operation around the world.

Various types of technology are currently being tested; none are commercially available or provide any real energy curves. This technology is in its infancy however it is expected to be commercially available within the next 3-5 years. The wave hub an SWRDA developed programme, will give the UK a testing site for the four leaders of this developing technology.

South West England Wave Hub Project

Wave Hub is a groundbreaking renewable energy project in the South West of England that aims to create the UK's first offshore facility for the demonstration and proving of the operation of arrays of wave energy generation devices.

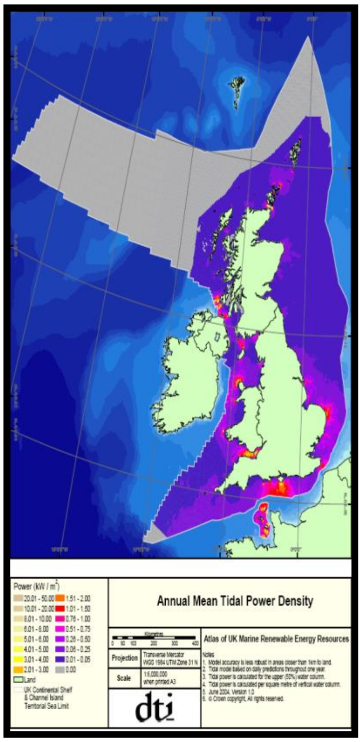
An artist's impression of the Wave Hub. The wave energy converters are the 'MRC1000' being developed by ORECon of Plymouth (right) and 'Pelamis' by Pelamis Wave Power Ltd of Edinburgh.

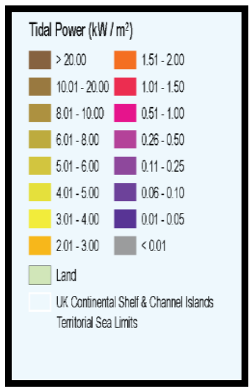
Image by Industrial Art Studio Ltd, St Ives, Cornwall.
www.ind-art.co.uk

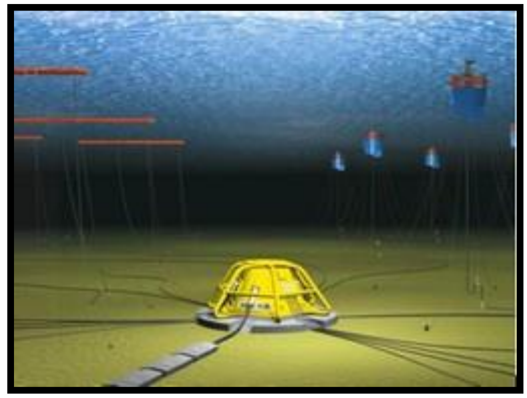
4.11 TIDAL STREAM

4.11.1 Methodology for Assessment

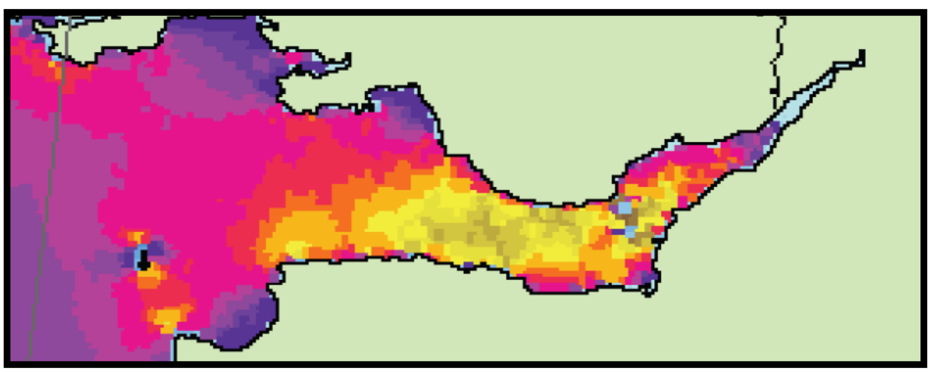
To identify the tidal stream power available in the Severn estuary the Annual Mean Tidal power density is identified using national datasets available from the BERR (formerly DTI) as shown below.





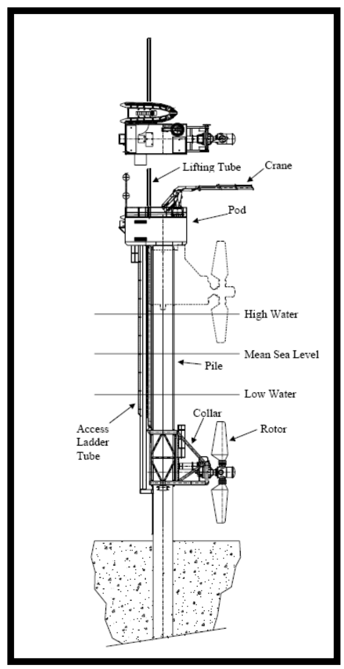


4.11.2 Resource Potential



Exmoor National Park has the advantage of being in the vicinity of one of the largest tidal zones in the UK, The Severn estuary. Most of the Exmoor coast for example, is capable of delivering 2.01 – 5.00 kW/m2 (the yellow area).

It for this reason that it has been the primary test centre for the UK's leading designer of tidal stream power SEGEN. The first site used for testing the SEGEN equipment is located offshore from Foreland point near Lynton the project began in 2003 and is ongoing.



As mentioned this tidal turbine is not yet operational to the point where it is feeding electricity into the grid. The potential is however there and further investigation is needed to understand how far the equipment is from commercial deployment.

The North Devon turbine is 11m in diameter (95.0 m^2 swept area) and with a capacity of 300 kW at its peak flow.

It is assumed that around one third of the capacity will be useful output providing **100KW**

The annual energy resource can be calculated as:

100 kW x 8400 hrs = 840,000 kWh per annum. **0.8 MWh**

The RE resource off the coast of Exmoor using tidal technology has the potential to deliver in excess of all of Exmoor's needs. One scheme that is being considered for example off illfracombe is looking to deploy 2000 hydro turbines to generate 500MW and 985,000MWh.

4.11.3 Assessment

Because the technology is still largely under development this assessment will not be able to provide any meaningful data. However, it is expected that the technology will become commercially available within the next 3-5 years and could make a significant contribution to the RE resource for the Exmoor coast.

Planning and other Regulatory Matters

Specific information unknown – see section on planning

4.11.4 Description of Technology

Tidal energy is generated by the relative motion of the Earth, Sun and the Moon, which interact via gravitational forces. Periodic changes of water levels, and associated tidal currents, are due to the gravitational attraction by the Sun and Moon. The magnitude of the tide at a location is the result of the changing positions of the Moon and Sun relative to the Earth, the effects of Earth rotation, and the local shape of the sea floor and coastlines.

A tidal energy generator uses this phenomenon to generate energy. The stronger the tide, either in water level height or tidal current velocities, the greater the potential for tidal energy generation.

End Report