England and Wales Hydropower Resource Assessment

Funded By Department of Energy & Climate Change (DECC) & Welsh Assembly Government (WAG)

Final Report

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1 EXECUTIVE SUMMARY

Interest in renewable energy continues to grow in light of concerns regarding security of energy supply and climate change, as well as in light of the UK and EU setting legally binding targets for increasing the share of energy consumed from renewable sources and reducing CO2 emissions.

Hydropower is one of the most cost effective means of producing clean renewable electricity, generally with a higher efficiency, reliability, and capacity factor than solar, wind, and ocean energy (wave and tidal energy) technologies. It is also likely that hydropower has a better energy payback ratio than other power generation technologies.

As a result of changes in technology, better financial incentives (the Renewables Obligation and feed in tariff), rise in fossil fuel costs and the need for a comprehensive action to mitigate climate change, some small scale hydropower schemes previously regarded as unfeasible may now be able to be developed.

This report, jointly funded by the Department of Energy and Climate Change and the Welsh Assembly Government provides an assessment of the remaining hydroelectric potential in England and Wales.

This assessment involved a review of previous national and regional studies of hydropower resource capacity and the development of a methodology to improve the quantification of hydro sources. This methodology was then applied to the data collected for previous studies (notably the 1989 Energy Technology Support Unit's report[1] 'Small Scale Hydroelectric Generation Potential in the UK') in order to provide an updated assessment of the current viable hydropower potential in England and Wales. This update took into account current economic and technical considerations.

The resulting range of potential viable installed hydropower capacity is as follows:

[1] Small Scale Hydroelectric Generation Potential in the UK. Volume 1-3. Univ of Salford for the Energy Technology Support Unit (ETSU), Department of Energy, 1989.

English Region	Number of Sites	Potential (kW)
Anglian	126	4,920 - 13,370
North West	284	32,000 - 37,700
Midlands	157	18,000 - 32,400
Southern	36	1,100 - 2,600
South West	322	20,000 - 29,400
Thames	125	16,200 - 30,120
North East	318	27,330 - 39,810
England Total	**1368**	**119,550 – 185,400**

Wales	Number of Sites	Potential (kW)
Wales Total	**324**	**26,730 - 63,000**

Total	Number of Sites	Potential (kW)
England & Wales	**1692**	**146,280 – 248,400**

The total potential identified by this study for England and Wales is in the range of 146,280-248,400 kW. This is a substantial increase from the original 1989 ETSU study which identified about 34 MW for England and Wales. It is clear from this new analysis that recent advances in technology development, reduced equipment costs and financial incentives have provided a further opportunity to exploit resource that was considered unviable at the time of previous studies.

2 INTRODUCTION

Interest in renewable energy continues to grow in light of concerns with regard to security of supply and climate change. The UK government and the EU have set demanding and legally binding targets for renewable energy. The UK Renewable Energy Strategy, published in July 2009, envisages that, by 2020, electricity from renewable sources may contribute 117 TWh, or 30% of the total expected electricity demand. This would be a major contribution towards the binding requirement on the UK to generate 15% of all energy consumed in 2020 from renewable sources[2].

Small scale hydropower is one of the most cost effective means of producing clean renewable electricity, generally with a higher efficiency, reliability, and capacity factor than solar, wind, and ocean energy (wave and tidal energy) technologies[3].

The total amount of electricity generation capacity in the UK from hydro power is nearly 1.5GW from hydropower schemes with reservoirs and run-of-river schemes. Pumped storage is not included in this value since it is a net-user of electrical power.

Earlier studies carried out to assess the potential of small[4] hydropower in the UK, e.g. *Small scale hydroelectric generation potential in the UK* (1989) and *Resource assessment of low-head hydropower in Europe* (1995) (discussed later in this document) excluded many potential sites because of concerns with regard to commercial feasibility and the limitations of equipment then available. The viability of many of these excluded sites is now likely to be enhanced due to the increased incentives offered under the developing feed-in tariff and the Renewables Obligation (RO) mechanism, especially in light of the proposed revisions of the RO which highlight the need for two Renewable Obligation Certificates per MWh for projects under 50kW[5]. Such incentives will improve the rate of return on renewable installations, and give rise to profits after shorter periods. Also, new technologies are now available to harness hydropower at lower heads and at more competitive prices.

This report completes the work contracted by and to the British Hydropower Association (BHA), and jointly funded by the Department of Energy and Climate Change and the Welsh Assembly Government, and outlines potential next steps, which would strengthen confidence in the results so far obtained. Existing data from previous studies, mainly the ETSU study[6], has been used and analysis undertaken using revised criteria to come up with a modified estimate of the potential of viable hydropower capacity in England and Wales. Due to the nature of the methodology employed to process the data (explained in detail in Chapter 7), it is not possible to indentify individual sites. Rather, the study provides an indication of concentration of hydropower schemes on a regional basis (see details in Chapter 8).

[2] http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/res/res.aspx

[3] Ocean Energies encompasses; Marine Current Energy and Wave Energy

[4] Small Hydropower is defined as a hydropower scheme between 1 and 10MW in power output

[5] http://www.r-e-a.net/policy/REA-policy/RET/common/BluePrint REA Consultation, page 34

[6] Small Scale Hydroelectric Generation Potential in the UK. Volume 1-3. Univ of Salford for the Energy Technology Support Unit (ETSU), Department of Energy, 1989.

3 BACKGROUND AND SCOPE

Several studies have been carried out in the past to catalogue the available small hydro power (from 1 to 20MW plant capacity) resource in the UK. However, the assumptions in these studies are now incorrect due to technical improvements and economic changes.

Many of the incentives currently available for green generators, for example the Climate Change Levy and the Renewables Obligation, were not available at the time of these original studies. Hydro schemes that would not have been commercially feasible 20 years ago, in 1989, may well be so now, particularly in the light of rising electricity prices. As discussed in Section 4, sites with lower heads and power outputs were sometimes omitted altogether from resource assessments on the grounds of commercial viability and limitations of technology.

Recent research carried out in the UK, such as on the ultra-low head siphon turbine operating at a variable speed[7], suggests that these types of turbines can be a cost-effective alternative to the Kaplan turbine, which was the traditional technology considered in the previous studies. Kaplan turbines are highly engineered sophisticated equipment and therefore have an associated high cost; they are generally not economic at sizes less than 500 kW. In addition, high costs can sometimes be incurred by developers of hydropower schemes due to the need to comply with environmental regulations, such as installation of fish passes for the protection of fisheries. It may be that new technologies, such as Archimedean screws for power generation, may have less impact on fish than traditional turbines leading, in some cases, to more straightforward authorisation.

With the availability of improved technology and the incentives noted above, it is believed that a large proportion of previously rejected schemes could now be economically viable. With this background, it was considered important that an assessment of such previously overlooked hydro resource was undertaken to establish a realistic potential of small hydropower schemes in England and Wales. This study is a first step in that direction.

A comprehensive hydropower resource assessment study was developed to achieve this goal, with the study consisting of a number of tasks. The study was designed to utilise the available dated data and undertake analysis using current financial and technological models. The task list for this study was as follows:

1. Review of Existing Studies
2. Methodology and Design Criteria
3. Development of a GIS Database
4. Mapping out in GIS - Populate the Database with available information (e.g. ETSU Study)
5. Review and Reanalysis of Current Data
6. Conclusions and Next Steps

[7] IT Power, Derwent Hydro and GP Electronics, *Siphon Propeller Turbines Operating at Variable Speed*. Report to DTI, New and Renewable Energy Programme, (2003).

Potential future tasks are as follows:

7. New data search using hydrodynamic modelling
8. Model validation through selected sample site investigation
9. Update and refinement of the GIS database

Tasks 1 to 6 have been completed and are reported here.

4 REVIEW OF EXISTING STUDIES

TASK 1

The previous studies that were identified and reviewed under this study are:

- Salford Civil Engineering (ETSU) - Small Scale Hydroelectric Generation Potential in the UK – 1989
- Resource Assessment of Low-head Hydropower in Europe (Joule Study)[8] (1995)
- Environmental Resources North West Study[9] - 2001
- TV Energy South East England Study[10] - 2004
- Dulas, Energie & WDA Welsh Study[11] - ~ 2004
- Scottish Hydropower Study[12] - 2008

This study reviewed two of the major studies carried out with a view to identifying perceived restrictions on development that may no longer be valid and the conclusions are set out below.

4.1 Small Scale Hydroelectric Generation Potential in the UK

This study is the only detailed review of small-scale hydropower in the UK. It was carried out on behalf of the Energy Technology Support Unit (ETSU) of the Department of Energy in 1989. Since it was contracted to Salford University Civil Engineering Limited, it is commonly referred to as the "Salford Study" or ETSU study. The scope of the review was limited to the sites with power outputs of more than 25 kW in grid connected areas, and more than 50 kW in remote areas. The lower limit was chosen purely to reduce the number of sites studied to make it proportionate to the resource available for the study. The upper limit of the studied schemes was 5 MW, which is the same value as that previously chosen by the Watt Committee[13] as being the minimum size generally considered for investment by the then public electricity generating boards. The ETSU study also disregarded all the hydropower schemes below 2m of head with existing structures, and below 3m head without any existing structures. Such low head sites were considered to be uneconomic for development using commercially available conventional water turbines. The study further adds that the lack of such low-cost technology has led to research into new machinery in UK and other areas.

A total small hydro resource of 322 MW was identified in the UK, with a large majority (over 80%) in Scotland, with only 19 MW identified for England and 15 MW for Wales. The

[8] IT Power, Stroom Lijn & University of Kassel. Low-Head Hydropower in Europe. Report for Commission of the European Communities. 1995

[9] http://www.nwrpb.org.uk/downloads/documents/imported/181066779294.PDF 21/04/09

[10] TV Energy & MWH. Low Head Hydro Power in the South-East of England – A Review of the Resource and Associated Technical, Environmental and Socio-Economic Issues. February 2004

[11] Dulas, Energie and WDA. Wales Technology Map: Electricity from renewable energy sources (RES-e)

[12] http://www.sistech.co.uk/SISTechHydropowerResourceStudy.html 21/04/09

[13] Watt Committee, *Small-scale Hydropower*, Report No. 15 (1985).

number of rejected sites in England alone was more than a thousand. The site database of the ETSU study is given in Annex 3 & 4.

Summary of the criteria used and justification provided in the ETSU Study is provided in Table 1.

Table 1 Summary of Criteria used in ETSU Study

Criteria/Limitations	Justification	Remarks
Gross head must be greater than 2m	Heads less than 2m deemed to be uneconomical	This study considers head height greater than 1m.
Sites with heads of between 2m and 3m must have existing civil works	High construction cost of new river structures would make economic power production unlikely; could also introduce severe institutional and environmental barriers	Situation unlikely to have changed as regards structures – it will be difficult to acquire licenses for a completely new structure across a river.
For sites with local demand, potential installed capacity must be greater than 25kW	Considered uneconomical below this output	Due to improvements in technologies, this should be altered to 'no lower limit'.
For remote sites, potential installed capacity must be greater than 50kW	Remote sites with capacity below 50kW considered to be uneconomic for connection to local grid	25 kW should the lower limit for schemes at remote sites
Sites which would involve the construction of large diversion works (such as weirs on large rivers) or dams were not considered	Likely to present significant environmental and land drainage problems	Situation unlikely to have changed
Q_{mean} used to characterise flow	Mean available flow1 provides reasonable first estimate of the flow which is likely to yield max economic benefit.	
Prices of electricity and energy values	Current rates applied	Need to change and update to new electricity prices. Also, Government incentives such as ROCs will need to be taken into account

4.2 Resource Assessment of Low-head Hydropower in Europe (1995)

This Europe-wide study of available small hydro resource was carried out as part of the EC JOULE II review. Three countries, Germany, the Netherlands and the UK, were selected for examination. In the UK, only three major catchments in central-southern UK, consisting of

the Thames, Severn and Trent rivers, were studied for potential low head resource. In this study, 89 potential low head hydro schemes with a power output of more than 100 kW and heads of less than 5 m were investigated. The total catchment area covered was nearly 35,000 km2. The total economic potential in the areas studied (Thames and Severn-Trent) was quantified as 105 GWh/year if the electricity price was 8 Euro cents per KWh. The Joule study suggests that with the exception of one or two small developments on the Derwent, the low head resource in these regions of the UK was largely unexploited. A summary of the criteria used and justification provided in the Joule Study is shown in Table 2.

Table 2 Criteria and Justification used in Joule Study

Criteria/Limitations	Justification	Remarks
All sites must have weirs or civil structures in place	High construction cost of new river structures would make economic power production unlikely; could also introduce severe institutional and environmental barriers	Situation unlikely to have changed since the study
Gross head at low flow must be between 1.5 and 5metres	1.5m – chosen to limit study to sites sufficiently large to connect to grid; and to maximise chance of obtaining existing data with accurate head and flow information	Head at low flow reviewed in light of emergence of new turbine types. There should be no upper limit on the head but a lower limit of 1m is included.
Minimum mean theoretical power of 100kW	Generally less feasible below this output	Minimum size should be 25 kW
Only about ¼ of the UK (Central – southern areas) assessed.	Project had limited scope	The current study will cover whole of England and Wales
Q50 used to characterise flows	No justification provided.	Reasonable assumption to make as it is the median flow.
Mean total efficiency	70%	Efficiencies reviewed in light of contemporary technology
Head loss	0.20m – consistent with values used by developers in 1994	Head loss reviewed in light of contemporary technology
Economic parameters such as interest rate, rate of inflation etc	Current rates were applied	Applied new rates applicable

4.3 Regional Studies

In more recent years there have been a number of efforts made to establish hydropower potential around the UK, often by region. One of the important studies is the Low Head Hydropower Resource Study[14] for the South East, and further review is provided at paragraph 4.3.2. The study identified various old mill sites and weirs whereby the technical resource was estimated to be more than 13 MW with a limit of 3 kW and minimum of 1 m head. A total of 525 sites were identified across the region.

There have been other attempts to quantify potential, such as in the following reports:

4.3.1 Welsh Report, 1980[15]

In addition to the notable ETSU study, a previous hydro study on the Welsh potential returned a considerably higher result.

The 'Welsh Report', 1980, returned a figure of 63MW of unused hydro for Wales, compared to 20MW in the ETSU & the Dulas, Energie & WDA study[16]. This was largely due to different assumptions and criteria specified. For example, the Welsh Report used a higher turbine efficiency (akin to modern turbines) whereas this was reduced to 60% in ETSU study. Sites were also rejected in the ETSU study due to low head, or a combination of less than 50kW size and distance from grid infrastructure.

4.3.2 SEEDA 2004 Low-head Resource Study for South East

TV Energy and collaborators such as MWH and IT Power conducted a resource study for the SE region, supported by SEEDA.

Of particular interest to this discussion are the comments arising from the study with respect to the ETSU study. For the same region, the ETSU states a potential (arising from 13 sites) of 3.2MW. The SEEDA study increases this to a theoretical potential of 13.6MW and a more practical 5.3MW (including planning, connection and other restrictive criteria). This is a 70% increase in installed capacity for the region over the 15 year period. As the economic and technical situation has become even more favourable for the hydro market, it is fair to assume this percentage has increased again and may be representative of other regions within the UK.

It is noted that the SEEDA study identified 212 sites in its high level map study whereas for the same region the ETSU study only located 157 sites. This represents a 35% increase in site numbers.

Whilst it is likely that these sites will be less viable and have less favourable head and flow characteristics, with current technologies and financial incentives they are worth revisiting as they may provide other development advantages, for example potential for localised supply or close proximity to grid connection.

[14] Low Head Hydro Power in the South-East of England: A Review of the Resource and associated Technical, Environmental and Socio-Economic Issues (2004).

[15] This current study uses the information from Welsh Report as quoted in the ETSU report. It has not been possible to further analyse the 63MW figure.

[16] Dulas, Energie and WDA. Wales Technology Map: Electricity from renewable energy sources (RES-e)

5 METHODOLOGY AND DESIGN CRITERIA

TASK 2

Any theoretical and technical potential needs to be assessed against a set of criteria to arrive at realistic estimation of the resource which can be practically developed.

A methodology was produced for the detailed hydro resource study. It should however be noted that not all criteria referred to below were used to generate the hydropower resource assessment carried out and reported in this document but this methodology is highlighted to be the one preferred by the industry for any new data search; a modernisation of that used for the ETSU study. Details of the results and their methodology can be found in Section 7.

Assessment criteria were developed based on current circumstances, including status of equipment and current legislation which allows better incentives for renewables compared to those available during the production of the ETSU study. For example, one of the criteria which was revised was the minimum head below which a scheme was fundamentally considered unviable. Additionally, this activity involved developing methodology and algorithms to calculate a number of outputs such as cost of a scheme, energy outputs, revenues, hydrological data, financial parameters and grid connection.

5.1 Assessment Criteria

The new selection criteria were used in the following way.

- To assess rejected sites in previous studies with a view to determine whether the sites could now be included in the count.
- To assess any sites included in the previous studies with a view to determining whether they are still viable.
- To assess the viability of new sites identified during this study.

The sites considered in this study are both run of river, sites with reservoirs and sites within the Water Supply Industry.

One important point to note is that the feasibility of a scheme cannot just be measured in economic terms. If a scheme is not economically feasible, it could still be viable in terms of demonstration, educational and for other purposes.

The ultimate output of a resource assessment is the quantification of the total viable hydropower potential. This will require that appropriate hydropower schemes will have to be identified and assessed for viability against the criteria set out below.

5.1.1 Site Hydrology

Hydropower schemes with a lower head will generally produce electricity at a higher investment cost than those with a higher head, if all other parameters remain the same. In previous studies of this kind, the head available at a scheme has been one of the key criteria to rule a scheme in or out in terms of viability or further consideration. As mentioned before, the ETSU study rejected all the sites that had a head of 2m or less. The study also rejected the sites with a head of 3m or less if there were no previous structures present. It was considered that sites below those heads were uneconomic for development.

Similarly, the Joule study ruled out sites with less than 1.5m gross head at low flow (implying maximum or near maximum head) suggesting that schemes below 1.5m were "probably unfeasible in general".

A Kaplan or a propeller turbine has been traditionally preferred and available for a low head site until recently. Waterwheels and Archimedean screws are being increasingly considered for hydropower schemes and are being installed at various sites across England and Wales, often at very low head, sometimes below 1.5m.

It is assumed for the purposes of this current study that any site with a head less than 1m is likely to be prohibitively expensive even though technically viable.

5.1.2 Infrastructure

The requirement for having some kind of infrastructure, such as an old mill site or a site with a weir, has been a determining factor in selecting a site for consideration in the previous studies. Due to increased focus on environmental protection of rivers by the introduction of Water Framework Directives, it is likely to be very difficult to make a case to put in a new dam, gates or weir structures in a stretch of river where none already exist. Additionally, installing a new structure is likely to increase the cost of the development to an unacceptable level. Hence this criterion was applied for new sites to be considered in this resource study.

Availability of existing grid access near the site of development is also an important factor in determining the viability of a hydropower scheme because of the potential cost and time delays in obtaining consents for, and installing, new grid infrastructure.

5.1.3 Capacity

A decision was made at the outset as regards the upper and lower limit of a hydropower scheme capacity. For the purposes of this study, no maximum size for a scheme has been identified. The option of setting a lower limit to 25 kW, the same limit set by the ETSU Study has been considered. However, it was recognised that by doing so many of thousands of old mill sites would be excluded from this study. These types of sites can benefit from the very small scale hydro technologies (pico hydro - Hydropower installations from 0 to 5kW) now commercially available in the UK. Therefore, for sites with local demand, no limit in terms of power output is set and resource is quantified based on the information that is available, irrespective of the size. However, for remote sites, the lower limit for schemes is set at 25kW (see Table 1).

5.1.4 Economics

The economics of a scheme is one of the key criteria that will decide whether a scheme is likely to be developed. The new feed-in-tariff and improvements on Renewable Obligation (as outlined in the introduction) currently proposed are expected to improve the rate of return for developers over the coming years.

A full economic assessment of the hydro resource in England and Wales would need new data as the historical data is too limited to allow suitable analysis. For example many sites excluded from the ETSU study do not have specified head and flow characteristics.

It is important to note that hydropower plants have a life expectancy of between 25 and 50 years which can be extended to over 100 years with refurbishment and upgrade. A report

by Hydro-Quebec assesses that the energy payback ratio for a run-of-river hydro plant is between 170 and 267[17] and is the highest of any generation technology.

5.1.5 Social and Environmental Aspects

A hydropower scheme should not be considered viable or unviable solely on financial grounds. A commercial business may want to develop a hydropower scheme to achieve certain financial gains, but a local authority may want to develop the scheme from an educational point of view. There may be certain circumstances where a commercial developer may have to look at developing a hydropower scheme among other renewable energy projects in order to fulfil certain legal obligations. Also, a hydropower scheme could become viable in the context of an overall development of an area, or from associated environmental benefits, even though its justification might be marginal on purely economic grounds.

Environmental considerations are an important factor in developing hydropower schemes. The proposed European Water Framework Directive[18] specifies a number of aspects related to the ecological environment that have to be considered in the planning of a hydropower scheme. Included in these are the protection of fish species and the maintenance of water quality. There is an expectation, within the proposed legislation, that the local ecological environment is maintained or even improved while developing hydropower schemes in Europe.

[17] Comparing Energy Options: Energy Payback Ratio. Hydro-Québec. July 2005.

[18] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. European Union.

6 GIS DATABASE

TASK 3

This task required a Geographical Information System (GIS) database to be developed. This involved, in part, identifying and setting up various fields that will accommodate the current and future data related to hydropower in England and Wales. This involved several iterations and trials with sample data to test out the structure and its usefulness to the requirement, before inputting the large amount of data.

TASK 4

ArcGIS 9.0 was used to set up the database. After all the data on each hydropower scheme was input, it was possible to map out hydropower schemes using various queries such as scheme capacity, head, flow or other parameters. For example, easy reference could be enhanced by representing different hydro schemes with different symbols; each symbol could signify a different head or head range. It was also possible to view potential sites on a map differentiated and categorised by other relevant parameters such as flow or presence of a weir.

7 REVIEW AND RE-ANALYSIS OF CURRENT DATA

TASK 5

In light of the changes in the technology, economic environment and available government support which have occurred since the ETSU study was undertaken, it is worthwhile to re-adjust some of the study's assumptions.

Changes in technology, better financial incentives, rise in fossil fuel costs and the need for a comprehensive action to mitigate climate change have meant that the hydropower schemes previously regarded as unfeasible can now be developed.

The ETSU Study identified sites in England and Wales in two categories:

- Sites having a development potential, with details of site capacity and other parameters (Potential Sites)
- Sites rejected for several reasons (Rejected Sites)

In this activity, the list of Potential Sites was updated to match current circumstances and it gives rise to a new higher potential capacity. Additionally, more than 1,300 sites in England and Wales were listed as not having a potential in the ETSU Study and no data exists for those sites. To re-evaluate these sites several assumptions were defined and a sensitivity analysis undertaken allowing an estimate of capacity figures to be assigned to each of the sites. Assumptions were made to determine a higher value (optimistic) and a lower value (pessimistic) of capacity for each site. The total potential power installed for all the Potential Sites and the Rejected Sites, from the ETSU Study, have been calculated on this basis giving a range of capacity for the hydropower schemes. This was done on the basis of the regions defined by the Environment Agency to reflect catchment areas.

7.1 Specific Change of Assumptions

The specific details for the change of assumptions are listed in a table on the next page. These are split into:

A) Change of assumptions for the 'Accepted' sites.

B) New power calculations for 'Rejected' sites.

For group A) the assumptions brought the figures into the 21st century with better turbine efficiencies and more appropriate load factors.

For group B) estimates relating to the head and flow were made alongside assumptions about the likelihood of development - this exhibits a higher variance and these are represented with pessimistic and optimistic figures.

Focus	Criteria/Limitations	Justification	Remarks
ETSU Study 'Accepted' Sites	Plant Efficiency of 80% utilised for calculations of power output	Utilisation of contemporary Turbines and Plant, allowing good efficiency.	Consistent with efficiencies seen in practice.
	Mean Flow (Q_{mean})values were used in the calculation of power output, which were to an accuracy of ±0.01(m^3/S)	Only values available from the ETSU Study.	ETSU study values assumed accurate
	Average Head Values were used in the calculation of power output, which were to an accuracy of ±0.1(m)	Only values available from the ETSU Study.	ETSU study values assumed accurate
ETSU Study 'Rejected' sites	Where flow data was required for any schemes (for the calculation of power), an average 'Mean Flow' was taken from the 'accepted' sites datasets in that particular region.	The Mean flows used are considered to be a good approximation for use in the calculation of available power at these sites.	None
	P25' sites included from rejection list and are assumed to be sites that are at an average power output of 12.5kW.	P25 sites are sites which were rejected for being at less than 25kw, here these are assumed to be sites that are at an average power output of 12.5kW.	The study therefore encompasses all those rejected sites which were less than 25kw, regardless of scheme payback.

Focus	Criteria/Limitations		Justification	Remarks
	P50 sites are assumed to be sites that are at an average power output of 37.5kW		P50 sites are sites which were rejected for having Power less than 50kW, with no on-site demand. Here these are assumed to be sites that are at an average power output of 37.5kW, as this is the average of 25kW and 50kW.	Many developments and technological advances (eg remote grid connections) over the two decades allows for the inclusion of these sites
	H2 sites are assumed to be at a head of between 1metre and 2, therefore 1.5m, as the sites with less than 1m would have not been considered.		Heads less than 1m deemed to be uneconomical	Sites with 1m head have a very poor payback rate.
	DIY sites are assumed to be sites that are at an average power output of 12.5kW		DIY Sites were considered to have power less than 25kW, and suitable for small development, therefore included in this study.	No comment
	NC sites are assumed to be at a head of between 2metres and 3, therefore a head of 2.5m is allocated to these sites.		Sites with less than 2m head would have been coded within 'H2'	New value assumed to have reasonable accuracy
	Plant Efficiency of 75% utilised for calculations of power output given that these tend to be smaller sizes.		Utilisation of contemporary Turbines and Plant, allowing good efficiency.	Consistent with efficiencies seen in practice.
All sites	Old Region Name- Northumbrian	Positioned Within-North East	The regions were transposed from the previous study due to a renaming of the regions by the Environment Agency.	No comment
	Old Region Name-Severn Trent	Positioned Within-Midlands		
	Old Region Name-Wessex	Positioned Within-South West		
	Old Region Name-Yorkshire	Positioned Within-North East		

Focus	Criteria/Limitations	Justification	Remarks
	Gravity taken to be 9.81(m/S^2)	Normal Figure	No comment
	Sites which would involve the construction of large diversion works (such as weirs on large rivers) or dams were not considered	Likely to present significant environmental and land drainage problems	Total output figures would be greater if these sites were included.

8 RESULTS

The table below gives an indication of the results from the re-analysed Potential and Rejected Sites using the upper and lower bounds as discussed earlier.

English Region	**Number of Sites**	**Potential (kW)**
Anglian	126	4,920 - 13,370
North West	284	32,000 - 37,700
Midlands	157	18,000 - 32,400
Southern	36	1,100 - 2,600
South West	322	20,000 - 29,400
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England Total	**1368**	**119,550 – 185,400**

Wales	**Number of Sites**	**Potential (kW)**
Wales	324	26,800 - 63,000

England and Wales	**Number of Sites**	**Potential (kW)**
Total	**1692**	**146,280 - 248,400 kW**

The clear, large range to the data represents the sensitivity of the assumptions required to enable extrapolation of the data. The lower, pessimistic, figure still represents over a 100% increase compared to the ETSU study in the predicted hydro potential in England and Wales representing the change in economic and technical climate that now exists in the market place. It should be noted that it is likely that the potential figure will be higher than that shown here as studies suggest that the ETSU study did not identify all potential sites in its analysis (see sections 4.1 and 4.3).

The locations marked on the maps in the next section, represent concentrations of hydro sites, but not individual sites. There are hundreds of sites identified in previous studies with very little data, in many cases only the location and name of the sites and for many of these estimated average head and flow were employed to ascertain the capacity. This means that the value assumed for any particular site may be underestimated or overestimated but these discrepancies will be smoothed out through the combination of sites into groups, thereby giving a better estimate of total power potential.

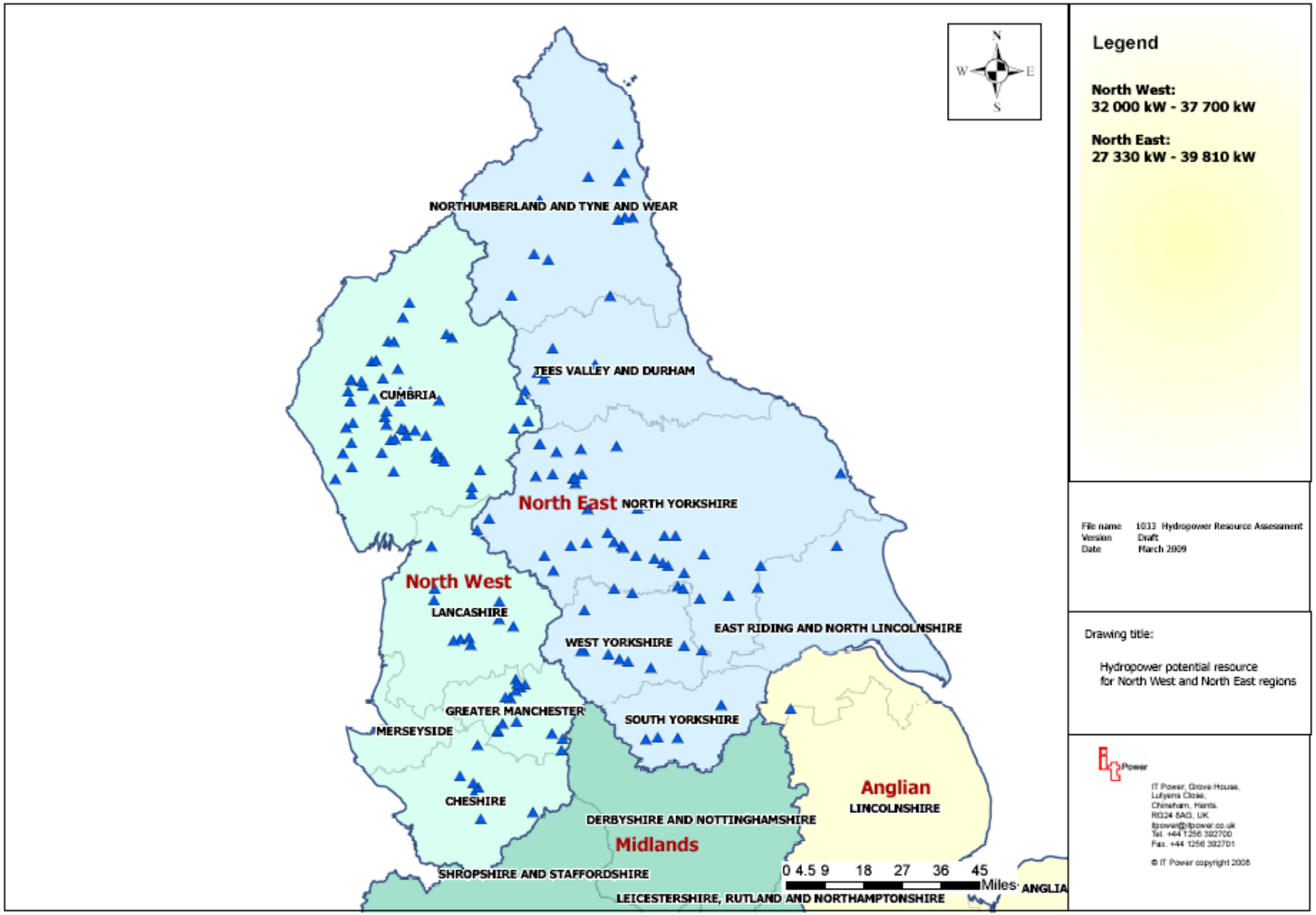
Even though the maps give only an indication of the general potential in different locations, the detailed list of sites that the ETSU study assumed viable at the time of that study is

shown in Annex 3; Annex 4 shows the list of sites rejected by the 1989 ETSU study. Some of these might now be potentially viable.

8.1.1 GIS Analysis

The data from this analysis was input into the GIS database specifically established for the purpose of this study. The data used for this is given in Annex 3 & 4. The maps are broken down into the regions above.

The range of installed capacity is included in the legend; the blue triangles indicate clusters of potential sites and not the individual site as explained above.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WEST YORKSHIRE
GREATER MANCHESTER
SOUTH YORKSHIRE
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CHESHIRE
DERBYSHIRE AND NOTTINGHAMSHIRE
Midlands
SHROPSHIRE AND STAFFORDSHIRE
0 4.5 9 18 27 36 45
Miles
LEICESTERSHIRE, RUTLAND AND NORTHAMPTONSHIRE
ANGLIA
Legend
North West:
32 000 kW - 37 700 kW
North East:
27 330 kW - 39 810 kW
File name: 1033 Hydropower Resource Assessment
Version: Draft
Date: March 2009
Drawing title:
Hydropower potential resource
for North West and North East regions
IT Power, Grove House,
Lutyens Close,
Chineham, Hants.
RG24 8AG, UK
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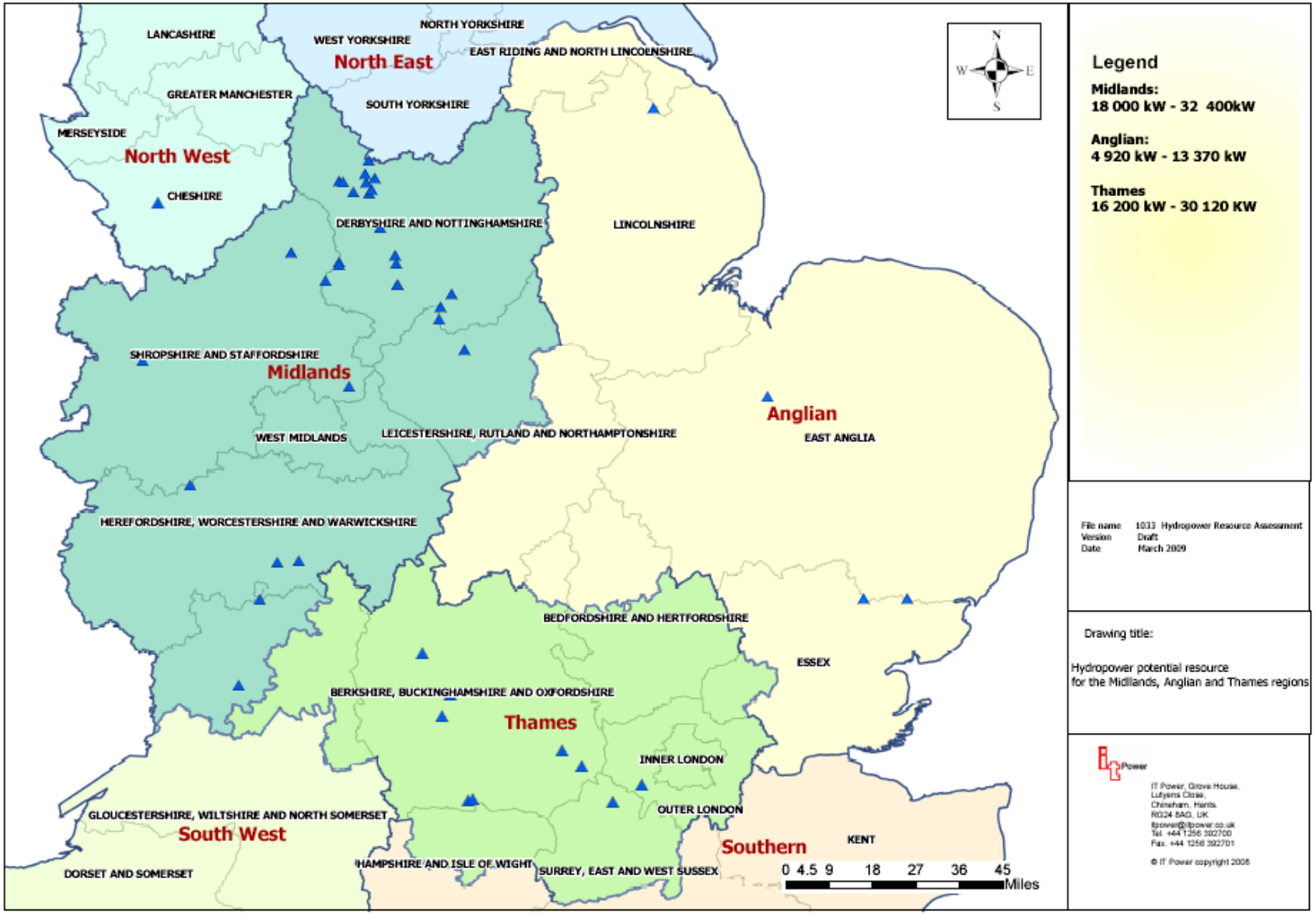
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North East
EAST RIDING AND NORTH LINCOLNSHIRE
GREATER MANCHESTER
SOUTH YORKSHIRE
MERSEYSIDE
North West
CHESHIRE
DERBYSHIRE AND NOTTINGHAMSHIRE
LINCOLNSHIRE
SHROPSHIRE AND STAFFORDSHIRE
Midlands
Anglian
EAST ANGLIA
WEST MIDLANDS
LEICESTERSHIRE, RUTLAND AND NORTHAMPTONSHIRE
HEREFORDSHIRE, WORCESTERSHIRE AND WARWICKSHIRE
BEDFORDSHIRE AND HERTFORDSHIRE
ESSEX
BERKSHIRE, BUCKINGHAMSHIRE AND OXFORDSHIRE
Thames
INNER LONDON
OUTER LONDON
GLOUCESTERSHIRE, WILTSHIRE AND NORTH SOMERSET
South West
Southern
KENT
HAMPSHIRE AND ISLE OF WIGHT
SURREY, EAST AND WEST SUSSEX
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Miles
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Legend
Midlands:
18 000 kW - 32 400kW
Anglian:
4 920 kW - 13 370 kW
Thames
16 200 kW - 30 120 KW
File name 1033 Hydropower Resource Assessment
Version Draft
Date March 2009
Drawing title:
Hydropower potential resource
for the Midlands, Anglian and Thames regions
IT Power
IT Power, Grove House,
Lutyens Close,
Chineham, Hants.
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Tel. +44 1256 392700
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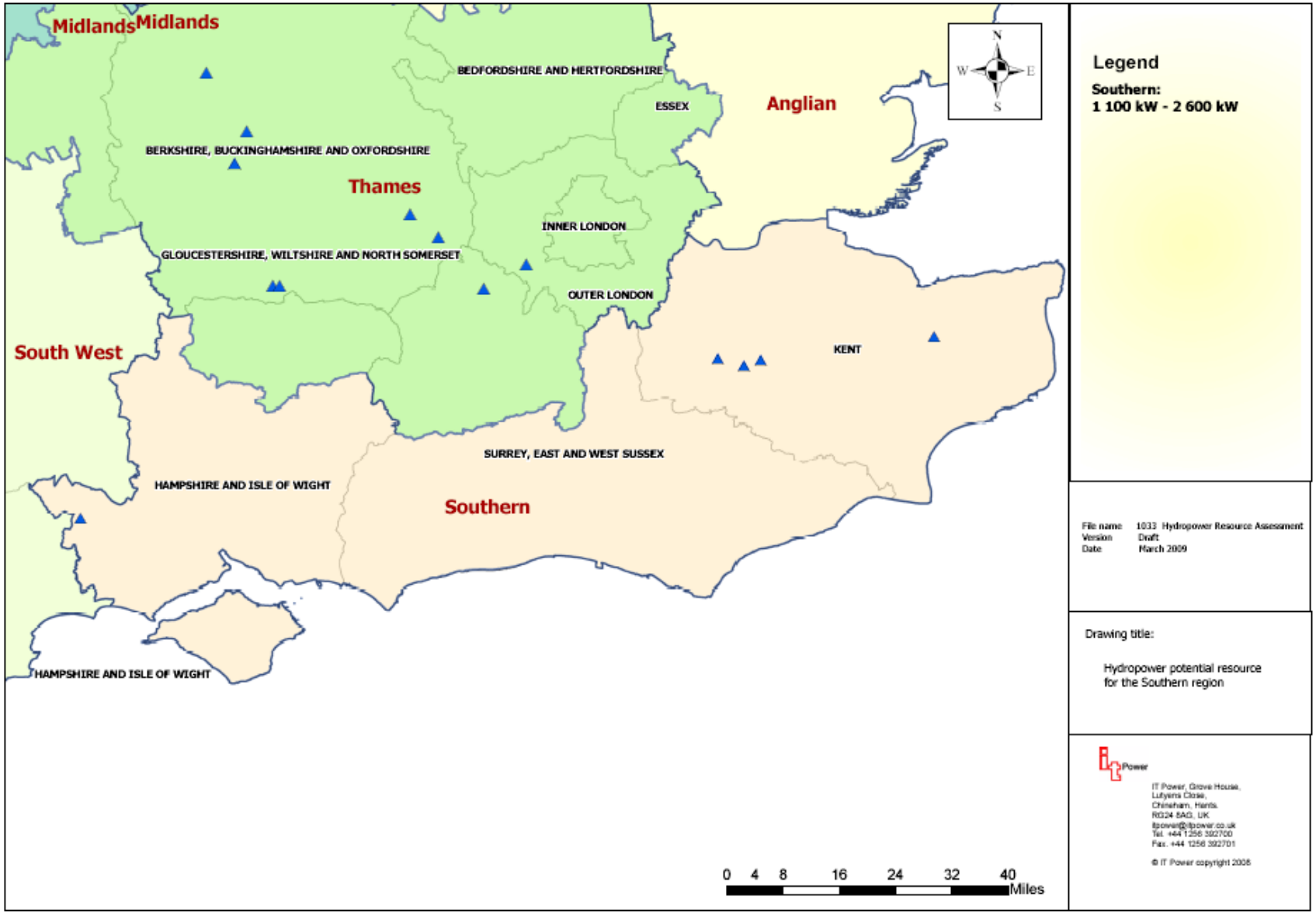
Midlands
Midlands
BEDFORDSHIRE AND HERTFORDSHIRE
ESSEX
Anglian
BERKSHIRE, BUCKINGHAMSHIRE AND OXFORDSHIRE
Thames
INNER LONDON
GLOUCESTERSHIRE, WILTSHIRE AND NORTH SOMERSET
OUTER LONDON
South West
KENT
SURREY, EAST AND WEST SUSSEX
HAMPSHIRE AND ISLE OF WIGHT
Southern
HAMPSHIRE AND ISLE OF WIGHT
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0 4 8 16 24 32 40
Miles
Legend
Southern:
1 100 kW - 2 600 kW
File name: 1033 Hydropower Resource Assessment
Version: Draft
Date: March 2009
Drawing title:
Hydropower potential resource for the Southern region
Power
IT Power, Grove House, Lutyens Close, Chineham, Hants. RG24 8AG, UK
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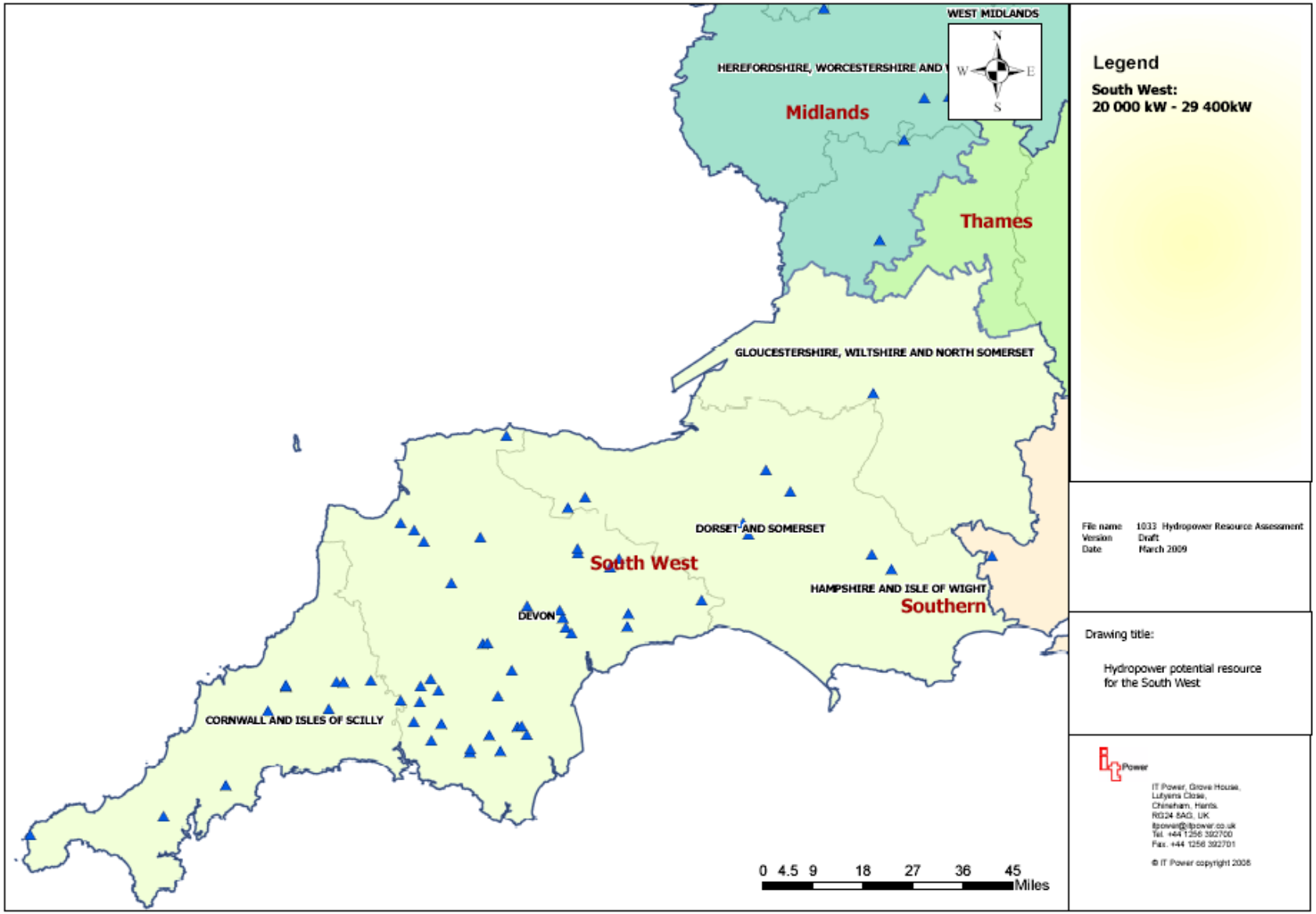
WEST MIDLANDS
HEREFORDSHIRE, WORCESTERSHIRE AND
Midlands
Thames
GLOUCESTERSHIRE, WILTSHIRE AND NORTH SOMERSET
DORSET AND SOMERSET
South West
HAMPSHIRE AND ISLE OF WIGHT
Southern
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Miles
Legend
South West:
20 000 kW - 29 400kW
File name 1033 Hydropower Resource Assessment
Version Draft
Date March 2009
Drawing title:
Hydropower potential resource for the South West
IT Power, Grove House, Lutyens Close, Chineham, Hants. RG24 8AG, UK.
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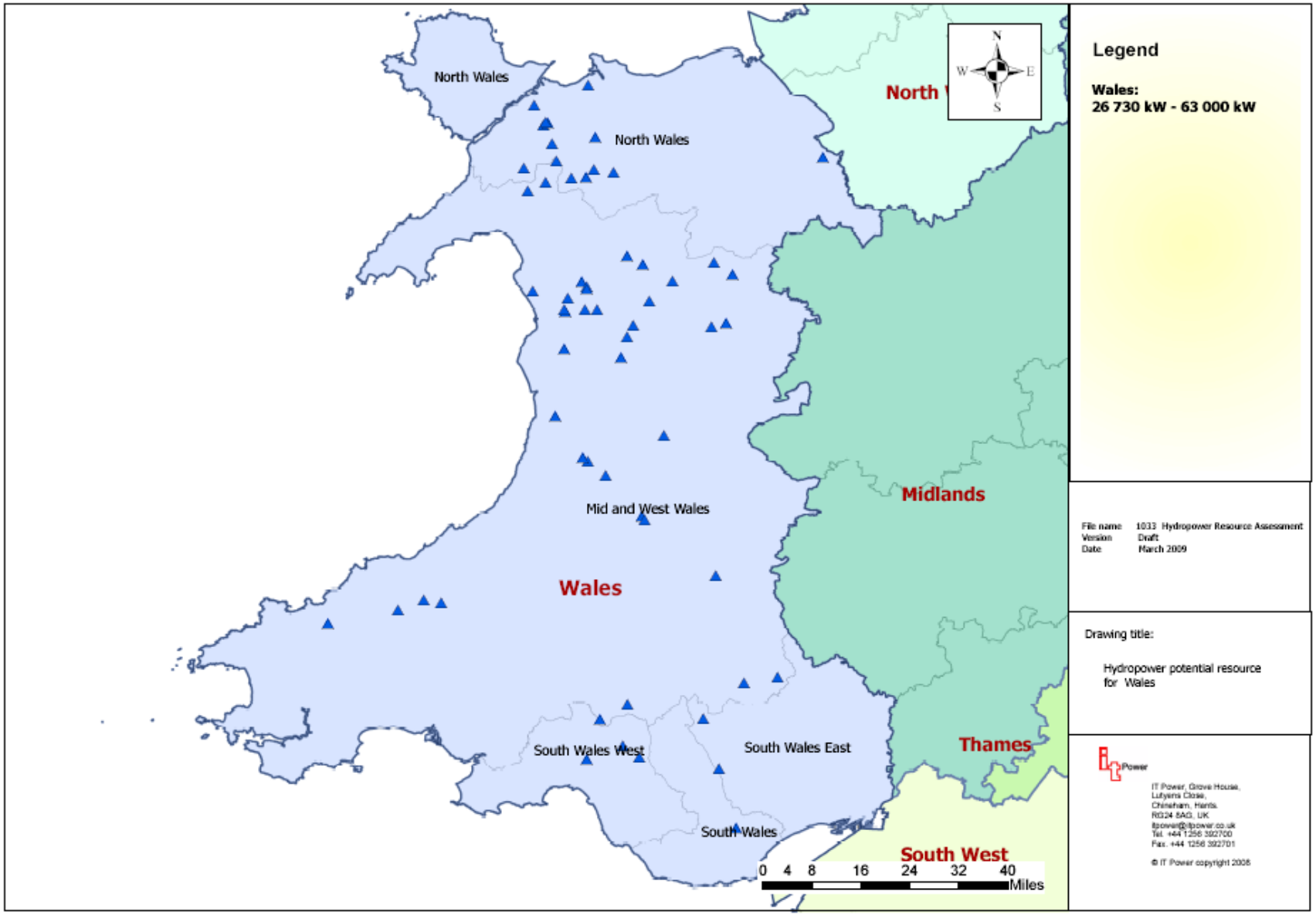
North Wales
North Wales
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South Wales East
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Miles
Legend
Wales:
26 730 kW - 63 000 kW
File name: 1033 Hydropower Resource Assessment
Version: Draft
Date: March 2009
Drawing title:
Hydropower potential resource for Wales
IT Power, Grove House, Lutyens Close, Chineham, Hants. RG24 8AG, UK
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8.1.2 Discussion on GIS analysis

Due to the way the historical data used was originally collected, it is not easy to further split the potential sites into constituent counties.

This report has given an indication of the concentrations present in each region of England and in Wales. At this stage and with the data currently available it is not reasonable to be more specific. This has also been explained in the previous section. This is a key element which could be outlined in a secondary work stage. The outputs of such work would fill the gaps in the existing data that can be added to the GIS.

9 RESULTS, CONCLUSIONS AND POSSIBLE NEXT STEPS

9.1 Results and Conclusions

There is a renewed interest in hydropower in the UK in light of the new UK and EU targets for the generation of energy from renewable sources, and corresponding improvements to incentive schemes such as the RO and Feed in Tariff.

Attempts have been made in the past to quantify the UK hydro resource, mainly the 1989 ETSU study and some later regional studies; most of them relying in turn on the ETSU study itself. A vast number of schemes were eliminated from counting due to various reasons relevant at that time e.g. unavailability of technology. However, due to new incentives for renewable energy and improvements in technologies, many of the "rejected" sites are now likely to be viable and hence there is a need to re-quantify the hydropower resource; this re-assessment was the purpose of this study.

The main results are:

- The review of previous studies has identified a number of criteria for re-assessing the viability of the potential hydropower schemes identified previously.
- A methodology was developed for quantifying the hydropower resource; this has taken into account the advances in technology and the current energy and economic drivers.
- Hydro sites previously considered as having potential, and those rejected in earlier studies, have been reassessed against the methodology.
- A GIS database was built and populated with information on some of these sites; it can be further populated in future to improve its usefulness as a tool for mapping the hydropower resource.
- The results of the re-analysis of existing studies have been added to the GIS database and produced a new figure for the total hydro resource present in England and in Wales.
- An upper and lower bound estimate of revised potential sites shows the range of hydropower potential, from 'Pessimistic to Optimistic, is between 129,800 – 185,400 kW for England and between 26,800 - 63,000 kW for Wales.
- There is documented evidence to suggest that there are gaps in the historic data indicating that there are many sites that have not yet been identified. .

9.2 Possible Next Steps

Possible futures work could involve using hydrodynamic modelling, validated against historic data, to identify new potential sites. These new sites, through intelligent pooling, could then be physically visited in order to verify the model further.

The ultimate output would be a model and GIS database comprising of historic, verified sites and newly identified verified sites giving a revised total hydro potential for England and Wales. The basic stages for the potential next steps are:-

- Hydrodynamic model build
- Model development

- Model validation against existing historic data taken from the GIS database
- New site identification
- GIS interface
- Intelligent data pooling and selection of sample sites
- Physical site visit
- Model refinement and validation
- Update of the GIS database with a full data-set based upon historic information discussed in this report and new data indentified in the potential next step.
- Revised potential for exploitable hydropower in England and Wales.

10 ANNEX 1: ABBREVIATIONS AND TERMS

Term	Definition
ArcGIS	Computer Software Product
DIY	ETSU study sites which were assumed to be sites that are at an average power output of 12.5kW
DTI	Department of Trade and Industry (Now Department of Energy and Climate Change (DECC)
Energy payback	The total energy produced over the lifetime of a power plant divided by the energy needed to build, operate, fuel and decommission it
ETSU	Energy Technology Support Unit
EU	European Union
GIS	Geographical Information System
GWh/year	Gigawatt Hours per year
H2	ETSU study sites which were assumed to be at a head of between 1 and 2 m.
kW	Kilowatt
m	Metres
m/s^2	Acceleration - metres per second squared
MW	Megawatt
P25	ETSU study sites which were rejected for being at less than 25kw.
P50	ETSU study sites which were rejected for having Power less than 50kW.
Q_{50}	50th percentile Flow rate, used to characterise flows
Q_{mean}	Mean Flow of water, used to characterise flow
ROCs	Renewable Obligation Certificates
SEEDA	South East England Development Agency
Small Hydro	Hydropower installations from 1 to 20MW

11 ANNEX 2: DEFINITIONS

Kaplan Turbines:

Kaplan Turbines are 'reaction' turbines, with propellers similar in appearance to those on boats and ships (although they turn much more slowly), which run submerged and create pressure differences across their blades to extract energy from the available head. However, these have adjustable blades which can be used to configure the turbine to suit the varying flow available in the river without losing the efficiency significantly.

Archimedean Screw Turbines

Archimedean Screws have traditionally been used to convey materials including water working as a pump. In this configuration a prime mover is required to drive the screw to pump water or covey other materials. In recent years, a different application of the Archimedean Screw is becoming popular. The screw, when run in reverse by allowing water at a higher level to flow to a lower level through the screw, actually produces power which can be used to drive an electric generator to produce electricity.

There are now several installations of Archimedean Screw Turbines in the UK.

12 ANNEX 3: ETSU DATABASE – SELECTED SITES

[Comms to add link]

13 ANNEX 4: ETSU DATABASE – REJECTED SITES

[Comms to add link]