Space heating demand of Cornwall – maps and methodology

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CORNWALL COUNCIL

Executive Summary

Space heating is the energy required by buildings in order to maintain a suitable internal temperature. This report produces maps of space heating for the entirety of Cornwall and explains the accompanying methodology used for their production.

This report aims to provide as full a picture as possible given the time and experience constraints associated with it. Although not every building in the county has been modelled, enough have been to provide an accurate representation of the county.

The maps represent both domestic and non-domestic heat energy demand in a method allowing each to be identified on the same map. Heat use is aggregated into areas, output areas in the case of domestic and postcode areas for non-domestic. Some non domestic buildings are shown individually depending on how the data was sourced, for example school data could only be obtained for individual schools.

The results modelled include total energy per year (MWh/a), average annual energy density (MWh/km^2/a) and average annual power density (MW/km^2/a). Individually calculated building are represented only with energy (MWh/a). These variables have been calculated for every area, however the maps in this report only show domestic areas with power density over 3MWh/km^2/a as this was found to be the threshold of economic viability by consultancy Aecom (formerly 'Faber Maunsell'). Non-domestic results have power density over 3MWh/km^2/a where applicable and all have total energy use of over 200MWh/a. This results in all areas represented on the maps produced from this report being both economical and demanding significant levels of space heating energy.

All heat energy represented is the amount of energy required to heat a building only and does not include the energy lost through heating system inefficiencies. This fits the purpose of the report as if a district heating system is installed the amount of energy lost in heating systems of buildings becomes irrelevant once a district heating system is installed.

Where possible energy use has been compared to government and council datasets, all domestic data was compared to the Department of Energy and Climate Change measured gas use data and produced very high statistical correlation. Schools and council buildings that use gas for heating were also compared to measured energy data and showed greater energy disparity compared to domestic but still demonstrated correlation. This shows the space heating results of this report demonstrate strong similarity to the space heating actually used in the county.

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1 Introduction

Space heating is the energy used within buildings to raise the internal temperature to a level which is comfortable for its occupants. The annual space heating requirement varies throughout the year with larger energy requirements in winter than in summer due to seasonal changes in outside temperature. This report calculates the average annual space heating requirements of buildings.

Cornwall Council has commissioned a space heating energy demand map of the whole county in order to gain a greater understanding of energy use in the county and locate areas suitable for district heating systems. The methodology for producing the map is explained in the appendices of the report to allow its reproduction and updating. The report is to be included as part of the evidence base for Cornwall Council's core strategy and will be used in planning processes in the future.

2 Prior Heat Mapping Work

The amount of relevant work produced and available to the public or within Cornwall Council is limited with only four heat map examples discovered, one of them commissioned by Cornwall Council. These are analysed and briefly explained below.

2.1.1 Scottish heat map

This was commissioned by the Scottish Government to inform the development of policy to support the growth of renewable heat in Scotland. This used CO_2 emissions data from the National Atmospheric Emissions Inventory as a proxy to derive heat use on a square kilometre grid. This was combined with locations of large heat users, large heat producers and areas of significant potential biomass production to allow for links between supply and demand to be identified. This included process heat as well as space heating and aggregated the two to produce a single heat use per square kilometre.

2.1.2 West Midlands

Halcrow Group Limited has produced a heat mapping and feasibility study commissioned by Advantage West Midlands. This uses lower super output area areas as a base and uses census 2001 housing type data along with 2007 council tax band data to identify the number of houses. The average energy use per house type is then applied to the houses in each area and summed to produce a total energy demand for each lower super output area. Non-domestic is calculated using site specific standard industrial code (SIC) codes and energy based on the number of employees per site or the type of industry.

2.1.3 Camborne, Pool, Illogan and Redruth regeneration area

Aecom have produced a report for the Camborne, Pool, Illogan and Redruth (CPIR) regeneration area identifying areas of high heat demand density and non-domestic point loads in the area. This will form the basis for a strategic district heating network in the area by identifying the areas of greatest heat use. The domestic results are based on output areas and all non-domestic loads are shown as individual demands. This method produces maps to a localized scale where individual housing estates, office blocks and factories can be identified.

2.1.4 Pembrokeshire

Aecom are producing a heat map of Pembrokeshire in a similar style to the CPIR report. This is still in production so is mostly confidential.

3 Domestic Map Production

3.1 Overview

The map uses the most up to date data to calculate current heat use. Where available, growth areas will be mentioned but no calculations undertaken. The energy calculated is the final energy required to heat a building which does not include fuel type and heating efficiencies except during certain comparisons with external datasets which only represent total gas consumption.

Demonstrating energy this way does not account for fuel poverty[1] which is prevalent in every output area to differing degrees, therefore energy use is likely to be overestimated as households save reduce the temperature of their house to save money. This is however advantageous when looking at district heat networks as the heat supplied by district heat networks is typically cheaper than the system it replaces, or there is little incentive to install it, and as a result heat use generally increases towards ideal levels once a system in installed. This method therefore shows an ultimately more realistic demand once a distributed heat system is installed.

A single methodology is used for all domestic houses which is based upon Office for National Statistics (ONS) datasets and Standard Assessment Procedure (SAP) 2005 worksheets[2]. This results in data being shown in output areas which on average encompass one hundred and twenty five houses each. This allows individual household data to remain anonymous whilst maintaining the trends of each output area. Towns, where heat demand is highest, have the advantage of smaller output areas due to denser housing and therefore more spatially accurate information can be obtained. However output areas on the extremities of towns may include areas of fields which reduce the average heat energy density of the output area when the section with houses may use significantly more heat than indicated.

3.1.1 Alternative heat use models

Three domestic scenarios have been modelled which are based different levels of housing efficiency. They are all based on the current numbers and locations of houses.

Scenario 1: Energy modelled with current housing energy efficiency.

Scenario 2: Energy modelled with cost effective[3] energy efficiency measures installed – where every house is modelled with double glazing, adequate loft insulation and cavity wall insulation for houses with cavity walls.

Scenario 3: Energy modelled with all potential energy efficiency measures installed – this is identical to 'scenario 2' but with the addition of external solid wall insulation for houses with no cavity walls.

[1] Fuel poverty is defined as any household with domestic energy costs of greater than 10% of its annual income on domestic energy, this includes heating the house to an adequate level of warmth.

[2] The Standard Assessment procedure 2005 is the Governments standards assessment procedure for energy rating of dwellings. It is adopted by the Government as part of the UK national methodology for calculation of the energy performance of buildings and to provide energy ratings for dwellings

[3] These are efficiency measures that will pay back the capital cost of installing them.

Scenario 2 and 3 are modelling potential future space heating demand as double glazing, loft insulation and wall insulation are seeing trends of higher uptake. They have the drawback of not modelling future housing numbers or locations; however they do show potential heating demand trends of current houses which will comprise the majority of housing stock for many years in the future. These are useful as it is prudent to attach buildings to a heat main which have the most efficiency measures all ready installed, and this is what is demonstrated with the extra scenarios.

3.2 Methodology

The methodology is explained fully in appendix A

3.2.1 Housing type energy requirements

Sixteen housing categories are modelled to represent the housing stock in Cornwall. Each category models a different housing type and levels of insulation which are found in the UK and as specific to Cornwall as possible wherever possible. Sixteen categories is adequate to produce representative results and any greater number of categories would increase the complexity and quantity of calculations required. The below graph shows the results of modelling each of the categories in the Standard Assessment Procedure 2005 produced which is produced by BRE[4].

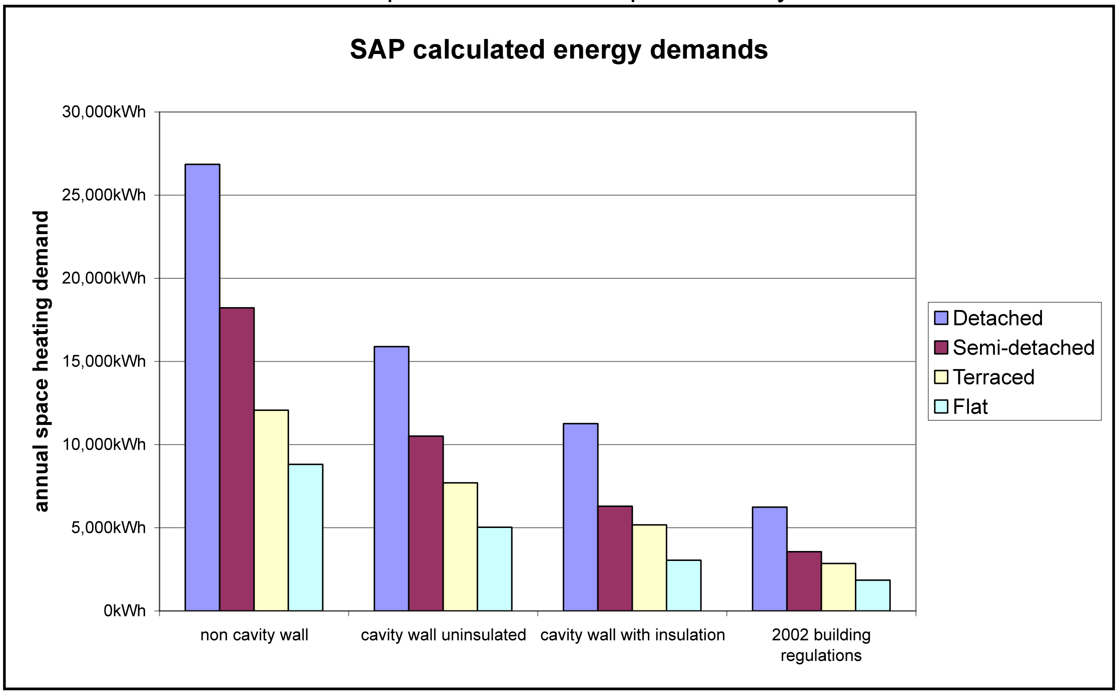


Figure 1: Space heating energy demand of each of the sixteen housing categories.

3.3 Comparison to Department of Energy and Climate Change data

The department of Energy and Climate Change produces energy use statistics for middle super output areas and, for Cornwall, lower super output area. This uses actual recorded meter data that is summed into statistical areas and separated into

[4] BRE – Previously the Buildings Research Establishment.

domestic and non-domestic. The method by which domestic and non-domestic are identified from the data is not known, however it is assumed that it is based on the amount of consumption per meter. The domestic side of this data was compared directly to the results calculated in this report.

The results of this are summarized below, lower and middle super output area graphical results in appendix A.

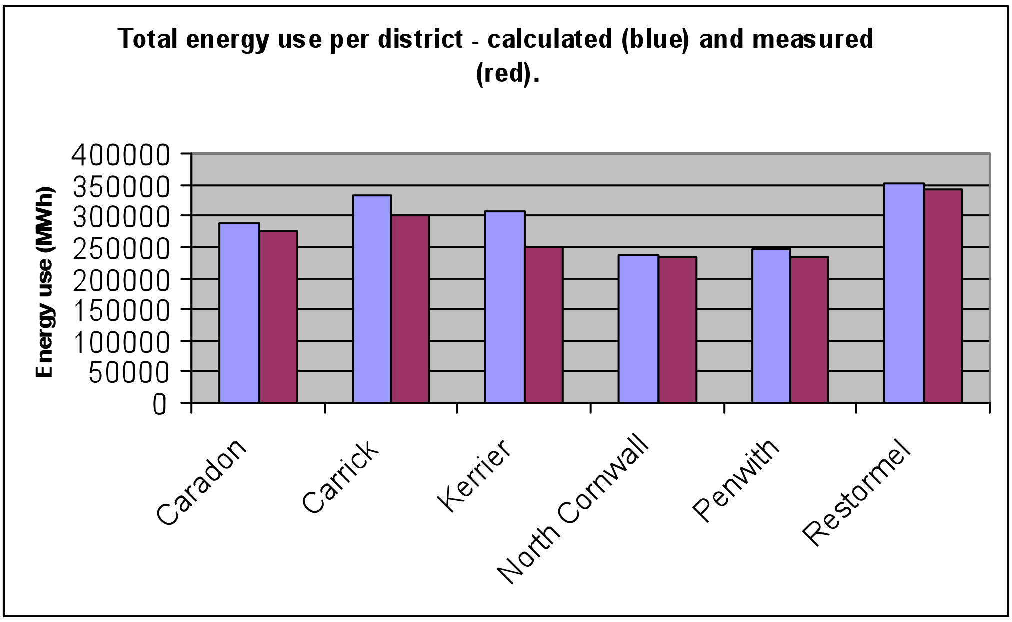


Figure 2: Comparison of calculated and measured gas use per previous district.

3.3.1 Correlation and potential for anomalies in the data

The two data sets show strong visual correlation (including middle and lower output area graphs) and very strong statistical correlation. The linear regression analyses, which produce a number from zero to one with one being perfect statistical correlation and zero being no correlation, produced 0.9118 for the middle super output areas and 0.9483 for the lower super output areas.

In some areas the energy discrepancy is very high and this is most pronounced in Kerrier, the calculated natural gas use is also higher than the measured energy use in every district. A potential reason for this is fuel poverty which acts to reduce domestic energy use as people in fuel poverty lack the ability to afford adequate energy or energy efficiency measures.

The datasets showing fuel poverty represents the entirety of Cornwall and the natural gas data only includes areas with gas connections and comparing the whole of Cornwall to only some areas of Cornwall will not provide a reliable comparison. Also in areas of very few gas connections the data will become less accurate as individual natural gas users have greater influence over the total gas use trends for the area. To make the comparisons fairer two comparisons have been produced one compares areas with 50% or more domestic gas connections and another compares areas with 80% or more domestic gas connections. This will compare like-for-like lower super output areas and provide greater accuracy. The two graphs produced from the comparisons showing fuel poverty and the energy disparities are below, positive energy disparity figures indicate an over estimate of calculated energy use and negative indicate an underestimate of calculated energy use:

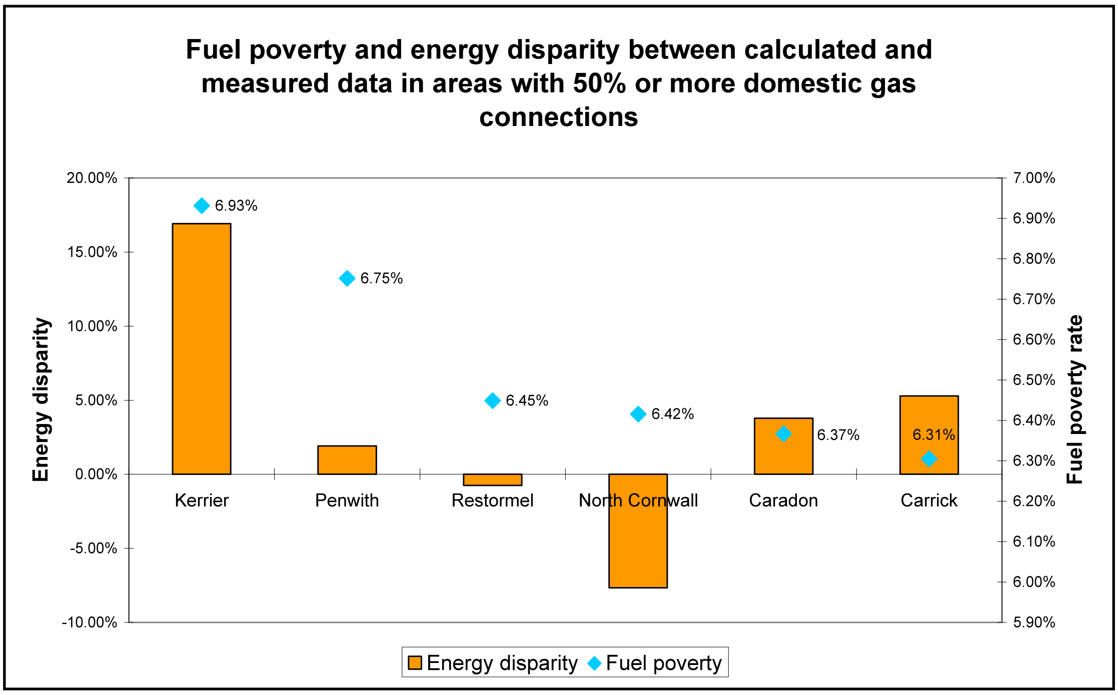
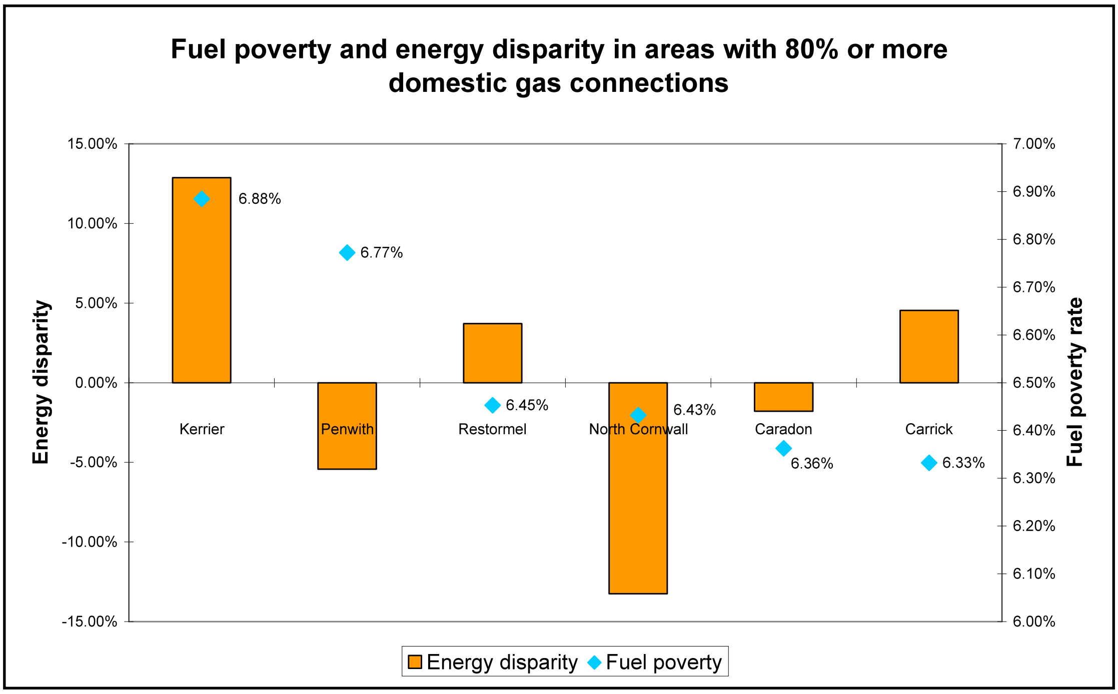


Figure 3: Fuel poor households based on the full income definition[5] of fuel poverty compared to the energy disparity between the calculated and measured energy data in areas of at least 50% domestic gas connections.



[5] Full income includes housing subsidies (Housing Benefit and mortgage interest payments) as household income; basic income excludes this from the definition of household income.

Figure 4: Fuel poor households based on the full income definition of fuel poverty compared to the energy disparity between the calculated and measured energy data in areas of at least 80% domestic gas connections.

There does appear to be a link between the rate of fuel poverty and energy disparity per district showing that lower fuel poverty generally leads to greater natural gas consumption. This trend is shown in Kerrier, Penwith, Restormel and North Cornwall, however this trend is not continued in Caradon and Carrick and in Restormel only for the 50% gas connections model.

The fuel poverty index dataset from which the fuel poverty levels were calculated does not quantify the severity of fuel poverty which could be an indicator of energy use. Households in greater severity of fuel poverty will potentially spend less on heating; it may also be true that they cannot afford more efficient houses or to implement efficiency measures so their houses may also require more energy than average to heat. Households barely in fuel poverty will not have this problem to such an extent. A potential situation could be Caradon and Carrick containing fewer but more severe cases of fuel poverty.

From this it is not possible to state that fuel poverty is the leading cause of the disparities but it is likely to be a significant cause. This also does not rule out the data from the Department of Energy and Climate Change containing errors or assumptions which affect their results.

A potential source of error could arise from the assumptions made which effectively model sixteen house types which are replicated throughout the entire county which in reality is not true as every house is unique. However this simple model has produced representative results because most output areas have a mix of houses so any assumptions will be averaged out but in certain output areas this effect may be multiplied such as in the centre of Penzance where the heating load is modelled as $18.6 MWkm^{-2}$ per year which is significantly higher than anywhere else. The reason for this is the area is filled entirely with solid walled terraced houses that have a floor area below that used in the models so most and potentially all of the houses are overestimated in the model. This is not to say the heat load is not extremely high in Penzance, rather it is unlikely to be as high as shown in the models. Penzance appears to be the most extreme example but others areas where house dimensions digress from the average over an entire output area may show similar anomalous results.

4 Non-Domestic Map Production

4.1 Overview

The majority of the data for non-domestic was sourced from the Valuation Office Agency and Cornwall Council with the remainder sourced from several independent sources such as Truro College and the National Health Service. The disparity of non-domestic data sources compared to domestic means the heating demand for some buildings and building types could not be produced but enough buildings were modelled to show an adequate representation.

All non-domestic buildings are represented as point energy demands on the map, regardless of whether they are representing a postcode area or an individual building, because representing energy density would require coloured areas that might overlap with the domestic coloured output areas. Heat density is calculated for non-domestic but not shown on the maps with this report, it is calculated in the form of ArcGIS shapefiles.

Non-domestic buildings are only included when the energy use is over 200MWh/a. This figure was chosen despite being reasonably minor because there are likely to be locations where several of these instances are in very close proximity and could effectively form a single higher load. Postcode areas are also only shown when energy use is over 200MWh/a per year but the heat density must be over $3MW/km^{-2}/a$ which is the threshold of economic viability.

The energy per building was calculated using the floor area of each building which was multiplied by the relevant energy benchmark from the Chartered Institution of Building Services Engineers Technical Memorandum 46 (CIBSE TM46) energy benchmark publication. Each benchmark represents heating demand per square metre of floor area. The benchmarks are based on degree days which are a measure based on the average daily outside temperature relative to 15.5°C and used to calculate the heating or cooling requirements of a building based on the external temperature[6]. The report is based on degree day results taken from Kent which is in the South East region of their calculations and this area receives twenty percent more degree days, i.e. is colder, than the Devon and Cornwall region. This was compensated for in the calculations for this report.

The amount of energy shown per building is the optimum amount used but this may differ between buildings. Non-domestic buildings are not influenced by fuel poverty however the efficiency of individual buildings can vary more than houses as building regulations are different for non-domestic. This may be mitigated with the completion of the Non-residential Energy Efficiency Database (NEED) report which sets out to define individual businesses energy efficiency; this could then be combined with the current data to make a very accurate picture of non-domestic energy use.

4.1.1 Sources and datasets used

VOA summary valuation data for the six previous districts of Cornwall.

[6] An average outside temperature of 14.5°C for one day results in a single heating degree day, 13.5°C over a single day results in two heating degree days. Degree days above 15.5°C are cooling degree days as cooling is required to maintain adequate internal temperature. Degree days can be summed into other time periods, for example this report sums them into a year.

Cornwall Council education team – GIS shapefiles of schools
CC estates team – floor area of CC buildings
Cornwall Council energy management team – supplied energy use
ERIC – NHS hospitals
CIBSE TM46
Cornwall Council intranet mapping – fire station and leisure centre locations
Cornwall College
Truro and Penwith College

4.2 Modelled buildings

Individual buildings are modelled if they have space heating demand of over 200MWh per year and space heating within postcode areas is included if its energy demand is over 200MWh per year and energy density over $3MW/km^2/a$.

4.2.1 Non-Domestic rates

Non-domestic rates are maintained by the Valuation Office Agency and the summary valuation data is the only comprehensive list of non-domestic floor space available. The data contains shops, offices, warehouses and factories and there are seventeen thousand and nine entries for Cornwall.

4.2.2 Other point loads above 200MWh per year

- State schools
- Further Education facilities
- NHS hospitals
- Leisure centres
- Large council owned buildings
- Council buildings over $1000m^2$

4.3 Not modelled buildings

These are buildings or building types that were not modelled because the data is either not available or the logistics of acquiring and processing it could not be accommodated in the time available.

4.3.1 Non-domestic Rates exclusions

Building types such as health, education, leisure, accommodation, institutional facilities and military bases are not covered by the Valuation Office Agency data and are not shown in the map except for state operated health, state education and state operated leisure facilities. The data does not include floor area for all buildings, pubs and hotels for example, so these could not be included on the map either. This may not be a comprehensive list but covers most of the buildings not included in the maps.

4.4 Methodology

The full methodology can be found in Appendix B.

4.5 *Comparison to other data*

Data to compare non-domestic energy use is only available for certain buildings such as schools and other council related buildings because their energy use is recorded by the council. The Department of Energy and Climate Change gas use data cannot be used for comparing non-domestic gas use against because a complete set of non-domestic buildings cannot be obtained for Cornwall, it is not known how many buildings use natural gas and the data does not separate space heating from industrial process gas use. Some Council related buildings can be compared because the council records their gas consumption.

4.5.1 Schools

The heating energy demand of schools is calculated from internal floor area then compared to the measured gas use data from Cornwall Council's energy management team. The schools compared are those with calculated heat use of over 200MWh/a with gas connections because these are the only schools that can be compared.

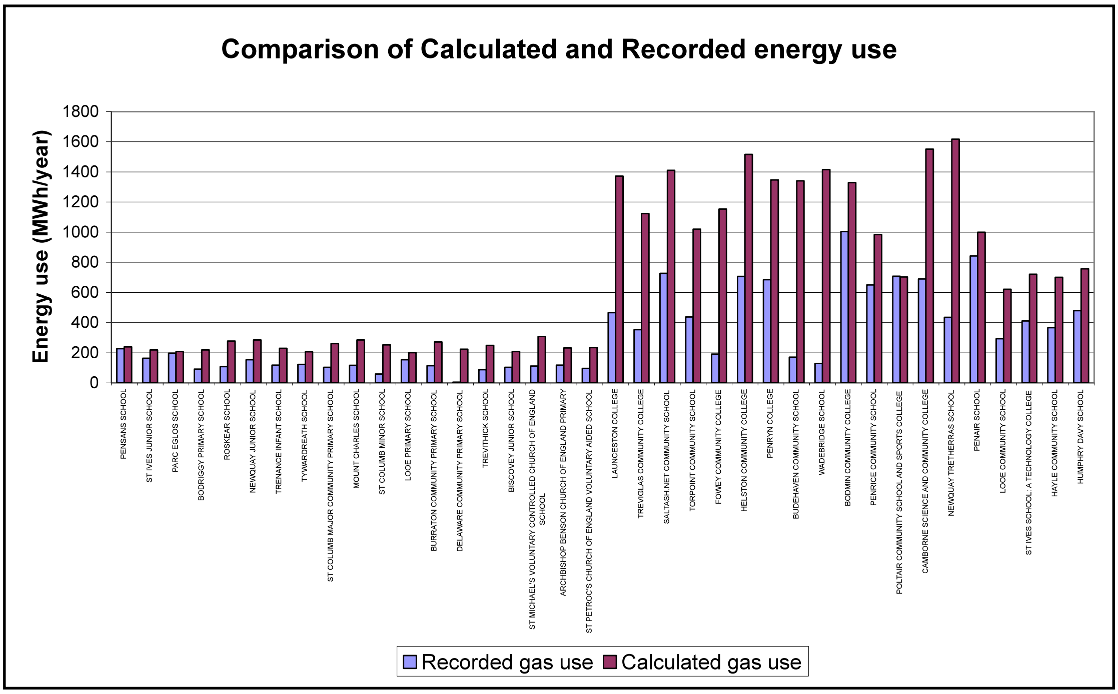


Figure 5: Comparison of calculated and measured school heating demand.

The graph shows the calculated results to be roughly fifty percent higher than the actual gas use would suggest. The reason for this is unknown, however it is most likely that the energy benchmark overstates school heating demand or Cornish schools are particularly efficient, don't heat adequately or incorporate alternative forms of heating such as electricity as well as gas use. This will result in anomalously high readings on the maps, however as it is known that school energy use is anomalous and roughly the extent of the anomaly this can be compensated for.

4.5.2 Other buildings

There is a limited stock of remaining Council buildings to compare because only energy use from the previous County Council and not the district Council's is held with the energy management team.

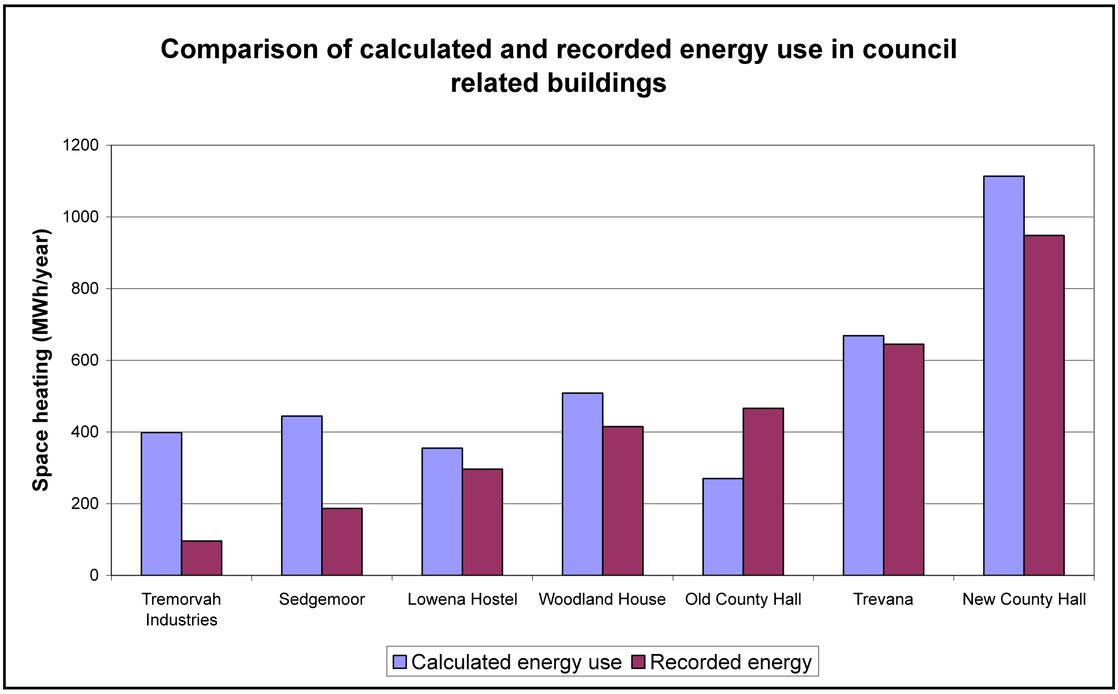


Figure 6: Comparison of ex-County Council buildings calculated and recorded energy use.

These results show a much closer correlation than that shown with schools; however Tremorvah Industries, Sedgemoor and Old County Hall all differ significantly. Potentially Tremorvah Industries could have a large amount of unheated storage space and Old County Hall is an old building and therefore likely to be more inefficient than the other buildings.

5 Conclusion and Recommendations

This is the first map of its type in the UK to be produced to such a large scale and this puts Cornwall Council at great advantage and a leader in the UK when planning for district heating schemes. This report defines where district heating is most suitable and viable, for example St Austell is the largest town in Cornwall based on population but overall has low heat density and therefore is mostly uneconomic for the installation of district heating whereas towns such as Falmouth and St Ives which have lower populations and are geographically smaller are more suited for district heating.

The maps produced for this report represent energy and power density for locations and buildings across Cornwall which during the consideration for a district heating system is only one of the factor to consider, albeit a very important factor. Other factors for consideration have not been researched in this report as most are site specific or depend on time based projections but this report can act as a base for district heating planning. The maps produced indicate the geographical areas where heat is demanded which will act as a base for more specific investigations to be produced. This is now achievable using this single piece of work rather than undertaking specific research for every location assumed to be suitable and this will save time and money for the Council. Projects which may have found inadequate amounts of heat demand previously can be avoided as the maps from this report will indicate where potential areas are and where there is little or no potential. The maps can be used in the planning process which will enable new developments to be planned to fit in with an existent or planned heating network and therefore reduce carbon emissions of new developments, especially with renewably generated heat, and potentially reduce energy bills to those on the heat network.

The methodology used for domestic heat shows very strong statistical correlation between measured natural gas data from the Department for Energy and Climate Change and the gas use calculated from this report. The linear regression analysis technique was used where one indicates perfect correlation and zero indicates no correlation, the two results obtained were 0.9118 and 0.9483 which is very high correlation. Some areas digress more than others; Kerrier for example demonstrates most digression but also has the highest rate of fuel poverty in the Cornwall and AECOM also found this trend from their heat mapping work in the area. If fuel poverty is the reason for the energy discrepancy then district heating will be beneficial in reducing fuel poverty in the area.

With such a high correlation between actual gas use and calculated gas use the methodology employed in this report can be considered accurate for purpose and applied to other areas of the UK for other heat demand reports.

5.1 Significant areas of heat demand

The amount of economically viable heat demanded for each urban area has been calculated from ArcGIS and imported into Excel, the results of this are shown below. One significant difference is the large difference between the amount of heat demanded by domestic and that by non-domestic and as such they are represented separately or domestic would not be indiscernible from the non-domestic data. The table below represents the total economically viable heat energy demand (not power density) that exists in each urban area in Cornwall ranked in terms of domestic energy demand. These tables and graphs do not rank towns in order of district heating potential, rather energy is one of many aspects to consider when planning a district heating scheme.

Town Names	Domestic (MWh/a)	Postcode Areas (MWh/a)	Individual Buildings (MWh/a)	Total non-Domestic (MWh/a)	Total energy (MWh/a)
Falmouth – Penryn	59.4	11842.5	5924.4	17766.9	17826.2
Penzance-Newlyn-Heamoor	43.3	4329.5	6480.7	10810.2	10853.5
Camborne - Pool – Redruth	36.3	25755.7	14114.5	39870.2	39906.4
Truro – Threemilestone	22.8	7007.0	38658.8	45665.7	45688.6
St Austell – St Blazey	18.8	6043.9	9811.0	15854.9	15873.6
Falmouth	47.86	8516.83	4351.8448	12868.7	12916.5
Penzance	27.52	2507.23	4983.372	7490.6	7518.1
Camborne	23.35	2086.71	2788.448	4875.2	4898.5
St Ives	21.4	292.6	1995.2	2287.8	2309.2
Truro	20.82	6472.22	1586.268	8058.5	8079.3
Saltash	16.6	1709.5	3237.1	4946.6	4963.2
St Austell	15.46	5132.8	8784.3896	13917.2	13932.6
Newquay	13.0	4002.9	33898.6	37901.5	37914.5
Redruth	12.9	13352.47	2335.8	15688.3	15701.2
Newlyn	11.83	1822.25	0	1822.3	1834.1
Torpoint	11.8	0.0	1297.1	1297.1	1308.9
Penryn	11.49	3325.7	1572.516	4898.2	4909.7
Porthleven	7.94	0	203.916	203.9	211.9
Looe	7.12	0	821.652	821.7	828.8
Hayle	6.7	2181.08	4012.728	6193.8	6200.5
Bude and Stratton	4.63	2067.96	2438.052	4506.0	4510.6
Wadebridge	4.6	1060.4	2166.744	3227.1	3231.7
Fowey	4.25	0	1394.664	1394.7	1398.9
Perranporth	4.17	462.4	0	462.4	466.6
Bodmin	4.2	14633.7	3909.8	18543.4	18547.6
Helston	4.02	4228.89	3223.74	7452.6	7456.7
Padstow	3.95	0	0	0.0	4.0
Mevagissey	3.89	0	0	0.0	3.9
Liskeard	3.87	1034.46	3851.76	4886.2	4890.1
Launceston	3.8	9837.33	2338.5	12175.8	12179.6
Lostwithiel	3.57	0	0	0.0	3.6
Carharrack - St Day	2.91	0	0	0.0	2.9
St Columb Major	1.72	5406.51	260.532	5667.0	5668.8
St Just in Penwith	1.68	267.48	768.636	1036.1	1037.8
Callington	0.93	591.87	1436.724	2028.6	2029.5

Table 1: Space heat demand in urban centres.

The potential for towns in terms of domestic and non-domestic are ranked from highest to lowest, also included under the domestic heading are the designations for each town:

Domestic			Non-domestic	
Town/area Name	Town designation	Heat demand (MWh/a)	Town/area name	Heat demand (MWh/a)
Falmouth – Penryn	SSCT	59.35	Truro – Threemilestone	45,666
Penzance – Newlyn – Heamoor	B	43.26	Camborne – Pool – Redruth	39,870
Camborne – Pool – Redruth	SSCT	36.25	Falmouth – Penryn	17,767
Truro – Threemilestone	SSCT	22.83	St Austell – St Blazey	15,855
St Austell – St Blazey	B	18.76	Penzance – Newlyn – Heamoor	10,810
Falmouth	SSCT	47.86	Newquay	37,902
Penzance	B	27.52	Bodmin	18,543
Camborne	SSCT	23.35	Redruth	15,688
St Ives	B	21.35	St Austell	13,917
Truro	SSCT	20.82	Falmouth	12,869
Saltash	SSCT	16.58	Launceston	12,176
St Austell	B	15.46	Truro	8,058
Newquay	B	12.97	Penzance	7,491
Redruth	A	12.9	Helston	7,453
Newlyn	B	11.83	Hayle	6,194
Torpoint	A	11.79	St Columb Major	5,667
Penryn	A	11.49	Saltash	4,947
Porthleven	-	7.94	Penryn	4,898
Looe	B/C	7.12	Liskeard	4,886
Hayle	B	6.7	Camborne	4,875
Bude and Stratton	B	4.63	Bude and Stratton	4,506
Wadebridge	B	4.6	Wadebridge	3,227
Fowey	C	4.25	St Ives	2,288
Perranporth	-	4.17	Callington	2,029
Bodmin	B	4.16	Newlyn	1,822
Helston	B	4.02	Fowey	1,395
Padstow	C	3.95	Torpoint	1,297
Mevagissey	-	3.89	St Just in Penwith	1,036
Liskeard	B	3.87	Looe	822
Launceston	B	3.8	Perranporth	462
Lostwithiel	C	3.57	Porthleven	204
Carharrack – St Day	-	2.91	Padstow	0
St Columb Major	-	1.72	Mevagissey	0
St Just	C	1.68	Lostwithiel	0
Callington	B/C	0.93	Carharrack - St Day	0

Table 2: Town ranking of heat demand by domestic and non-domestic energy demand.

Strategically important cities and towns (SSCT) include the cluster of Redruth - Camborne, Truro and Falmouth - Penryn with a second cluster incorporating Saltash and Plymouth. 'B' designated towns are market and coastal towns and villages and 'C' designated locations are towns and villages with some potential for growth. 'B/C' towns are yet to be properly defined. The graphs of the above table are below:

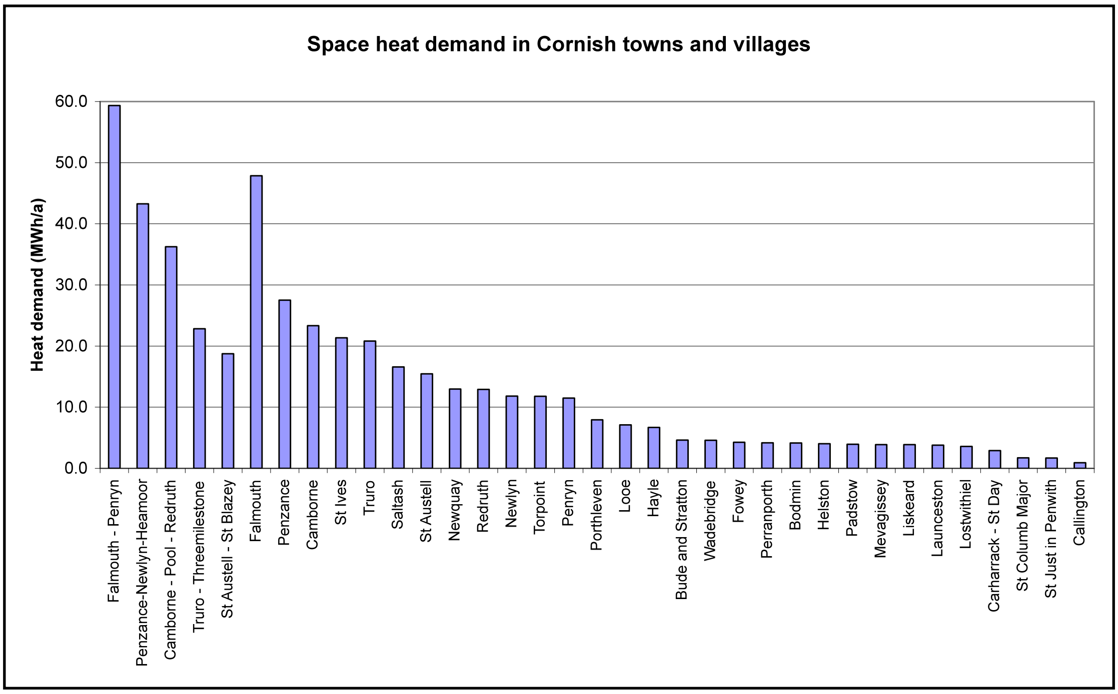


Figure 7: Domestic and non-domestic heat demand in urban centres.

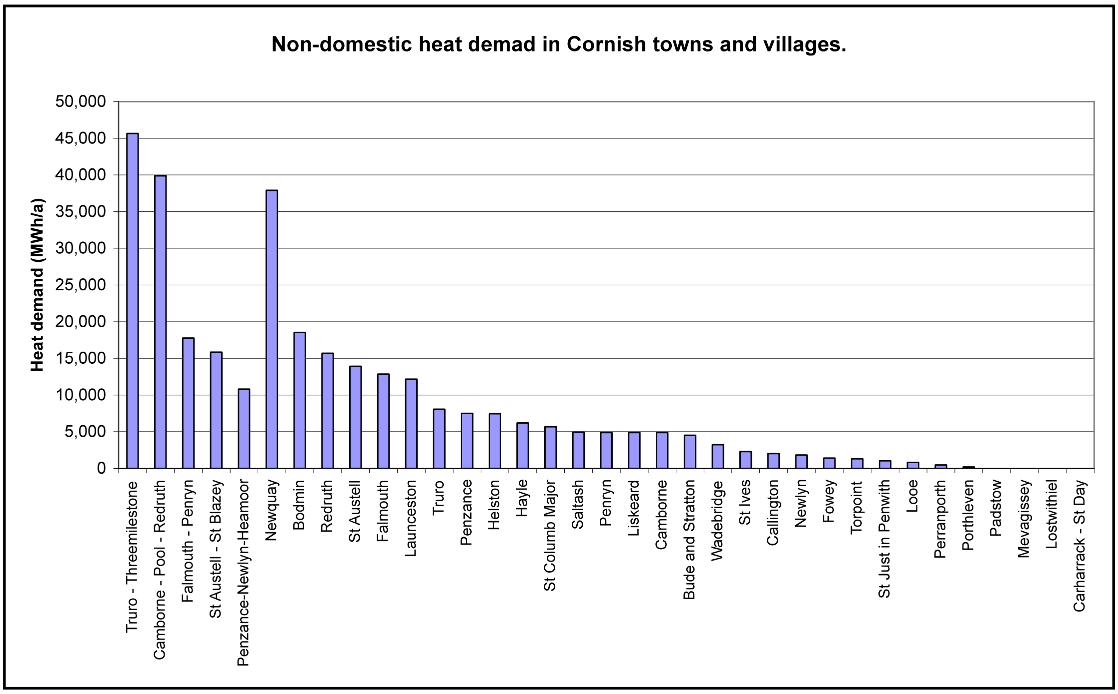


Figure 8: Non-domestic heat demand in urban centres.

The above graph shows only non-domestic heat use but also effectively represents total heat use as domestic energy use is miniscule in comparison.

5.2 *Further Work*

5.2.1 Locate sources of heat or heating fuel.

There are industrial processes within Cornwall where high quality excess heat is generated and currently expelled to the atmosphere. These businesses can be heat sources for distributed heat networks, provide revenue from previously wasted heat and the recipients of the heat will potentially get reduced price heating.

There will also be sources of fuel within Cornwall, for example forestry and energy crops. These have the advantage of being local, renewable and potentially sustainable. This may again provide revenue stream not previously utilized and will promote sustainable forestry and agricultural practises if undertaken correctly.

5.2.2 Undertake financial and CO_2 analysis

This will help answer the question of which houses to connect to district heating networks depending on the connection criteria. For example older housing stock may be more suitable for carbon savings but newer stock may be more financially viable due to the required compliance with new housing carbon regulations.

5.2.3 Improve mapping technique

Cornwall Council holds a database called the Cornwall Land and Property Gazetteer (CLPG) which contains the location and brief description of every building within the county. This will allow every non-domestic building to be shown individually with its energy demand on the map and this will allow clusters of buildings to be shown allowing a visual check to see where higher energy quantities may be demanded. Further analysis can quantify the energy demand. Residential can benefit through the locating of every house on the map as some areas with economical heat use are not represented on the map due to large amounts of open land being included in the output area in which they are located, this is especially a problem on town fringes and small villages. Plotting every house will show where clusters of houses are located, this will allow the location of potentially economic areas in overall uneconomic output areas and within economic output areas the specific areas of greatest energy demand can be identified. This method can be applied to locate specific housing types such as vulnerable or social housing as these buildings may require special consideration for district heating.

The Cornwall Land and Property Gazetteer during the production of this report was in the process of transformation from six individual mapping databases from the previous districts into a single database for Cornwall council and therefore could not be used.

5.2.4 Associate maps with planned growth areas

There are areas within the county where new houses and businesses will be developed and upon completion will require space heating, these areas are not shown on the maps in this report as they are yet to be finalized. It may be possible to calculate the heat demand of these areas based on projected building regulations and planned buildings to produce space heating maps in identical or compatible style to that already produced for this report. This will aid with future housing planning as district heating will alter the economics especially once zero carbon housing comes into force in 2016. A list of designated growth areas is below. Strategically important cities and towns include the cluster of Redruth and Camborne, Truro and Falmouth and Penryn with a second cluster incorporating Saltash and Plymouth. ‘B’ designated towns are market and coastal towns and villages and 'C' designated locations are towns and villages with some potential for growth. 'B/C' towns are yet to be properly defined, the planned eco towns are also included:

Designation	Settlement
Strategically significant towns or cities	Camborne/Pool/Illogan/Redruth Falmouth/Penryn Saltash/Torpoint Truro (inc Threemilestone)
Potential B Settlement	St Austell (inc. St Blazey/Par) Penzance (inc Newlyn) Newquay Bodmin Launceston Liskeard Bude/Stratton/Poughill St Ives/Carbis Bay Helston Wadebridge Hayle
Potential B/C Settlement	Callington Camelford Looe
Potential C Settlement	Lostwithiel Fowey Padstow St Columb Major St Just
Eco town	Bugle clustered with Stenalees Foxhole clustered with Nanpean Trewoon Penwithick

Table 3: List of growth towns and designation within Cornwall

5.2.5 Potential methodology for growth area energy use

The methodology for potential growth areas can be undertaken in a similar method to that for current buildings. The main difference is the greater uncertainty over the number and location of new buildings. Another uncertainty is the applicable building regulations to each development, this is set at the time when planning permission is granted. If the applicable building regulations are known then this can easily be accounted for in the standard assessment procedure. The remainder of the analysis should proceed without much digression from the methodology used in this report. There will not be a means of comparing the output of this methodology until the housing site is completed and been in use for a year to allow for the collation of the Department of Energy and Climate Change gas use data. For this reason if a heat methodology for future development is to be used it will be on its own merits and the methodology must be very clearly examined. Two potential methodologies are outlined below:

Method one – assuming only square area of growth area is known:

1. Identify the square area of the proposed growth areas
2. Assume a likely housing density
3. Assume the likely housing mix
4. The space heating needs of the house can be calculated from the building regulations using the standard assessment procedure 2005. The relevant building regulations are those in force at the time planning permission for the development was granted.
5. Sum the energy requirements from all the houses into areas comparable to output areas and show the output as power density.

Method two – assuming absolute numbers of new houses are known:

1. Identify the number and type of houses or businesses being built. If possible also their planned location.
2. Calculate the space heating requirements of the buildings based on the building regulations in force at the time planning consent was granted or through energy benchmarks for non domestic buildings.
3. Sum the buildings energy requirements into areas that can be used alongside output areas and output represented as power density.
4. Non-domestic buildings can be shown as point loads enabling domestic and non-domestic to be shown on the same map.

6 Glossary

6.1.1 ArcGIS

A series of geographical information system (GIS) programmes in a single programme enabling the creation and manipulation of maps.

6.1.2 Degree day

A measure of the relative external temperature to the internal temperature of a building against a benchmark. Every every degree difference in temperature relative to a benchmark that occurs over a twenty-four hour period on average is a degree day. The UK uses a benchmark of 15.5°C, degree days experienced below this are heating degree days and those experienced above are cooling degree days.

6.1.3 District heating

A heating system where heat is generated in a central location and distributed through pipes to users in contrast to the predominant system in the UK where households generate and distribute the heat in their own homes.

6.1.4 Efficiency

The amount of useful energy output from a system as a proportion or percentage of the total energy input to the system. E.g. if a heating boiler burns 100kWh of gas and 20kWh is expelled through the flue and 80kWh is used to heat the building then the system is 80% efficient.

6.1.5 Energy

The ability of a system to do work i.e. heat a house to a comfortable level. Measured in Joules (J)

6.1.6 Fuel poverty

Fuel poverty is defined as any household with domestic energy costs of greater than 10% of its annual income on domestic energy, this includes heating the house to an adequate level of warmth.

6.1.7 Kilowatt (kW)

A unit of power equal to one thousand watts

6.1.8 Kilowatt hour (kWh)

A unit of energy equal to one kilowatt multiplied by the number of seconds in one hour.

6.1.9 Lower super output area

A lower super output area is a single area composed of several output areas but fewer than the middle super output area.

6.1.10 Megawatt (MW)

A unit of power equal to one million Watts.

6.1.11 Megawatt hour (MWh)

A unit of energy equal to one megawatt multiplied by the number of seconds in one hour.

6.1.12 Middle super output area

A middle super output area is a single area composed of several lower layer super output areas.

6.1.13 Output area

The smallest area for which detailed 2001 Census results are available. Output Areas (OAs) were created specifically for statistical purposes on the basis of data from the 2001 Census, using objective and systematic criteria in an automatic zoning process, and providing a consistent geographical building brick throughout England and Wales.

They have an average population size of 125 households and around 300 residents, each clustered around a single mode, always above the confidentiality thresholds of at least 100 residents and 40 households. They generally fit exactly within the boundaries of parishes/communities and wards as at the reference date of 31 December 2002, and comprise where possible of whole postcode units as at the time of the Census. The boundaries were created to enclose as compact an area as possible, although shapes may be attenuated by underlying patterns of settlement and postcodes. Where possible, OA boundaries were drawn to contain populations with homogenous characteristics, and around small, free-standing settlements.

6.1.14 Power

Is the rate of doing work and measured in Watts (W) which is the energy transfer per second (Energy/second)

6.1.15 Space heating

This is the heating of a space, in the case of this report the internal spaces of a building

Appendices

6.2 *Appendix A - Domestic methodology*

6.2.1 Sources of data

- Census 2001 data - Household spaces and accommodation type (KS16) at OA level
- AECOM – Provided some data used in the standard assessment procedure 2005 as the data was not readily available within the council. Also provided guidance on how to complete the procedure.
- The number of houses with a natural gas connection in each output area and the number of houses in fuel poverty per output area sourced from the fuel poverty index file ‘Cornish FPi data_OA.xls’.
- Middle super output area gas data from: http://www.decc.gov.uk/en/content/cms/statistics/regional/regional.aspx
- Lower super output area gas data. Obtained through direct communication with the Department of Energy and Climate Change (DECC) and contained on the ‘G’ in Cornwall Council.
- Cornwall Council’s energy management team – supplied council related building gas and electricity use - schools, offices etc

6.2.2 Number of existing dwellings

This explains the process of defining the total number of houses and proportion of housing types in every output area in Cornwall.

1. 2001 Census household spaces and accommodation type (KS16) data used to identify detached, semi-detached, terraced, flats, second home and caravan/mobile unit in every output area within Cornwall.
2. There are inaccuracies between the sum of each type of dwelling per output area and the total shown in the total housing count column of roughly +/-1% per output area. An assumption was made after discussions with Robin Miller or Corporate Intelligence that the numbers in the columns relating to specific housing types are correct and the numbers in the total housing count column are incorrect. The total column was replaced with the actual sum of the housing type columns.
3. Dwelling stock by council tax band 2007 was used to identify the number of dwellings per output area, 2007 is the most recent data available. The total dwelling stock per output area is compared to the 2001 total housing stock to ascertain the numbers of new builds or demolitions in each output area.
4. New builds are then added to the total housing per output area in a new column. The percentage of new builds that are flats or detached houses is calculated from communities and local government data on new house builds, this is from 2001. Numbers of flats are taken directly from the data and it is assumed that new houses under the heading of four or more bedrooms are detached houses. The results from this were used in every output area with no alterations between them i.e. ‘x’ percent flats was used for each output area. Semi-detached and terraced are apportioned relative to their abundance in the 2001 census data and where no semi-detached or terraced are built the detached and flat new build percentages are increased to equal

100% between them whilst retaining the same proportion between the two as is in the communities and local government data.

5. Second homes and caravans/mobile units are removed from the data at this stage as these do not constitute reliable heat loads. This is done by not including them in any further calculations and reducing the housing count per output area to compensate for this.

6.2.3 Output area – square area

1. Population density (UV02) data set provides the hectares per OA which is converted into km^2 per OA.

6.2.4 Energy efficiency and types of each house

This sets out how the energy use of different house design and insulation levels are modelled in such a way to be representative of reality but not unnecessarily complex. This uses sixteen different housing types, each of which is individually modelled.

1. Sixteen housing types have been identified using detached, semi-detached, terraced and flat categories. Each has four sub categories relating to efficiency: solid wall, un-insulated cavity, insulated cavity and 2002 building regulations and are numbered 1, 2, 3 and 4 respectively.
2. The percentage of solid and cavity walled houses per output area was sourced from the fuel poverty index Excel file.
3. English house condition survey data provides a ratio of insulated to un-insulated cavity walls per house type in the UK, this is a single proportion and is used in every output area. The following table is produced.

	Detached	Semi-detached	Terraced	Flats
Solid wall	D1	S1	T1	F1
cavity wall un-insulated	D2	S2	T2	F2
cavity wall with insulation	D3	S3	T3	F3
2002 building regulations	D4	S4	T4	F4

Table 4: The sixteen housing categories used.

4. The English House Condition Survey ‘dwelling type compared with tenure’ dataset contains more house types than the census data does. It contains bungalows and high rise flats which are not in the census data so for this reason they are removed from the dataset and the total housing count in the ‘dwelling type compared with tenure’ table is increased or decreased to reflect this so the percentages of the remaining housing still adds up to 100. Low rise and converted flats have been combined to produce a single field of flats and their attributes averaged in a 50/50 mix.

5. Any increase in dwelling numbers from the 2001 census were placed in the 2002 building regulations category as this is when regulations changed[7].
6. Where the number of dwellings in an output area decreased, no 2002 building regulation buildings were modelled and the 2001 stock is reduced according to the relative abundance of each housing type in 2001.

6.2.5 Standard Assessment Procedure 2005 models

1. The latest standard assessment procedure 2005 document and worksheets sourced from the BRE website (http://projects.bre.co.uk/sap2005/).
2. Sixteen SAP models were produced, one for each house type, the assumptions used are mostly based on values from within the standard assessment procedure and the English house condition survey.
3. The results provide annual space heating energy requirement and the amount of gas required to heat each house category, the latter will allow comparison with measured energy use from the Department of energy and Climate Change.

6.2.6 Standard Assessment Procedure methodology

This methodology only explains cells where input is required and there is no mention of the cells where only calculations based on inputs in other cells are undertaken as these cells are clearly defined in the SAP worksheet. A SAP worksheet can be found here: http://projects.bre.co.uk/sap2005/pdf/SAP2005_9-83.pdf. An example of the worksheet used can also be found in the appendix but the accompanying report is not attached.

Overall dwelling dimensions

1. Floor area
    - This is based on English House Condition Survey data, the age of dwellings is also included in the dataset so that dwelling areas can be represented in age bands, this is from the dataset (Summary Statistics Table SS2.0: Stock profile, 2006).
    - Over the last century energy efficiency measures have increased and based on data provided from AECOM, it is assumed that category 1 is pre 1919, category 2 is 1919 – 1974, category 3 is 1975 – 2002 and category 4 is post 2002.
2. Storey height

1 This is taken from values provided by AECOM and each house type and age band has different heights. These are shown in the table below:

[7] Building regulations changed most recently in 2006 but houses built under these regulations will be few compared with the total housing stock and their inclusion would increase the complexity of the models and were subsequently not modelled.

Category	Ground Floor (m)	First floor (m)	Category	Ground Floor (m)	First floor (m)
D1	3	3	S1	2.7	2.7
D2	2.6	2.3	S2	2.5	2.5
D3	2.6	2.3	S3	2.3	2.3
D4	2.6	2.3	S4	2.6	2.3
T1	2.7	2.7	F1	2.7	2.5
T2	2.5	2.5	F2	2.5	2.5
T3	2.3	2.3	F3	2.3	2.5
T4	2.6	2.3	F4	2.3	2.5

Table 5: Storey height of each category of house modelled.

Ventilation rate

1. There are assumed to be one chimney and one intermittent or passive vent for categories 1,2 and 3 and category 4 has one intermittent or passive vent only.
2. Pressurization tests are used (thus negating the need for cells 11 to18). Categories 1, 2 and 3 have values of 15 and category 4 has a value of 10, these can be found in part L of the building regulations.
3. The number of sides on which sheltered: For category D is 1, category S is 2, category T1, T2 and T3 2 with T4 being 3 and all of category F is 3.
4. The air change rate applicable in all cases is cell ‘d)’ ‘natural ventilation or whole house positive input ventilation from loft’.

Heat loss and heat loss parameter

1. Doors are assumed to be $1.85m^2$ each based on SAP assumptions and categories D, S and T have two doors each and category F has one door.
2. Window area is calculated as 25% of total floor area minus door area for D, S and T and as 15% of total floor area minus door area for F.
3. Ground floor area is equal to the area stated in the overall dwelling dimension section at the beginning of the worksheet.
4. Total wall area assumes the square root of the ground floor area to be equal to one side of the house (i.e. a square building), this is multiplied by four to get the perimeter length of the house. This is then multiplied by the sum of the heights of each storey to produce the total wall area. The window and door area is then subtracted from this to provide the net wall area.
5. Roof area is assumed to be equal to the first floor area.
6. Door U-value[8] is assumed to be $3Wm^{-2}K^{-1}$ for categories 1,2 and 3 and category 4 is $2Wm^{-2}K^{-1}$.
7. Window U-value is based on the mix of double and single glazed installation ratios that are based on the ratios when the building was built and this is based on data from AECOM, below. Single glazed are taken as $4.8Wm^2K^{-1}$ and double taken as 2.5 $Wm^{-2}K^{-1}$ apart from post 2002 regulations which is 2 $Wm^{-2}K^{-1}$.

[8] The U-value describes how well a building component such as windows, walls, doors etc conducts heat per unit area. It is dependent on the building component in question and the temperature differential between its two exposed surfaces and has an output shown in W/m^2K^{-1}. Lower U-values result in less energy transfer and therefore less heat losses.

	pre 1919	1919 - 1975	1975-2002	post 2002
% single glazed	46%	16%	14%	0%
% double glazed	54%	84%	86%	100%
further potential for double	21%	16%	14%	0%
Solid wall	100%	22%		
Un-insulated cavity wall		50%	50%	
Insulated cavity wall		28%	50%	100%

Table 6: glazing and wall effieincy measures by age band of house.

8. Ground floor U values are based on data from AECOM and they reduce as dwelling age decreases i.e. become more efficient.
9. Wall U value is based on values from the SAP 2005 document.
10. Roof U value is based on data supplied from AECOM, all U-values used are shown below:

U-values	pre 1919	1919 - 1975	1975-2002	post 2002
Single glazed	*4.80*	*4.80*	*4.80*	*4.80*
Double glazed	*2.50*	*2.50*	*2.50*	*2.00*
Replaced single glazing	*2.00*	*2.00*	*2.00*	*2.00*
Window value used	**3.558**	**2.868**	**2.822**	**2**
Roof	**0.40**	**0.35**	**0.29**	**0.16**
Wall	**2.1**	**1.402**	**0.675**	**0.35**
Floor	**1.2**	**0.51**	**0.35**	**0.25**

Table 7: U-values of glazing, roofing, walls and floors by age band of house.

Water heating energy requirements

1. Boiler volume for category D is 200litres, categories S and T is 150litres and category F is 120litres.
2. It is assumed that no combi boilers are used and no domestic solar hot water heating is installed.

Internal Gains

1. Central heating energy pump is assumed to use 10W in all categories.
2. Nle/N[9] is assumed to be 0.3 in every case.
3. E_b[10] is assumed to be 9.3kWh/m^2 in every case.

Solar Gains

[9] NLE is the number of fixed low energy lighting outlets (including sockets or complete luminaries capable of taking only low-energy lamps, and also compact fluorescent lamps that fitted into ordinary lighting sockets) and N is the total number of fixed lighting outlets (only the ratio NLE/N is needed).

[10] E_b is the average energy consumption for lighting in the UK if no low energy lighting is used.

1. It is assumed that internal gains are only made from the east and west directions and all other aspect rows are empty. The East and west values in each column are identical for each building category i.e. the category 1 g^+ column is 0.63 whereas categories 2, 3 and 4 have 0.76 in the g^+ column.
2. The access factor, Flux and FF columns are identical for all sixteen housing types being 0.77, 48 and 0.7 respectively.

<u>Mean internal temperature</u>

1. The mean internal temperature and the temperature differences between zones are interpolated from an excel table using the 'VLOOKUP' function from a table copied from the SAP 2005 document into Excel.
2. Living area of every house is assumed to be 0.15 based on data provided by AECOM.

<u>Degree days</u>

1. The degree day figure is calculated using the 'VLOOKUP' function from the degree day table that is copied from the SAP 2005 document into excel.
2. Annual energy use not including heating efficiencies is calculated from this.

6.2.7 Data output

1. The heating energy requirement of each house type is summed into each output area based on the number of each category of house.
2. Annual energy density and Power density per square kilometre ($MWkm^{-2}$) were calculated as well as total energy per output area.
3. This was exported to Arc GIS and shown spatially.

6.2.8 Standard assessment procedure worksheet

1. Overall dwelling dimensions

	Area (m²)		Average storey height (m)		Volume (m³)
Ground floor	(1a)	×		=	(1)
First floor	(2a)	×		=	(2)
Second floor	(3a)	×		=	(3)
Third and other floors	(4a)	×		=	(4)
Total floor area (1a) + (2a) + (3a) + (4a) =	(5)				
Dwelling volume			(1) + (2) + (3) + (4) =		(6)

2. Ventilation rate

			m³ per hour
Number of chimneys		× 40 =	(7)
Number of open flues		× 20 =	(8)
Number of intermittent fans or passive vents		× 10 =	(9)
Number of flueless gas fires		× 40 =	(9a)

Air changes per hour

Infiltration due to chimneys, flues and fans = (7)+(8)+(9)+(9a) = ÷ box (6) = (10)

If a pressurisation test has been carried out, proceed to box (19)

Number of storeys in the dwelling (11)

Additional infiltration [(11) - 1] × 0.1 = (12)

Structural infiltration: *0.25 for steel or timber frame or 0.35 for masonry construction* (13)
if both types of wall are present, use the value corresponding to the greater wall area (after deducting areas of openings); if equal use 0.35

If suspended wooden floor, *enter 0.2 (unsealed) or 0.1 (sealed)*, else enter 0 (14)

If no draught lobby, enter 0.05, else enter 0 (15)

Percentage of windows and doors draught stripped (16)

Window infiltration 0.25 - [0.2 × (16) ÷ 100] = (17)

Infiltration rate (10) + (12) + (13) + (14) + (15) + (17) = (18)

If based on air permeability value, then $[q_{50} \div 20]$+(10) in box (19), otherwise (19) = (18) (19)
Air permeability value applies if a pressurisation test has been done, or a design or specified air permeability is being used

Number of sides on which sheltered (20)
(Enter 2 in box (20) for new dwellings where location is not shown)

Shelter factor 1 - [0.075 × (20)] = (21)

Adjusted infiltration rate (19) × (21) = (22)

Calculate effective air change rate for the applicable case:

If balanced whole house mechanical ventilation air throughput (in ach, see 2.6.6) = (22a)

If balanced with heat recovery efficiency in % allowing for in-use factor = (22b)

a) If balanced mechanical ventilation with heat recovery (22) + (22a) × [1 – (22b) ÷ 100] = (23)

b) If balanced mechanical ventilation without heat recovery (22) + (22a) = (23a)

c) If whole house extract ventilation or positive input ventilation from outside
if (22) < 0.25, then (23b) = 0.5; otherwise (23b) = 0.25 + (22) (23b)

d) If natural ventilation or whole house positive input ventilation from loft
if (22) ≥ 1, then (24) = (22); otherwise (24) = 0.5 + [(22)² × 0.5] (24)

Effective air change rate - enter (23) or (23a) or (23b) or (24) in box (25) (25)

3. Heat losses and heat loss parameter

ELEMENT	Gross area (m²)		Openings		Net Area (m²)		U-value		A×U (W/K)	
Doors						×		=		(26)
Windows (type 1)*						×	1/[(1/U-value)+0.04]	=		(27)
Windows (type 2)*						×	1/[(1/U-value)+0.04]	=		(27a)
Rooflights*						×	1/[(1/U-value)+0.04]	=		(27b)
Ground floor						×		=		(28)
Walls (type 1)		-		=		×		=		(29)
Walls (type 2)		-		=		×		=		(29a)
Roof (type 1)		-		=		×		=		(30)
Roof (type 2)		-		=		×		=		(30a)
Total area of elements ΣA, m²					(32)					

**for windows and rooflights, use effective window U-value calculated as given in paragraph 3.2*
the above table is expanded as necessary to allow for all different types of element e.g. 6 wall types

Fabric heat loss, W/K	(26)+(27)+(27a)+(27b)+(28)+(29)+(29a)+(30)+(30a) =		(33)
Thermal bridges - Σ (l×Ψ) calculated using Appendix K			(34)
if details of thermal bridging are not known calculate y× (32) [see Appendix K] and enter in (34)			
Total fabric heat loss	(33) + (34) =		(35)
Ventilation heat loss	(25) × 0.33 × (6) =		(36)
Heat loss coefficient, W/K	(35) + (36) =		(37)
Heat loss parameter (HLP), W/m²K	(37) ÷ (5) =		(38)

4. Water heating energy requirements

		kWh/year	
Energy content of hot water used from Table 1 column (b)			(39)
Distribution loss from Table 1 column (c)			(40)

If instantaneous water heating at point of use, enter "0" in boxes (40) to (45)
For community heating use Table 1 (c) whether or not hot water tank is present

Water storage loss:

a) If manufacturer's declared loss factor is known (kWh/day):			(41)
Temperature factor from Table 2b			(41a)
Energy lost from water storage, kWh/year	(41) × (41a) × 365 =		(42)

b) If manufacturer's declared cylinder loss factor is not known :

Cylinder volume (litres) including any solar storage within same			(43)

If community heating and no tank in dwelling, enter 110 litres in box (43)
Otherwise if no stored hot water (this includes instantaneous combi boilers) enter '0' in box (43)

Hot water storage loss factor from Table 2 (kWh/litre/day)			(44)
If community heating and no tank in dwelling, use cylinder loss from Table 2 for 50 mm factory insulation			
Volume factor from Table 2a			(44a)
Temperature factor from Table 2b			(44b)
Energy lost from water storage, kWh/year	(43) × (44) × (44a) × (44b) × 365 =		(45)

Enter (42) or (45) in box (46)			(46)
If dedicated solar storage is within cylinder, box (47) = (46) × [(43) – (H11)] ÷ (43), else			(47)
Primary circuit loss from Table 3			(48)
Combi loss from Table 3a (enter "0" if not a combi boiler)			(49)
Solar DHW input calculated using Appendix H (enter "0" if no solar collector)			(50)
Output from water heater, kWh/year	(39)+(40)+(47)+(48)+(49) – (50) =		(51)
Heat gains from water heating,	0.25 × [(39)+(49)]+0.8 × [(40)+(47)+(48)] =		(52)

include (47) in calculation of (52) only if cylinder is in the dwelling or hot water is from community heating

5. Internal gains

		Watts	
Lights, appliances, cooking and metabolic (Table 5)			(53)
Reduction of internal gains due to low energy lighting (calculated in Appendix L)			(53a)
Additional gains from Table 5a			(53b)
Water heating	(52) ÷ 8.76 =		(54)
Total internal gains	(53) + (53b) + (54) – (53a) =		(55)

6. Solar gains

	Access factor Table 6d		Area m²		Flux Table 6a		$g_{\perp}$ Table 6b		FF Table 6c		Gains (W)	
North		×		×		× 0.9 ×		×		=		(56)
Northeast		×		×		× 0.9 ×		×		=		(57)
East		×		×		× 0.9 ×		×		=		(58)
Southeast		×		×		× 0.9 ×		×		=		(59)
South		×		×		× 0.9 ×		×		=		(60)
Southwest		×		×		× 0.9 ×		×		=		(61)
West		×		×		× 0.9 ×		×		=		(62)
Northwest		×		×		× 0.9 ×		×		=		(63)
Rooflights		×		×		× 0.9 ×		×		=		(64)

Total solar gains:	[(56) + ... + (64)] =		(65)
Total gains, W	(55) + (65) =		(66)
Gain/loss ratio (GLR)	(66) ÷ (37) =		(67)
Utilisation factor (Table 7, using GLR in box (67)			(68)
Useful gains, W	(66) × (68) =		(69)

7. Mean internal temperature

		°C	
Mean internal temperature of the living area (Table 8)			(70)
Temperature adjustment from Table 4e, where appropriate			(71)
Adjustment for gains	{[(69) ÷ (37)] - 4.0} × 0.2 × R =		(72)
R is obtained from the 'responsiveness' column of Table 4a or Table 4d			
Adjusted living room temperature	(70) + (71) + (72) =		(73)
Temperature difference between zones (Table 9)			(74)
Living area fraction (0 to 1.0)	living room area ÷ (5) =		(75)
Rest-of -house fraction	1 - (75) =		(76)
Mean internal temperature	(73) - [(74) × (76)] =		(77)

8. Degree days

Temperature rise from gains	(69) ÷ (37) =		(78)
Base temperature	(77) - (78) =		(79)
Degree-days, *use box (79) and Table 10*			(80)

9. Space heating requirement

Space heating requirement (useful), kWh/year	0.024 × (80) × (37) =		(81)

For range cooker boilers where efficiency is obtained from the Boiler Efficiency Database or manufacturer's declared value, multiply the result in box (81) by $(1 - \Phi_{case}/\Phi_{water})$ where Φ_{case} is the heat emission from the case of the range cooker at full load (in kW); and Φ_{water} is the heat transferred to water at full load (in kW). Φ_{case} and Φ_{water} are obtained from the database record for the range cooker boiler or manufacturer's declared value.

9a. Energy requirements - individual heating systems, including micro-CHP			
Note: when space and water heating is provided by community heating use the alternative worksheet 9b			
Space heating:			
Fraction of heat from secondary/supplementary system *(use value from Table 11, Appendix F or Appendix N)*			(82)
Efficiency of main heating system, %			(83)
(SEDBUK or from Table 4a or 4b, adjusted where appropriate by the amount shown in the 'efficiency adjustment' column of Table			
Efficiency of secondary/supplementary heating system, % *(use value from Table 4a or Appendix E)*			(84)
Space heating fuel (main) requirement, kWh/year	[1 - (82)] × (81) × 100 ÷ (83) =		(85)
Space heating fuel (secondary), kWh/year	(82) × (81) × 100 ÷ (84) =		(85a)
Water heating:			
Efficiency of water heater, %			(86)
(SEDBUK or from Table 4a or 4b, adjusted where appropriate by the amount shown in the 'efficiency adjustment' column of Table			
Energy required for water heating, kWh/year	(51) × 100 ÷ (86) =		(86a)

6.2.9 Comparison to other datasets

1. The Department of Energy and Climate Change data has domestic and gas energy use at middle super output area and lower super output area levels measured from every gas meter in each area.
2. The sixteen house categories were summed into middle and lower super output areas by repeating the methodology described above but using Middle and lower output areas as the base rather than output areas.
3. Natural gas connections per output area were summed into middle and lower super output areas, data sourced from the fuel poverty index Excel file, and the gas heating requirements of houses within each middle super output area was multiplied by the number of on-gas houses in each area as well as the average UK gas boiler efficiency from BRE MAC curves technical document. Efficiency of 75.75% was used.
4. This was compared to the actual use to ascertain the accuracy of correlation.

<u>Standard assessment procedure - Primary natural gas energy requirements</u>

1. The fraction of heat from the secondary or supplementary heating system (i.e. not the primary heating system) was assumed to be 0.1 in all cases.
2. The efficiency of both space and water heating systems is assumed to be the same for every house based on an average from the BRE MAC (Marginal Abatement Cost) curves document - this is 75.75% for every house.
3. Secondary heating fuel requirements were not calculated as this would not have come from natural gas so has no use in the comparison.
4. The space heating and water heating values are summed together to provide the total natural gas requirements of the house which can be compared to the Department of Energy and Climate Change data.

6.2.10 Middle Super Output Area

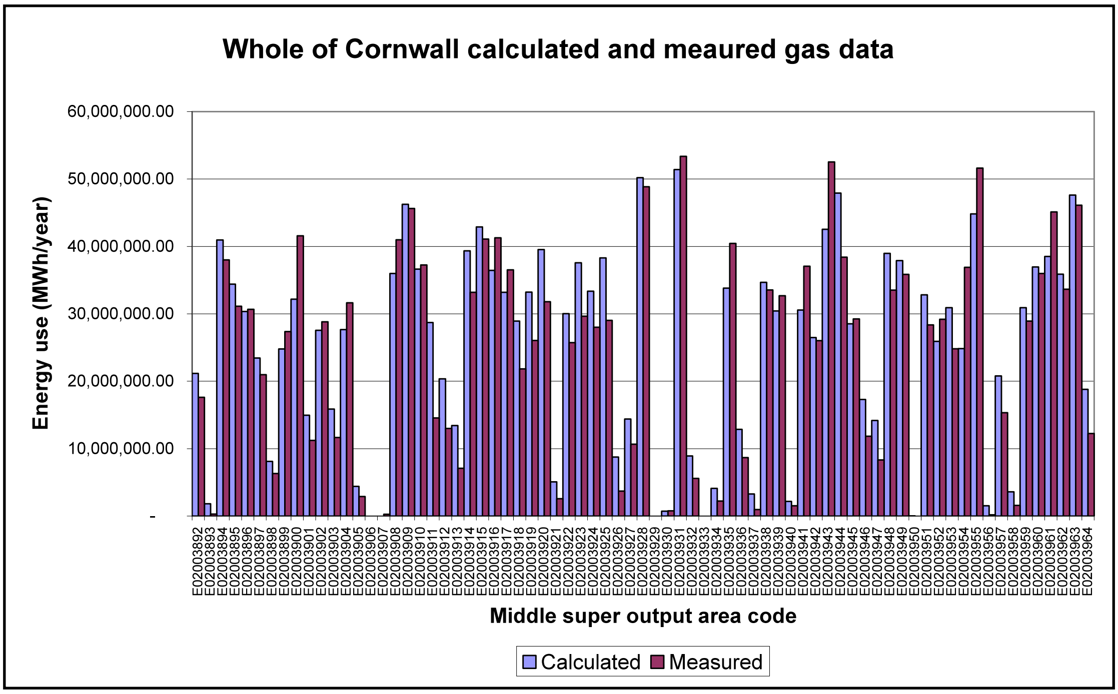


Figure 9: Middle super output area comparison of measured and calculated natural gas use.

6.2.11 Lower Super Output Area

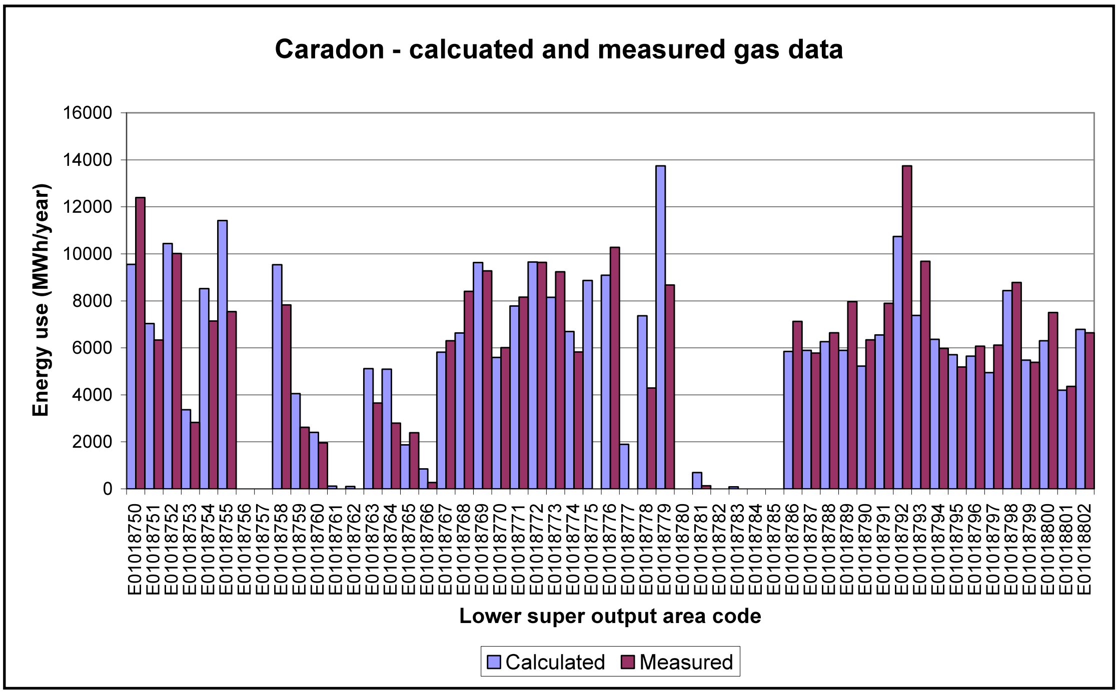


Figure 10: Caradon lower super output area gas use comparison

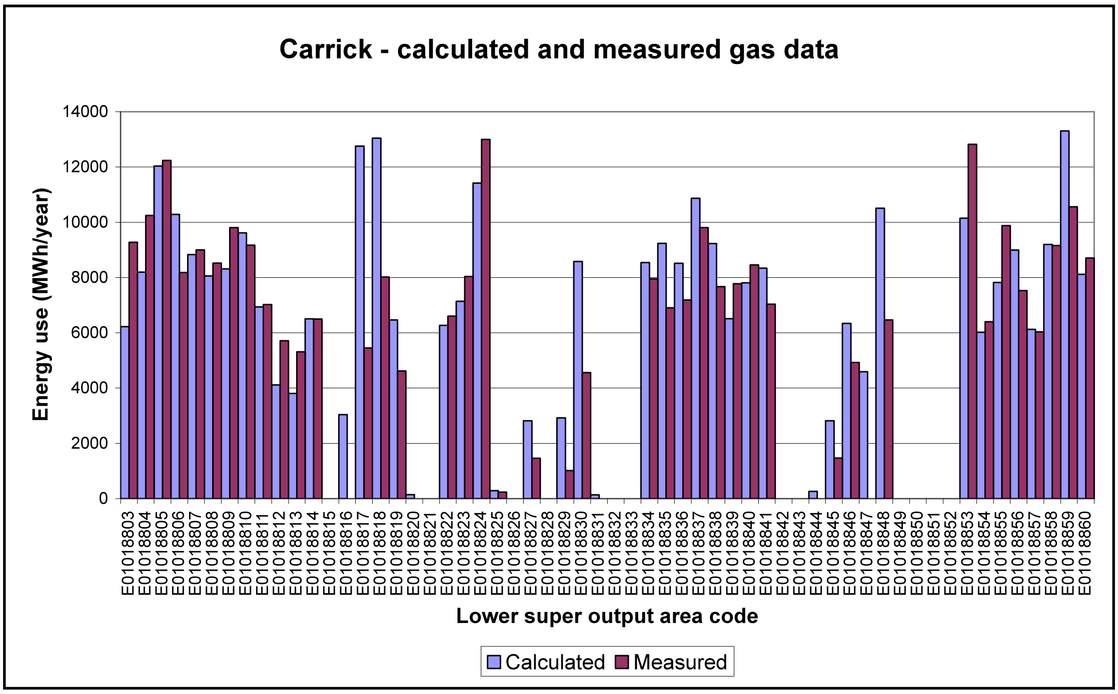


Figure 11: Carrick lower super output area gas use comparison

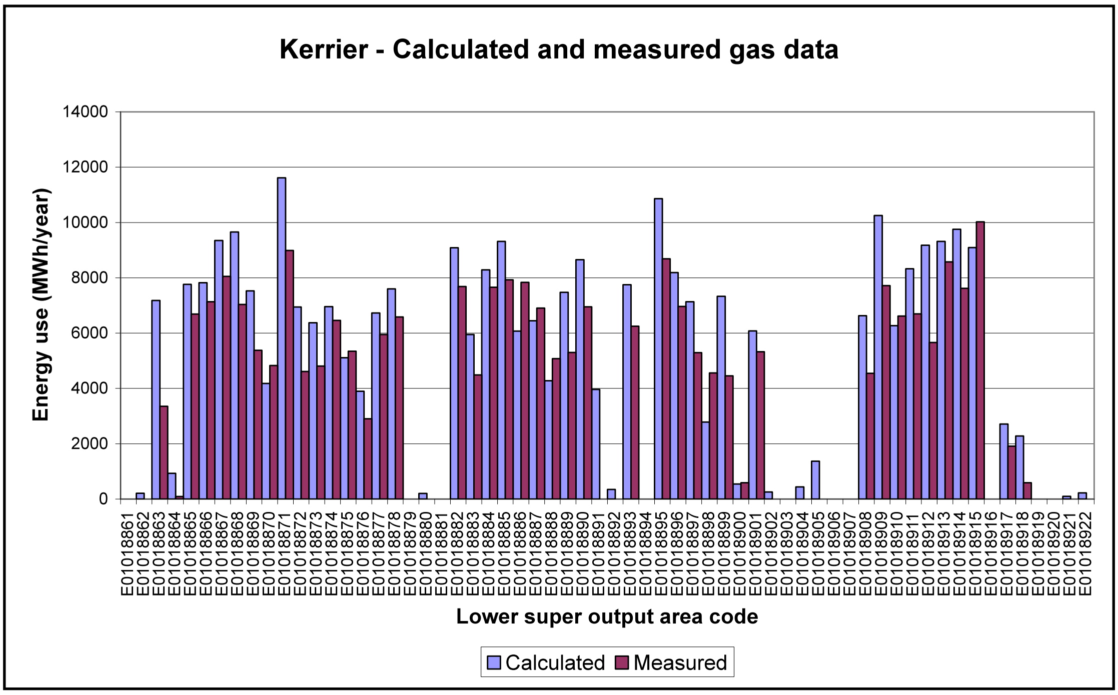


Figure 12: Kerrier lower super output area gas use comparison

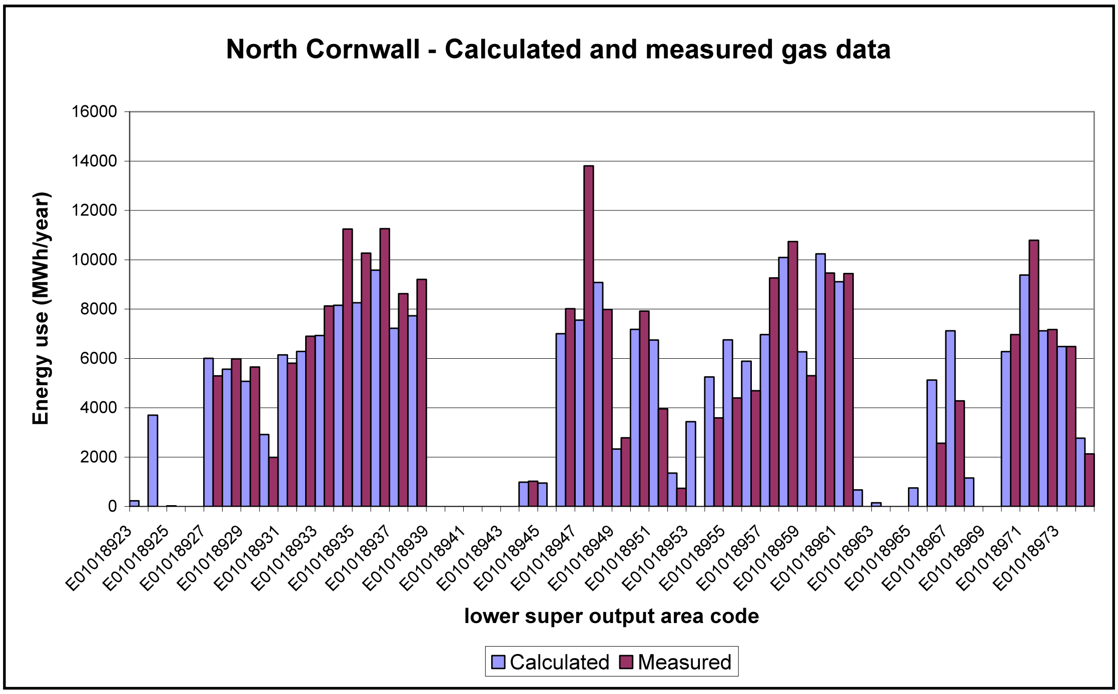


Figure 13: North Cornwall lower super output area gas use comparison

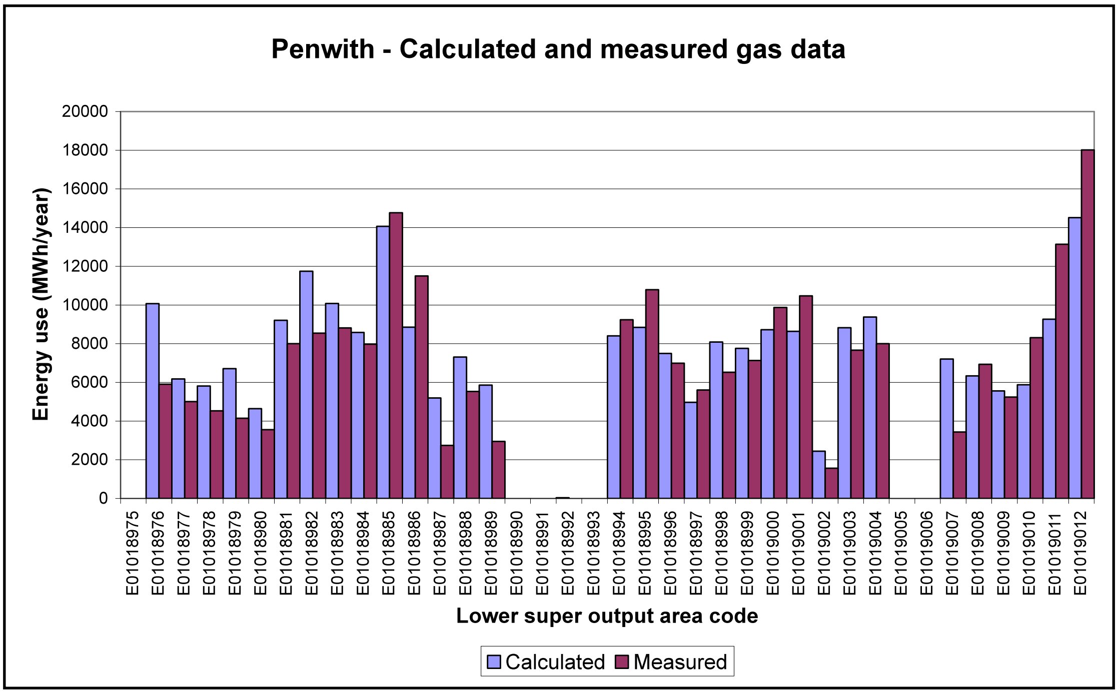


Figure 14: Penwith lower super output area gas use comparison

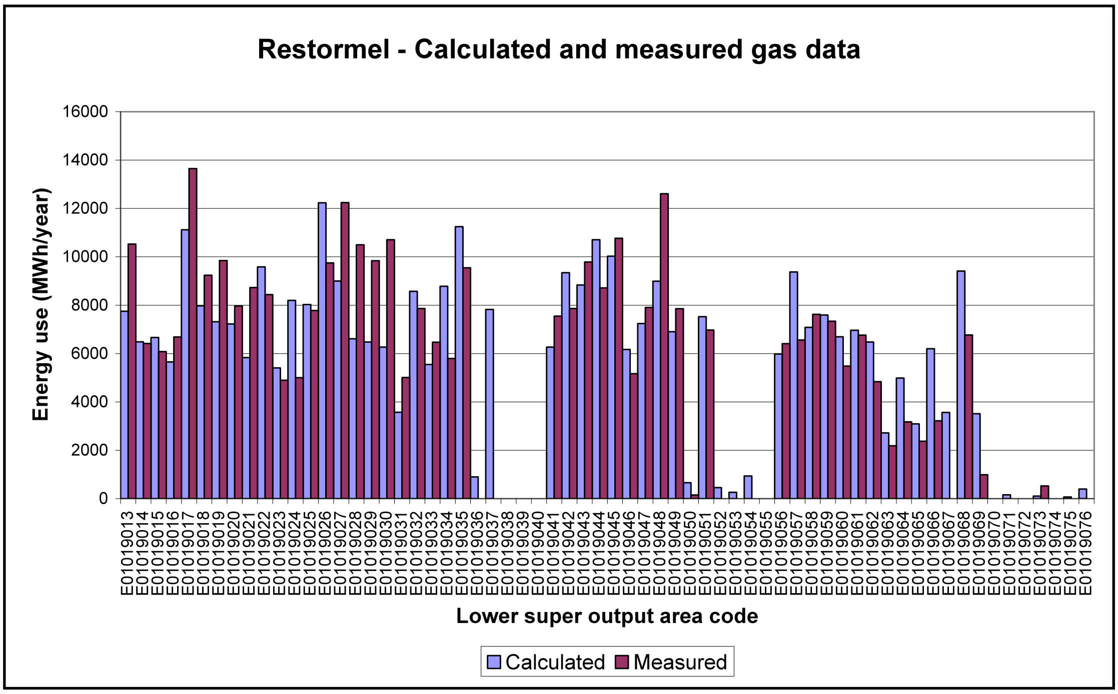


Figure 15: Restormel lower super output area gas use comparison

6.3 *Appendix B - Non-domestic methodology*

6.3.1 VOA data

1. The business rates Valuation Office Agency data for the six former districts within Cornwall was obtained.
2. data from each of the six districts copied and pasted into a single Excel worksheet for ease of use
3. Redundant properties are present in the data, these were removed by sorting the data by the “To date” column and then deleting all properties with a ‘To Date’ entry leaving only current properties.
4. From the property description column all 729 different property descriptions were extracted from the 17,009 different properties. These were each allocated the most relevant CIBSE TM46 energy benchmark which were all reduced by 20% to account for the 20% fewer degree days in Devon and Cornwall relative to Kent where the benchmarks are based.
5. Using the “VLOOKUP” function the energy benchmarks were then applied to all 17,009 properties and the benchmark multiplied by the total floor area column to provide space heating demand per year in kWh. This was then multiplied by one thousand to represent MWh.
6. The energy data was summed into the postcodes they are located within, this is provided with the Valuation Office Agency data. This produced a single space heating energy per postcode area.
7. The postcode format in the Valuation Office Agency data was altered so that it was compatible with the GIS Postcode shape files used by ArcGIS.
8. To find the area of each postcode area ArcGIS was used where postcode shapefiles were queried for their area and the results exported into Excel. This allowed the energy density to be calculated in $MWkm^{-2}a^{-1}$.
9. The calculated energy and power density of each postcode area were imported into ArcGIS and combined with the postcode shapefiles to enable the results to be shown spatially.

6.3.2 Council related energy loads

6.3.3 Schools

1. Council GIS shape files plotting every state school in the county were used to locate the schools.
2. The CIBSE TM46 energy benchmark for schools was multiplied by floor area of every school, floor area acquired from within the council also.
3. The energy demand results were combined with the schools shapefiles and the points labelled with energy use in $MWha^{-1}$.

6.3.4 NHS hospitals

1. The Estates Return and Information Collection (ERIC) produced by the NHS provides the floor area of every hospital in the UK, from this all Cornish hospitals floor areas were obtained.
2. The floor area of every hospital was multiplied by the relevant energy benchmark.
3. Each NHS hospital was plotted by hand using ArcGIS as shapefiles could not be obtained.

4. The energy benchmarks were merged with the shapefiles so energy use and location were shown spatially.

6.3.5 Leisure facilities

1. Council run leisure facilities shapefile obtained to identify location of each.
2. Type of facility identified to see if heat was actually used, boating lakes and skate parks for example were removed from the data as they do not require any heat
3. Intranet mapping used to find the area of each leisure facility and assuming only one floor per building the relevant energy benchmark was applied.
4. The energy results were merged with the leisure centre shapefiles to show the energy use spatially.

6.3.6 Further education facilities

1. Sites identified and plotted using ArcGIS.
2. Estate/energy management teams at each institution contacted and floor areas or energy use obtained where possible.
3. Floor areas multiplied with relevant CIBSE TM46 energy benchmark to calculate final energy use.
4. Truro College supplied direct energy use, the heating efficiency was assumed to be 75% and space heating demand calculated.
5. Space heating energy use merged with the shapefile to show energy results spatially.

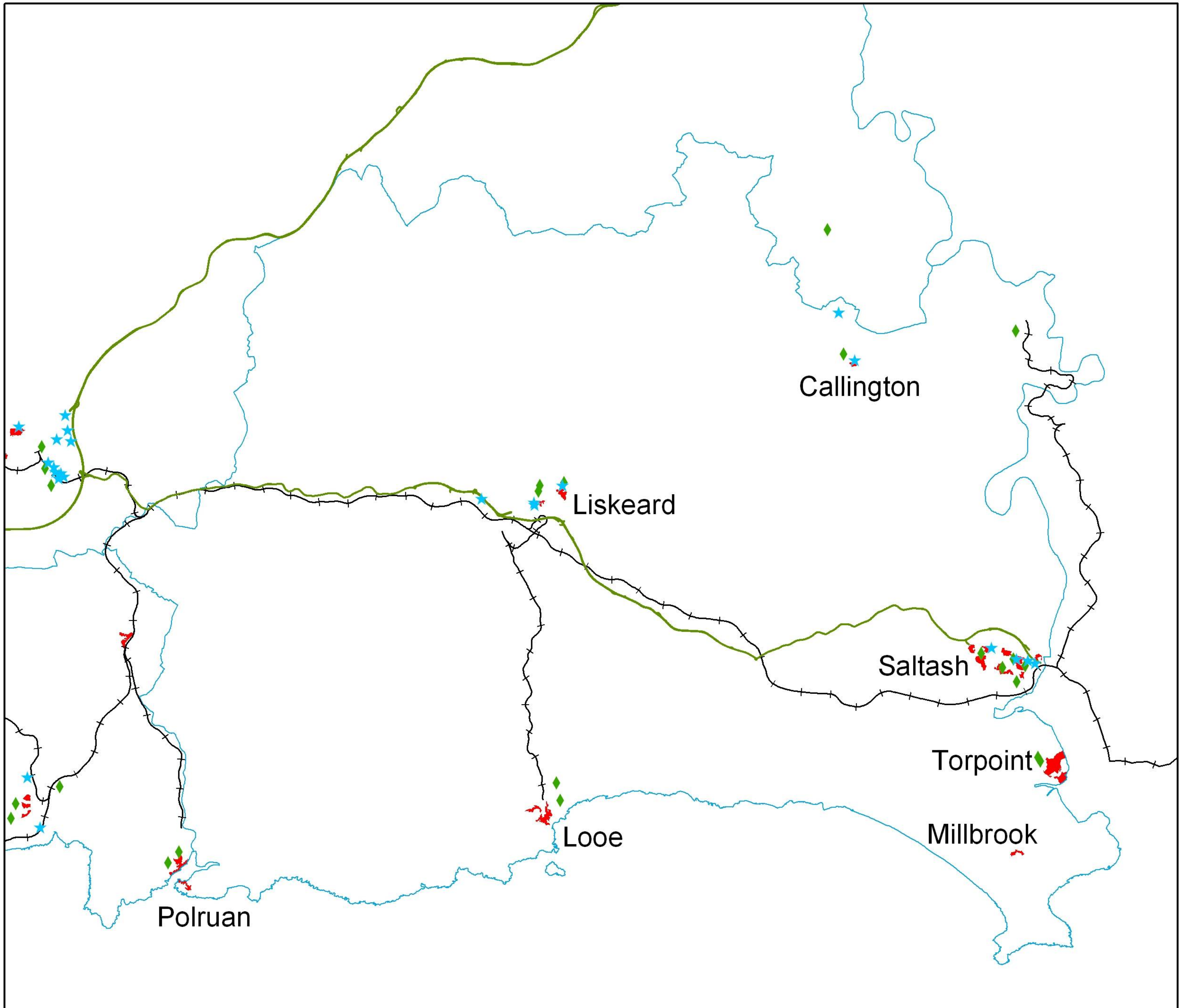
6.4 Appendix C - Maps

6.4.1 Overview map

6.4.2 Maps of districts

These are maps of residential space heating demand in Cornwall based at output area level. Due to the small scale required to show a whole district only economically viable areas are shown, these are areas with demands greater than three megawatts per square kilometre, the locations where economically viable heat demands occur are labelled. They also do not show the magnitude of demand because this would not be clear at the small scale of the maps. Maps of greater detail showing urban centres follow the district maps.

Caradon



one and all onen hag oll
CORNWALL COUNCIL

Legend

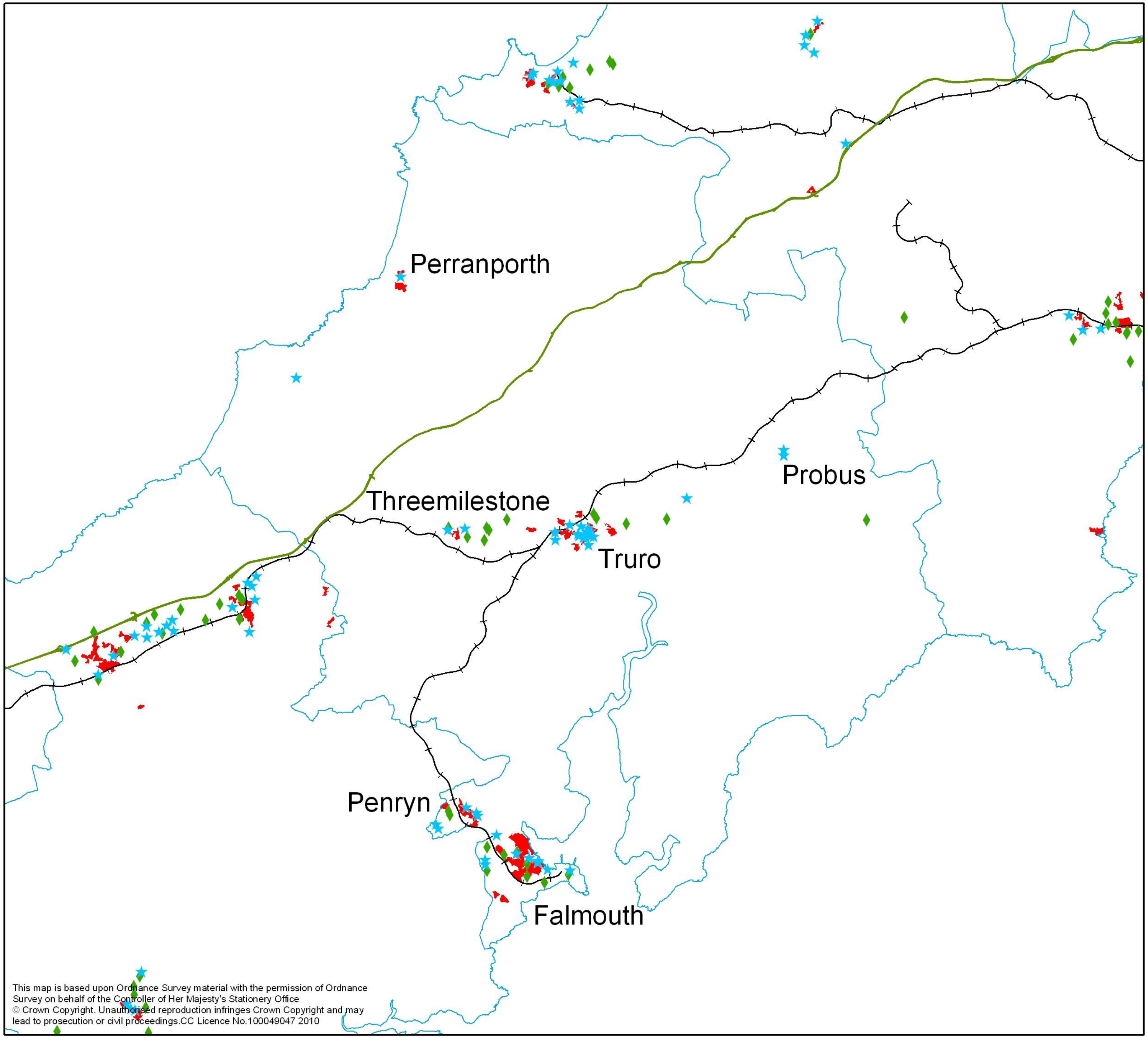
- rail
- Trunk road
- Economically viable domestic > 3MW/km2/a
- Potential anchor load > 3MW/km2/a and > 200MWh/a
- Economically viable non-domestic > 200MWh/a

N E S W

0 2.5 5 10

Kilometres

1:200,000



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CORNWALL
COUNCIL

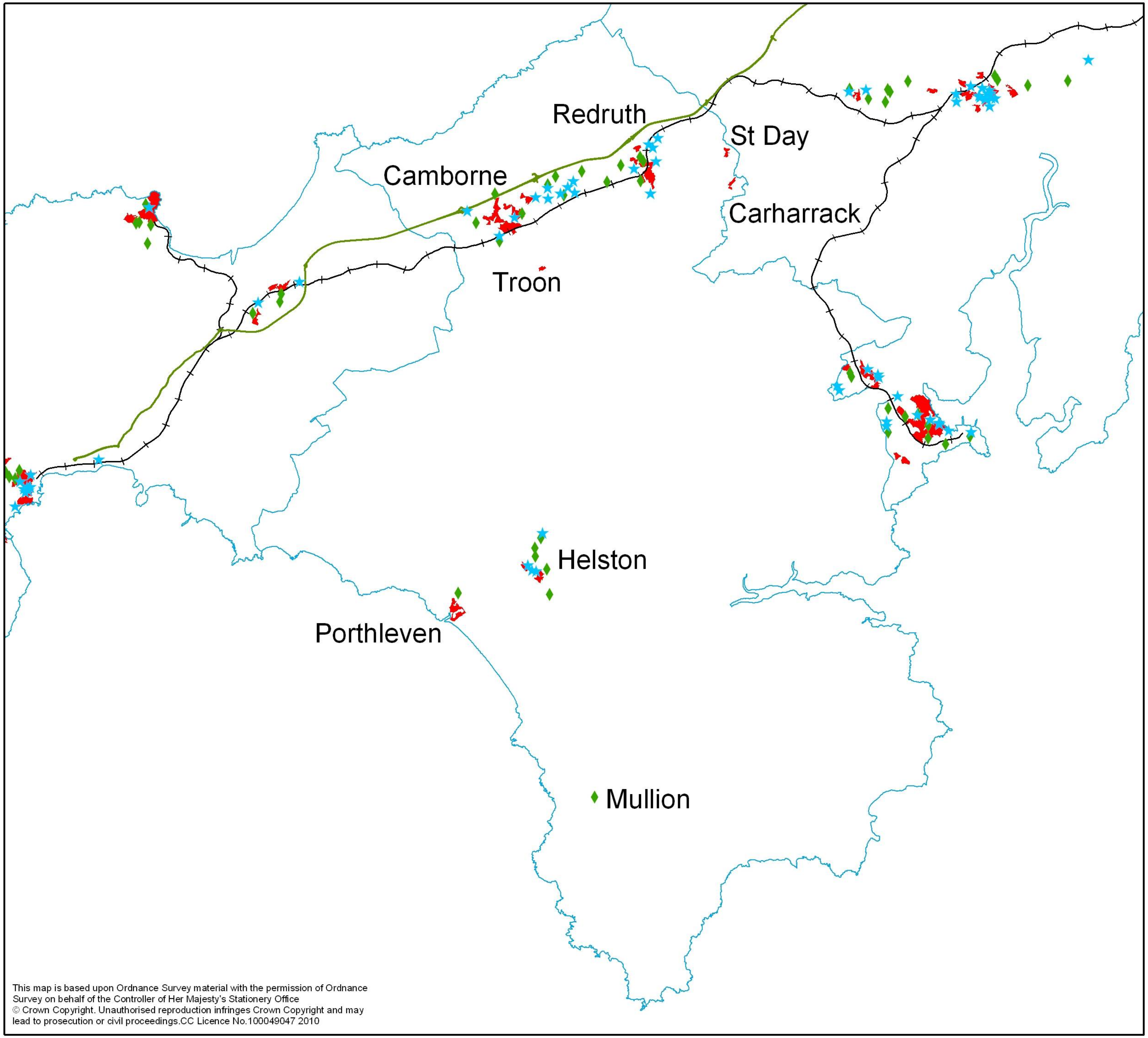
Carrick

Legend

rail
Trunk road
Economically viable domestic > 3MW/km2/a
Potential anchor load > 3MW/km2/a and > 200MWh/a
Economically viable non-domestic > 200MWh/a

N W E S

0 2.5 5 10
Kilometres
1:200,000



one and all onen hag oll
CORNWALL
COUNCIL

Kerrier

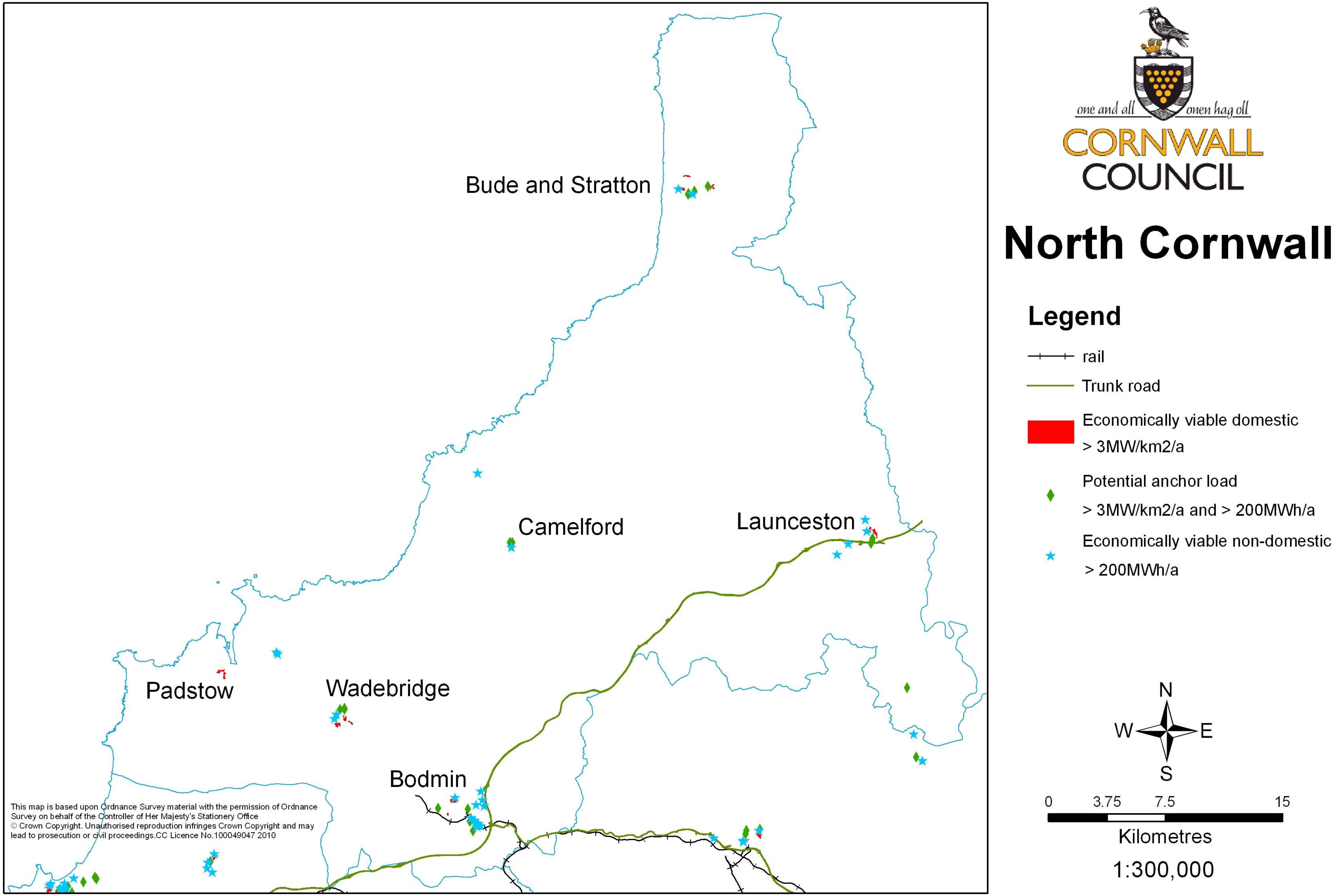
Legend

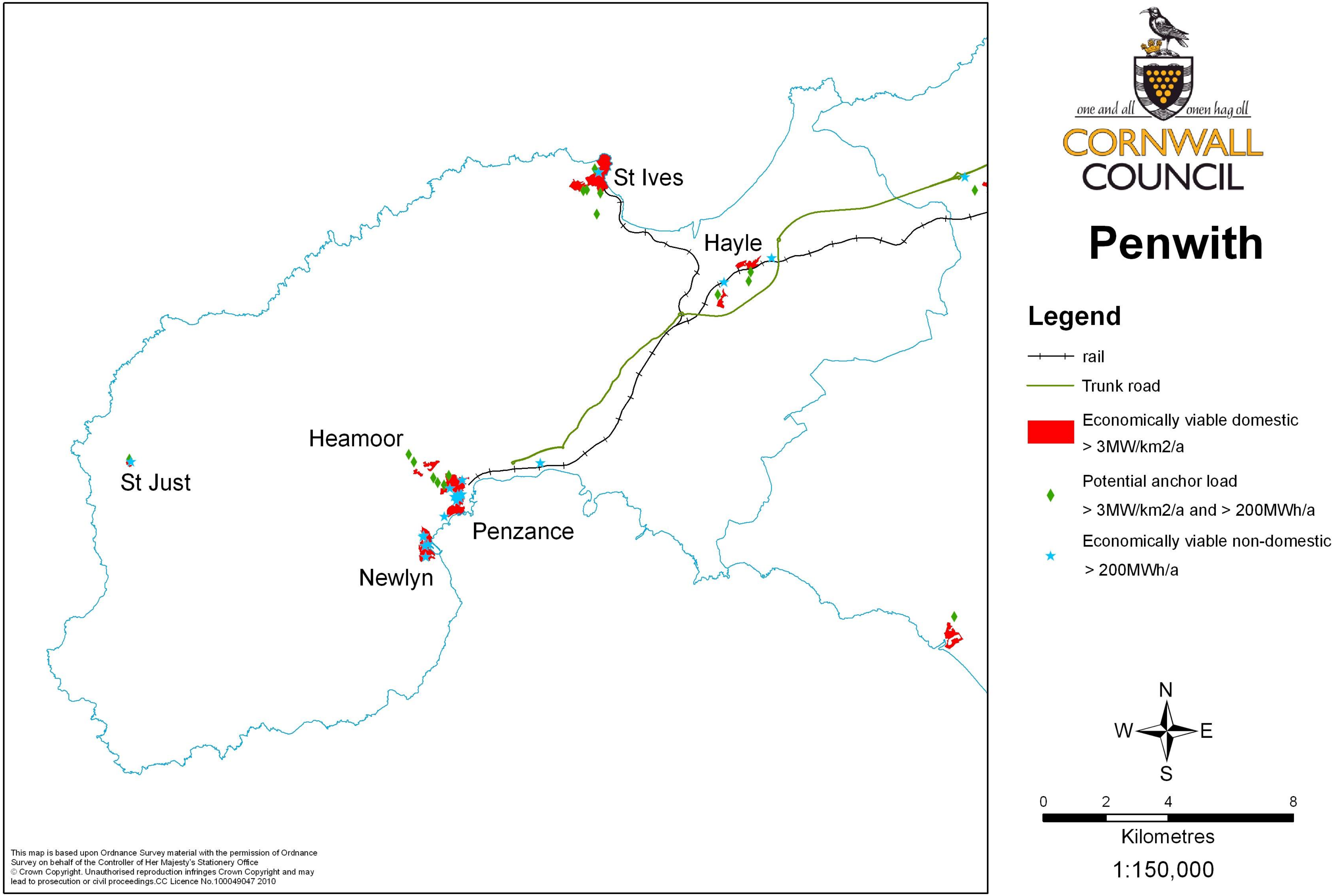
- rail
- Trunk road
- Economically viable domestic > 3MW/km2/a
- Potential anchor load > 3MW/km2/a and > 200MWh/a
- Economically viable non-domestic > 200MWh/a

N W E S

0 2.5 5 10
Kilometres
1:200,000

North Cornwall




one and all
onen hag oll
CORNWALL
COUNCIL
Penwith
St Ives
Hayle
Heamoor
St Just
Penzance
Newlyn
Legend
rail
Trunk road
Economically viable domestic
> 3MW/km2/a
Potential anchor load
> 3MW/km2/a and > 200MWh/a
Economically viable non-domestic
> 200MWh/a
N
W
E
S
0
2
4
8
Kilometres
1:150,000
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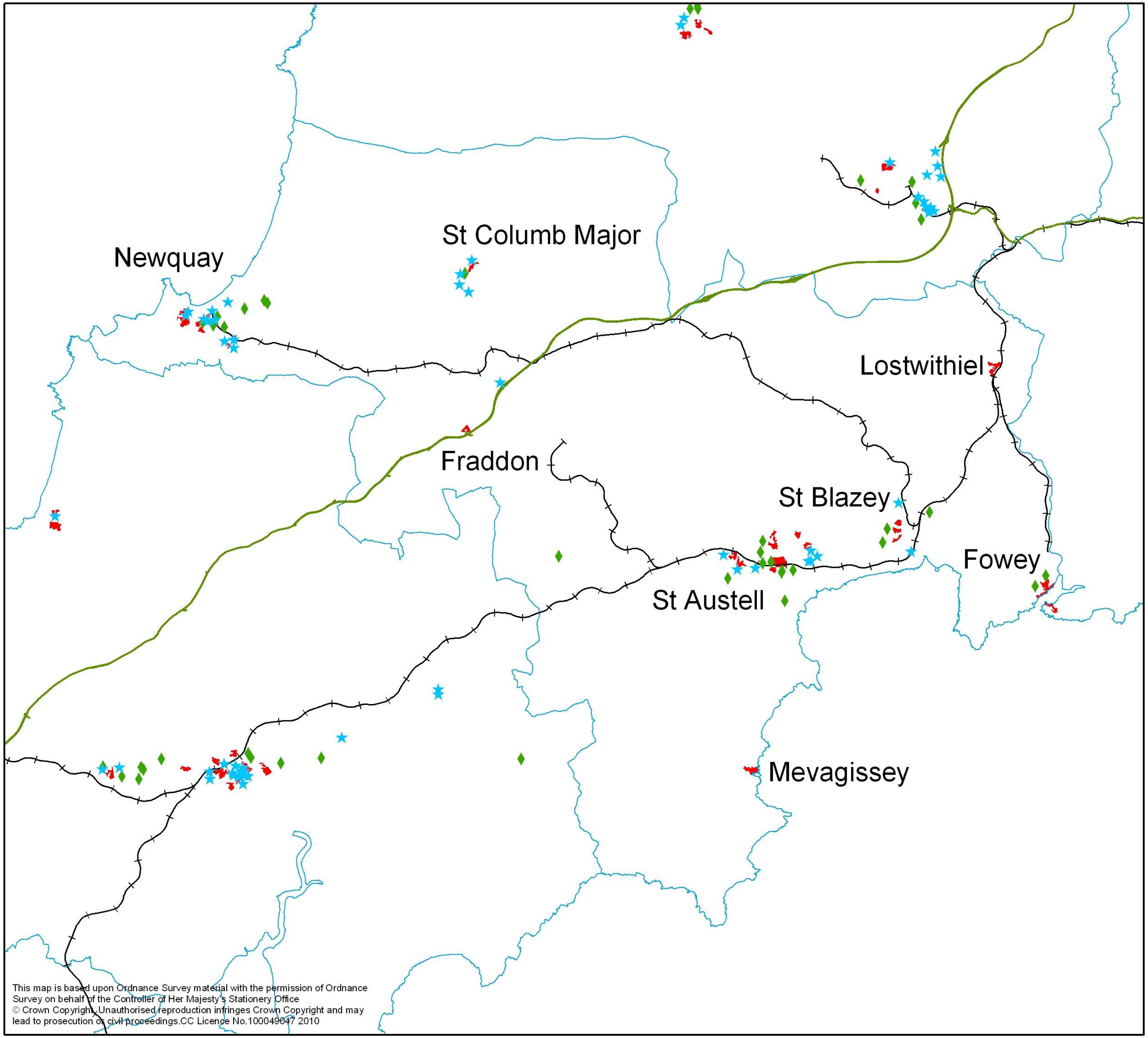
Restormel



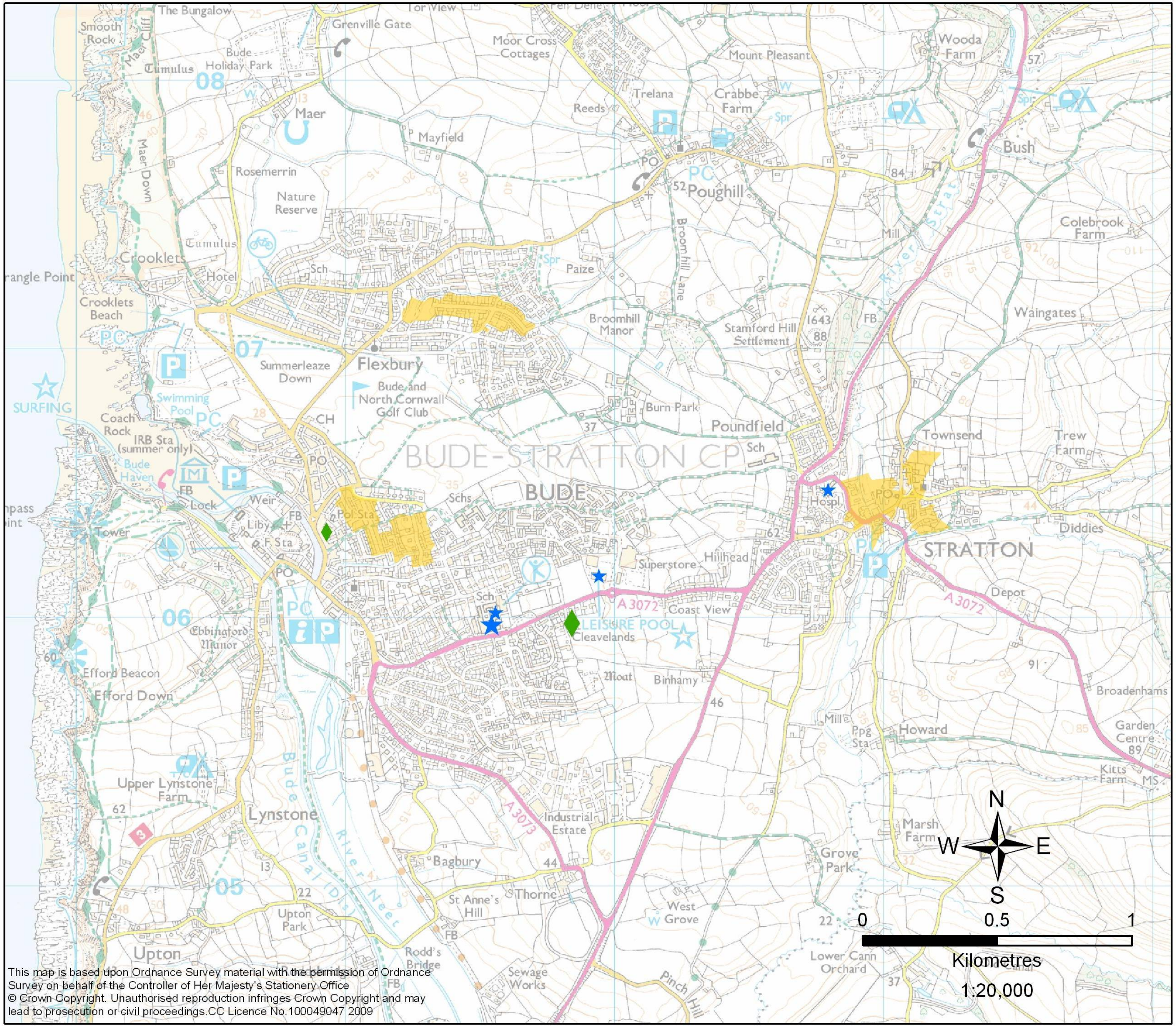
Legend

- rail
- Trunk road
- Economically viable domestic > 3MW/km2/a
- Potential anchor load > 3MW/km2/a and > 200MWh/a
- Economically viable non-domestic > 200MWh/a

N E S W

0 2.5 5 10
Kilometres
1:200,000

Bude and Stratton



Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

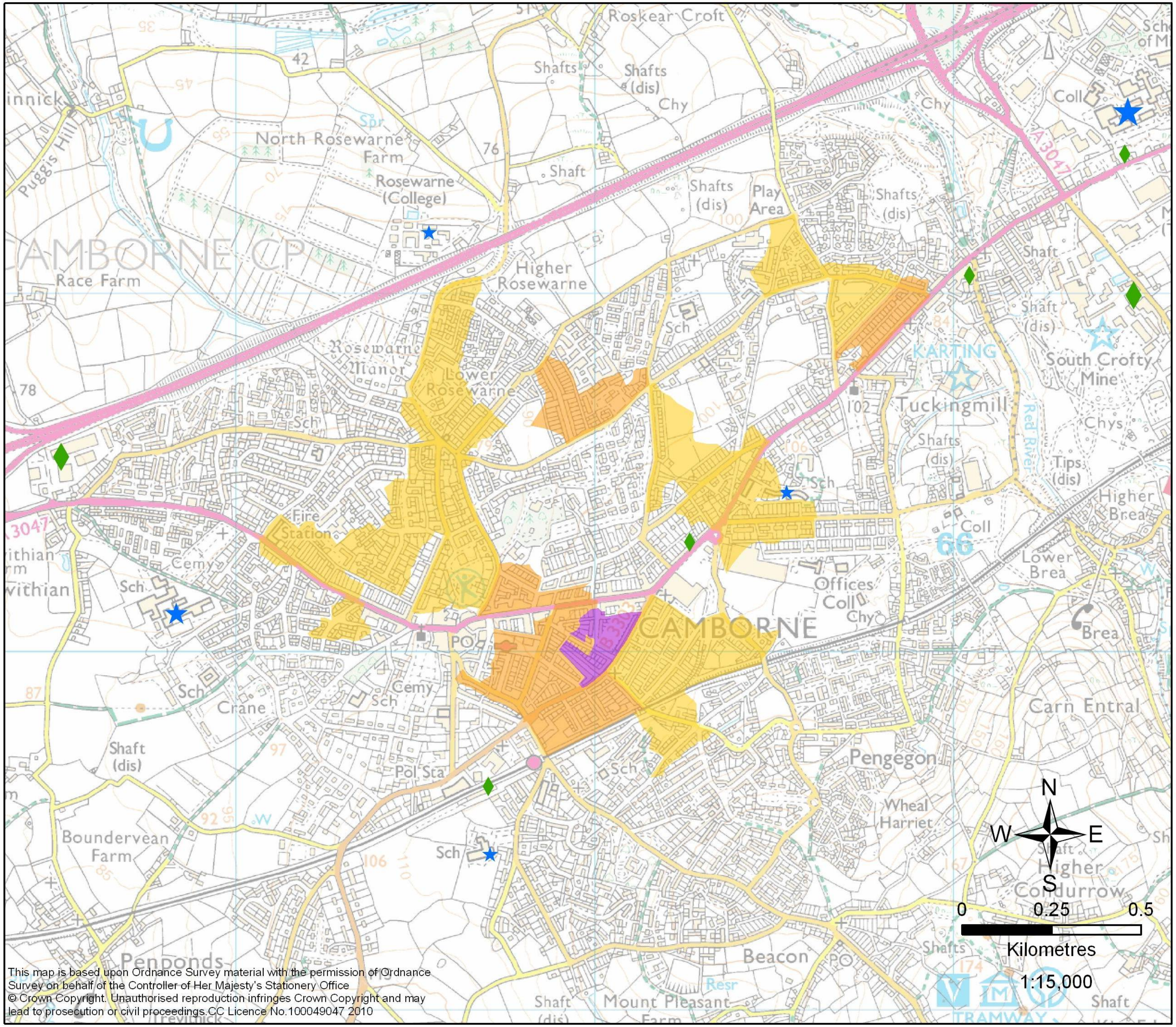
Energy (MWh/a)

- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000



one and all onen hag oll
CORNWALL COUNCIL

Camborne

Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

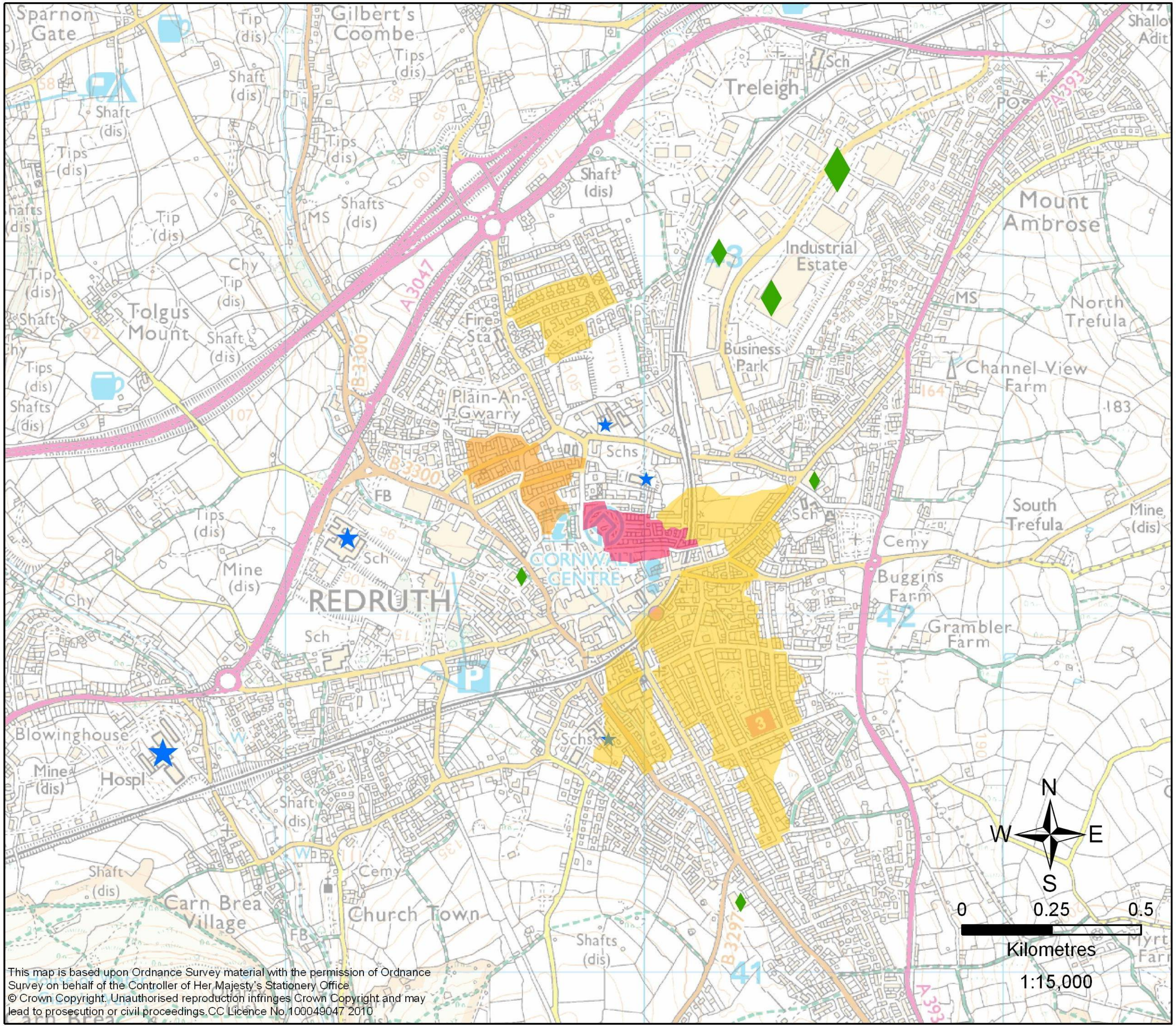
Energy (MWh/a)

- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000



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CORNWALL COUNCIL

Redruth

Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

Energy (MWh/a)

- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

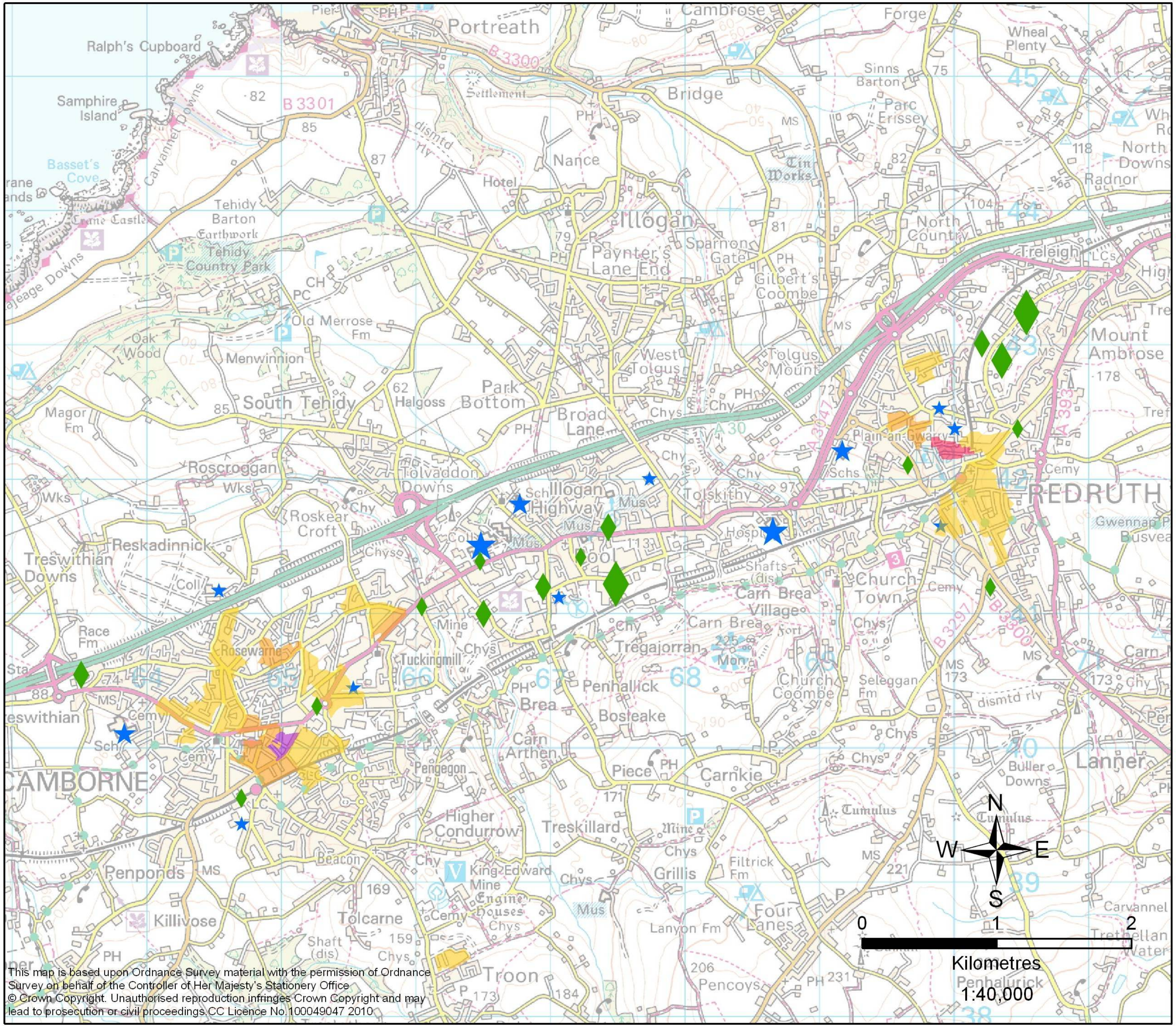
Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000

CORNWALL COUNCIL

one and all — onen hag oll

Redruth and Camborne



Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

Energy (MWh/a)

- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000

CORNWALL COUNCIL

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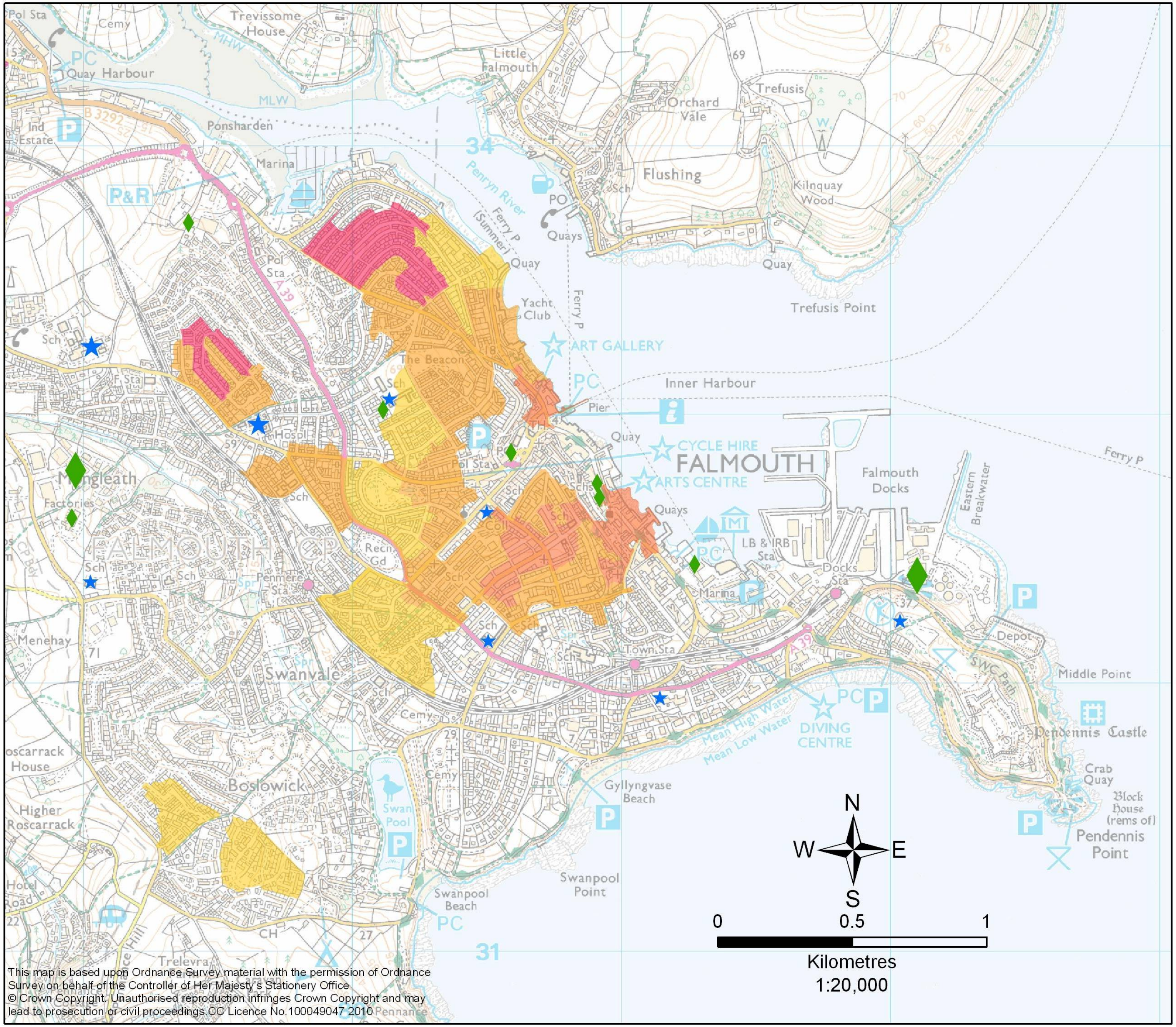
Falmouth



Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

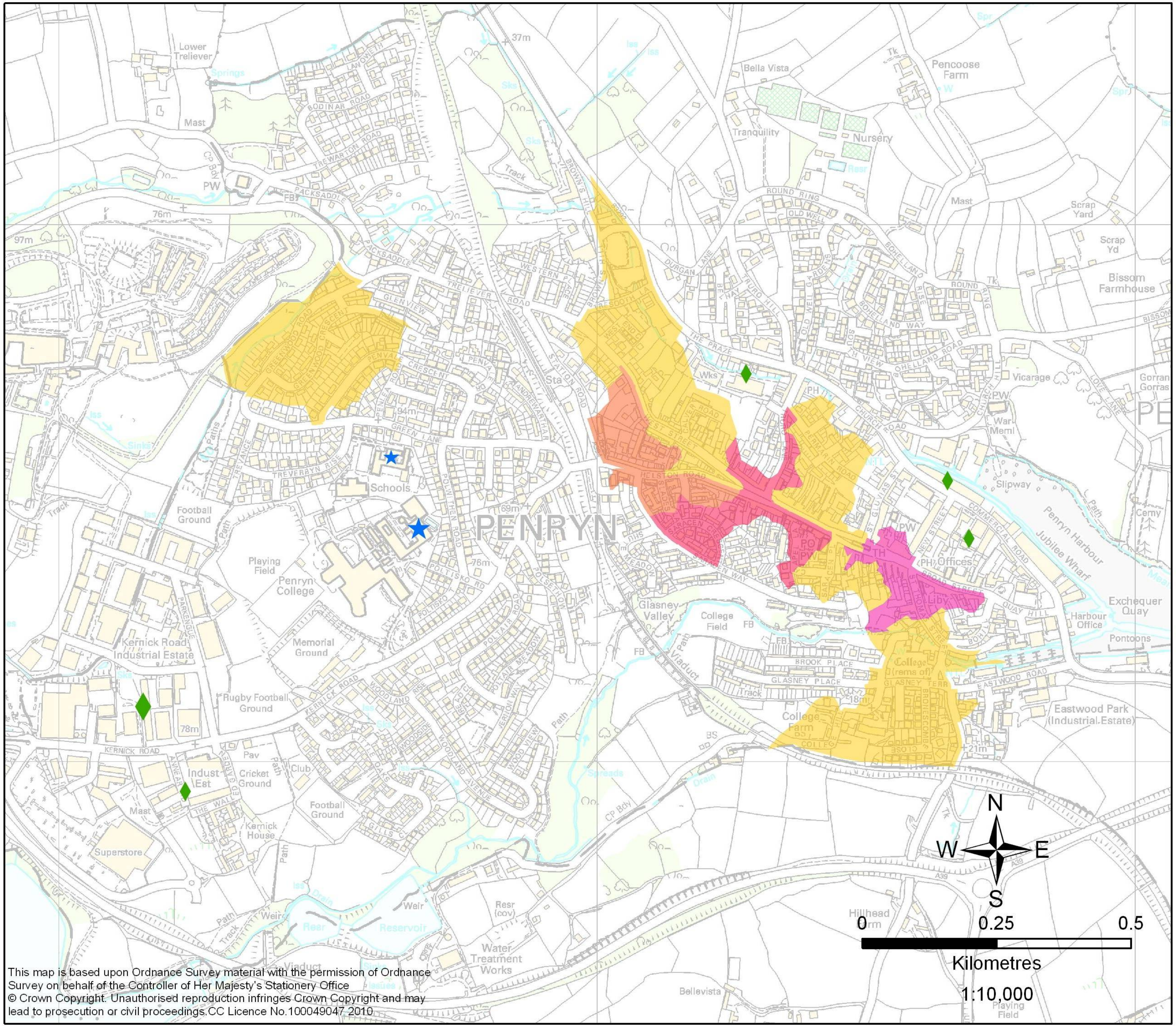
Energy (MWh/a)

- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000



CORNWALL COUNCIL
one and all onen hag oll

Penryn

Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

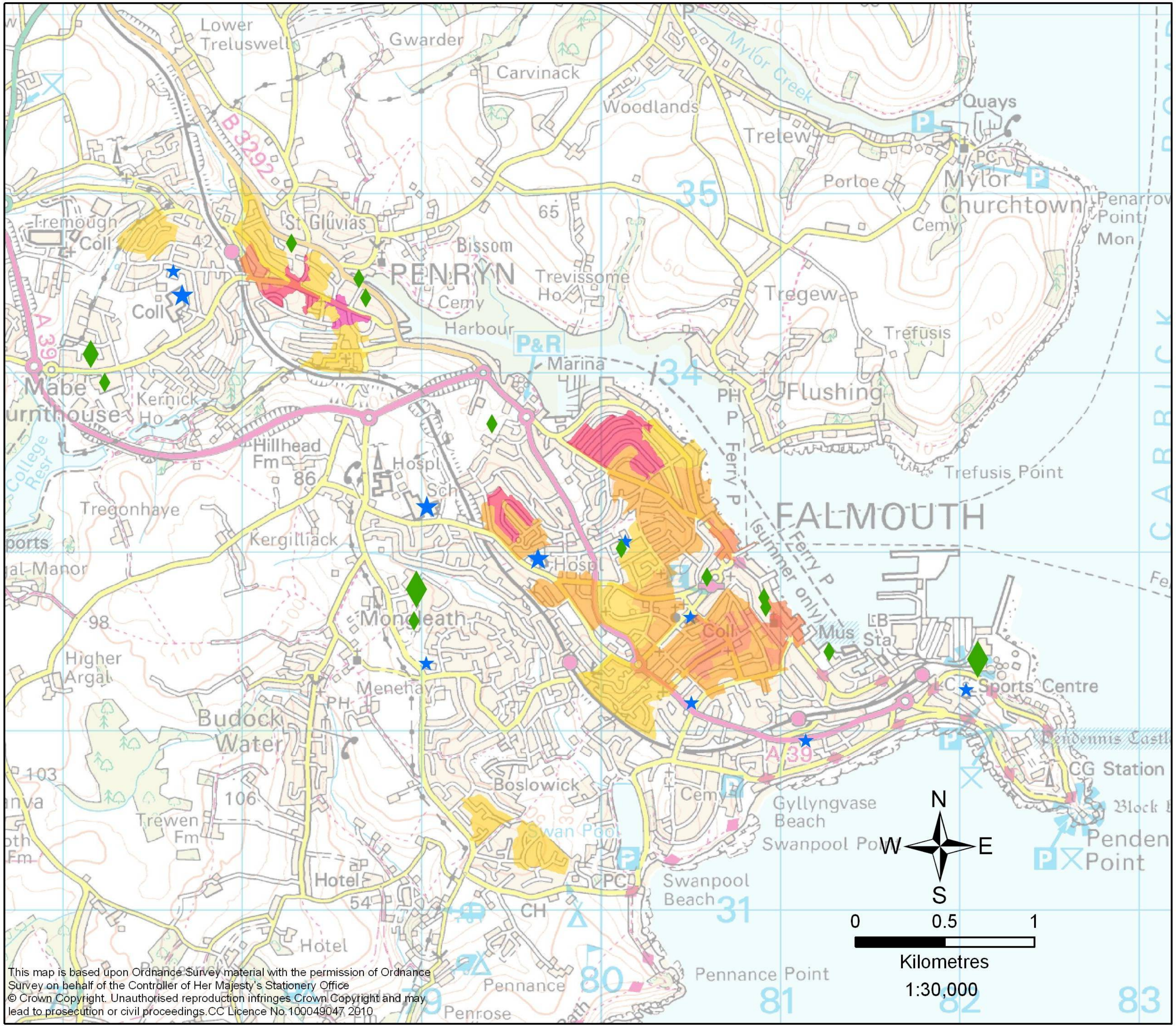
Energy (MWh/a)

- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000



one and all onen hag oll
CORNWALL COUNCIL

Falmouth and Penryn

Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

Energy (MWh/a)

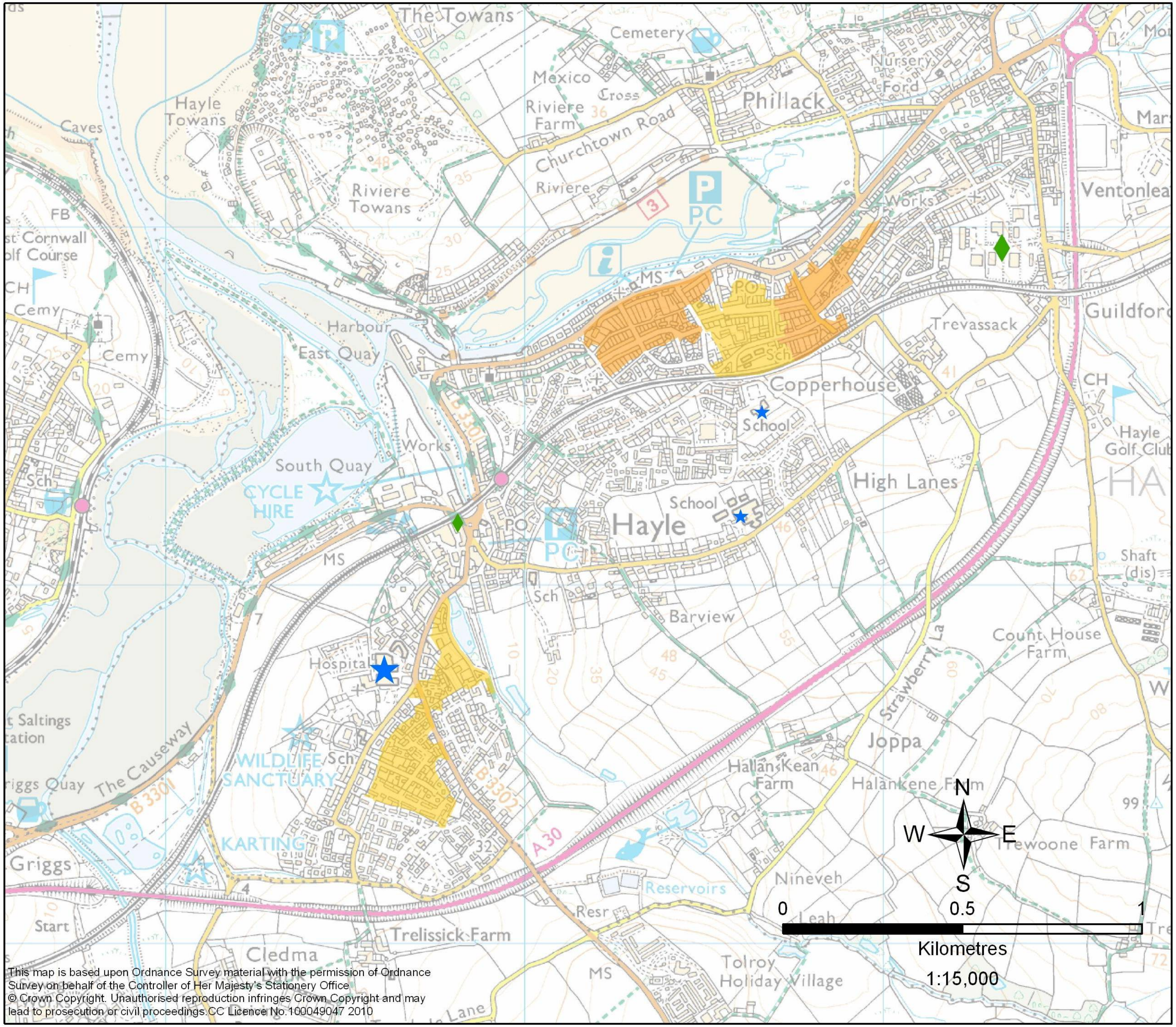
- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000

Hayle



Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

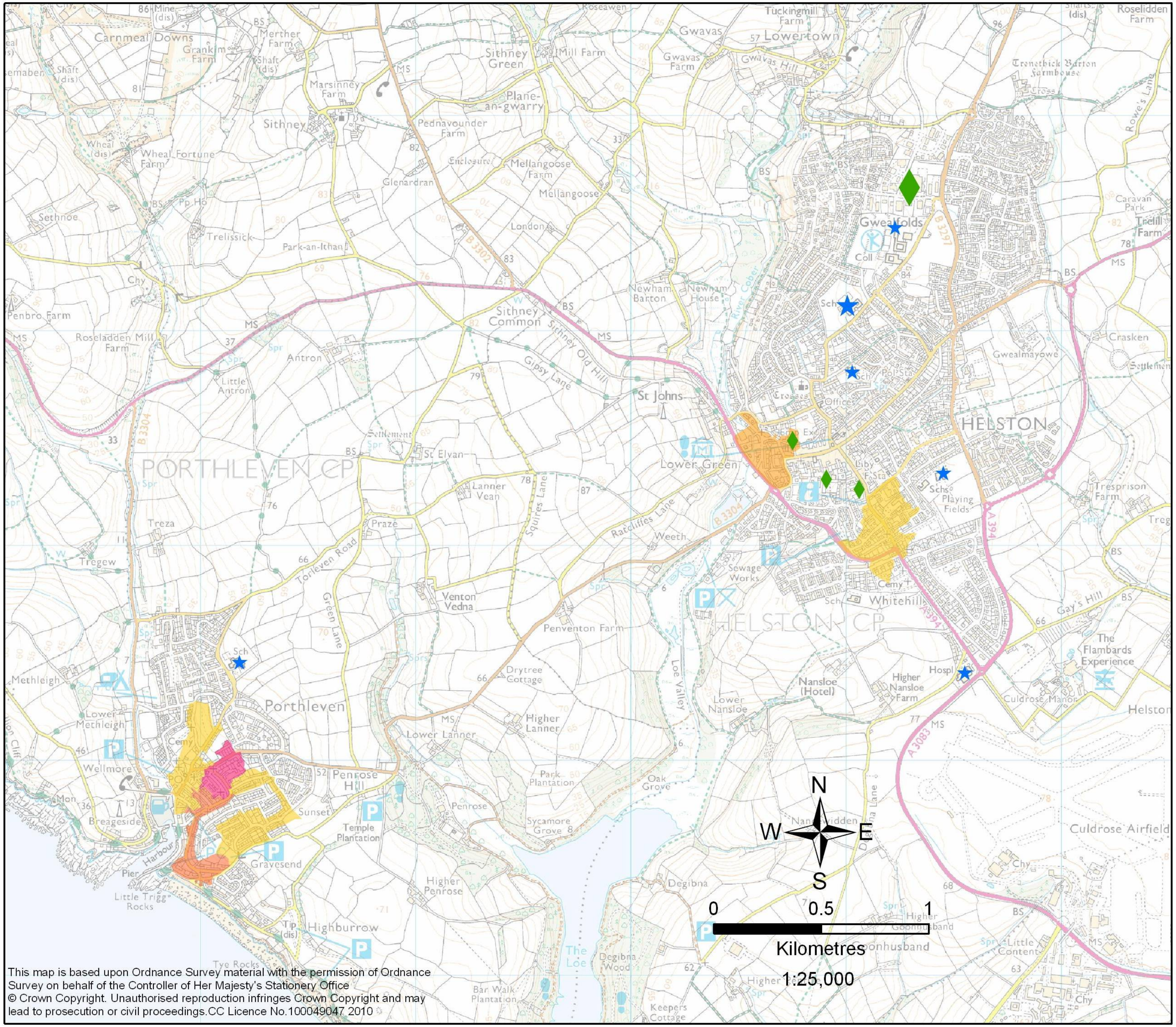
Energy (MWh/a)

- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000



one and all onen hag oll
CORNWALL COUNCIL

Helston and Porthleven

Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

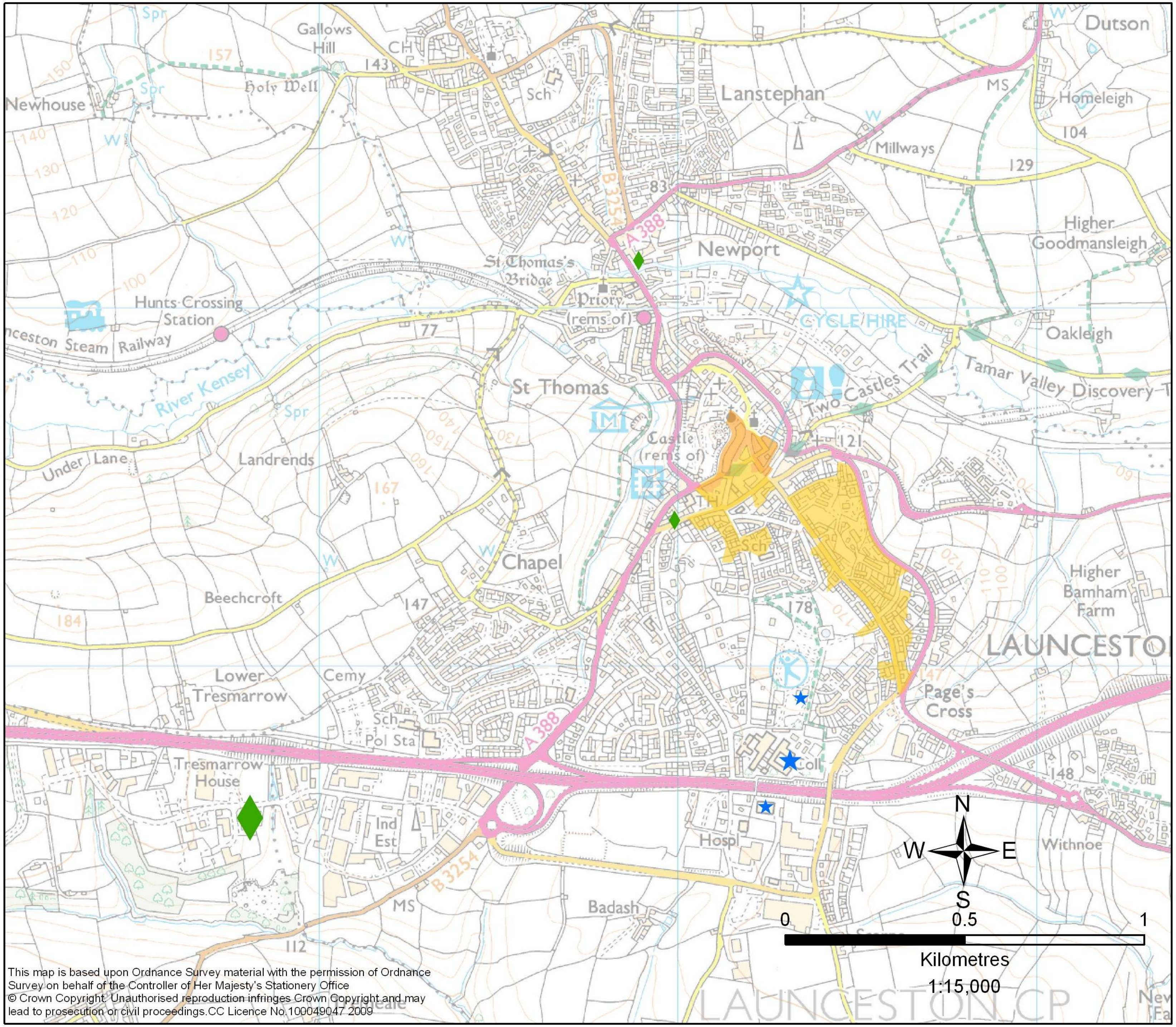
Energy (MWh/a)

- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000



one and all onen hag oll
CORNWALL COUNCIL

Launceston

Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

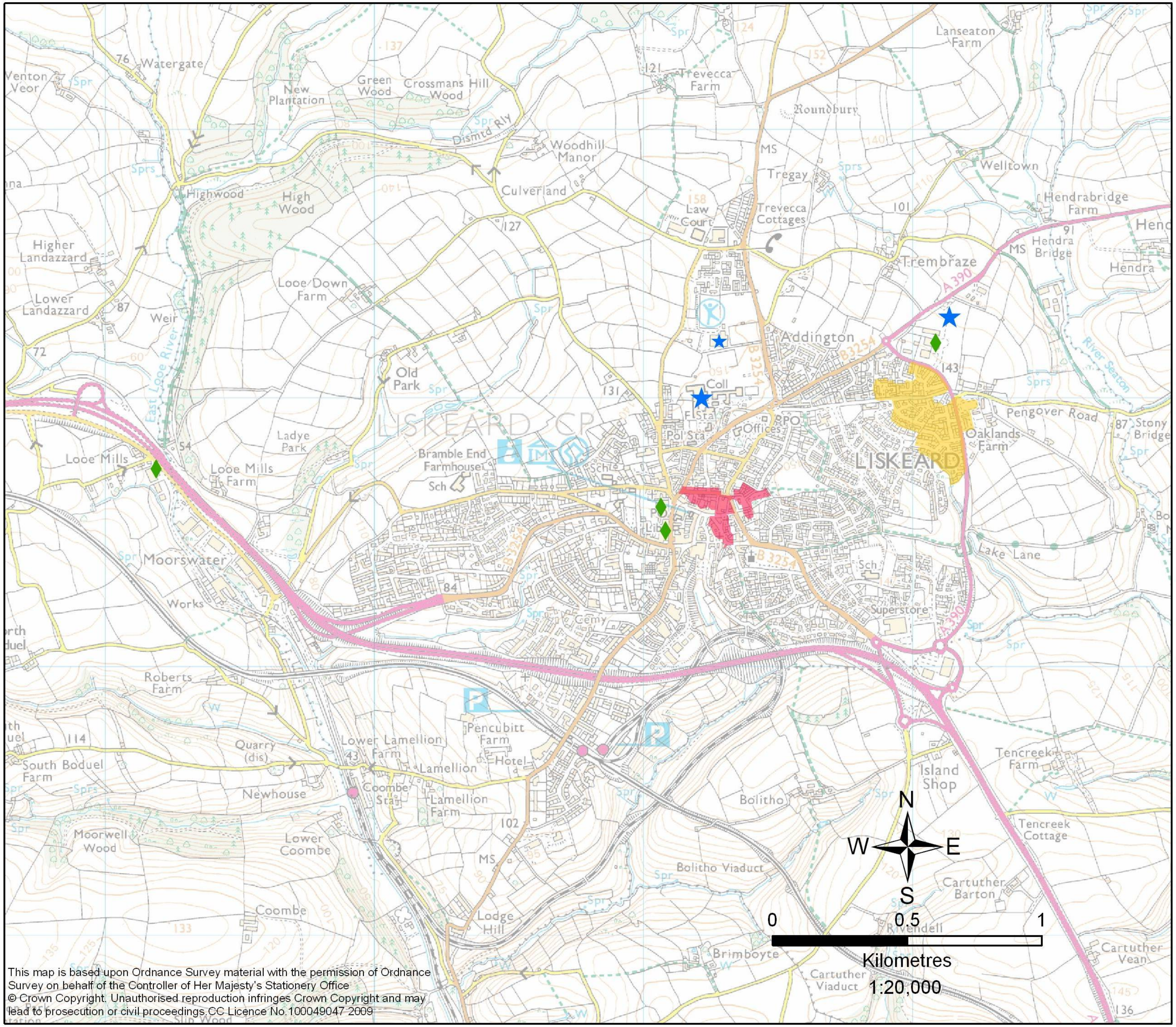
Energy (MWh/a)

- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000



one and all onen hag oll
CORNWALL COUNCIL

Liskeard

Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

Energy (MWh/a)

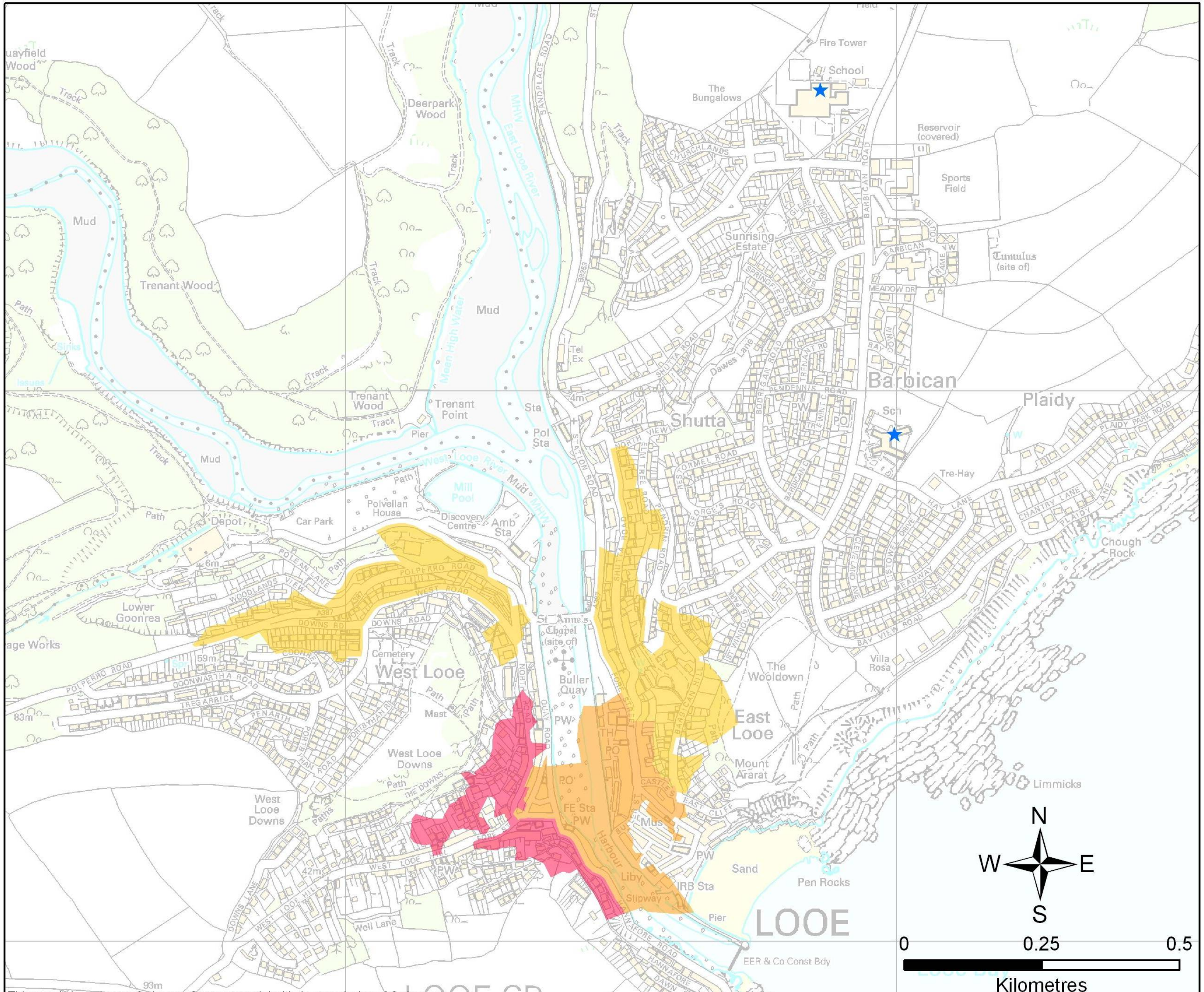
- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000

Looe



Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

Energy (MWh/a)

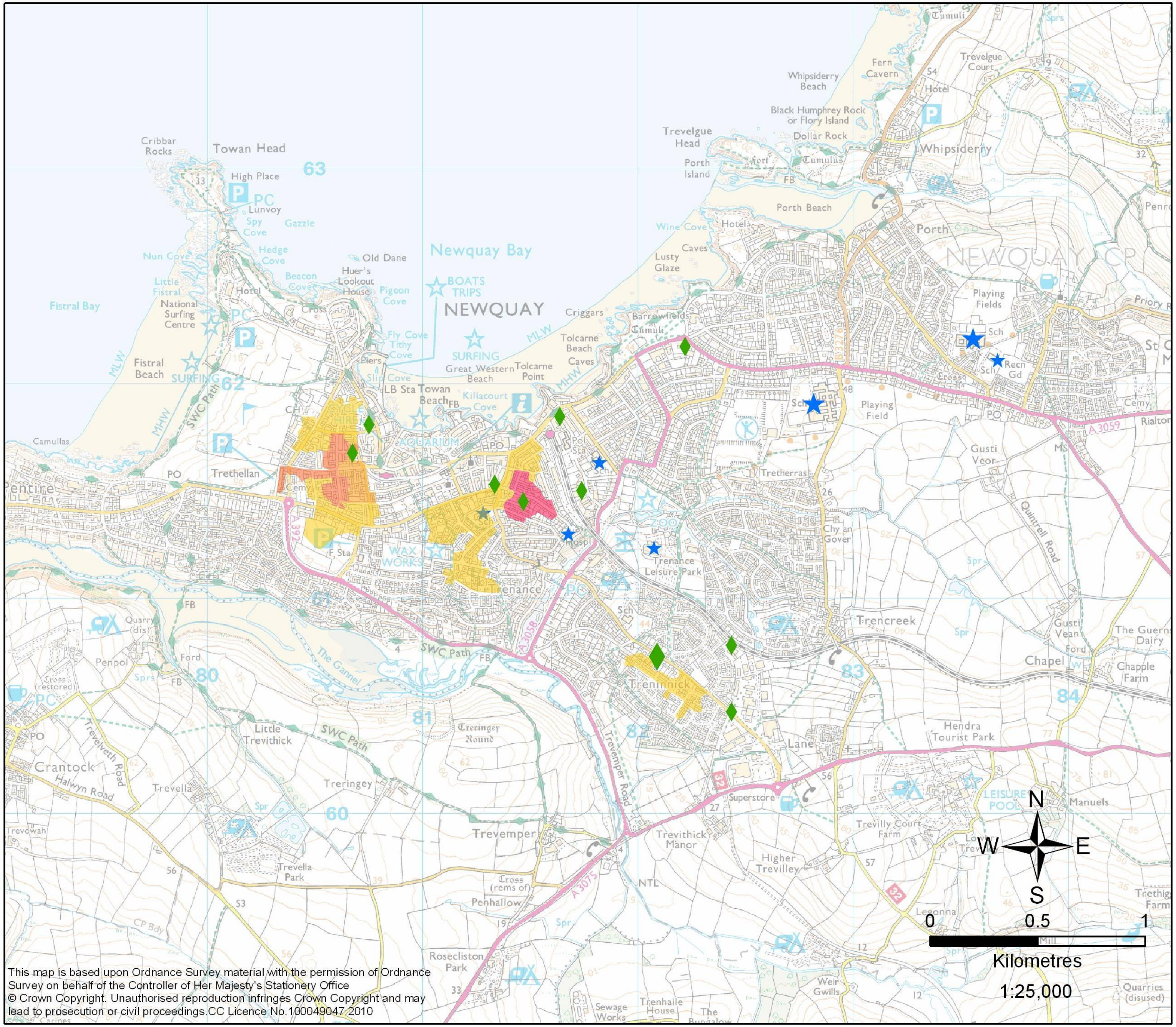
- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000

Newquay



Legend

Domestic

Power density (MW/km2/a)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

Energy (MWh/a)

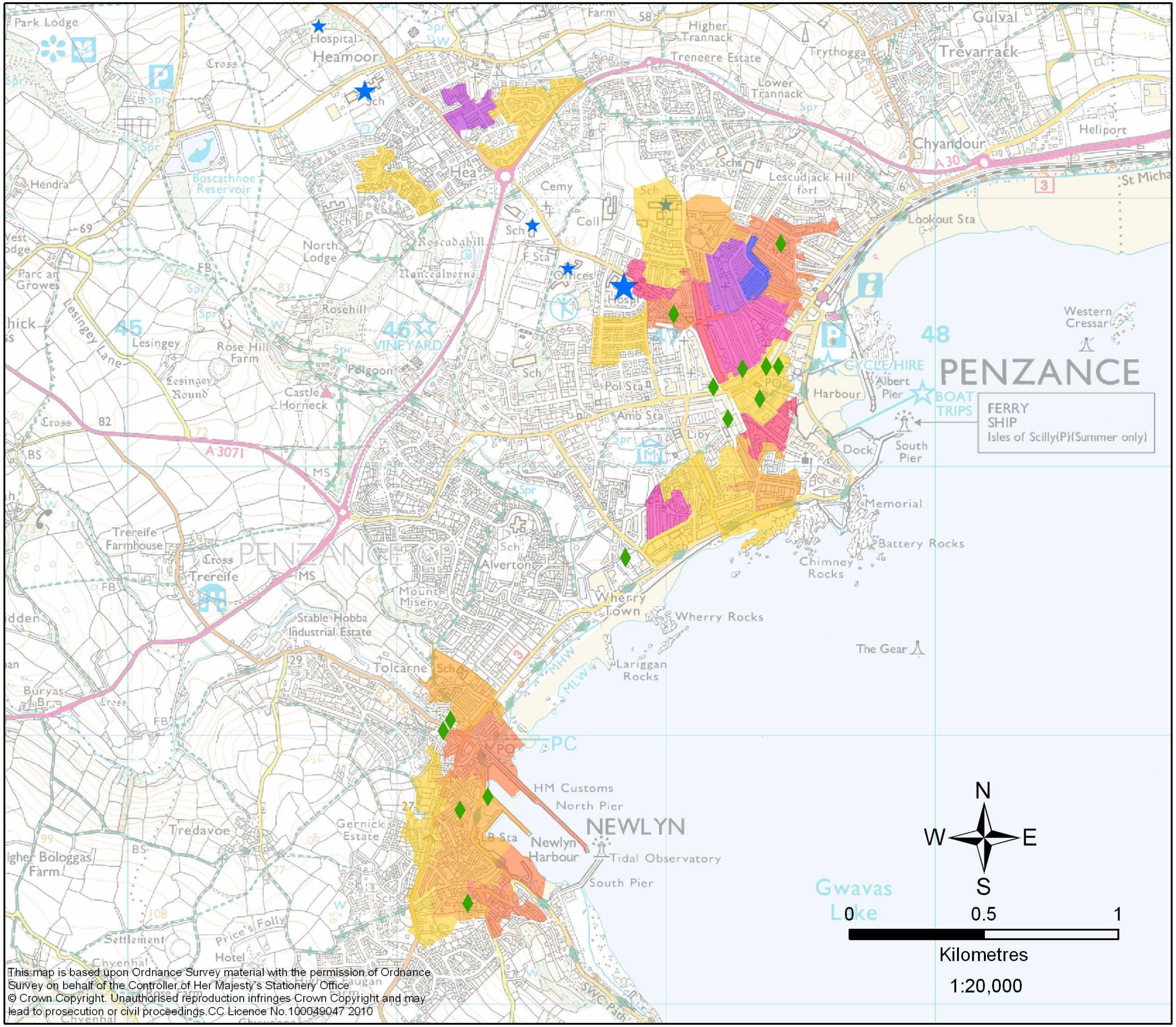
- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)

- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000

Penzance, Newlyn and Heamoor



This map is based upon Ordnance Survey material with the permission of Ordnance Survey on behalf of the Controller of Her Majesty's Stationery Office

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CORNWALL COUNCIL

Legend

Domestic

Power density (MW/km2/a)
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 20

Non-domestic (postcode areas)

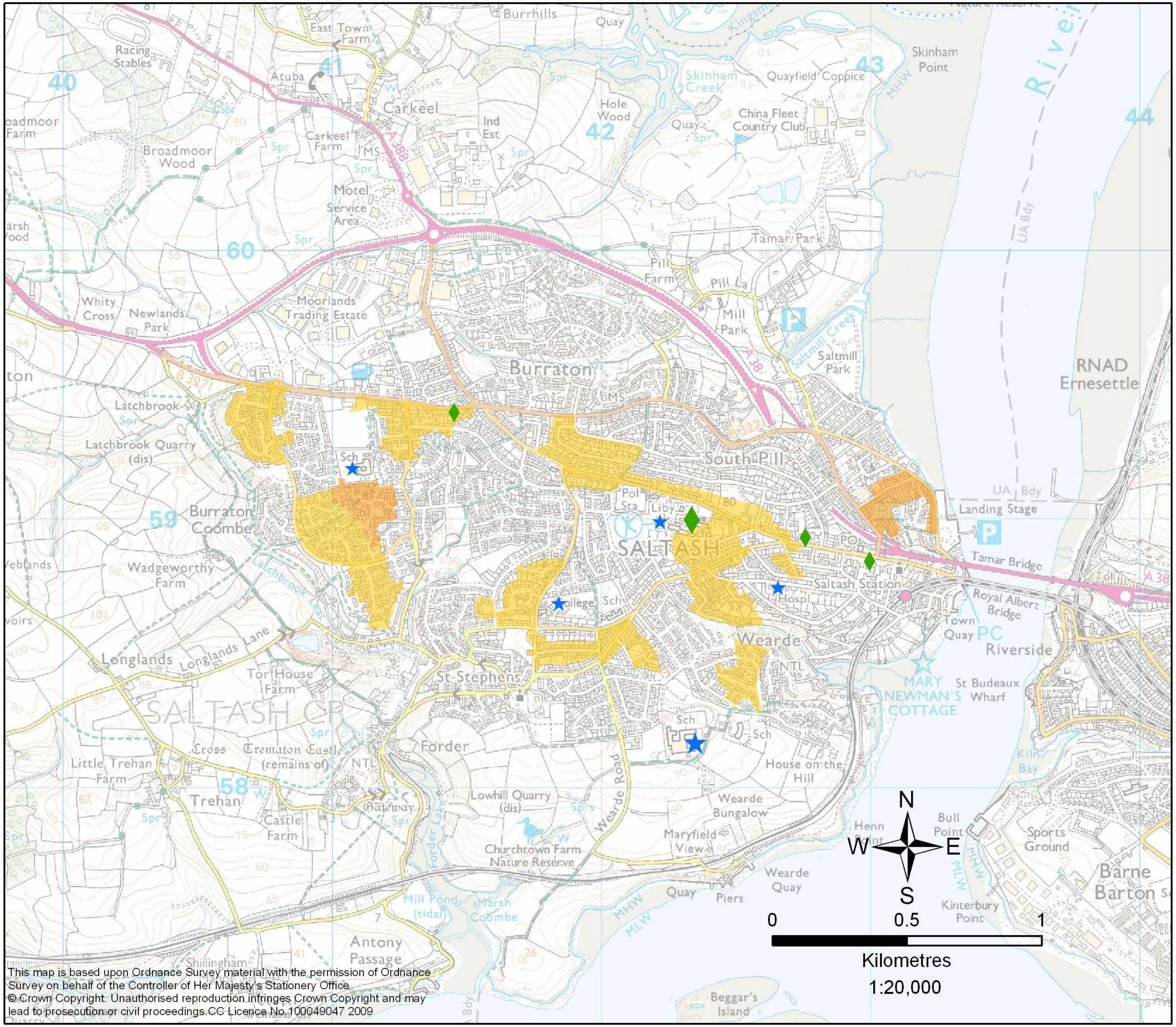
Energy (MWh/a)
- 200 - 800
- 800 - 2000
- 2000 - 4000
- 4000 - 9000

Non-domestic (single loads)

Energy (MWh/a)
- 200 - 900
- 900 - 2000
- 2000 - 5000
- 5000 - 40000

CORNWALL COUNCIL

Saltash



Legend

Domestic

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- 4000 - 9000

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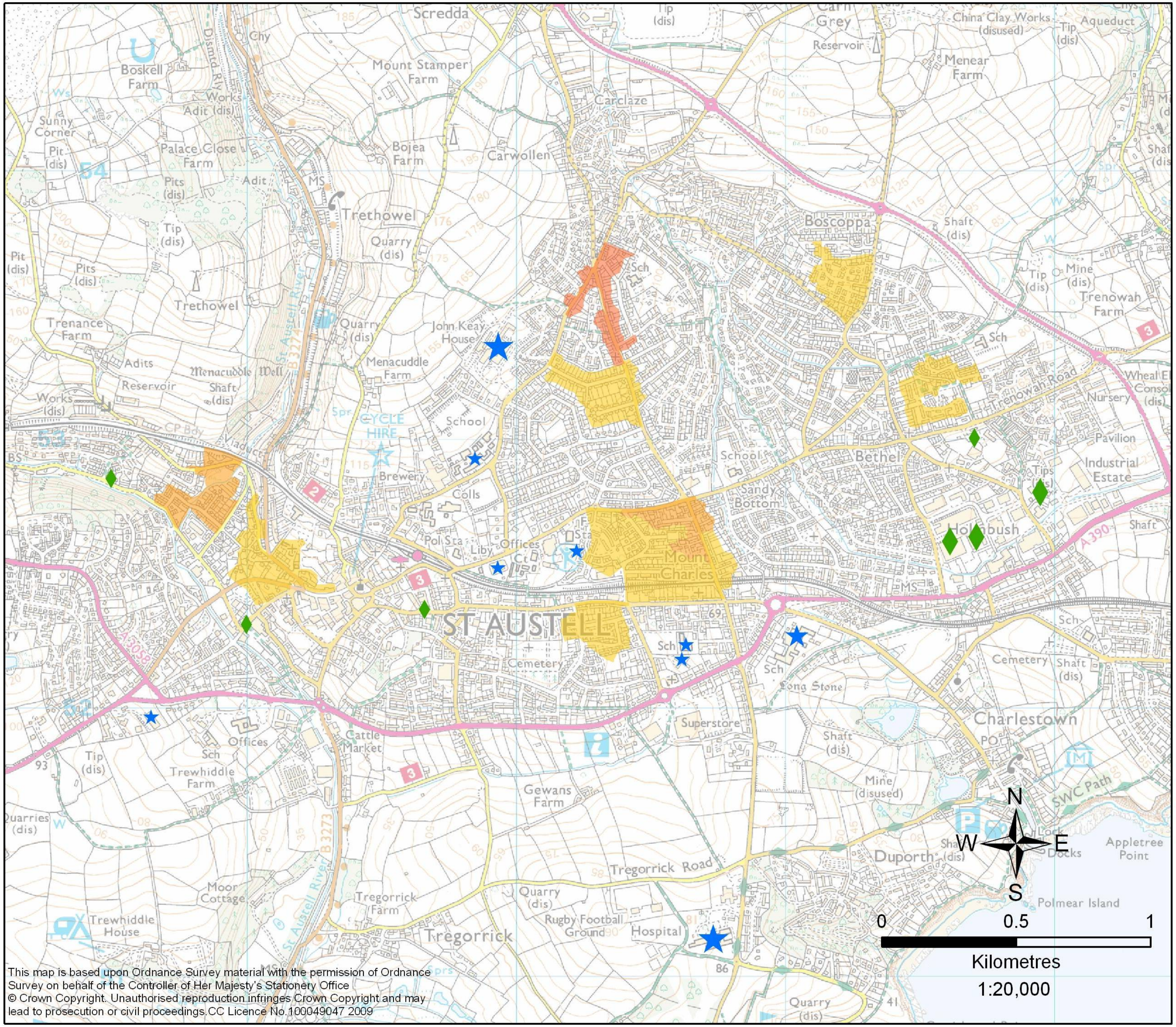
St Austell



Legend

Domestic

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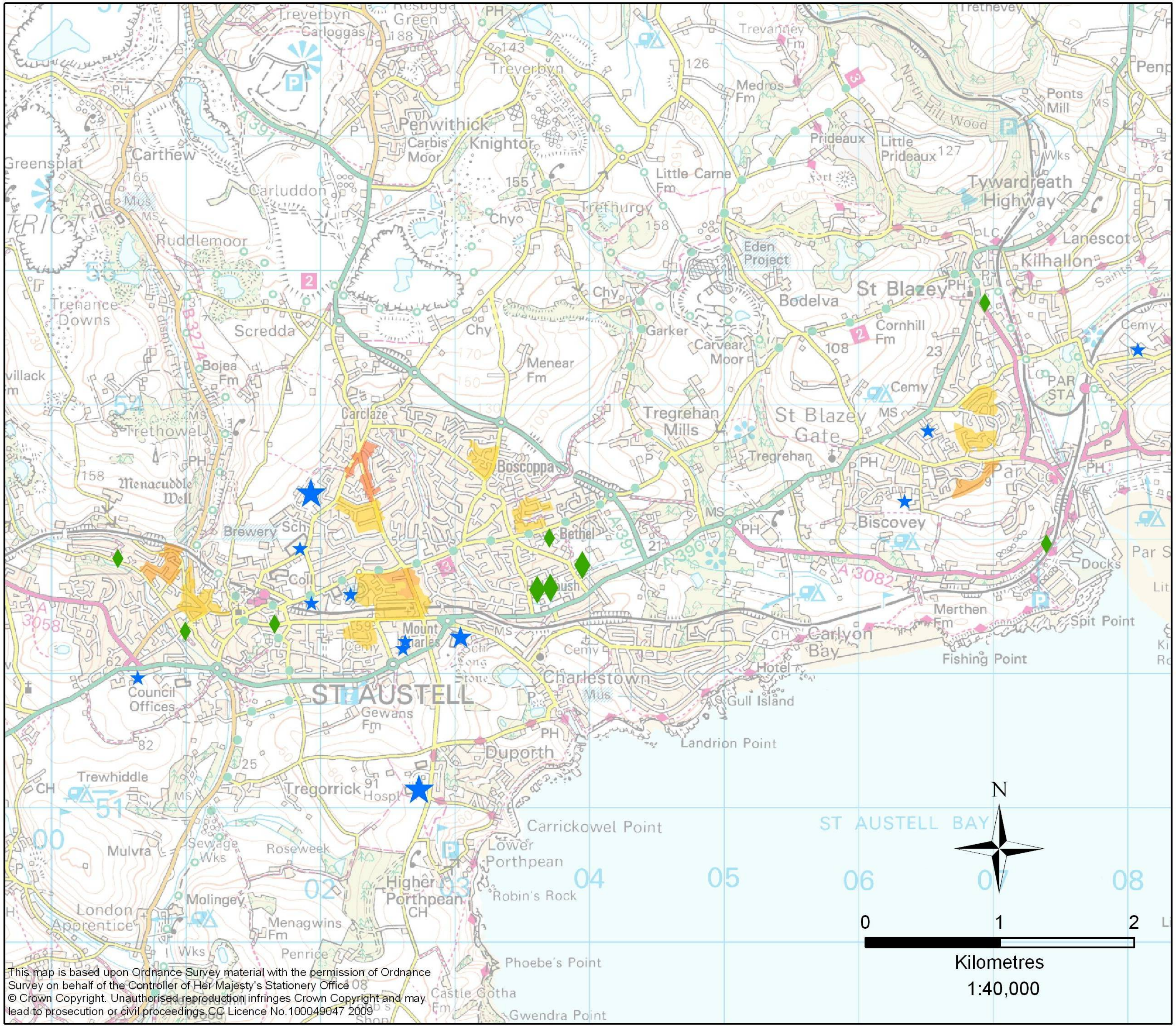
St Austell and St Blazey



Legend

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CORNWALL COUNCIL

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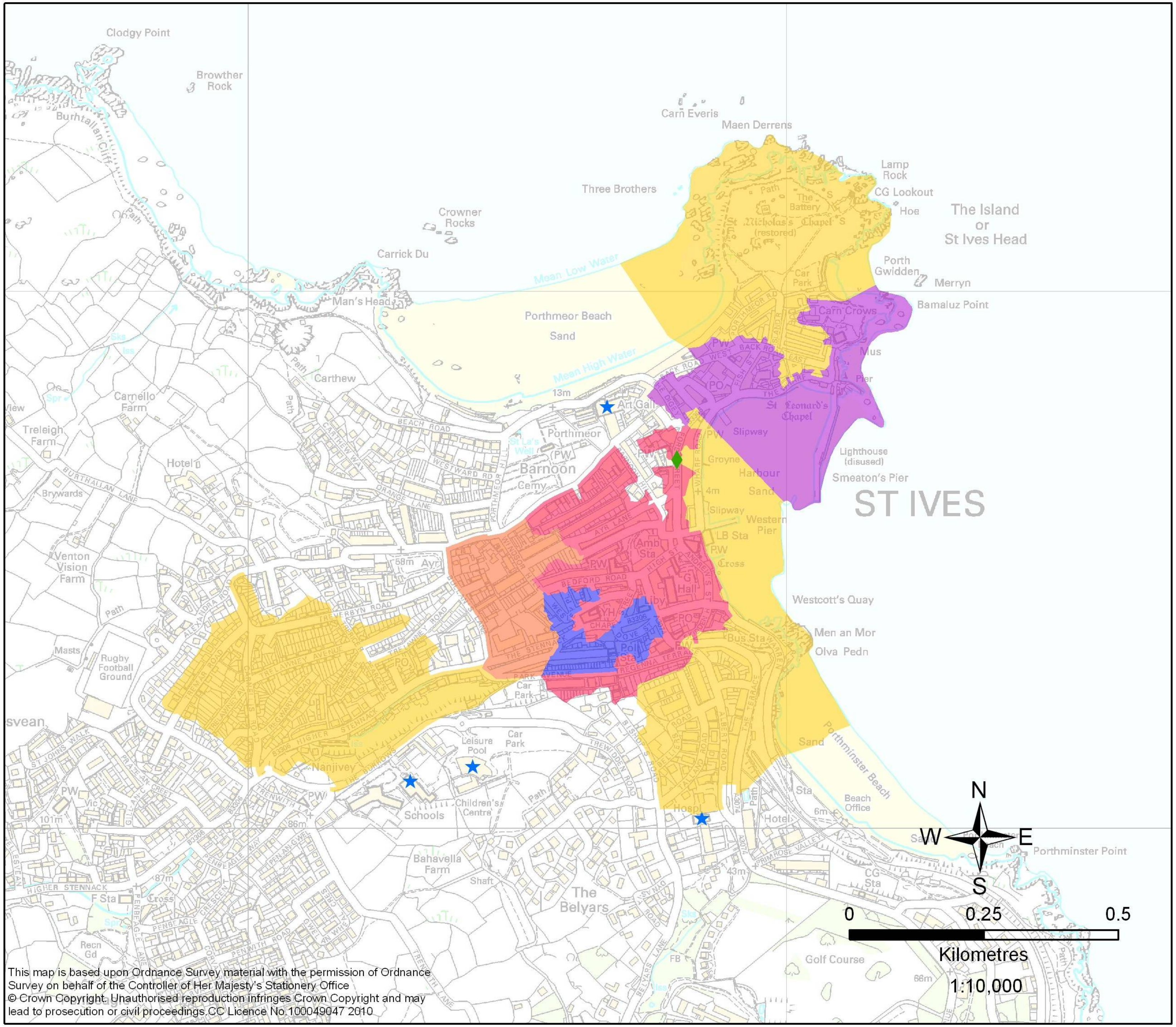
St Ives



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Legend

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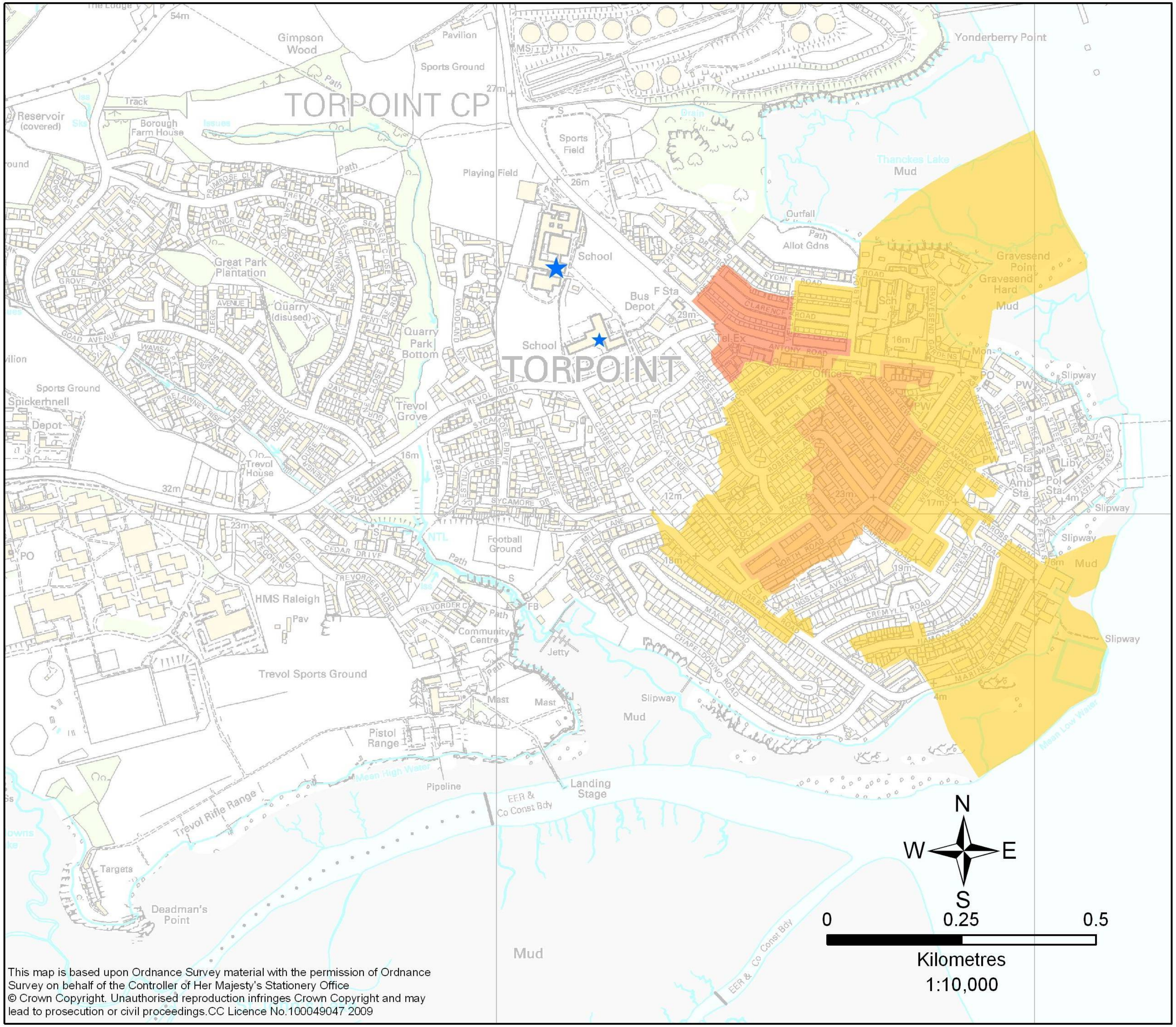
Torpoint



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Legend

Domestic

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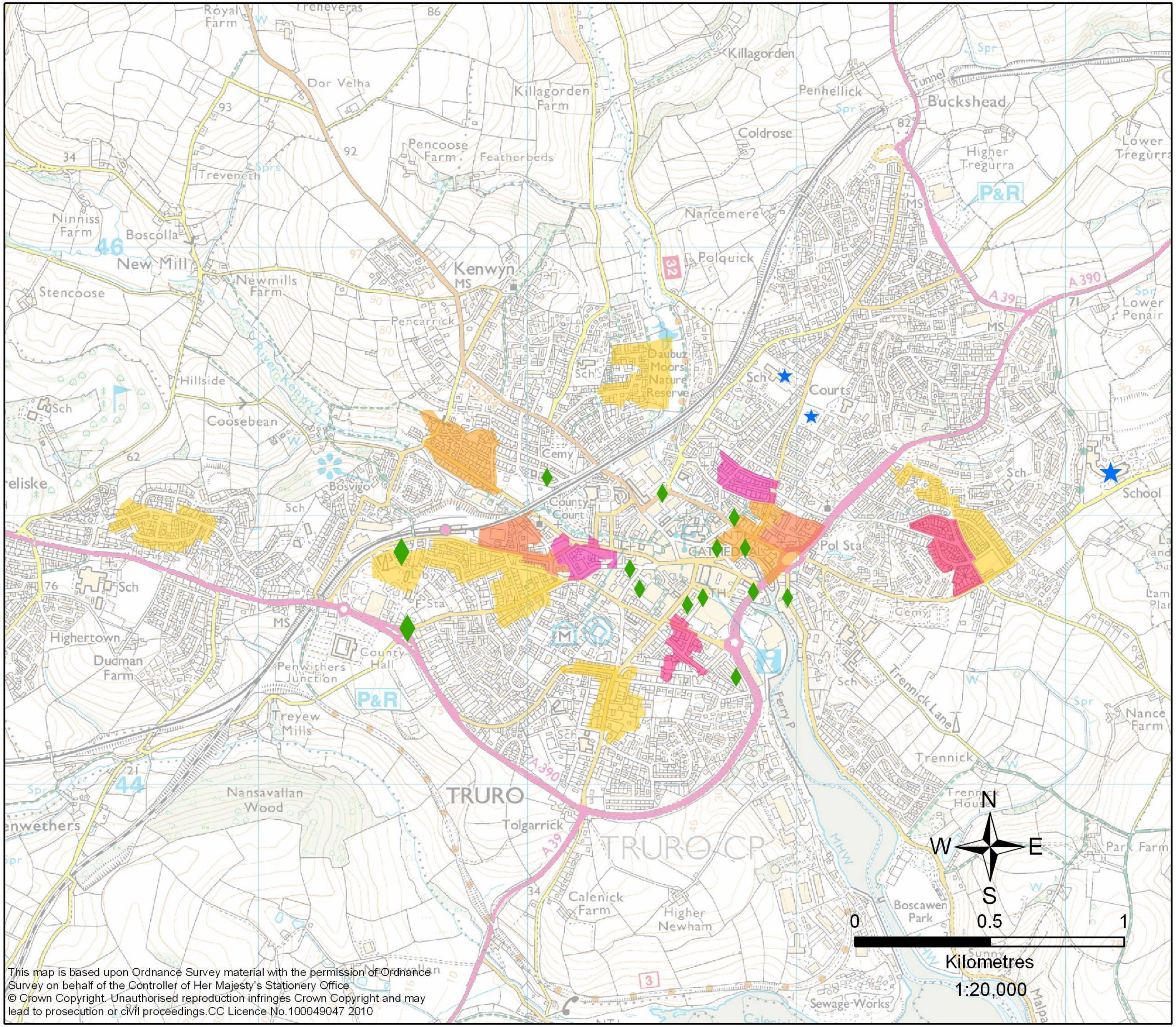
Truro



Legend

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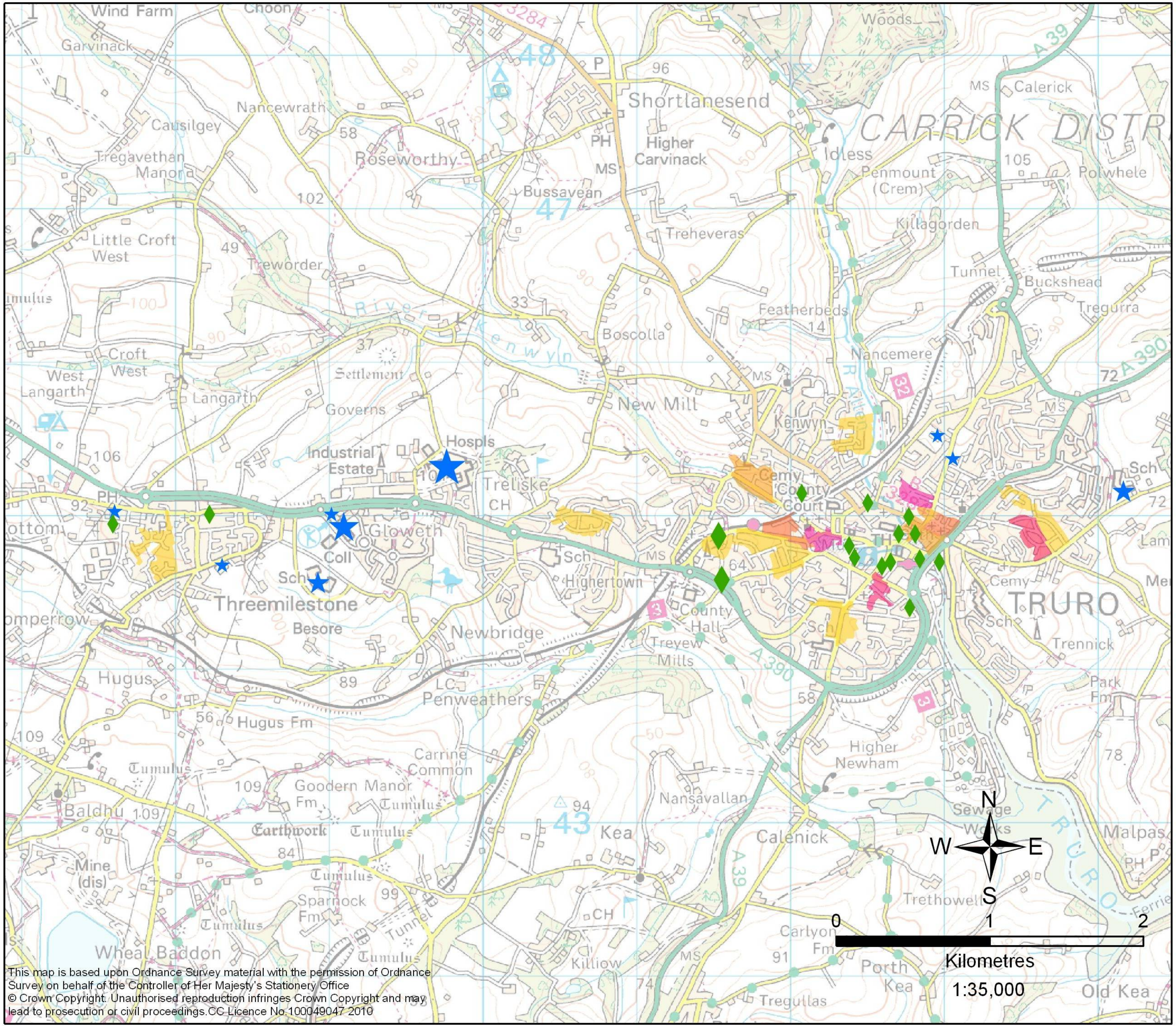
Truro and Threemilestone



Legend

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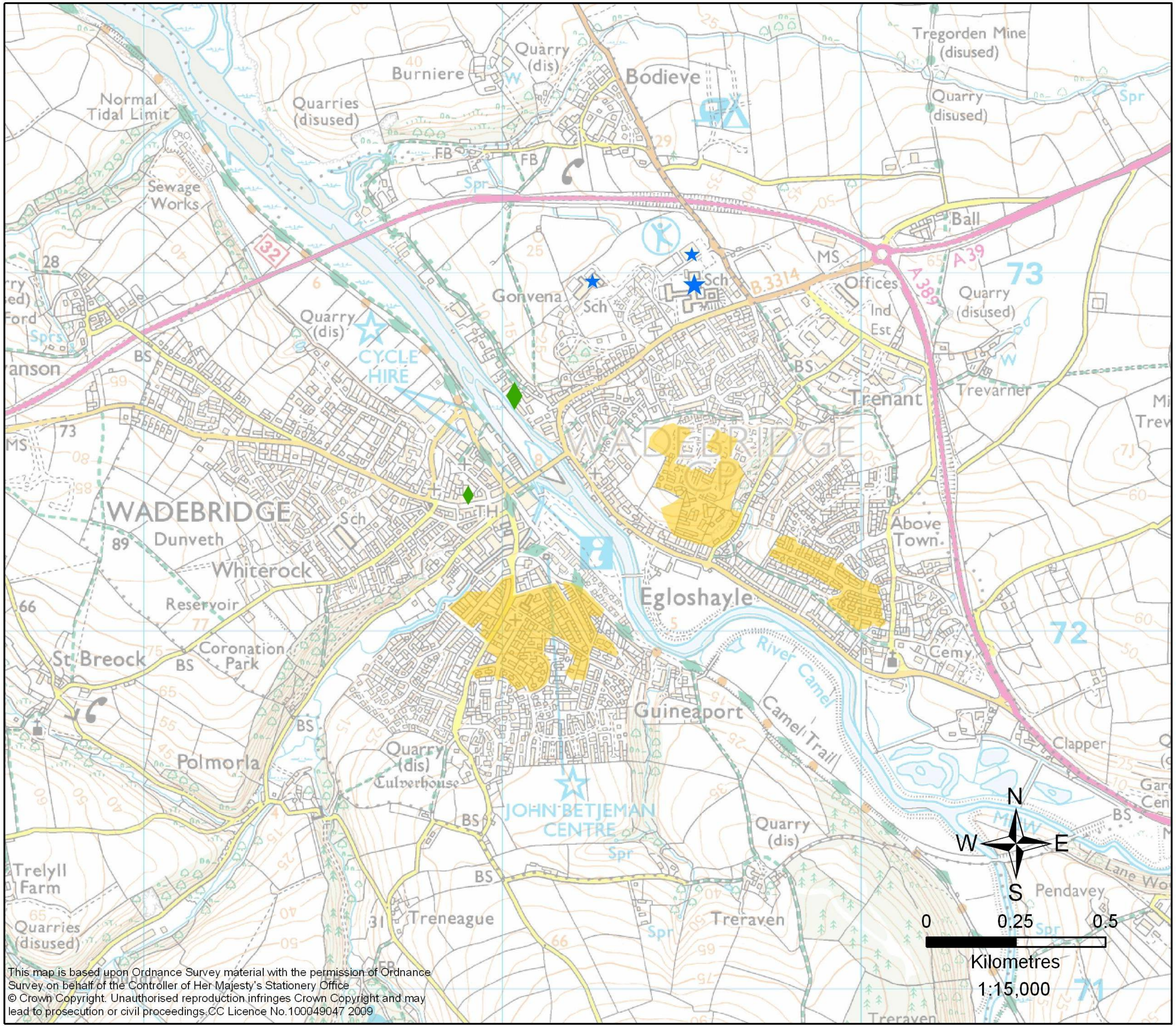
Wadebridge



Legend

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