LCRI Convergence Cross Cutting Themes

Scenario Modelling for a Low Carbon Wales

Written evidence to the National Assembly for Wales Environment and Sustainability Committee; *inquiry into energy policy and planning in Wales.*

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1. Introduction

This written evidence draws on insights from the work of the Scenario Modelling for a Low Carbon Wales Cross Cutting Theme of the Low Carbon Research Institute (LCRI) Convergence Energy Programme.

The Low Carbon Research Institute (LCRI) Convergence Energy Programme was launched in September 2009, with funding from the Welsh European Funding Office matched from Welsh universities and industry. It is a research, development and innovation programme aiming for long-term economic growth and the creation of employment opportunities for Wales by acting in the following priority areas: (i) Hydrogen technologies; (ii) Large scale power generation (iii) Marine energy; (iv) Solar PV; (v) Low carbon built environment; and cross cutting themes (vi) Scenario Modelling; (vii) Welsh Energy Sector Training.

The Scenario Modelling for a Low Carbon Wales Cross Cutting Theme represents a relatively small component of the LCRI's overall research portfolio. Its overall objective is to develop an integrated scenario and modelling framework to support innovation and industrial development underpinning the transition to a low carbon economy for Wales. In the longer term this will enable the LCRI to model the potential contribution to a low Carbon Wales of the emerging technologies developed through its Industrial Research Projects.

Specifically we aim to: i) critically review current scenarios and energy models to examine their utility in a Welsh context; ii) compile a GIS database of Welsh energy resources, infrastructure and demand; iii) specify an integrated 'Welsh Energy Transitions' modelling framework capable of rigorously appraising the long-term carbon-reduction, economic and market potentials of the novel technologies and solutions being developed by the LCRI; iv) develop a range of credible socio-technical scenarios to explore plausible pathways for a transition to a low carbon economy in Wales. This work commenced in July 2010 and is currently scheduled to run through until June 2013.

In relation to the call for eveidence to this inquiry, although our broader research on the regional governance of low carbon transitions highlights the progressive contribution of the Welsh Government to addressing climate and energy issues under devolution, we have not undertaken specific research into the implications for Wales of the current consenting regime for major onshore and offshore energy infrastructure.

The following note addresses the current evidence base with respect to 'regional' scale integrated energy modelling for Wales and assessment of the potential contribution of different low carbon and renewable energy technologies towards achieving the Welsh Government's carbon reduction aspirations and targets. We begin by drawing together the suggested recommendations that flow from this submission.

2. Suggested Recommendations

- There is a clear need to improve the evidence base and our capacity to undertake 'regional' scale integrated energy modelling and assessments for

Wales, in order to better support effective implementation of the Welsh Government's progressive carbon reduction policy aspirations and targets going forward.

- The potential contributions of different technologies need to be assessed in parallel and against common background techno-economic scenarios. An integrated approach when examining the options for the energy system of the future will reveal the critical factors which are within the competence of different actors and inform on potential policy interventions in the planning system.
- Regional scale integrated modelling would also provide more accurate indicators towards monitoring the progress against the 3% annual emission reduction target, together with a detailed re-assessment of the reduction potential, based on Wales-specific data in sectors where notable differences exist between the UK as a whole and Wales.
- Further research is also required to establish the most appropriate and effective indicators and metrics for monitoring progress against the Welsh Government's policy objectives of achieving emission reductions at end user levels and promoting renewable power generation.

2. Summary of Key Points

There is considerable expertise and a range of well established tools available for integrated energy system modelling and assessment at a national (UK) scale [1]. However, the capacity to undertake detailed regional scale integrated modelling and assessments is much less well advanced.

Whilst a number of partial assessments have been undertaken of the potential contribution of different technologies and policy measures, as far as we are aware there is currently no integrated energy system model for Wales.

In this context the LCRI Scenario Modelling for a Low Carbon Wales Cross Cutting Theme is currently: i) compiling a Welsh Energy Atlas – a GIS database of Welsh energy resources, infrastructure and demand from publicly available sources; and ii) working on the development of an integrated Welsh energy modelling framework with the objective of rigorously appraising the long-term carbon-reduction, economic and market potentials of the novel technologies and solutions being developed by the LCRI. However, the LCRI has relatively limited resources available for this work (approximately 84 months of researcher time over 3 years).

The Welsh Energy Atlas aims to highlight the spatial aspect of energy technologies and policies and encourage partners and stakeholders to adopt an innovative approach in considering future investments and development potential. In the first instance, it aims to collate and review available information that may be relevant in the

[1] Summarised in recent reviews by, among others, the Energy Research Partnership (*Energy innovation milestones to 2050 report, March 2010*), the Tyndall Centre (*Mander, S. L., Bows, A., et al. 2008 The Tyndall decarbonisation scenarios-Part I: Development of a backcasting methodology with stakeholder participation. Energy Policy 36(10): 3754-3763*) and the Transition Pathways to a Low Carbon Economy consortium (*Hughes, N., Strachan, N., 2010. Methodological review of UK and international low carbon scenarios, Energy Policy 38 (10) : 6056 – 6065*) as part of their ongoing work in the field.

discussion on energy issues in the Welsh context. Having brought this knowledge together, it will then seek to promote an integrated approach to answering some of the prominent research and policy questions, through connecting multiple layers of information on resources, impacts and interactions across different sectors. It will also seek to bring this information to the attention of interested groups and stakeholders that may not have access to GIS in order to process and analyse the data themselves.

The Energy Atlas has the potential to integrate a large amount of information from different sources and provide valuable information relating to the needs of specific regions in Wales. To this extent the Scenario Modelling project is keen to investigate output formats and contributions that may be of interest to regional stakeholders. (For further details see *Spatial Overview of the Welsh Energy System*, attached as Annex 1). The LCRI Scenario Modelling for a Low Carbon Wales Cross Cutting Theme has also been undertaking the development of a GIS Solar Atlas for Wales, in order to improve the future assessment of the potential for deployment of Photovoltaics(PV) and solar thermal technologies across Wales (further details are available from the authors of this evidence submission).

Targeting residential emissions (including indirect emissions from electricity) is one of the key areas for achieving the 3% annual greenhouse gas emission reductions target in sectors within devolved competence by 2020. In Wales, the residential sector has a larger share of "hard to treat" properties compared to the rest of the UK[2]. Therefore the potential for energy efficiency improvement of the housing stock in Wales is higher than elsewhere in the UK, albeit with a higher associated marginal cost. At the time of writing there is no representative residential "stock model" for Wales. As part of our work to develop an integrated Welsh energy modelling framework, we are therefore in the process of establishing a residential sub-model to address stock-specific constraints and opportunities that arise from specific strategies.

4. The current evidence base

Despite a wealth of studies at UK level, it can be challenging to derive insights into the regional scope of the different technologies and transition pathways. This is because most research does not address UK regions and devolved administrations separately, although some studies do offer disaggregated results, for example the Committee on Climate Change (CCC) report "Building a low-carbon economy - the UK's contribution to tackling climate change (2008)".

We are aware that on occasions the CCC, within its role to work closely with devolved administrations and take into account differences between the regions, provides advice to the Welsh Government on its Climate Change Strategy and carbon reduction targets. However, unlike in the case of Scotland, which has its own Climate Change Act, a similar study has not been commissioned for Wales.

Assessments of individual technologies and their limitations in the Welsh policy context are available through two Wales-specific projects commissioned by the Welsh Government:

[2] W. Baker, I. Preston. Targeting energy efficient resources in Wales. Report to Welsh Assembly Government. Centre for Sustainable Energy, 2006.

AEA's "Policy options development and appraisal for reducing greenhouse gas emissions in Wales (2008)"[3] sets a baseline for emissions under a business as usual scenario and lists policy options for GHG reductions in support of the aims and commitments set out by the Welsh Government. The study ranks options in terms of cost and highlights priority policy interventions per sector. A short comparison across sectors was attempted but no aggregate results were derived since the interactions between the different measures across sectors were not taken into account.

The Tyndall Centre, in their work "Towards a 2°C future: emission reduction scenarios for Wales (2009)"[4], examined the pathways and implications of achieving emission reductions beyond the 3% already pledged in policy documents. The analysis focuses mainly on the devolved sectors, while assuming successful implementation of the Renewable Energy Route Map, which implies electricity demand being fulfilled by zero-carbon generation by 2025. The Tyndall report has identified and accounted for overlapping activities in the sectors examined. It has also acknowledged that the implementation of the Renewable Energy Route Map may face potentially serious impediments and require considerable effort on the part of the Welsh Government.

The above studies are a useful staring point for setting emission baselines and scoping out the potential contribution of certain technologies in the transition to a Low Carbon Wales. However, they highlight that more research is needed on the emerging technologies and pathways identified, especially when it comes to enabling or disruptive factors and system interactions.

The target of 3% reduction per year, relates to all direct emissions of the six greenhouse gases in Wales except those covered by the EU Emissions Trading Sscheme (EUETS). In addition, recognising the importance of reducing electricity consumption, power generation emissions (which for the most part are covered by the EU ETS) are also included in the 3% target for monitoring purposes, by assigning them to the end-user of the electricity in each of the non-traded sectors. So in effect the 3% target is to be calculated on the basis of all direct emissions, except those from heavy industry and energy generation, and including electricity consumption. According to the policy, a UK-wide carbon intensity factor is to be used to convert this electricity use into tonnes of CO_2 equivalent. Investigating electricity consumption at end-user level is essential in order to devise measures that will influence demand and optimise supply.

However, it is questionable whether using a UK-wide factor to convert electricity use to GHG emissions is the best way to monitor progress against this target in the medium to longer term. Welsh Government aims, as stated in "A Low Carbon Revolution – The Welsh Assembly Government Energy Policy Statement"(2010), to be able to generate twice as much renewable electricity annually in 2025 as presently consumed in Wales, with a view to expand this to cover all local energy needs by low carbon electricity by 2050. Further research is therefore required to establish the most

[3] Forster, D. and P. Levy (2009). Policy Options Development & Appraisal for Reducing GHG Emissions in Wales - Report to the Welsh Assembly Government, E. Gmitrowicz, Editor. AEA Group.

[4] Calverley, D., Wood,R. et al (2009). Towards a 2°C future: emission reduction scenarios for Wales. A research report by The Tyndall Centre, commissioned by the Climate Change Commission of the Welsh Assembly Government.

appropriate and effective indicators and metrics for monitoring progress against the Welsh Government's twin policy objectives of achieving emission reductions at end user levels and promoting renewable power generation.

While there is inherent complexity in distinguishing the Welsh energy system from that of the UK, it is essential to adopt the "island" approach if we are to gain any insights about the effect of devolved policy decisions, as the Tyndall study also indicates. This could offer an insight into the balance of energy supply and demand within Wales, and the associated emission levels and marginal costs which will define whether new technologies are competitive or not. In addition, research has shown[5] that the effectiveness of energy saving measures in terms of carbon emission reductions is dependent on the marginal emission factor of the large scale power generator at the time[6] they come into effect. This underlines the importance of understanding the dynamics of the different resources available in the power sector. The picture is further complicated by the potential impacts of the forthcoming UK Electricity Market Reform upon the economic environment for renewable energy, as well as the potential impact of new technologies, such as smart grids/controls and meters, which could impact both the supply and demand sides.

A recent report commissioned by the Welsh Government has provided an assessment of onshore wind projects in progress and the potential for further capacity within the Strategic Search Areas[7].

The importance of Marine resources for the Welsh energy system is recognised and documented in a number of studies looking into the potential for marine energy in the region[8].

The PV Solar Energy Road Map for Wales[9] maps the current position of technologies, markets, industrial capacity and supply chain of PV in Wales and outlines development strategies to achieve future aspirations in the sector.

There is an established research and stakeholder network looking into the future of hydrogen applications for Wales[10].

A number of choices may be available for each sector, which will come with a different set of pros and cons in terms of feasibility, cost, resources, maturity, time

[5] Among others research by A.D. Hawkes (Estimating marginal CO2 emissions rates for national electricity systems, Energy Policy, 38 (2010) 5977-5987) and Bettle et al (Interactions between electricity-saving measures and carbon emissions from power generation in England and Wales, Energy Policy, 34 (2006) 3434-3446).

[6] Both in terms of point in the pathway they may be ready for implementation and the actual time of operation and influence they have on the daily or seasonal supply /demand curve

[7] Strategic Search Area (SSA) Reassessment and Validation - Research Report to the Welsh Assembly Government. 2010, Ove Arup and Partners.

[8] Wales specific studies performed by, among others, PMSS (Wales Marine Renewable Energy site Selection, 2006), the Marine Energy Task group for Wales (Marine Renewables and their context within the Wales Spatial Plan, Pembrokeshire -the Haven, 2009) and RPS (The Marine Renewable Energy Strategic Framework (MSREF) for Wales)

[9] A PV Solar Energy Road Map for Wales, prepared by Dr Anne Stafford, Centre for SolarEnergy Research (CSER), Glyndŵr University in association with OpTIC Technicum, v.2 updated 2008.

[10] Hydrogen Valley Initiative and Cymru H2 Wales (2004) A Vision of the Hydrogen Economy in Wales - Placing Wales in a position to take full advantage of the hydrogen economy.

and scale of deployment etc. In addition, a number of these choices might be mutually dependent or exclusive, may have to compete for resources or have knock-on effects on other sectors. The potential for energy and emission savings of emerging technology options should not be explored in ways that de-couple them from other developments that may be taking place at the same time. In practice, technologies will have to compete for resources, depend on infrastructure investments and may have a very limited time window in which to capture the readily accessible share of the market. The commercial readiness of competing technologies and the economic climate may reduce deployment potential and impact, especially if technologies are targeted at the same sector.

Increasingly, technologies that tackle energy supply and demand at a distributed level become both available and necessary, in order to achieve energy efficiency and emission reduction targets, and the responsibility for their implementation is passed further down the administrative level. It follows that to ensure the effectiveness of such measures at a regional level their deployment needs to account for the differences between the different areas of implementation.

5. Conclusion

The suggested recommendations that flow from this submission can be found in section 2, above. We repeat them in brief form here

- There is a clear need to improve the evidence base and our capacity to undertake ‘regional’ scale integrated energy modelling and assessments for Wales.
- The potential contributions of different technologies need to be assessed in parallel and against common background techno-economic scenarios, using an integrated approach.
- Regional scale integrated modelling would also provide more accurate indicators towards monitoring the progress against 3% annual emission reduction target, with a detailed re-assessment of the reduction potential based where appropaiate on Wales-specific data.
- Further research is also required to establish the most appropriate and effective indicators and metrics for monitoring progress against the Welsh Government’s policy objectives of achieving emission reductions at end user levels and promoting renewable power generation.

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Annex to the Written evidence to the National Assembly for Wales Environment and Sustainability Committee; *inquiry into energy policy and planning in Wales.*

LCRI LOW CARBON RESEARCH INSTITUTE

Cyngor Cyllido Addysg Uwch Cymru
Higher Education Funding Council for Wales
hefcw

ERDF
Llywodraeth Cymru
Welsh Government
Ewrop & Chymru: Buddsoddi yn eich dyfodol
Cronfa Datblygu Rhanbarthol Ewrop
Europe & Wales: Investing in your future
European Regional Development Fund

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

LCRI Convergence Cross Cutting Themes

Scenario Modelling for a Low Carbon Wales

Working Document

Spatial overview of the Welsh Energy System

Aliki Georgakaki and Eleni Ampatzi

5th September 2011

This working paper provides a summary of the Welsh Energy Atlas compiled as part of the Low Carbon Research Institute's Convergence Cross Cutting Themes project "Scenario Modelling for Low Carbon Wales". For extended analysis on any of the topics mentioned please contact:

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Introduction

This document provides a sample/summary of the information gathered up to now in the context of the Welsh Energy Atlas as part of the Low Carbon Research Institute's Convergence Cross Cutting Themes project "Scenario Modelling for Low Carbon Wales".

The Welsh Energy Atlas aims to highlight the spatial aspect of energy technologies and policies and encourage partners and stakeholders to adopt an innovative approach in considering future investments and development potential. In the first instance, it aims to collate and review available information that may be relevant in the discussion on energy issues in the Welsh context. Having brought this knowledge together, it will then seek to promote an integrated approach to answering some of the prominent research and policy questions, through connecting multiple layers of information on resources, impacts and interactions across different sectors. It will also seek to bring this information to the attention of interested groups and stakeholders that may not have access to GIS in order to process and analyse the data themselves.

The Low Carbon Research Institute (LCRI) Convergence Energy Programme was launched in September 2009, with funding from the Welsh European Funding Office matched from Welsh universities and industry. It is a research, development and innovation programme aiming for long-term economic growth and the creation of employment opportunities for Wales by acting in the following priority areas: (i) Hydrogen technologies; (ii) Large scale power generation (iii) Marine energy; (iv) Solar PV; (v) Low carbon built environment; and cross cutting themes (vi) Scenario Modelling; (vii) Welsh Energy Sector Training.

The Scenario Modelling for a Low Carbon Wales Cross Cutting Theme represents a relatively small component of the LCRI's overall research portfolio. Its overall objective is to develop an integrated scenario and modelling framework to support innovation and industrial development underpinning the transition to a low carbon economy for Wales. In the longer term this will enable the LCRI to model the potential contribution of the emerging technologies developed through its Industrial Research Projects to a low Carbon Wales.

While the present document does not include all the maps or information collected it aims to list the sources and data themes reviewed so far and provides some information on ongoing work on data sourcing and compilation to form the background for discussions on further development and applications. The purpose is to demonstrate the possibilities and the scope for a more elaborate analysis than the one permitted by the resources available to the project at present.

As a side activity the Energy Atlas will also map LCRI interaction with stakeholders in Wales in terms of partners, businesses and local councils who are involved in projects or consultations benefiting from LCRI expertise on emerging energy technologies.

The Energy Atlas has the potential to integrate a large number of information from different sources and answer queries addressed to the needs of specific regions. To this extent the Scenario Modelling project is keen to investigate output formats and contributions that may be of interest to regional stakeholders. Links have already been created to other research projects which are interested in using outputs from the Atlas. Given that many of the challenges faced in the transition to a low carbon future, as well as the new technologies developed along the way have a geographical aspect to them the Atlas will both serve as a

background to and complement the modelling framework. Development and dissemination will continue but will have to be selective in terms of the amount and completeness of the information included due to resource constraints.

1 Geographical reference

The UKBORDERS and Digimap Map & Dataset collections provided through EDINA [1] are used as base maps for the Energy Atlas and also provide information on – among others – geography, land use and administrative areas.

1.1 Super Output Areas

Output Areas (OAs) are the base unit of 2001 Census outputs. They are based on groups of postcodes and fit within the boundaries of electoral wards/divisions and parishes/communities as at the end of 2002. There are 9769 OAs in Wales. The minimum population of OAs is 100 and the mean 300 [2, 3].

1.1.1 Lower Layer SOAs

Lower Layer SOAs are built from groups of contiguous OAs and are constrained by the boundaries of Standard Table (ST) wards. They were automatically generated to be as consistent in population size as possible, typically containing from four to six OAs. There are 1896 Lower Layer SOAs in Wales. The minimum population of Lower Layer SOAs is 1000 and the mean 1500 [2, 3].

1.1.2 Middle Layer SOAs

Middle Layer SOAs are built from groups of contiguous Lower Layer SOAs and are constrained by the boundaries of local authorities (LAs) as at the end of 2002. They were initially generated to be of consistent population size, but were subjected to modifications proposed by LAs and their strategic partners in a nationwide consultation. There are 413 Middle Layer SOAs in Wales. The minimum population of Middle Layer SOAs is 5000 and the mean 7200 [2, 3].

1.2 Local Authorities

Wales is subdivided into 22 unitary authorities with responsibilities for all aspects of local government [2].

1.3 Spatial Planning Areas

The Spatial Planning Area boundaries were devised for the purpose of statistical data analysis used to inform the Wales Spatial Plan. The definition of the areas from a policy perspective is based on a "fuzzy" boundary concept. The Spatial Planning Areas are comprehensively defined in terms of LSOAs, however they cross local authority boundaries and also present overlaps between them. While these add complexity in terms of data analysis and visual representation, the format was retained due to its "practical and political sense" as it represents work done on the Spatial Plan prior to the boundary definition [4]. The geographical data for the Spatial Planning Area boundaries were provided by the Welsh Government Cartographics department [5].

An overview of the extent and overlap of the Spatial Planning Areas is given in Figure 1. A visual representation of Local Authorities, Middle and Lower Super Output Areas is given in Figure 2. These administrative areas form the basis for data collection and analysis for the Atlas.

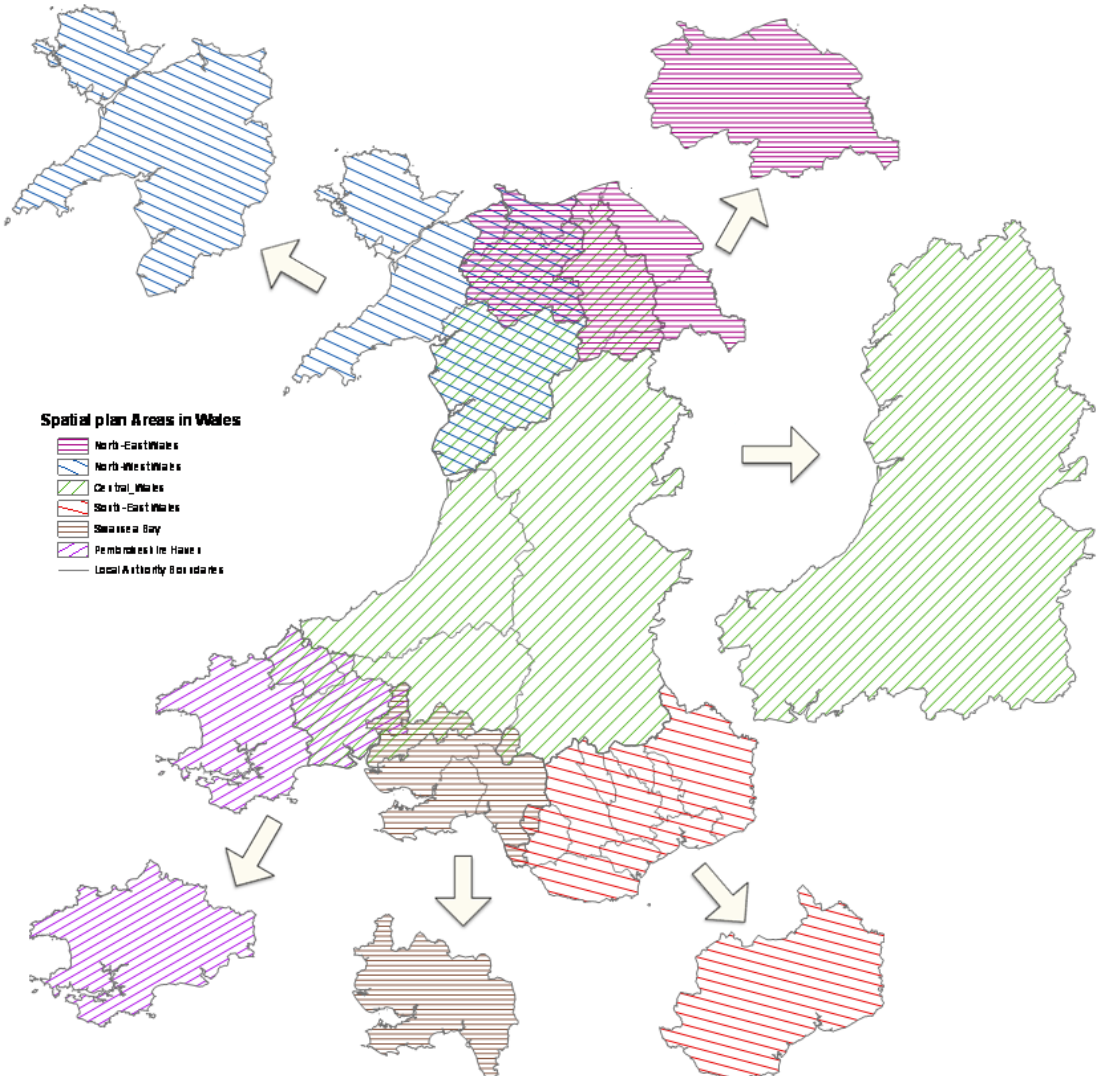

Figure 1: Overview of the boundaries and overlap of the Wales Spatial Plan Areas. Data source: Cartographics, Welsh Government [5].

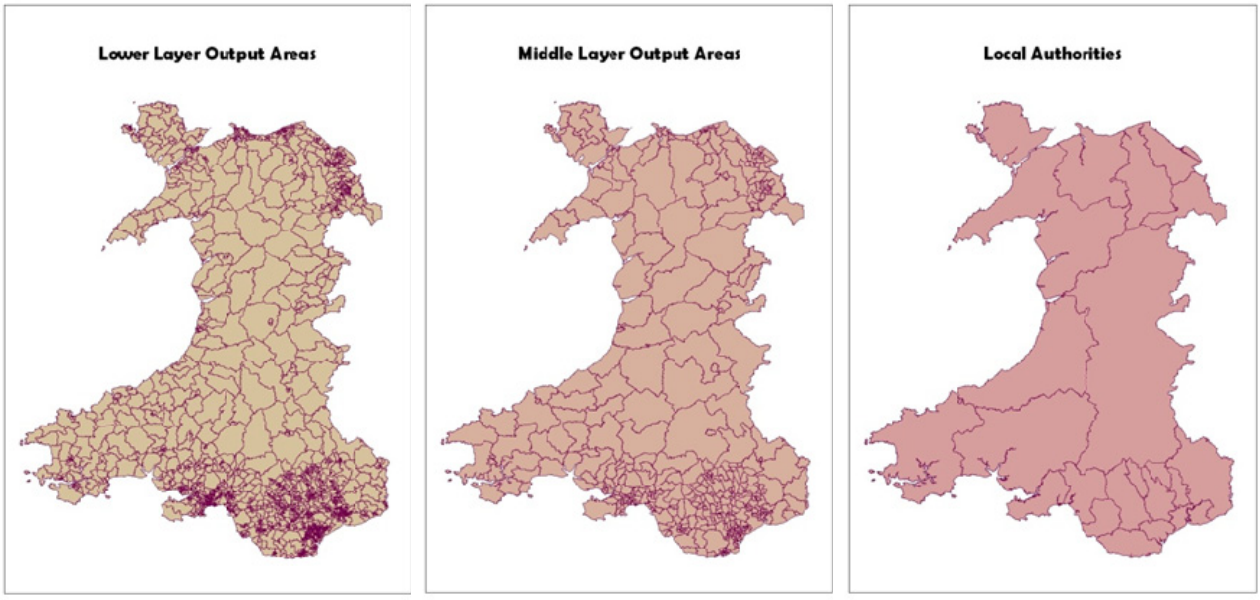

Figure 2: Local authority, middle layer and lower layer output area boundaries for Wales. Data source: EDINA [1].

2 Energy Production

Information on current installed generation capacity and projects under construction or consideration can be obtained from various sources such as OFGEM and DECC [6]. This can be supplemented with data about demonstration projects and be compared and contrasted against the estimated potential for the regions.

2.1 Renewable Resources

2.1.1 Solar Potential

At the moment there is poor knowledge on the regional solar potential across Wales. To account for the spatial variability of insolation, a GIS-based analysis using the topography and the built environment across Wales is undertaken within the project. The analysis, which will be supplemented by a study on the sky conditions across Wales, will provide insolation and shadowing data across the region which will be added to the Atlas [7].

2.1.2 Marine

A project commissioned by BERR in 2007 has produced the existing UK Marine Renewable Energy Resources Atlas. In 2008, an online, interactive webGIS version of the UK Marine Renewable Energy Resources Atlas with improved underlying resource datasets was launched [8]. The charts in the Atlas indicate the distribution of potential resource for the future deployment of renewable energy technologies – offshore wind, wave and tidal and contain the information layers given in Table 1. Examples of offshore wind, wave and tidal power resources for Wales referring to spring means for wind power density, significant wave height and tidal power are displayed in Figure 3.

Table 1: Information contained in the UK Marine Renewable Energy Resources Atlas by BERR [8].

Tidal Resource	Wave Resource	Wind Resource
Peak flow for a mean spring tide	Annual mean significant wave height	Annual mean wind speed at 100m
Peak flow for a mean neap tide	Seasonal mean significant wave height	Seasonal mean wind speed at 100m
Mean spring tidal power	Annual mean wave power – full wave field	Annual mean wind speed at 80m
Mean neap tidal power	Seasonal mean wave power – full wave field	Seasonal mean wind speed at 80m
Average tidal power		
Mean spring tidal range		
Mean neap tidal range		

The Marine Renewable Energy Strategic Framework (MSREF) for Wales undertaken by RPS for the Welsh Government has investigated the potential marine renewable energy resource of Welsh Territorial Waters and in the process collected and compiled a number of GIS layers relevant to marine energy developments, which are of relevance to the Atlas [9].

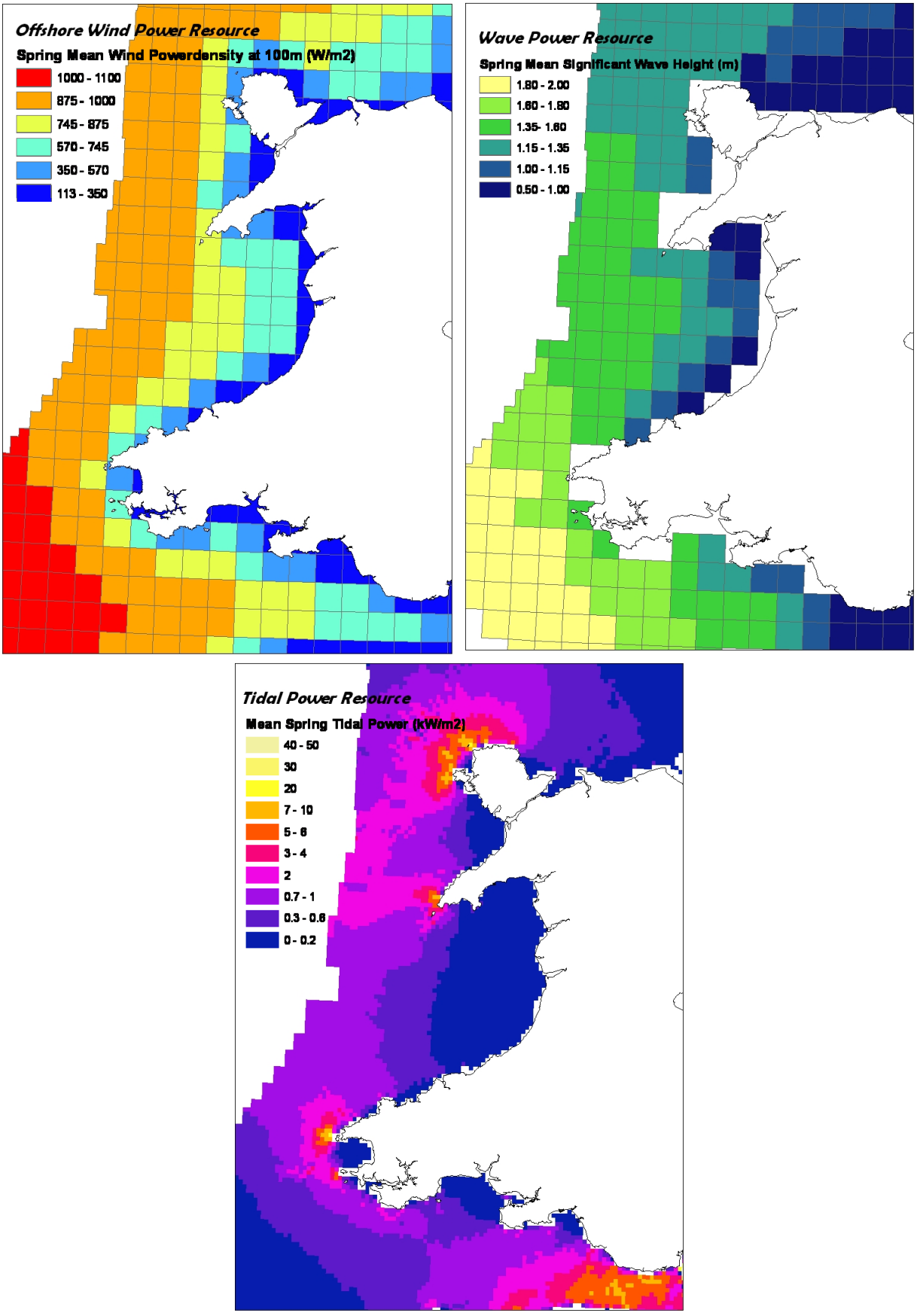

Figure 3: Examples of offshore wind, wave and tidal power resources for Wales. Data source: BERR [8].

2.2 *Electricity Generation*

Electricity generation stations are for the most part well recorded and documented in statistics, and maps for a number of technologies have previously been included in policy documents [10]. The challenge in terms of tracking power generation capacity comes from the increasing number of renewable, distributed generation installations, information about the size and status of which is not always readily available. In the following a number of sources has been used in order to map power generation capacity in Wales.

2.2.1 Power Generation Stations

In terms of large scale power generation the latest version of the Digest of UK Energy Statistics [11] quotes a total of just over 7 GW of installed capacity for Wales split by prime mover as indicated in Figure 4. The power stations have been plotted in Figure 5 along with additional combined heat and power systems [12], installations included in the ROC scheme (see section 2.2.3) and pumped storage stations. This map only depicts capacity in operation, however, data collection includes planned infrastructure as well as proposed changes to existing producers, which will form the background for the modelling framework.

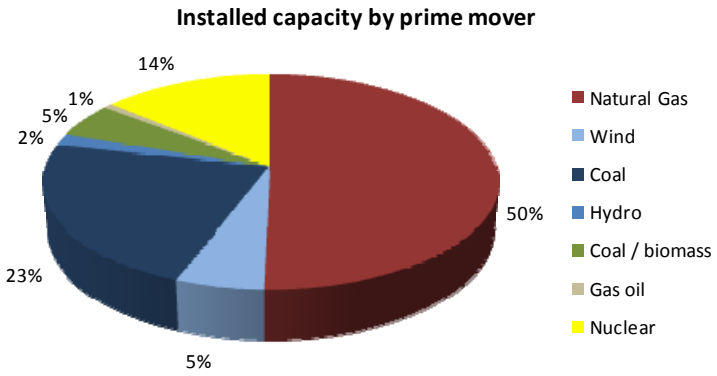

Figure 4: Power generation capacity installations in Wales (capacity over 1MW) split by prime mover. Data source: DECC [11]

2.2.2 Wind Power

Mapping wind power capacity provides a number of challenges, not so much in terms of operating capacity as in terms of the projects in development and the stage they may have reached in the planning system. Despite of a number of databases and reporting schemes, information in the public domain is often conflicting. A number of databases [6, 13-16] cross referenced with information from developers[1], news pieces (e.g.[17]) and other public domain data have been used to compile the wind power database which contains projects operating, under construction, consented, submitted for consideration and in planning. Uncertainties in the planning process and economic climate as well as the availability of grid capacity or other arising issues in the planning and/or supply chain mean that a number of projects often shift between the above categories and tracking their progress may require a considerable resources. Figure 6 shows the current picture of existing and planned wind projects for Wales while Figure 7 shows the capacity grouped by project status.

The TAN 8 Strategic Search Areas (SSAs) for large scale wind developments area are also shown in Figure 6. Note that SSA boundaries are only intended to be used as an indicative/fuzzy boundary set. The local authorities will have the final say on the definitive boundary for each area [5].

[1] References to all the developer sites for respective wind farms not listed here but are linked in the database and can be provided on request along with additional resources.

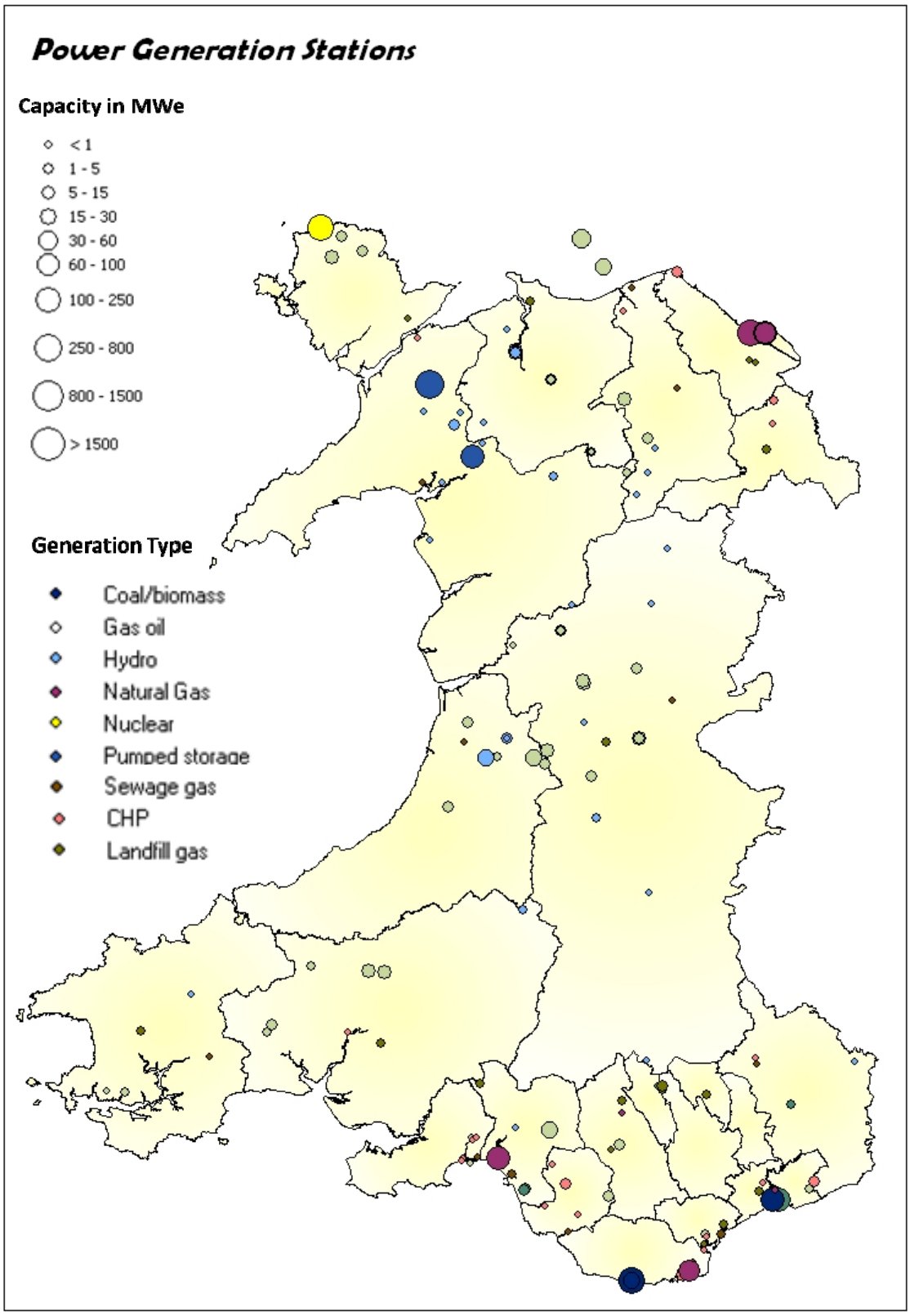

Figure 5: Power generation capacity across Wales according to size and type.
Data source: DECC [6,11, 12], Ofgem [18, 19].

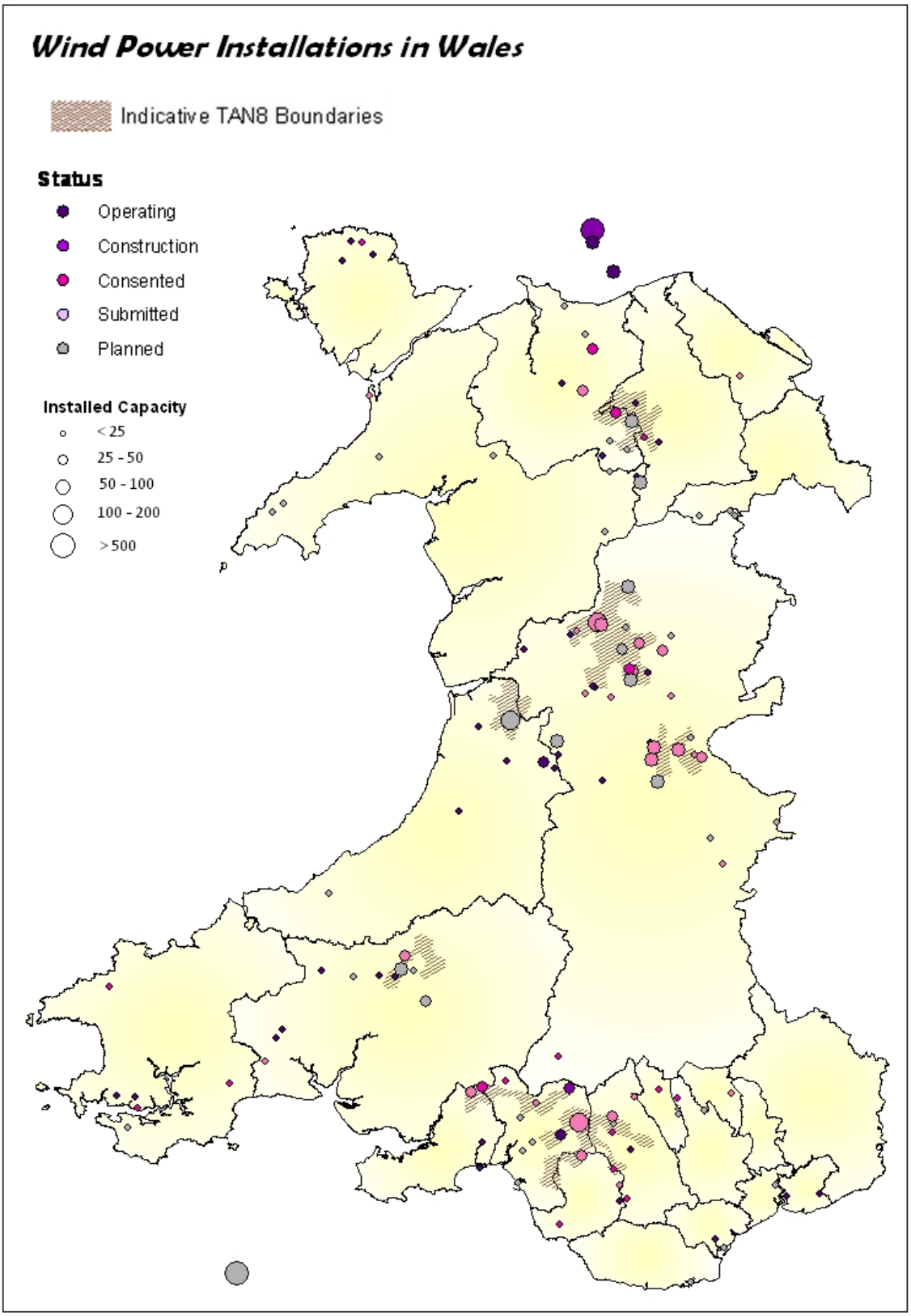

Figure 6: Wind power generation sites by capacity and development status. Compiled using data from various sources (see section 2.2.2).

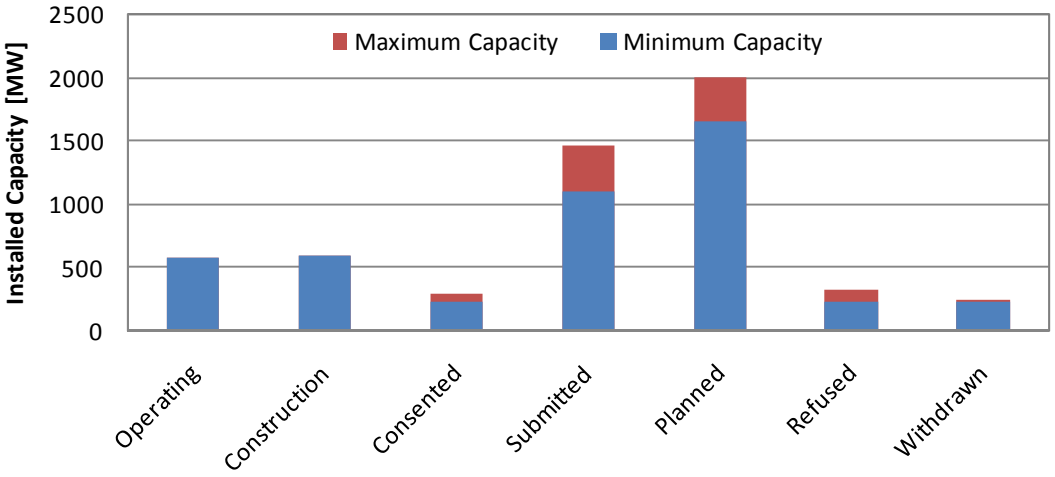

Figure 7: Wind power projects included in the Atlas by project status. Compiled using data from various sources (see section 2.2.2).

2.2.3 Installations under the Renewable Obligation Certificate (ROC) scheme

Information on installations under the Renewable Obligation Certificate (ROC) scheme is available through Ofgem [18]. The register listed 111 producers in Wales with a total capacity of 1.1 GW. The capacities registered by the different generation types and the respective shares in capacity and numbers of installations are given in Figure 8.

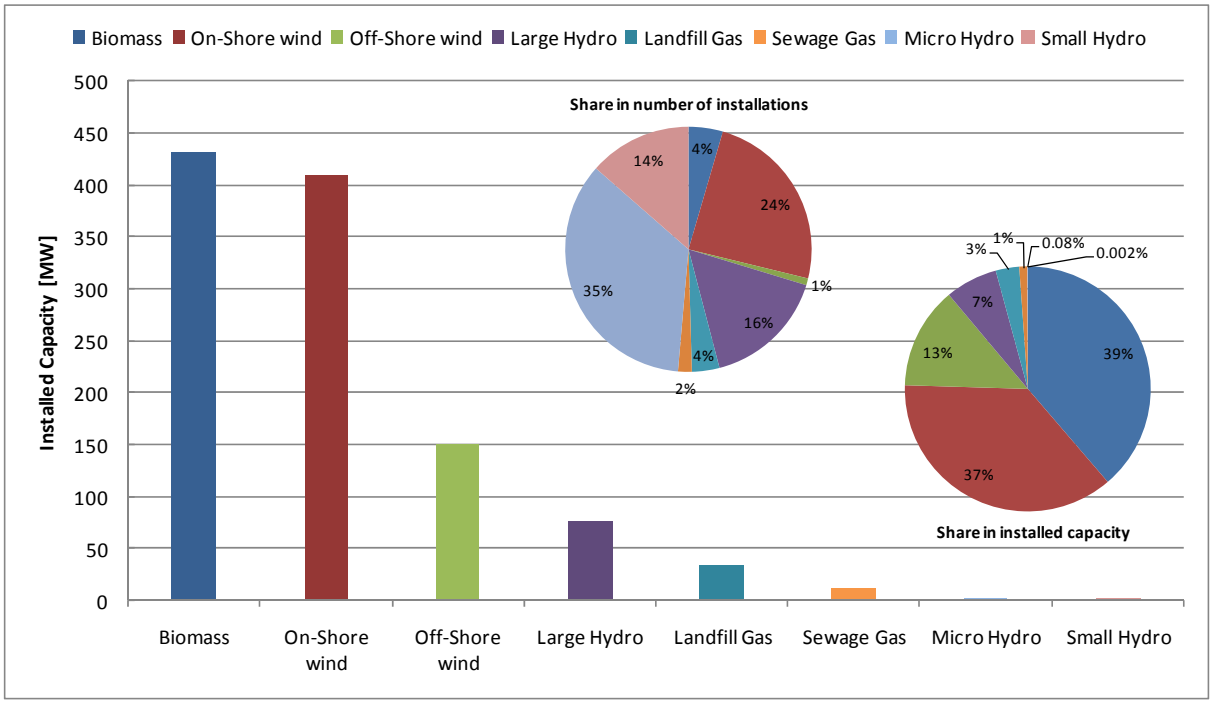

Figure 8: Installations in Wales registered with "live" status under the Renewable Obligation Certificate (ROC) scheme, last update August 2011. Data source: Ofgem [18].

2.2.4 Feed in Tariff Installations

Ofgem publishes quarterly reports listing accredited installations under the Feed-in Tariff scheme. The information below is from the reporting period ending June 2011 [19]. Information and statistical reports about accredited stations can also be obtained through the Ofgem E-Serve public reports (former ROC Register)[18]. The statistical report for June 2011 lists 1767 installations of 6MW capacity in total. In their majority these are domestic photovoltaic applications as displayed in Figure 9 which shows the split of FiT installations in Wales according to type and technology. Figure 10 shows the distribution of FiT installations across Local Authorities in Wales. Powys has the greatest share of FiT capacity, at 16.5% of the total, Pembrokeshire and Gwynedd follow with just over 9%, while the smallest uptake is seen in Blaenau Gwent, Merthyr Tydfil and Newport the capacity in each of which is under 1% of the total for Wales. The information reported above is also mapped in Figure 11.

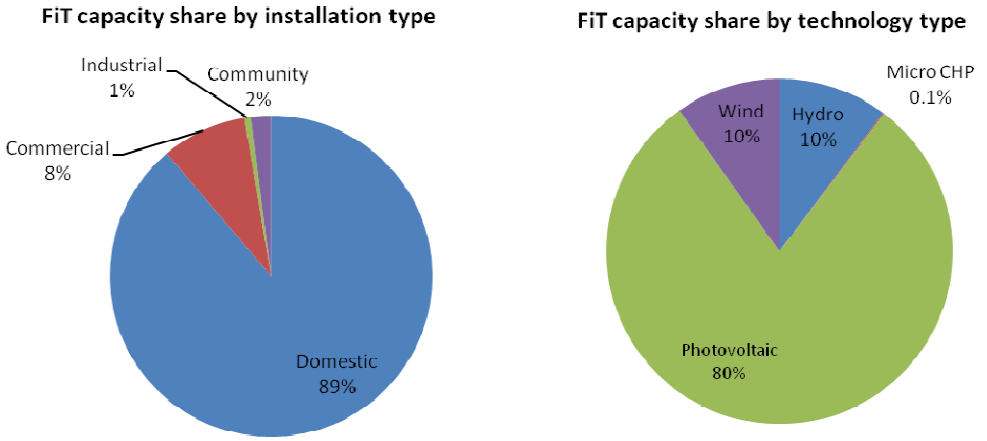

Figure 9: FiT capacity split for Wales according to installation technology and type. Data source: Ofgem [19].

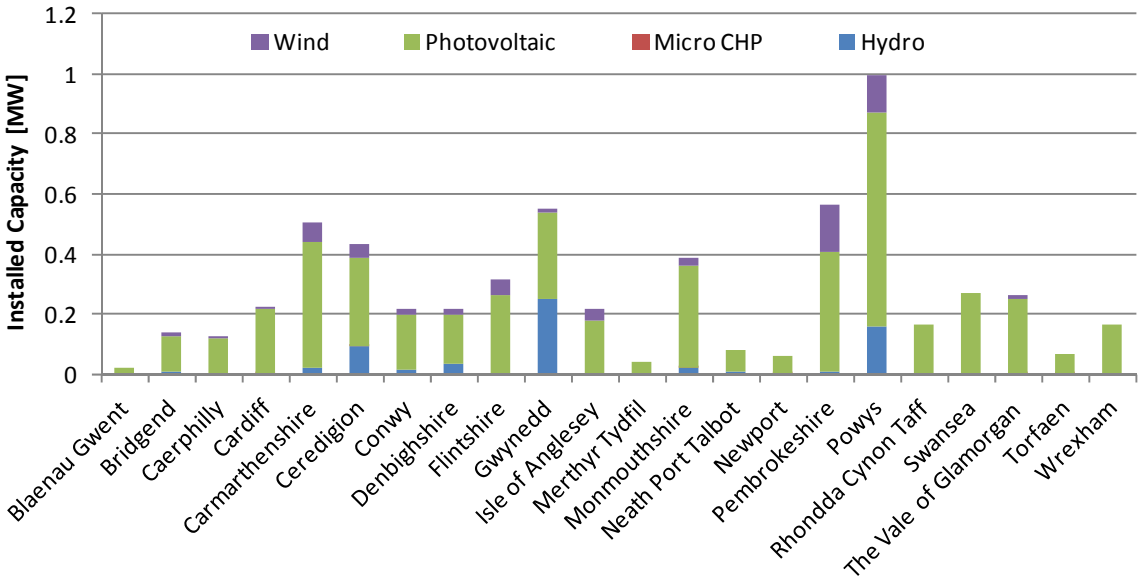

Figure 10: FiT capacity registered per Local Authority and by technology type. Data source: Ofgem [19].

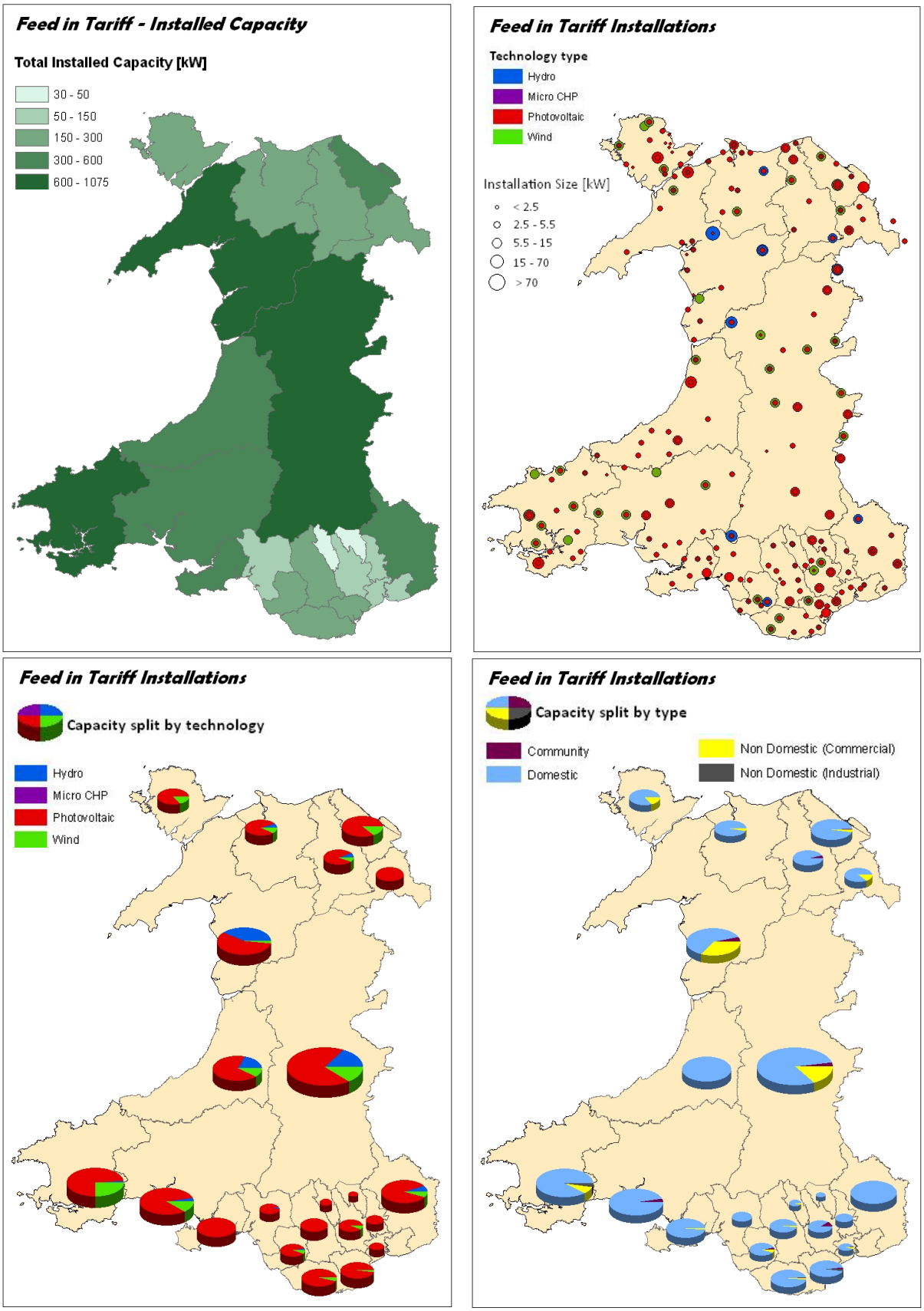

Figure 11: Capacity of Feed-in-Tariff installations in Wales at Local Authority and Postcode level. Further distinction at Local Authority level according to technology used and application type. Data source: Ofgem [19].

3 Energy Consumption

DECC publish sub-national statistics of both domestic and non-domestic electricity and gas consumption data at regional and local authority level (22 administrative units in Wales) as well as estimates at a Middle Layer Super Output Area (MLSOA) [20]. Electricity and gas consumption totals at MLSOA are mapped in Figure 12. The statistics contain estimates for domestic and commercial/industrial electricity and gas sales as well as number of meters and consumption averages. Electricity estimates are provided both for ordinary and Economy 7 customers. Total and average electricity consumption estimates both for domestic and non-domestic customers are given in Figure 13 (no distinction for ordinary or Economy 7 customers). Respective maps for gas consumption are presented in Figure 15.

There are disclosure issues with some of the data, meaning that not all information can be included in the statistics or allocated to MLSOA. In preparing the maps unallocated consumption has been equally divided between the areas in question. Non-domestic industrial half hourly meter electricity consumption (relating to larger business consumers) is presented at LA level (Figure 14) as the data cannot be disaggregated further for reasons of disclosure.

All data presented refers to 2008 statistics. Data for 2009 has also recently become available.

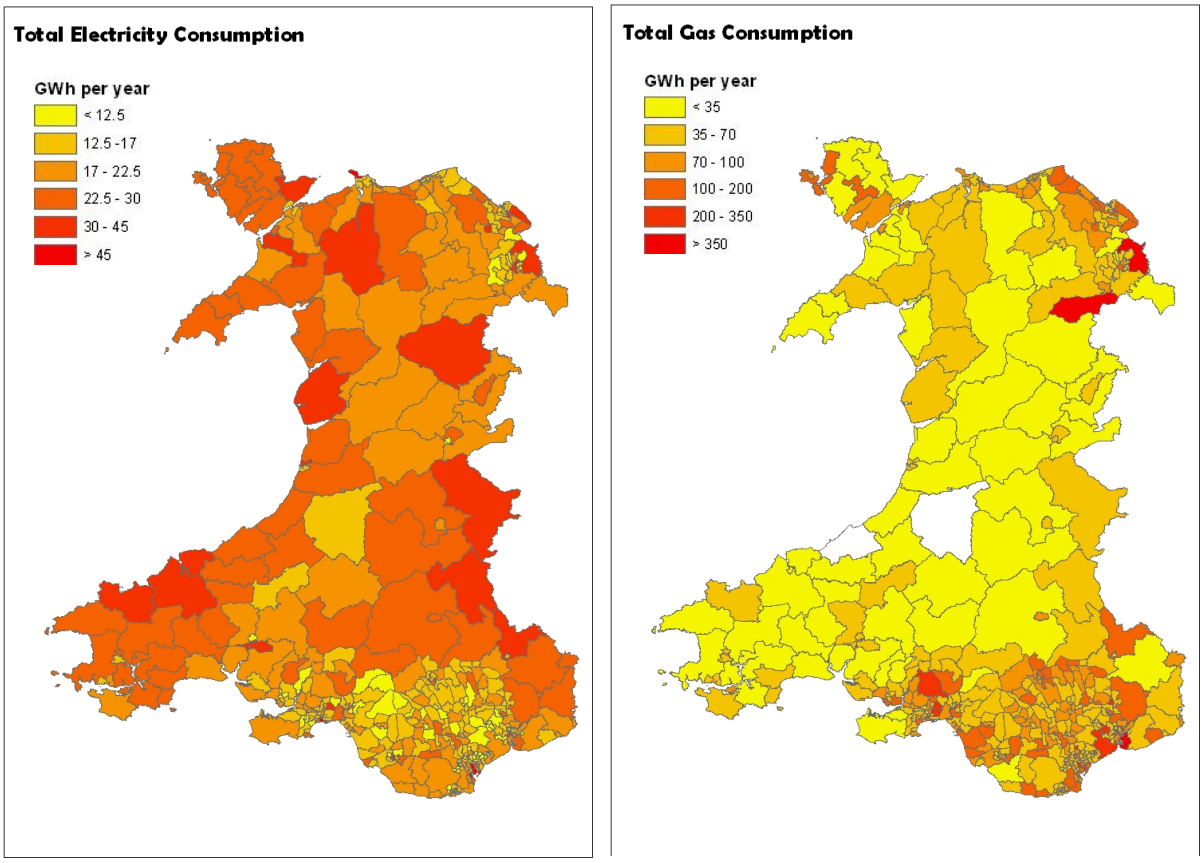

Figure 12: Electricity and gas consumption totals at MLSOA. Excludes industrial half hourly meter electricity consumption, major power stations and large industrial gas consumers. Data source:DECC [20].

3.1 Regional Electricity Consumption

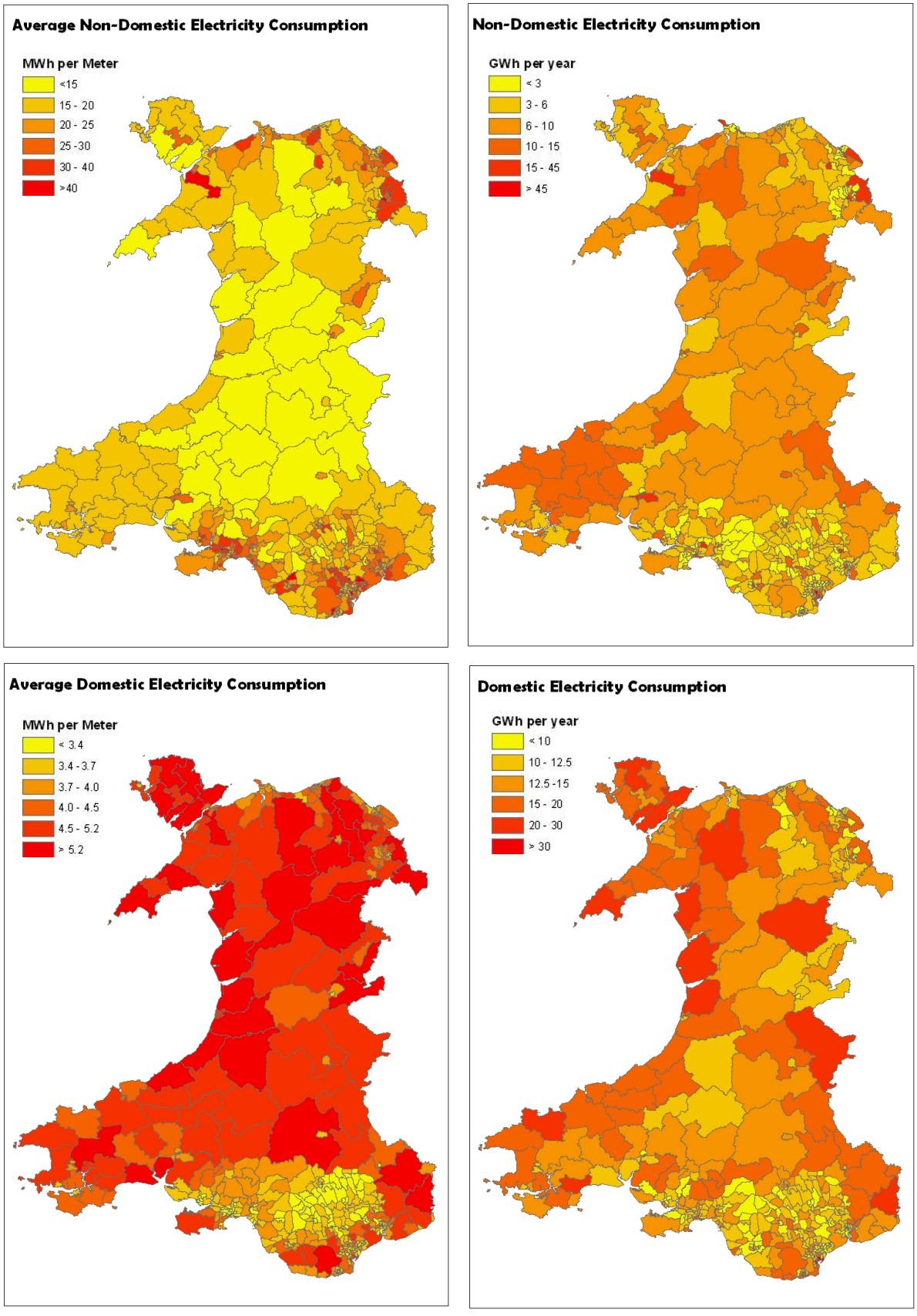

Figure 13: Electricity consumption by domestic and commercial/industrial consumers. Excludes industrial half hourly meter electricity consumption (relating to larger business consumers). Data source:DECC [20].

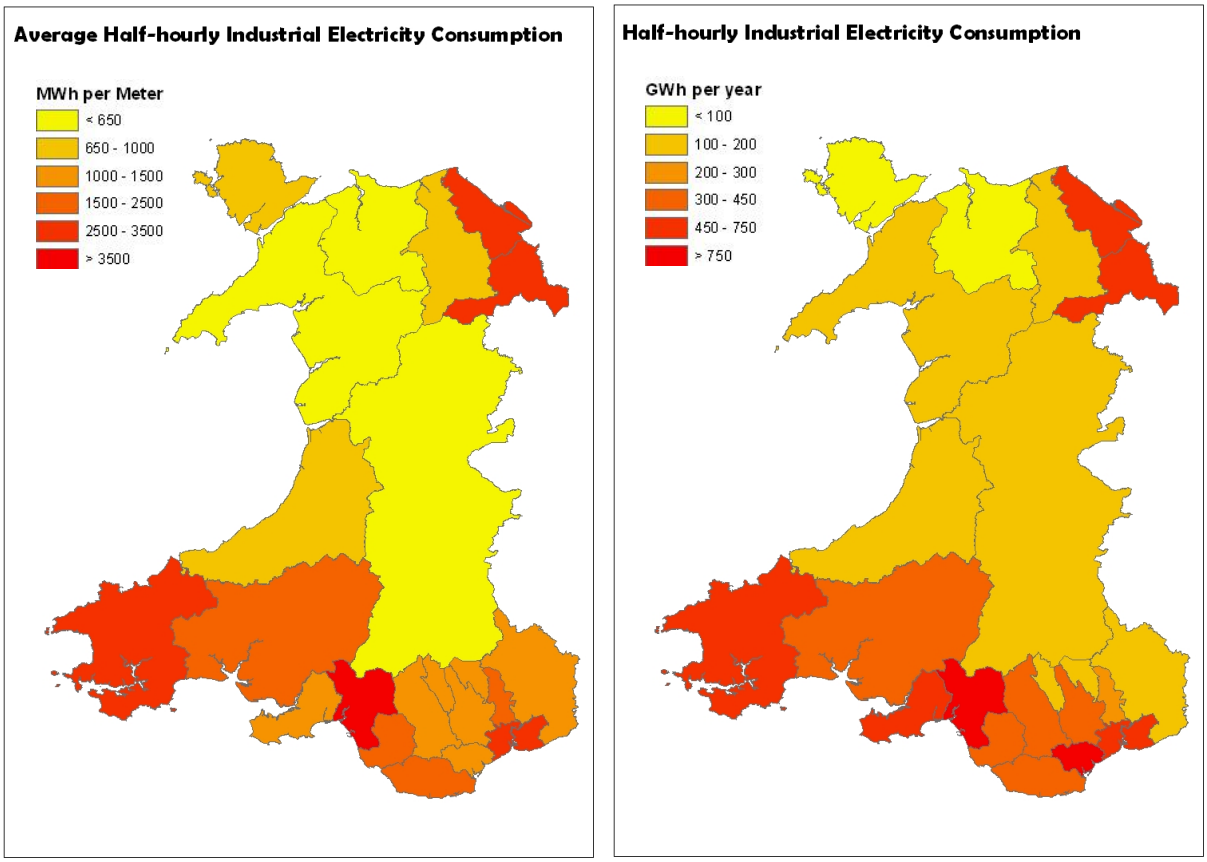

Figure 14: Industrial half hourly meter electricity consumption (relating to larger business consumers) within the LA. This data cannot be disaggregated to MLSOA due to disclosure issues. Data source:DECC [20].

3.2 Regional Gas Consumption

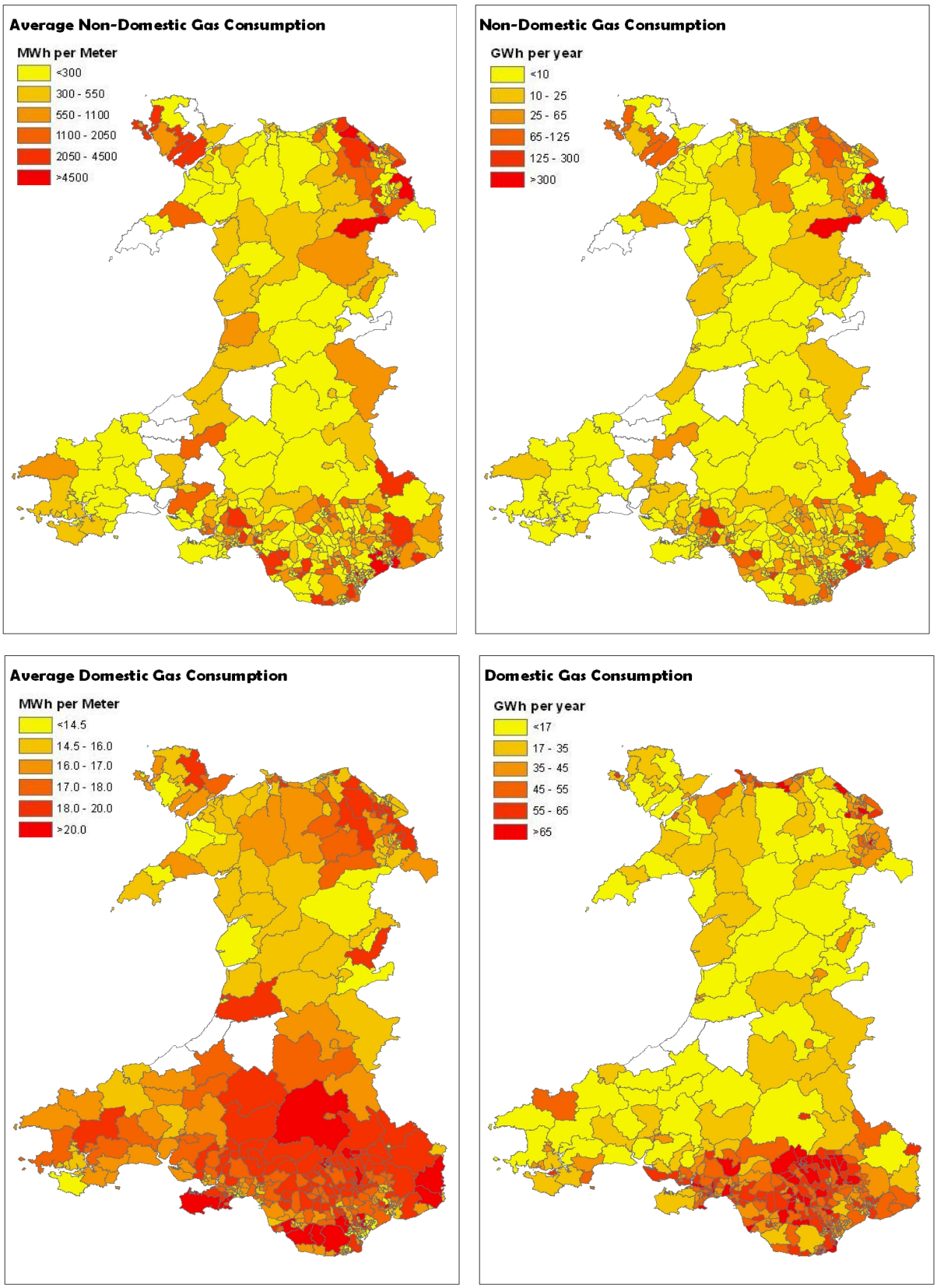

Figure 15: Gas consumption by domestic and commercial/industrial consumers. Excludes major power stations and large industrial consumers. Data source:DECC [20].

3.3 Specific Consumption

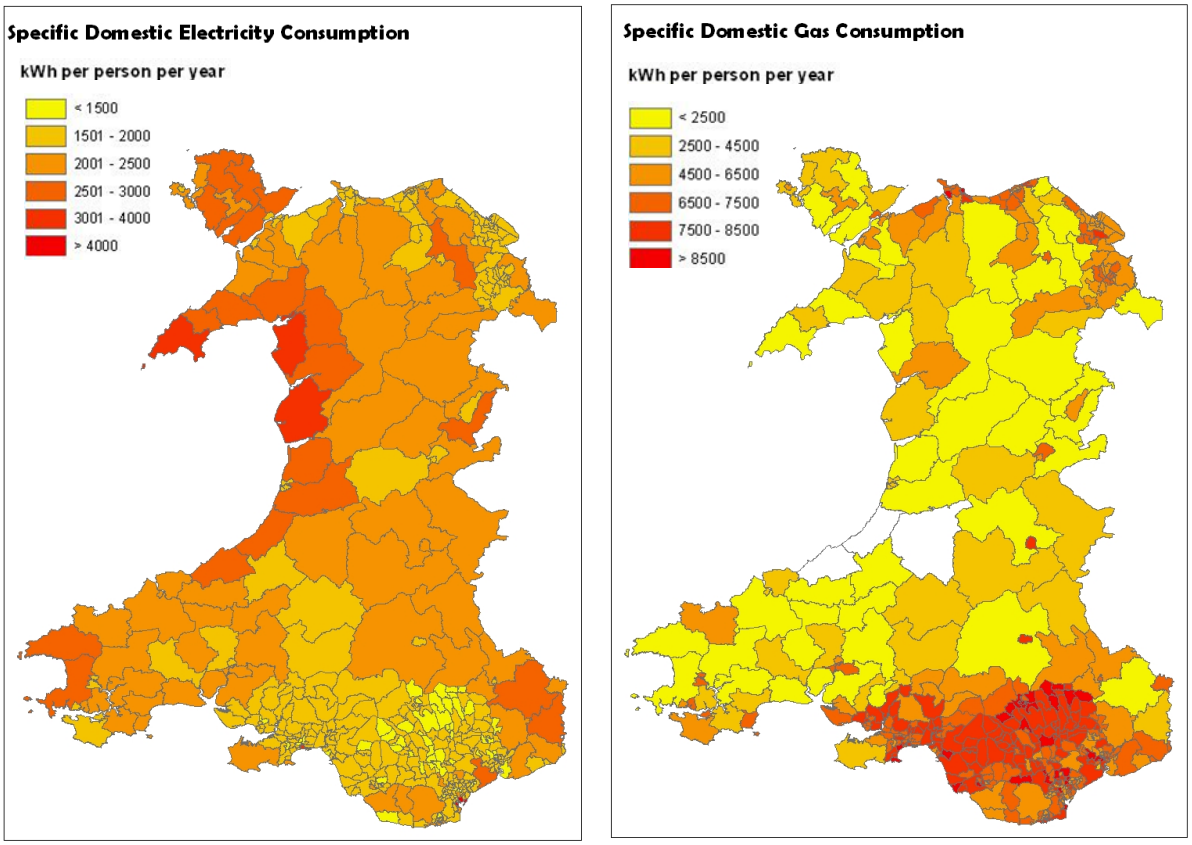

Figure 16: Specific electricity and gas consumption (expressed in kWh per person and year) derived from DECC [20] and ONS data [3].

3.4 Heat demand

DECC have also commissioned a revised UK industrial heat map [12] as part of the strategy to promote decentralised energy and combined heat and power applications in particular, which is of interest to the activities of the Atlas.

4 Emissions

The website of the UK National Atmospheric Emissions Inventory (NAEI) contains maps for a number of pollutants and data tables for emission sources that can be queried for emitters with Welsh relevance to be included in the energy Atlas [21]. Three sets of data are used in the Atlas: (i) the 1x1km emissions of CO_2, (ii) the area source data files and (ii) the large point source dataset.

4.1 The 1x1km emissions of CO_2

The maps of 1x1km emissions of CO_2 are compiled from the UK's National Atmospheric Emissions Inventory sponsored by DECC. These are reported as emissions by End User, whereby emissions from the production of fuels are included at the point of fuel use, including electricity. Emissions from point sources (larger industry sites) are not included in this file. Grid co-ordinates refer to the centre of the 1km squares. Emissions currently mapped refer to 2008. The layers available are:

- Industrial and commercial electricity emissions
- Industrial and commercial gas emissions
- Other industrial and commercial emissions
- Industrial offroad machinery emissions
- Agricultural emissions including stationary combustion (but not electricity or gas)
- Emissions from diesel railways
- Domestic electricity emissions
- Domestic gas emissions
- Domestic oil and solid fuel emissions
- Domestic other emissions
- Road transport emissions (petrol, diesel, other)

Figure 17 shows the layers with data for CO_2 Emissions from domestic consumption of electricity, gas, oil & solid fuels allocated to end user, while Figure 18 contains respective maps for industrial gas and electricity consumption and other industrial processes.

4.2 Area Source Data Files and Large Point Sources

Each file contains pollutant-specific gridded emissions for the year by CORINAIR SNAP[2] sectors. Emissions currently mapped refer to 2008. The sectors available are as follows:

- Combustion in Energy Production and Transformation
- Combustion in Commercial, Institutional, Residential and Agriculture
- Combustion in Industry
- Production Processes
- Extraction and Distribution of Fossil Fuels
- Solvent Use
- Road Transport
- Other Transport and Mobile machinery
- Waste Treatment and Disposal
- Agriculture, Forestry and Land use Change
- Nature
- Total area sources (sum of the above grids)
- Total emissions (including point sources)

CO_2 emissions from the layer "Combustion in Commercial, Institutional, Residential and Agriculture activities" are presented in Figure 20 as well as total emissions combining area and large point sources. Large point source emissions (Figure 20) are reported separately and added on to the area sources to provide the total mapped emissions.

[2] This is an internationally recognised system of reporting emission inventories and is used by EMEP and UNECE. http://uk-air.defra.gov.uk/reports/empire/naei/annreport/annrep96/app2_1.htm

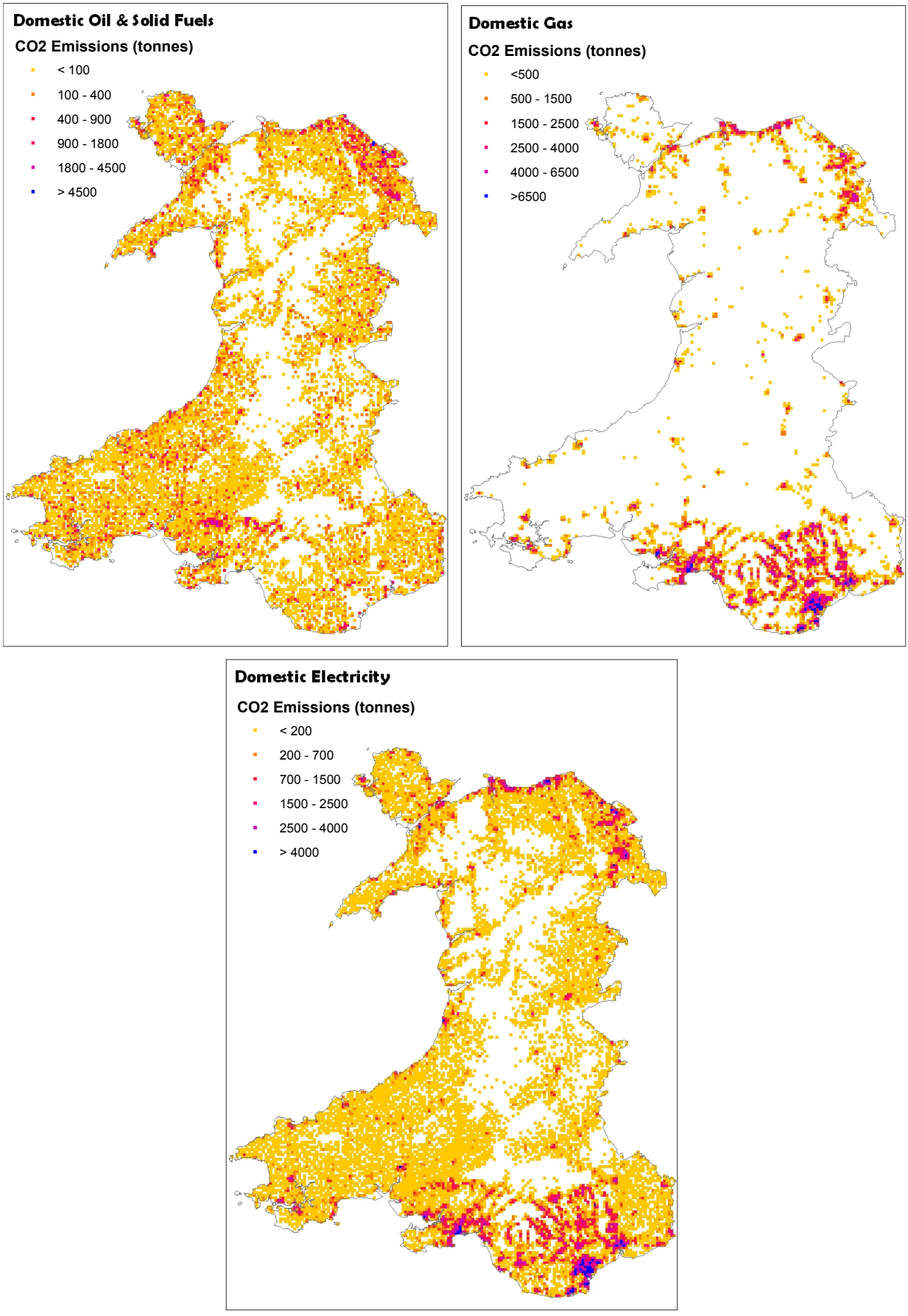

Figure 17: CO_2 Emissions from domestic consumption of electricity, gas, oil & solid fuels reported by end user. Data source: NAEI [21]

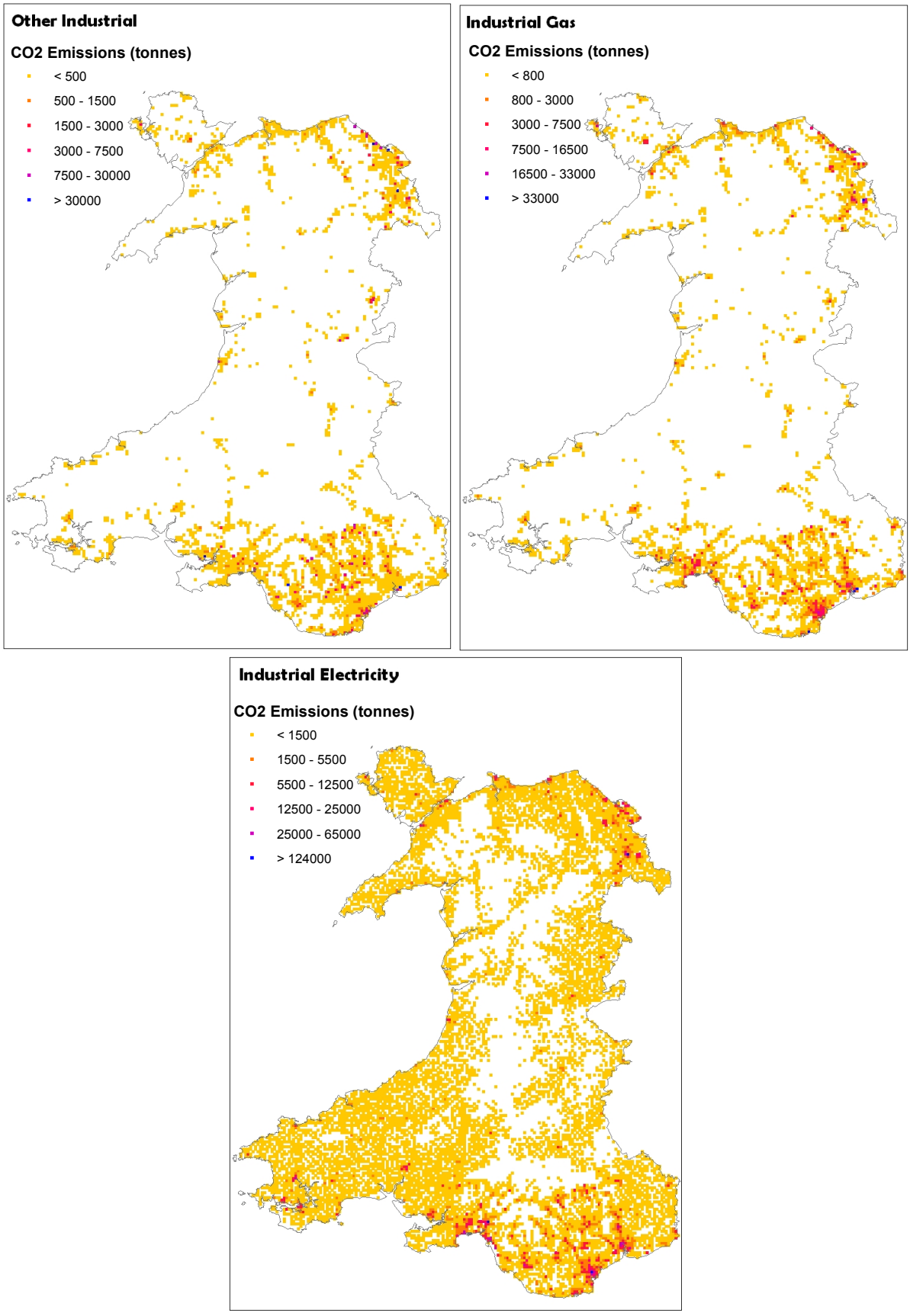

Figure 18: CO_2 Emissions by end user from industrial gas and electricity consumption and other industrial processes. Data source: NAEI [21]

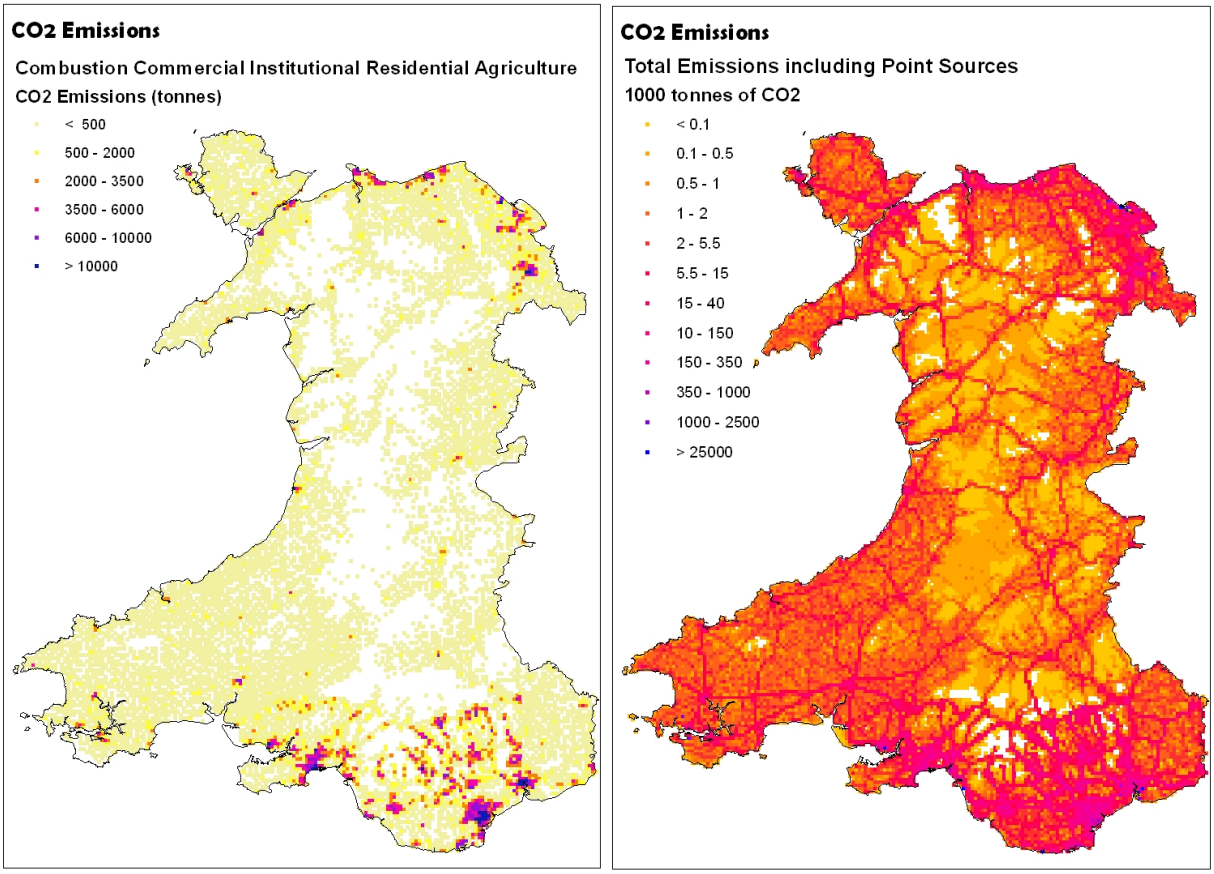

Figure 20: CO2 emissions by source area for Commercial/Institutional/Residential/Agriculture emitters and total CO2 area source emissions including large point sources. Data source: NAEI [21]

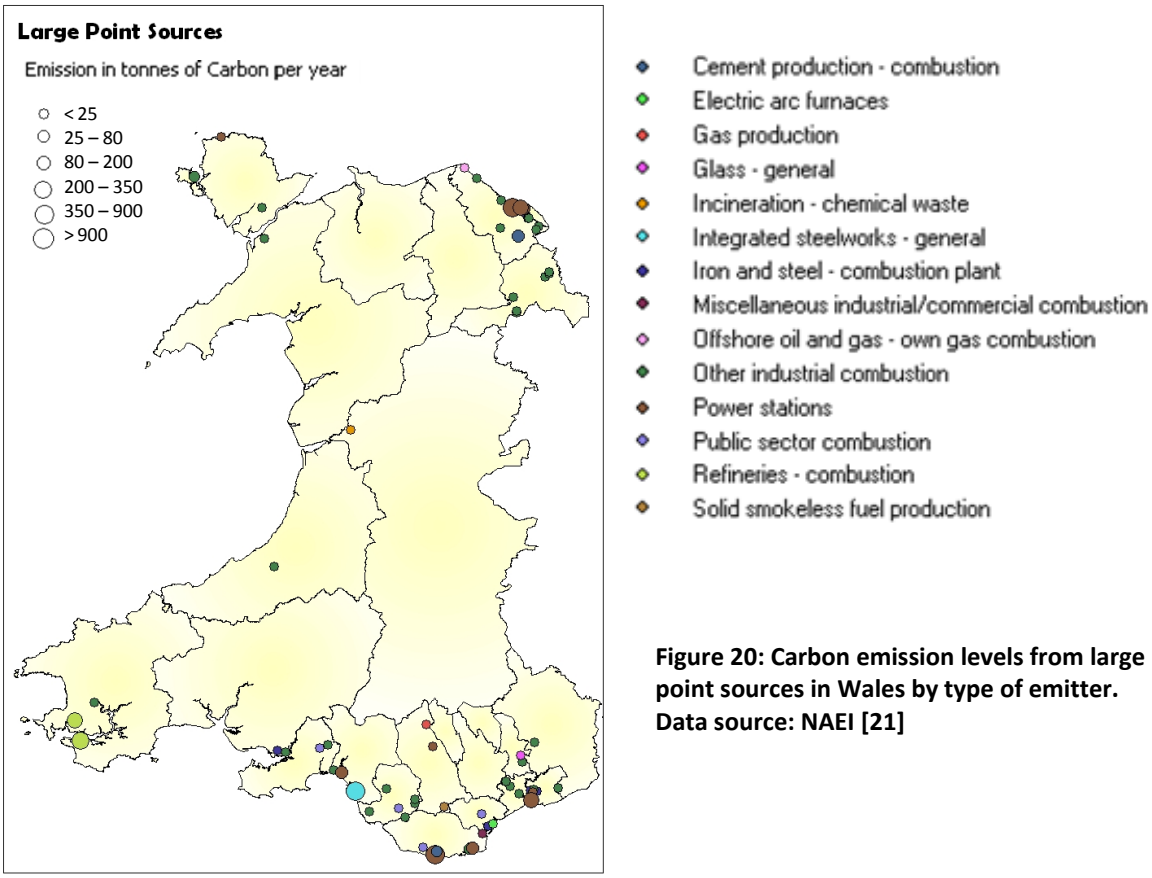

Figure 20: Carbon emission levels from large point sources in Wales by type of emitter. Data source: NAEI [21]

5 Ongoing and future work

The Energy Atlas could cover a large number of subject areas in different levels of detail, and incorporate ever expanding amounts of information. It can provide the background for various strands of research and policy support, but it would require considerable resources in order to keep information up to date and produce good quality indicators.

There are a number of subject areas such as the Heat Map and the MSRF marine energy maps and the Solar Atlas where work is ongoing. Furthermore, mapping of biomass resources which is undertaken by various projects will be of great relevance to the Atlas. However, one of the main aspects of the Atlas is to serve as the background on which to develop the modelling framework.

Given the limited resources of the project, and the fact that the work needs to progress with analysing the data in the context of an Energy Modelling Transitions Framework, addition of data to the Atlas will progress prioritising internal project needs.

At the same time there is an effort to co-ordinate with other researchers and data providers to avoid duplication and make sure that links to the data sources – if not the actual data – is provided in the context of the Atlas.

Similarly, while the project is in position to respond to requests for the development of indicators and targeted analysis in response to specific stakeholder needs, these activities will have to be balanced against the remaining workload.

We are actively seeking, additional resources to take work on the Energy Atlas forward.

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