

**Decarbonising the Local Economy: Planning for
Renewable Energy in Urban Areas**

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Abstract

Mechanisms for transitioning towards a low carbon economy include technological shifts, policy development and programs that require changes in behaviour. Arguably, local councils are well positioned to drive some or all of these. There is a range of mechanisms that councils have used and are proposing which could stimulate decarbonisation. Initial action is likely to involve means which are familiar and more or less accepted as being within councils' jurisdiction and established ways of working. Planning is one such established area of activity. Here we report on the potential for the incorporation of information and analysis of renewable energy resources into local planning policy. Using evidence gathered in three case study areas, one in the UK, two in Australia, the paper argues for better public information on the availability of renewable energy resources and presents the case either for a new type of resource plan or alternatively a modification to existing development plans to promote the harvesting of renewable energy in urban areas. The stages of analysis required are outlined and the potential benefits explained.

Decarbonising the Local Economy: Planning for Renewable Energy in Urban Areas

Introduction

Whilst there is general agreement worldwide on the need to reduce the global carbon footprint, two crucial factors inhibit rapid movement towards this widely agreed goal. First there is reluctance to subscribe to deep cuts in the short term because of concerns about cost and loss of competitiveness. Second there remains considerable debate about the best way to achieve the required reductions. This latter debate is not just about technological aspects of reducing resource and energy inputs into production processes to move away from fossil fuels but often encompasses social, behavioural and economic factors. Two broad approaches can be identified, namely top down and bottom up.

Many nations and states have set national carbon reduction targets employing time frames of up to fifty years. Such targets vary from the heroic 80% reductions over 1990 levels by 2050 set by the Californian state government to more modest 50% over 2004 levels in Sweden. The European Union has introduced a policy of carbon reduction of 20% over 1990 levels by 2020 whilst Australia lags behind somewhat in its conditional targets which range between 5% and 20% by 2020 (Australian Government, 2008). In some cases individual cities have unilaterally set targets. Examples include New York City which has set a carbon reduction target of 30% by 2030 (City of New York, 2008) and Toronto in Canada which has set a target of 30% reduction by 2020 and 80% reduction by 2050 (City of Toronto, 2009).

Progress on devolving national and regional targets to lower levels of government and across sectors is apparent in a number of states. The approach taken to greenhouse gas (GHG) emission reduction varies. Complex mechanisms of carbon accounting and carbon

trading with the aim of reducing global emissions, whilst allowing continued economic activity and growth as technological shifts gradually move economies away from fossil fuel dependency, are increasingly evident. Australia is in the process of setting a carbon cap and trade scheme which concentrates on electricity generation and other major industries in the expectation that dealing with the largest emitters will send price signals to consumers and induce behaviour change across all sectors of society (Department of Climate Change, 2008).

Meanwhile government in the UK has developed regional targets and identified specific sectors as a focus for carbon reduction measures. This includes devolving regional targets to specific local authority areas. Actions include a bundle of measures such as encouraging a greater mix and level of activity in respect of renewable energy developments, enhanced energy conservation measures in new and existing buildings, improved public transport opportunities, adapting grid infrastructure to accommodate new forms and locations of electricity generation, co-firing coal fired power stations with biomass, developing carbon capture and storage mechanisms and utilising energy from waste (Yorkshire & Humber Assembly 2007). In Australia, Garnaut has recommended to federal and state governments an approach which involves mitigation and adaptation measures (Garnaut, 2008) whilst state government intervention is apparent in the development of climate change strategies such as the Victorian government's green paper (Dept of Premier & Cabinet, 2009) and the South Australian Greenhouse Strategy (Government of South Australia, 2006). Common elements of action at this level include analysis of key threats resulting from climate change, eg flooding, bush fire and population heat stress and publication of strategic aims to mitigate or adapt to climate change. These include mandating standards for energy efficient buildings, strategic goals relating to shifting transport away from reliance on private cars and increasing the share of renewable energy.

The policy approach to GHG emission reduction is thus characterised by top down target setting, which ranges between imposing restrictions on a small number of large scale emitters as in the Australian case, and seeking to devolve targets further down the hierarchy in anticipation of greater bottom up action as in the UK and the Australian states. Arguably a combination of both approaches is likely to achieve greater GHG reductions than reliance on one. But the balance between the two may be critical. For example, it can be argued that a significant grass roots saving in GHG at the local level could reduce the incentive for major emitters to invest in carbon pollution minimising technologies since their targets are already being met through the actions of others. Alternatively if domestic and small scale energy consumers are convinced that the large emitters are meeting their targets they may feel that there is little need to change their energy consumption behaviour.

Our concern in this paper is to examine the bottom up approach – the scope of action at the local level to bring about carbon reductions. We do not seek to comment on or criticise national cap and trade schemes, but rather to highlight the potential which exists at the local level to achieve significant change, whilst noting that federal and local initiatives are in practice, likely to create both opportunities and obstacles to carbon reduction depending on their detailed provisions . In particular we attempt to highlight not only the measures which could be used but also the delivery vehicles which could be employed to achieve these results. We focus on the potential to mitigate GHG emissions within established urban areas by examining potential for embedding power generation within the urban environment, often called distributed energy sources. The potential advantages of distributed generation for increased security of supply (Coafee, 2008) and as more efficient and less polluting than conventional systems (Flavin& Lenssen, 1994, Pepermans et al, 2005) are attracting increasing interest, particularly in respect of the smart grid concept. This aims to transform

electricity distribution systems through integration of advanced communications, information, sensors, controls and distributed energy sources into the urban environment (Coll-Mayor et al, 2007). We argue that the planning system, or at least an approach which draws in large part on planning information and planning techniques, presents a key to unlocking this potential. We use examples of local area based assessment from an ongoing Australian Research Council (ARC) Linkage funded project *Carbon Neutral Communities: Making the Transition* to illustrate both the problems and opportunities involved in this bottom - up approach to climate change adaptation and mitigation.

To date action at the local level in Australia is patchy. Exemplar programs which contain a wide range of approaches are Moreland Energy Foundation (MEFL) and Northern Alliance for Greenhouse Action (NAGA) in Victoria. With support from local councils these two have set out both to educate, change behaviour and provide practical means by which communities can reduce their carbon footprint. Bulk purchasing of solar photovoltaic panels to improve the attractiveness of investment in these technologies by household and businesses is one approach which is proving successful. In a forthcoming article in *Energy Policy*, Moloney et al (2009) report on an extensive review of behaviour change projects around Australia and attempt to classify the different approaches which are emerging. A range of interventions are possible and it could be argued that a suite of solutions is more likely to achieve the desired goals than any single measure. However, two prerequisites are emerging as key. First, information is vital. If households, investors, businesses and governments are unaware of the potential and its relative costs and benefits, then change is likely to be small scale and piecemeal. Second, behaviour change is necessary, but programs which promote this are only likely to succeed if the new behaviour is mainstreamed and does not require major sacrifice of comfort, convenience or cost. Mainstreaming implies

that new forms of behaviour become normal expectations in society rather than being regarded as awkward, unusual, and expensive in terms of time, effort or money. One way of achieving this shift is by systemic change - fundamental change to the institutions, policies and regulations which govern and shape behaviour.

The authors have been involved with three assessments of spatial areas. The outcome of baseline, energy efficiency and renewable energy resource assessments for the community of Conisbrough and Denaby in northern England were reported by Kellett (2007). This study highlighted the surprisingly abundant renewable energy resource which existed in and around the community, capable, if fully exploited, of substituting for all of the baseline energy demand from buildings and completely eradicating the area's CO₂ footprint. The same methodological approach was applied to two Australian case study areas and reported by Kellett and Hamilton (2009) and Hamilton, Kellett and Moore (2008). The first study focuses on the City of Playford (Playford) in South Australia, the second on Manningham City Council (Manningham) in Victoria. The studies were divided into three stages. The first stage trialled a range of methods to attempt to arrive at an estimate of baseline energy demand and GHG emissions. The second stage assessed the renewable energy potential in the study area and compares this to the baseline picture. The third stage estimated the energy efficiency improvements across the residential, industrial, commercial and transport sectors and compared these to energy use projections over time. All of the studies show that the application of energy efficiency measures is often relatively cheap and cost effective in carbon reduction terms. Thus energy efficiency should be an initial consideration for GHG reduction initiatives. Programs such as the Victorian Energy Efficiency Target (VEET) (Essential Services Commission, 2009) and the New South Wales Energy Efficiency Trading Scheme (NEET) (NSW Department of Water & Energy, 2009) both of which target large

numbers of residential properties, represent pragmatic policy responses to this conclusion. Here we report only on the renewable energy resource assessment stage in each case.

Renewable Energy Assessment

The methodology adopted for the assessment of renewable energy resources in Playford and Manningham builds on the approach developed in the United Kingdom (UK) by Grant and Kellett (2002). This approach states that regardless of the energy source or the type of technology needed to harness it, a common approach requires renewable energy potential to be analysed according to the following criteria:

- The Resource Base – which is the total quantity of energy or power which physically exists
- The Resource – which is defined as that part of the resource base which could be utilised under present or future economic circumstances, using existing or modified currently available technology
- The Reserve – which is that part of the resource which has been proved to exist and which could be exploited cost effectively under prevailing economic circumstances.

The size of the Reserve is determined by the prevailing market price and can be complex to determine when different prices apply as is the situation, since market deregulation, in Australia. The logic of this approach derives from work on non –renewable resource assessments developed by McKelvey (1972) and described by Grant, Kellett and Mortimer (1994). Despite the differing nature of the resource in question, similar physical and economic constraints can be seen to be driving the process of analysis.

Case Study One City of Playford

Playford is a local government area located approximately 30 km north of Adelaide and forms part of the northern metropolitan area of Adelaide in South Australia. It is approximately 346 sq km in area and consists of 35 suburbs. It contains the Munno Para area first established in 1853 and the city of Elizabeth, designed and built in the 1950s to provide housing and industry for an influx of immigrants from Europe after the Second World War. Playford contains 19,000 ha of prime horticultural areas on the Northern Adelaide Plains and 7,150 ha of the Mount Lofty Ranges within its boundaries. There are 27,916 residential parcels mostly consisting of single storey detached dwellings, 2 district retail centres, 9 neighbourhood retail centres, 12 local retail centres and 3 rural townships also within its boundaries. Industry is located mainly in the Elizabeth South suburb where the General Motors Holden automobile manufacturing plant is located and in the Elizabeth West suburb. The population of Playford usually resident at 8 August 2006 was 70,011 which equated to 4.62% of the state's population (ABS 2007a). The physical characteristics of Playford are the key indicators of its renewable energy potential. Rainfall is low, there are few continuously flowing water courses and these have little fall as result of generally flat topography. The hydro power resource is therefore negligible. Similarly the coast of Playford is entirely within the Gulf of St Vincent which is relatively shallow and sheltered so offers only moderate wave energy potential. However, reasonably constant mean wind speeds, a relatively high level of insolation (annual mean daily exposure was 17.7 MJ/sq m) and a range of biomass sources suggest potential for wind, solar and biomass energy developments. Each of these is considered below.

Wind

The Vestas V52 wind turbine provides the largest resource base estimate at 32.1PJ/yr. Constraints such as buffer zones to residential areas, roads, reserves and watercourses and restrictive planning policies, most notably a 15km exclusion zone around the Edinburgh air force base reduce this potential to just three turbines. A second resource estimate, which significantly reduces the 15km exclusion zone, but maintains other planning constraints, suggests a resource of 3.7 PJ/yr of energy from 542 Vestas V52 turbines plus small 3kW turbines on each parcel. Of this resource, only 3.1 PJ/yr from the large turbines is cost effective and forms the reserve.

Biomass

The review of biomass resources for Playford identified that animal wastes, human wastes, straw, pasture fodder, cereal cropping stubble, forestry residue and wastes and green wastes were being generated. Much of the organic waste is currently being utilised for energy or other purposes. It was noted that several of the statistics required for the estimation of the biomass resource are difficult to obtain. A combination of the fact that much of the biomass resource is currently utilised and several of the technologies used to extract energy from biomass are not currently cost effective, suggests that there is a sharp difference between the resource base, resource and reserve quantities. Whilst the resource base is around 2.7 PJ/yr. the resource is much smaller at 0.06 PJ/yr and the reserve less again at 0.01 PJ/yr.

Solar

The solar resource base was calculated to be 2,235.3 PJ/yr. The resource calculation reduces this figure substantially since it considers only those areas such as suitably oriented rooftops which are capable of mounting solar collectors resulting in only 1.6 PJ/yr of solar

energy being easily extractable in Playford using current proven technology for solar water heating and solar photovoltaics (PV) placed on North facing roof (NFR) facets.. Only a small proportion of solar PV which is heavily price discounted using the Origin Energy Solar Cities scheme, which at the time of writing is active in some northern Adelaide suburbs, falls within the reserve calculation. Thus the total available solar reserve is currently 0.6 PJ/yr.

Insert table 1 here

Significance of Results for Playford

The use of the renewable energy resource estimation method demonstrates that a sizable resource and reserve exists in Playford. This is significant in terms of the impact that it could have on the demand for conventionally generated electricity and on the carbon footprint of the area. The analysis of the current energy and carbon baseline for Playford demonstrates that residential baseline energy demand is estimated to be somewhere between 1 and 1.63 PJ/yr, the industrial sector between 3.85 and 5.25 PJ/yr of energy, the commercial sector in between 0.38 and 0.82 PJ/yr of energy and the agricultural sector between 0.24 and 0.41 PJ/yr of energy, totalling between 8.48 and 12.23 PJ/yr of energy a mid range of 10.3 PJ/yr. These estimates compare to an estimated available renewable energy resource of 5.3 PJ/yr with a 3.7 PJ/yr reserve considered to be available under current economic conditions. The resource and reserve estimates are summarised in Table 2 together with the greenhouse gas emissions potentially able to be displaced through using renewable energy rather than fossil fuel derived electricity, gas and oil. Using renewable energy rather than gas for heating hot water would result in less GHG emissions being displaced as the combustion of gas produces less carbon emissions than electricity. Were the currently available reserve to be

fully exploited then around a third of existing energy demand could be met from sources which are carbon neutral and about 75% of baseline CO₂ emissions would be displaced. Should policy be altered such that all of the available resource be exploited then more than 50% of energy demand could be substituted by carbon neutral sources and more than 100% of current baseline CO₂ emissions could be displaced.

Insert table 2 here

Case Study Two Manningham City Council

Manningham is located 12 km east of the Melbourne Central Business District and is bounded on the north and west by the Yarra River and the Koonung Creek to the south. It contains 1200 ha of parks, gardens and reserves within its total area of 114 sq km. Land use is mainly residential with all or part of 11 suburbs within its boundaries. It contains 1 regional and 1 sub-regional retail centre and 30 local retail centres. Its businesses are mainly small commercial enterprises with one third home-based. The population of Manningham was 109,915 which was 2.23% of Victoria's population in 2006 (ABS 2007b). The rainfall in Manningham is higher than Playford (mean 659 mm at Bundoora climate monitoring station) and some streams may have permanent water. However the topography, while undulating in parts, is still relatively flat and there is minimal opportunity for hydro power. Manningham is also landlocked and therefore wave power is not an option. Fortunately Manningham experiences reasonably constant and high wind speeds (10 to 15 m/s), it has reasonable levels of insolation (annual mean daily solar exposure was 15.1 MJ/sq m at the Bundoora climate monitoring station (BOM, 2008)) and has some biomass sources which suggests potential for wind, solar and biomass energy developments.

Wind

The excellent wind resource in Manningham resulted in similar resource base estimates for both the Vestas V39 and V52 turbines. These were 41.2 PJ per annum and 40.0 PJ per annum respectively. Similar constraints with regard to airfields were present in Manningham as for Playford, but for Manningham the exclusion zones were 30 km. Approximately two thirds of Manningham fell within the 30 km zone around the Melbourne Tullamarine, Essendon or Moorabbin Airports. Even disregarding these exclusion zones, no sites for medium to large wind turbines could be located within Manningham following the filtering of proximity to residential dwellings, roads and conservation areas. Therefore the contribution of the medium and large turbines to the potential wind resource is nil. There was a potential resource base of up to 5.16 PJ/yr from small (3 kW) wind turbines placed evenly across Manningham. When placed one on each dwelling and on commercial and industrial buildings, this provides a potential resource of 4.37 PJ/yr. Comparing the cost to current retail electricity prices, all of this resource is economical and is a reserve.

Biomass

Biomass sources potentially available in Manningham total a small resource base of 0.69 PJ/yr, of which more than two thirds was already being used leaving a resource of 0.2 PJ/yr. The reserve which is currently able to be economically produced was much less at 0.01 PJ/yr.

Solar

The solar resource base for Manningham was calculated to be 649.9 PJ/yr, of which 22.13 PJ/yr was calculated to fall on north facing roof (NFR) facets. The resource which could be

harnessed using current technology of solar hot water and solar PV was estimated to be 3.13 PJ/yr. Use of the solar resource for heating water was economical, resulting in an estimated reserve of 0.93 PJ/yr.

Insert table 3 here

Significance of Results for Manningham LGA

The renewable energy resource assessment for Manningham (from Hamilton, Kellett and Moores, 2008) has been summarised and presented here as Table 3. In Table 4 the estimated carbon emissions potentially displaced by the renewable resource and reserve have been summarised.

The analysis of the current energy and carbon baseline for Manningham demonstrates that residential baseline energy demand is estimated to be somewhere between 2.95 and 3.87PJ/yr, the industrial sector between 0.75 and 0.81PJ/yr of energy, the commercial sector in between 0.67 and 1.6PJ/yr of energy and the transport sector between 5.1 and 7.5 PJ/yr totalling between 9.8 and 19.28PJ/yr of energy. The baseline demand estimates vary widely depending on the calculation method used. A mid range estimate of 14.54PJ/yr baseline energy demand was compared to an estimated available renewable energy resource of 8.05 PJ/yr with a 5.3 PJ/yr reserve considered to be available under current economic conditions. Thus, 36% of the current baseline energy demand could be substituted by a currently viable reserve and 55% by the available resource. Carbon reduction through implementation is even more significant with the renewable reserve displacing 90% of current CO₂ emissions and the resource 130%.

Insert table 4 here

Discussion

The evidence of the Australian case studies outlined above suggests that significant reductions in GHG emissions, in some instances of more than 100% may be possible in urban areas if local area analysis is employed. These results tally with the previous study in the UK (Grant and Kellett 2002). Awareness of potential on the part of local government, the public and renewable energy developers has already been noted above as an important factor in progressing towards carbon neutrality. So how might the outcomes of studies, such as those described above, be translated into a form where they are generally accessible and have the potential to initiate systemic change?

It could be argued that the development of the resources identified above can best be achieved by reliance on the market. However the relatively slow rate of uptake of renewable technologies to date, especially when viewed in the context of expressed targets for renewable energy and GHG reductions, suggests that further incentives are required. One way forward would be for government to consider the potential of local energy resource and infrastructure plans. These would be a mechanism to identify the available resource within a given spatial area, publicise the potential to interested organisations and inform householders of their potential for action. The analysis reported above demonstrates that a variety of renewable energy resources exist in any spatial area and that their exploitation may take place at different scales and in different spatial patterns. For example a range of combinations of wind farms with varying numbers and sizes of machines, solar power stations or panels on individual buildings is possible. Equally the intensity of development of such resources can vary. It may be dependent on the routing and capacity of the existing

electricity distribution network and modifications to this network may in turn have implications for the location and intensity of future urban development. These factors have direct implications not only for energy output and GHG abatement but also for amenity and land availability for alternative uses. Thus, decisions about renewable energy exploitation need to be seen in the light of land suitability and community attitudes to protection of built and natural heritage, as well as political and consumer commitment to the concept. The wind reserve in both cases studies was elastic, less as a result of relative costs but because of the restrictions placed upon wind development by land use designations, such as native bushland protection and airport exclusion zones. Similarly planning restrictions resulting from extensive urban development and requirements for open space buffer zones between wind turbines and residential areas inhibit the development of large scale wind energy in Manningham. In both study areas the solar resource is potentially larger than cited in the study results because it was initially defined relative to roof top space. Only roof top solar access was considered in the case studies on the basis that this was likely to be relatively uncontested on amenity grounds. If the community were to view the location of panels at ground level as acceptable, then the resource increases in size considerably.

The study methodology used illustrates that reserve estimates need to be set in the context of both carbon and financial cost savings. Indeed the boundary between resources and reserves is fluid. Changing attitudes to planning policy and changing energy costs can increase and decrease the reserve estimate. So a public debate about the degree of restriction on the location and operation of wind farms, for example, is a necessary prerequisite of plan formulation. As the public become increasingly aware of the need to reduce carbon emissions and of the environmental and financial costs involved, it will wish to be party to prioritisation of planning constraints. The estimates provided suggest that all of the 60-80% GHG emission reductions needed by 2050 could be achieved by focussing on

localised urban areas which can substitute fossil based energy sources by renewable energy. Public engagement with this issue could also lever changes in the development of the electricity distribution network, which to date has tended to derive its relative strength and routing from the relative locations of a few large generation sites and the areas of urban demand. A micro grid system, designed to be able to respond to changing levels of input at different times and to accommodate multiple small generators, would provide the flexibility necessary to adapt to changing energy resources and thus be inherently sustainable (Hatziaargyriou & Meliopoulos, 2002). This systemic shift would in turn open up more areas and transfer more resources into the reserve category.

A key debate therefore concerns the appropriate mechanisms for engaging the community in these issues and for expressing policy directions. Studies such as those cited above are easily replicable (Kellett & Hamilton, 2009) but making the results widely available and opening up a public debate on the potential offered in specific urban areas is more problematic. Strategic planning policy needs to incorporate these aspects but they also need to filter down to local development policy. Natural resource plans, which identify areas of natural heritage and ecological value in spatial terms, are a useful model. Renewable energy resource plans, which use the approaches outlined above to identify the range, quantity and location of renewable energy resources in a spatial area could provide the basis for a planning review which has the potential to achieve two objectives. Firstly, it could promote behaviour change through stimulating the localised exploitation of renewable energy resources. As more solar panels, wind turbines and other devices become evident within the urban environment they may become more familiar, acceptable and desirable. Fiscal mechanisms such as subsidies and feed in tariffs could be used to enhance such attitudinal change. The benefit of a closer spatial association between energy demand and supply,

apart from reduction in transmission losses, is an increased consumer awareness of the trade offs between the demand for energy and the amenity of the local environment.

Secondly, the consideration of energy infrastructure from a distributed perspective offers alternative settlement patterns which are less reliant on existing distribution infrastructure. Is there any evidence of such approaches to date? A recent study of GHG abatement policies in local development plans in Adelaide demonstrated that out of 26 council plans studied, 17 had no coverage and 9 had minimal coverage. On land capability assessment considering climate change risk, none of the 26 had any policies (Adelaide & Mount Lofty Ranges NRM Board, 2008). Criticism of these omissions in respect of principles of development control which fail to take climate change into account may be reasonable; but it may require a systemic shift in our perspective on the nature and role of development plans to usefully incorporate renewable energy potential. Nevertheless, there is a strong case for broadening the scope of development plans to assist in promoting renewable energy potential rather than adding another layer of complexity to the planning system by creating a further new type of plan as outlined above. The designation of zones for renewable energy development is the first essential step. As outlined above, a public reappraisal of constraints and relative values will be a component of defining these zones. These may sit uncomfortably within the current concept of local *development* plans, but if viewed as local *land use* plans, potentially they should not. Secondly, siting and design principles need to be made explicit for the different technologies of wind, solar, biomass etc to give positive guidance to developers. Publicising renewable energy potential and, subject to public acceptance, relaxing constraints on urban energy generation may provide the systemic change required to reap the significant clean energy harvest which exists in abundance in many urban areas.

Conclusions

The above discussion demonstrates that as well as top down price signals induced by carbon cap and trade mechanisms, local scale initiatives have great potential to accelerate the transition to a carbon neutral future. Several local area based studies using a similar methodology demonstrate that a significant renewable energy resource and reserve often exists within urban areas. Extracting its potential relies on localised analysis and action, the development of distributed power generation and a degree of household behaviour change. Local carbon reduction outcomes through urban renewable energy development can exceed 100% of baseline CO₂ emissions. To facilitate this trend the concept of renewable energy resource plans is floated but the argument for incorporating resource planning methods to inform and incorporate renewable energy resource policies into land use plans is preferred. As part of this process it is vital to engage the public in a debate about both behaviour change and the relative weight that should be given to competing constraints. Systemic change, which has been identified as a more robust approach than individual behaviour change programs, is likely to result. The case studies cited here are replicable elsewhere in Australia and offer an important way forward to reduce GHG emissions at a grass roots level.

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Table 1: Potential Renewable Energy Resource Base, Resource and Reserve for the Playford LGA

Renewable Energy Source	Resource Base PJ / yr	Resource PJ / yr	Reserve PJ / yr
Vestas V52 Wind Turbines	32.2	3.08	3.08
Whisper 500 Wind Turbines	3.69	0.6	0
Biomass	2.7	0.06	0.01
Total Solar on Buildings (NFR facets)	11.9	1.55	0.6

Table 2: Summary of Estimates of Renewable Resource and Reserve and Estimates of Carbon Emissions Potentially Able to be Displaced for Playford LGA

Renewable Resource	Resource PJ / yr	GHG Emissions Displaced Mt CO2-e / yr	Reserve PJ / yr	GHG Emissions Displaced Mt CO2-e / yr
Solar PV	0.95	0.229	0.008	0.002
SHW	0.6	0.143 (0.031*)	0.6	0.143*
Wind	3.7	0.885	3.1	0.740
Biomass	0.06	0.015	0.013	0.003
Total	5.3	1.272 (1.16*)	3.7	0.888 (0.776*)
* assumes electricity is displaced by renewable energy. If gas is displaced this figure would reduce.				

Table 3: Potential Renewable Energy Resource Base, Resource and Reserve for Manningham

Renewable Energy Source	Resource Base PJ / yr	Resource PJ / yr	Reserve PJ / yr
Vestas V52 Wind Turbines	40.0	0	0
Whisper 500 Wind Turbines	5.16	4.37	4.37
Biomass	0.69	0.2	0.01
Total Solar on Buildings (NFR facets)	22.13	3.13	0.93

Table 4: Summary of Estimates of Renewable Resource and Reserve and Estimates of Carbon Emissions Potentially Able to be Displaced for Manningham

Renewable Resource	Resource PJ per annum	GHG Emissions Displaced Mt CO2-e per annum	Reserve PJ per annum	GHG Emissions Displaced Mt CO2-e per annum
Solar PV	2.2	0.758	0	0
SHW	0.9	0.310 (0.047*)	0.9	0.310 (0.047*)
Wind	4.4	1.515	4.4	1.515
Biomass	0.2	0.069	0.001	<0.001
Total	8.05	2.652 (2.389*)	5.3	1.825 (1.562*)
* assumes electricity is displaced by renewable energy. If gas is displaced this figure would reduce.				