# An updated assessment of the technical and economic potential for renewable electricity generation in the pan-Hampshire area (v2.0)

A report to Hampshire County Council's Climate Change Team

Ellis Ridett (ellis.ridett@soton.ac.uk)
Ben Anderson (b.anderson@soton.ac.uk)

Energy and Climate Change Group, Faculty of Engineering & Physical Sciences, University of Southampton

*Project: Establishing a Robust Evidence for a Pan-Hampshire 2025-2050 Energy Strategy*

IN CONFIDENCE

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## Document history

| Date | Version | Notes |
|---|---|---|
| 22/2/2023 | V0.9 | Internal UoS review |
| 29/3/2023 | V1.0 | Submission to HCC |
| 28/3/2023 | V1.1 | Updated version responding to HCC comments and including additional material |
| 09/06/2023 | V2.0 | Updated onshore wind and utility solar constraints to include proximity to LV electricity network using data provided to the project by SSEN. |

## Contents

# 1 Executive Summary

Renewable electricity generation capacity in the pan-Hampshire area was 706 MW in 2021. Of this, 88% was photovoltaics with 185 MW in Test Valley, 97 MW in Winchester, 93 MW in Isle of Wight and 50 MW in East Hampshire districts but with little other installed renewable electricity generation capacity. This 706 MW of capacity generated 625 GWh in 2021, or just ~8% of the 7,520 GWh of electricity used in pan-Hampshire in 2020.

Increasing self-sufficiency in renewable electricity is one of the Hampshire County Council Climate Change Strategy's priorities and in response this report provides an updated assessment of the technical and economic potential for additional renewable electricity generation in the pan-Hampshire area. The report presents new technical analysis to identify suitable sites for tidal stream, offshore wind, onshore wind, utility-scale solar PV and rooftop solar PV systems using a robust, best-practice Multi-Criteria Decision Analysis (MCDA) approach which includes key factors that may impact site suitability and planning acceptance.

The results suggest that there is a maximum technical potential for 2,780 GWh of tidal stream generation, 10,040 GWh of offshore wind, 4,280 GWh of onshore wind, 53,301 GWh of utility-scale solar PV and a preliminary estimate of 460 GWh of rooftop solar PV. The reliance on large utility-scale developments tends to concentrate this potential capacity in a relatively small number of suitable areas although smaller scale solar PV 'farms' and urban rooftop PV offer some counter-balance.

As a result, with no other development, a single large offshore wind development could provide 134% of pan-Hampshire's current annual electricity use. In contrast, utility scale solar could provide 709% of current annual use if fully developed, but would be seasonally variable, whilst tidal stream could meet 37%. Full implementation of onshore wind could provide 57% of Hampshire's current electricity consumption while the preliminary estimates of rooftop solar PV would meet 6%. Full implementation of this technical potential would require an investment of ~£12bn but could produce over 940% of pan-Hampshire's current electricity use.

As it is unlikely that the full technical potential would be implemented, the report analysed a number of high-medium-low development scenarios that represent different levels of development and penetration. Of these the high, medium-high and medium-low scenarios all comfortably met or exceeded current electricity use, and may therefore be able to meet future electricity demand. These would also require significant investment (£5-£12bn). Even the low scenario could meet approximately 85% of current electricity demand. Given likely future increases in electricity demand, it is clear that significant investment will be required to deliver local energy generation at the scale of the high/medium-high and medium-low scenarios if future electricity 'import' to the region is to be avoided. This is especially the case given the need to enable intra-day and inter-seasonal storage where renewables are intermittent.

Beyond the utility scale investments required, the scenarios also highlight areas for potential smaller scale onshore wind or, especially, solar PV sites that could be implemented via community energy projects across Hampshire. While unlikely to be major contributors to decarbonising pan-Hampshire's overall electricity demand, these could offer significant contributions to decarbonising local supply and to stimulating local commercial or industrial activity.

Future work in this project will assess the extent to which known network constraints may affect the potential for these scenarios to be implemented without some form of mitigation – such as the encouragement of local demand, storage or network reinforcement. Future work could also use these results as the basis for a temporal electricity generation model to understand the potential need for and value of energy storage in a future pan-Hampshire renewable electricity system.

Finally, it should be noted that the results are not intended to provide the basis for a detailed cost/benefit analysis or business case for the areas or sites identified as suitable. They are only intended to provide an indication of the likely generation potential and CAPEX required if the scale of areas identified were to be implemented under the various scenarios.

# 2 Introduction

Both the Carbon Trust work and the University of Southampton 'Hampshire Energy Landscape Mapping' report (Anderson & Kingsley-Walsh, 2021) identified that renewable electricity generation in the Hampshire area was relatively low compared to demand. The University of Southampton's report found that the total installed renewable electricity generation capacity of the pan-Hampshire area[1] was 679 MW in 2018 rising to 706 MW in 2021[2]. Of this 706 MW, 88% was photovoltaics with 185 MW in Test Valley, 97 MW in Winchester, 93 MW in Isle of Wight and 50 MW in East Hampshire districts but with little other installed renewable electricity generation capacity other than municipal solid waste sites in Basingstoke and Dean, Portsmouth and New Forest. Interestingly, in 2021 Test Valley had the 5th highest installed renewable generation capacity amongst South East England local authorities and was the only one in the top 5 not to have offshore wind resource. Winchester and the Isle of Wight were 10th and 11th respectively, also relying almost exclusively on photovoltaics.

The installed 706 MW of capacity generated 625 GWh in 2021, or a mere ~8% of the 7,520 GWh (7.5 TWh) of electricity used in pan-Hampshire in 2020 (see Table 15). This implied that in 2020, 92% of Hampshire's electricity was 'imported' and therefore that the 3% per annum increase modelled by The Carbon Trust in a report for Hampshire County Council's Climate Change Strategy was unlikely to make a substantive difference in absolute terms. This is especially the case if the NG-ESO Future Energy Scenarios[3] of a 93%-144% increase in total annual electricity demand hold true. As Table 1 shows, all these scenarios are predicated on a 158%-257% increase in total installed capacity in which renewables play a major role.

| | 2021 | 2050 Scenarios | | | |
|---|---|---|---|---|---|
| | | *Consumer transformation* | *System transformation* | *Leading the way* | *Falling short* |
| **Annual** electricity **demand (TWh)** | 294 | 710 | 716 | 672 | 566 |
| % increase | | 141% | 144% | 129% | 93% |
| | | | | | |
| **Installed** electricity generation **capacity (GW)** | 107 | 382 | 318 | 363 | 276 |
| % increase | | 257% | 197% | 239% | 158% |

*Table 1 - Projected total annual GB electricity demand and installed capacity (Source: NG-ESO Future Energy Scenarios 2022)*

Building on this analysis, a recent University of Southampton master's dissertation (Li, 2022) used a Multi-Criteria Decision Analysis (MCDA) approach to identify suitable areas for utility-scale solar PV, onshore wind, and offshore wind sites across the pan-Hampshire area. The dissertation suggested a potential low-carbon electricity generation capacity of 6.75 GW based on 0.5 GW, 2.5 GW and 3.75 GW from offshore wind, onshore wind and utility-scale solar photovoltaics, respectively. This is a significant increase from the current (2021) installed renewables capacity of 706 MW (0.706 GW). The dissertation suggested that this would be able to generate ~ 3 TWh of electricity annually from offshore wind, 9.6 TWh from onshore wind, and 3.5 TWh from solar PV to provide a total of ~16.1 TWh of electricity per year. This is substantially more than the 7.5 TWh of electricity Hampshire used in 2020. The dissertation concluded that with the addition of limited biomass generation (0.4 TWh per year), Hampshire could be self-sufficient in electricity by 2050 even allowing for substantial demand growth. However, subsequent analysis suggested a number of shortcomings in the assumptions in the

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[1] Defined as the eleven local authority districts within the county of Hampshire together with the Isle of Wight and the Cities of Southampton and Portsmouth – see Table 15 in the Statistical Annex

[2] BEIS (2022) Renewable electricity by local authority 2014 – 2021 (https://www.gov.uk/government/statistics/regional-renewable-statistics)

[3] See https://www.nationalgrideso.com/future-energy/future-energy-scenarios

underlying modelling used in the dissertation which could potentially have led to substantial overestimation.

In response, this report presents new technical analysis to identify suitable sites for tidal stream, offshore wind, onshore wind, utility-scale solar PV and rooftop solar PV systems using a more robust MCDA approach with previously omitted key factors that may impact site suitability and planning acceptance.

The report provides details of this improved methodology, each factor and how it was used in the MCDA to identify suitable sites. The report then assesses the potential electricity generation capacity of the selected sites (MW or GW), the potential annual generation (MWh or GWh) and an estimate of the likely investment costs required. These are presented under a number of scenarios of high-medium-low implementation.

# 3 Methodology

This section summarises the MCDA used to identify suitable areas for each of the considered generation technologies. Potential installed capacity and generation is estimated using varying levels of penetration of the areas and capacity per area values which vary for each generation technology (See Section 3.3). To give a broad understanding of the initial finances to deploy the sites, capital expenditure (Capex) estimates are calculated using generation technology specific factors for £/MW of installed capacity.

*It should be noted that this technical model provides a tool to identify potential generation sites for the different considered technologies given the constraints and assumptions chosen. All corresponding capacities, generation and Capex results are estimates based on the sites and these assumptions. They should not be viewed as anything other than indicative of the potential capacity, generation and investment costs of these kinds of sites.*

## 3.1 Multi-Criteria Decision Analysis

To identify suitable areas, a MCDA approach was used with differing layers for each of the considered technologies. A MCDA approach works by overlaying each layer of data which will have an effect on site suitability (Marttunen, Mustajoki, Dufva, & Karjalainen, 2015). Each layer is given a condition (for example, less than 2000m from roads or greater than 200m from a marine protected area), which if satisfied is given a value of 1 and if not satisfied is given a value of zero. A layer is then described as a ‘hard’ constraint or ‘weighted’ layer.

A **hard** constraint layer is one that must be satisfied for the area to be deemed suitable (for example, greater than 20m from rivers for solar PV) and therefore has values of 1 (suitable) or 0 (unsuitable).

A **weighted** constraint layer is one that, whilst still affecting site suitability, is not absolute - unlike the hard constraint layers. Each weighted layer is then given a specific weight to determine how important it is which is multiplied by the original value (0 or 1) of the layer. The sum of the weights across all layers for a given technology must be 1. For example, looking at Figure *1*, a weight of 0.2 might be given for a specific weighted layer – such as proximity to a primary sub-station for onshore wind. This means that the areas which satisfy the condition are given a score of 1 * 0.2 = 0.2 and areas that do not satisfy the condition are given a score of 0 * 0.2 = 0.

The total score for a given area is calculated as shown below:

$$S = (V_{hard,1} * V_{hard,2} * \dots * V_{hard,n}) * \sum_{i}^{n} (V_{weighted,n} * w_i)$$

Where *S*, the suitability, is the product of all the values of the hard constraints (0 or 1) ($V_{hard}$) multiplied by the sum of the weights (w) multiplied by the values of all the weighted layers ($V_{weighted}$). Clearly if any hard constraint has a value of 0 then the overall value of S will be 0 and the site will not be selected. If all hard constraints are 1 (suitable) then the value of S will depend on the weighted sum of the weighted constraints. In common with studies reported in the literature, this model does not use a perfect score of $S = 1$ as the threshold for site suitability but uses $S >= 0.8$ to allow for data inconsistencies and the inclusion of less-than-perfect sites which may still be possible to exploit. A worked example of the approach for three sites is provided in Table 16 in the Statistical Annex.

Different hard constraints, weighted layers and corresponding weights for each generation technology were set based on previous work, a review of the literature and feedback from local energy stakeholders. These are shown in Figure *1* and it should be noted that these parameters can be varied and the consequences for subsequent site-selection evaluated by re-running the MCDA model.

In contrast to version 1.0 of this report, this version (2.0) uses network location data in the onshore constraints models (onshore wind and solar PV) in place of a radius around primary substations. This is expected to substantially increase the suitability of onshore areas which are some distance from a substation but which are within 1km of the low voltage network.

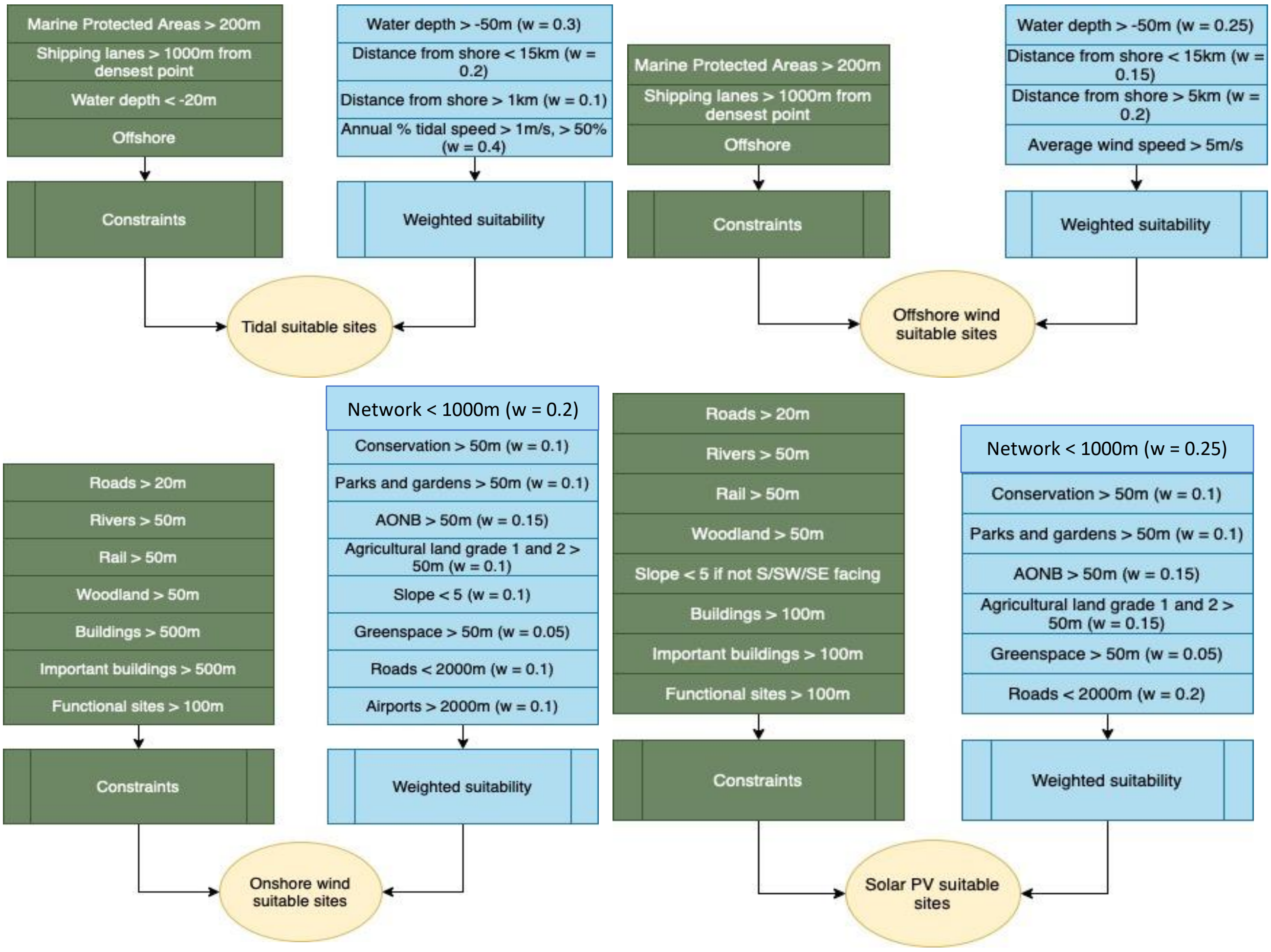

*Figure 1 – MCDA constraint and weighted suitability layers used to identify suitable sites for each utility-scale generation technology.*

The MCDA model was implemented at the default granularity of ~ 350m x 350m grid squares in ArcGIS Pro. Other granularities would be feasible but this was considered an appropriate granularity for the purposes of this estimation and enabled a relatively rapid model run.

## 3.2 Level of development scenarios

The grid squares (areas) deemed suitable (S >= 0.8) by the MCDA (Technical maximum) were then filtered via varying percentage levels of implementation to form four scenarios (high, medium-high, medium-low and low – see Table 2). These scenarios are intended to show the impact of different rates of implementation of the considered renewable generation technologies on potential installed capacity, generation and capital expenditure required to reach or exceed the current and potential future levels of electricity demand. Note that these scenarios only provide estimates for capacities, generation and Capex based on the MCDA and should not be used to form a business case for specific areas.

*Table 2 – Details of the % implementation assumptions for the different scenarios.*

| Scenario | Offshore wind | Tidal | Utility-scale solar PV | Onshore wind | Rooftop solar PV |
|---|---|---|---|---|---|
| Technical maximum | 100% of site | 100% of site | 100% of areas | 100% of areas | All buildings |
| High | 50% | 50% | 25% of areas | 25% of areas | 25% of all buildings |
| Medium-high | 25% | 25% | 20% of areas | 20% of areas | 20% of all buildings |
| Medium-low | 10% | 10% | 15% of areas | 15% of areas | 15% of all buildings |
| Low | 5% | 5% | 10% of areas | 10% of areas | 10% of all buildings |

### 3.2.1 Offshore sites

For the offshore sites, a large area was initially selected to estimate the maximum potential area that could be developed off the coast of the Hampshire area. As there was likely to be a greater area suitable for offshore wind than for tidal stream, due to greater restrictions on tidal stream, the tidal stream site location took preference over the offshore wind site and so the proposed tidal sites were selected before the proposed offshore wind site. There has been little research on potential interferences regarding co-location of tidal and offshore wind generation sites. However, one study suggests that not only can co-location provide a greater generation output than single source sites but can also reduce the levelised cost of energy generation for the site due to shared infrastructure (D. Lande-Sudall, T. Stallard, & P. Stansby, 2019). For all technologies, co-location can also assist with reducing intermittency issues that naturally occur due to the nature of renewable energy and can help balance peaks and troughs in generation. The simplistic either/or model for offshore sites implemented here could therefore be re-assessed by future proposals.

In the UK, the vast majority of offshore wind developments are located in the North Sea or Irish Sea and not off the South coast in the English Channel. This may be largely due to social or political rejection on the basis of potential harm to tourism, Areas of Outstanding Natural Beauty and heritage[4] rather than technical constraints although the density of commercial and leisure shipping also plays a role. However, the Rampion Wind Farm is a large, 400 MW (116 x 3.45 MW turbines) wind farm located off the coast of Brighton in the English Channel. This shows that large offshore wind developments are possible off the South coast of the UK in the English Channel and therefore

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[4] See for example the 2015 Navitus Bay decision: https://www.gov.uk/government/news/planning-decision-for-navitus-bay-offshore-wind-park

that further developments that can address social, political, environmental and shipping concerns could be pursued.

Different scenarios were then considered to show how a different penetration and size of these systems would influence estimated potential generation. The range of scenarios and their corresponding level of deployment is shown in Table 2. A relatively ambitious ‘high’ implementation rate of 50% of the suitable area was assumed, declining to a ‘low’ of 5% for illustrative purposes.

### 3.2.2 Onshore sites

For onshore wind and solar PV, the scenarios implemented the percentages of the technical maximum suitable areas obtained from the MCDA as described in Table 2. In contrast to the offshore sites, a relatively conservative assumption of a ‘high’ implementation rate of 25% was assumed declining to a ‘low’ of 10%. Note that under this method specific ‘sites’ were not selected – the scenarios are simply a percentage of the Technical maximum values identified for all suitable areas from the MCDA (i.e. where $S > 0.8$).

If an area is deemed suitable for both onshore wind and solar PV development, it is possible for either or both technologies to be developed in these areas. Co-location for the installation of both solar PV and wind farms over the same area is possible however there are co-location interferences that reduces the feasibility of the systems (Yin, Cheng, Chen, & Wu, 2020). For example, through wind turbines’ shading and penumbra on PV surfaces which will reduce the solar PV electricity generation output. If co-location is not possible, onshore wind should be preferred due to the likely fewer areas suitable for development compared to solar PV (due to the stricter constraints and weighted layers requirements). In addition, the higher capacity per area and higher load factor of onshore wind (~31.84%) compared to solar PV (~11%) would tend to make wind a preference for such a site as more electricity could be produced per unit area.

### 3.2.3 Rooftop solar

In addition to the technologies described in Figure *1*, the report also includes analysis to determine the area of rooftops which are suitable for rooftop solar PV installation.

The original intention was to use Light Detection and Ranging (LiDAR) Digital Surface Model (DSM) data for this purpose. LiDAR DSM data is high resolution data (1m resolution) which represents the elevation of the tallest surface at a given spatial point. However, due to the high resolution of LiDAR data, file sizes are large and can only be downloaded in small areas. As a result, it has proven impractical to collect, process and analyse the data for the whole of the study area using this methodology. In consequence, a subset of the LiDAR data has been analysed as case studies of Southampton and Winchester.

In addition to these LiDAR case studies and in order to provide interim ‘whole of Hampshire’ indicators for comparison, estimations were therefore also made using a range of assumed penetration levels of rooftop solar PV, an average installed capacity of 4 kW and an estimate of the total roof area of all buildings in Hampshire. As with the onshore scenarios, the high scenario was defined to be 25% of all roofs, falling to 10% in the low scenario (see Table 2).

## 3.3 Installed capacity and electricity generation estimation

The areas identified as suitable for each technology were then used to estimate the potential installed capacity and therefore annual generation for each generation technology and scenario. To calculate the capacity, the potential site area ($km^2$ or $m^2$ in the case of rooftops) was multiplied by a capacity per area ($MW/km^2$ or $kW/m^2$) factor. These factors were determined from the capacity and area of different operational and proposed generation projects in the UK to account for gaps between, for example, solar PV panel rows or wind turbines and also to account for any transformers or other equipment that may be required on a generation site.

The capacity determined was then multiplied by the hours in a year (8760) and by a load factor, which is a measure of the efficiency of electricity generation, to give the estimated annual generation in GWh. For example, if a 10 MW generator had a load factor of 20% then it would produce 2 MWh in 1 hour and, on average, 17,520 MWh (17.5 GWh) per year. The capacity per unit area factors and load factors used for each generation technology are shown in Table 3. Note that the results reported in Section 5 have been rounded to avoid inappropriate expectations of precision.

*Table 3 – Capacity per unit area and load factors for each generation technology*

| Generation technology | Capacity per unit area factor (MW/km$^2$) | Load factor (%) |
|---|---:|---:|
| Utility-scale solar PV | 49.42 | 11 |
| Onshore wind | 6.67 | 39 |
| Offshore wind | 5.53 | 39 |
| Tidal stream | 5.99 | 25 |
| Rooftop solar PV | 0.125 (kW / m$^2$) | 11 |

Table 3 makes clear that generation from wind resources has the highest load factor so wind generation from wind should be favoured to provide a large proportion of Hampshire electricity demand. Although solar PV generation has a relatively low load factor, it has a high capacity per unit area and its generation output is greatest in the summer day-time so will be able to supply a large proportion of Hampshire's electricity demand during these months and times. Generation from tidal stream has the valued benefit of being predictable, as tide times are known, which can be invaluable to Distribution Network Operators (DNO) who need to tackle the intermittency issues that come with an increasing renewable penetration. Rooftop solar PV generation will be heavily concentrated within urban areas and cities, which may have low potential for utility-scale generators. These different generation types also have differing temporal generation profiles so a diverse energy mix would be required to provide a generation balance and to satisfy Hampshire electricity demand in the absence of demand response or energy storage (Boehme, 2006).

This methodology assumes that the complete area of the suitable areas are used for generation which will not always be the case, especially in some of the larger sites which may encounter planning and DNO objection due to grid/distribution network capacity or technical connection issues. Aspects of this will be explored under current known network constraints in subsequent work. Although investment in both the national grid and local distribution networks may ameliorate these concerns in the future, projection of future connection capacity is beyond the remit of this report as it would require detailed knowledge of NG-ESO and SSEN's investment plans. Therefore, the methodology proposed for the capacities and corresponding electricity generation should only be used as a guide based on the above assumptions.

## 3.4 Capital Expenditure estimation

To give an estimate of the development Capex for each of the generation technologies, technical key assumptions for 2025 made by the Department for Business, Energy & Industrial Strategy in their Electricity Generation Costs 2020 report (Department for Business Energy and Industrial Strategy, 2020) were used. These provide pre-development and construction costs per kW of required capacity by commissioning year, which are summed together to give the total Capex. For reference, projections of these costs to 2040 are provided in Table 17 in the Statistical Annex. These project reductions in CAPEX for utility-scale solar and off-shore wind in particular.

However, the BEIS projections do not give costs for tidal stream generation which was sourced from (D. Lande-Sudall, T. Stallard, & P. K. Stansby, 2019). For rooftop solar PV, an average purchase and installation cost of £6,000 for a 4 kW system was assumed. These Capex estimations are shown in below in Table 4.

*Table 4 – Capital Expenditure (£/kW) for each generation source.*

| Generation technology | Capex (£/kW) |
|---|---:|
| Utility-scale solar PV | 450 |
| Onshore wind | 1,120 |
| Rooftop solar PV | 1,500 |
| Offshore wind | 1,630 |
| Tidal | 2,500 |

These estimates were then multiplied by the kW capacity of each site (1000 kW = 1 MW) to give the total Capex of the development. This was then summed for each scenario for each district and for the whole pan-Hampshire area. Note that the reported results have been rounded to avoid inappropriate expectations of precision.

*Clearly the Capex results are estimates based on generic values - each site may require different work to be completed for full operation and so these indicative estimates **cannot** be used as a guide to the actual cost of implementation at specific sites.*

# 4 Data

## 4.1 MCDA data inputs

The data used in the MCDA is shown in Table 5, identifying where it was obtained, whether it is open access, the scale of the data, and what it was used for. Note that in contrast to version 1.0 of this report, this version of the report includes network location data provided by SSEN.

*Table 5 – Data collection table stating source, whether it is open access, the scale and what it is used for.*

| Data | Source | Access | Scale | Use |
|---|---|---|---|---|
| Weather data | Weather Underground | Open - create download loop to save individual daily weather files | 1/2 hour | Actual wind speeds and solar irradiance across the Hampshire area |
| Network locations | SSEN | Closed – accessed through SSEN agreement | NA | MCDA for on-land resources |

| | | | | |
|---|---|---|---|---|
| Substation locations | SSEN | Open | NA | MCDA for on-land resources |
| Buildings shapefiles | OS OpenMap - Local | Open | NA | MCDA for all on-land resources |
| Roads shapefiles | OS | Open | NA | MCDA for all on-land resources |
| Woodland shapefiles | OS OpenMap - Local | Open | NA | MCDA for all resources |
| Functional sites shapefiles | OS | Open | NA | MCDA for all on-land resources |
| Greenspace shapefiles | OS | Open | NA | MCDA for all on-land resources |
| Rivers shapefiles | OS | Open | NA | MCDA for all resources |
| Agriculture shapefiles | OS | Open | NA | MCDA for all on-land resources |
| Contour line shapefiles | OS | Open | 50m/5m | MCDA for all on-land resources - create aspect-slope layer |
| AONB shapefiles | data.gov.uk | Open | NA | MCDA for all on-land resources |
| Boundary shapefiles | OS | Open | NA | Fixed project boundary |
| Airports | ArcGIS REST | Open | NA | MCDA for onshore wind |
| Heritage sites shapefiles | data.gov.uk | Open | NA | MCDA for all on-land resources |
| Shipping lanes shapefiles | data.gov.uk | Open | NA | MCDA for offshore wind and tidal resources |
| Tidal times/heights | | Open | NA | Determine tidal current flow in Solent |
| Sediment type | | Open | NA | MCDA for offshore wind and tidal resources |
| Water depth | General Bathymetric Chart of the Oceans | Open | NA | MCDA for offshore wind and tidal resources |
| Marine protected areas shapefiles | JNCC | Open | NA | MCDA for offshore wind and tidal resources |
| LiDAR | Edina Digimap | Open | 1m | Rooftop PV suitability |

## 4.2 Mapping data

The maps reported below were developed using ArcGIS Pro under license to the University of Southampton using the following data:

- Basemaps: ArcGIS Data service world topography map © ESRI, 2023
- Local Authority boundaries: © Office for National Statistics licensed under the Open Government Licence v.3.0

# 5 Results

## 5.1 Suitable areas

This section discusses the suitable sites identified by the MCDA for each generation technology. The red areas of the maps indicate a score of 0 (not suitable) and the yellow areas indicate a score of 1 (suitable), which satisfies all criteria. Sites that only satisfy some criteria but are still suitable are shown as shades of orange (0.8-0.99). The methodology or rationale for selection of specific sites within the 'suitable' areas is discussed in each section where relevant and readers should refer to the constraints and weights described in Figure *1*.

Note that the existing 706 GW of renewables installed in the area have not been excluded from the analysis and are assumed to lie within the suitable areas. This means that the estimated 'new potential capacity' and CAPEX for solar PV and, to more limited extent, onshore wind will be slight over-estimates.

### 5.1.1 Tidal stream

The suitable areas for tidal stream generation are shown in Figure 2. It can be seen that there is a large area off the south coast of the Isle of Wight in the English Channel that satisfies all criteria (S = 1) and is deemed as very suitable. There are also large areas which have a do not satisfy all criteria but are still suitable for this analysis (0.8 < S < 1).

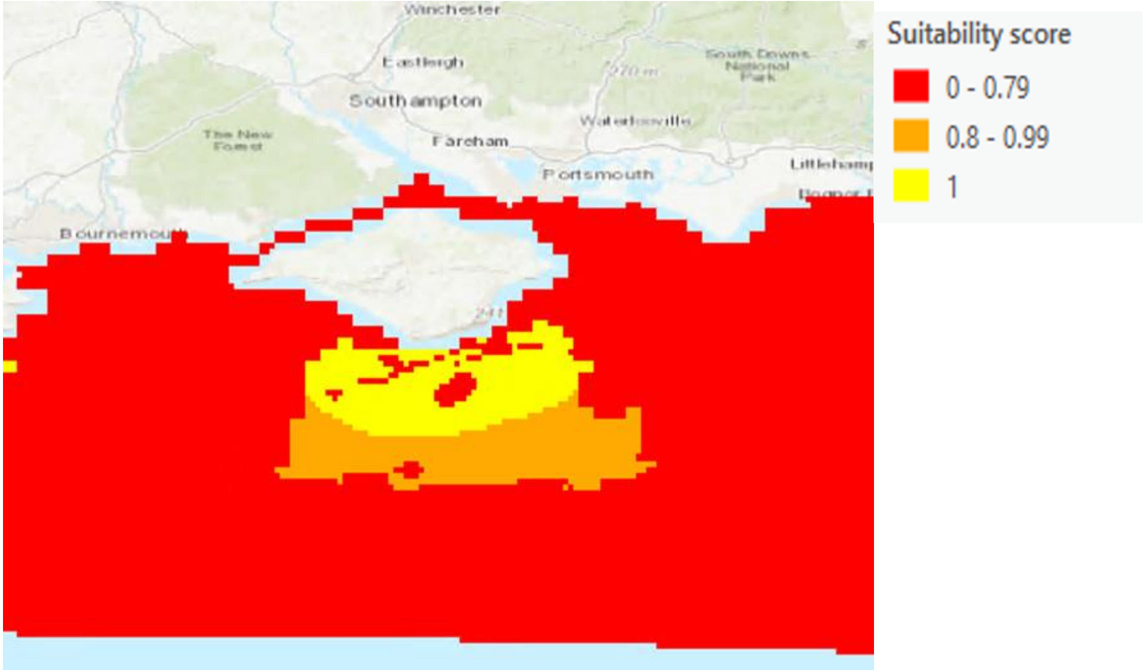

*Figure 2 – Suitable areas for tidal stream development as determined by the MCDA.*

To assess maximum and then progressively smaller tidal stream sites, a very large site was selected (Figure 3). This 'full' (100%) site was then reduced to 50%, 25%, 10% and 5% as defined by the scenarios (see Table 6). For simplicity these sites are shown as nested areas in Figure 3 but note that the precise locations of these are not set and could be located anywhere within the suitable areas (S > 0.8) shown in Figure 2.

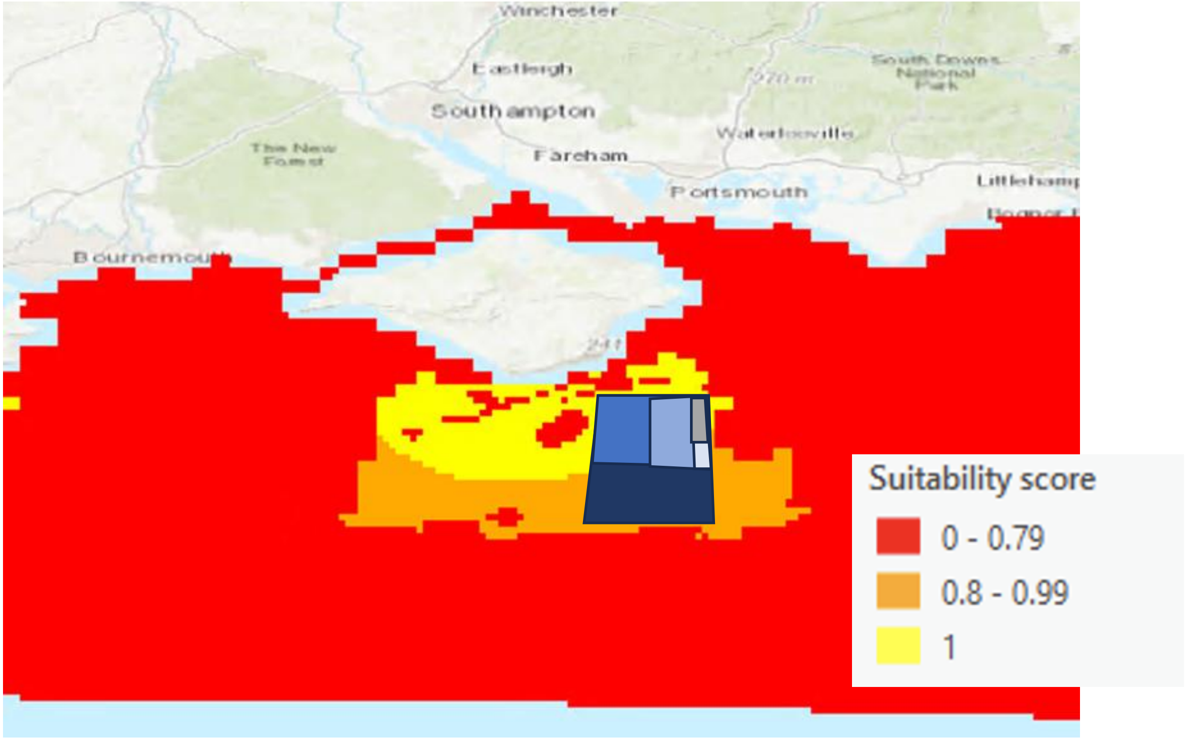

*Figure 3 – Potential tidal stream sites (100% - 5% indicated).*

Indicative estimates for the different sized tidal stream sites, including installed capacity (MW), annual generation (GWh) and estimated Capex (£ million) are given in Table 6. The estimated maximum annual generation of 2,780 GWh under the 100% scenario represents 37% of current pan-Hampshire electricity demand (see Table 11Table 11).

*Table 6 –Tidal stream scenario results.*

| Site size | Area (km$^2$) | Capacity (MW) | Annual generation (GWh) | Capex (£m) |
|---|---|---|---|---|
| 100% | 212 | 1,270 | 2,780 | £3,175m |
| 50% | 106 | 635 | 1,390 | £1,587m |
| 25% | 53 | 317.5 | 690 | £793m |
| 10% | 21.2 | 127 | 270 | £317m |
| 5% | 10.6 | 63.5 | 139 | £158m |

### 5.1.2 Offshore wind

The areas suitable for offshore wind generation are shown in Figure 4. It can be seen that there are some large areas off the south coast of the Isle of Wight in the English Channel that satisfy all criteria and are deemed as suitable.

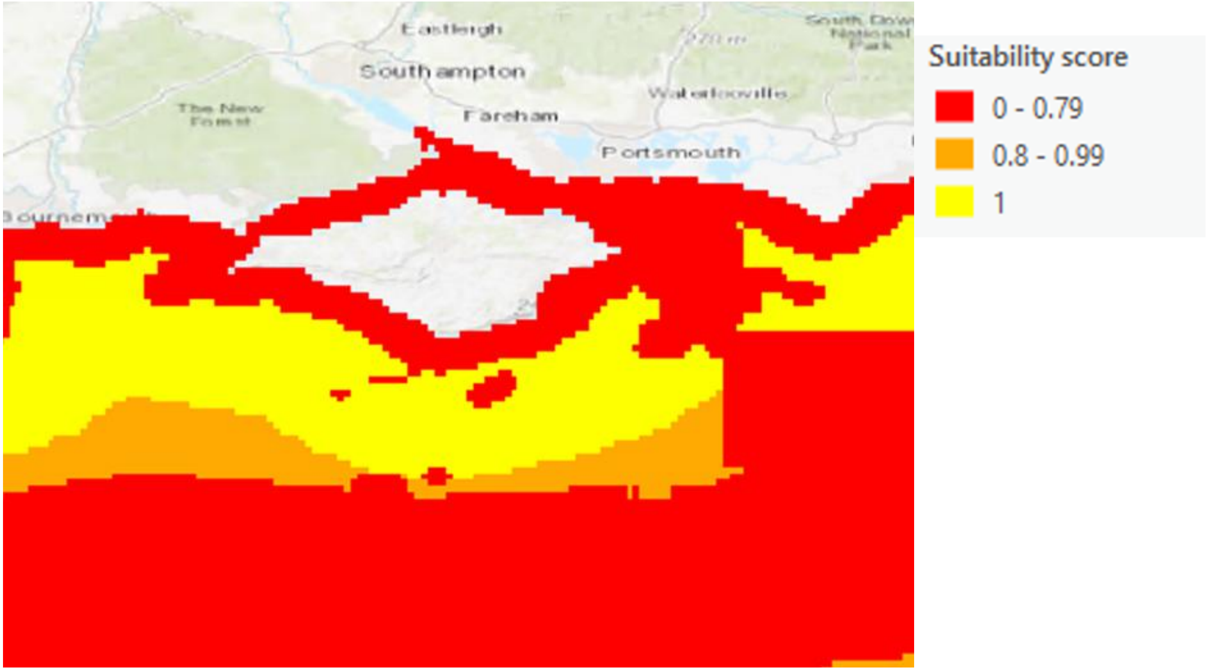

*Figure 4 - Suitable areas for offshore wind development as determined by the MCDA.*

As with the tidal stream a very large site was initially selected (Figure 5). This was then split to 50%, 25%, 10% and 5%. As before, this illustrates the size of the sites, the locations of these are not set and can be located anywhere in the suitable areas (S > 0.8) in Figure 4. Note, the region selected for the potential offshore wind site is off the south-west coast of the Isle of Wight in roughly the location proposed for the rejected Navitus Bay wind farm. This is because there was a greater suitable area for offshore wind than for tidal stream, which was more geographically limited, so the tidal stream site selection took precedence over the offshore wind site. However, Figure 4 shows that an offshore wind site could be developed in other areas around the English Channel.

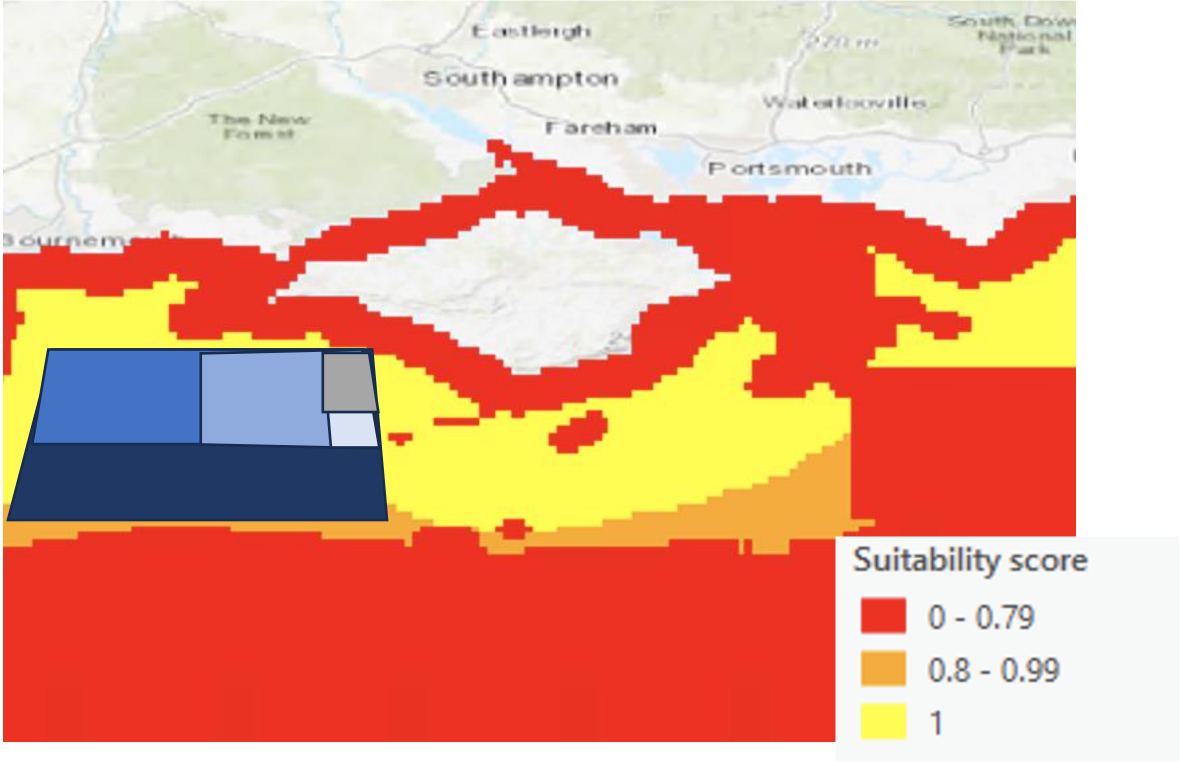

*Figure 5 – Potential offshore wind sites (100% - 5% indicated)*

Indicative estimates for the different sized offshore wind sites, including installed capacity (MW), annual generation (GWh) and estimated Capex (£ million) are given in Table 7. The estimated maximum annual generation of 10,040 GWh under the Full scenarios represents 134% of current pan-Hampshire electricity demand (see Table 11).

*Table 7 –Offshore wind scenario results.*

| Site size | Area (km$^2$) | Capacity (MW) | Annual generation (GWh) | Capex (£) |
|---|---:|---:|---:|---:|
| 100% | 651 | 3,600 | 10,040 | £5,870m |
| 50% | 325.5 | 1,800 | 5,020 | £2,930m |
| 25% | 162.8 | 900 | 2,510 | £1,470m |
| 10% | 65.1 | 360 | 1,250 | £590m |
| 5% | 32.6 | 180 | 625 | £295m |

### 5.1.3 Onshore wind

The suitable areas for onshore wind generation within the pan-Hampshire area are shown in Figure 6. This shows that, based on the MCDA assumptions, there is limited scope for onshore wind in Hampshire. However, it can be seen that there are a number of areas of varying size that are deemed suitable for onshore wind generation with some of the largest areas identified in the New Forest district.

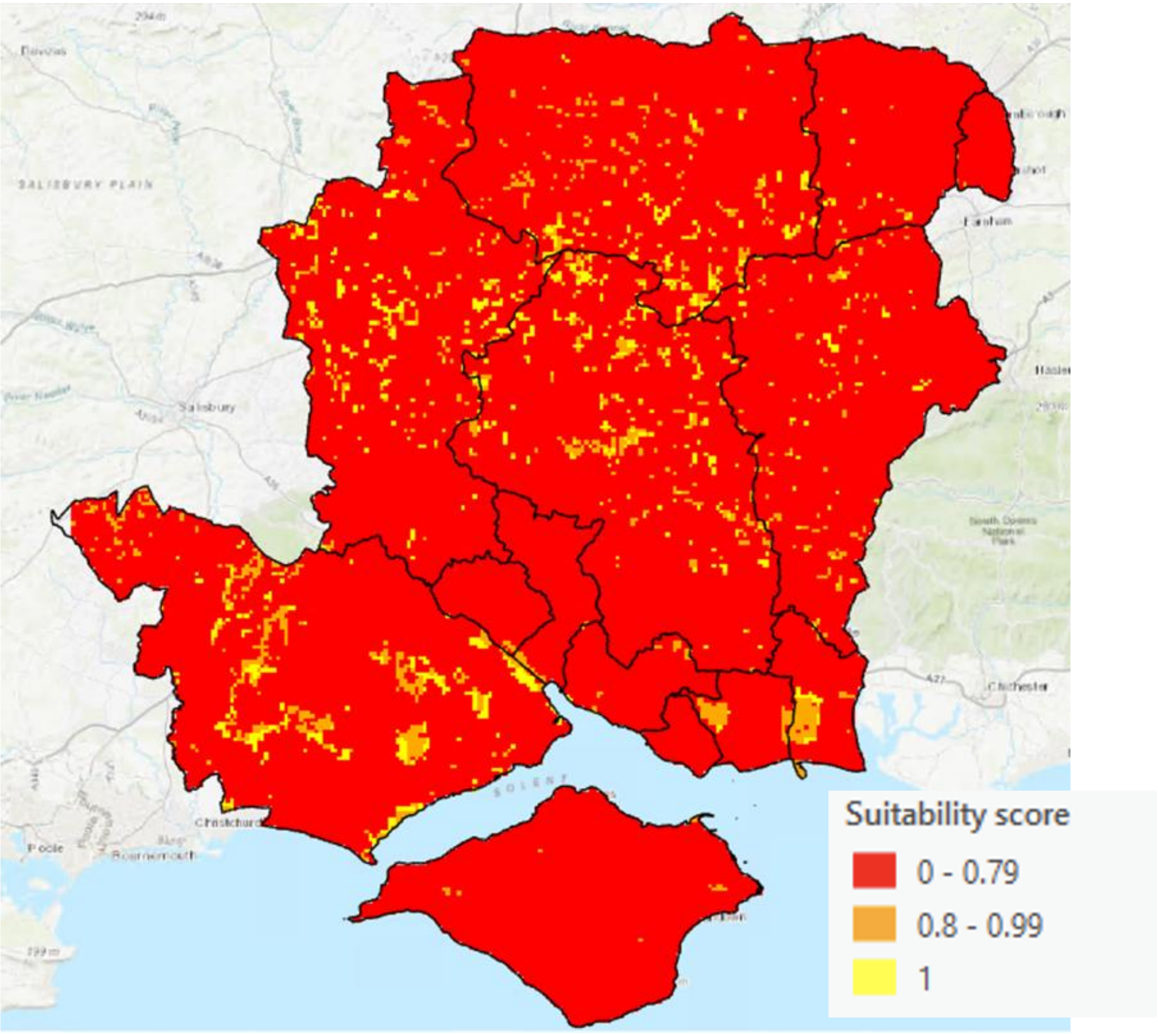

*Figure 6 – Suitable areas for onshore wind development as determined by the MCDA (Local Authority district boundaries shown. Note areas of water in Southampton, Havant and Portsmouth have not been filtered out as they have been deemed 'suitable' even if implementation may be impractical).*

To estimate the scale of onshore wind sites that could be developed, different percentages of the suitable areas as defined by the scenarios were considered. Indicative estimates based on Figure 6, including total land area, capacity, generation and Capex are given in Table 8. The estimated maximum annual generation of 4,277 GWh under the 100% scenario represents 57% of current pan-Hampshire electricity demand (see Table 11).

*Table 8 –Onshore wind scenario results (assumed to include the currently installed 59 GW).*

| Site size | Area (km$^2$) | Capacity (MW) | Annual generation (GWh) | Capex (£) |
|---|---|---|---|---|
| 100% | 170.07 | 1,252 | 4,277 | £1,402m |
| 25% | 42.52 | 313 | 1069 | £351m |
| 20% | 34.01 | 250 | 855 | £280m |
| 15% | 25.51 | 188 | 642 | £210m |
| 10% | 17.01 | 125 | 428 | £140m |

### 5.1.4 Utility-scale solar photovoltaics

The suitable areas for utility-scale solar PV generation within the pan-Hampshire area are shown in Figure 7. This shows substantially more potential in terms of land area than was the case for onshore wind. It can also be seen that there are a wide range of areas of varying size that are deemed suitable for solar PV generation.

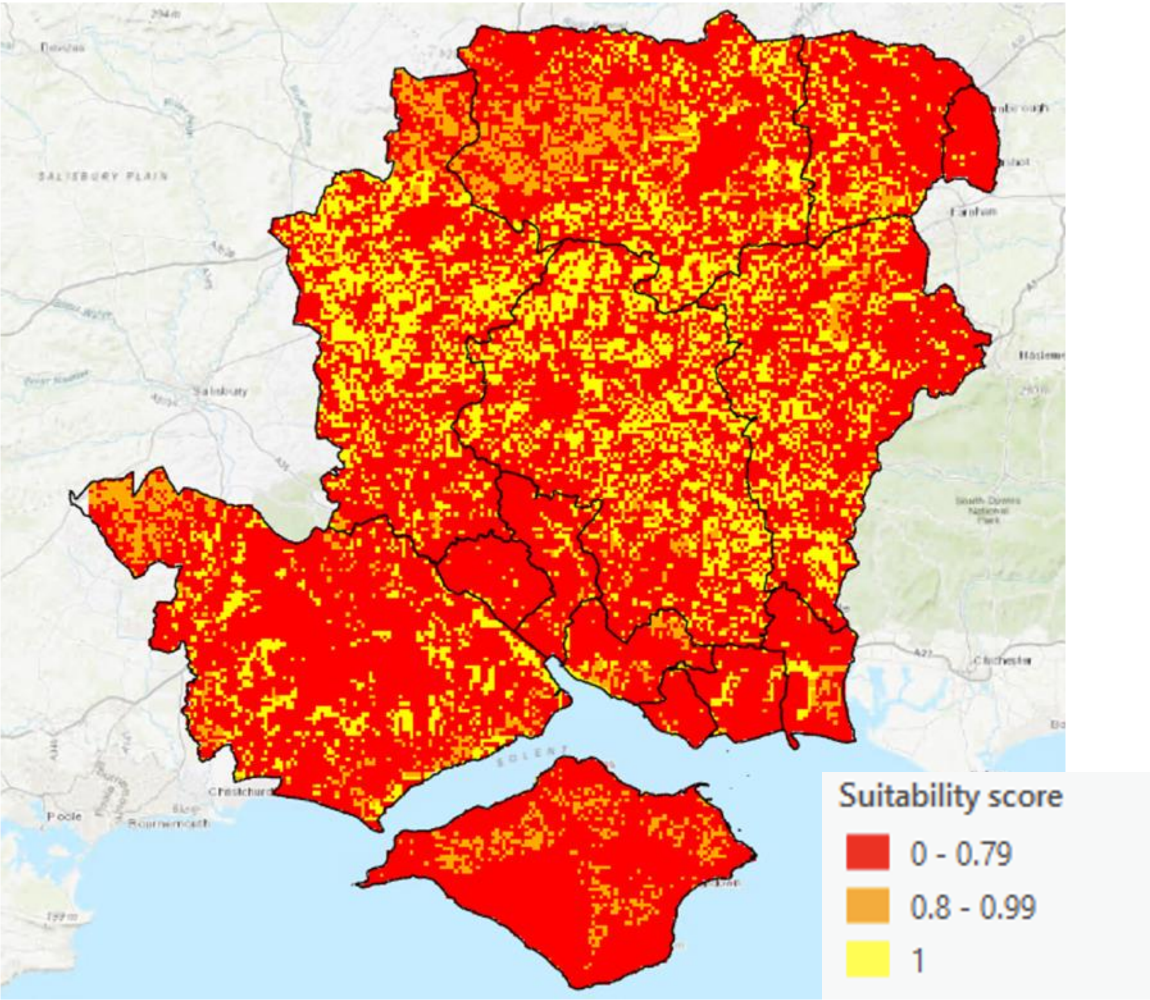

*Figure 7 - Suitable areas for utility-scale solar PV development as determined by the MCDA (Local Authority district boundaries shown)*

To understand the level of utility-scale solar PV that could be developed, varying development penetration levels were considered based on Figure *7* and the pre-defined scenarios. Indicative estimates including total land area, capacity, generation and Capex are given in Table 9. The estimated maximum annual generation of 51,361 GWh under the 100% scenario represents 709% of current pan-Hampshire electricity demand (see Table 11). This result is extremely unlikely but nevertheless indicates the substantial area of land in Hampshire that is deemed technically suitable.

*Table 9 – Utility-scale solar PV scenario results (assumed to include the currently installed 621 GW).*

| Site size | Area (km$^2$) | Capacity (MW) | Annual generation (GWh) | Capex (£) |
|---|---:|---:|---:|---:|
| 100% | 1075.29 | 53,301 | 51,361 | £23,985m |
| 25% | 268.82 | 13,325 | 12,840 | £5,996m |
| 20% | 215.06 | 10,660 | 10,272 | £4,792m |
| 15% | 161.29 | 7,995 | 7,704 | £3,598 |
| 10% | 107.53 | 5,330 | 5,136 | £2,399 |

### 5.1.5 Rooftop solar photovoltaics

In addition to the technologies described in Figure *1*, the report also includes analysis to determine rooftops which are suitable for rooftop solar PV installation.

The original intention was to use Light Detection and Ranging (LiDAR) Digital Surface Model (DSM) data for this purpose. LiDAR DSM data is high resolution data (1m resolution) which represents the elevation of the tallest surface at a given spatial point. LiDAR data can be used to determine if a rooftop is suitable for the installation of a rooftop solar PV by assessing the aspect, slope and area of a rooftop. For optimal performance of a rooftop solar PV system in the UK, it should be placed on a south-facing, 35° angled rooftop although this is not always exactly possible. Here, a suitable rooftop is defined as one in which a minimum of a 1 kW solar PV system can be installed (8 $m^2$ rooftop area required), with an orientation east through south to west and at an angle between 15° to 70° (Palmer, Koumpli, Cole, Gottschalg, & Betts, 2018).

However, due to the high resolution of LiDAR data, file sizes are large and can only be downloaded in small areas. As a result, it has proven impractical to collect, process and analyse the data for the whole of the study area using this methodology. In consequence, a subset of the LiDAR data has been analysed as case studies of Southampton and Winchester. Heavily built-up urban areas such as Southampton are likely to have low utility-scale generation potential due to the high concentration of buildings. They will however have greater potential than other, more rural districts for rooftop solar PV generation. The results for Southampton and Winchester are included to demonstrate the practicality and potential value of the methodology and to give case studies for discussion.

In addition to these LiDAR case studies and in order to provide interim ‘whole of Hampshire’ indicators for comparison, estimations were therefore also made using a range of assumed penetration levels of rooftop solar PV, an average installed capacity of 4 kW and an estimate of the total roof area of all buildings in Hampshire.

#### *5.1.5.1 Southampton LiDAR case study*

Analysis is currently ongoing to determine rooftops which are suitable for rooftop solar PV installation using Light Detection and Ranging (LiDAR) data. In the meantime a case study of an urban area in the City of Southampton district is shown in Figure 8.

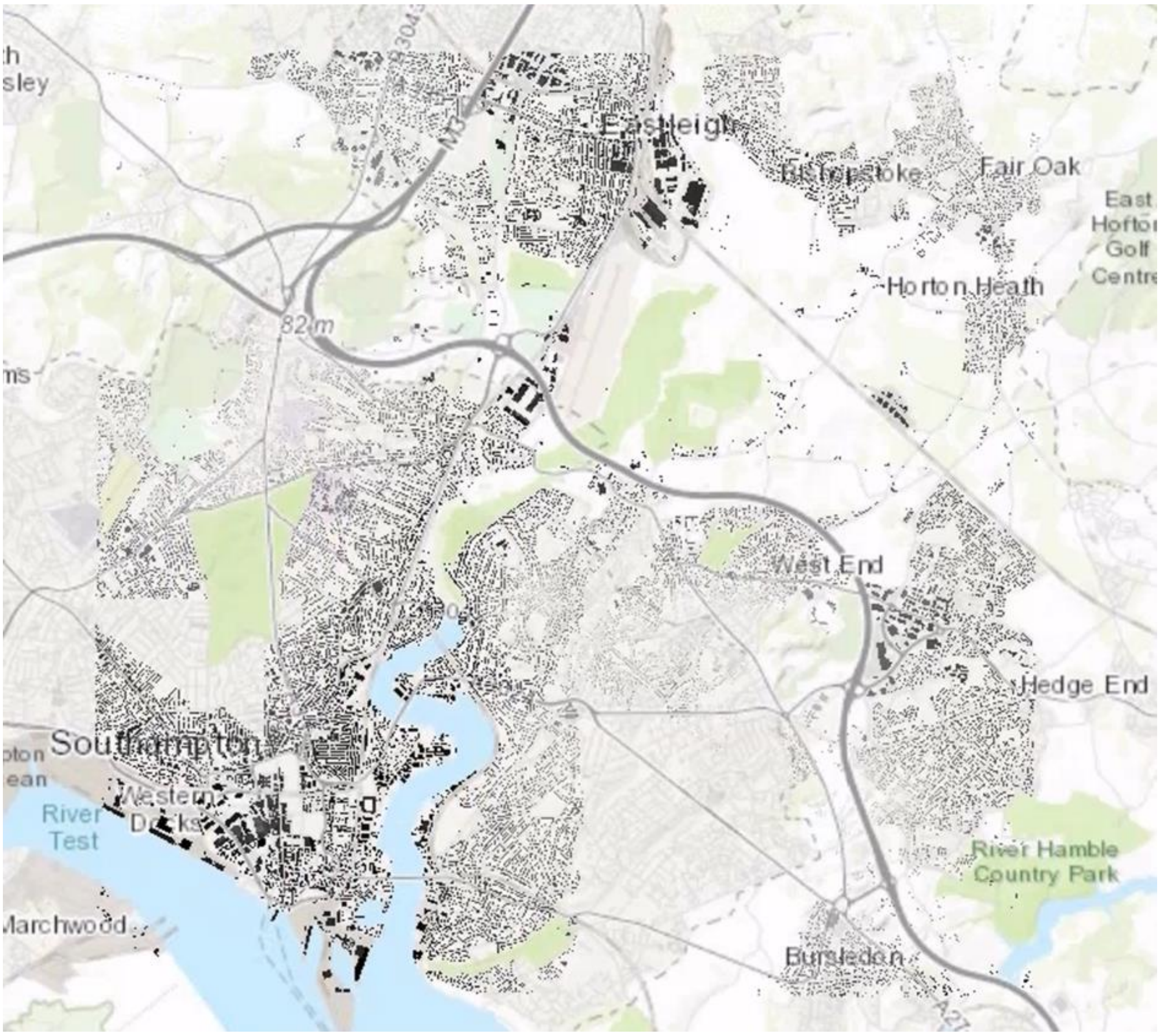

*Figure 8 – LiDAR DSM data rooftop sample area covering the wider-Southampton region..*

Within this case study area of 45,537 buildings, 30,576 (67%) had at least one area which satisfied the criteria which deemed it as suitable for a rooftop solar PV system (see Figure 9). Some of the larger rooftops, had multiple areas which were suitable for larger rooftop arrays. In this area, if 100% of the suitable rooftop areas were used for rooftop solar PV installations, then approximately 275.7 MW of installed capacity could be utilised. This would generate approximately 169 GWh of electricity per year and should be contrasted with the total 2020 electricity consumption of 824 GWh for the City of Southampton[5].

However, it is unlikely that all of these rooftops would install a rooftop solar PV system. As a more realistic estimate, half of the suitable roofs (33.5% of buildings) would generate ~85 GWh per year, a quarter (16.75%) would generate 42 GWh per year and a tenth of these (6.7%) would generate 17 GWh per year.

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[5] Source: https://www.gov.uk/government/statistics/total-final-energy-consumption-at-regional-and-local-authority-level-2005-to-2020 - see also Table 15 in the Statistical Annex

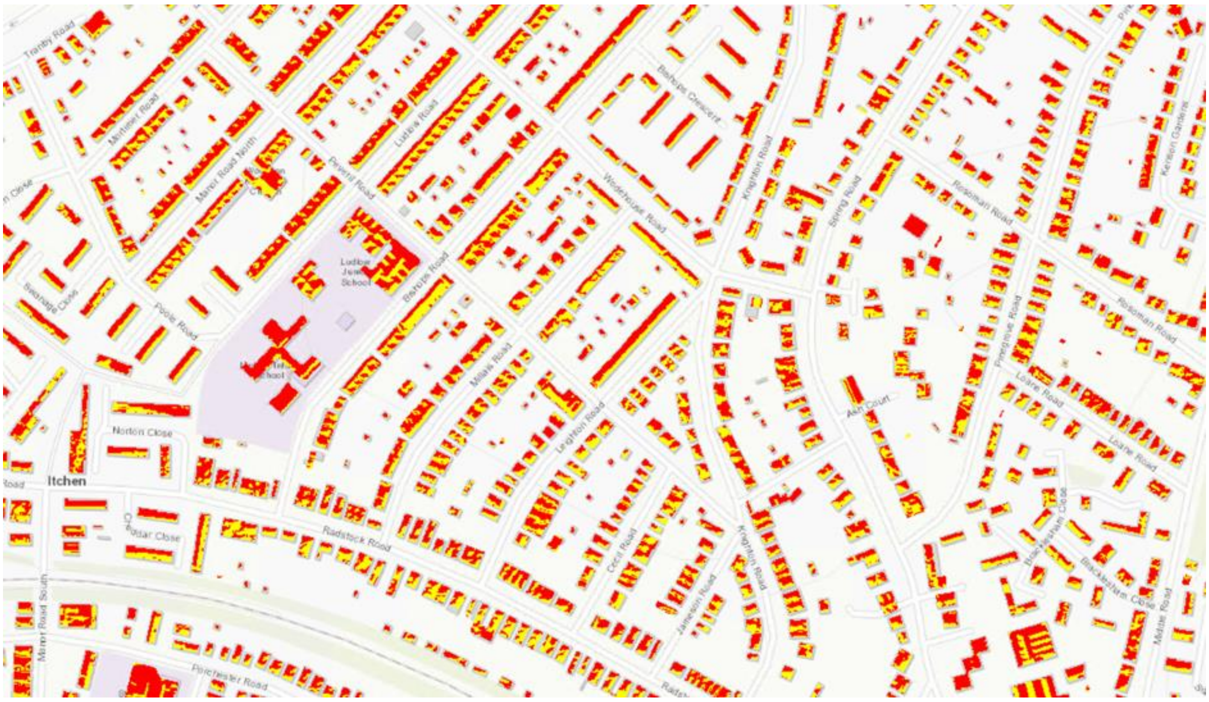

*Figure 9 – Close up image of the suitable (yellow) and unsuitable (red) rooftop areas in the selected Southampton City region.*

### *5.1.5.2 Winchester LiDAR case study*

The methodology was also tested on the wider-Winchester City area (Figure 10). The area selected had a total of 13,696 buildings (according to the OS Buildings dataset), of which 10, 797 (78.8%) had a rooftop surface that was deemed as suitable for a rooftop PV installation of at least 1 kW. Figure 11 shows potential installed capacity per buildings in the area. It is clear that the majority of the buildings in the area have a suitable area for installation at varying capacities. The total potential installed capacity for all rooftops in the area was 83.2 MW which would generate ~80 GWh of electricity per year, half of the suitable rooftop capacity would generate ~40 GWh per year and a quarter would generate ~ 20 GWh per year. This should be contrasted with total 2020 electricity consumption of 557 GWh for the district[6].

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[6] Source: https://www.gov.uk/government/statistics/total-final-energy-consumption-at-regional-and-local-authority-level-2005-to-2020 - see also Table 15 in the Statistical Annex

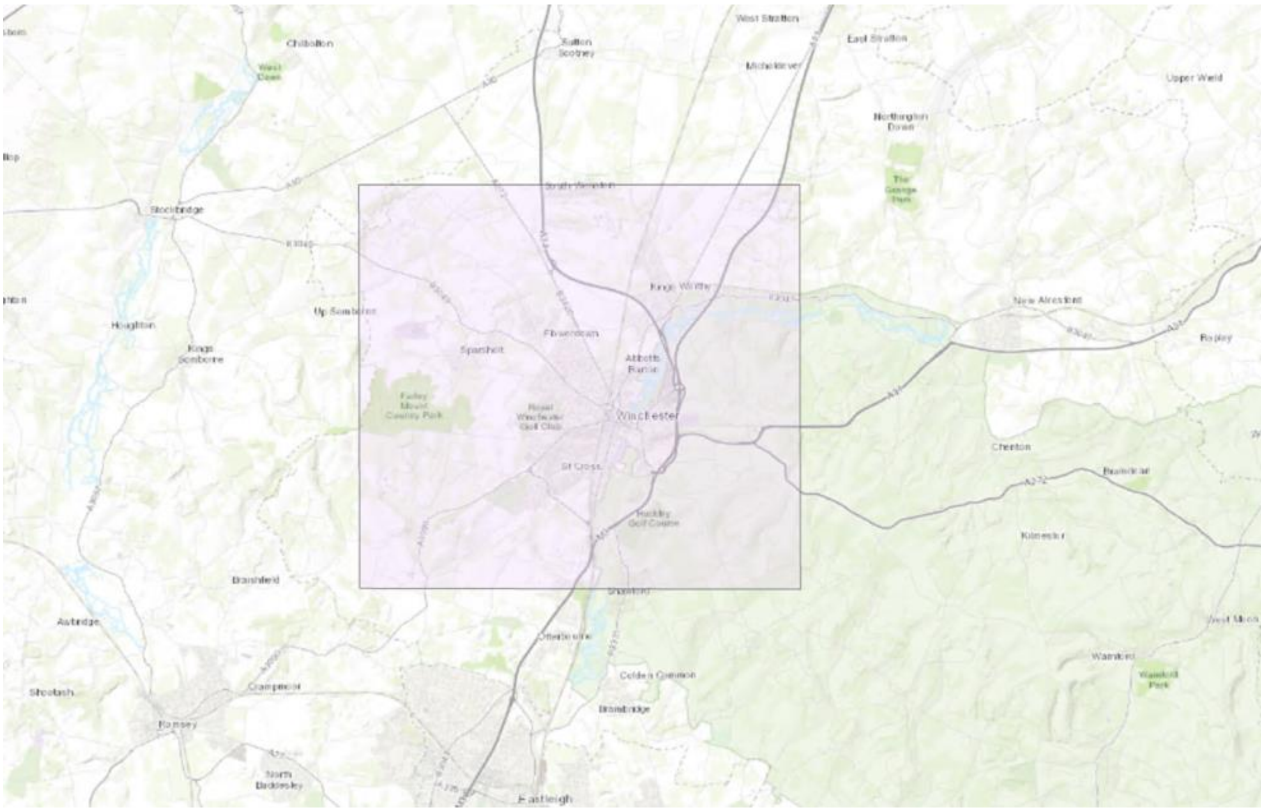

*Figure 10 – The wider-Winchester City region selected to test the LiDAR rooftop suitability methodology.*

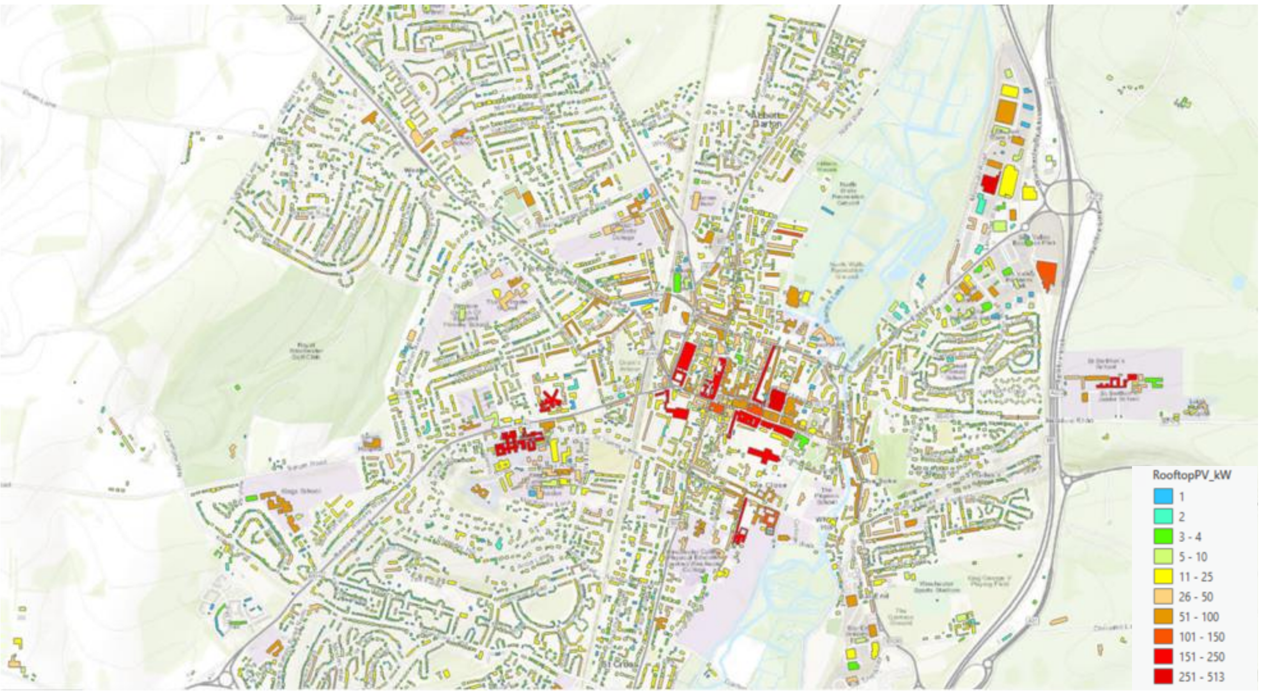

*Figure 11 – Close-up image showing the potential rooftop solar PV capacity (kW) for each building in the wider-Winchester City area.*

### *5.1.5.3 Pan-Hampshire average-based estimates*

In addition, to provide interim indicative results for the whole of Hampshire, estimates are made based on different penetration levels of rooftop solar PV systems and an average installed capacity of 4 kW. There are approximately 482,000 buildings (domestic and non-domestic) in the pan-Hampshire area (OS OpenMap Local Buildings dataset). Indicative estimates for the rooftop solar PV penetration potential, including total number of installed systems, capacity, generation and Capex is given in Table 10. The estimated maximum annual generation of 460 GWh under the 25% of roofs scenario represents just 6% of current pan-Hampshire electricity demand (see Table 11).

*Table 10 – Estimated total installed capacity (MW) and annual generation (GWh) for differing penetration levels of rooftop solar PV systems.*

| Penetration | Number of buildings | Installed capacity (MW) | Annual generation (GWh) | Capex (£) |
|---|---:|---:|---:|---:|
| 25% | 120,500 | 482.0 | 460 | £720m |
| 20% | 96,400 | 385.6 | 370 | £580m |
| 15% | 72,300 | 289.2 | 280 | £430m |
| 10% | 48,200 | 192.8 | 190 | £290m |
| 5% | 24,100 | 96.4 | 90 | £140m |

The Capex shown in Table 10 is an estimated total Capex for all systems in the area. However, unless very large-scale PV installation schemes emerge, these costs are likely to be paid at an individual property or street/community level.

### 5.1.6 Summary

Maximum estimated annual generation (GWh/year) for all selected suitable areas, corresponding installed capacities, and load factors is presented in Table 11 below. The purpose of this table is not to show a realistic estimate of how much electricity could be generated but to show how much electricity could be generated under the maximum possible, and therefore unrealistic, implementation.

For context, Hampshire's electricity use in 2020 was 7,520 GWh and the results from Li's MSc model are included in the first column for comparison.

*Table 11 – Maximum annual generation (GWh/year) estimates for generation technology under 'full' development of all suitable and selected sites.*

| | MSc Dissertation (Li, 2022) | This study | | | |
|---|---|---|---|---|---|
| Generation technology | Max annual GWh | Max annual GWh | % of maximum annual GWh | % of current annual use | Capex (£) |
| Tidal stream | - | 2,780 | 4% | 37% | £3,175m |
| Offshore wind | 3,000 | 10,040 | 14% | 134% | £5,870m |
| Onshore wind | 9,600 | 4,277 | 6% | 57% | £1,402m |
| Utility-scale solar PV | 3,500 | 51,361 | 75% | 683% | £23,985m |
| Rooftop solar PV (25% penetration) | - | 460 | 1% | 6% | £720m |
| Total | 16,100 | 68,918 | | 916% | £35,152m |

The table makes clear that Li's results rely on substantially over-estimated onshore wind generation largely as a result of not excluding (or not sufficiently down-weighting) sites on high grade agricultural land, AONBs and those which lay across linear infrastructure such as road and rail. In addition, Li's methodology selected sites with a relatively low weighting threshold (75/100) which would have been achieved simply by a high-speed wind site (50/100) within 3km of a road (10/100) and within 5 km of the electricity grid (10/100) and more than 2km from an urban area (8/100). Further, Li relied on manual selection of a few sites for solar PV in contrast to the updated approach which includes all sites where S > 0.8.

It is also clear that a very large proportion of the potential maximum total annual generation (75%) could be provided by maximum utility scale solar implementation, providing 709% of current annual use. However, this would be seasonally variable and concentrated at solar maximums making some form of intra-day and inter-seasonal storage a necessity.

With no other development, a single large offshore wind development could provide 135% of the pan-Hampshire's annual electricity use highlighting the importance of offshore wind to increasing Hampshire's electricity generation to near or above self-sufficiency.

Maximum implementation of onshore wind would meet 57% of current annual demand while the full tidal stream could meet 37%. The simple average-install based estimates of rooftop solar PV would meet less than 10%.

## 5.2 Scenarios

### 5.2.1 Overview

In contrast to the technical maximums reported above, a range of scenarios were created to estimate the effect that different rates of deployment would have on generation, Capex and how close Hampshire could get to 100% self-sufficiency in electricity. These were high, medium-high, medium-low, and low, which represent the different level of deployment of the considered generation technologies as described in Table 2. The purpose of these scenarios is to show an approximate energy mix to achieve different levels of self-sufficiency in electricity across the Hampshire area and are based on approximate values for installed capacity, annual generation and Capex. The scenarios should be used to give an idea of potential generation and Capex from a varying installed capacity, rather than viewed as scenarios that are likely to occur. The level of penetration can be made up from any of the suitable sites as identified by the MCDA.

Indicative results for the corresponding installed capacity, annual generation and Capex estimations for each scenario are presented in Sections 5.2.2 and 5.2.3.

### 5.2.2 Installed capacity and electricity generation estimation

Building on Table 11, estimated annual generation (GWh/year) for each scenario, obtained from the suitable areas, corresponding installed capacities and load factors (Table 3) is presented Table 12 below. As before, the purpose of this analysis is not to calculate precisely how much electricity could be generated from the specific sites selected, but instead to estimate how much electricity can be generated from this approximate penetration mix and installed capacity of the considered technologies.

Table 12 presents a broad range of total electricity generation estimations in the Hampshire area illustrating the potential for a diverse energy mix. The results show that the 'low' scenario does not meet current pan-Hampshire electricity use (7,520 GWh in 2020) but all other scenarios either meet or exceed this value. The high scenario would accommodate a near trebling of Hampshire's electricity use, a level of increase in excess of those implied by the NG-ESO Future Energy Scenarios 2022 shown in Table 1.

*Table 12 – Annual generation (GWh/year) estimates and % of total annual generation for each scenario and generation technology.*

| | High | | Medium-high | | Medium-low | | Low | |
|---|---|---|---|---|---|---|---|---|
| **Generation technology** | GWh | % | GWh | % | GWh | % | GWh | % |
| Tidal stream | 1,390 | 7% | 700 | 5% | 280 | 3% | 140 | 2% |
| Offshore wind | 5,020 | 24% | 2,510 | 17% | 1,000 | 10% | 500 | 8% |
| Onshore wind | 1,070 | 5% | 860 | 6% | 640 | 6% | 430 | 7% |
| Utility-scale solar PV | 12,840 | 62% | 10,270 | 70% | 7,700 | 78% | 5,140 | 80% |
| Rooftop solar PV | 460 | 2% | 370 | 3% | 280 | 3% | 190 | 3% |
| Total | 20,780 | | 14,700 | | 9,910 | | 6,390 | |

It is clear that a large proportion of the total annual generation could be provided by utility-scale solar PV development for all scenarios, highlighting the importance of solar PV to increasing Hampshire's annual electricity generation to at least the 2020 level of 7,520 GWh and subsequently to the levels implied under the NG-ESO Future Energy Scenarios. It should be noted however that in the absence of significant intra-day and/or inter-seasonal storage this would only make a significant contribution to meeting (or exceeding) summer day-time demand. Where local storage of this kind is available then this could help to locally meet urban (winter) evening peak demand thus reducing congestion on potentially constrained urban distribution networks.

As would be expected, offshore wind features more strongly than onshore wind. Urban areas such as Southampton City or Portsmouth City proved to have low utility-scale generation potential of any kind but will have greater potential for rooftop solar PV installations. Such installations would contribute further to the spatial distribution of generation across Hampshire, especially in urban areas.

These annual generation estimates suggest how a range of penetration and size of developments could contribute to increasing Hampshire's renewable electricity generation. Any of the sites considered or excluded for each scenario could be developed and so the scenarios and site suitability maps should be used as indicators for review, rather than a guide for development.

### 5.2.3 Capital Expenditure estimation

Using the Capex (£/kW) for each generation technology from Table 4, a total Capex for each scenario was estimated and reported in Table 13 below.

*Table 13 – Capital expenditure estimate for each scenario and generation technology (£ million).*

| Scenario | High | Medium-high | Medium-low | Low |
|---|---|---|---|---|
| Tidal stream | £1,590 | £800 | £320 | £160 |
| Offshore wind | £2,930 | £1,470 | £590 | £300 |
| Onshore wind | £350 | £280 | £210 | £140 |
| Utility-scale solar PV | £6,000 | £4,790 | £3,600 | £2,400 |
| Rooftop solar PV | £720 | £580 | £430 | £290 |
| Total | £11,590 | £7,330 | £5,150 | £3,290 |

The Capex estimations in Table 13 show that significant investment is required to achieve the scenarios and for Hampshire to work towards becoming self-sufficient in electricity from renewable sources. There are opportunities for some of the smaller onshore wind sites or solar PV farms to be organised by community-led projects across Hampshire. For rooftop solar PV systems, these are likely to be paid for at individual property level but could also be developed as part of a community scheme or retrofitting scheme.

# 6 Discussion

## 6.1 Current results

This analysis used a robust, data-driven MCDA approach to identify suitable sites to develop renewable generators across and off the coast of Hampshire. The analysis identified a number of possible utility-scale solar PV, tidal stream, onshore wind, and offshore wind sites and investigated the potential for rooftop solar PV systems. By considering a range of scenarios, estimations of the potential installed capacity and electricity generation were identified to suggest the level of penetration required to increase Hampshire's electricity demand to close to self-sufficiency.

This analysis shows that self-sufficiency at an annual level would need to rely on utility-scale solar PV and offshore wind development. With no other development, a single large offshore wind development could provide 134% of pan-Hampshire's current annual electricity demand. In contrast, fully implemented utility scale solar could provide 709% of current annual demand, but would be seasonally variable, whilst fully implemented tidal stream could meet 37%. Full implementation of onshore wind could meet 57%. However, full implementation of the preliminary estimates of rooftop solar PV would meet only 6%.

Estimations of the corresponding Capex were then identified, indicating the required potential level of investment to fully develop the identified sites. Full implementation of this technical potential would require an investment of ~£35,152bn but could produce over 942% of pan-Hampshire's current electricity use.

However, these full 'technical maximum' implementation results are likely to be unrealistic overestimations. Analysis of the proportional implementation scenarios suggests that of the high-medium-low development scenarios, only the low failed to meet or exceeded current electricity use - meeting 85% of Hampshire's current electricity demand (Table 14). The other scenarios may therefore be able to meet future electricity demand but would also require significant investment (£5-£12bn). Given likely future increases in electricity demand, it is clear that significant investment will be required if electricity 'import' is to be avoided, especially with the need to enable intra-day and inter-seasonal storage where renewables are intermittent.

The purpose of this analysis is not to provide a detailed model of potential electricity generation and the investment required to achieve the goals of the area, but instead to provide knowledge of the suitable areas to develop on for each of the considered generation technologies. For this reason, it should not be used to provide a return on investment business case to compare potential output, revenue, corresponding development and running costs, but to identify where developments could occur. The model can be easily amended to suit the needs of a stakeholder to change the parameters linking the data to the model or to provide more spatially-specific analysis.

## 6.2 Similarity to available district level analysis

This analysis builds on existing work completed by local district, city and Hampshire County councils and provides a tool to identify suitable areas and review them for potential development. This will help achieve renewable energy aspirations without the need to conduct initial suitability analysis.

To put these results in context, the Test Valley Renewable and Low Carbon Energy study (LUC, 2020) estimated that there was technical potential for 1,735 MW for onshore wind, 425 MW for ground-mounted solar PV, 169 MW for rooftop solar PV, and 196 MW for solar water heating systems in the district. As can be seen by comparing with Table 8, the figures for onshore wind in particular may be substantially over-estimated.

In contrast the Basingstoke Climate Change Study (WSP, 2021) presents a more conservative estimate of renewable potential for the area, suggesting 22.6 MW of utility-scale solar PV and 45.3 MW of rooftop solar PV. It determines the suitability of land for onshore wind but does not suggest a potential installed capacity as it says that it may not be feasible in the area. In contrast the results of the MCDA model reported here suggest there may be some potential (Figure 6).

The Isle of Wight Mission Zero climate strategy (Isle of Wight Council, 2021) identifies different targets and requirements for the Isle of Wight Council to achieve their target of becoming net-zero by 2040. To achieve this the strategy states that 278 MW of solar PV and 23.9 MW of onshore wind will have to be developed between 2020 and 2040.

While the results presented in this report have not been disaggregated to district level and do not take account of potential local variation in parameters (see Figure *1*), this could form the basis for future work at the district or even parish levels. The latter could help in the selection of community energy sites and also the selection of areas for large scale rooftop PV installation as part of area level retrofit schemes.

## 6.3 Opportunities for the pan-Hampshire area and each district

Pan-Hampshire's total electricity demand in 2020 was 7,520 GWh while approximately 627.7 GWh (8%) was generated from low-carbon sources, of which 555 GWh was from solar PV and 59 MWh was from onshore wind. With the electrification of heat and transport, electricity demand across Hampshire will increase and so the required investment to increase Hampshire's renewable power generation portfolio to satisfy this electricity demand will also increase.

The generation estimations across each scenario reported in Table 12 have been summarised to give total potential generation (Table 14). This was compared to the 2020 level of electricity demand (7,520 GWh) to give a percentage of demand, and an indicator of the excess electricity that may be available. The estimated CAPEX for each scenario is also included. Note that no allowance has been made for the existing 624 GWh of renewables already installed in these estimates as they are assumed to be contained with the selected 'suitable areas'.

*Table 14 – Summary of the total annual potential generation identified for each scenario combined with existing generation and compared to the current electricity demand across Hampshire (GWh). Estimated CAPEX is also included for reference*

| **Scenario** | **High** | **Medium-high** | **Medium-low** | **Low** |
|---|---|---|---|---|
| Total potential generation (GWh) | 20,800 | 14,700 | 9,900 | 6,400 |
| % of 2020 demand | 276% | 195% | 132% | 85% |
| Excess (GWh) | 13,300 | 7,180 | 2,380 | -1,120 |
| | | | | |
| CAPEX (£m) | £11,590 | £7,330 | £5,150 | £3,290 |

For the high and medium-high and medium-low scenarios, the combined generation is estimated to comfortably meet or exceed current electricity demand levels, and the high/medium-high scenarios may be able to meet future electricity demand as projected by the NG-ESO Future scenarios (~250% increase).

Excess electricity could be ‘exported’ or used locally to produce hydrogen via electrolysis (splitting of water into hydrogen and oxygen), to support de-carbonisation of heat or be converted to some other energy vector to act as inter-seasonal energy storage. However, it should be noted that the scenarios that provide this level of surplus electricity would also require significant investment. This highlights the level of development and investment that would be needed to achieve local self-sufficiency in electricity from renewable sources, especially with an inevitably increasing electricity demand and the need to enable intra-day and inter-seasonal storage where renewables are intermittent. The CAPEX for such storage is **not** included in these estimates.

# 7 Conclusion

This analysis demonstrates a robust, data-driven methodology to identify suitable sites for tidal stream, offshore wind, onshore wind and utility-scale solar PV across and off the coast of the Hampshire region using a MCDA approach. It also tests a methodology to determine the number of rooftops that are suitable for rooftop solar PV systems using LiDAR DSM data. The report then summarises estimates of technical potential installed capacity, annual generation and corresponding Capex for different scenarios. These scenarios represented different levels of deployment of the considered generation sources.

The analysis identified that there are large areas deemed suitable for **offshore wind and tidal developments**, with large potential sites possible. Offshore wind sites proved to be an important contribution to achieving self-sufficiency in electricity from renewable sources under current levels of demand due to their large potential and availability.

There were also a large number of areas deemed suitable for **utility-scale solar PV** development across Hampshire. These would provide an opportunity to supply a large proportion of Hampshire’s electricity demand, especially during summer months, with the potential for excess production for other uses or for intra-day/inter-seasonal storage.

Fewer areas were deemed suitable for **onshore wind** development due to the stricter criteria in the model, however, in some districts such as the New Forest there was a relatively high technical potential for onshore wind developments. Some of the areas identified were within close proximity to each other so could be developed simultaneously and coupled together to form one larger site.

For **rooftop solar PV**, the greatest potential will occur in more built-up urban areas which will have a lower utility-scale generation potential. This will help with the spatial distribution of generation across Hampshire and may be able to alleviate urban electricity network constraints.

The technical potential installed capacity was used to estimate annual generation for the identified areas under a range of development scenarios. For the more extreme high, medium-high and medium-low scenarios, generation was estimated to exceed current (2020) electricity demand for Hampshire and in the case of the high/medium-high scenarios may also meet future NG-ESO demand growth projections. Any excess could be used to produce hydrogen through electrolysis or provide an energy source for other industrial or commercial use. For the other low scenarios, generation was not estimated to exceed current levels of electricity demand across Hampshire. This gap between annual generation and total electricity demand will only widen as the rate of electrification of heat and transport increases, increasing electricity demand further. If pan-Hampshire wishes to approach self-sufficiency in renewable electricity, significant development will clearly be required.

To give an indication of the investment required for such developments, estimates of the Capex for each of the generation technologies were calculated. The results showed that significant investment in renewable development would be required to achieve self-sufficiency in electricity in renewable sources under future growth trajectories (£5 - £12bn – see Table 14). There are also opportunities for some of the smaller onshore wind sites or solar PV farms to be organised by community-led projects across Hampshire. For rooftop solar PV systems, these are likely to be paid for at individual property level but could also be developed as part of a community scheme or retrofitting scheme.

It should be noted that the model can easily be edited to suit the needs of a particular stakeholder. For example, future work could vary the constraint weightings (Figure *1*) to understand the sensitivity of the analysis. These weightings could also be varied depending on the requirements and importance of a specific layer or constraint to a district or region, potentially providing new results under local contexts or future policy scenarios.

For the generation estimates to be improved, the use of network modelling software such as HOMER could produce hourly energy system fluctuations for generation. This would help assess the value of storage to help provide a balance between generation and demand.

Further, the addition of an area-level retrofit model would help spatialise potential rooftop PV installations by combining PV development with retrofit requirements. This would also support the economic analysis for the rooftop PV systems.

Finally, it must be re-iterated that the purpose of this analysis was not to provide a detailed model of potential electricity generation and the investment required for specific sites. The purpose was to provide indicators of the suitable areas to develop for each of the considered generation technologies and subsequent estimates of installable capacity and annual energy generation under various mixed-generation scenarios. For this reason, the results should not be used as basis for specific site business cases.

# 8 References

Anderson, B & Kingsley-Walsh, M (2021) *Hampshire Energy Landscape Mapping: Summary and Gap Analysis: Final report to Hampshire County Council*. Southampton: Faculty of Engineering and Physical Sciences (Energy & Climate Change Division), University of Southampton (https://eprints.soton.ac.uk/457740/ )

Boehme, T. T., J; Wallace, R; Bialek, J. (2006). *Matching Renewable Electricity Generation with Demand*. Retrieved from

Department for Business Energy and Industrial Strategy. (2020). *Electricity Generation Costs 2020*. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911817/electricity-generation-cost-report-2020.pdf

Isle of Wight Council. (2021). *Mission Zero: Climate and Environment Strategy 2021 - 2040*. Retrieved from https://www.iow.gov.uk/azservices/documents/2570-Mission-Zero-Climate-and-Environment-Strategy-2021-2040-final.pdf

Lande-Sudall, D., Stallard, T., & Stansby, P. (2019). Co-located deployment of offshore wind turbines with tidal stream turbine arrays for improved cost of electricity generation. *Renewable and Sustainable Energy Reviews, 104*, 492-503. doi:https://doi.org/10.1016/j.rser.2019.01.035

Lande-Sudall, D., Stallard, T., & Stansby, P. K. (2019). Co-located deployment of offshore wind turbines with tidal stream turbine arrays for improved cost of electricity generation. *Renewable and Sustainable Energy Reviews, 104*, 492-503. doi:10.1016/j.rser.2019.01.035

LUC. (2020). *Test Valley Renewable and Low Carbon Energy Study*. Retrieved from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi4yr-9h-39AhVPE8AKHQN6CAIQFnoECBsQAQ&url=https%3A%2F%2Ftestvalley.gov.uk%2Fassets%2Fattach%2F12719%2FTest-Valley-Renewable-and-Low-Carbon-Energy-Study.pdf&usg=AOvVaw1wWjKcxZs1JeKnNdGoa2v

Marttunen, M., Mustajoki, J., Dufva, M., & Karjalainen, T. (2015). How to design and realize participation of stakeholders in MCDA processes? A framework for selecting an appropriate approach. *EURO Journal on Decision Processes, 3*(1), 187-214. doi:https://doi.org/10.1007/s40070-013-0016-3

Palmer, D., Koumpli, E., Cole, I., Gottschalg, R., & Betts, T. (2018). A GIS-Based Method for Identification of Wide Area Rooftop Suitability for Minimum Size PV Systems Using LiDAR Data and Photogrammetry. *Energies, 11*(12), 3506. Retrieved from https://www.mdpi.com/1996-1073/11/12/3506

WSP. (2021). *Basingstoke Climate Change Study*. Retrieved from https://www.basingstoke.gov.uk/content/doclib/3415.pdf

Yin, P.-Y., Cheng, C.-Y., Chen, H.-M., & Wu, T.-H. (2020). Risk-aware optimal planning for a hybrid wind-solar farm. *Renewable Energy, 157*, 290-302. doi:https://doi.org/10.1016/j.renene.2020.05.003

# 9 Statistical Annex

## 9.1 'Pan-Hampshire'

Table 15 reports a number of summary energy statistics for the Council areas considered part of pan-Hampshire for the purposes of this report.

In 2021 Test Valley had the 5th highest installed renewable generation capacity of all South East England local authorities and was the only one of the top 5 not to have offshore wind resource. Winchester and the Isle of Wight were 10th and 11th respectively, relying almost exclusively on photovoltaics.

*Table 15 - Council areas considered part of pan-Hampshire for the purposes of this report*

| Council | Total energy use (2020, GWh) | Total electricity use (2020, GWh) | Total installed renewable generation (2021, MW) | Total installed photovoltaics (2021, MW) |
|---|---:|---:|---:|---:|
| Basingstoke and Deane | 3,954 | 791 | 55.9 | 37.5 |
| East Hampshire | 2,671 | 432 | 50.2 | 50.2 |
| Eastleigh | 2,383 | 491 | 32.2 | 24.6 |
| Fareham | 1,927 | 402 | 28.8 | 28.8 |
| Gosport | 978 | 257 | 4.6 | 4.6 |
| Hart | 1,999 | 436 | 17.2 | 16.5 |
| Havant | 1,776 | 375 | 14.6 | 10.5 |
| Isle of Wight | 2,386 | 520 | 96.5 | 93.1 |
| New Forest | 13,985 | 727 | 71.9 | 44.1 |
| Portsmouth | 3,338 | 775 | 33.0 | 12.8 |
| Rushmoor | 1,582 | 354 | 4.4 | 4.4 |
| Southampton | 3,233 | 824 | 13.8 | 12.7 |
| Test Valley | 3,214 | 580 | 185.9 | 184.6 |
| Winchester | 3,076 | 557 | 97.8 | 97.4 |
| **Total** | **46,502** | **7,520** | **706.8** | **621.8** |

Data sources:

- BEIS (2021) Subnational total final energy consumption, United Kingdom, 2005 – 2020 (https://www.gov.uk/government/statistics/total-final-energy-consumption-at-regional-and-local-authority-level-2005-to-2020)
- BEIS (2022) Renewable electricity by local authority 2014 – 2021 (https://www.gov.uk/government/statistics/regional-renewable-statistics)

## 9.2 MCDA worked example

Table 16 provides a worked example for 3 sites using the equation described in Section 3.1. Site 1 has a Suitability score of 0 as it fails to achieve at least one hard constraint, Site 2 meets all hard constraints but partially meets the weighted constraints and so achieves a Suitability score of less than 1 while Site 3 meets all constraints and so achieves a Suitability score of 1. In this instance:

- Site 1 is unsuitable as it fails a hard constraint
- Site 2 would not be considered Suitable as the sum of weights is less than 0.85
- Site 3 would be considered Suitable as the sum of weights is 1

*Table 16- MCDA worked example using two sites*

| | Layer | Weight | Site 1 features | Site 1 scores | Site 2 features | Site 2 scores | **Site 3 features** | **Site 3 scores** |
|---|---|---|---|---|---|---|---|---|
| Hard | h1 | | 0 | | 1 | | 1 | |
| | h2 | | 1 | | 1 | | 1 | |
| | h3 | | 0 | 0 | 1 | 1 | 1 | 1 |
| **Weighted** | w1 | 0.2 | 1 | 0.2 | 1 | 0.2 | 1 | 0.2 |
| | w2 | 0.3 | 0 | 0 | 0 | 0 | 1 | 0.3 |
| | w3 | 0.5 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 |
| | | | | | | | | |
| Suitability | | | | **0** | | **0.7** | | **1** |

## 9.3 CAPEX projections

The analysis of CAPEX used 2025 projections published by the Department for Business, Energy & Industrial Strategy in their Electricity Generation Costs 2020 report (Department for Business Energy and Industrial Strategy, 2020). The table below show the projected variation in these costs over time from this source.

| | **2025** | 2030 | 2035 | 2040 | % decrease 2025-2040 |
|---|---|---|---|---|---|
| Utility scale solar | **450** | 450 | 350 | 350 | 22% |
| Onshore wind | **1120** | 1120 | 1020 | 1020 | 9% |
| Offshore wind | **1630** | 1430 | 1230 | 1230 | 25% |

*Table 17:2025-2040 CAPEX projections (Source: BEIS, 2020)*