Programme Area: Nuclear

Project: Power Plant Siting Study

Title: Project Summary Report

Abstract:

The project explored siting criteria and siting constraints against the nuclear expansion scenarios. It also identified and considered opportunities to enable the inclusion of additional sites should the expansion scenarios be constrained. There were seven objectives of the project which were addressed through the baseline assessment of a long list of sites (which considered their suitability for twin 1,650 MWe units with direct cooling), a set of six sensitivity analyses and two other studies. This deliverable provides and summary of the key project findings.

Context:

The aim of the Power Plant Siting Study project is to explore the different opportunities and constraints involved in developing sites in England and Wales for new low carbon power plants. The study will considers new nuclear as well as fossil fueled power stations using carbon capture and storage technologies. The study is important to understand the different features which could either make a potential site suitable or, alternatively, prevent its viability. This study is intended to inform whether there is likely to be competition for development sites between low carbon technologies, which could be a future constraint in the low carbon replacement of the UK's ageing power plants. It will help inform the ETI's technology strategy development work, which is looking at how to accelerate the development of new energy technologies for a UK transition to a low carbon economy.

Power Plant Siting Study

Project Summary Report

Prepared by Atkins for the Energy Technologies Institute

21 August 2015

Plan Design Enable

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This document has 80 pages including the cover.

Document history

Job number: 5130548			**Document ref: Project Summary Report**			
Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
Rev 01 Draft A	Draft for issue	JK	PM	CC	DN	16/01/15
Rev 01 Final	Final for issue	JK	PM	CC	DN	21/01/15
Rev 02 Draft A	Draft for issue	JK	CC	DN	DN	06/03/15
Rev 02 Final	Final for issue	JK	CC	DN	DN	17/03/15
Rev 03 Draft A	Draft for issue	JK	PM	MN	DN	26/06/15
Rev 03 Final	Final for issue	JK	JW	MN	DN	21/08/15

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Glossary

AIL	Abnormal Indivisible Load
CCS	carbon capture and storage
CEGB	Central Electricity Generating Board
COMAH	Control of Major Accident Hazards
DUKES	Digest of UK Energy Statistics
ETI	Energy Technologies Institute
Gen	Generation
GIS	geographic information system
GW_e	gigawatt electric
km^2	square kilometre
m	metre
MOD	Ministry of Defence
MW_e	megawatt electric
NPS	National Policy Statement
NSDI	Nuclear Spatial Data Infrastructure
ONR	Office of Nuclear Regulation
OS	Ordnance Survey
SMR	small modular reactor
UK	United Kingdom
UKAEA	United Kingdom Atomic Energy Authority

1. Executive Summary

The United Kingdom (UK) Government has three potential deployment scenarios for new nuclear power. These involve replacement of 16 GW_e capacity by 2030 and expansion to either 40 GW_e or 75 GW_e by 2050. The work undertaken for the replacement scenario suggests that site availability may be a potential constraint for the two expansion scenarios. The extent of the constraint was however not known and the aim of this project was to identify it. In addition, it was anticipated that the potential constraint will be aggravated by competing requirements to identify sites for new thermal power plants with carbon capture and storage (CCS).

The project explored siting criteria and siting constraints against the nuclear expansion scenarios. It also identified and considered opportunities to enable the inclusion of additional sites should the expansion scenarios be constrained. The project represents the first stage of a multi stage assessment process for new nuclear power plants leading up to the award of a Nuclear Site Licence and the other licences and approvals required for each site. Therefore the total capacities determined in the project are the starting points that are likely to lead to a lower capacity being deployed by 2050. The generating capacity that is achieved is ultimately dependent on many factors, most of which are beyond the scope of this project. The factors that are likely to reduce the overall capacity include those that are related to the procedural and regulatory requirements and those that are related to site specific characteristics.

Two sets of assumptions were applied in the project. The first set, which was provided by the Energy Technologies Institute (ETI), specified the basic principles that applied to the project. The second set was important in bounding the scope, budget and breadth of the project.

The long list of sites considered in the project included existing nuclear licensed sites in England and Wales, and brownfield and greenfield sites. Of the two hundred and sixty two sites on the long list, locations could be determined for two hundred and fifty.

A two stage assessment methodology for the sites was employed. Stage 1 involved the application of five exclusionary criteria addressing:

- demographics;
- exclusionary military activities;
- presence within an internationally designated ecological site;
- size of site; and
- access to sources of cooling water.

Stage 2 was applied to sites that passed the stage 1 assessment. This involved the application of ten discretionary criteria by suitably qualified and experienced experts. The criteria addressed:

- flood risk;
- coastal processes (as represented by coastal erosion);
- proximity to hazardous facilities;
- proximity to civil aircraft movements;
- proximity to non-exclusionary military activities;
- proximity to internationally designated ecological sites;
- presence within, or proximity to nationally designated ecological sites;
- potential for negative effects on areas of amenity, cultural heritage and landscape value;
- size of site to accommodate operations; and
- access to suitable sources of cooling water.

The criteria used in the project are the same as those used in the Alternative Sites Assessment. This enabled continuity with that project. The overall methodology is closely based on the application of the Strategic Siting Assessment criteria, which were used in the Government's Strategic Siting Assessment for new nuclear power plants.

There were seven objectives of the project which were addressed through the baseline assessment of the long list of sites (which considered the suitability of these sites for twin 1,650 MW_e units with direct cooling), a set of nine sensitivity analyses and two other studies. The sensitivity analyses addressed:

- cooling water (which considered direct and indirect cooling and 1,650 MW_e,1,400 MW_e and 1,150 MW_e units);
- the additional site capacity from introducing alternative smaller plants (which considered 300 MW_e units in regions);
- site availability for large thermal plant with CCS (which addressed sites on the coast and estuaries on the east coast of England and included consideration of potential competition between thermal power plants with CCS and nuclear power plants);
- the potential capacity at existing UK nuclear licensed sites (which addressed the potential capacity that may be developed adjacent to existing nuclear licensed sites whilst limiting the development at any site to twin large units);
- deployment of new nuclear plants at more than 2.5 GW_e to 3.5 GW_e per site (which addressed the potential capacity that may be developed adjacent to existing nuclear licensed sites without limiting the development at any site to twin large units);
- the approach to sites with ecological designations (which involved the development of a more robust approach to ecology at the sites);
- two river catchments (which involved the reappraisal of the cooling water availability in two river catchments, using the Environment Agency's Water Resources geographic information system (GIS), and the reassessment of the potential capacity);
- the heat demand networks twice over (which determined whether it was possible to provide sufficient heat to satisfy twice over the heat demand networks that were identified in the System Requirements for Alternative Nuclear Technologies project that had been undertaken for the ETI, using sites and regions that are suitable for, or are likely to be feasible for 300 MW_e units); and
- the heat demand networks once over (which determined whether it was possible to provide sufficient heat to satisfy once over the heat demand networks that were identified in the System Requirements for Alternative Nuclear Technologies project using sites and regions that are suitable for, or are likely to be feasible for 300 MW_e units, in conjunction with a significant programme of development of 1,650 MW_e, 1,400 MW_e and 1,150 MW_e units).

The two rivers catchments sensitivity analysis explored notable conservatism identified earlier in the project, in the cooling water sensitivity analysis. This notable conservatism related to the assessment of cooling water availability for rivers.

The reason for considering whether the heat demand networks could be satisfied twice over was to make allowance for the fact that not all of the sites identified as being suitable for, or being likely to be feasible for 300 MW_e units are likely to be developed. Decreasing the requirement to satisfying the heat demand networks only once over allowed consideration of whether a significant programme of development of 1,650 MW_e, 1,400 MW_e and 1,150 MW_e units for baseload electricity could be achieved at the same time as satisfying the heat demand networks. There are forty four heat demand networks that relate to the larger urban areas of England and Wales.

Supporting work was carried out to identify sufficient sites for 300 MW_e units to satisfy the heat demand networks twice over. This involved:

- the reappraisal of the long list to identify brownfield and greenfield sites on the long list, and extensions to existing nuclear licensed sites that are suitable for, or are likely to be feasible for 300 MW_e units; and
- the identification of sites additional to those sites that were considered elsewhere in the project that are likely to be feasible for 300 MW_e units).

In the reappraisal of the long list and the identification of additional sites, some of the methodologies employed for assessing the first nine of the ten discretionary criteria were less detailed than those that had previously been used in the project. This was because the work addressed a greater number of sites, with an accompanying reduction in the level of certainty associated with the results of the assessments. This led

to the sites being described as 'likely to be feasible' or 'not likely to be feasible', rather than the sites passing or failing the assessment.

The Water Resources GIS was used to determine the cooling water availability for rivers in the two river catchments sensitivity analysis, the heat demand networks twice over sensitivity analysis, the heat demand networks once over sensitivity analysis and the supporting work for the heat demand networks sensitivity analyses. This meant that cooling water availability was based on recent actual flows in rivers rather than natural flows in rivers.

The two other studies addressed:

- other opportunities which may arise to contribute to the group of potential sites for new nuclear power plants (which focused on defence sites within the Ministry of Defence (MOD) Estate and those regulated by the Office of Nuclear Regulation (ONR)); and
- the preferred locations for technology demonstrators.

In the two river catchments sensitivity analysis the use of the Water Resources GIS meant that some of the sites that previously failed the cooling water sensitivity analysis passed the two river catchments sensitivity analysis. In addition, more sites passed in conjunction and the maximum capacity for new nuclear deployment at these sites was comparable with the established and planned capacity for thermal generation on the two river catchments.

In the reappraisal of the long list the distance for access to sources of cooling water was relaxed to be 20 km or less (rather than 2 km or less). It should however be remembered that the feasibility of transporting water over 20 km needs to be demonstrated for each individual case. The criterion addressing the size of site to accommodate operations was also relaxed so that the presence of existing development and major waterbodies between the site and the source of cooling water was not taken into account. This provided a greater choice of cooling water sources, which meant that sites could access cooling water sources with greater cooling water availability. The use of the Water Resources GIS also had an influence on the results. The results demonstrated that nineteen brownfield and greenfield sites on the long list could help satisfy the heat demand networks. In addition, if mitigation / compensatory measures for ten of the eleven extensions are accepted, five initial extensions and six further extensions to nuclear licensed sites could also help satisfy the heat demand networks.

A total of twenty two sites on the coast and estuaries in the east of England were identified as potentially suitable for thermal power plants with CCS. The analysis did not explicitly consider inland sites, therefore to take account of this, three inland brownfield sites were reserved for large thermal power plants with CCS. It was concluded that, in principle, there should be sufficient sites for thermal power plants with CCS without significantly reducing the capacity for nuclear power plants. However, in practice, particular sites might be taken for thermal power plants with CCS (or other activities) before development for nuclear power plants is progressed. In addition, prior to the determination of the capacity for new nuclear deployment by 2050, three extensions to nuclear licensed sites were reserved for Generation (Gen) IV plants.

If mitigation / compensatory measures for the site are accepted, one greenfield site could be considered for development of large units and the potential maximum capacity for new nuclear deployment at this site by 2050 is 3.3 GW_e. Six brownfield sites could be considered for development of large units and the potential maximum capacity for new nuclear deployment at these brownfield sites by 2050 is 9.9 GW_e.

Based on the consideration of a maximum of twenty inland regions, the indicative capacity for deployment of 300 MW_e units in brownfield and greenfield regions by 2050 amounts to twenty eight 300 MW_e units, which provides a total of 8.4 GW_e. There is potential to increase this by considering more regions.

Relaxation of the distance for access to sources of cooling water and the criterion addressing the size of site to accommodate operations, and the use of the Water Resources GIS were also applied in the identification of additional sites. Thirty one additional sites were identified that are likely to be feasible for 300 MW_e units and could help satisfy the heat demand networks. Seventeen of these have sources of cooling water that are independent of all other waterbodies providing cooling water for the other sites, regions and extensions to nuclear licensed sites considered in the project. The current indicative capacity that is likely to be feasible for development of 300 MW_e units at these seventeen additional sites by 2050 amounts to sixty two 300 MW_e units which provides a total of 18.6 GW_e.

The result for the potential maximum additional nuclear power plant generating capacity for large units for new deployment next to existing nuclear licensed sites in England and Wales before 2050 amounts to 23.65 GW_e, with a further 3.0 GW_e of 300 MW_e units. The initial extension at one other nuclear licensed site

provides a further 2.1 GW_e of 300 MW_e units which needs to be taken into account. The capacity at the initial extensions assumes a nominal limit of twin large units. If that limit is relaxed to allow development beyond twin large units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site), the result for the potential maximum additional nuclear power plant generating capacity for large units for new deployment next to existing nuclear licensed sites in England and Wales before 2050 amounts to a further 14.85 GW_e, with a further 1.5 GW_e of 300 MW_e units.

The first set of options for realising site capacity necessary to deliver 75 GW_e of new nuclear by 2050 consisted of a collation of the capacities presented above. This first set of options achieves the required capacity of 75 GW_e of new nuclear by 2050 to meet the third deployment scenario for nuclear expansion by including six of the seven possible pathway options. The total current indicative capacity for new nuclear development by 2050 as determined for the first set of options is 85.3 GW_e. This total takes account of the reservation of the three sites for large thermal power plants with CCS and the three extensions for Gen IV plants.

There is an opportunity to increase the total capacity for the first set of options by identifying further additional sites from the thirty one additional sites that are likely to be feasible for inclusion in the first set of options.

The second set of options was derived from the results of the heat demand networks once over sensitivity analysis, which involved conjunctive assessment using an optimisation model. This set of options therefore addressed realising site capacity necessary to deliver 75 GW_e of new nuclear by 2050 whilst satisfying the heat demand networks once over, using 300 MW_e units, in conjunction with a significant programme of development of 1,650 MW_e units. The required capacity of 75 GW_e of new nuclear by 2050 to meet the third deployment scenario for nuclear expansion is achieved by including seven of the ten possible pathway options. Inclusion of the eighth pathway option provides a total potential maximum capacity of 94.6 GW_e and means that the heat demand networks are satisfied once over.

The total current indicative capacity for new nuclear development by 2050 as determined for the second set of options is 113.2 GW_e. This total takes account of the reservation of the three sites for large thermal power plants with CCS and the three extensions for Gen IV plants. The major factors in determining this result were:

- the relaxation of the distance for access to sources of cooling water to address 20 km or less (rather than 2 km or less); and
- the relaxation of the criterion addressing the size of site to accommodate operations, so that the presence of existing development and major waterbodies between the site and the source of cooling water was not taken into account.

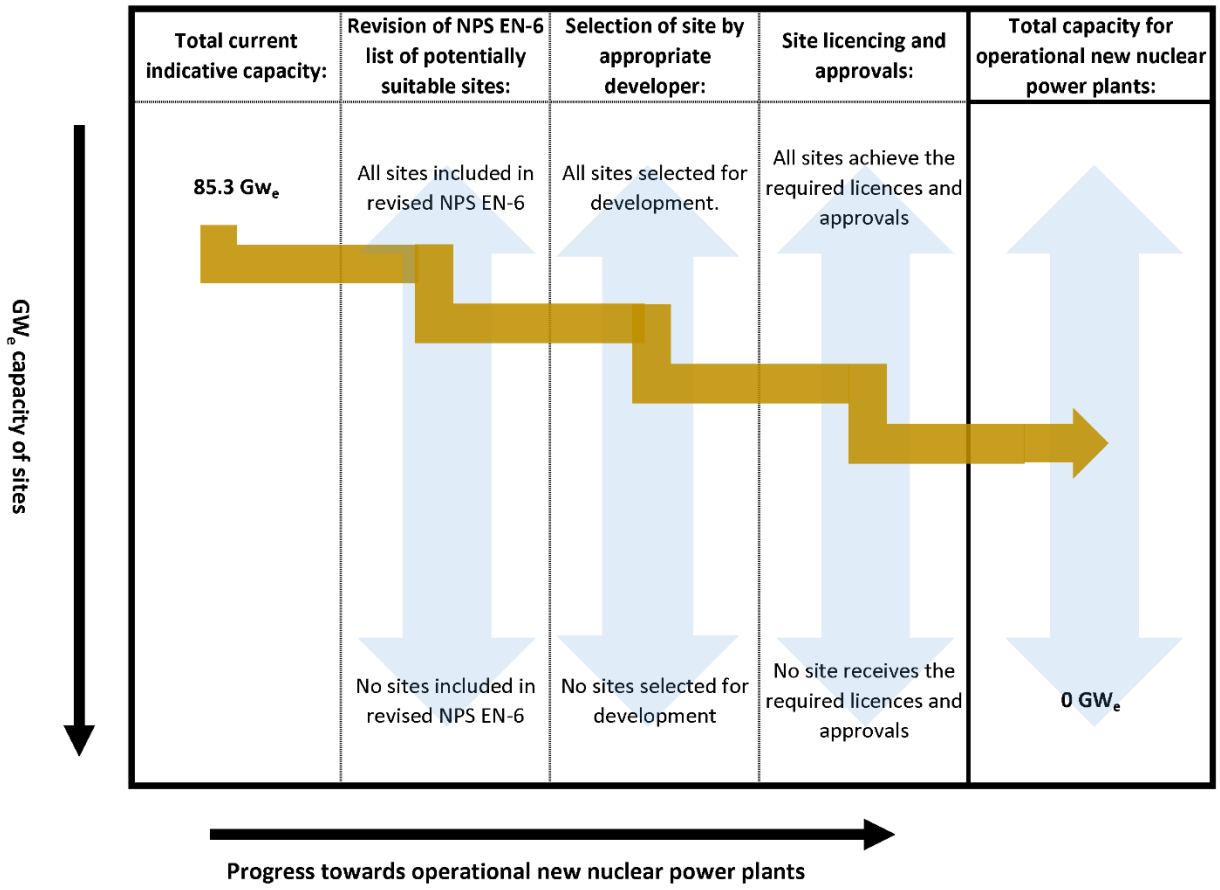
It should however be remembered that the feasibility of transporting water over 20 km needs to be demonstrated for each individual case.

Key uncertainties associated with the assessment of some of the discretionary criteria may affect the results for both sets of options. As stated above, this project represents the first stage of a multi stage assessment process for new nuclear power plants leading up to the award of a Nuclear Site Licence and the other licences and approvals required for each site. Therefore neither of the total current indicative capacities of 85.3 GW_e or 113.2 GW_e, as determined for the two sets of options, is likely to be the capacity that is deployed by 2050. The generating capacity that is achieved is ultimately dependent on many factors, most of which are beyond the scope of this project. These factors are likely to reduce the number of sites that are developed for new nuclear power plants by 2050 and therefore the capacity that is deployed by 2050 is likely to be substantially less than either of the two total current indicative capacities. Some of these factors are related to the procedural and regulatory requirements leading up to the award of a Nuclear Site Licence and the other licences and approvals required to allow the power plant to operate. There are three main steps in that process that need to be met, which are the following:

- a revision of the National Policy Statement (NPS) for Nuclear Power Generation (EN-6) to include sites that are suitable for new nuclear power plants beyond 2025;
- selection of the site by an appropriate developer; and
- a complete set of site licences and approvals being in place for the proposed site.

Figure 1-1 illustrates the likely reduction in the 85.3 GW_e total indicative capacity determined for the first set of options as a result of procedural and regulatory requirements. A similar likely reduction applies to the 113.2 GW_e total indicative capacity determined for the second set of options. The other factors that are likely to reduce the capacity are those related to site specific characteristics.

Figure 1-1: Likely Reduction in Capacity for First Set of Options during Progress towards Operational New Nuclear Power Plants



The results of the study of defence sites within the MOD Estate and those regulated by the ONR demonstrated that two MOD sites that are scheduled for disposal offer potential opportunities for siting nuclear power plants by 2050, but their overall capacity would be limited. Further MOD sites that are located 2 km or less from the coast or estuaries offer additional opportunities for increasing the number of potential sites and the capacity for new nuclear power plants in the future. Two sites regulated by the ONR are worthy of consideration, but subject to the use of cooling technologies other than water cooling.

Five existing nuclear licensed sites were identified as the most likely locations for small modular reactor (SMR) demonstrators. Only one existing nuclear licensed site was identified as a possible location for a large Gen IV plant demonstrator.

The objectives of the project have been met. The project has involved the consistent application of the exclusionary and discretionary criteria. This rigorous approach has allowed the recognition of constraints associated with the identification of sites and opportunities that were pursued in the project, or that could be pursued, to increase the total current indicative capacity. The analysis of the capacity for large units is not final and absolute. It is possible that a developer could be successful in developing a site that has not been considered in the project or that has failed on two or more criteria. The assessment process has drawn upon what is viewed as being reasonable in terms of good engineering practice, safe and reliable operation, and effects on the environment and other established activities. Further work would be required on the sites, regions and extensions to nuclear licensed sites identified in the project to confirm their suitability for new nuclear power plants.

2. Introduction

This section introduces the power plant siting study which has been carried out by Atkins for the Energy Technologies Institute (ETI). The study addressed siting criteria and siting constraints for developing new nuclear power in the United Kingdom (UK) by 2050. It represents the first stage of the multi stage assessment process for new nuclear power plants leading up to the award of a Nuclear Site Licence and the other licences and approvals required to allow the power plant to operate.

2.1. Background to the Project

The UK Government has the following three potential deployment scenarios for new nuclear power:

- replacement of 16 GW_e capacity by 2030;
- expansion to 40 GW_e by 2050; and
- expansion to 75 GW_e by 2050.

The replacement scenario is being carried out through private sector investment. Eleven sites were nominated by industry into the Government's Strategic Siting Assessment process for new nuclear power plants. Nominations for eight of these were accepted and development programmes have been announced at five of the sites. These five sites are Hinkley Point, Sizewell, Oldbury, Wylfa and Moorside. Development of these five sites will provide approximately 16 GW_e of replacement capacity by 2030. Work undertaken for the replacement scenario suggests that site availability may be a potential constraint for the two expansion scenarios. The extent of the constraint was however not known and the aim of this project was to identify it. In addition, it was anticipated that the potential constraint will be aggravated by competing requirements to identify sites for new thermal power plants with carbon capture and storage (CCS).

2.2. Project Objectives

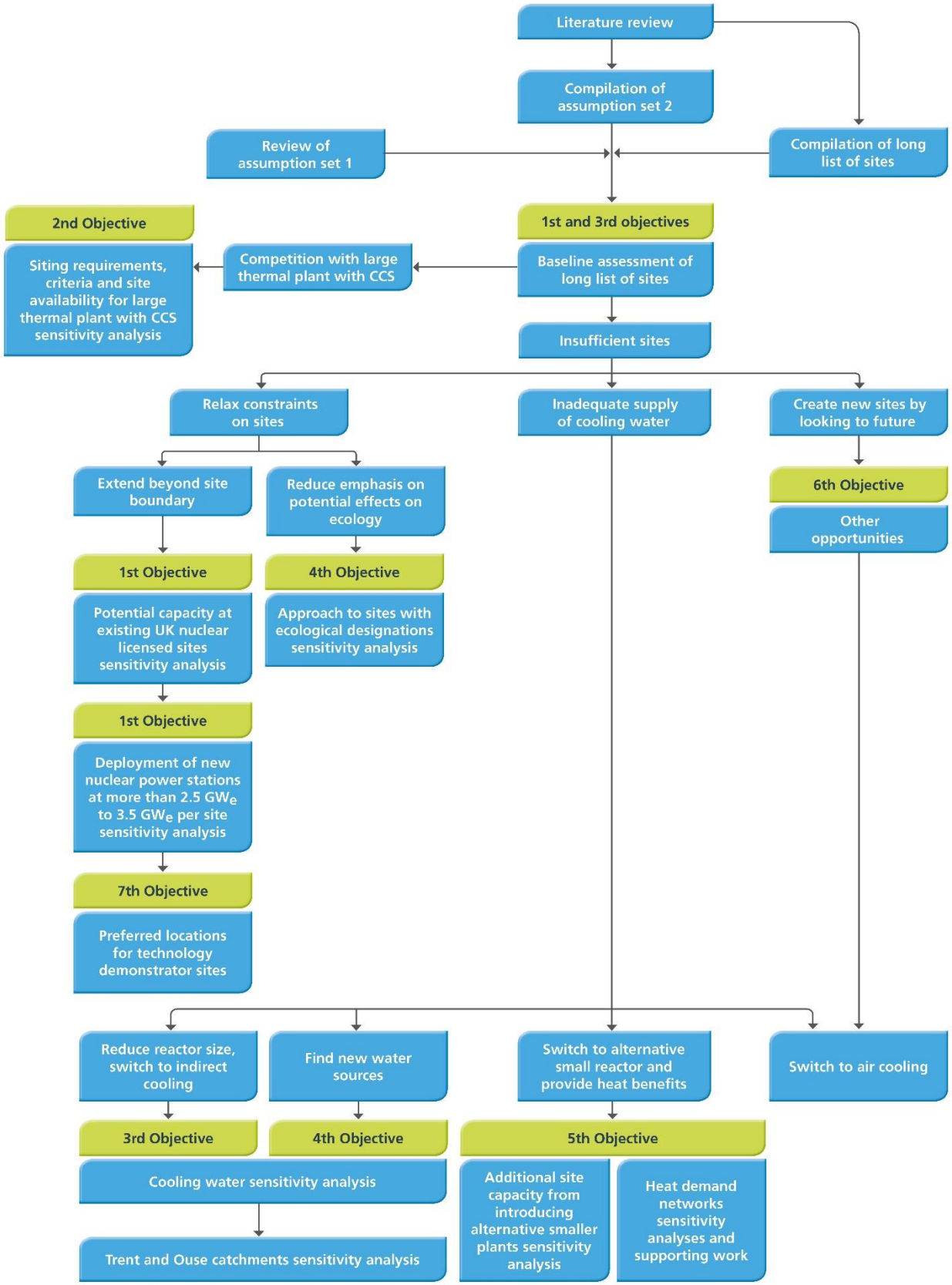
The project explored siting criteria and siting constraints against the nuclear expansion scenarios. It also identified and considered opportunities to enable the inclusion of additional sites, should the expansion scenarios be constrained. The seven objectives of the project were as follows:

- indicate the capacity of nuclear power likely to be generated from anticipated Generation (Gen) III+ nuclear plant designs developed at existing nuclear sites, thermal power plant brownfield sites, and new greenfield sites;
- indicate the number of sites likely to be suitable for CCS and identify where there is likely to be a conflict of sites suitable for both technologies (CCS and nuclear);
- identify the individual siting constraints which have greatest impact on the two nuclear expansion scenarios identified;
- through a range of sensitivity studies, identify potential changes in site selection criteria which would be necessary to deliver sufficient sites for the nuclear expansion scenarios;
- make recommendations for the siting characteristics of alternative technologies to make good the shortfall from Gen III+ nuclear; these are expected to include a reduced requirement for cooling water;
- identify other issues, constraints or assumptions which may change over the next 35 years to make more sites available for Gen III+ nuclear capacity; and
- identify preferred locations for nuclear power technology demonstrator sites.

2.3. Scope of Work

The scope of work for the project involved the characterisation and quantification of the site related constraints to developing new nuclear power in the UK by 2050. Figure 2-1 provides a summary of the work flow and how the project objectives were achieved.

Figure 2-1: Summary of Work Flow for Scope of Work



The brief literature review at the start of the project addressed the identification of siting criteria, siting constraints and potential locations for the development of nuclear power plants in the UK. The results of the literature review were used to inform the project assumptions and the long list of sites considered in the project.

The project sought to provide answers to the following questions:

- what are the site challenges associated with developing new nuclear power plants at each of the existing nuclear licensed sites in England and Wales? What is the likely maximum additional nuclear power plant electricity generating capacity for new deployment next to existing nuclear power plants before 2050, including and beyond plans already announced by developers?
- which existing brownfield power generation sites could be considered for nuclear power development and what is the likely maximum generating capacity for new nuclear deployment at brownfield sites by 2050?
- which greenfield sites could be considered for nuclear power development and what is the likely maximum capacity for new nuclear deployment at greenfield sites by 2050?
- which sites (brownfield and greenfield), and with what total potential capacity, are suitable for nuclear power development but would be preferentially allocated to thermal power plants with CCS consistent with the above assumptions?
- what are the dominant criteria which exclude sites from nuclear power deployment at existing brownfield and new greenfield sites, and what changes would need to be made to these criteria to increase significantly the number of sites available for nuclear power deployment?
- what changes should be considered to supporting assumptions used in the analysis, and why, in order to increase the number of sites available for potential deployment of nuclear?
- what additional assumptions or opportunities would increase the number of potential sites and capacity for new nuclear by 2050?
- from siting considerations, what are the likely site requirements for technology demonstrator plants such as small modular reactors (SMRs) or a 1,200 MW_e sodium cooled fast breeder reactor? Given the overall constraints on site availability, what are the most likely locations for siting these demonstrator plants?
- is it possible to identify sufficient sites that could be considered for 300 MW_e units to satisfy twice over the heat demand networks identified in the Systems Requirements for Alternative Nuclear Technologies project that had been carried out for the ETI by Mott MacDonald[1]?
- is it possible to satisfy once over the heat demand networks identified in the System Requirements for Alternative Nuclear Technologies project in conjunction with a significant programme of development of 1,650 MW_e, 1,400 MW_e and 1,150 MW_e units for baseload electricity?

The reason for considering whether the heat demand networks could be satisfied twice over was in order to make allowance for the fact that not all of the sites identified for 300 MW_e units are likely to be developed. Decreasing the requirement to satisfying the heat demand networks only once over allowed consideration of whether a significant programme of development of 1,650 MW_e, 1,400 MW_e and 1,150 MW_e units for baseload electricity could be achieved at the same time as satisfying the heat demand networks.

2.4. Introduction to Report Sections

Section 3 to Section 8 of the report provide information on the following:

- the two sets of assumptions (ETI assumptions and additional assumptions) employed in the project, the long list of sites considered in the project and the web based geographic information system (GIS) created for the project;

[1] System requirements for alternative nuclear technologies, Summary Report, Prepared by Mott MacDonald for the Energy Technologies Institute, August 2015.

- the assessment methodology for the baseline assessment, the baseline assessment of the long list of sites (which identifies sites that are suitable for twin 1,650 MW_e units using direct cooling), the nine sensitivity analyses with the supporting work for two of these sensitivity analyses, and two other studies;
- the outcomes of the sensitivity analyses;
- options for realising site capacity necessary to deliver 75 GW_e of new nuclear by 2050;
- options for realising site capacity necessary to deliver 75 GW_e of new nuclear by 2050 whilst satisfying the heat demand networks once over; and
- conclusions.

The last three of the nine sensitivity analyses explored notable conservatism relating to the assessment of cooling water availability for rivers and opportunities identified earlier in the project, and considered the provision of heat to satisfy the heat demand networks.

3. Key Project Assumptions and Inputs

3.1. Assumption Sets

The ETI had specified a set of assumptions which was to be used as the basis for the baseline assessment and which inform the scope and value of the sensitivity analyses to be carried out in the project. These assumptions specified the basic principles that were to be applied in the project. Additional assumptions that were important in bounding the scope, budget and breadth of the project were collated and recorded. The key project assumptions included the following:

- criteria for the siting of new nuclear power plants beyond 2030 will be the same as those for nuclear power plants developed up to 2030;
- developers will preferentially seek sites with access to sufficient cooling water for direct cooling;
- for a range of reasons, future nuclear power plants will be developed as twin or triple reactor units with an individual unit generation of between 1,150 MW_e and 1,650 MW_e and a combined site generation capacity of around 2.5 GW_e to 3.5 GW_e per site;
- a hierarchy of site selection will apply as follows: existing nuclear reactor licensed sites; other UK nuclear licensed sites; conventional power plant sites (brownfield sites); and greenfield sites;
- the effects of climate change on the availability of cooling water for abstraction and on the dispersion of the plume of water with an elevated temperature arising from the discharge of cooling water will not be considered;
- for the two river catchments sensitivity analysis, the reappraisal of the long list, the identification of additional sites and the heat demand networks sensitivity analyses, the Environment Agency's Water Resources GIS will be used in the cooling water assessment to determine cooling water availability for rivers;
- for the reappraisal of the long list, the identification of additional sites and the heat demand networks sensitivity analyses, the distance for access to sources of cooling water will be relaxed to be 20 km or less (rather than 2 km or less); and
- for the reappraisal of the long list, the identification of additional sites and the heat demand networks sensitivity analyses, the presence of existing development and major waterbodies between the site and the source of cooling water will not be taken into account and therefore will not be considered to be a barrier.

3.2. Long List of Sites

A long list of sites for consideration in the project was created. This included:

- nuclear licensed sites in England and Wales regulated by the Office of Nuclear Regulation (ONR) (excluding defence related sites);
- potential sites previously considered by the Central Electricity Generating Board (CEGB) as provided in the Alternative Sites Assessment[2];
- sites on the 2013 Digest of UK Energy Statistics (DUKES) list of operational sites (for thermal power plants); and
- sites on the lists of current and former electricity-generating power plants in England and Wales found on Wikipedia (for thermal power plants).

The areas 'worthy of further consideration' from the Alternative Sites Assessment were then added to the list, as were Braystones and Kirksanton. The latter two sites were nominated by industry into the Government's Strategic Siting Assessment as potential sites for development of new nuclear power plants. Sites from the

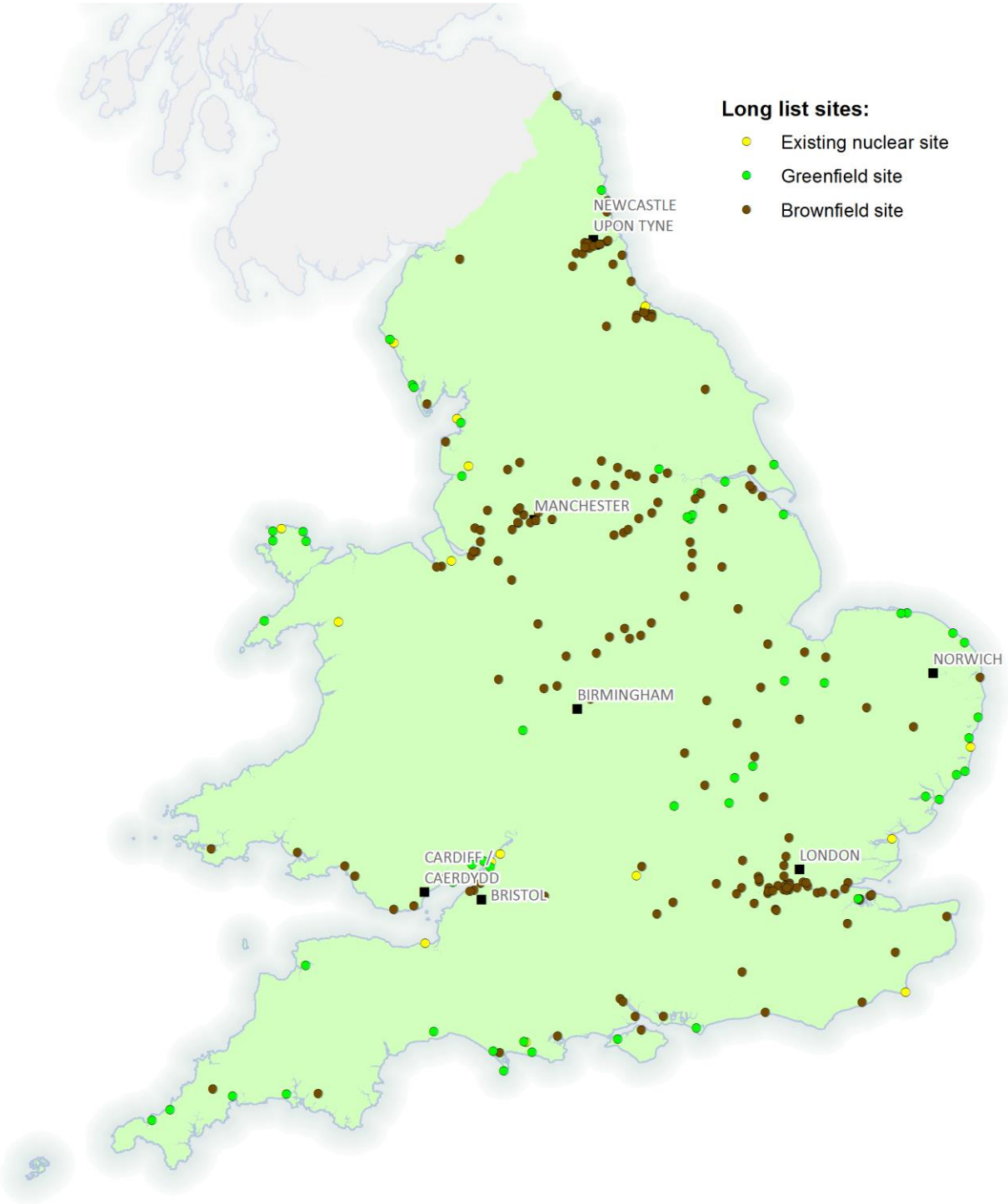
[2] A consideration of alternative sites to those nominated as part of the Government's Strategic Siting Assessment process for new nuclear power stations, Prepared by Atkins for the Department of Energy and Climate Change, November 2009.

DUKES list and the lists of current and former electricity-generating power plants in England and Wales were described as brownfield sites. The sites on the long list with known locations were loaded on to the Nuclear Spatial Data Infrastructure (NSDI) that was created for the project, along with their boundaries. Figure 3-1 shows the distribution of the 250 sites for which a location could be determined.

3.3. Nuclear Spatial Data Infrastructure

Geographic Information System technology underpinned the project, making it more manageable and robust through the use of an interactive GIS website that allowed datasets to be overlaid on a map of England and Wales to a high level of detail and accuracy. The NSDI (based on Autodesk MapGuide Enterprise) was created for the project and customised to meet its needs. Ordnance Survey (OS) data and data relating to designated ecological sites, designated heritage assets, rivers, lakes, canals, flood zones, coastal erosion, Ministry of Defence (MOD) exclusionary and non-exclusionary activities, civil airports, Control of Major Accident Hazard (COMAH) facilities; and population were incorporated into the NSDI.

Figure 3-1: Distribution of Sites on Long List for Which a Location Could be Determined



4. Baseline Assessment, Sensitivity Analyses and Other Studies

4.1. Assessment Methodology for Baseline Assessment

4.1.1. Overview of Assessment Methodology

The sites were subject to a two stage assessment process. Stage 1, which was carried out using the desktop GIS with the results uploaded into the NSDI, involved the application of exclusionary criteria. Exclusionary criteria are criteria that for safety, regulatory or other reasons exclude a site from further consideration. Stage 2 involved the application of discretionary criteria and was carried out by suitably qualified and experienced experts assisted by use of the NSDI. Discretionary criteria are criteria that are considered, for various reasons, to make a site unsuitable for development of a nuclear power plant. The criteria considered in the assessment process are not exhaustive and other criteria will need to be addressed in the further stages of the multi stage assessment process for new nuclear power plants.

The following sections provide more information on the assessment criteria for the baseline assessment of the long list of sites. The approach to the assessment methodology is considered to be a robust and rigorous application of the siting criteria, which are the same as those used in the Alternative Sites Assessment. This enabled continuity with that project.

4.1.2. Stage 1 Assessment – Exclusionary Criteria

The stage 1 assessment involved the application of five exclusionary (E) criteria:

- criterion E1 - demographics, which involved exclusion of land at the site where the population exceeds the semi-urban criterion. Figure 4-1 shows the areas where the population exceeds the semi-urban criterion;
- criterion E2 - exclusionary military activities, which involved exclusion of land at the site that is located in areas where exclusionary military activities take place. Figure 4-2 shows the locations of these areas;
- criterion E3 - within an internationally designated ecological site, was used to exclude land at the site that is located within an internationally designated ecological site (i.e. Special Protection Area, Special Area of Conservation or Ramsar site). Figure 4-3 shows the location of internationally designated ecological sites;
- criterion E4 - size of site, which involved the exclusion of sites with an area less than 1.2 km^2. In addition the whole 1.2 km^2 was required to pass the demographic criterion (criterion E1); and
- criterion E5 - access to sources of cooling water, which involved the exclusion of sites that were more than 2 km from the coast and estuaries.

4.1.3. Stage 2 Assessment – Discretionary Criteria

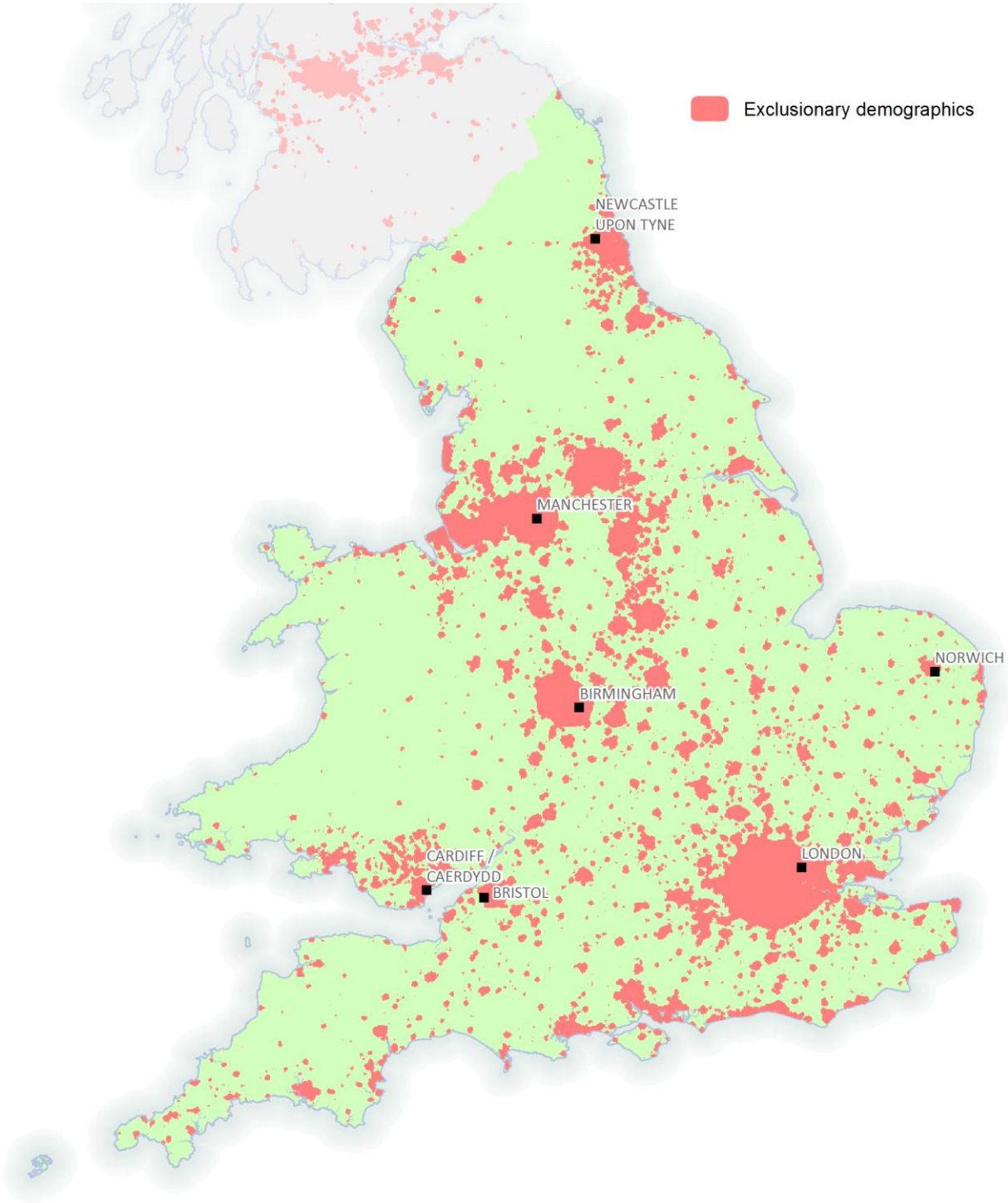
The stage 2 assessment was applied to sites that passed the stage 1 assessment. Stage 2 involved the application of 10 discretionary (D) criteria:

- criterion D1 - flood risk, which excluded areas where the flood risk is too great. Figure 4-4 shows the areas of England and Wales at risk of flooding from rivers and the sea, which are the principle sources of flood risk considered for criterion D1;
- criterion D2 - coastal processes (as represented by coastal erosion), which excluded sites at which coastal change is likely to cause difficulties for the long term safety of a nuclear power plant;
- criterion D3 - proximity to hazardous facilities, which involved exclusion of sites with a large liquefied natural gas storage installation within 2 km of the site, or a refinery or large scale petroleum storage installation adjacent to, or within 1 km of the site;

- criterion D4 - proximity to civil aircraft movements, which involved exclusion of sites within 1.5 miles of the reference point (which is generally the centre of the runway) for civil airports;
- criterion D5 - proximity to non-exclusionary military activities, which involved the exclusion of a site if non-exclusionary military activities are likely to cause significant difficulties to the development of a nuclear power plant on the site or the development itself could compromise the activities. The parts of the country covered by non-exclusionary military activities are shown in Figure 4-5;
- criterion D6 - proximity to internationally designated ecological sites, which involved retaining a site if it was reasonable to conclude that there would be no likely significant adverse effects on an internationally designated ecological site, taking into account reasonable mitigation measures;
- criterion D7 - nationally designated ecological sites, which involved excluding a site if it was within a nationally designated ecological site (e.g. Site of Special Scientific Interest, National Nature Reserve or Marine Conservation Zone / Marine Nature Reserve) unless it appeared possible to position the nuclear power plant outside the nationally designated site. In addition a site was excluded if it is unlikely to gain a Section 28[3] consent. Figure 4-6 shows the locations of the nationally designated ecological sites;
- criterion D8 - areas of amenity, cultural heritage and landscape value, which involved excluding a site because of its location within an area of amenity, cultural heritage or landscape value if the negative influence of the development on these areas was likely (taking into account any reasonable mitigation measures and existing development in the area) to make the development of a new nuclear power plant on the site only a theoretical possibility. Figure 4-7 shows the areas of amenity, cultural heritage and landscape value considered in the project;
- criterion D9 - size of site to accommodate operations, which involved excluding the site if it was not reasonably free from unsuitable topography and land use factors such as major roads, rivers, railway lines and other obstructions that cannot reasonably be moved. The site was also excluded if there was significant existing development (for example a town or a major road or railway line) surrounding the site or between the site and the source of cooling water; and
- criterion D10 - access to suitable sources of cooling water, which involved excluding a coastal site if its elevation above low tide was too great. In addition, for both coastal and estuarine sites, the quantity of water available for abstraction had to be adequate to satisfy the cooling water requirement for twin 1,650 MW_e units using direct cooling. Adequate dispersion of the plume of water with an elevated temperature arising from the discharge of the cooling water was also required.

[3] Wildlife and Countryside Act 1986 (as amended).

Figure 4-1: Areas of England and Wales Where Population Exceeds Semi-urban Criterion



Data derived from the HSE National Population Database, supplied under licence.

Figure 4-2: Location of Exclusionary Military Activities in England and Wales

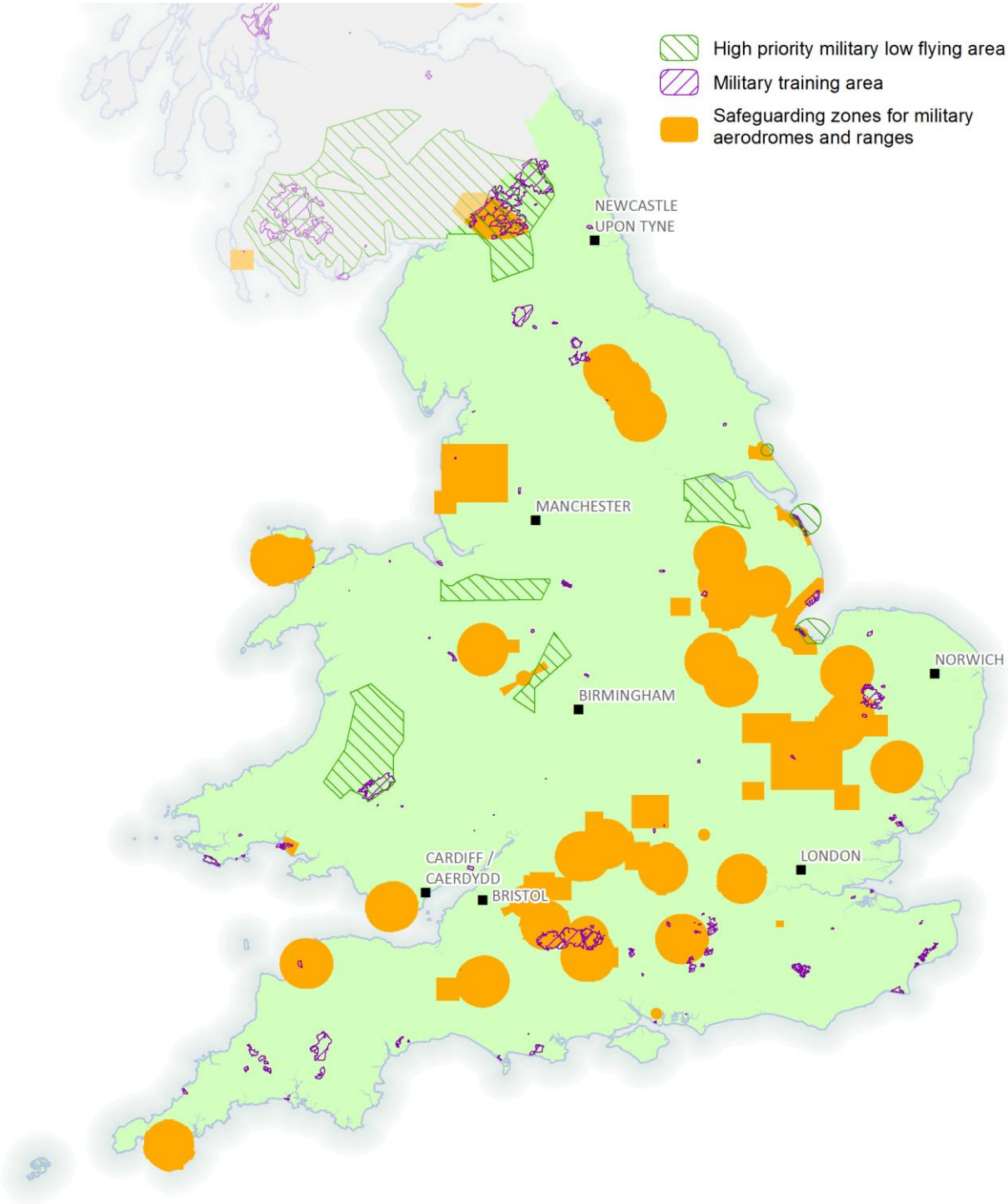


Figure 4-3: Location of Internationally Designated Ecological Sites in England and Wales

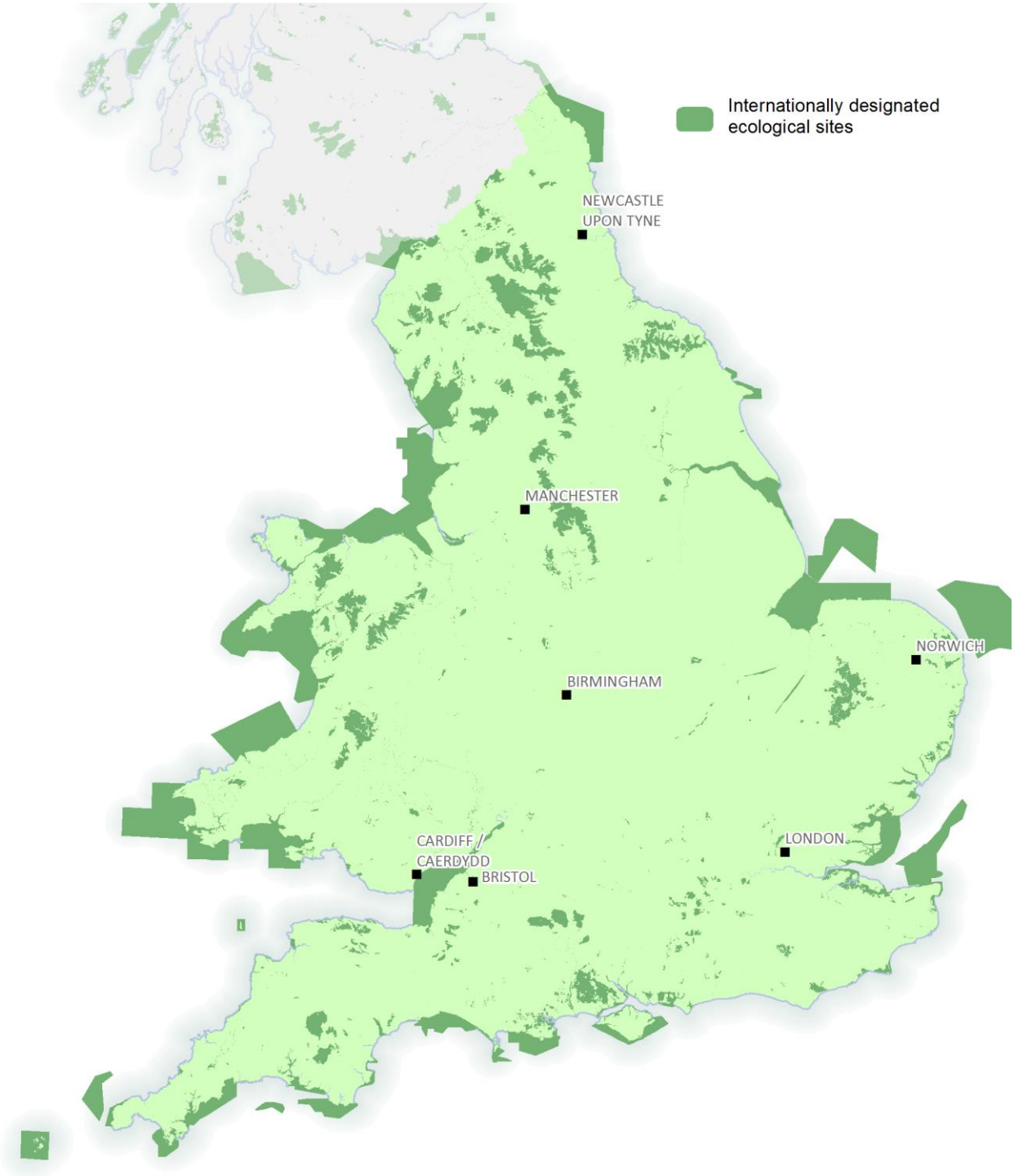


Figure 4-4: Areas of England and Wales at Risk of Flooding from Rivers and the Sea

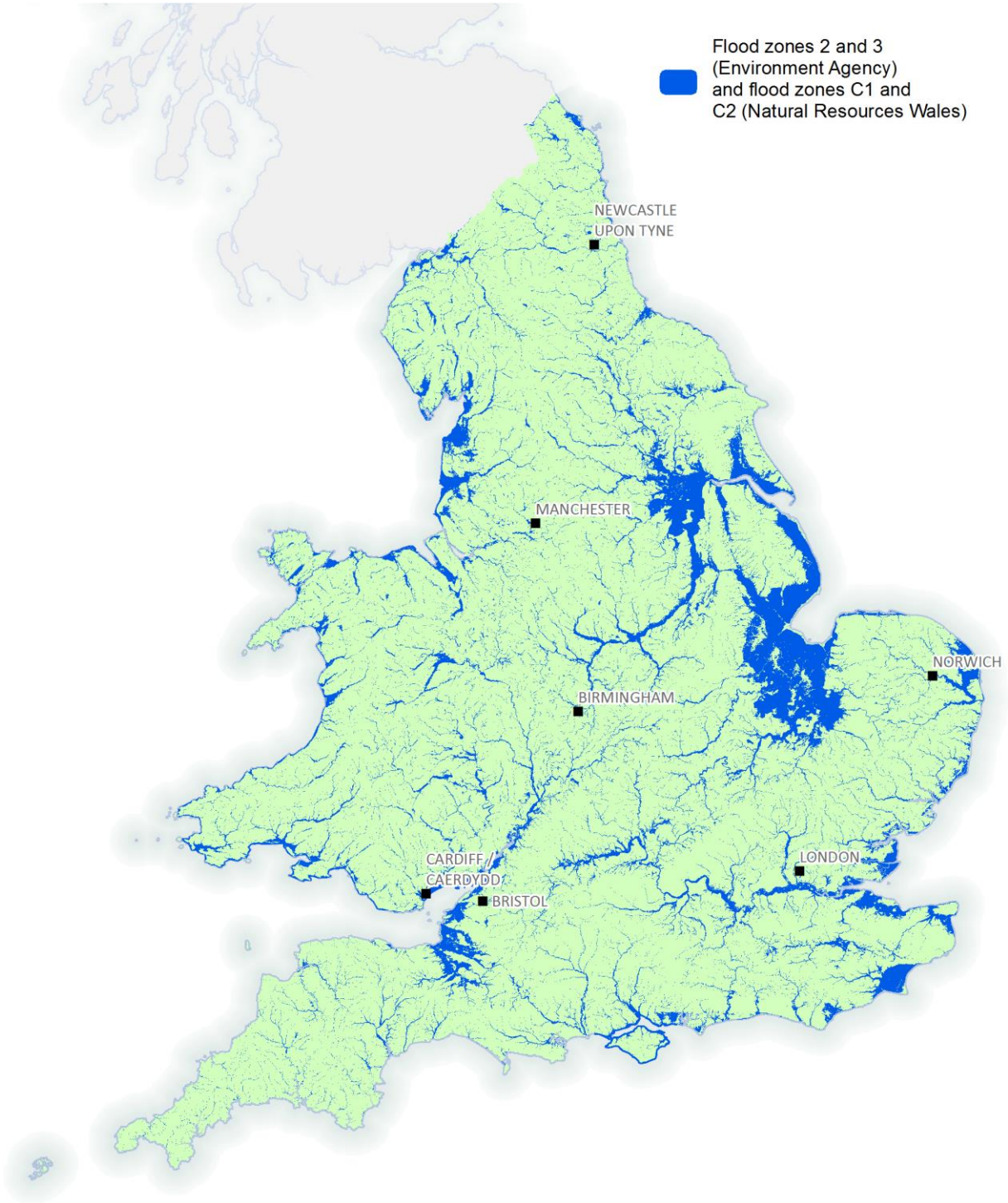


Figure 4-5: Location of Non-exclusionary Military Activities in England and Wales

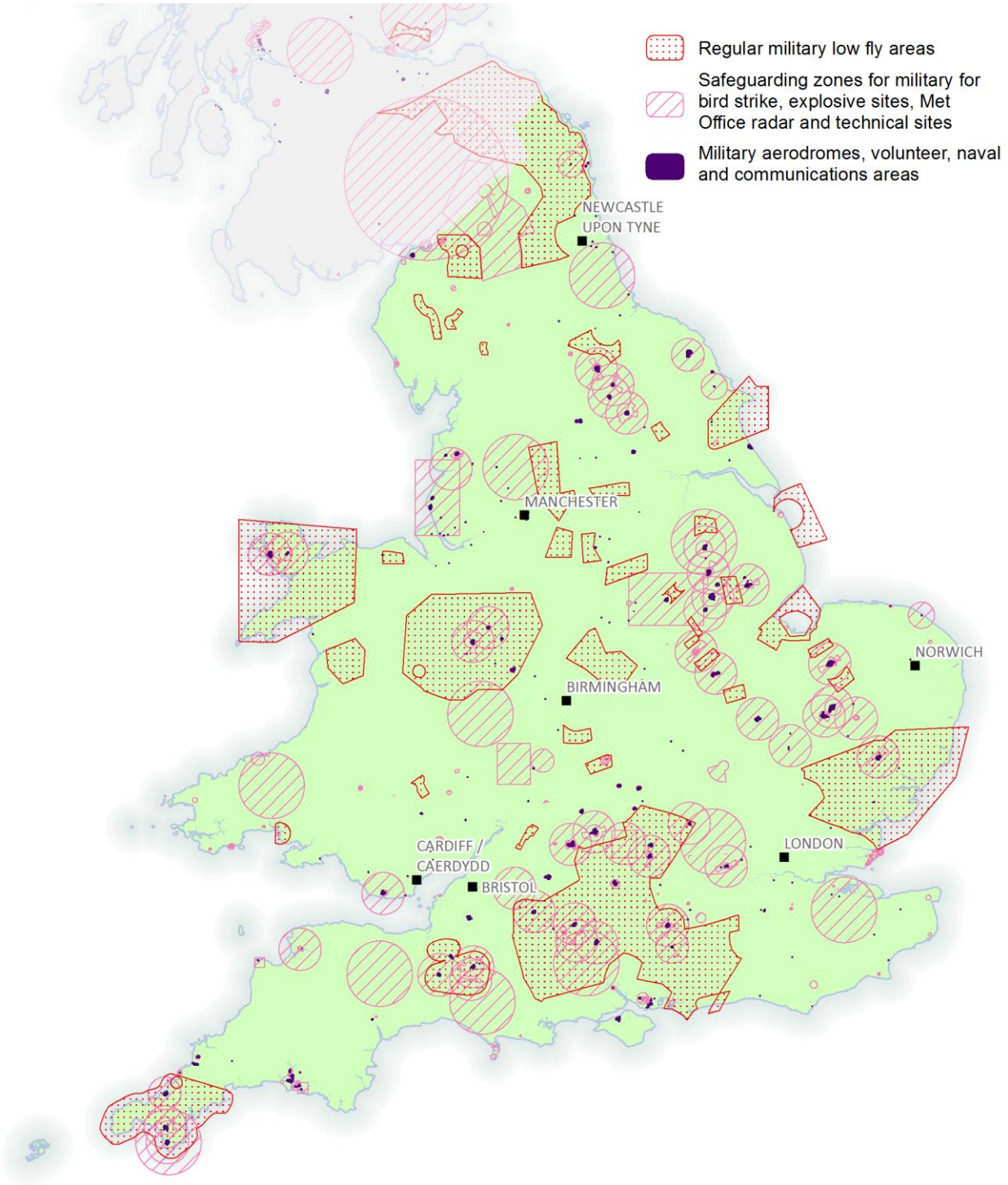


Figure 4-6: Location of Nationally Designated Ecological Sites in England and Wales

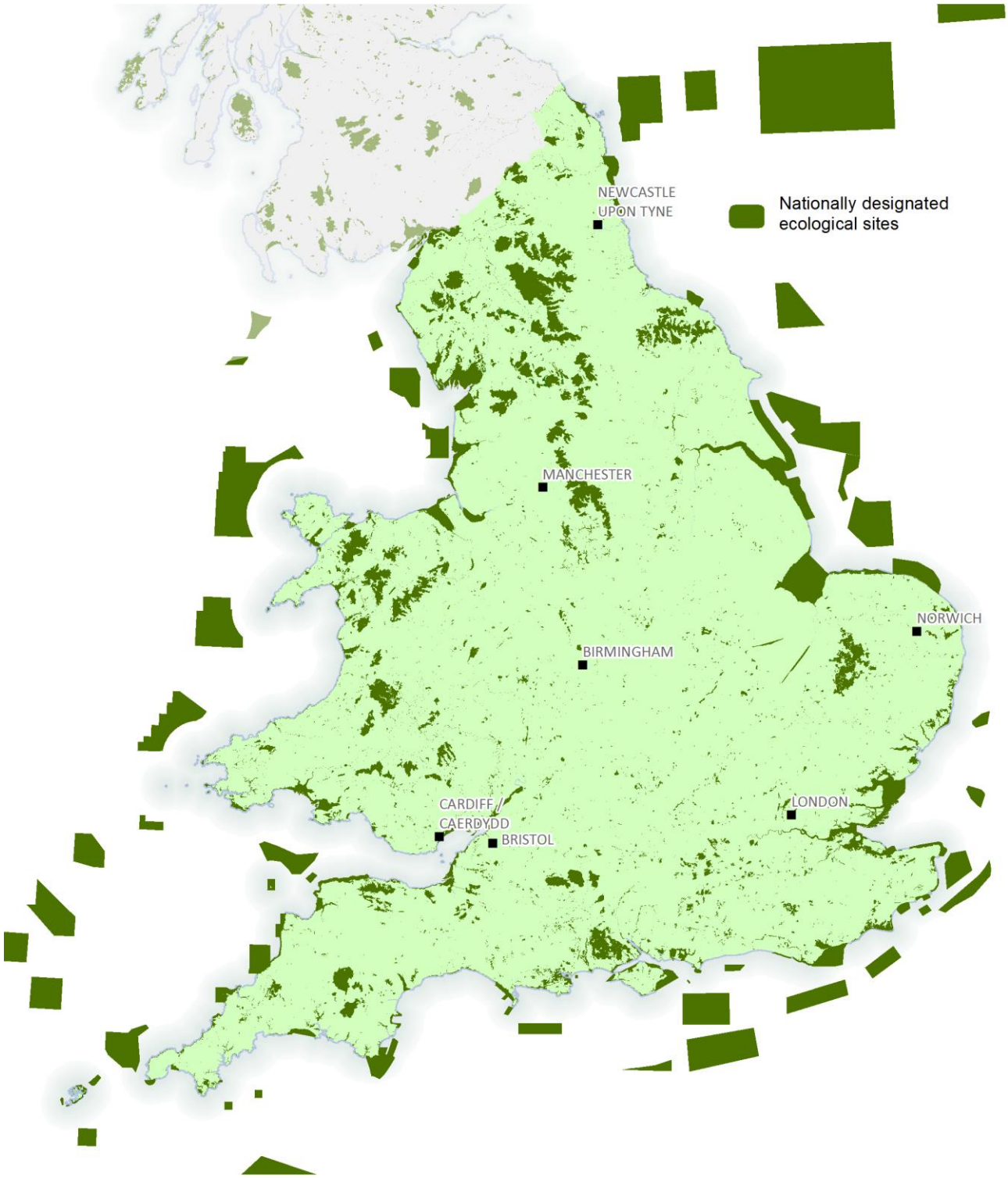


Figure 4-7: Areas of Amenity, Cultural Heritage and Landscape Value in England and Wales

4.2. Baseline Assessment of Long List

4.2.1. Objective

The objective of the baseline assessment was to determine which of the sites on the long list satisfied the exclusionary and discretionary criteria provided in Section 4.1. The sites were considered for twin 1,650 MW_e units with direct cooling and needed to be located 2 km or less from the coast or estuaries. The assessment methodology was as described in Section 4.1.

4.2.2. Results

One hundred and nine sites failed on criterion E5 - access to sources of cooling water. These 109 sites were considered in the cooling water sensitivity analysis. No brownfield sites passed the stage 2 assessment. Only one greenfield site passed the stage 2 assessment, on the basis that the power plant is set back from the coast by a distance of at least 320 m. This is the distance by which the coastline at the site may have retreated in 100 years. Setting the power plant back from the coast is possible as the size of the site is sufficiently large to allow this.

Only one site, a brownfield site, failed solely on criterion D10 - access to suitable sources of cooling water and therefore was automatically carried forward to the cooling water sensitivity analysis. There were no sites that failed solely on criterion D6 - proximity to internationally designated ecological sites. In the light of the latter result, one brownfield site and two greenfield sites that failed on the combination of criteria D10 and D6 were carried forward to the cooling water sensitivity analysis and to the ecological designations sensitivity analysis. Four greenfield sites failed on the combination of criteria D6 and D8 - areas of amenity, cultural heritage and landscape value. These four sites were also carried forward to the ecological designations sensitivity analysis.

4.2.3. Conclusions

A greenfield site was the only site to pass the baseline assessment, being suitable for twin 1,650 MW_e units with direct cooling. Therefore the potential maximum capacity for new nuclear deployment at this greenfield site is 3.3 GW_e. The sites that were carried forward to the cooling water sensitivity analysis are considered further in Section 4.3.2, and those that were carried forward to the ecological designations sensitivity analysis are considered further in Section 4.8. The 109 sites that failed on criterion E5 - access to sources of cooling water are considered in Section 4.3.3. The sites that failed on criterion E4 - size of site should be considered for 300 MW_e units, which require a smaller site area. The reappraisal of these sites for 300 MW_e units is addressed in Section 4.10.

4.3. Cooling Water Sensitivity Analysis

4.3.1. Objective

The objective of the cooling water sensitivity analysis was to determine the sites on the long list with access to sufficient cooling water for:

- indirect cooling from the coast or estuaries for 1,650 MW_e twin units; or
- direct or indirect cooling from the coast or estuaries for 1,400 MW_e or 1,150 MW_e twin units; or
- direct or indirect cooling from inland waterbodies for 1,650 MW_e, 1,400 MW_e or 1,150 MW_e single units.

It should be recognised that cooling water requirements for nuclear power plants are very different from those for thermal power plants. A full consideration of cooling water requirements under extremes of drought or temperature will be addressed as part of the regulatory requirements leading up to award of a Nuclear Site Licence and the other licences and approvals required to allow the power plant to operate. Such a consideration is beyond the scope of this project.

4.3.2. Coast and Estuaries

Assessment Methodology and Assessment Approach

The assessment methodology for criterion D10 - access to suitable sources of cooling water was as described in Section 4.1.3, with the addition of the consideration of indirect cooling for 1,650 MW_e twin units, and direct and indirect cooling for 1,400 MW_e and 1,150 MW_e twin units. The four sites (two brownfield and two greenfield) that failed the baseline assessment on criterion D10 (either alone or in combination with criterion D6 - proximity to internationally designated ecological sites) were considered against criterion D10.

Results

On the basis of the results for all discretionary criteria other than criterion D6 - proximity to internationally designated ecological sites, the two greenfield sites were suitable for 1,650 MW_e twin units with indirect cooling. However, as these sites failed the baseline assessment on criterion D6 (as well as on criterion D10 - access to suitable sources of cooling water) they failed the sensitivity analysis. These two sites had already been carried forward to the ecological designations sensitivity analysis. One of the brownfield sites failed the sensitivity analysis solely on criterion D10. The other brownfield site failed the sensitivity analysis on criteria D6 and D10.

4.3.3. Inland Waterbodies

Assessment Methodology and Assessment Approach

The 109 sites that failed the baseline assessment on criterion E5 - access to sources of cooling water were considered. Revised criteria, where necessary, were used in the assessments. Therefore for criterion E4 - size of site, an area for the size of site for a single unit of 1.0 km^2 or greater was used. For criterion E5, sites that are more than 2 km from an inland waterbody were excluded. The assessment methodology for criterion D10 - access to suitable sources of cooling water, as described in Section 4.1.3, was revised to address inland waterbodies for 1,650 MW_e, 1,400 MW_e and 1,150 MW_e single units. The approach for rivers involved conservatism, as a result of using flows based on natural flows for rivers and allowable abstractions for cooling water based on the minimum allowable percentage of these flows.

Results

Five brownfield sites passed the stage 2 assessment. Four of these sites passed for single 1,400 MW_e units with indirect cooling. The fifth passed for a single 1,650 MW_e unit with indirect cooling. Some of the sites are related by river network. It was determined that, within the conservatism of the approach to the assessment of cooling water availability for rivers, the overall capacity would be limited to a single 1,400 MW_e unit and a single 1,650 MW_e unit. Some of the sites on the river network have supported thermal power plants to a greater capacity than the levels of nuclear capacity determined here. The reasons for this include the conservatism in the approach to criterion D10 - access to suitable sources of cooling water for rivers, the reduction in allowable abstractions from rivers over time and the lower efficiency (and therefore greater cooling water requirement) of a nuclear power plant compared to that of a thermal power plant of the same generating capacity. No greenfield sites passed the stage 2 assessment.

4.3.4. Conclusions

Five brownfield sites passed the cooling water sensitivity analysis, with four of these being suitable for a single 1,400 MW_e unit and the fifth suitable for a single 1,650 MW_e unit. Once allowance was made for sites that are related by river network, it was determined that, within the conservatism of the approach to the assessment of cooling water availability for rivers, the overall capacity would be limited to a single 1,400 MW_e unit and a single 1,650 MW_e unit. Therefore the indicative maximum capacity for new nuclear deployment at these two brownfield sites by 2050 is 3.05 GW_e. This indicative maximum capacity is likely to be an underestimate for the reasons described in Section 4.3.3. The results obtained from the sensitivity analysis should be reassessed using the Environment Agency's Water Resources GIS to relax the conservatism in the assessment. The reassessment of the sites using the Water Resources GIS is addressed in Section 4.9.

The three sites that had been carried forward to the ecological designations sensitivity analysis because they failed the baseline assessment on criterion D6 - proximity to internationally designated ecological sites and therefore failed the cooling water sensitivity analysis on criterion D6, are considered further in Section 4.8. These sites also failed the baseline assessment on criterion D10 - access to suitable sources of cooling water. The sites that failed the cooling water sensitivity analysis on criterion E4 - size of site should be considered for 300 MW_e units, which require a smaller site area. The sites that failed on criterion D10 should also be considered for 300 MW_e units, which use a smaller quantity of cooling water. The reappraisal of these sites for 300 MW_e units is addressed in Section 4.10.

4.4. Additional Site Capacity from Introducing Alternative Smaller Plants Sensitivity Analysis

4.4.1. Objective

The objective of the alternative smaller plants sensitivity analysis was to identify regions of England and Wales which provide additional sites for 300 MW_e units and to determine the capacity of these regions for these units. The coastal and estuarine regions consisted of lengths of the coastline or lengths of land bordering an estuary, whilst an inland region consisted of the land bordering a stretch of river or canal, or the land surrounding a lake or reservoir.

4.4.2. Assessment Methodology and Assessment Approach for Coastal and Estuarine Regions

Seven of the 270 areas on the coast and estuaries provided in the Alternative Sites Assessment were taken forward as coastal and estuarine regions for consideration in the sensitivity analysis. Revised criteria, where necessary, were used in the assessments. Therefore criterion E4 - size of site was applied using areas of 0.1 km^2 and 0.11 km^2 as the sizes of site for each of the 300 MW_e units employing direct cooling or indirect cooling respectively. The assessment methodology for criterion D10 - access to suitable sources of cooling water as described in Section 4.1.3 was revised to address 300 MW_e units using direct and indirect cooling.

4.4.3. Assessment Methodology and Assessment Approach for Inland Regions

The starting point for the assessment of the inland regions was the whole of England and Wales apart from land that is 2 km or less from the coast or estuaries. Twenty inland regions were selected for consideration by the experts. This was the number of regions that had been specified as the maximum number for assessment in the sensitivity analysis. Revised criteria, where necessary, were used in the assessments. Criterion E4 - size of site was applied after the selection of regions, using areas of 0.1 km^2 and 0.11 km^2 as the size of site for each of the 300 MW_e units employing direct cooling or indirect cooling respectively. Criterion E5 - access to sources of cooling water was revised to exclude land that was more than 2 km from an inland waterbody. The assessment methodology for criterion D10 - access to suitable sources of cooling water as described in Section 4.1.3 was revised to address inland waterbodies for 300 MW_e units using direct and indirect cooling.

4.4.4. Results

Some of the regions considered in the sensitivity analysis are related to the other regions by the river network to form a group. This (conservatively) restricted the total number of units in the groups of regions to seventeen 300 MW_e units. For the independent regions, the total number of units in the regions was an additional eleven 300 MW_e units.

4.4.5. Conclusions

The capacity for deployment of 300 MW_e units in brownfield and greenfield regions by 2050 amounts to twenty eight 300 MW_e units which provides a total of 8.4 GW_e. It should be remembered that this is an indicative capacity as it is based on the results from only 20 inland regions. Assessment of more inland regions is likely to lead to greater capacity. In addition the indicative capacity is likely to be an underestimate as a result of the conservatism associated with the adopted approach for assessing cooling water availability for rivers. Also, the sites mentioned in Section 4.2.3 and Section 4.3.4 for consideration for 300 MW_e units,

may prove suitable for these units. This is also likely to lead to greater capacity for 300 MW_e units. The reappraisal of these sites for 300 MW_e units is addressed in Section 4.10.

4.5. Siting Requirements, Criteria and Site Availability for Large Thermal Plant with CCS Sensitivity Analysis

4.5.1. Objective

The objective of the large thermal plant with CCS sensitivity analysis was to identify siting requirements, criteria and site availability for large thermal power plants with CCS. Once the site availability had been identified, an additional objective was to determine the potential for development overlap with sites that are also suitable for nuclear power plants.

4.5.2. Assessment Methodology and Assessment Approach

Three combinations of types and capacities of large thermal power plants with CCS were adopted in this sensitivity analysis. The site selection criteria as applied for nuclear power plants were reviewed taking account of information in the public domain on siting of thermal power plant with CCS and revised assumptions suitable for thermal power plant with CCS were formulated. These revisions were based on the fact that thermal power plants with CCS are less hazardous than nuclear power plants and therefore some of the criteria were relaxed compared to those employed for nuclear power plants.

Criterion E1 - demographics was relaxed compared to the methodology described in Section 4.1.2, so that the site could be situated where the population density exceeds the semi-urban criterion but not within a city centre. Criterion E4 - size of site was also relaxed compared to the methodology described in Section 4.1.2 so that the size of site was greater than or equal to 0.56 km^2. In addition, the whole of this site area could be situated where the population density exceeds the semi-urban criterion, but not within the city centre. Criterion E5 - access to sources of cooling water was as described in Section 4.1.2, but was restricted to the east coast of England.

The assessment methodology for criterion D10 - access to suitable sources of cooling water as described in Section 4.1.3 was revised to address the three combinations of types and capacities of thermal power plants with CCS using direct and indirect cooling. Sites on the long list that are located 2 km or less from the coast or estuaries on the east coast of England, other than existing nuclear licensed sites, were considered for inclusion in the sensitivity analysis. Sixteen sites were carried through to the stage 2 assessment.

4.5.3. Results

Ten of the 16 sites carried through to the stage 2 assessment passed the sensitivity analysis. The other six sites failed solely on criterion D6 - proximity to internationally designated ecological sites. The ETI had provided a scenario by power plant type and capacity for new electrical generation for thermal power plants with CCS to be deployed by 2050. Thermal power plants with CCS were allocated to sites in order to fulfil this scenario. Power plants were first allocated to three sites on the east coast of Scotland, followed by the ten sites that passed the sensitivity analysis. Finally the sites that were not assessed in detail in the sensitivity analysis were considered and further power plants with CCS were allocated to a subset of these. On this basis it was concluded that a minimum of a further 23 sites was required to fulfil the ETI scenario.

At face value this would suggest that there would be competition between thermal power plants with CCS and nuclear power plants for the one site that passed the baseline assessment. However, the following additional items need to be taken into consideration:

- there are potentially more sites for thermal power plants with CCS than the sites that have been considered above (including sites on the west coast of England and Wales, and inland sites) and therefore there is likely to be less competition for sites;
- an extreme scenario for new electrical generation capacity for thermal power plants with CCS was considered in the sensitivity analysis; consideration of a mid-range scenario reduces the minimum number of further sites to fulfil the scenario to two; and
- the criteria for selection of sites for nuclear power plants are so strict in comparison to those for thermal power plants with CCS that the nuclear developers might be expected to prioritise securing any site that passed the baseline assessment.

Figure 4.8 provides an illustrative distribution of sites for thermal power plants with CCS, including the six sites that failed the sensitivity analysis solely on criterion D6 - proximity to internationally designated ecological sites. Thermal power plants with CCS have been allocated to these six sites on the basis that it was considered likely that these sites could be brought back into consideration through the ecological designations sensitivity analysis. Further comment on this is provided in Section 4.8.7.

4.5.4. Conclusions

Ten sites passed the large thermal plant with CCS sensitivity analysis. Nine of these sites were brownfield sites and one was a greenfield site. The greenfield site was the only site that passed the baseline assessment. Based on the information provided in Section 4.5.3, it is concluded that, in principle, there should not be an issue as far as competition for sites with thermal power plants with CCS is concerned. However, other factors which are not considered in this project (e.g. transmission system availability) will influence developers to identify sites that are commercially advantageous. Therefore competition between nuclear power plants and thermal power plants with CCS may be greater than the above information suggests. Further comment on the six sites that failed the sensitivity analysis solely on criterion D6 - proximity to international designated sites is provided in Section 4.8.7.

4.6. Potential Capacity at Existing UK Nuclear Licensed Sites Sensitivity Analysis

4.6.1. Objective

The objective of the existing UK nuclear licensed sites sensitivity analysis was to appraise the potential capacity that may be developed adjacent to existing nuclear licensed sites by 2050 whilst limiting the development at any site to twin large units (i.e. 2.5 GW_e to 3.5 GW_e per site). The limit of twin large units was adopted in this project but it is recognised that triple large units are proposed for Moorside, which is proposed to have a new nuclear power plant by 2030.

4.6.2. Background

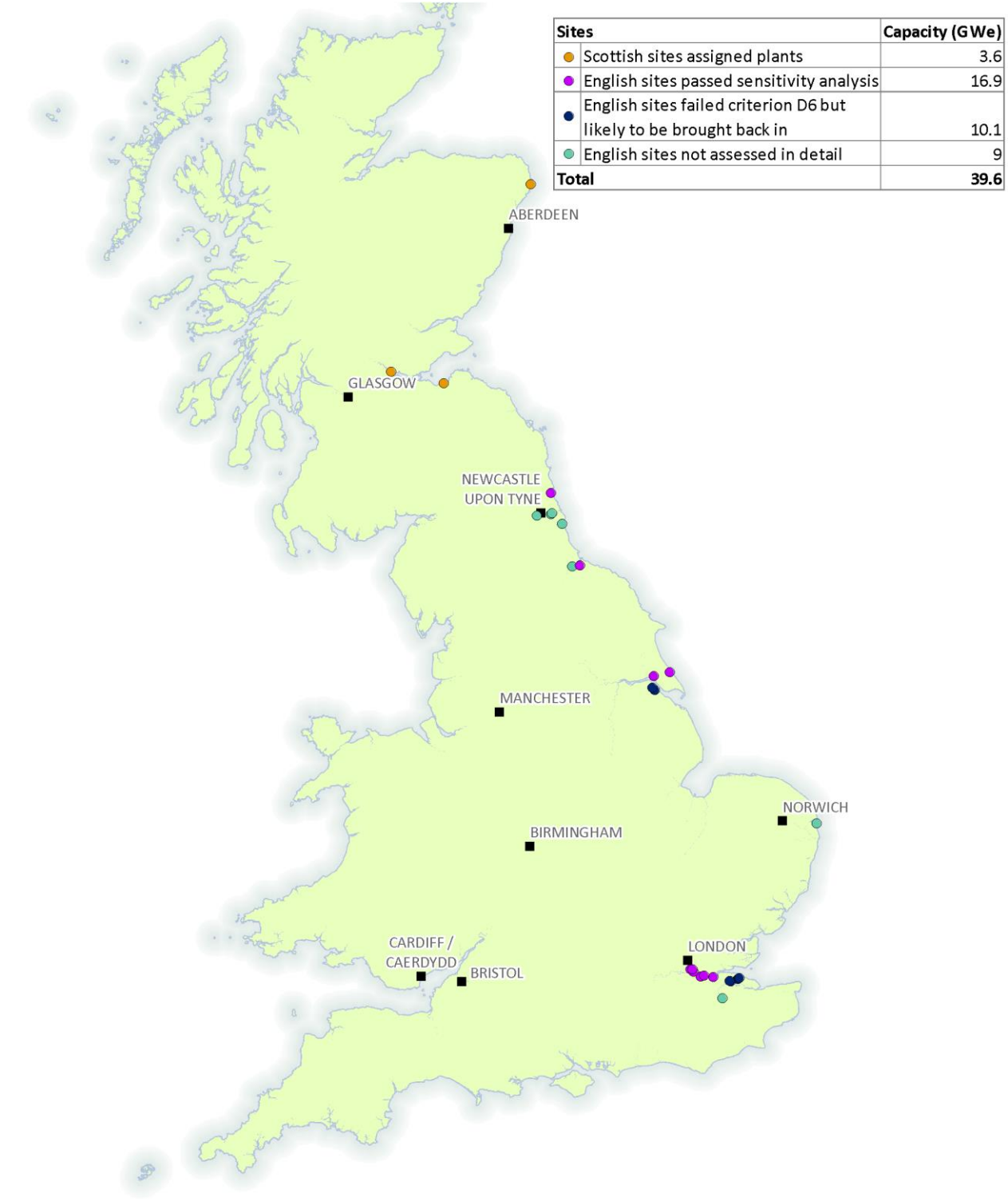
The sensitivity analysis did not consider the extensions to the five nuclear licensed sites which are proposed to have new nuclear power plants by 2030. This is because, for the purposes of this project, development is assumed to have already reached 2.5 GW_e to 3.5 GW_e at these sites. In addition, two other existing nuclear licensed sites were excluded. One of these sites had failed the baseline assessment on criterion E2 - exclusionary military activities. For the other it was considered that the future of the site is as a business park rather than as a site for nuclear power plants.

The land areas that were considered in the sensitivity analysis were initial extensions to the nuclear licensed sites. For the four existing nuclear licensed sites which were nominated into the Government's Strategic Siting Assessment, the extensions were initially taken as the nominated areas and then modified as necessary. For the other four existing nuclear licensed sites, suitable areas of land adjacent to the existing sites were sought as extensions. In all cases the aim was to find 1.2 km^2 of land to allow the location of 1,650 MW_e, 1,400 MW_e or 1,150 MW_e twin units on these extensions. However, if this proved impossible the available area of land was considered for the location of a single 1,650 MW_e, 1,400 MW_e or 1,150 MW_e unit, a single 300 MW_e unit, or multiple 300 MW_e units.

4.6.3. Assessment Methodology

Revised assessment methodologies for criteria appropriate for the proposed number and capacity of nuclear power plants, cooling water technique (direct or indirect) and cooling water source (coast, estuaries, reservoirs or rivers) were employed for each extension.

Figure 4-8: Illustrative Distribution of Sites for Thermal Power Plants with CCS



4.6.4. Results

The overview of the results for the sensitivity analysis is as follows:

- four extensions failed solely on criterion D6 - proximity to internationally designated ecological sites and were carried forward to the ecological designations sensitivity analysis;
- one extension failed on criteria D1 - flood risk, D6 - proximity to internationally designated ecological sites and D7 - nationally designated ecological sites, and was carried forward to the ecological designations sensitivity analysis;
- one extension failed on criteria D6 and D10 - access to suitable sources of cooling water, and was carried forward to the ecological designations sensitivity analysis;
- one extension failed solely on criterion D10; and
- one extension passed for 300 MW_e units.

No extensions to nuclear licensed sites in England and Wales passed the sensitivity analysis for 1,650 MW_e, 1,400 MW_e or 1,150 MW_e units.

4.6.5. Additional Studies

As part of the sensitivity analysis, three additional studies were carried out. The purpose of the studies was the determination of the sites challenges, in addition to access to suitable sources of cooling water, at the existing nuclear licensed sites and the extensions to these sites. The studies addressed the following topics:

- access for Abnormal Indivisible Loads (AILs) to existing nuclear licensed sites;
- high level analysis of the ground conditions at existing nuclear licensed sites; and
- high level assessment of the scale of flood defence works likely to be required to manage flood risk safely at the extensions to the existing nuclear licensed sites.

4.6.6. Conclusions

The likely maximum additional nuclear power plant electricity generating capacity for new deployment next to existing nuclear power plants in England and Wales before 2050 amounts to the capacity already announced by developers, which provides a total of 15.4 GW_e. One extension in England and Wales passed the sensitivity analysis for 300 MW_e units, being suitable for two 300 MW_e units. This provides a total of 0.6 GW_e of 300 MW_e units. In conjunction with the capacity announced by developers, this increases the likely maximum additional nuclear power plant electricity generating capacity for new deployment next to existing nuclear power plants in England and Wales before 2050 to a total of 16 GW_e.

The extensions that failed on criterion D6 - proximity to internationally designated ecological sites, either alone, or in conjunction with criterion D10 - access to suitable sources of cooling water, or in conjunction with criteria D1 - flood risk and D7 - nationally designated ecological sites, are considered further in Section 4.8. Only access by water for AILs at one existing nuclear licensed site falls into the difficult category. The results from consideration of ground conditions indicated that there are no major ground condition challenges which will limit development at the existing nuclear licensed sites. Two extensions fall into the most challenging category for the scale of flood defence works likely to be required to manage flood risk safely.

4.7. Deployment of New Nuclear Power Plants at More than 2.5 GW_e to 3.5 GW_e per Site Sensitivity Analysis

4.7.1. Objective

The objective of the more than 2.5 GW_e to 3.5 GW_e per site sensitivity analysis was to appraise the potential capacity that may be developed adjacent to existing UK nuclear licensed sites without limiting the development at any site to twin large units (i.e. 2.5 GW_e to 3.5 GW_e per site).

4.7.2. Background

The five existing nuclear licensed sites which are proposed to have new nuclear power plants by 2030 were included in the sensitivity analysis. The sensitivity analysis had three stages which generally addressed the second, third and fourth extensions respectively at the existing nuclear licensed sites, where such further extensions were possible. These three stages included the number of extensions that had been specified as the maximum number of extensions for assessment in the sensitivity analysis. At each stage of the sensitivity analysis, an extension was added to each of the nuclear licensed sites until:

- the capacity of the source of cooling water was exhausted; or
- opportunities for extensions were exhausted because the land included in any additional extension would fail the assessment criteria; or
- no more land was available because of the presence of infrastructure or settlements.

In all cases the aim was to find 1.2 km^2 of land to allow location of 1,650 MW_e, 1,400 MW_e or 1,150 MW_e twin units on the extensions. However, if this proved impossible the available area of land was considered for the location of a single 1,650 MW_e, 1,400 MW_e or 1,150 MW_e unit, or a single 300 MW_e unit, or multiple 300 MW_e units.

4.7.3. Assessment Methodology

The assessment methodology was the same as that used for the existing UK nuclear licensed sites sensitivity analysis.

4.7.4. Results

The overview of the results for the sensitivity analysis is as follows:

- one extension passed for twin 1,650 MW_e units and one extension passed for a single 1,650 MW_e unit;
- seven extensions failed solely on criterion D6 - proximity to internationally designated ecological sites and were carried forward to the ecological designations sensitivity analysis;
- two extensions failed on criteria D6 and D10 - access to suitable sources of cooling water; and
- three extensions failed solely on criterion D10.

4.7.5. Additional Studies

As part of the sensitivity analysis, two additional studies were carried out. The purpose of these studies was the determination of the site challenges, in addition to access to suitable sources of cooling water, at the existing nuclear licensed sites and the extensions to the sites. These studies addressed the following topics:

- high level analysis of ground conditions at existing nuclear licensed sites, which considered the five existing nuclear licensed sites which are proposed to have new nuclear power plants by 2030; and
- high level assessment of the scale of flood defence works likely to be required to manage flood risk safely at extensions to the existing nuclear licensed sites.

4.7.6. Conclusions

The potential maximum additional nuclear power plant electricity generating capacity for new deployment beyond twin large units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear power plants in England and Wales before 2050 amounts to a total of 4.95 GW_e. No further extensions to nuclear licensed sites in England and Wales passed the sensitivity analysis for 300 MW_e units. The extensions that failed solely on criterion D6 - proximity to internationally designated ecological sites are considered further in Section 4.8. The results from the consideration of ground conditions indicated that there are no major ground condition challenges which will limit development at the five existing nuclear licensed sites which were considered. Four extensions fell into the most challenging category for the scale of flood defence works likely to be required to manage flood risk safely.

4.8. Approach to Sites with Ecological Designations Sensitivity Analysis

4.8.1. Objective

The objective of the ecological designations sensitivity analysis was to develop a strategy which reduces the emphasis on environmental effects associated with the development of the required number of sites.

4.8.2. Introduction

The results from the baseline assessment demonstrated that, in conjunction with criteria D8 - areas of amenity, cultural heritage and landscape values and criterion D10 - access to suitable sources of cooling water, criterion D6 - proximity to internationally designated ecological sites was a dominant constraint on the siting of nuclear power plants. Therefore, an ecological strategy was developed which minimises the risk of sites being excluded through an over-precautious screening of ecological effects associated with the development of sites. The ecological designations sensitivity analysis was applied to sites brought forward from the baseline assessment and two of the sensitivity analyses:

- sites that failed the baseline assessment on criterion D6 and one other criterion (either criterion D8 or D10);
- initial extensions that failed the existing UK nuclear licensed sites sensitivity analysis solely on criterion D6, or on criteria D6 and D10, or on criteria D6, D1 - flood risk and D7 - nationally designated ecological sites; and
- further extensions that failed the more than 2.5 GW_e to 3.5 GW_e per site sensitivity analysis solely on criterion D6.

4.8.3. Methodology

The sensitivity analysis focused on internationally designated ecological sites, with particular consideration given to implications with regard to The Conservation of Habitats and Species Regulations (2010), which transposes the Habitats Directive 1992 into UK law, and on nationally designated sites. The method for the sensitivity analysis was designed with the aim of allowing a more robust approach to ecology and, possibly, allowing additional potential sites to be identified. This will not compromise the UK's duties under the Habitats Directive, since any sites selected as a potential site for a nuclear power plant will be subject to further assessments. It should be noted that there are limitations associated with the methodology. The methodology involved identifying ecological mitigation measures and compensatory measures that could be used at the site to avoid significant adverse ecological effects. Mitigation measures are measures put in place to avoid adverse ecological effects and compensatory measures are used to compensate for adverse ecological effects that cannot be avoided.

4.8.4. Results

In terms of criteria D6 - proximity to internationally designated ecological sites and D7 - nationally designated ecological sites, 19 of the 20 sites that were considered passed the sensitivity analysis. However, owing to some sites having failed on other criteria, a total of only 13 sites could be brought back into consideration as potential sites for nuclear power plants. These were:

- two greenfield sites that were carried forward from the baseline assessment;
- four initial extensions to nuclear licensed sites which were carried forward from the existing UK nuclear licensed sites sensitivity analysis; and
- seven further extensions to nuclear licensed sites which were carried forward from the more than 2.5 GW_e to 3.5 GW_e per site sensitivity analysis.

4.8.5. Conclusions for Baseline Assessment and Cooling Water Sensitivity Analysis

If mitigation / compensatory measures are accepted for the two greenfield sites that were carried forward from the baseline assessment, the result for the baseline assessment remains unchanged as follows:

- one greenfield site passed the baseline assessment with a potential maximum capacity for new nuclear deployment by 2050 of 3.3 GW_e.

If mitigation / compensatory measures for the two greenfield sites are accepted, the results for the cooling water sensitivity analysis for sites 2 km or less from the coast or estuaries are now as follows:

- two greenfield sites pass for twin 1,650 MW_e units with indirect cooling.

Therefore, if mitigation / compensatory measures for the two greenfield sites are accepted, there are now three greenfield sites (for twin 1,650 MW_e units with indirect cooling) which could be considered for nuclear power development and the potential maximum capacity for new nuclear deployment at these greenfield sites by 2050 is now 9.9 GW_e.

If mitigation / compensatory measures for the two greenfield sites are accepted, the indicative maximum capacity at brownfield sites as determined in the cooling water sensitivity analysis remains unchanged. Therefore there are still only two brownfield sites which could be considered for nuclear power development and the indicative maximum capacity for new nuclear deployment at these brownfield sites by 2050 is still 3.05 GW_e.

4.8.6. Conclusions for Additional Site Capacity from Introducing Alternative Smaller Plants Sensitivity Analysis

The results from the approach to sites with ecological designations sensitivity analysis do not affect the results from the alternative smaller plants sensitivity analysis. Therefore the current indicative capacity for deployment of 300 MW_e units in brownfield and greenfield regions by 2050 remains unchanged at a total of twenty eight 300 MW_e units, which provides a total of 8.4 GW_e.

4.8.7. Conclusions for Siting Requirements, Criteria and Site Availability for Large Thermal Plant with CCS Sensitivity Analysis

The six sites that failed the large thermal plant with CCS sensitivity analysis solely on criterion D6 - proximity to internationally designated ecological sites were also considered in the ecological designations sensitivity analysis. It was concluded that it was likely that all six of these sites could be brought back into consideration as potential sites for large thermal power plants with CCS. If mitigation / compensatory measures for these six sites are accepted, this means that all six sites that failed the large thermal plant with CCS sensitivity analysis solely on criterion D6 are likely to be available as potential sites for thermal power plants with CCS. Hence the minimum number of further sites for thermal power plants with CCS that are required to fulfil the ETI scenario for new electrical generation for thermal power plants with CCS to be deployed by 2050 is likely to be reduced from 23 to 17. Therefore taking into consideration the additional items that had previously been taken into consideration in Section 4.5.3, it is concluded that, in principle, it is even more likely that there should not be an issue as far as competition for sites with thermal power plants with CCS is concerned.

4.8.8. Conclusions for Potential Capacity at Existing Nuclear Sites Sensitivity Analysis

If mitigation / compensatory measures are accepted for three of the four initial extensions to nuclear licensed sites that were carried forward from the existing UK nuclear licensed sites sensitivity analysis, the results for the potential maximum additional nuclear power plant generating capacity for new deployment next to existing nuclear power plants in England and Wales before 2050 now amounts to a total of 23.65 GW_e. If mitigation / compensatory measures are accepted for the fourth initial extension to a nuclear licensed site that was carried forward, two site extensions now pass the potential capacity at existing UK nuclear licensed sites sensitivity analysis for 300 MW_e units. This now provides a total of 3.0 GW_e of 300 MW_e units. In conjunction with the capacity for large units listed here, this increases the potential maximum additional nuclear power plant electricity generating capacity for new deployment next to existing nuclear power plants in England and Wales before 2050 to a total of 26.65 GW_e.

4.8.9. Conclusions for Deployment of New Nuclear Power Plants at More than 2.5 GW_e to 3.5 GW_e per Site Sensitivity Analysis

If mitigation / compensatory measures are accepted for six of the seven further extensions to nuclear licensed sites which were carried forward from the more than 2.5 GW_e to 3.5 GW_e per site sensitivity analysis, the results for the potential maximum additional nuclear power plant generating capacity for new deployment beyond twin large units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) before 2050 now amounts to a total of 19.8 GW_e. If mitigation / compensatory measures are accepted for the seventh further extension to a nuclear licensed site which was carried forward, this extension now passes the sensitivity analysis for 300 MW_e units. This now provides a total of 1.5 GW_e of 300 MW_e units. In conjunction with the capacity for large units listed here, this increases the potential maximum additional nuclear power plant electricity generating capacity for new deployment beyond twin large units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear power plants in England and Wales before 2050 to a total of 21.3 GW_e.

4.9. Two River Catchments Sensitivity Analysis

4.9.1. Objective

The objective of the two river catchments sensitivity analysis was to reappraise the cooling water availability in two river catchments using a methodology that involves less conservatism and thereby reassess whether the sites on the long list in these two river catchments could be considered for nuclear power generation. These sites included the five brownfield sites that passed the cooling water sensitivity analysis.

It should be recognised that cooling water requirements for nuclear power plants are very different from those for thermal power plants. A full consideration of cooling water requirements under extremes of drought or temperature will be addressed as part of the regulatory requirements leading up to award of a Nuclear Site Licence and the other licences and approvals required to allow the power plant to operate. Such a consideration is beyond the scope of this project.

4.9.2. Introduction

In the cooling water sensitivity analysis, which is presented in Section 4.3, five brownfield sites passed the stage 2 assessment. Four of these passed for a single 1,400 MW_e unit and the fifth passed for a single 1,650 MW_e unit. Some of the sites are related by river network. It was determined that, within the conservatism of the approach for assessing cooling water availability for rivers, the overall capacity would be limited to a single 1,400 MW_e unit and a single 1,650 MW_e unit. Therefore the indicative maximum capacity for new nuclear deployment at these two brownfield sites by 2050 was determined to be 3.05 GW_e. This indicative maximum capacity is likely to be an underestimate for the reasons described in Section 4.3.3. The cooling water availability in the two river catchments on which these sites are located was reappraised using a revised methodology. The revised methodology involved the use of the Environment Agency's Water Resources GIS to assess the availability of cooling water for rivers. The Water Resources GIS was not available for use in the project until this stage.

4.9.3. Assessment Methodology and Assessment Approach

The 30 brownfield sites on the long list that are located 2 km or less from the rivers in the two river catchments were assessed for direct and indirect cooling for 1,650 MW_e, 1,400 MW_e and 1,150 MW_e single units. The assessment methodologies for all criteria other than criterion D10 - access to suitable sources of cooling water were the same as those used for rivers in the cooling water sensitivity analysis. In line with the use of the Water Resources GIS, the methodology for criterion D10 was the same as that used for rivers in the cooling water sensitivity analysis with two exceptions. The first of these was that flows were based on recent actual flows in rivers. The second was that allowable abstractions for cooling water were based on the allowable percentages of the natural flows for rivers.

4.9.4. Results

Nine brownfield sites passed the stage 2 assessment for single 1,650 units with indirect cooling. These sites are related by river network. It was determined that an overall capacity of nine 1,650 MW_e units was possible, making a total of 14.85 GW_e. This total capacity is comparable with the established total capacity for thermal generation in the two river catchments and the planned total capacity.

4.9.5. Conclusions

Nine brownfield sites passed the two rivers catchments sensitivity analysis, each being suitable for a single 1,650 MW_e unit with indirect cooling. Once allowance was made for sites that are linked by river network, it was determined that it is possible to have a single 1,650 MW_e unit at each of these sites. Therefore the potential maximum capacity for new nuclear deployment at these brownfield sites by 2050 is 14.85 GW_e. This potential maximum capacity is comparable with the established and planned total capacity for thermal generation in the two river catchments.

4.10. Reappraisal of Long List to Support Heat Demand Networks Sensitivity Analyses

4.10.1. Objective

The objective of the reappraisal of the long list was to support the heat demand networks sensitivity analyses. This was by identifying brownfield and greenfield sites on the long list that are suitable for, or are likely to be feasible for 300 MW_e units and could help satisfy the heat demand networks. In addition, the work considered whether the extensions to nuclear licensed sites in England and Wales derived in the existing UK nuclear licensed sites sensitivity analysis and the more than 2.5 GW_e to 3.5 GW_e per site sensitivity analysis are suitable for, or are likely to be feasible for 300 MW_e units and could thus help satisfy the heat demand networks.

4.10.2. Background

The heat demand networks were identified in the System Requirements for Alternative Nuclear Technologies project and relate to the larger urban areas of England and Wales. A total of 44 heat demand networks were considered in this project. These were all the heat demand networks in England and Wales. A maximum distance of 30 km from a heat demand network was used in the work. Heat loss and pumping power requirement over this distance were determined to be relatively small. It should however be remembered that the feasibility of transporting heat over 30 km needs to be demonstrated for each individual case.

4.10.3. Reappraisal of Brownfield and Greenfield Sites on Long List

Assessment Methodology and Assessment Approach

The brownfield and greenfield sites on the long list that were considered for reappraisal were sites that:

- passed the baseline assessment;
- failed stage 1 of the baseline assessment on criterion E4 - size of site;
- passed the cooling water sensitivity analysis;
- failed stage 1 of the cooling water sensitivity analysis on criterion E4;
- failed stage 1 of the cooling water sensitivity analysis on criterion E5 - access to sources of cooling water; and
- failed stage 2 of the cooling water sensitivity analysis on criterion D10 - access to suitable sources of cooling water.

The two greenfield sites discussed in Section 5.2.1 were excluded, so that a total of 63 sites were taken forward for reappraisal. Once sites that are greater than 30 km from a heat demand network were dismissed, 56 sites remained.

Revised criteria, where necessary, were used in the assessments. Therefore for criterion E4 - size of site, an area for the size of site for each 300 MW_e unit employing direct or indirect cooling of 0.15 km^2 was used. For criterion E5 - access to sources of cooling water, sites that are more than 20 km from the coast or estuaries, or more than 20 km from a river were excluded. It should however be remembered that the feasibility of transporting water over 20 km needs to be demonstrated for each individual case.

In the stage 2 assessment, for all criteria other than criterion D10 - access to suitable sources of cooling water, the sites were described as 'likely to be feasible' or 'not likely to be feasible'. This was instead of sites passing or failing the assessment and was because some of the methodologies employed for assessing criteria D1 to D9 were less detailed than those that had previously been used in the project. The reason for this was that the reappraisal addressed a greater number of sites with an accompanying reduction in the level of certainty associated with the results of the assessments. For criterion D10 the approach of passing or failing sites was preserved. Criterion D9 - size of site to accommodate operations was relaxed so that the presence of existing development and major waterbodies between the site and the source of cooling water was not taken into account. For sites with the coast or an estuary as the source of cooling water the assessment methodology for criterion D10 as described in Section 4.1.3 was revised to address 300 MW_e units using direct or indirect cooling. For sites with a river as the source of cooling water the assessment methodology for criterion D10 as described in Section 4.9.3 was revised to address 300 MW_e units using direct or indirect cooling.

Results

Ten brownfield sites passed the stage 2 assessment. The number of 300 MW_e units at each of these sites ranged from six to more than 10. If mitigation / compensatory measures are accepted, one further brownfield site and one greenfield site pass the stage 2 assessment. The number of 300 MW_e units at each of these sites was more than 10. For three brownfield sites and three greenfield sites, the results for the stage 2 assessment were that the sites were likely to be feasible. The number of 300 MW_e units at each of these sites ranged from one to more than nine. If mitigation / compensatory measures are accepted, one further brownfield site is likely to be feasible. The number of 300 MW_e units at this site was four. This provided a total of 19 sites on the long list that could help satisfy the heat demand networks.

4.10.4. Reappraisal of Initial Extensions to Nuclear Licensed Sites

Assessment Methodology and Assessment Approach

Extensions to nuclear licensed sites that were addressed in the existing UK nuclear licensed sites sensitivity analysis were considered for reappraisal, apart from one which was excluded. This was because this nuclear licensed site is already being developed as a business park. Once extensions that are greater than 30 km from a heat demand network were dismissed, five extensions remained. The assessment methodologies for criteria E4 - size of site and E5 - access to sources of cooling water, were as described in Section 4.10.3. The source of cooling water for all extensions was the coast or an estuary. Therefore the assessment methodology for criterion D10 - access to suitable sources of cooling water was as described in Section 4.10.3. For four of the extensions, the information from the ecological designations sensitivity analysis was carried forward to this reappraisal.

Results

One extension passed the stage 2 assessment and a further four pass if mitigation / compensatory measures are accepted. The number of 300 MW_e units at the extensions ranged from five to 10. These five initial extensions to nuclear licensed sites could help satisfy the heat demand networks.

4.10.5. Reappraisal of Further Extensions to Nuclear Licensed Sites

Assessment Methodology and Assessment Approach

Extensions to nuclear licensed sites that were addressed in the more than 2.5 GW_e to 3.5 GW_e per site sensitivity analysis were considered for reappraisal, apart from one extension. This was because the full area of this extension was considered in the reappraisal of the initial extensions to nuclear licensed sites. Once extensions that are greater than 30 km from a heat demand network were dismissed, nine extensions remained. The assessment methodologies for criteria E4 - size of site and E5 - access to sources of cooling water, were as described in Section 4.10.3. The source of cooling water for all extensions was the coast or an estuary. Therefore the assessment methodology for criterion D10 - access to suitable sources of cooling water was as described in Section 4.10.3. For six of the extensions, the information from the ecological designations sensitivity analysis was also carried forward to this reappraisal.

Results

Six further extensions to nuclear licensed sites pass the stage 2 assessment if mitigation / compensatory measures are accepted. The number of 300 MW_e units at the extensions ranged from four to nine. These six further extensions to nuclear licensed sites could help satisfy the heat demand networks.

4.10.6. Additional Studies for Brownfield and Greenfield Sites that Could Help Satisfy Heat Demand Networks

As part of the work to reappraise the long list, three additional studies were carried out. The purpose of the studies was the determination of the site challenges, in addition to access to suitable sources of cooling water, at the 19 brownfield and greenfield sites on the long list that could help satisfy the heat demand networks. These studies addressed the following topics:

- indicative access for AILs to the sites;
- a very high level analysis of two major ground constraints at the sites; and
- a very high level assessment of the scale of flood defence works potentially required to manage flood risk safely at the sites.

4.10.7. Conclusions

Nineteen brownfield and greenfield sites on the long list could help satisfy the heat demand networks. None of these sites falls into the indicative difficult category for access for AILs. The results from the consideration of the two major ground constraints indicate that none of the sites falls into the major category for landslides and underground cavities. Nine sites fall into the most challenging category for the scale of flood defence works potentially required to manage flood risk safely at the sites.

One initial extension to a nuclear licensed site could help satisfy the heat demand networks. Four initial extensions could also help satisfy the heat demand networks if mitigation / compensatory measures are accepted. If mitigation / compensatory measures are accepted, six further extensions could help satisfy the heat demand networks.

4.11. Identification of Additional Sites to Support Heat Demand Networks Sensitivity Analyses

4.11.1. Objective

The objective of the identification of additional sites was to support the heat demand networks sensitivity analyses by selecting and assessing 44 additional sites for 300 MW_e units that could help satisfy one or more of the heat demand networks. The sites could have the coast or an estuary, or a river as the source of cooling water. The work had an additional objective of identifying sufficient sites to help satisfy the heat demand networks twice over. These sites were for use in the heat demand networks twice over sensitivity analysis.

4.11.2. Assessment Methodology and Assessment Approach

The starting point for the assessment was the whole of England and Wales apart from land that is greater than 30 km from the boundary of any heat demand network. This amounted to a substantial part of England and Wales. Forty four additional sites were selected for consideration by the experts. This was the number of additional sites specified as the maximum number for assessment in the work. Revised assessment methodologies for criteria, where necessary, were used in the assessments. Criterion E4 - size of site was applied at the site selection stage, using an area of 0.15 km^2 as the size of site for each of the 300 MW_e units employing direct or indirect cooling. To apply criterion E5 - access to sources of cooling water, areas of land that were more than 20 km from the coast or an estuary or more than 20 km from a river were excluded.

In the stage 2 assessment, for all criteria other than criterion D10 - access to suitable sources of cooling water, the sites were described as ‘likely to be feasible’ or ‘not likely to be feasible’. This was because some of the methodologies employed for assessing criteria D1 to D9 were less detailed than those that had previously been used in the project. The reason for this was that the reappraisal addressed a greater

number of sites with an accompanying reduction in the level of certainty associated with the results of the assessments. For criterion D10 the approach of passing or failing sites was preserved. Criterion D9 - size of site to accommodate operations, was relaxed so that the presence of existing development and major waterbodies between the site and the source of cooling water was not taken into account. The methodologies for criterion D10 were as described in Section 4.10.3.

4.11.3. Results

Thirty one of the additional sites are likely to be feasible. For these additional sites the capacity for 300 MW_e units ranged from one unit using indirect cooling to 11 units using indirect cooling. It should however be remembered that the feasibility of transporting water over 20 km needs to be demonstrated for each individual case. For 13 of these 31 additional sites the coast or estuary was the source of cooling water. For the remaining 18 additional sites the source of cooling water was a river. Seventeen of the 31 additional sites have a source of cooling water that is independent of all other waterbodies providing cooling water for the other sites, regions or extensions to nuclear licensed sites considered in the project (including any of the other 16 additional sites amongst these 17 and the 14 other additional sites that are likely to be feasible).

4.11.4. Additional Studies

As part of the identification of additional sites, three additional studies were carried out. The purpose of the studies was the determination of the site challenges at the 31 additional sites that are likely to be feasible plus 21 of the regions identified in alternative smaller plants sensitivity analysis that could help satisfy the heat demand networks (because they are located 30 km or less from a heat demand network). These site challenges are in addition to access to suitable sources of cooling water. The studies addressed the following topics:

- indicative access for AILs to the additional sites or regions;
- a very high level analysis of two major ground constraints at the additional sites or regions; and
- a very high level assessment of the scale of flood defence works potentially required to manage flood risk safely at the additional sites or regions.

4.11.5. Conclusions

Thirty one of the additional sites were likely to be feasible. For these sites the capacity for 300 MW_e units ranged from one unit using indirect cooling to 11 units using indirect cooling. This result was based on the consideration of 44 additional sites (which was the number of additional sites that had been specified as the maximum number for assessment in the work). The total capacity that is likely to be feasible for the 17 additional sites with independent sources of cooling water from all of the other sites, regions or extensions to nuclear licensed sites that have been considered in the project (including any of the other 16 additional sites amongst these 17 and the 14 other additional sites that are likely to be feasible) is sixty two 300 MW_e units which equals 18.6 GW_e.

None of the 31 additional sites that could help satisfy the heat demand networks falls into the indicative difficult category for access for AILs. One of the 21 regions that could help satisfy the heat demand networks falls into the indicative difficult category for access for AILs. The results from the consideration of the two major ground constraints indicate that none of the 31 additional sites or 21 regions falls into the major category for landslides and underground cavities. One of the additional sites and 12 of the regions fall into the most challenging category for the scale of flood defence works potentially required to manage flood risk safely at the additional sites or regions.

4.12. Heat Demand Networks Twice Over Sensitivity Analysis

4.12.1. Objective

The objective of the heat demand networks twice over sensitivity analysis was to determine whether it was possible to satisfy twice over the heat demand networks using the sites and regions that are suitable for, or are likely to be feasible for 300 MW_e units. The reason for considering whether the heat demand networks could be satisfied twice over was in order to make allowance for the fact that not all of the sites identified for 300 MW_e units are likely to be developed. The heat demand for each of the identified heat demand networks was obtained from the System Requirements for Alternative Nuclear Technologies project[1].

4.12.2. Assessment Methodology and Assessment Approach

The following groups of sites and regions that are suitable for, or are likely to be feasible for 300 MW_e units were considered in the sensitivity analysis:

- extensions to nuclear licensed sites;
- brownfield and greenfield sites on the long list;
- regions from the alternative smaller plants sensitivity analysis; and
- additional sites.

A site selection model to optimise the allocation of 300 MW_e units to the heat demand networks was applied in the sensitivity analysis according to a set of constraints. These constraints included the following:

- the heat demand for each heat demand network must be satisfied twice over from at least two separate sites or regions, except where the heat demand is being met by extensions to nuclear licensed sites which were included in the NPS for Nuclear Power Generation (EN-6), in which case once over applied;
- the centre point of the site or region must be located a maximum of 30 km from the boundary of a heat demand network;
- the centre point of the site or region must preferably be located a maximum of 20 km from the source of cooling water;
- cooling water for a site or region can come from only one source;
- heat from a site or region can be distributed between one or more heat demand networks;
- the presence of existing development and major waterbodies between the site or region and the source of cooling water must not be considered to be a barrier, as it is assumed that cooling water can be transported under (or over) these;
- the presence of existing development and major waterbodies between the site or region and the heat demand network(s) must not be considered to be a barrier, as it is assumed that hot water can be transported under (or over) these;
- sufficient cooling water in conjunction must be available for the sites and regions allocated to the heat demand networks;
- the two greenfield sites that are discussed in Section 5.2.1 must be excluded; and
- application of a specified order for the allocation of the above listed groups of sites and regions to the heat demand networks.

For sites and regions with a river as the source of cooling water, the assessment methodology for criterion D10 - access to suitable sources of cooling water, as described in Section 4.9.3, was revised to address 300 MW_e units with direct or indirect cooling.

The site selection optimisation model that was developed sought to maximise the heat supplied to the heat demand networks whilst maintaining the constraints on cooling water, including conjunctive capacity. The use of the optimisation model involved an iterative approach for working through the above listed groups of sites and regions in the specified order.

4.12.3. Results

Owing to demand being met by extensions to nuclear licensed sites which were included in the NPS for Nuclear Power Generation (EN-6), the heat demands for six heat demand networks were met once over. The heat demands for all other heat demand networks were met twice over, apart from one where the demand was met only once over. It should however be remembered that the feasibility of transporting water over 20 km needs to be demonstrated for each individual case.

4.12.4. Conclusions

It was possible to satisfy twice over the heat demand networks, allowing for the heat demands for six of the heat demand networks being met by extensions to nuclear licensed sites that were included in the NPS for Nuclear Power Generation (EN-6). Only one heat demand network was an exception to this, where the heat demand was met only once over.

4.13. Heat Demand Networks Once Over Sensitivity Analysis

4.13.1. Objective

The objective of the heat demand networks once over sensitivity analysis was to determine whether it was possible to satisfy once over the heat demand networks in conjunction with a significant programme of development of 1,650 MW_e, 1,400 MW_e and 1,150 MW_e units for baseload electricity. Decreasing the requirement to satisfying the heat demand networks only once over allowed consideration of whether a significant programme of development of 1,650 MW_e, 1,400 MW_e and 1,150 MW_e units could be achieved at the same time as satisfying the heat demand networks.

4.13.2. Assessment Methodology and Assessment Approach

The following groups of sites that are suitable for 1,650 MW_e, 1,400 MW_e or 1,150 MW_e units were considered in the sensitivity analysis:

- brownfield and greenfield sites on the long list; and
- extensions to nuclear licensed sites.

The following groups of sites and regions that are suitable for, or are likely to be feasible for 300 MW_e units were also considered in the sensitivity analysis:

- brownfield and greenfield sites on the long list that are not suitable for 1,650 MW_e, 1,400 MW_e or 1,150 MW_e units;
- regions from the alternative smaller plants sensitivity analysis;
- extensions to nuclear licensed sites that are not suitable for 1,650 MW_e, 1,400 MW_e or 1,150 MW_e units; and
- additional sites.

The sensitivity analysis first addressed satisfying the heat demand networks once over using 300 MW_e units. This requires 21.3 GW_e of capacity. The following constraints were applied within the site selection model to optimise the allocation of sites and regions to the heat demand networks:

- the heat demand for each heat demand network must be satisfied once over using one or more sites for each network;
- the centre point of the site or region must be located a maximum of 30 km from the boundary of a heat demand network;
- the centre point of the site or region must preferably be located a maximum of 20 km from the source of cooling water;
- cooling water for a site or region can come from only one source;
- heat from a site or region can be distributed between one or more heat demand networks;
- sufficient cooling water in conjunction must be available for the sites and regions allocated to the heat demand networks;
- the two greenfield sites discussed in Section 5.2.1 must be excluded;
- the three brownfield sites discussed in Section 5.2.1 must be reserved for thermal power plants with CCS and the associated cooling water requirements for these sites must be considered prior to the cooling water requirements of any other site or region;

- the three extensions to nuclear licensed sites discussed in Section 5.2.1 must be reserved for Gen IV plants and were therefore removed from consideration in the sensitivity analysis;
- the presence of existing development and major waterbodies between the site or region and the source of cooling water must not be considered to be a barrier, as it is assumed that cooling water can be transported under (or over) these;
- the presence of existing development and major waterbodies between the site or region and the heat demand network(s) must not be considered to be a barrier, as it is assumed that hot water can be transported under (or over) these; and
- application of a specified order for the allocation of the above listed groups of sites and regions to the heat demand networks.

For sites and regions used for 300 MW_e units with a river as the source of cooling water, the assessment methodology for criterion D10 - access to suitable sources of cooling water as described in Section 4.9.3 was revised to address 300 MW_e units using direct or indirect cooling. For sites used for 1,650 MW_e, 1,400 MW_e or 1,150 MW_e units with a river as the source of cooling water, the assessment methodology for criterion D10 was as described in Section 4.9.3.

The optimisation model that was developed in the heat demand networks twice over sensitivity analysis was used in this sensitivity analysis. Once satisfying the heat demand networks once over had been addressed, the remaining possible capacity for new nuclear power plants was identified and maximised based on the remaining availability of cooling water. To do this, groups of sites were considered in the order laid out below. Throughout this process, where necessary, allowance was made for conjunctive cooling water use with the sites required to satisfy the heat demand networks once over and the groups of sites from the list below as they were incorporated into the process.

The order for consideration of the groups of sites was as follows:

- the remaining extensions to nuclear licensed sites and remaining sites that are suitable for 1,650 MW_e, 1,400 MW_e or 1,150 MW_e units;
- the remaining sites that are not suitable for 1,650 MW_e, 1,400 MW_e or 1,150 MW_e units but are suitable for, or are likely to be feasible for 300 MW_e units that could help satisfy the heat demand networks but are not required to satisfy the networks; and
- the remaining extensions to nuclear licensed sites and regions that are not suitable for 1,650 MW_e, 1,400 MW_e or 1,150 MW_e units but are suitable for 300 MW_e units that cannot help satisfy the heat demand networks.

4.13.3. Results

Heat demands for all heat demand networks were met once over. It should however be remembered that the feasibility of transporting water over 20 km needs to be demonstrated for each individual case. A total conjunctive capacity of 58.8 GW_e was obtained with an additional conjunctive capacity that is likely to be feasible of 39.0 GW_e.

4.13.4. Conclusions

It was possible to satisfy the heat demand networks once over in conjunction with a significant programme of development of 1,650 MW_e, 1,400 MW_e and 1,150 MW_e units for baseload electricity. The total conjunctive capacity was 58.8 GW_e with an additional conjunctive capacity that is likely to be feasible of 39.0 GW_e, of which 21.3 GW_e satisfied the heat demand networks once over.

4.14. Other Opportunities

4.14.1. Objective

The objective of the consideration of other opportunities was to identify other areas of opportunity which may arise to contribute to the group of potential sites for new nuclear power plants. The work focused on defence sites which fall within the MOD Estate and / or are regulated by the ONR.

4.14.2. Methodology

The first step in the methodology involved examination of the MOD Estate subject to the rationalisation / divestment programme and assessment of whether the MOD sites being rationalised / divested could contribute to the group of potential sites for new nuclear power plants. The second step involved assessment of the rest of the MOD Estate with a view to identifying potentially suitable sites for further assessment at a later date. The sites addressed in these two steps were assessed using the majority of the stage 1 assessment methodology, that is, they had to pass criterion E1 - demographics, criterion E2 - exclusionary military activities, criterion E3 - within an internationally designated ecological site and criterion E5 - access to sources of cooling water. The third step in the methodology involved reviewing defence sites already regulated by the ONR. The fourth step involved evaluation of the MOD sites that were excluded on criterion E5 and sites from the long list that were excluded from the cooling water sensitivity analysis on criterion D10 - access to suitable sources of cooling water. These sites could be worthy of consideration subject to new technologies, such as air cooling.

4.14.3. Results of Assessment of MOD Estate

Two MOD sites in England and Wales scheduled for disposal passed all four exclusionary criteria. These sites are located 2 km or less from the coast or estuaries. It should be noted that none of the sites on the long list failed the baseline assessment or the cooling water sensitivity analysis because of safeguarding zones associated with the MOD sites being divested.

Thirty eight aerodromes / airfields in England and Wales passed all four exclusionary criteria. Seven of the 38 sites are located 2 km or less from the coast or estuaries. An additional two sites in England and Wales failed solely on criterion E5 - access to sources of cooling water. Fifty four sites in the training estate in England and Wales passed all four exclusionary criteria. Eleven of the 54 sites are located 2 km or less from the coast or estuaries. An additional 11 sites in England and Wales failed solely on criterion E5. Only 11 technical sites / naval facilities in England and Wales passed all four exclusionary criteria (together with one storage and supply depot). Six of the technical sites / naval facilities are located 2 km or less from the coast or estuaries. An additional two sites in England and Wales failed solely on criterion E5.

Amongst current MOD nuclear licensed sites that are regulated by the ONR, only two sites in England and Wales may be worthy of further consideration as the location for a nuclear power plant. These sites would be subject to the acceptability of alternative cooling technologies, such as air cooling.

4.14.4. Results for Alternative Cooling Technologies

In the assessment of the rest of the MOD Estate, 15 sites in England and Wales were identified as meeting criterion E1 - demographics, criterion E2 - exclusionary military activities, and criterion E3 - within an internationally designated ecological site, but failing on criterion E5 - access to sources of cooling water, i.e. having no access to a source of cooling water. These are all candidates to be revisited to consider the utilisation of alternative cooling technologies, such as air cooling. In the baseline assessment, the sites that were more than 2 km from the coast and estuaries (i.e. inland sites) failed on criterion E5, but these sites were considered in the cooling water sensitivity analysis. Of these 109 sites, one was discounted on application of criterion E5. In the stage 2 assessment, application of criterion D10 - access to suitable sources of cooling water led to the failure of 15 sites. The one site that failed on criterion E5 and these 15 sites are candidates to be revisited to consider the utilisation of alternative cooling technologies, such as air cooling.

4.14.5. Conclusions

Two of the MOD sites scheduled for disposal passed all four exclusionary criteria and could possibly contribute to the group of potential sites for new nuclear power plant development in England and Wales. As 38 aerodromes / airfields and 54 sites in the training estate in England and Wales passed all four exclusionary criteria, these two groups of sites are considered to be first priority sites and should be afforded continued consideration. Eleven technical sites / naval facilities in England and Wales passed all four exclusionary criteria, together with one storage and supply depot. Therefore this group of sites is considered as second priority and should be afforded less consideration. Two MOD nuclear licensed sites in England and Wales already regulated by the ONR may be worthy of further consideration to locate a nuclear power plant, subject to the acceptability of alternative cooling technologies, such as air cooling. There are 15 MOD sites in England and Wales and 16 sites from the long list that are candidates to be revisited as potential sites to locate nuclear power plants based on alternative cooling technologies.

4.15. Preferred Locations for Technology Demonstrator Sites

4.15.1. Objective

The objective of the work on preferred locations for technology demonstrator sites was to consider from a siting perspective the potential preferred location(s) for demonstrators for one or more SMRs and a large Gen IV 1,200 MW_e sodium cooled fast breeder reactor. Technology demonstrator sites are used to demonstrate the use of a new technology to interested parties.

4.15.2. Introduction and Criteria

Historically, the United Kingdom Atomic Energy Authority (UKAEA) developed technology demonstrators at four of the existing nuclear licensed sites. Three of these nuclear licensed sites are in England and Wales. Only one of these three sites was included in the study. The other two nuclear licensed sites were excluded because it was considered that the future of these sites is as business parks rather than as sites for nuclear power plants. Of the remaining existing nuclear licensed sites in England and Wales, two were excluded from the study. These two nuclear licensed sites failed the baseline assessment; one had failed on criterion E2 - exclusionary military activities and the other on criterion D1 - demographics. The nuclear licensed sites that were included in the study were ranked based on the results of the application of a set of criteria. In the majority of cases the existing nuclear licensed sites themselves were considered in the study. In the other cases, extensions to the nuclear licensed sites or the combination of the nuclear licensed site plus part of an extension were considered.

Four criteria were employed in the study and the sites were assessed against these criteria in the order presented below. Sites that failed against a criterion were not carried forward for consideration against the remaining criteria. The criteria were as follows:

- history of demonstrators at the site;
- remoteness of the site;
- access to suitable sources of cooling water; and
- availability of required land at the site.

4.15.3. Results

The results demonstrated that seven nuclear licensed sites are possible locations for SMR demonstrators. Only one site (the nuclear licensed site that has a history of demonstrators) met the requirements for a large demonstrator site and is therefore proposed as the most likely location for a demonstrator for a large Gen IV plant. The timing for building the SMR demonstrator was taken to be between 2020 and 2025. Consideration was given to whether each of the seven nuclear licensed sites could meet this timescale, by considering the timescale for decommissioning at each of the sites. Only five of the seven nuclear licensed sites could meet this timescale. These five nuclear licensed sites are possible locations for SMR demonstrators.

4.15.4. Conclusions

Based on the four criteria employed in the study and the timing of between 2020 and 2025 for building the SMR demonstrator, five existing nuclear licensed sites are the most likely locations for siting SMR demonstrator plants. In addition, only one existing nuclear licensed site is a possible location for a large Gen IV plant demonstrator.

5. Outcomes of the Sensitivity Analyses

5.1. Objective

The objective of the summary of outcomes from the sensitivity analyses was the effective collation and evaluation of the results of the sensitivity analyses and the other studies considered in the project, and the provision of answers to the questions addressed by the project as listed in Section 2.3. These answers are shown in bold type in this section. The secondary objective was to assist with the determination of the following:

- pathway options for realising sufficient sites for the deployment of 75 GW_e of new nuclear by 2050; and
- pathway options for realising sufficient sites for the deployment of 75 GW_e of new nuclear by 2050 whilst satisfying the heat demand networks once over.

5.2. Overview of Baseline Assessment, Sensitivity Analyses and Supporting Work

5.2.1. Exclusion of Two Greenfield Sites, and Reservation of Three Brownfield Sites and Three Extensions to Nuclear Licensed Sites

The one greenfield site that passed the baseline assessment is situated on the east coast of England. Coastal erosion in the vicinity of this site is complex and as a result of these complexities it is considered highly unlikely that the site would in fact be developed for a new nuclear power plant. Hence this greenfield site was excluded from the greenfield sites for allocation of new nuclear power plants as described in Section 4.8.5.

One other greenfield site needed further consideration. This site is located on the same estuary as some of the extensions to the nuclear licensed sites. Given the choice of siting new nuclear power plants on an extension to a nuclear licensed site or on a greenfield site that is close by, it is considered that the former approach would be viewed as preferable. Therefore this greenfield site was also excluded from the greenfield sites for allocation of new nuclear power plants as described in Section 4.8.5.

Amongst the sites that were not explicitly included in the large thermal plant with CCS sensitivity analysis are inland sites. It is likely that some of the inland sites will be used for thermal power plants with CCS. To take account of this, three inland brownfield sites were reserved for large thermal power plants with CCS. Therefore these three brownfield sites were removed from consideration for new nuclear power plants in the project. The use of inland sites for thermal power plants with CCS will bring the additional challenge of the requirement to transport carbon dioxide across land. However, as the identification of an inland site for inclusion in the Department of Energy and Climate Change's CCS commercialisation programme demonstrates, it is reasonable to consider inland sites for future deployment of thermal power plants with CCS.

A programme of development of Gen IV plants will not be able to be established unless there are sites available for these plants. To allow for this, three extensions to nuclear licensed sites were reserved for Gen IV plants. Therefore these three extensions to nuclear licensed sites were removed for consideration for new nuclear power plants in the project.

The results obtained from the project are provided in the following sections, taking account of the exclusion and reservation of the sites discussed above. The assumed development dates (2030, 2040 or 2050) for the new nuclear power plants are also included in these sections. These dates were derived by applying judgement to describe the sequence in which sites are developed and are considered to be illustrative.

5.2.2. Results for Baseline Assessment and Cooling Water Sensitivity Analysis as Modified by Two River Catchments Sensitivity Analysis

The results of the two river catchments sensitivity analysis modified the results for brownfield sites for the baseline assessment and the cooling water sensitivity analysis that are shown in Section 4.8.5.

If mitigation / compensatory measures are accepted, there is now only one greenfield site which could be considered for nuclear power development and the potential maximum capacity for new nuclear deployment at this greenfield site by 2050 is 3.3 GW_e (assumed development date of 2050).

The results for brownfield sites change from those shown in Section 4.9.5. There are now six brownfield sites which could be considered for nuclear power development and the potential maximum capacity for new nuclear deployment at these brownfield sites by 2050 is 9.9 GW_e (assumed development date of 2040).

5.2.3. Results for Additional Site Capacity from Introducing Alternative Smaller Plants sensitivity Analysis

The current indicative capacity for development of 300 MW_e units in brownfield and greenfield regions by 2050 remains unchanged from that shown in Section 4.8.6 at twenty eight 300 MW_e units (14 with an assumed development date of 2040 and the remaining 14 with an assumed development date of 2050), which provides a total of 8.4 GW_e.

5.2.4. Results for Siting Requirements, Criteria and Site Availability for Large Thermal Plant with CCS Sensitivity Analysis

The exclusion and reservation of the sites discussed in Section 5.2.1 do not change the conclusion that, in principle, there should not be an issue for nuclear power plants as far as competition for sites with thermal power plants with CCS is concerned.

5.2.5. Results for Potential Capacity at Existing UK Nuclear Licensed Sites Sensitivity Analysis

If mitigation / compensatory measures are accepted for three of the five initial extensions to nuclear licensed sites, the results for the potential maximum additional nuclear power plant generating capacity for new deployment next to existing nuclear licensed sites in England and Wales before 2050 remain unchanged from those shown in Section 4.8.8. Therefore they still provide a total of 23.65 GW_e (15.4 GW_e with an assumed development date of 2030 and the remaining 8.25 GW_e with an assumed development date of 2040).

If mitigation / compensatory measures are accepted for a fourth of the five initial extensions, the results for 300 MW_e units remain unchanged from those shown in Section 4.8.8. Therefore they still provide a total of 3.0 GW_e of 300 MW_e units (assumed development date of 2040).

5.2.6. Results for Deployment of New Nuclear Power Plants at More than 2.5 GW_e to 3.5 GW_e per Site Sensitivity Analysis

If mitigation / compensatory measures are accepted for four of the six further extensions to nuclear licensed sites, the results for the potential maximum additional nuclear power plant generating capacity for new deployment beyond twin large units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear licensed sites in England and Wales before 2050 change from those shown in Section 4.8.9. They now provide a total of 14.85 GW_e (6.6 GW_e with an assumed development date of 2040 and the remaining 8.25 GW_e with an assumed development date of 2050).

If mitigation / compensatory measures are accepted for a fifth of the six further extensions, the result for 300 MW_e units remains unchanged from that shown in Section 4.8.9. Therefore this extension still provides a total of 1.5 GW_e of 300 MW_e units (assumed development date of 2050).

5.2.7. Reappraisal of Long List to Support Heat Demand Networks Sensitivity Analyses

Brownfield and Greenfield Sites

As a result of the reservation of the sites discussed in Section 5.2.1, the results for the reappraisal of the brownfield and greenfield sites on the long list change from those shown in Section 4.10.3 to be as follows:

- seven brownfield sites now pass the stage 2 assessment. The number of 300 MW_e units at each of these sites ranged from six to more than 10 (assumed development date of 2040);
- if mitigation / compensatory measures are accepted, one further brownfield site and one greenfield site still pass the stage 2 assessment. The number of 300 MW_e units at each of these sites was more than 10 (assumed development date of 2040);
- three brownfield sites and three greenfield sites are still likely to be feasible. The number of 300 MW_e units at each of these sites ranged from one to more than nine (assumed development date for the brownfield sites of 2040 and assumed development date for the greenfield sites of 2050); and
- if mitigation / compensatory measures are accepted, one further brownfield site is still likely to be feasible. The number of 300 MW_e units at this site was four (assumed development date of 2040).

This now provides a total of 16 sites on the long list that could help satisfy the heat demand networks.

Initial Extensions to Nuclear Licensed Sites

The reservation of the sites discussed in Section 5.2.1 does not change the results for the reappraisal of the initial extensions to nuclear licensed sites from those shown in Section 4.10.4. The results remain that one extension passed the stage 2 assessment and a further four pass if mitigation / compensatory measures are accepted. The number of 300 MW_e units at the extensions ranged from five to ten. These five initial extensions to nuclear licensed sites could still help satisfy the heat demand networks.

One of these five initial extensions to nuclear licensed sites failed the more than 2.5 GW_e to 3.5 GW_e per site sensitivity analysis. The coast was the source of cooling water for this initial extension. This source of cooling water is independent of all the other waterbodies providing cooling water for all the other sites, regions and extensions to nuclear licensed sites that were considered in the project.

Therefore an extra 2.1 GW_e at this initial extension to a nuclear licensed site can be added to the total generating capacity for 300 MW_e units listed in Section 5.2.5.

Further Extensions to Nuclear Licensed Sites

As a result of the reservation of the sites discussed in Section 5.2.1, the results for the reappraisal of the further extensions to existing nuclear licensed sites change from those shown in Section 4.10.5 to be as follows:

- four further extensions to nuclear licensed sites pass the stage 2 assessment if mitigation / compensatory measures are accepted. The number of 300 MW_e units at the extensions ranged from four to nine.

These four further extensions to nuclear licensed sites could still help satisfy the heat demand networks.

5.2.8. Identification of Additional Sites to Support Heat Demand Networks Sensitivity Analyses

The reservation of the sites discussed in Section 5.2.1 does not change the results for the identification of additional sites from those shown in Section 4.11.3. Thirty one of the additional sites are still likely to be feasible. For these sites the capacity for 300 MW_e units ranged from one unit using indirect cooling to 11 units using indirect cooling. These 31 sites could still help satisfy the heat demand networks.

The total capacity that is likely to be feasible for the 17 additional sites that are not linked by cooling water to any other sites, regions or extensions to nuclear licensed sites that have been considered in the project

(including any of the other 16 additional sites amongst these 17 and the 14 other additional sites that are likely to be feasible) also does not change from that shown in Section 4.11.5.

Therefore the current indicative capacity that is likely to be feasible for development of 300 MW_e units at the brownfield and greenfield additional sites by 2050 amounts to sixty two 300 MW_e units which provides a total of 18.6 GW_e (12.9 GW_e with a development date of 2040 and 5.7 GW_e with a development date of 2050).

The above listed capacity could be increased. This would require a conjunctive assessment of the cooling water requirements for all of the 31 additional sites that are likely to be feasible in conjunction with the other sites, regions and extensions to nuclear licensed sites contributing to the capacity listed in Section 5.2.2 to Section 5.2.6 and the initial extension providing an extra 2.1 GW_e listed in Section 5.2.7.

5.2.9. Heat Demand Networks Twice Over Sensitivity Analysis

The results for the heat demand networks twice over sensitivity analysis are not considered in the light of the reservation of the sites discussed in Section 5.2.1. This is because these results were used to guide the development of the methodology for the heat demand networks once over sensitivity analysis rather than being considered independently.

5.3. Heat Demand Networks Once Over Sensitivity Analysis

The following constraints were incorporated into the methodology for the heat demand networks once over sensitivity analysis, therefore they are already accounted for in the results of the sensitivity analysis:

- exclusion of the two greenfield sites discussed in Section 5.2.1;
- reservation of the three brownfield sites for large thermal power plants with CCS as discussed in Section 5.2.1; and
- reservation of three extensions to nuclear licensed sites for Gen IV plants as discussed in Section 5.2.1.

The results for the heat demand networks once over sensitivity analysis provided below include the results for the one initial extension to a nuclear licensed site that passed the reappraisal of the initial extensions to nuclear licensed sites but failed the more than 2.5 GW_e to 3.5 GW_e per site sensitivity analysis. The results for 1,650 MW_e units are provided first.

If mitigation / compensatory measures are accepted for three of the six initial extensions to nuclear licensed sites, the results for the potential maximum additional nuclear power plant generating capacity for 1,650 MW_e units for new deployment next to existing nuclear licensed sites in England and Wales before 2050 provide a total of 23.65 GW_e (15.4 GW_e with an assumed development date of 2030 and the remaining 8.25 GW_e with an assumed development date of 2040).

Six brownfield sites could be considered for 1,650 MW_e units for nuclear power development and the potential maximum capacity for new nuclear deployment at these brownfield sites by 2050 is 9.9 GW_e (assumed development date 2040).

If mitigation / compensatory measures are accepted, one greenfield site could be considered for 1,650 MW_e units for nuclear power development and the potential maximum capacity for new nuclear deployment at this greenfield site by 2050 is 3.3 GW_e (assumed development date of 2050).

If mitigation / compensatory measures are accepted for two of the six further extensions to nuclear licensed sites, the results for the potential maximum additional nuclear power plant generating capacity for 1,650 MW_e units for new deployment beyond twin large units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear licensed sites in England and Wales before 2050 provide a total of 8.25 GW_e (3.3 GW_e with an assumed development date of 2040 and 4.95 GW_e with an assumed development date of 2050).

The results for 300 MW_e units that are involved in satisfying the heat demand networks are provided next.

If mitigation / compensatory measures are accepted for the fourth of the six initial extensions to nuclear licensed sites, the initial extensions that are involved in satisfying the heat demand networks that pass the sensitivity analysis for 300 MW_e units provide a total of 3.6 GW_e of 300 MW_e units.

The results for 300 MW_e units at six brownfield sites that are involved in satisfying the heat demand are as follows:

- **If mitigation / compensatory measures are accepted for two of the six brownfield sites, 6.0 GW_e (assumed development date of 2040); and**
- **3.0 GW_e which is likely to feasible (assumed development date of 2040).**

The result for 300 MW_e units at three greenfield sites that are involved in satisfying the heat demand networks is as follows:

- **3.9 GW_e which is likely to be feasible (assumed development date of 2050).**

The current indicative capacity for development of 300 MW_e units in brownfield and greenfield regions which are involved in satisfying the heat demand networks by 2050 is as follows:

- **4.5 GW_e (1.8 GW_e with an assumed development date of 2040 and 2.7 GW_e with an assumed development date of 2050).**

The current indicative capacity which is likely to be feasible for development of 300 MW_e units at additional brownfield and greenfield sites which are involved in satisfying the heat demand networks by 2050 is as follows:

- **21.3 GW_e (13.5 GW_e with an assumed development date of 2040 and 7.8 GW_e with an assumed development date of 2050).**

If mitigation / compensatory measures are accepted for three more of the six further extensions to nuclear licensed sites, the results for the further extensions that are involved in satisfying the heat demand networks that pass the sensitivity analysis for 300 MW_e units provide a total of 6.6 GW_e of 300 MW_e units (2.7 GW_e with an assumed development date of 2040 and 3.9 GW_e with an assumed development date of 2050).

Finally, the results for 300 MW_e units that are not involved in satisfying the heat demand networks are provided below.

The sixth of the six initial extensions to nuclear licensed sites which is not involved in satisfying the heat demand networks passes the sensitivity analysis for 300 MW_e units and provides a total of 0.6 GW_e of 300 MW_e units.

The current indicative capacity for development of 300 MW_e units in brownfield and greenfield regions which are not involved in satisfying the heat demand networks by 2050 is as follows:

- **7.8 GW_e (2.7 GW_e with an assumed development date of 2040 and 5.1 GW_e with an assumed development date of 2050).**

The current indicative capacity which is likely to be feasible for development of 300 MW_e units at additional brownfield and greenfield sites which are not involved in satisfying the heat demand networks by 2050 is as follows:

- **10.8 GW_e (5.4 GW_e with an assumed development date of 2040 and 5.4 GW_e with an assumed development date of 2050).**

The overall results provide a total conjunctive capacity of 58.8 GW_e with an additional conjunctive capacity that is likely to be feasible of 39.0 GW_e, of which 21.3 GW_e is required to satisfy the heat demand networks once over.

5.4. Site Challenges

Nuclear developers will consider the totality of the challenges at a site when deciding whether or not to develop that site. So, despite the fact that a site meets the criteria employed in the assessments carried out in this project, it may be rejected for development on the basis of the totality of the challenges.

5.4.1. Existing Nuclear Licensed Sites

Table 5-1 shows the challenges relating to access to suitable sources of cooling water at the extensions to nuclear licensed sites in England.

Table 5-1: Categorisation of Cooling Water Challenges at Extensions to Nuclear Licensed Sites in England and Wales

Minor	Moderate	Major
Seven extensions	Three extensions	Four extensions

The results shown in Table 5-1 were combined with the results of the three additional studies for the extensions to the nuclear licensed sites to provide a collation of the site challenges. **The challenges within the collation that fall into the major category are as follows:**

- **access to suitable sources of cooling water at four extensions to nuclear licensed sites;**
- **access by water for AILs at one nuclear licensed site; and**
- **the scale of flood defence works at six extensions to nuclear licensed sites.**

5.4.2. Brownfield and Greenfield Sites on Long List that are Suitable for, or are Likely to be Feasible for 300 MW_e Units

Table 5-2 shows the challenges relating to access to suitable sources of cooling water at the brownfield and greenfield sites on the long list that are suitable for, or are likely to be feasible for 300 MW_e units.

Table 5-2: Categorisation of Cooling Water Challenges at Brownfield and Greenfield Sites on Long List that are Suitable for, or are Likely to be Feasible for 300 MW_e Units

Minor	Moderate	Major
Two sites	16 sites	One site

The results shown in Table 5-2 were combined with the results of the three additional studies for brownfield and greenfield sites on the long list that are suitable for, or are likely to be feasible for 300 MW_e units to provide a collation of the site challenges. **The challenges within the collation that fall into the major category are as follows:**

- **access to suitable sources of cooling water at one site; and**
- **the scale of flood defence works potentially required at nine sites.**

5.4.3. Additional Sites that are Likely to be Feasible for 300 MW_e Units

Table 5-3 shows the challenges relating to access to suitable sources of cooling water at the additional sites that are likely to be feasible for 300 MW_e units.

Table 5-3: Categorisation of Cooling Water Challenges at Additional Sites that are Likely to be Feasible for 300 MW_e Units

Minor	Moderate	Major
13 additional sites	13 additional sites	Five additional sites

The results shown in Table 5-3 were combined with the results of the three additional studies for the additional sites that are likely to be feasible for 300 MW_e units to provide a collation of the site challenges. **The challenges within the collation that fall into the major category are as follows:**

- **access to suitable sources of cooling water at five additional sites; and**
- **the scale of flood defence works potentially required at one additional site.**

5.4.4. Regions that are Suitable for 300 MW_e Units

Table 5-4 shows the challenges relating to access to suitable sources of cooling water in regions that are suitable for 300 MW_e units.

Table 5-4: Categorisation of Cooling Water Challenges in Regions that are Suitable for 300 MW_e Units

Minor	Moderate	Major
Zero regions	10 regions	11 regions

The results shown in Table 5-4 were combined with the results of the three additional studies for regions that are suitable for 300 MW_e units to provide a collation of the challenges in the regions. **The challenges within the collation that fall into the major category are as follows:**

- **access to suitable sources of cooling water in 11 regions;**
- **access for AILs in one region; and**
- **the scale of flood defence works potentially required in 12 regions.**

5.5. Changes to Supporting Assumptions

This section provides information on changes that were considered, and should be considered, to the supporting assumptions used in the project, in order to increase the number of sites available for nuclear power development. It also provides information on the reasons for these changes.

The exclusionary criterion that caused the failure of the majority of sites on the long list was criterion E1 - demographics. Therefore relaxation of this criterion would offer the greatest opportunity for increasing the number of sites available for nuclear power development. The ONR would have to sanction such a relaxation and there is no indication that anything of this nature is being considered.

In the baseline assessment 32 sites (including nine existing nuclear licensed sites) failed on criterion E4 - size of site, whilst in the cooling water sensitivity analysis 19 sites (including three existing nuclear licensed sites) also failed on this criterion. The 39 brownfield and greenfield sites amongst these 51 sites were considered for 300 MW_e units in the reappraisal of the long list. The results of the reappraisal demonstrated that three sites, all of which failed the baseline assessment on criterion E4, were likely to be feasible for 300 MW_e units. **Therefore decreasing the size of site, with an associated decrease in reactor capacity led to three sites from the 39 being likely to be feasible for 300 MW_e units.** Twenty three of the 39 sites still failed on criterion E4. **The alternative to decreasing the size of site would be to adopt a more compact layout for nuclear power plants which would maximise the capacity without the need to decrease the size of site.**

Relaxing criterion E5 - access to sources of cooling water so that the distance to sources of cooling water was 20 km or less (rather than 2 km or less) provided a greater choice of cooling water sources. This meant that sites could access cooling water sources with greater cooling water availability.

This was demonstrated by the fact that three inland sites which failed the cooling water sensitivity analysis on criterion D10 - access to suitable sources of cooling water, passed the reappraisal of the long list whilst still using rivers as their sources of cooling water. It should however be remembered that the feasibility of transporting water over 20 km needs to be demonstrated for each individual case. Another change adopted in the reappraisal of the long list was the use of the Environment Agency's Water Resources GIS in the determination of cooling water availability for rivers. This also had an influence on the results.

Based on the results of the baseline assessment and the cooling water sensitivity analysis, criterion D10 - access to suitable sources of cooling water was amongst the dominant discretionary criteria which precluded sites from nuclear power development. This observation relates to cooling water assessments using flows based on natural flows in rivers and allowable abstractions based on the minimum allowable percentage of these flows. When the Water Resources GIS was used instead for the determination of cooling water availability for rivers, sites that had previously failed the cooling water sensitivity analysis passed the two river catchments sensitivity analysis. In addition, it was determined that more sites passed in conjunction

and the maximum capacity for new nuclear deployment at these sites was comparable with the established and planned total capacity for thermal generation on the two river catchments. **The use of the Water Resources GIS led to more sites passing criterion D10 and greater capacity at some sites.**

In the identification of additional sites to support the heat demand networks sensitivity analyses, the following changes were made:

- criterion E5 - access to sources of cooling water was relaxed so that the distance to sources of cooling water was 20 km or less (rather than 2 km or less); and
- the Water Resources GIS was used in the determination of cooling water availability for rivers.

These changes had the added benefit that the additional sites could be located further from rivers with an accompanying decrease in flood risk.

In the reappraisal of the long list and the identification of additional sites, some of the methodologies employed for assessing criteria D1 to D9 were less detailed than those that had previously been used in the project. This was because the work addressed a greater number of sites with an accompanying reduction in the level of certainty associated with the results of the assessments. This led to the sites being described as likely to be feasible or not likely to be feasible. **The sites that are likely to be feasible should be reassessed using the assessment methodologies for criteria D1 to D9 that were employed for the rest of the sites, regions and extensions to nuclear licensed sites considered in the project.**

No site on the long list failed solely on criterion D9 - size of site to accommodate operations and this criterion was not a dominant criterion which precluded sites from nuclear power development. However, for regions of England and Wales, criterion D9 was one of the two dominant discretionary criteria that caused the failure of regions and one of the two discretionary criteria which contributed to the failure of regions. Relaxation of criterion D9 to allow inclusion of land the other side of a major road, a railway line, or a major river or canal from the waterbody that is being considered as the source of cooling water would result in the exclusion of less land from the regions. Also, relaxation of criterion E5 - access to sources of cooling water by increasing the allowed distance to cooling water to be greater than 2 km would result in the inclusion of more land in the regions. In addition, this land would be less likely to be excluded as a result of flood risk as it would be located further from the river which is the major source of flooding for inland regions.

Increasing the amount of land that is included in the regions by relaxing criterion E5 - access to sources of cooling water and decreasing the amount of land that is excluded from the regions by relaxing criterion D9 - size of site to accommodate operations would lead to an increase in the land area remaining in the regions. This would lead to an increase in the number of 300 MW_e units that could be allocated to some of the regions.

The effects of climate change were not allowed for in the methodology for criterion D10 - access to suitable sources of cooling water. **Work to include the effects of climate change should be carried out.**

A further change to an assumption which should be considered is an extension to the large thermal plant with CCS sensitivity analysis. **This would involve consideration of sites that are located more than 2 km from the coast and estuaries on the east coast of England in the sensitivity analysis.** This would not increase the number of sites available for nuclear power deployment, but would provide further information on sites for large thermal power plants with CCS and potential overlap with inland sites that are also suitable for nuclear power plants.

5.6. Other Opportunities

This section addresses any additional opportunities that would increase the number of potential sites and the capacity for new nuclear by 2050. **No additional assumptions that would increase the number of potential sites and the capacity were identified.**

Two MOD sites scheduled for disposal that are located 2 km or less from the coast or estuaries offer potential opportunities for siting new nuclear power plants. These two sites should be subject to a stage 2 assessment to determine their suitability. The MOD sites that passed criterion E1 - demographics, criterion E2 - exclusionary military activities, criterion E3 - within an internationally designated ecological site and criterion E5 - access to sources of cooling water and are located 2 km

or less from the coast or estuaries appear to offer the best opportunity for increasing the number of potential sites and capacity for new nuclear in the future.

5.7. Preferred Locations for Technology Demonstrator Sites

The four criteria addressing likely site requirements for technology demonstrator plants employed in the work on preferred locations for technology demonstrator sites were as follows:

- **history of demonstrators at the site;**
- **remoteness of the site;**
- **access to suitable sources of cooling water; and**
- **availability of required land at the site.**

Given the above criteria and the timing of between 2020 and 2025 for building the SMR demonstrators, five existing nuclear licensed sites are the most likely locations for siting SMR demonstrator plants. In addition only one existing nuclear licensed site is a possible location for a large Gen IV plant demonstrator.

6. Options for Realising Site Capacity Necessary to Deliver 75 GW_e of New Nuclear by 2050

6.1. Objective

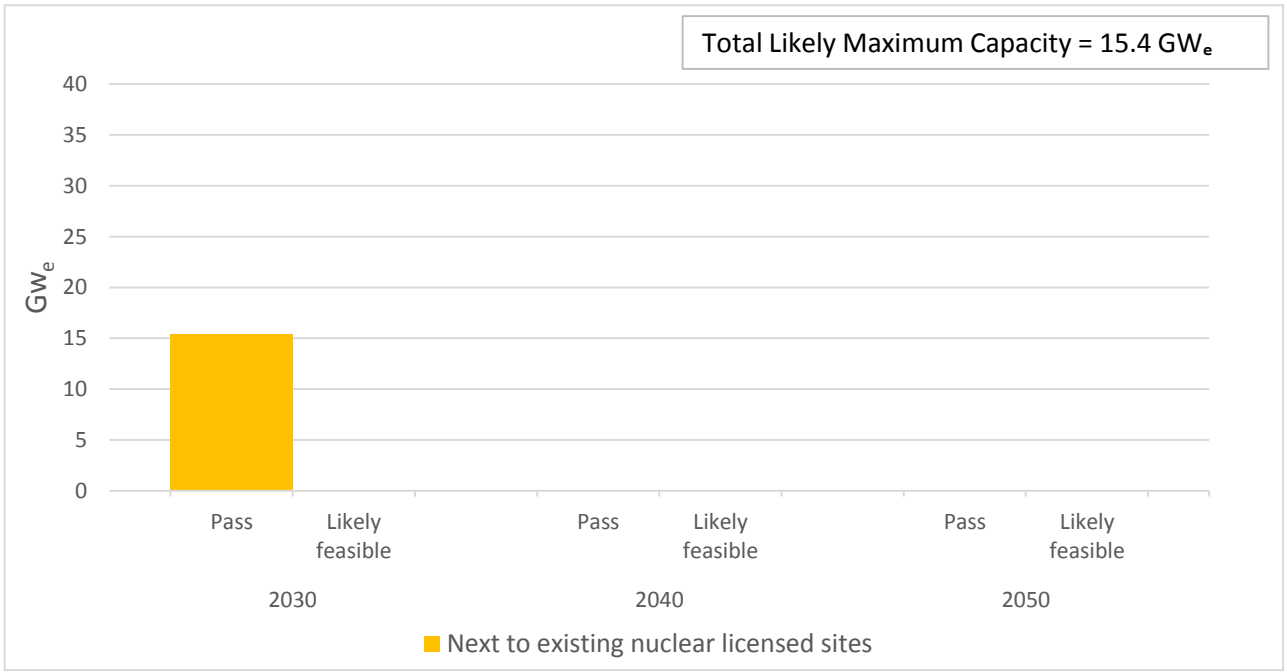
The objective of the consideration of the first set of options was to identify pathway options for realising site capacity necessary to deliver 75 GW_e of new nuclear by 2050.

6.2. Pathway Options

As stated in Section 2, this project represents the first stage of a multi stage assessment process for new nuclear power plants leading up to the award of a Nuclear Site Licence and the other licences and approvals required for each site.

Without acceptance of mitigation / compensatory measures, the capacity for new nuclear development for large units next to existing nuclear licensed sites in England and Wales is equivalent to the capacity already announced by developers. This capacity is 15.4 GW_e as described in Section 4.6.6. Figure 6-1 shows this capacity assigned to its assumed development date (2030). The total capacity shown in Figure 6-1 is described as the total likely maximum capacity.

Figure 6-1: Capacity for Large Units Next to Existing Nuclear Licensed Sites without Acceptance of Mitigation / Compensatory Measures



The principle of acceptance of mitigation / compensatory measures has been established for some of the nominated sites for new nuclear development presented in the National Policy Statement (NPS) for Nuclear Power Generation (EN-6)[4]. Therefore the next logical step in the pathway options is consideration of the capacities if mitigation / compensatory measures are accepted, taking account of the following:

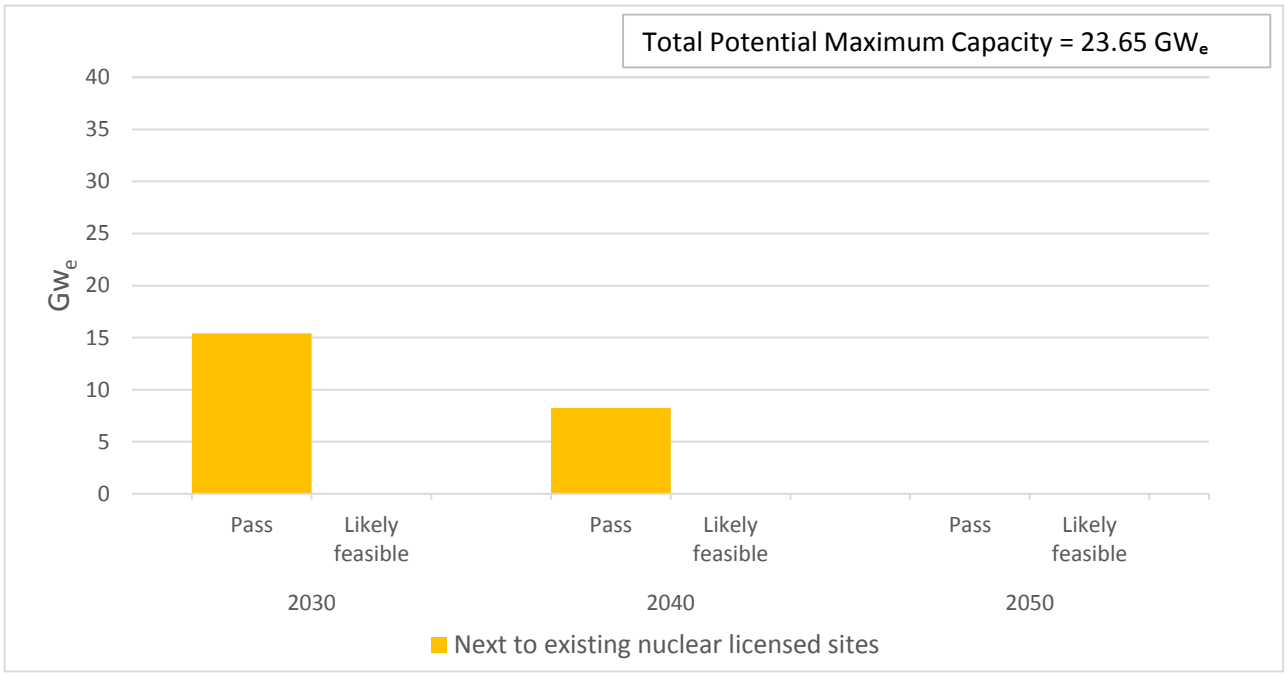
- the exclusion of the two greenfield sites discussed in Section 5.2.1; and

[4] National Policy Statement for Nuclear Power Generation (EN-6), Department of Energy and Climate Change, July 2011.

- the reservation of three brownfield sites for thermal power plants with CCS and the reservation of three extensions to nuclear licensed sites for Gen IV plants, as discussed in Section 5.2.1.

Therefore the capacity for new nuclear development of large units next to existing nuclear licensed sites in England and Wales increases by 8.25 GW_e to 23.65 GW_e, as described in Section 5.2.5 and shown in Figure 6-2. The total capacity shown in Figure 6-2 is described as the total potential maximum capacity. This is because, although the average size of unit for the extra capacity shown in this figure is 1.65 GW_e, units of a lower capacity may be developed at the sites. Indeed, this is the case for the large units that make up the capacity shown in Figure 6-1 for which the average size of unit is 1.4 GW_e.

Figure 6-2: Capacity for Large Units Next to Existing Nuclear Licensed Sites if Mitigation / Compensatory Measures are Accepted, Excluding Two Greenfield Sites, and Reserving Three Brownfield Sites and Three Extensions to Nuclear Licensed Sites

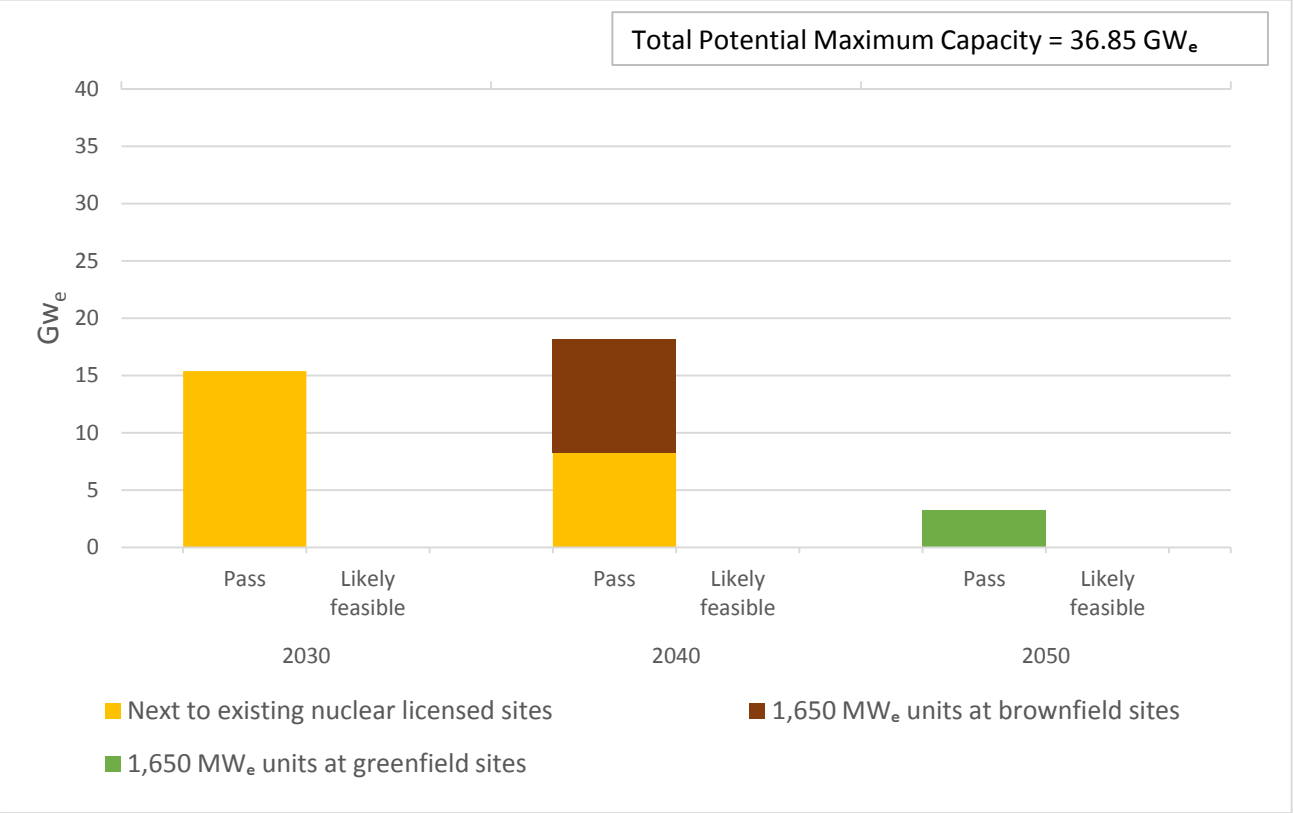


All the capacities discussed in the rest of this section take account of the exclusion of the two greenfield sites, and the reservation of the three brownfield sites and the three extensions to nuclear licensed sites.

Development at brownfield and greenfield sites is the next logical step in the pathway options to realising the required capacity of 75 GW_e. Including development at brownfield and greenfield sites increases the capacity for new nuclear development by 2050 by 13.2 GW_e as described in Section 5.2.2, to 36.85 GW_e as shown in Figure 6-3. The total capacity shown in Figure 6-3 is described as the total potential maximum capacity.

Including development at brownfield and greenfield sites is preferable to deployment beyond twin units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear licensed sites. This is because the latter would concentrate the development around a limited number of sites with the associated environmental effects being focused on these areas and the local communities. In addition, there would be distinct disadvantages from the developers' and operators' perspectives, including enhanced overall development risk and reduced system resilience. Plus there would be the need for upgrade and reinforcement work to the transmission infrastructure at the existing nuclear licensed sites.

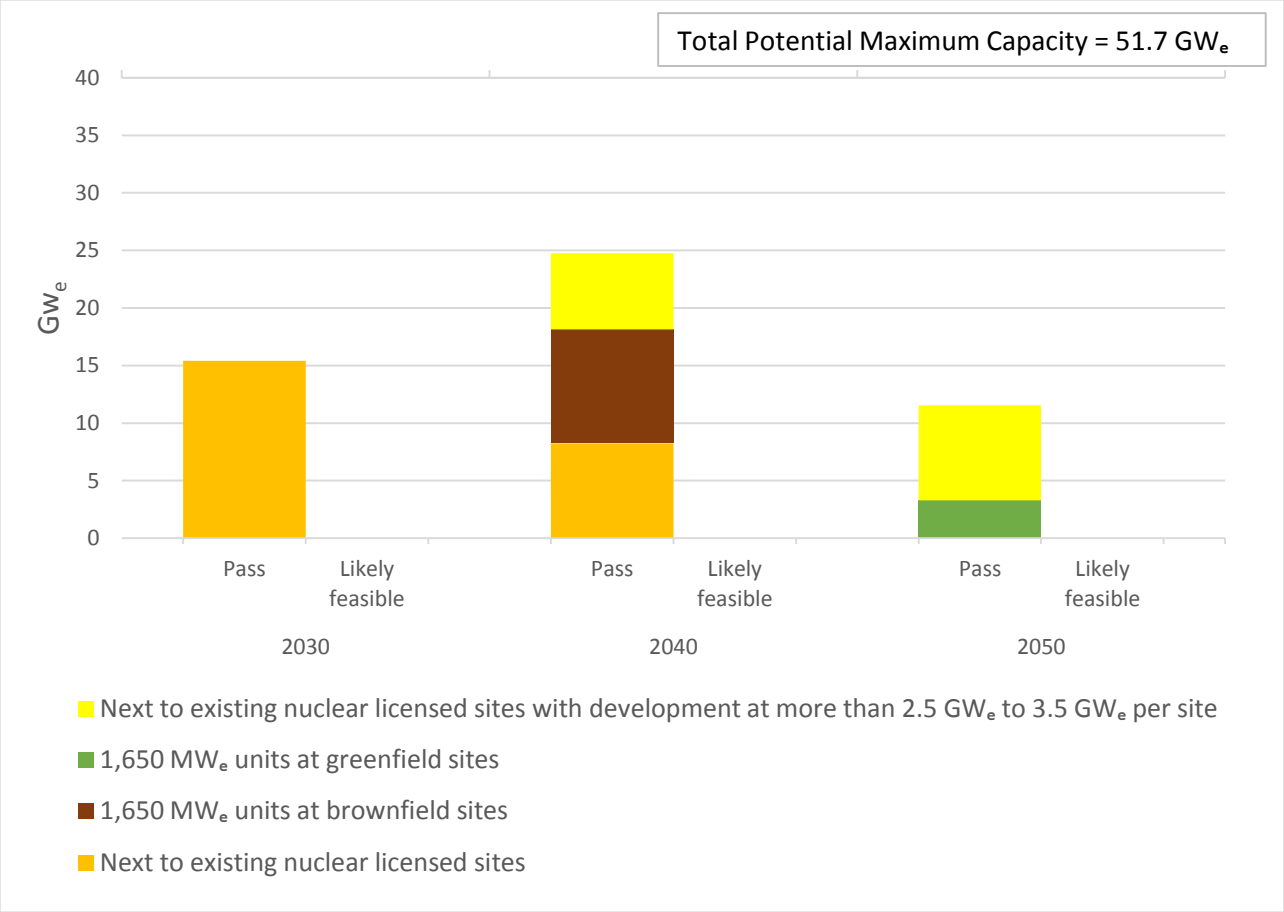
Figure 6-3: Capacity for Large Units as Shown in Figure 6-2 with Addition of Capacity at Brownfield and Greenfield Sites



As previously stated in Section 5.2.4, it is considered that, in principle, there should not be an issue as far as competition for sites with thermal power plants with CCS is concerned. However, inland sites were not explicitly included in the large thermal plant with CCS sensitivity analysis. To take account of this and the fact that it is likely that some inland sites will be used for thermal power plants with CCS, three brownfield sites were removed from consideration for new nuclear power plants in the project. Therefore the surrender of site capacity to thermal power plants with CCS has already been addressed. Although, as stated in Section 4.5.4, other factors which are not included in this project (e.g. transmission system availability) will influence developers to identify sites that are commercially advantageous. Therefore competition may be greater than suggested here and further capacity could in fact be lost to thermal power plants with CCS. Hence all of the remaining brownfield and greenfield sites that passed the baseline assessment and the cooling water sensitivity analysis as modified by the two river catchments sensitivity analysis can be included in this pathway option.

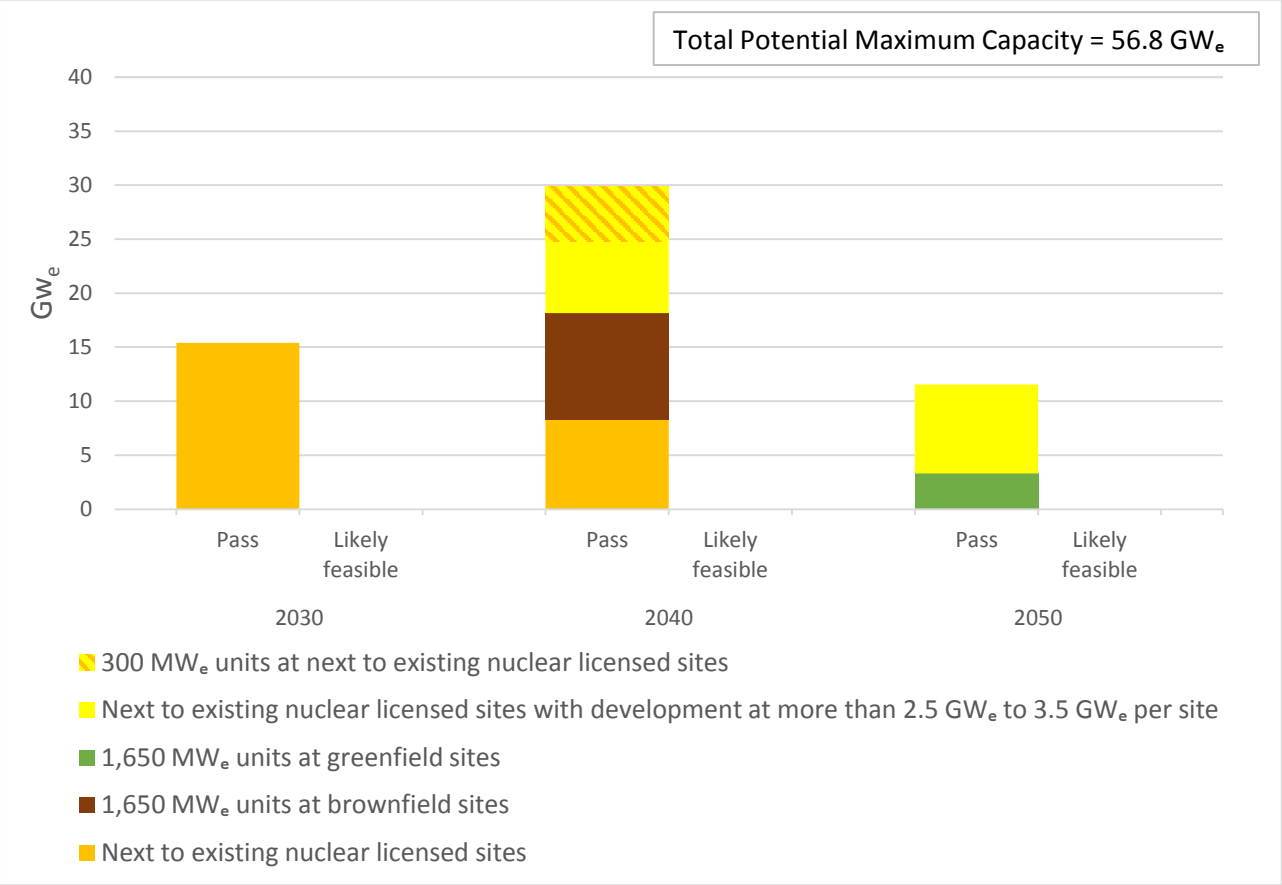
Deployment beyond large twin units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear licensed sites increases the total capacity for new nuclear development by 2050 by 14.85 GW_e as described in Section 5.2.6, to 51.7 GW_e as shown in Figure 6-4. The total capacity shown in Figure 6-4 is described as the total potential maximum capacity. The pathway option of including deployment beyond large twin units next to existing nuclear licensed sites will involve the disadvantages that have previously been discussed. It should be noted that this total potential maximum capacity exceeds the 40 GW_e specified in the second deployment scenario for nuclear expansion.

Figure 6-4: Capacity for Large Units as Shown in Figure 6-3 with Addition of Capacity from Deployment beyond Twin Large Units



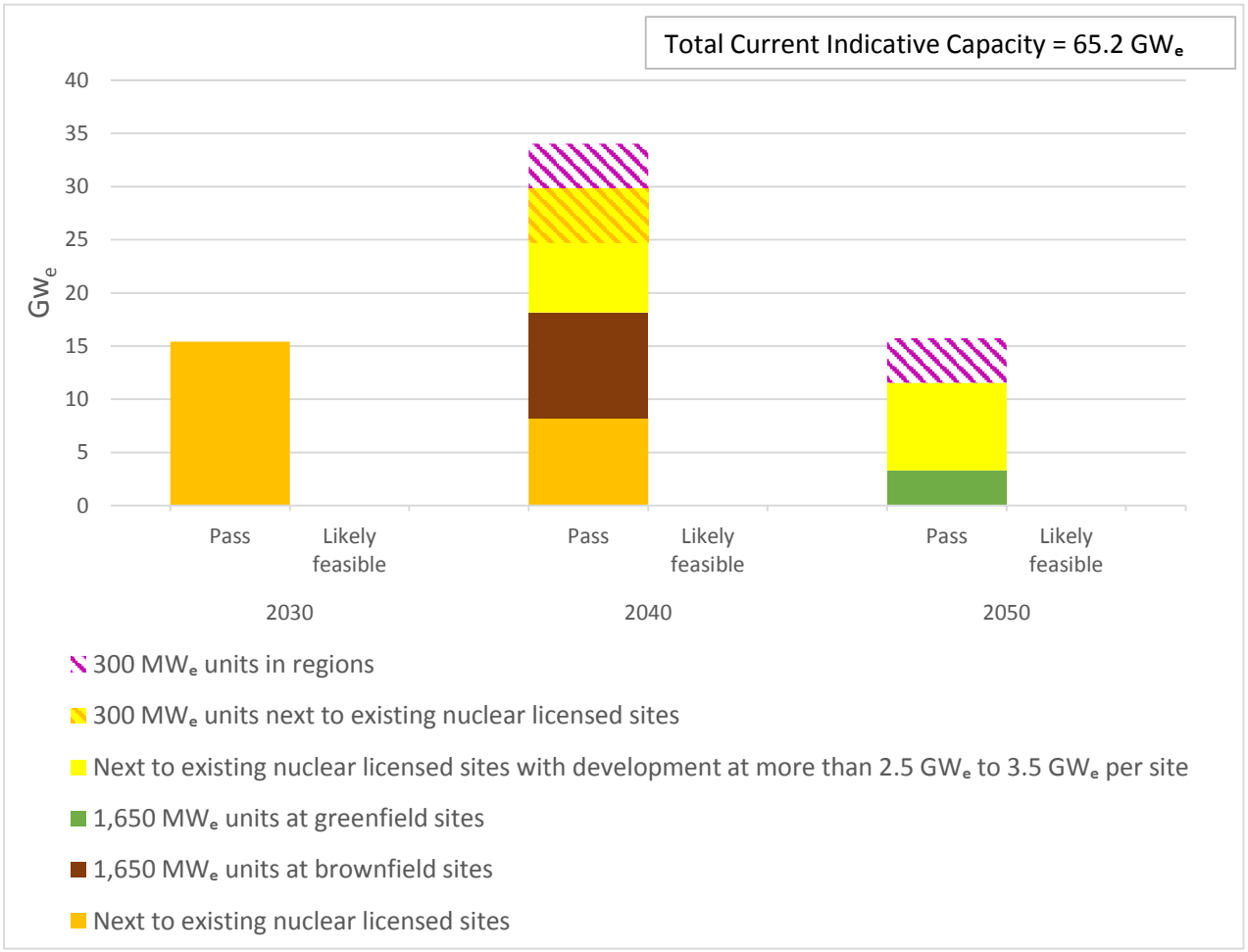
Yet again the previous pathway option does not achieve the required capacity of 75 GW_e. The summary of outcomes from the sensitivity analyses also provided information on the additional capacities for 300 MW_e units. The first option for inclusion of 300 MW_e units is to include those next to existing nuclear licensed sites, as determined in the existing nuclear licensed sites sensitivity analysis and described in Section 5.2.5, plus for the initial extension to a nuclear licensed site that provides an extra 2.1 GW_e as described in Section 5.2.7. This increases the total capacity for new nuclear development by 2050 by 5.1 GW_e to 56.8 GW_e, as shown in Figure 6-5. The total capacity shown in Figure 6-5 is described as the total maximum potential capacity.

Figure 6-5: Capacity as Shown in Figure 6-4 with Addition of Capacity for 300 MW_e Units Next to Existing Nuclear Licensed Sites



The addition of the 300 MW_e units in brownfield and greenfield regions is the next logical pathway option, as this avoids concentrating even more development next to existing nuclear licensed sites. Including this pathway option means that the total capacity for new nuclear development by 2050 increases by 8.4 GW_e as described in Section 5.2.3, to 65.2 GW_e as shown in Figure 6-6. The total capacity shown in Figure 6-6 is described as the total current indicative capacity. It should be remembered that only 20 inland regions were assessed in the alternative smaller plants sensitivity analysis, as this was the maximum number allowed for in the project. As discussed in Section 4.4.5 and Section 5.5, the capacity could be increased. Therefore the capacity associated with 300 MW_e units in brownfield and greenfield regions can be viewed as an indicative capacity.

Figure 6-6: Capacity as Shown in Figure 6-5 with Addition of Capacity for 300 MW_e Units in Brownfield and Greenfield Regions



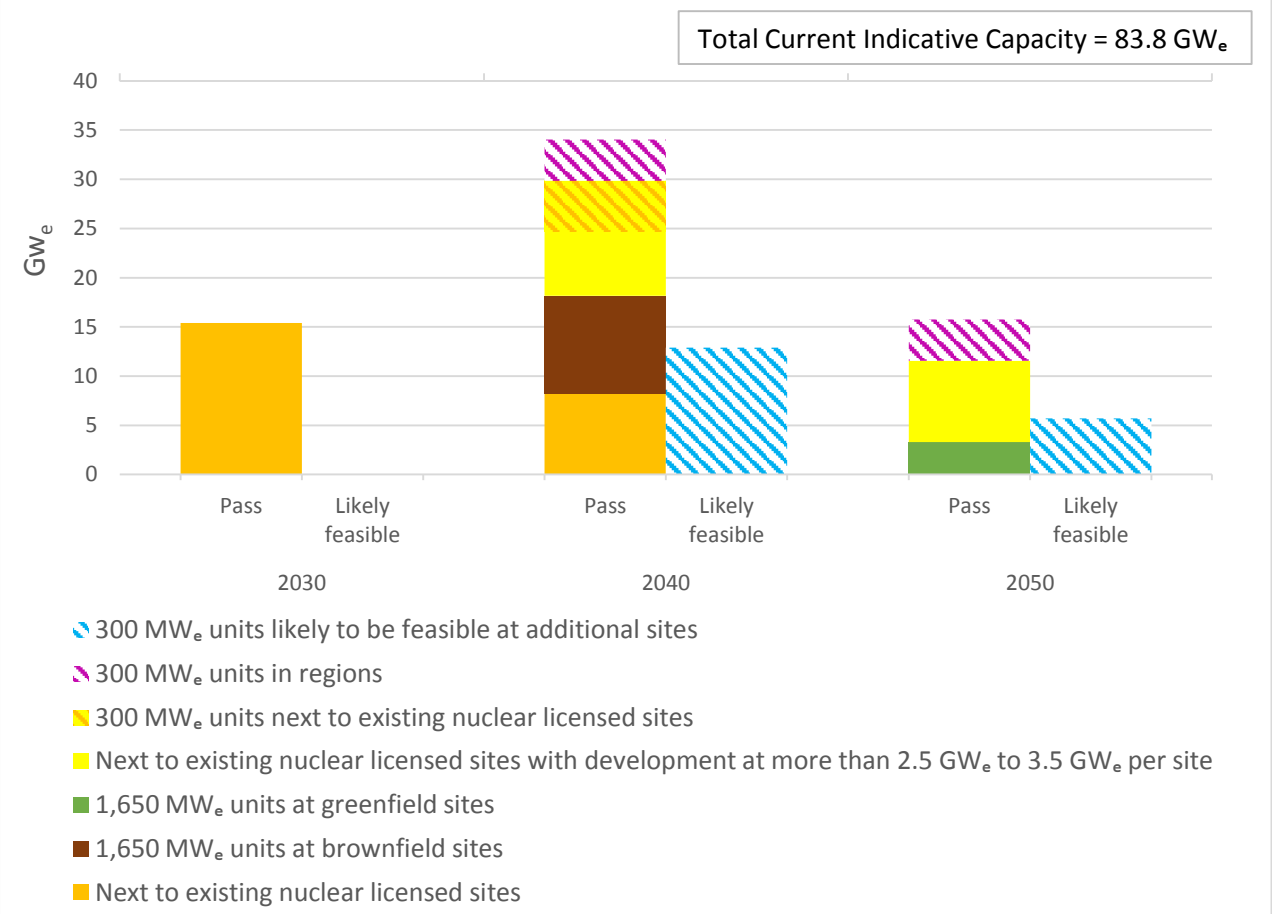
As the previous pathway option still does not achieve the required capacity, the next pathway option is to include 300 MW_e units at the brownfield and greenfield additional sites that are located on waterbodies that are independent of all the other waterbodies providing cooling water for the other sites, regions and extensions to nuclear licensed sites considered in the project, as discussed in Section 5.2.8. Including this pathway option means that the total capacity for new nuclear development by 2050 increases by 18.6 GW_e to 83.8 GW_e, as shown in Figure 6-7. The capacity shown in Figure 6-7 is described as the total current indicative capacity. The following items should be remembered in relation to this increase in capacity:

- the capacity associated with the additional sites is capacity that is likely to be feasible;
- if a conjunctive assessment of cooling water requirements, as described in Section 5.2.8, was to be carried out more capacity associated with the 14 other additional sites could be included; and
- only 44 additional sites were assessed in the identification of additional sites, as this was the maximum number allowed for in the project.

Hence the 18.6 GW_e capacity could be decreased because the sites may not pass when assessed using the assessment methodologies for criteria D1 to D9 that were employed for the rest of the sites, regions and extensions to nuclear licensed sites considered in the project. Alternatively, the capacity could be increased by including more additional sites. Therefore the capacity associated with 300 MW_e units at brownfield and greenfield additional sites can be viewed as an indicative capacity.

It should be noted that this total current indicative capacity exceeds the 75 GW_e specified in the third deployment scenario for nuclear expansion. Therefore the inclusion of just 18.6 GW_e from the identification of additional sites provides a total current indicative capacity that exceeds 75 GW_e.

Figure 6-7: Capacity as Shown in Figure 6-6 with Addition of Capacity for 300 MW_e Units at Brownfield and Greenfield Additional Sites



As described in Section 5.2.6, there is a further 1.5 GW_e of capacity associated with 300 MW_e units involving deployment beyond large twin units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear licensed sites. Therefore the total current indicative capacity for new nuclear development by 2050 as determined for the first set of options is 85.3 GW_e.

6.3. Uncertainties

The key uncertainties associated with the assessment of the discretionary criteria that may affect the results for the first set of options provided in Section 6.2 relate to criterion D1 - flood risk, criterion D2 - coastal processes (as represented by coastal erosion), criterion D6 - proximity to internationally designated ecological sites, criterion D7 - nationally designated ecological sites, criterion D9 - size of site to accommodate operations and criterion D10 - access to suitable sources of cooling water. Uncertainties relating to the other discretionary criteria are viewed as negligible in comparison to these, owing to the straightforward nature of their assessment methodologies.

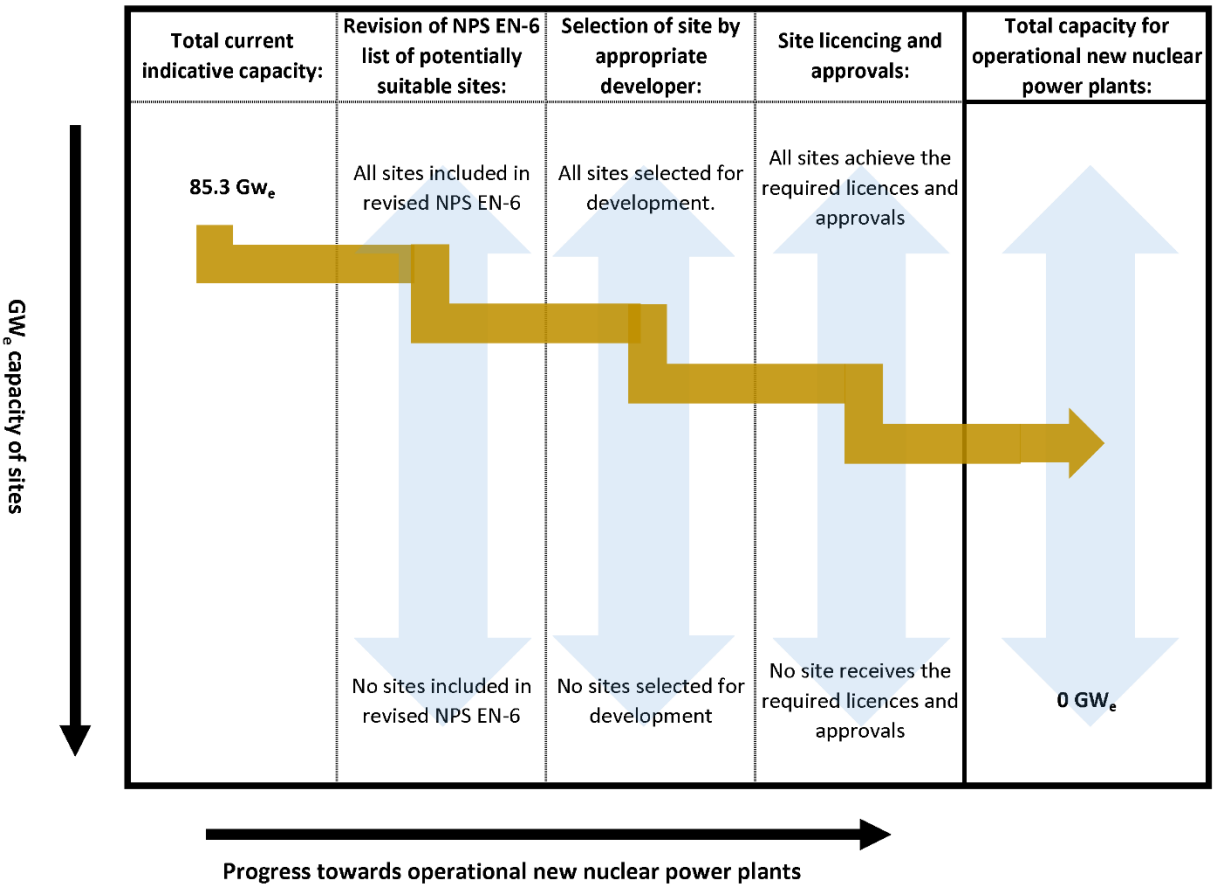
6.4. Progress towards Operational Nuclear Power Plants

As stated in Section 2, this project represents the first stage of the multi stage assessment process for new nuclear power plants, leading up to the award of a Nuclear Site Licence and other licences and approvals required for each site. Therefore the total current indicative capacity of 85.3 GW_e determined in Section 6.2 for the first set of options is the starting point that is likely to lead to a lower capacity being deployed by 2050. The generating capacity that is achieved is ultimately dependent on many factors, most of which are beyond the scope of this project. These factors are likely to reduce the number of sites that are developed for new nuclear power plants by 2050, and consequently the 85.3 GW_e capacity determined for the first set of options. Some of these factors are related to the procedural and regulatory requirements leading up to the award of a Nuclear Site Licence and other licences and approvals required to allow the power plant to operate. There are three main steps in that process that need to be met, which are the following:

- revision of the NPS for Nuclear Power Generation (EN-6) to include sites that are suitable for new nuclear power plants beyond 2025;
- selection of the site by an appropriate developer; and
- a complete set of site licences and approvals being in place for the proposed site.

Figure 6-8 illustrates the likely reduction in the 85.3 GW_e capacity determined for the first set of options, as a result of procedural and regulatory requirements. The other factors that are likely to reduce overall capacity are those that are related to site specific characteristics.

Figure 6-8: Likely Reduction in Capacity for First Set of Options during Progress towards Operational Nuclear Power Plants



6.5. Conclusions

The required capacity of 75 GW_e of new nuclear by 2050 to meet the third deployment scenario for nuclear expansion is achieved by including six of the seven possible pathway options. In addition, the 40 GW_e specified in the second deployment scenario for nuclear expansion is achieved by developing 1,650 MW_e units next to existing nuclear licensed sites in England and Wales, at brownfield and greenfield sites, and by including deployment beyond large twin units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear licensed sites. The total current indicative capacity for new nuclear development by 2050 as determined for the first set of options is 85.3 GW_e.

The contribution to the total capacity from 300 MW_e units in brownfield and greenfield regions and at brownfield and greenfield additional sites can be viewed as an indicative capacity. Further work should be carried out to identify further additional sites from the 31 that are likely to be feasible for inclusion in the total capacity, by undertaking a conjunctive assessment of capacity. Also further work should be carried out to confirm whether the additional sites pass criteria D1 to D9 when assessed using the assessment methodologies that were employed for the rest of the sites, regions and extensions to nuclear licensed sites considered in the project. In addition, further work could be carried out to identify more inland regions and additional sites for 300 MW_e units.

There are key uncertainties associated with the assessment of some of the discretionary criteria that may affect the results for the first set of options. This project represents the first stage of a multi stage assessment process for new nuclear power plants leading up to the award of a Nuclear Site Licence and the other licences and approvals required for each site. Therefore the total current indicative capacity of 85.3 GW_e is the starting point that is likely to lead to a lower capacity being deployed by 2050. The generating capacity that is achieved is ultimately dependent on many factors, most of which are beyond the scope of this project.

7. Options for Realising Site Capacity Necessary to Deliver 75 GW_e of New Nuclear by 2050 Whilst Satisfying Heat Demand Networks Once Over

7.1. Objective

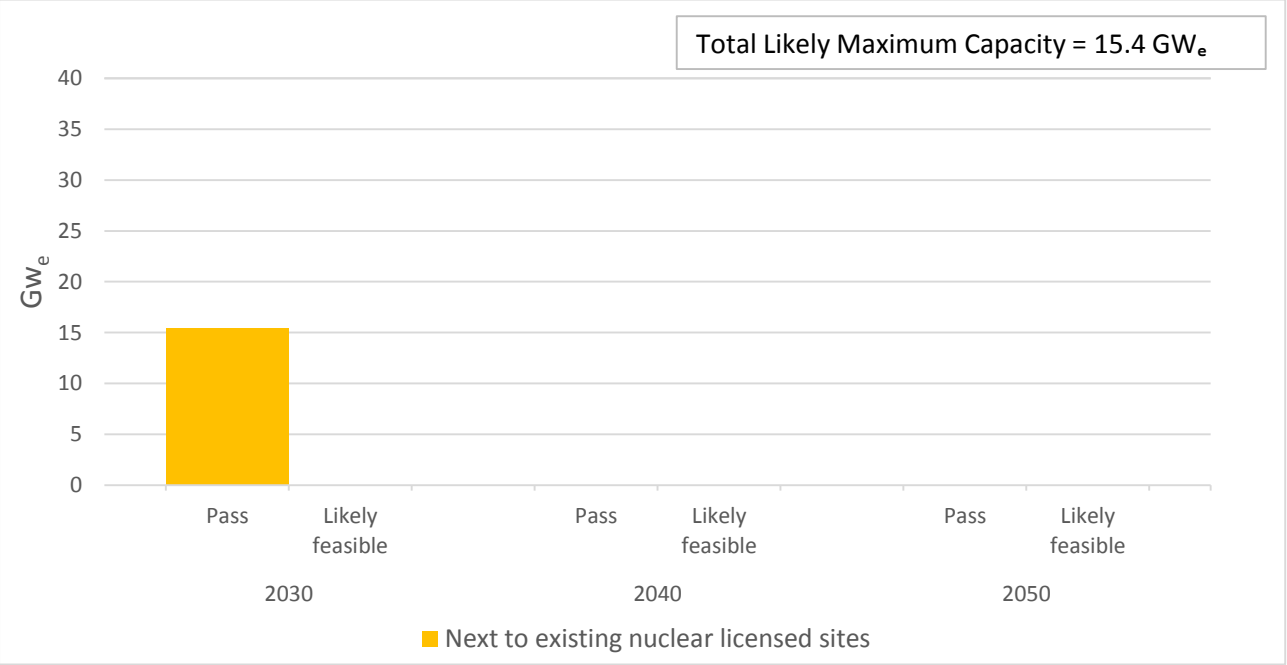
The objective of the consideration of the second set of options was to identify pathway options for realising site capacity to deliver 75 GW_e of new nuclear by 2050 whilst satisfying the heat demand networks once over.

7.2. Pathway Options

As stated in Section 2, this project represents the first stage of a multi stage assessment process for new nuclear power plants leading up to the award of a Nuclear Site Licence and the other licences and approvals required for each site.

Without acceptance of mitigation / compensatory measures, the capacity for new nuclear development for large units next to existing nuclear licensed sites in England and Wales is equivalent to the capacity already announced by developers. This capacity is 15.4 GW_e as described in Section 4.6.6. Figure 7-1 shows this capacity assigned to its assumed development date (2030). The total capacity shown in Figure 7-1 is described as the total likely maximum capacity.

Figure 7-1: Capacity for Large Units Next to Existing Nuclear Licensed Sites without Acceptance of Mitigation / Compensatory Measures



The principle of acceptance of mitigation / compensatory measures has been established for some of the nominated sites for new nuclear development presented in the NPS for Nuclear Power Generation (EN-6). Therefore the next logical step in the pathway options is consideration of the capacities if mitigation / compensatory measures are accepted, taking account of the following:

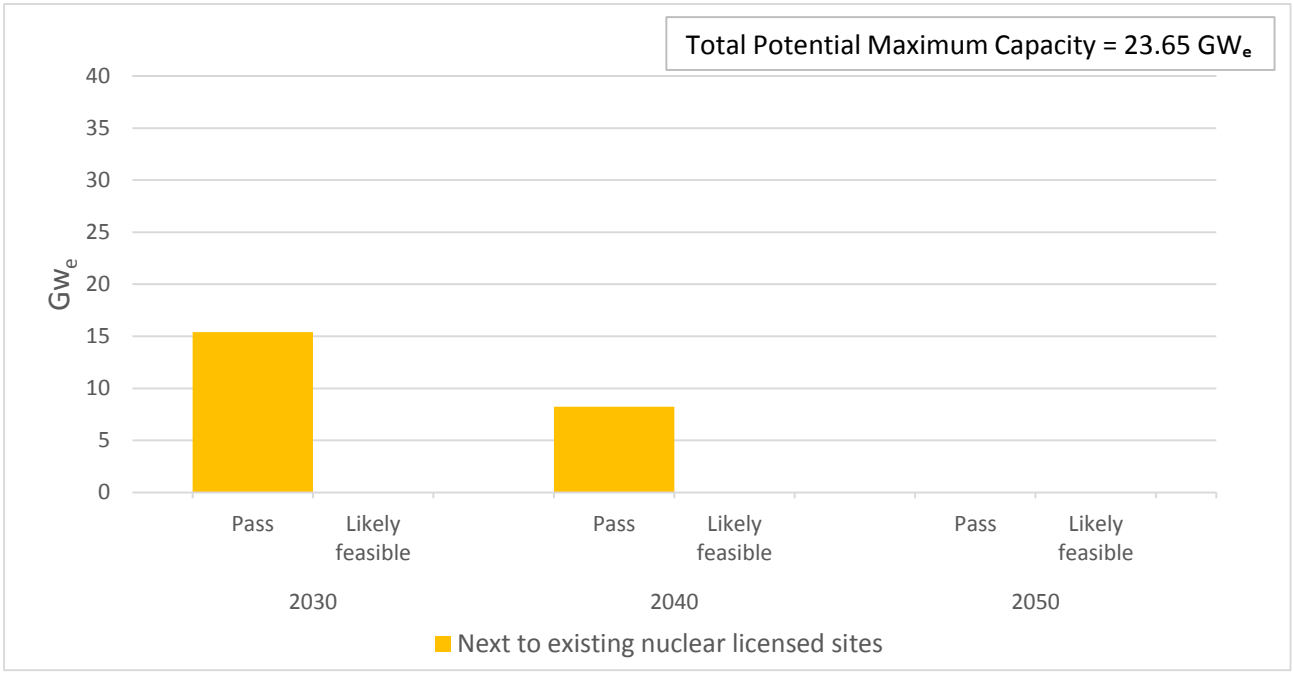
- the exclusion of the two greenfield sites discussed in Section 5.2.1; and

- the reservation of three brownfield sites for thermal power plants with CCS and the reservation of three extensions to nuclear licensed sites for Gen IV plants, as discussed in Section 5.2.1.

Both of the above listed items were incorporated into the heat demand networks once over sensitivity analysis, hence all the capacities discussed in the remainder of this section take account of these items.

Therefore the capacity for new nuclear development of large units next to existing nuclear licensed sites in England and Wales increases by 8.25 GW_e to 23.65 GW_e, as described in Section 5.3 and as shown in Figure 7-2. The total capacity shown in Figure 7-2 is described as the total potential maximum capacity. This is because, although the average size of unit for the extra capacity shown in this figure is 1.65 GW_e, units of a lower capacity may be developed at the sites. Indeed, this is the case for the large units that make up the capacity shown in Figure 7-1 for which the average size of unit is 1.4 GW_e.

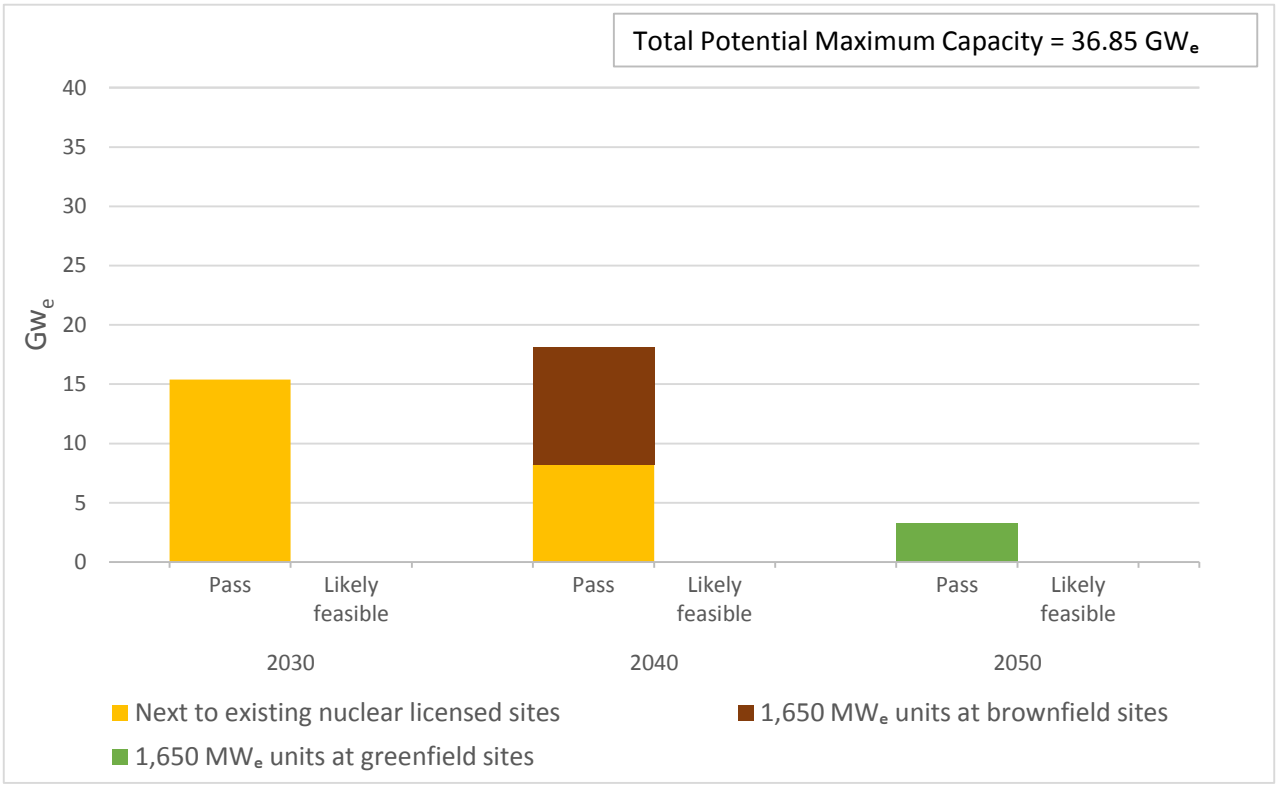
Figure 7-2: Capacity for Large Units Next to Existing Nuclear Licensed Sites if Mitigation / Compensatory Measures are Accepted



Development of large units at brownfield and greenfield sites is the next logical pathway option to realising the required capacity of 75 GW_e. Including development at brownfield and greenfield sites increases the capacity for new nuclear development by 2050 by 13.2 GW_e as described in Section 5.3, to 36.85 GW_e as shown in Figure 7-3. The total capacity shown in Figure 7-3 is described as the total potential maximum capacity.

Including development at brownfield and greenfield sites is preferable to deployment beyond twin units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear licensed sites. This is because the latter would concentrate the development around a limited number of sites with the associated environmental effects being focused on these areas and the local communities. In addition, there would be distinct disadvantages from the developers' and operators' perspectives, including enhanced overall development risk and reduced system resilience. Plus there would be the need for upgrade and reinforcement work to the transmission infrastructure at the existing nuclear licensed sites.

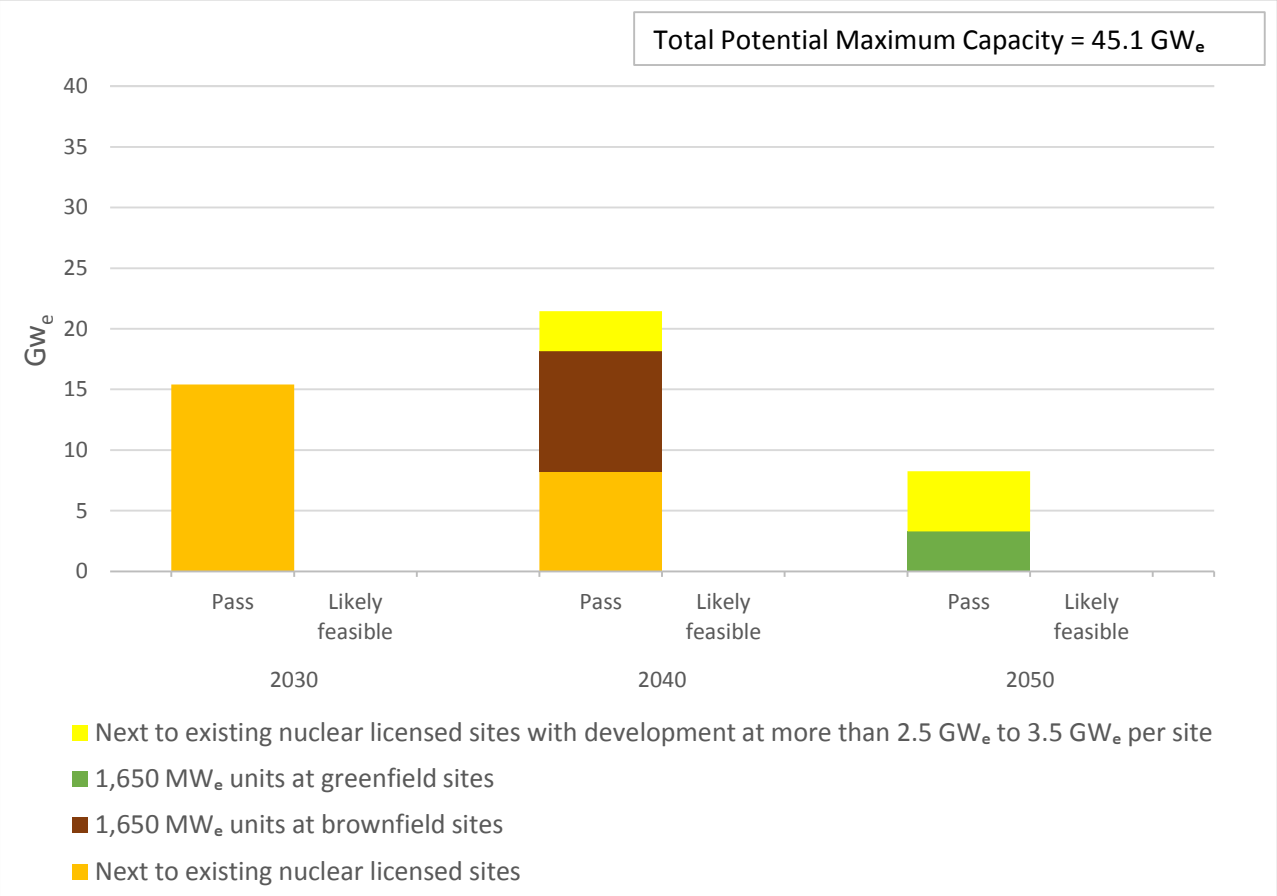
Figure 7-3: Capacity for Large Units as Shown in Figure 7-2 with Addition of Capacity at Brownfield and Greenfield Sites



As previously stated in Section 5.2.4, it is considered that, in principle, there should not be an issue as far as competition for sites with thermal power plants with CCS is concerned. However, inland sites were not explicitly included in the large thermal plant with CCS sensitivity analysis. To take account of this and the fact that it is likely that some inland sites will be used for thermal power plants with CCS, three brownfield sites were removed from consideration for new nuclear power plants in the project. Therefore the surrender of site capacity to thermal power plants with CCS has already been addressed and incorporated into the methodology for the heat demand networks once over sensitivity analysis. Although, as stated in Section 4.5.4, other factors which are not included in this project (e.g. transmission system availability) will influence developers to identify sites that are commercially advantageous. Therefore competition may be greater than suggested here and further capacity could in fact be lost to thermal power plant with CCS. Hence all the brownfield and greenfield sites used for 1,650 MW_e units can be included in this pathway option.

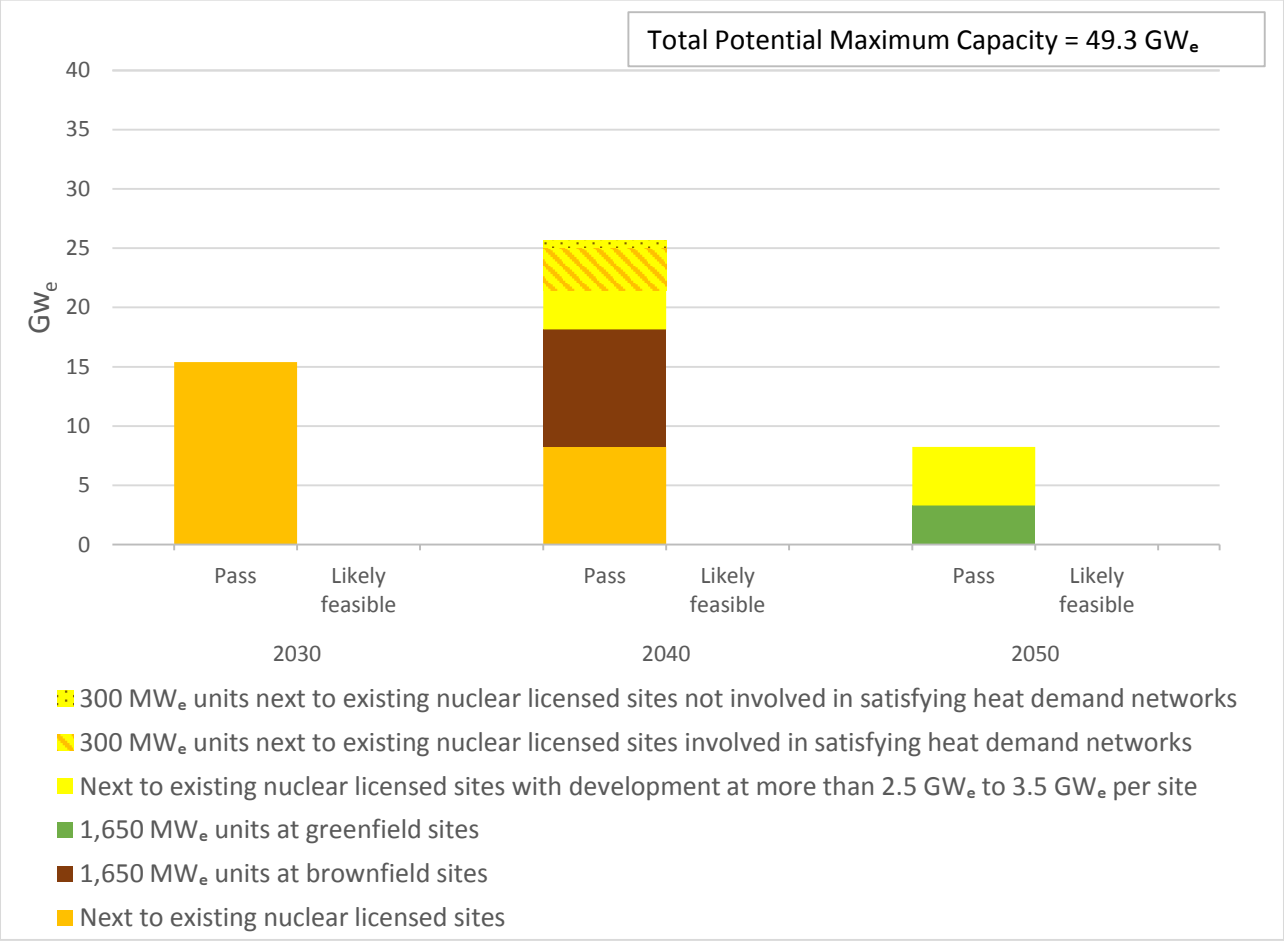
Deployment beyond large twin units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear licensed sites increases the total capacity for new nuclear development by 2050 by 8.25 GW_e as described in Section 5.3, to 45.1 GW_e as shown in Figure 7-4. The total capacity shown in Figure 7-4 is described as the total potential maximum capacity. The pathway option of including deployment beyond large twin units next to existing nuclear licensed sites will involve the disadvantages that have previously been discussed. It should be noted that this total potential maximum capacity exceeds the 40 GW_e specified in the second deployment scenario for nuclear expansion.

Figure 7-4: Capacity for Large Units as Shown in Figure 7-3 with Addition of Capacity from Deployment beyond Large Twin Units



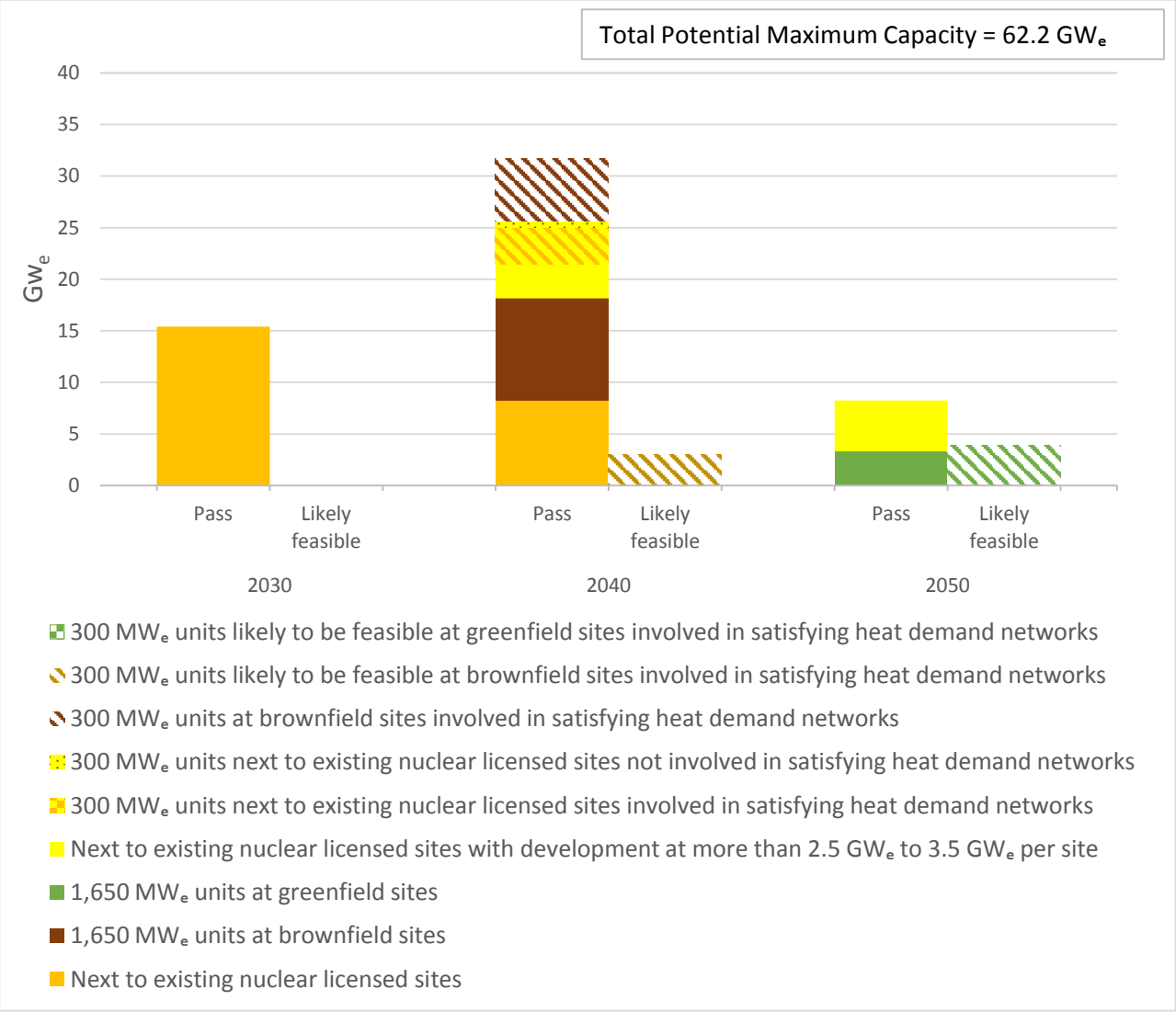
The previous pathway option does not achieve the required capacity of 75 GW_e. In the heat demand networks once over sensitivity analysis, extensions to existing nuclear licensed sites and sites that are not suitable 1,650 MW_e, 1,400 MW_e or 1,150 MW_e units but are suitable for, or are likely to be feasible for 300 MW_e units were used for 300 MW_e units. Some of these units were used to help satisfy the heat demand networks whilst others were not. The advantage of the former arrangement is that the waste heat produced by the units is used as well as the electricity. The first option for inclusion of 300 MW_e units is to include those next to existing nuclear licensed sites whether they are involved in satisfying the heat demand networks or not. The reason for the lack of differentiation is that the likelihood of development is equal in both cases. This increases the total capacity for new nuclear development by 2050 by 4.2 GW_e (3.6 GW_e of which is involved satisfying the heat demand networks and 0.6 GW_e of which is not) as described in Section 5.3, to 49.3 GW_e as shown in Figure 7-5. The total capacity shown in Figure 7-5 is described as the total potential maximum capacity.

Figure 7-5: Capacity as Shown in Figure 7-4 with Addition of Capacity from 300 MW_e Units Next to Existing Nuclear Licensed Sites



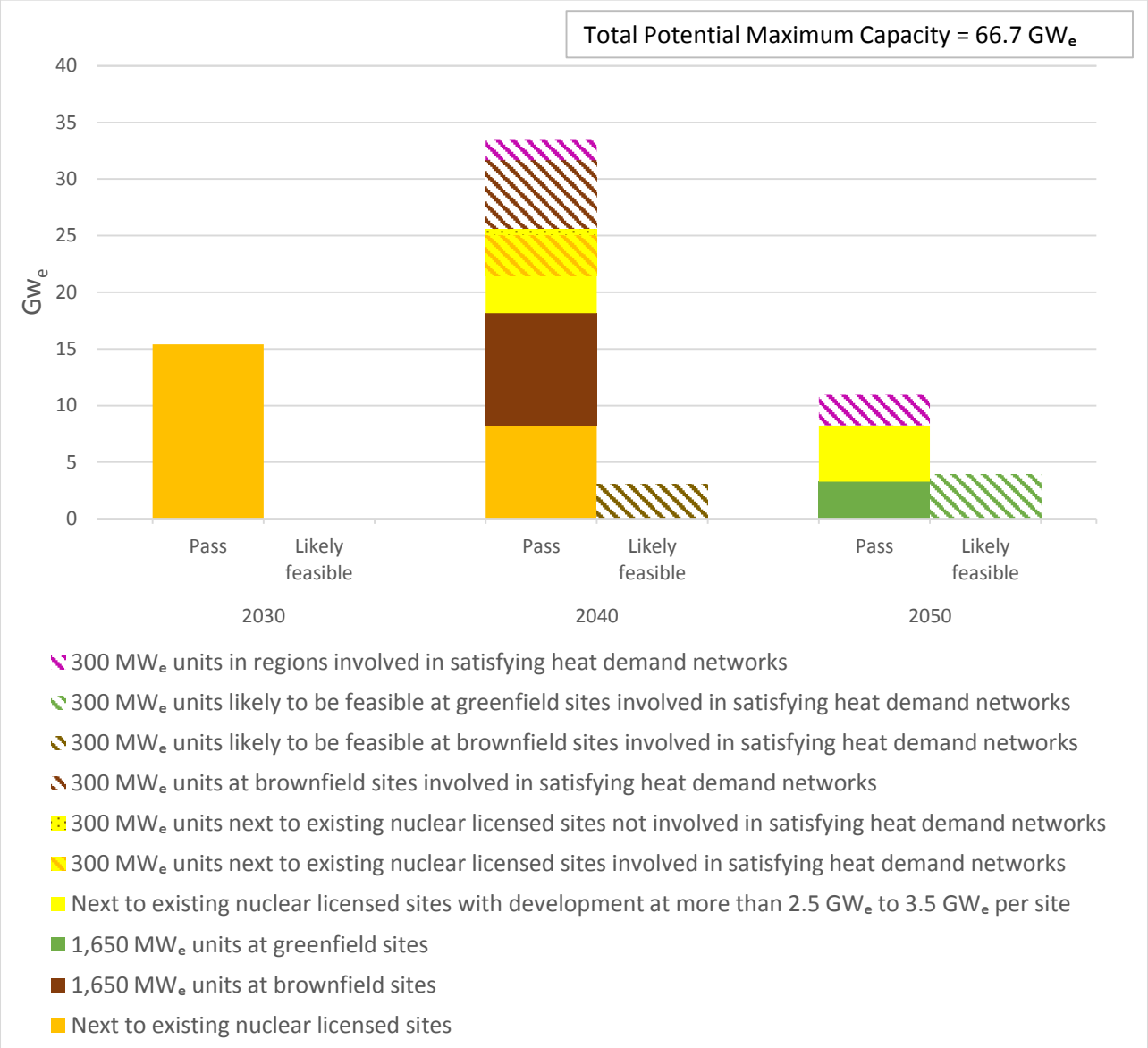
Addition of the 300 MW_e units at brownfield and greenfield sites is the next logical pathway option, as this avoids concentrating even more development next to existing nuclear licensed sites. All these units are involved in satisfying the heat demand networks. Including this pathway option means that the total capacity for new nuclear development by 2050 increases by 9.0 GW_e at brownfield sites (3.0 GW_e of which is only likely to be feasible) and 3.9 GW_e at greenfield sites as described in Section 5.3, to 62.2 GW_e as shown in Figure 7-6. The total capacity shown in Figure 7-6 is described as the total potential maximum capacity.

Figure 7-6: Capacity as Shown in Figure 7-5 with Addition of Capacity from 300 MW_e Units at Brownfield and Greenfield Sites



As the previous pathway option still does not achieve the required capacity, the next pathway option is to include 300 MW_e units in brownfield and greenfield regions which are involved in satisfying the heat demand networks. Including this pathway option means that the total capacity for new nuclear development by 2050 increases by 4.5 GW_e as described in Section 5.3, to 66.7 GW_e as shown in Figure 7-7. The total capacity shown in Figure 7-7 is described as the total potential maximum capacity.

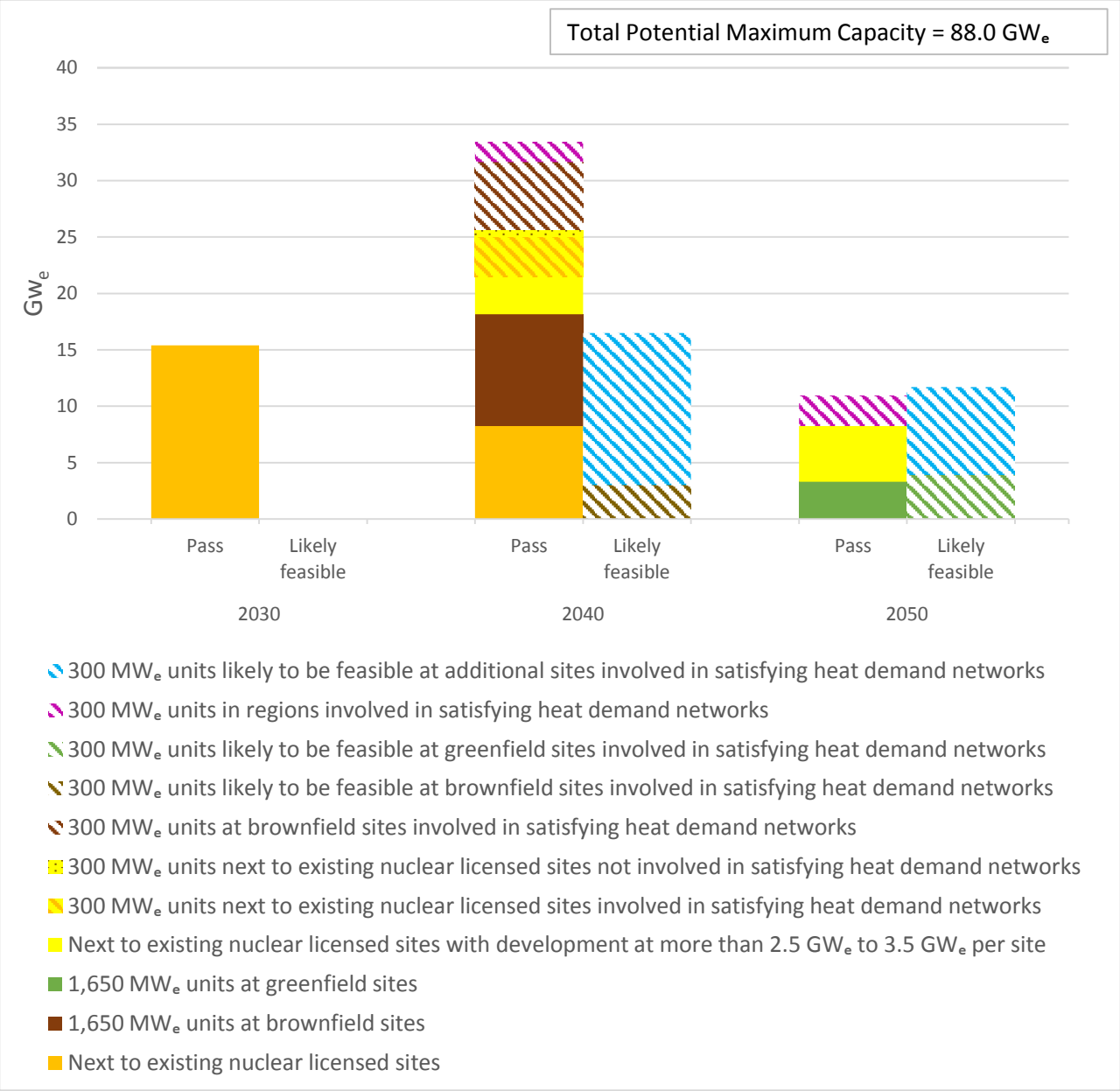
Figure 7-7: Capacity as Shown in Figure 7-6 with Addition of Capacity from 300 MW_e Units in Brownfield and Greenfield Regions



As the previous pathway option still does not achieve the required capacity, the next pathway option is to include 300 MW_e units at the brownfield and greenfield additional sites which are involved in satisfying the heat demand networks. Including this pathway option means that the total capacity for new nuclear development by 2050 increases by 21.3 GW_e (all of which is only likely to be feasible) as described in Section 5.3, to 88.0 GW_e as shown in Figure 7-8. The total capacity shown in Figure 7-8 is described as the total potential maximum capacity.

It should be noted that this total potential maximum capacity exceeds the 75 GW_e specified in the third deployment scenario for nuclear expansion.

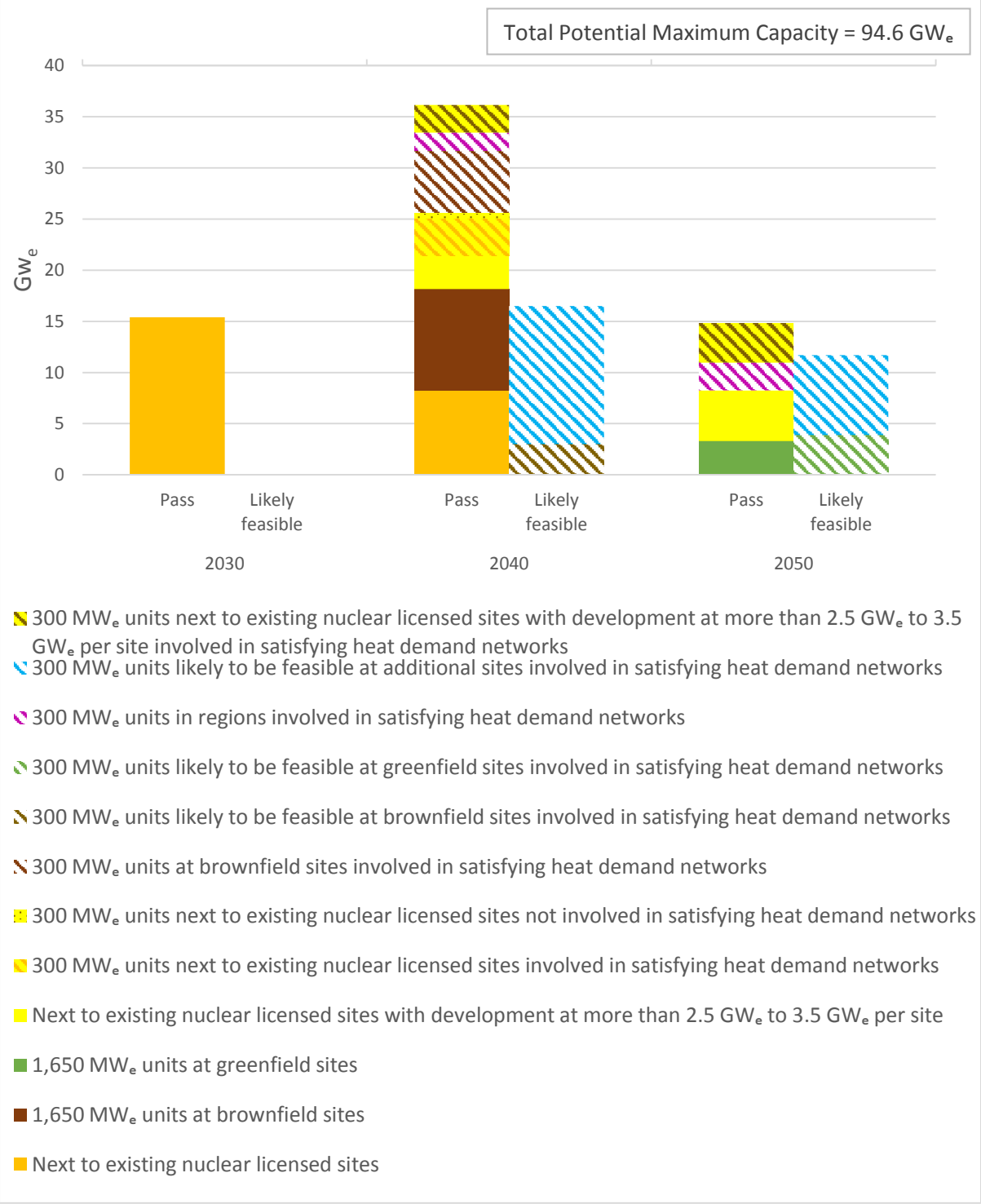
Figure 7-8: Capacity as Shown in Figure 7-7 with Addition of Capacity from 300 MW_e Units at Brownfield and Greenfield Additional Sites



Although inclusion of the previous pathway option increases the total capacity so that it exceeds 75 GW_e, it does not include all the sites required to satisfy the heat demand networks. The next pathway option is to include the 300 MW_e units involving deployment beyond large twin units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear licensed sites which are involved in satisfying the heat demand networks. Including this pathway option means that the total capacity for new nuclear development by 2050 increases by 6.6 GW_e as described in Section 5.3, to 94.6 GW_e as shown in Figure 7-9. The total capacity shown in Figure 7-9 is described as the total potential maximum capacity.

It should be noted that this total potential maximum capacity not only exceeds the 75 GW_e specified in the third deployment scenario for nuclear expansion but also includes all the capacity required to satisfy the heat demand networks once over.

Figure 7-9: Capacity as Shown in Figure 7-8 with Addition of Capacity from 300 MW_e units With Deployment beyond Large Twin Units



As described in Section 5.3, there is still further capacity as follows:

- 7.8 GW_e in brownfield and greenfield regions which are not involved in satisfying the heat demand networks; and
- 10.8 GW_e at brownfield and greenfield additional sites (all of which is only likely to be feasible) which are not involved in satisfying the heat demand networks.

It should be remembered that only 20 inland regions were assessed in the alternative smaller plants sensitivity analysis, as this was the maximum number allowed for in the project. As discussed in

Section 4.4.5 and Section 5.5, the capacity could be increased. Therefore the capacity associated with 300 MW_e units in the brownfield and greenfield regions which were not used to help satisfy the heat demand networks can be viewed as an indicative capacity. It should also be remembered that only 44 additional sites were assessed in the identification of additional sites, as this was the maximum number allowed for in the project. Therefore the capacity could be increased by considering more additional sites. Hence the capacity associated with the 300 MW_e units at additional sites which are not used to help satisfy the heat demand networks can also be viewed as an indicative capacity.

Therefore the total current indicative capacity for new nuclear development by 2050, whilst satisfying the heat demand networks once over, as determined for the second set of options is 113.2 GW_e.

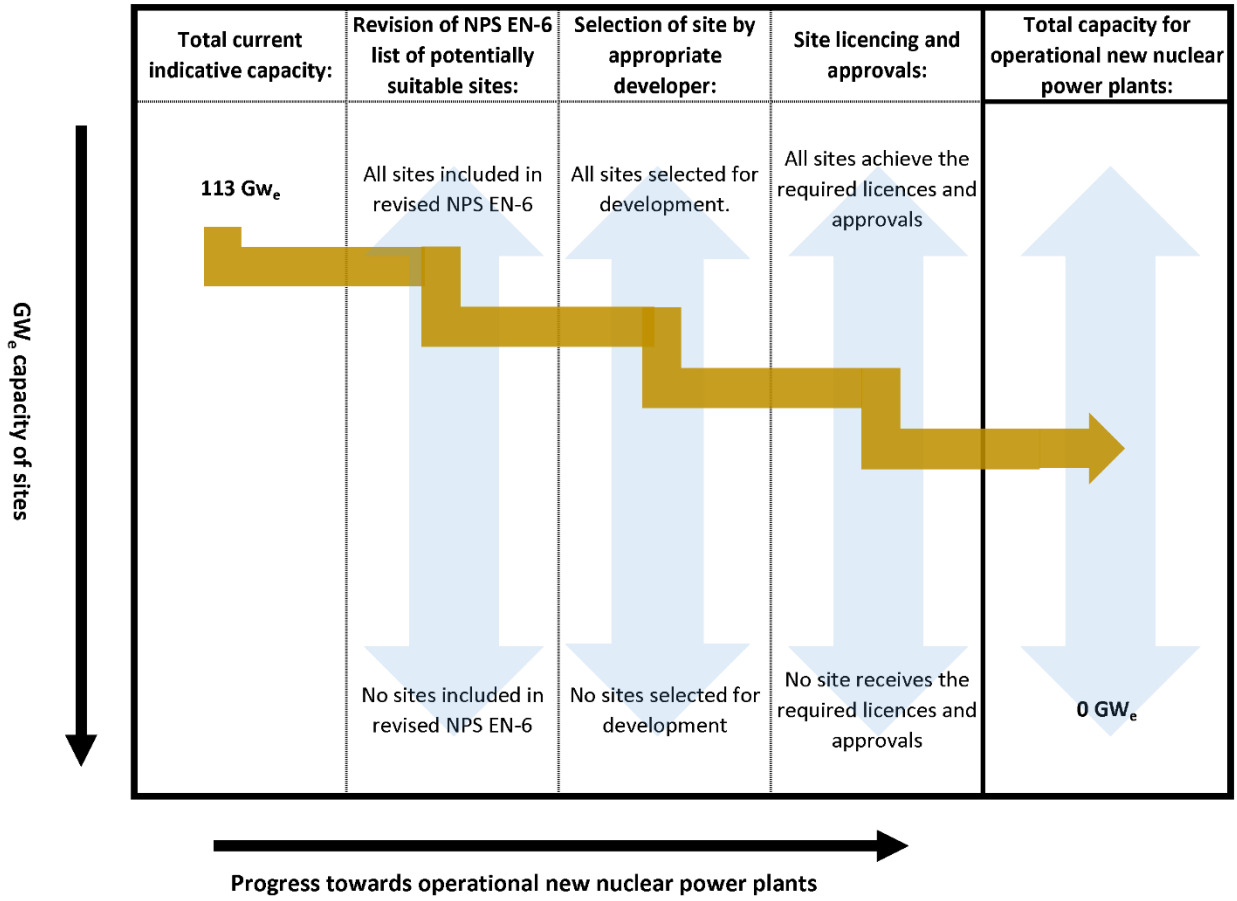
7.3. Uncertainties

All the key uncertainties associated with the assessment of the discretionary criteria presented in Section 6.3 may also affect the results for the second set of options provided in Section 7.2. In addition, there are key uncertainties relating to the optimisation model used in the heat demand networks once over sensitivity analysis that may also affect the results.

7.4. Progress towards Operational Nuclear Power Plants

As stated in Section 2, this project represents the first stage of a multi stage assessment process for new nuclear power plants leading up to the award of a Nuclear Site Licence and the other licences and approvals required for each site. Therefore the total current indicative capacity of 113.2 GW_e determined in Section 7.2 for the second set of options is the starting point that is likely to lead to a lower capacity being deployed by 2050. The generating capacity that is achieved is ultimately dependent on many factors, most of which are beyond the scope of this project. These factors are likely to reduce the number of sites that are developed for new nuclear power plants by 2050, and consequently the 113.2 GW_e capacity determined for the second set of options. Some of these factors are related to the procedural and regulatory requirements leading up to the award of a Nuclear Site Licence and the other licences and approvals required to allow the power plant to operate. The three main steps in that process that need to be met are listed in Section 6.4. Figure 7-10 illustrates the likely reduction in the 113.2 GW_e capacity determined for the second set of options, as a result of procedural and regulatory requirements. The other factors likely to reduce overall capacity are those that relate to site specific characteristics.

Figure 7-10: Likely Reduction in Capacity for Second Set of Options during Progress towards Operational New Nuclear Power Plants



7.5. Conclusions

The required capacity of 75 GW_e of new nuclear by 2050 to meet the third deployment scenario for nuclear expansion is achieved by including seven of the ten possible pathway options. Inclusion of the eighth pathway option provides a total potential maximum capacity of 94.6 GW_e and means that the heat demand networks are satisfied once over. In addition, the 40 GW_e specified in the second deployment scenario for nuclear expansion is achieved by developing 1,650 MW_e units next to existing nuclear licensed sites in England and Wales, at brownfield and greenfield sites and by including deployment beyond twin large units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear licensed site. The total current indicative capacity for new nuclear development by 2050 as determined for the second set of options is 113.2 GW_e.

Further work should be carried out to confirm whether the additional sites pass criteria D1 to D9 when assessed using the assessment methodologies that were employed for the rest of the sites, regions and extensions to nuclear licensed sites considered in the project. The contribution to the total capacity from 300 MW_e units in brownfield and greenfield regions and at brownfield and greenfield additional sites that were not used to help satisfy the heat demand networks can be viewed as an indicative capacity. Further work could be carried out to identify more inland regions and additional sites for 300 MW_e units.

There are key uncertainties associated with the assessment of some of the discretionary criteria that may affect the results for the second set of options. This project represents the first stage of a multi stage assessment process for new nuclear power plants leading up to the award of a Nuclear Site Licence and the other licences and approvals required for each site. Therefore the total current indicative capacity of 113.2 GW_e is the starting point that is likely to lead to a lower capacity being deployed by 2050. The generating capacity that is achieved is ultimately dependent on many factors, most of which are beyond the scope of this project.

8. Conclusions

This project represents the first stage of a multi stage assessment process for new nuclear power plants leading up to the award of a Nuclear Site Licence and the other licences and approvals required for each site. Two sets of options for realising site capacity necessary to deliver 75 GW_e of new nuclear by 2050 were identified. The difference between these two sets of options was that the second set addressed the delivery of 75 GW_e whilst satisfying the heat demand networks once over. The heat demand networks were those that were identified in the System Requirements for Alternative Nuclear Technologies project.

The first set of options for realising site capacity achieves the required capacity of 75 GW_e of new nuclear by 2050 to meet the third deployment scenario for nuclear expansion by including six of the seven possible pathway options. In addition, the 40 GW_e specified in the second deployment scenario for nuclear expansion is achieved by developing 1,650 MW_e units next to existing nuclear licensed sites in England and Wales, at brownfield and greenfield sites and by including deployment beyond twin large units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear licensed sites. The total current indicative capacity for new nuclear development by 2050 as determined for the first set of options is 85.3 GW_e.

In the first set of options, the contribution from 300 MW_e units in the regions and at additional sites can be viewed as an indicative capacity. For the additional sites this is because only 17 of the 31 additional sites that were likely to be feasible were included. Further work should be carried out to identify further additional sites from the 31 additional sites for inclusion in the total capacity by undertaking conjunctive assessment of the overall capacity.

The second set of options for realising site capacity achieves the required capacity of 75 GW_e of new nuclear by 2050 to meet the third deployment scenario for nuclear expansion by including seven of the ten possible pathway options. Inclusion of the eighth pathway option provides a total potential maximum capacity of 94.6 GW_e and means that the heat demand networks are satisfied once over. In addition, the 40 GW_e specified in the second deployment scenario for nuclear expansion is achieved by developing 1,650 MW_e units next to existing nuclear licensed sites in England and Wales, at brownfield and greenfield sites and by including deployment beyond twin units (i.e. at more than 2.5 GW_e to 3.5 GW_e per site) next to existing nuclear licensed sites. The total current indicative capacity for new nuclear development by 2050 as determined for the second set of options is 113.2 GW_e.

Both sets of options allow for the reservation of three brownfield sites for thermal power plants with CCS and the reservation of three extensions to nuclear licensed sites for Gen IV plants. In addition, a separate study identified a total of 22 sites on the coast and estuaries on the east coast of England as potentially suitable for thermal power plants with CCS. It was concluded from this study that, in principle, these should be sufficient sites for thermal power plants with CCS without significantly reducing the capacity for nuclear power plants. However, in practice, particular sites might be taken for thermal power plants with CCS before development for nuclear power plants is progressed.

Key uncertainties associated with the assessment of some of the discretionary criteria may affect the results for both sets of options. As stated above, this project represents the first stage of a multi stage assessment process for new nuclear power plants leading up to the award of a Nuclear Site Licence and the other licences and approvals required for each site. Therefore the total current indicative capacities as determined for both sets of options are the starting points that are likely to lead to a lower capacity being deployed by 2050 than either of the capacities determined for the two sets of options. The generating capacity that is achieved is ultimately dependent on many factors, most of which are beyond the scope of this project. Some of these factors are related to the procedural and regulatory requirements leading up to the award of a Nuclear Site Licence and the other licences and approvals required to allow the power plant to operate. The other factors are related to site specific characteristics.

Two MOD sites that are scheduled for disposal and are located 2 km or less from the coast or estuaries offer potential opportunities for siting nuclear power plants on the timescale of 2040 or 2050, but their overall capacity would be limited. Further MOD sites that are located 2 km or less from the coast or estuaries appear to offer the best opportunities for increasing the number of potential sites and capacity for new nuclear power in the future.

Further work could be carried out to identify more regions and more additional sites for 300 MW_e units. In addition, further work should be carried out to confirm whether the additional sites that are likely to be feasible pass the assessment using the assessment methodologies for criteria D1 to D9 that were employed for the rest of the sites, regions and extensions to nuclear licensed sites considered in the project.

Use of the Environment Agency's Water Resources GIS to determine the availability of cooling water for rivers for criterion D10 - access to suitable sources of cooling water led to some inland sites that previously failed the cooling water sensitivity analysis passing the two river catchments sensitivity analysis. Also, more sites passed in conjunction and the maximum capacity for new nuclear development at the sites was comparable with the established and planned total capacity for thermal generation on the two river catchments.

Relaxing criterion E5 - access to sources of cooling water so that the distance to sources of cooling water was 20 km or less (rather than 2 km or less) provided a greater choice of cooling water sources. This meant that sites could access cooling water sources with greater cooling water availability. This was demonstrated by the fact that three inland sites which failed the cooling water sensitivity analysis on criterion D10 - access to suitable sources of cooling water passed the reappraisal of the long list whilst still using rivers as their sources of cooling water. Criterion D9 - size of site to accommodate operations was also relaxed in the reappraisal of the long list so that the presence of existing development and major waterbodies between the site and the source of cooling water was not taken into account. The other change adopted in the reappraisal of the long list was the use of the Water Resources GIS in the determination of cooling water availability for rivers.

The relaxation of criteria E5 - access to sources of cooling water and D9 - size of site to accommodate operations, in conjunction with the change to the use of the Water Resources GIS, as noted above, was also applied in the identification of additional sites. These changes had the added benefit that the additional sites could be located further from rivers with an accompanying decrease in flood risk.

No allowance was made for any of the effects of climate change in the methodology for criterion D10 - access to suitable sources of cooling water. Work to include the effects of climate change should be carried out.

It can be concluded that the objectives of the project have been met. The project has involved the consistent application of the exclusionary and discretionary criteria. This rigorous approach has allowed the recognition of constraints associated with the identification of sites and opportunities that were pursued, and could be pursued, to increase the total likely maximum capacity. The analyses of the capacity for large units are not final and absolute. It is possible that a developer could be successful in developing a site that has not been considered in the project or that has failed the assessment on two or more of the discretionary criteria. The assessment process has drawn upon what is viewed as being reasonable in terms of good engineering practice, safe and reliable operation, and effects on the environment and other established activities. Further work would be required on all the sites, regions and extensions to nuclear licensed sites identified in the project to confirm their suitability for new nuclear power plants.

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