# Norfolk Boreas Offshore Wind Farm

# Preliminary Design Report

Photo: *Ormonde Offshore Wind Farm*

Applicant: Norfolk Boreas Limited
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## Glossary of Acronyms

| | |
|---|---|
| DAS | Design and Access Statement |
| DCO | Development Consent Order |
| EIA | Environmental Impact Assessment |
| HVDC | High Voltage Direct Current |
| LVIA | Landscpae and Visual Impact Assessment |

## Glossary of Terminology

| | |
|---|---|
| Indicative mitigation planting | Areas identified for mitigation planting at the onshore project substation, Necton National Grid substation extension and the A47 junction. |
| National Grid substation extension | The permanent footprint of the National Grid substation extension. |
| Norfolk Boreas | Norfolk Boreas Wind Farm including the onshore and offshore infrastructure. |
| Norfolk Vanguard | Norfolk Vanguard Offshore Wind Farm, sister project of Norfolk Boreas. |
| Onshore project substation | A compound containing electrical equipment to enable connection to the National Grid. The substation will convert the exported power from HVDC to HVAC, to 400kV (grid voltage). This also contains equipment to help maintain stable grid voltage. |
| The Applicant | Norfolk Boreas Limited. |

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## 1 Introduction

At the Issue Specific Hearing 5 for the Norfolk Boreas Offshore Wind Farm, held on 24th July 2020, a request was made by the Examining Authority, for the Applicant to provide further information regarding the design of the onshore project substation, in accordance with Action Point 12 as follows;

Action 12: Provide materials options for the converter halls and sketch design options for layout, massing and "agricultural style" for the proposed onshore project substation in light of more certainty regarding Norfolk Vanguard, for inclusion in the DAS.

In respect of Action 12 and in order to meet Deadline 14, this Preliminary Design Report has been prepared by OPEN with input from technical specialists at Vattenfall and Royal Haskoning DHV. It has been prepared as further information, which will guide and inform the Design Guide and the detailed design of the Norfolk Boreas onshore project substation. This document presents appropriate design options for the external architectural treatment of the convertor halls which form part of the onshore project substation, taking a responsive approach in respect of the characteristics of the local landscape.

It also considers consultation responses from local stakeholders, which overwhelmingly request that the onshore project substation be made as discreet as is physically possible. The preferred options presented will ensure that the onshore project substation is sensitive to the attributes of the local landscape, with visual impacts minimised as far as is practically possible through the use of appropriate design, building materials, layout, coloration and finishes, albeit whilst also complying with the exact functional requirements which must be adhered to, in order to fulfil performance, quality and safety standards associated with design and build of electrical infrastructure.

This Preliminary Design Report includes an overview of the approach taken based on the established design parameters and principles in existing documentation (Section 2); a review of the materials options for the convertor halls (Section 3); a colour analysis and review of potential façade colours for the external treatment of the convertor halls (Section 4); an overview of the zoning plan (Section 5) and how that could be reflected in an indicative onshore project substation site layout (Section 6) and conclusions relating to the proposed solution for the external appearance of the onshore project substation in terms of materials, colours and layout.

Figure 1: Photo of the Local Landscape 1

# 2 Approach

In terms of the detailed design of the onshore project substation, the initial stage of the approach needs to identify those aspects which present scope to explore alternative design options. The onshore project substation is a component of the electrical infrastructure. As such it has a specific set of functions, forming the terminal equipment to the high voltage direct current cables, and converting the direct current to alternating current for input into the National Grid.

The principal concern in the design of the onshore project substation, therefore, is that it meets its functional requirements and adheres to the safety, performance and efficiency standards that are set out in all relevant policy and guidance. Aspects typically considered in architectural design are set out below along with commentary regarding the potential scope for these aspects to undergo an exploration of design alternatives in respect of the onshore project substation.

## 2.1 Form and Mass

The form of the converter halls is determined by the space required to house the indoor components of the electrical infrastructure. The converter halls will, therefore, be no bigger than they are technically required to be to serve this function and within the maximum parameters defined by dDCO Requirement 16 (5); must not exceed a height of 19m above existing ground level and Requirement 16 (6); the total footprint of each convertor hall must not exceed 110m by 70m. The form of the converter halls will be determined by the rectangular footprint within which the electrical components are arranged. This layout determines a large rectangular building and while the shape of the roof presents various design options, the preferred option would be to use a traditional pitched roof as this would be most in-keeping with rural Norfolk. It would also reduce the perceived scale of the converter halls by drawing down the height of the wall heads, rather than building them up as would be required if a flat roof structure were to be used. While the scope for design options in terms of shape and mass are limited, Section 5 presents the Zoning Plan for the site, while Section 6 presents Isometric Visuals illustrating how the form and mass of the converter halls sit in the landscape.

## 2.2 Style

Large scale agricultural sheds are a common feature in the Norfolk landscape. The relatively flat and low-lying nature of the landscape means that these large structures can often appear exposed, apart from where woodland offers some form of screening. In order that the converter halls appear as discreet within their landscape setting, as is practically possible, it is proposed that this familiar style of functional shed is used. This will ensure that the converter halls do not appear as an unfamiliar style of building by paying reference to the many other modern-style sheds with a similar appearance. It would not be appropriate to mimic the more traditional style of agricultural sheds as they are of a much smaller scale and made of materials inappropriate for housing electrical infrastructure. The functional requirements of the converter halls limit the design options for the style of the architecture.

## 2.3 Materials

While the choice of materials for the construction of the converter halls will be largely influenced by their functional requirements, there is scope to explore a small range of options, which could potentially be appropriate. Section 3 sets out a comparative analysis of material options based on a set of criteria specific to the requirements of the converter halls, as well as other criteria including appearance, sustainability and cost.

## 2.4 Colours and Finishes

The choice of colours and finishes for the external surfaces of the converter halls presents the greatest scope in terms of alternative design options. These are explored in Section 4, where different colour options are applied to visualisations of the converter halls, in order to identify the most subtle appearance.

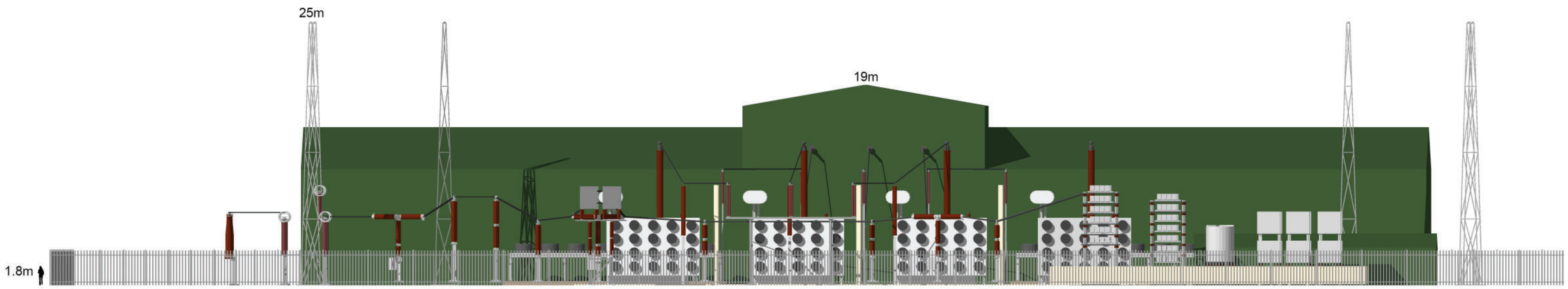


**Figure 2: Elevational Visualisation of Model**

# 3 Materials

## Consideration of Material Options

In this section, a comparative analysis of potentially suitable materials is presented, based on the technical requirements of the converter halls, as well as other important considerations.

The key technical requirements of the materials to be used in the construction of the converter halls are set out below;

- Strong enough to form robust and secure large-scale structures;
- Fire resistant and able to withstand high temperatures without the structural integrity of the material being compromised;
- Resistant to severe weather conditions, including high winds, water ingress and heat waves;
- Forming surfaces and joints that are completely impermeable to water;
- Suitable to form the large spans and surfaces required to construct large structures;
- Sufficiently durable to withstand the impacts of a 30 year lifecycle; and
- Low maintenance.

In addition to these key requirements there are other criteria that need to be considered in the selection of materials, which include;

- Volumes required and associated costs;
- Extent of prefabrication or in-situ construction of materials and associated requirement for specialist skills on site;
- Sustainability in terms of extraction and manufacture, transportation, construction processes and end of lifecycle re-use or recycling; and
- Appearance of materials, in terms of colour, texture and reflectiveness.

The four different materials considered in this comparative assessment include masonry, timber, fibre cement and sheet steel. In this section of the report, each of these four materials is assessed against the key technical requirements and other criteria, set out above.

**Figure 3: Materials** **Source:** Dezeen, Switchgear Station, C.-F.-Moller

**Figure 4: Materials** **Source:** Virkkunen & Co Architects, Lauttasaari electrical substation

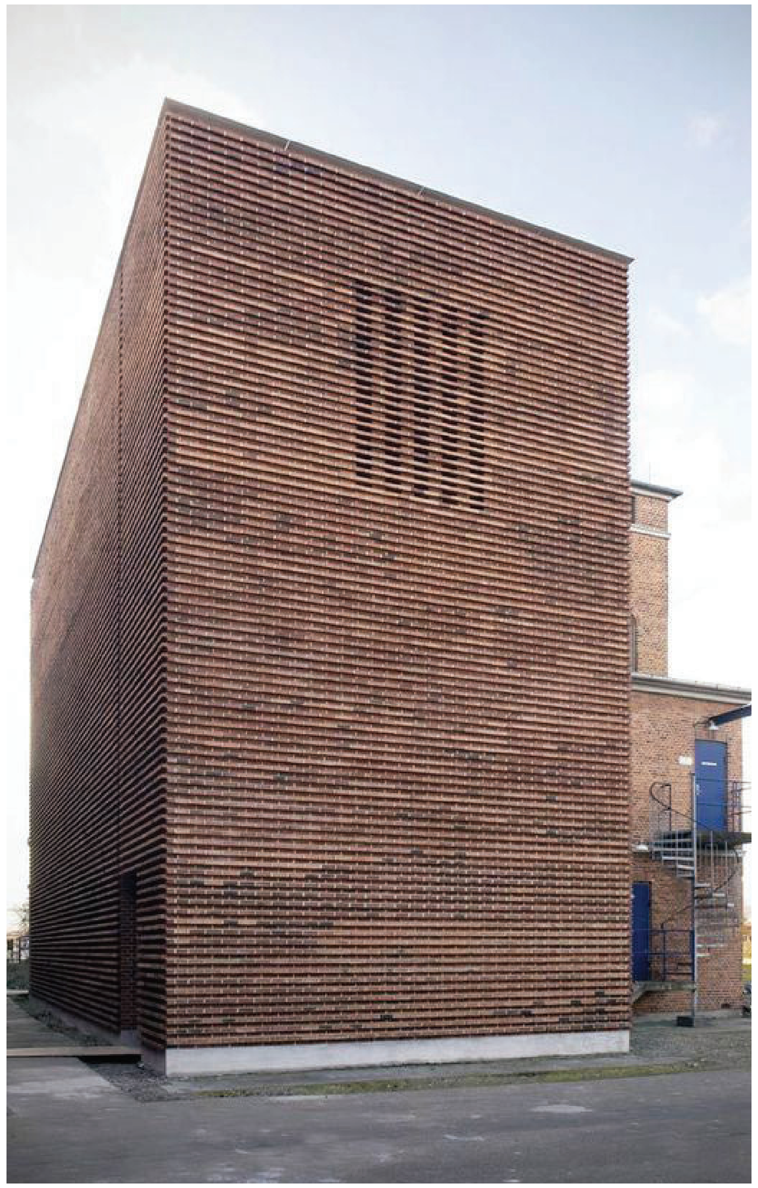

**Figure 5: Materials** **Source:** Gottlieb Paludan Architects, H.C.Ørsted Power Plant

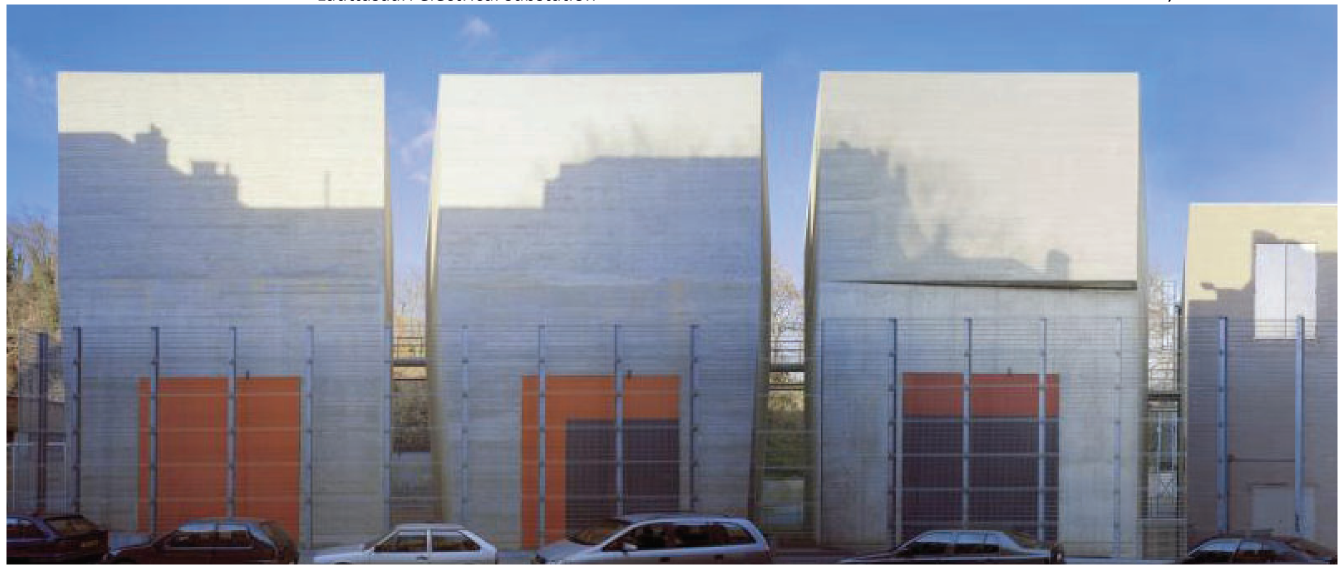

**Figure 6: Materials** **Source:** Substation Rou Pouplin (Dethier Architecture)

## 3.1 Masonry

Advantages

- Masonry can be used to build a strong and robust structure.
- Masonry is inherently fire resistant and can help keep the interior cool despite hot external conditions.
- Masonry provides good protection against severe weather conditions such as storms and heat waves.
- Masonry should provide a water-tight and impermeable structure, providing cavity walls and damp-proof courses are well-designed and carefully constructed.
- Masonry buildings are durable and low maintenance.
- It is possible to source most types of masonry relatively locally within the UK, thus reducing travel time, and masonry can be salvaged for re-use on other projects at the end of the lifecycle of the structures.

Disadvantages

- Masonry is not commonly used for such large-scale buildings in rural locations or to house electrical infrastructure.
- The colour range available is restricted to the natural colours of the materials or the colouring of the bricks.
- On site fabrication of large-scale buildings is time consuming and will increase the length of time for construction.
- Construction requires skilled tradespeople.
- All forms of masonry are comparatively more expensive, especially natural stone.
- The masonry just provides the external skin and an internal structure for support will still be required.

Figure 7: Masonry Example 1 **Source:** London Olympics Substation (NORD)

Figure 8: Masonry Example 2 **Source:** Marbjerg Waterworks, Roskilde_Gottlieb Paludan Architects

## 3.2 Timber

Advantages

- Timber is a renewable and recyclable material that can be sustainably sourced in the UK.
- Timber is a relatively low cost material that is readily available from local sources in the UK.
- If specified and detailed correctly, timber can provide a durable and relatively low maintenance material.
- Timber structures can be readily and quickly assembled on site from prefabricated sections and panels.
- The natural appearance of timber can fit well in a rural context where woodland and hedgerows provide enclosure.

Disadvantages

- Timber poses a serious fire risk in respect of the construction of the converter halls and would require special fire protection systems.
- Timber can be a high maintenance material which requires ongoing treatment to avoid deterioration in its appearance and structure.
- Timber can be susceptible to water leaks through joints, especially if flooding or storms occur.
- On site fabrication of large-scale buildings is time consuming and will increase the length of time for construction.
- The small scale of the wooden cladding can emphasis the large scale of the structure.
- An internal skin to the timber exterior is still required.
- Timber is susceptible to impact damage and insect attack if not properly treated.

**Figure 9: Timber Example 1** **Source:** Sick & Fischbach Architects, warehouse in Ochsenhausen

**Figure 10: Timber Example 2**

## 3.3 Fibre Cement

Advantages

- Fibre cement provides a robust material that is fire resistant, relatively low maintenance and relatively durable.
- Fibre cement is a relatively low-cost material that is readily available from local manufacturers in the UK.
- Fibre cement structures can be readily and quickly assembled on site from prefabricated panels.
- Large scale sheds made from fibre cement are a common feature in rural landscapes.
- Fibre cement can be recycled at the end of the lifecycle of the structure.
- Fibre cement presents a subtle matt finish in relatively subdued shades of grey that can appear fairly discreet in landscape settings.

Disadvantages

- Fibre cement sheets are smaller than metal sheets and therefore require more time for construction.
- Fibre cement panels can be heavy which means a more robust structural support system is required and larger foundations.
- An internal skin to the fibre cement is still required.
- The high cement content reduces the sustainability of this material as cement requires the extraction and treatment of raw minerals.
- The colour range available is restricted to shades of grey unless colour specified for bespoke panels.
- Fibre cement is susceptible to impact damage.

Figure 11: Fibre Cement Example 1 Source: Marley Eternit

Figure 12: Fibre Cement Example 2 Source: Coverworld UKl

## 3.4 Sheet Metal

Advantages

- Sheet metal provides a robust material that is fire resistant, very low maintenance and durable.
- Sheet metal is a relatively low-cost material that is available from local manufacturers in the UK.
- Prefabricated sheet metal panels are large and lightweight and can be readily and quickly assembled on site.
- Large scale agricultural and industrial sheds made from sheet metal are a common feature in rural landscapes.
- Sheet metal can contain recycled steel and also be recycled at the end of the lifecycle of the structure for reuse on other structures.
- Sheet metal provides a complete cladding system with no additional layers required.
- Insulated sheet metal panels will last beyond the 30 year lifecycle of the converter halls.
- The colour range available is extensive with also different types of finish available, making colour matching to local contexts possible.

Disadvantages

- Sheet metal can present a reflective surface if the appropriate finishes and coatings are not applied.
- Corrugated sheet metal can present a utilitarian appearance that looks unfinished.
- The smooth appearance of sheet metal can lack the texture and interest of other materials such as timber or masonry.
- The extraction of raw materials and production of sheet metal reduces the sustainability of this material, especially if also imported from overseas.
- Sheet metal is susceptible to impact damage.

**Figure 13: Sheet Metal Example 1** **Source:** Kingspan Corrugated Sheet, Asda Didcot Distribution Centre

**Figure 14: Sheet Metal Example 2** **Source:** Unstudio Architects, Electricity substation (50/10 kV)

### 3.5 Materials Conclusions

The comparative analysis of materials demonstrates that sheet metal is the most appropriate material for the construction of the converter halls. This is largely owing to its high performance and safety standards, as well as the ease with which it can be constructed, its robustness, durability and low maintenance requirements, its existing use in surrounding agricultural buildings and the range of colours which enable a colour match with the local landscape, as presented in Section 4: Colours, below.

The visualisations presented below presents a comparison between the use of smooth sheet metal panels (Figure 15) and corrugated metal sheets (Figure 16). This shows that from the distances at which the converter halls are likely to be viewed, the differences will be largely indiscernible. The options regarding finishes, such as smooth or corrugated will be considered further in the Design Guide. These visualisations demonstrate the 'Dark Green' colour used in the EIA visualisations.

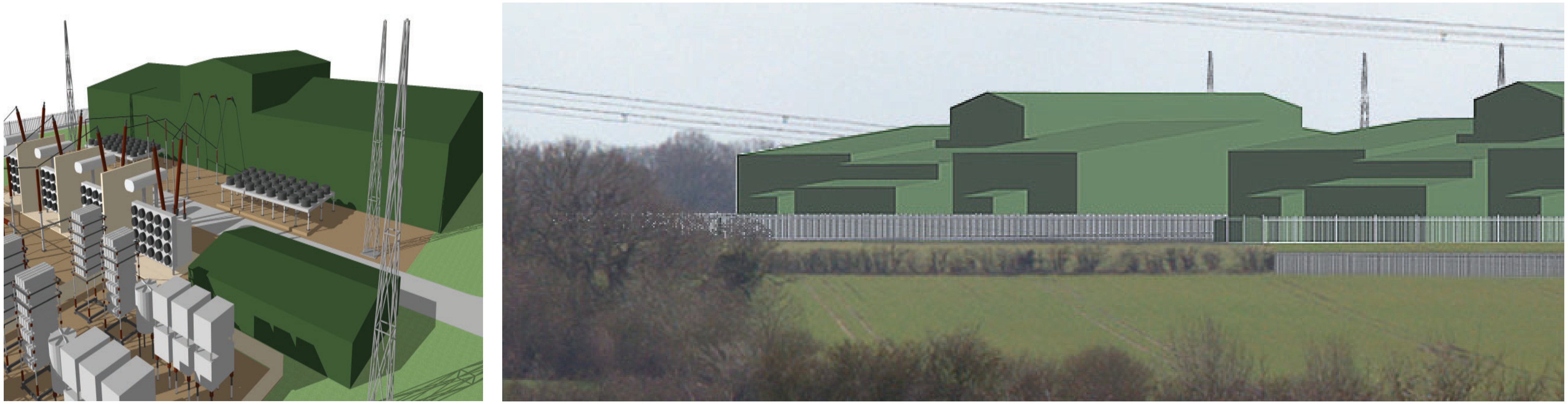

Figure 15: Smooth Finish Visualisation

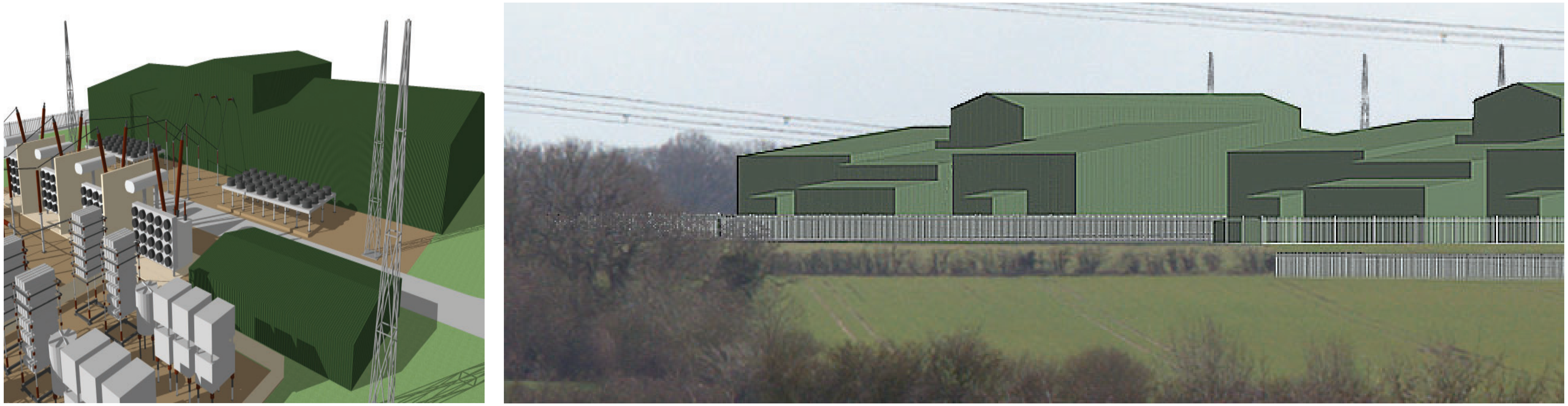

Figure 16: Corrugated Finish Visualisation

## 4 Colours

While the choice of materials to be used in the construction of the converter halls will be largely influenced by their functional requirements, the principal purpose in the selection of the colours and finishes is to ensure the converter halls are as discreet within their landscape setting, as is practically possible. The approach taken to test out various colour options, makes reference to the visual impact assessment carried out as part of the Norfolk Boreas EIA.

Those aspects of the assessment that are relevant to this report include an understanding of the extent to which the converter halls will be visible across the local landscapes and where this visibility coincides with roads, paths and settlements, thus highlighting those people whose views will be affected by the converter halls. These views are represented by the viewpoints used in the assessment. An understanding of how the converter halls are seen to sit within the landscape from these viewpoints is then important, in terms of whether they sit against an open skyline or enclosed woodland, as this will make a difference in terms of what colourings and finishes will work best to keep them as discreet as is practically possible.

Other important considerations include whether the converter halls are being viewed from the south or the north, as in views from the south they will be front-lit which means not only will colour choices appear brighter than in views from the north, but that finishes have a notable effect on the potential glare that can occur in views from the south. It is also important to remember how the colours in the landscape change, especially in a farmed landscape where rotational systems of crop growing can alter the colouration of the patchwork field pattern both seasonally and annually.

The process to explore the potential colour options combines an understanding of the colours present in the local landscape and the colours available in respect of the materials to be used. The comparative analysis of materials in Section 3 concluded that sheet metal clearly presented the most appropriate option in respect of the technical requirements of the converter halls. Sheet metal also presents a wide choice of colour options and finishes, which in terms of the design of the converter halls provides the scope to ensure a subtle and recessive appearance.

Figure 17: Photo of the Local Landscape 2

## 4.1 Colour Palette

Site work and photography have helped identify those colours that make up the farmed and wooded patchwork of the local landscape. These colours have been used as the basis for a colour match with the range of colours available as coatings for Kingspan metal sheeting. Rather than explore a broad range of colours, this analysis has looked to define a narrower range of more subtle and recessive colours that best match those colours in the local landscape, and in so doing will help to reduce the visual impact of the converter halls.

The colour palette presents the original dark green used in the EIA visualisations, along with eight alternative options. These are based on a natural, and relatively neutral palette of greens, greys and browns, all of which are suitably muted in tone. The visualisations on the following pages test out the colour options by applying these eight colours to the external surfaces of the converter halls. The viewpoint from the A47, opposite Spicer's Corner has been used, as, of all the EIA viewpoints, this shows the fullest extent of the converter halls. The Scenario 1 visualisation, used in the EIA, has been used to illustrate the different colour options. This is in order to ensure the visualisations illustrate the worst case scenario with the Norfolk Boreas and Norfolk Vanguard onshore project substations visible together.

While the visualisations show a single colour applied for each option, there is potentially scope to apply two or more colour options together. For example, a darker shade could be used around the lower level and a lighter colour around the upper level of the converter halls to enable the colours to better match the darker shades of the surrounding woodland and farmland and the lighter shades of the sky. Similarly, different colours could be used on the different aspects, for example, to enable the brighter front-lit sides to be toned down appropriately. This broader scope of colour selection will be explored further at the detailed design stage.


**Figure 18: Colour Palette**

## 4.2 Colour Options


**Figure 19: Dark Green Visualisation**


**Figure 20: Camouflage Visualisation**


**Figure 21: Goosewing Grey Visualisation**


Figure 22: Hollybush Visualisation


Figure 23: Khaki Green Visualisation


Figure 24: Merlin Grey Visualisation


Figure 25: Mushroom Visualisation

## Colour Options


Figure 26: Olive Green Visualisation


Figure 27: Quartz Grey Visualisation

## 5 Zoning Plan

The Zoning Plans (as presented in Figures 9 and 10 of the Design and Access Statement) illustrate the basic principle underpinning the indicative layout of the site for each scenario; whereby the converter halls will be located in the northern part of the site and the outdoor electrical infrastructure will be located in the southern part of the site.

Figure 28 shows Scenario 1, in which the Norfolk Boreas and Norfolk Vanguard projects would be implemented (although only Norfolk Boreas is shown on the Zoning Plan), and Figure 29 shows Scenario 2 in which only the Norfolk Boreas project would be implemented.

In both scenarios the converter halls would be located in the northern part of the site. This arrangement is guided by the functional requirement for the converter hall to connect the incoming HVDC cables to the north and for the outdoor electrical equipment to connect the outgoing 400 kV cables to the south.

This arrangement also has the advantage of keeping the larger structures grouped together and furthest away from settlement to the south. Furthermore, this configuration has been designed to optimise the enclosure afforded by Necton Wood, which sits to the north of the site and which provides a natural backdrop in views from the south, as well as screen in views from the north.

The Zoning Plans will form the basis of the detailed design that will be implemented post-consent.

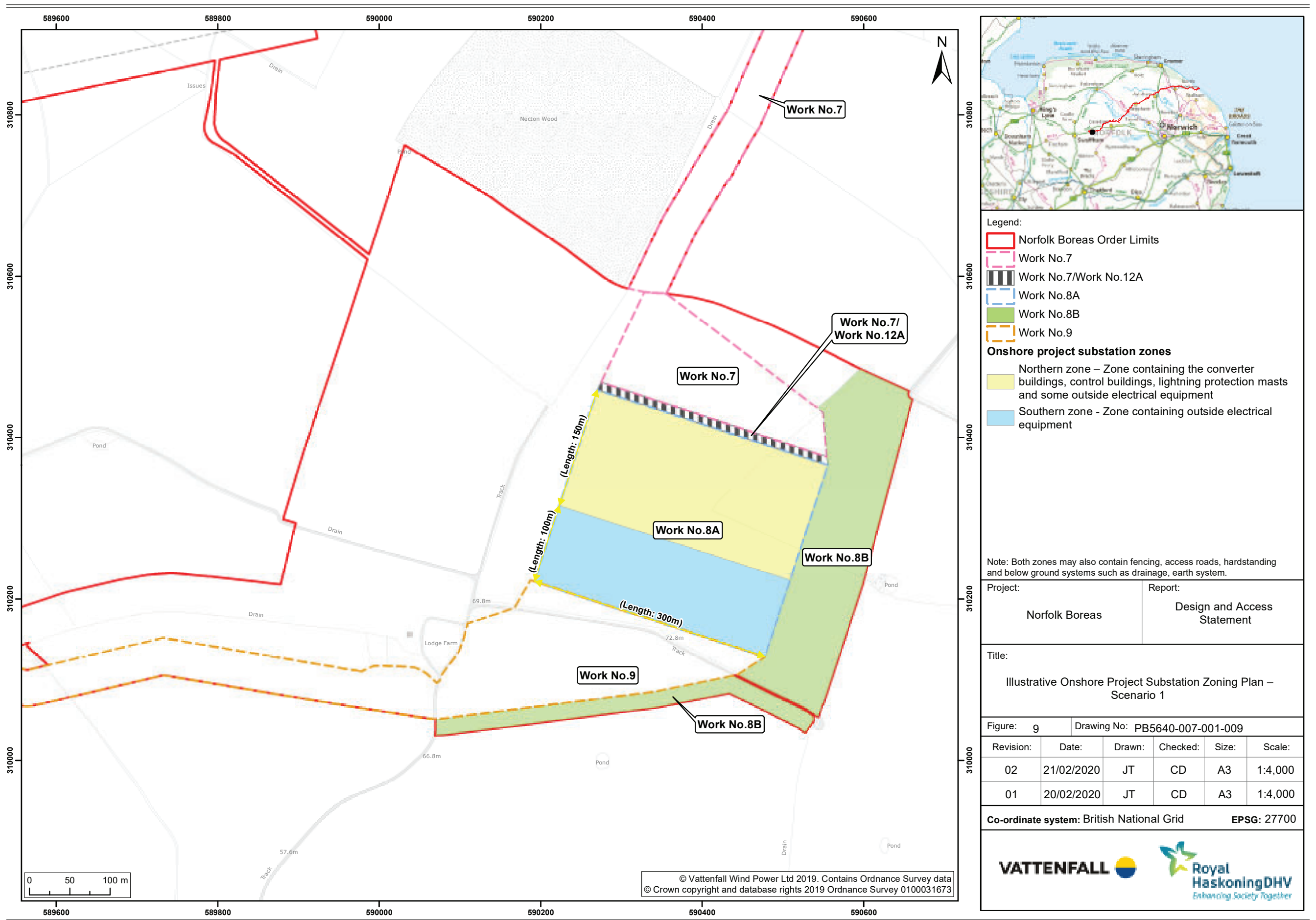


Figure 28: Scenario 1 Zoning Plan

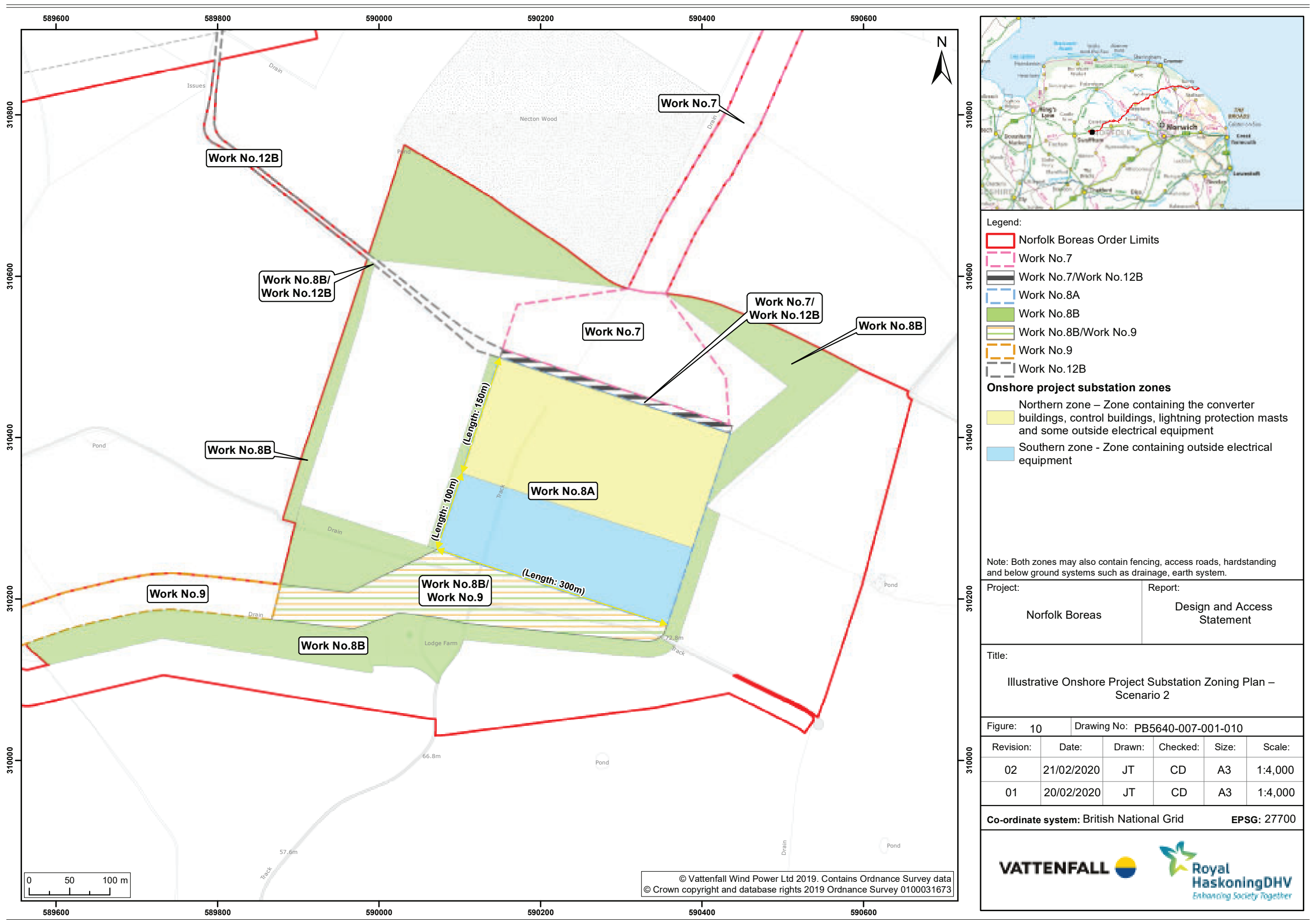


Figure 29: Scenario 2 Zoning Plan

## 6 Site Layout

Isometric visualisations have been prepared to illustrate how the Scenario 1 and Scenario 2 onshore project substations would sit in the landscape, as seen from a 'bird's eye view'. Figure 30 shows Scenario 1, in which the Norfolk Boreas and Norfolk Vanguard projects would be implemented, and Figure 31 shows Scenario 2 in which only the Norfolk Boreas project would be implemented.

The elevated viewpoint is positioned to the south-east of the site. The visualisations show the indicative model that was used in the EIA visualisations. While this presents an indicative interpretation of the onshore project substation, it does represent the key functional requirement underpinning the Zoning Plan, in which the converter halls are to be located in the northern part of the site, and the outdoor electrical infrastructure in the southern part.

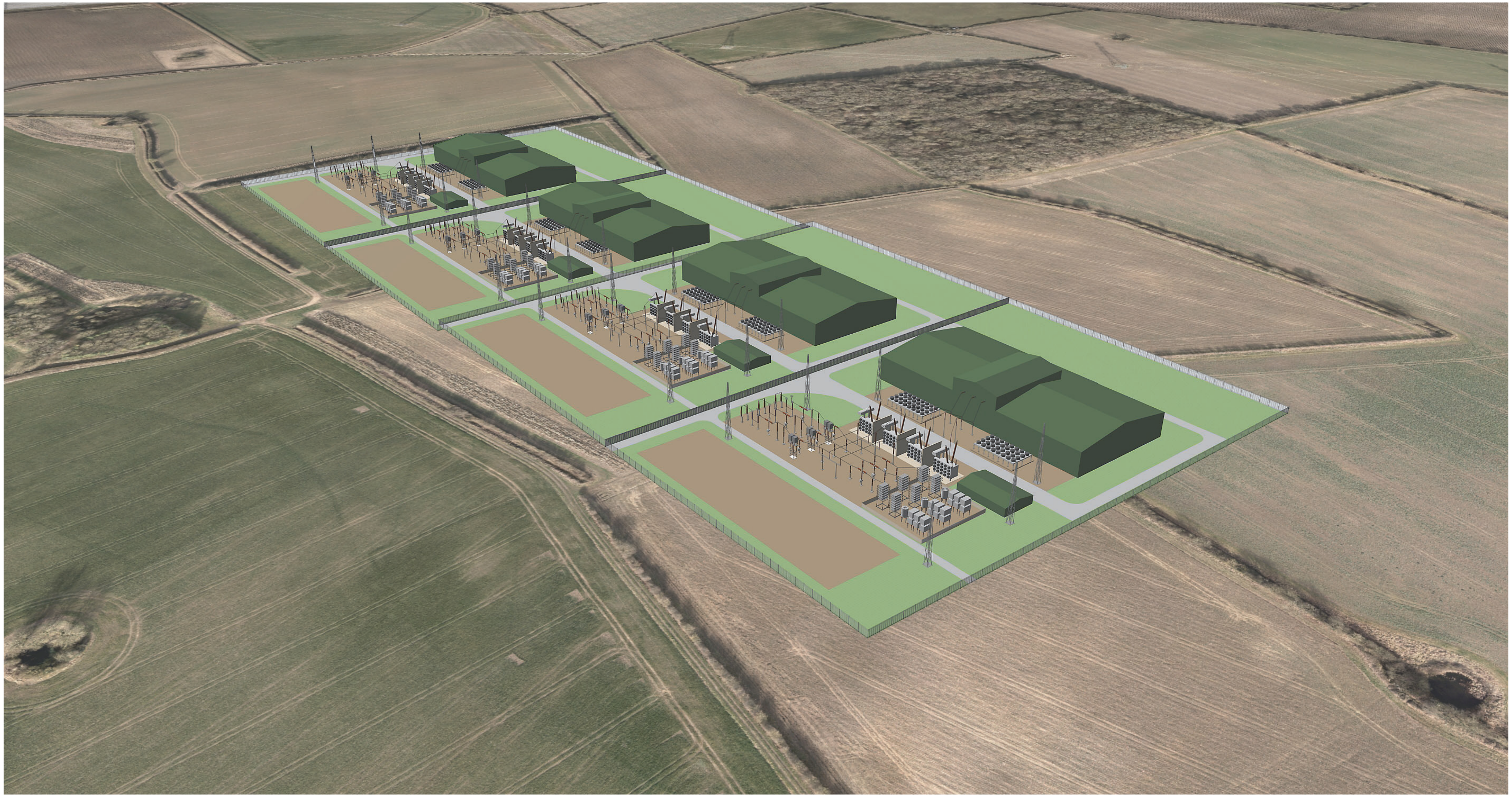

**Figure 30: Scenario 1 Isometric Visualisation**

Figure 31: Scenario 2 Isometric Visualisation

## 7 Summary

This Preliminary Design Report has been prepared in response to a request from the Examining Authority made as part of Norfolk Boreas Offshore Wind Farm Issue Specific Hearing 5. The request sought further information regarding the design of the converter halls, which form part of the onshore project substation. The detailed design of the converter halls will not be progressed until post consent, as new advancements in technology are likely to take place between application and post-consent stage, which could potentially make contemporary designs for the converter halls obsolete. Furthermore, detailed design requires the input of specialist contractors who are yet to be appointed.

The most important consideration in the design of the converter halls is that they meet the exact functional requirements as set out by Health and Safety obligations, Electrical Safety Regulations and electrical design specifications. These requirements inevitably impose restrictions in terms of the scope within which alternative design options can be explored. The size, form and mass of the converter halls will be determined by the size, form and mass of the electrical infrastructure they are required to house. In order to make these large buildings as discreet as is practically possible, the design must be simple and honest.

A modern-style shed structure presents the most suitable option as it will not draw undue attention, owing to the simplicity of its form and its association with the other similar modern-style shed structures, which are dispersed across the Norfolk landscape. It would also be somewhat dishonest to dress the converter halls up as a traditional farm sheds, when they are substantially larger and performing a completely different function. In respect of the suitability of traditional materials, such as timber, Section 3: Materials sets out the comparative disadvantages of using these materials in the construction of the converter halls.

While a comparative study has been used to explore the scope for alternative materials to be used in the construction of the converter halls, the outcome has been dictated by the very specific and stringent technical requirements associated with housing electrical infrastructure. Sheet metal is by far the most appropriate material, especially in light of the high performance and safety standards required when dealing with high voltage electrical infrastructure.

The colour and finishes for the materials, presents the most extensive scope, in terms of design options, with colour presenting the greatest scope for altering the appearance of the converter halls, as demonstrated by the colour test visualisations. This is why the focus of this report has been on the selection of colours and finishes that will help blend the converter halls in with the local landscape. To this end, the exploration of the colour options has highlighted the most subtle tones as being most appropriate.

This Preliminary Design Report sets out the initial parameters regarding the design options for the converter halls at the onshore project substation. Information in this report, as well as in the DAS, will be developed further as the project progresses and the iterative design evolves. This process and its outcomes will be documented in a Design Guide to accompany the final detailed design.