Oil & Gas
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Gas-to-Wire: UK SNS & EIS

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Photograph courtesy of Jan Arne Wold/Equinor.

Contents

1. Executive Summary

The UK Southern North Sea (SNS) and East Irish Sea (EIS) are established production basins. Since the 1960s, numerous gas fields have been brought on-stream following the development of extensive infrastructure. A more recent development has been the installation of large offshore windfarms in the vicinity of these gas fields. The addition of offshore electrical infrastructure (including sub-station platforms and subsea cables) to export windfarm power to shore has, in effect, extended the UK's national grid into the SNS and EIS.

The UK now generates more electricity from offshore wind than any other country in the world (Reference 1). Installed capacity, chiefly in the SNS and EIS, is currently at 6.8 GW, an increase of 1.7 GW since 2016 and is set to increase to 10 GW by 2020. Due to the intermittence of wind, annual utilisation factors of the associated power infrastructure are typically 40%.

This 'ullage' (spare capacity) in this power infrastructure presents an alternative route for the monetisation of nearby gas reserves, be that from currently-producing fields or in stranded resources. By the installation of offshore power generation facilities, operators could export electricity via established windfarm infrastructure instead of exporting gas to shore by pipeline.

Remaining SNS gas reserves are estimated at 2.8 trillion cubic feet (tcf) in current fields with a further 2.6 tcf of resources in proposed new developments, and 5.5 tcf in undeveloped discoveries and prospects (Reference 2). The EIS adds a further 0.5 tcf of reserves. Just one offshore 'gas-to-wire' facility could utilise around 2 bcf per annum and generate enough electricity to power around 50,000 homes.

In this document, the OGA sets out to describe the technical considerations associated with gas-to-wire in the SNS and EIS. It is noted that other benefits can be derived from gas-renewables collaboration including the reduction in operating costs, for instance by pooling logistics and establishing common standards.

2. Background

2.1 UK Southern North Sea & East Irish Sea

The UK SNS and EIS are established production basins which have contributed to the nation's energy supply for some fifty years. Since the 1960s, numerous gas fields have been brought on-stream following the development of offshore infrastructure routed to onshore terminals.

A more recent development, has been the installation of several large offshore windfarms. These are often close to or, in some cases, directly above gas fields. The addition of offshore electrical infrastructure (including sub-station platforms and subsea export cables) to export windfarm power to shore has in effect extended the UK's national grid into the SNS and EIS.

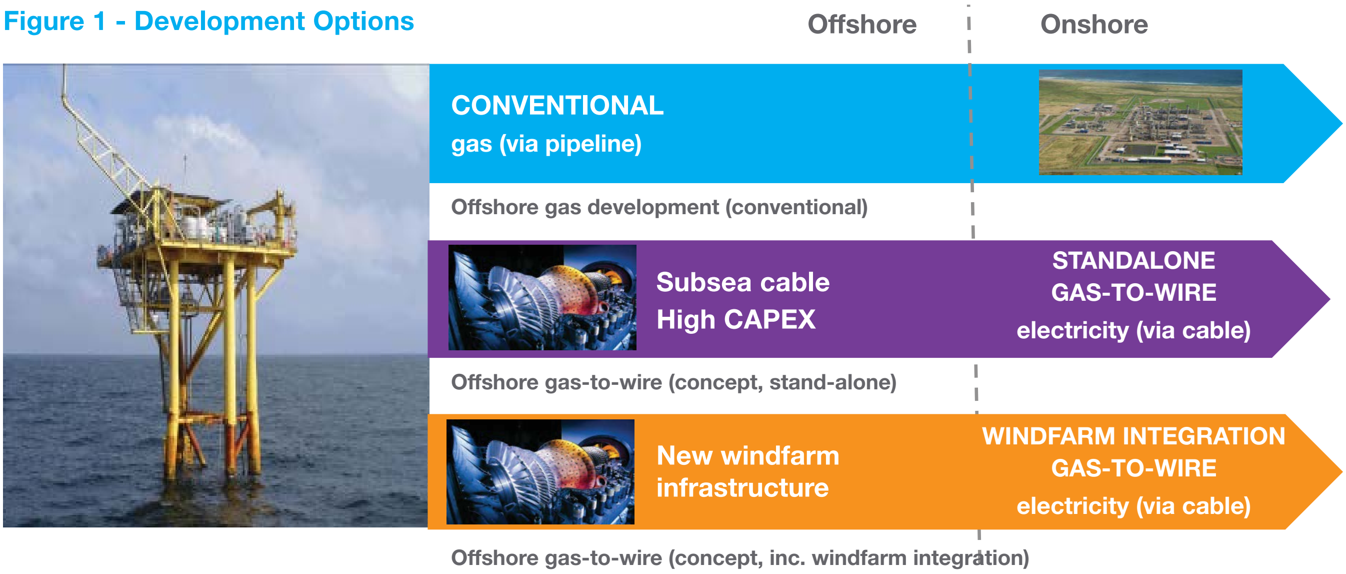
Key considerations currently noted in the gas and electrical sectors:

- **Gas:** a large cumulative volume of gas (chiefly in remote, marginal pools) remains uneconomic to develop by conventional means. Meanwhile, existing late-life fields, now operating well below peak production and facing increasing unit operating costs, are approaching the end of their economic life and cost-intensive decommissioning
- **Electricity:** the growing proportion of offshore wind power within the UK national grid creates technical and commercial complexities due to its intermittent nature. Flexible, low-cost power generators, such as gas, could prove to be in greater demand in future, especially to balance out troughs in windfarm output and to provide 'peak shaving' capacity at times of high grid demand

2.2 Gas-to-Wire

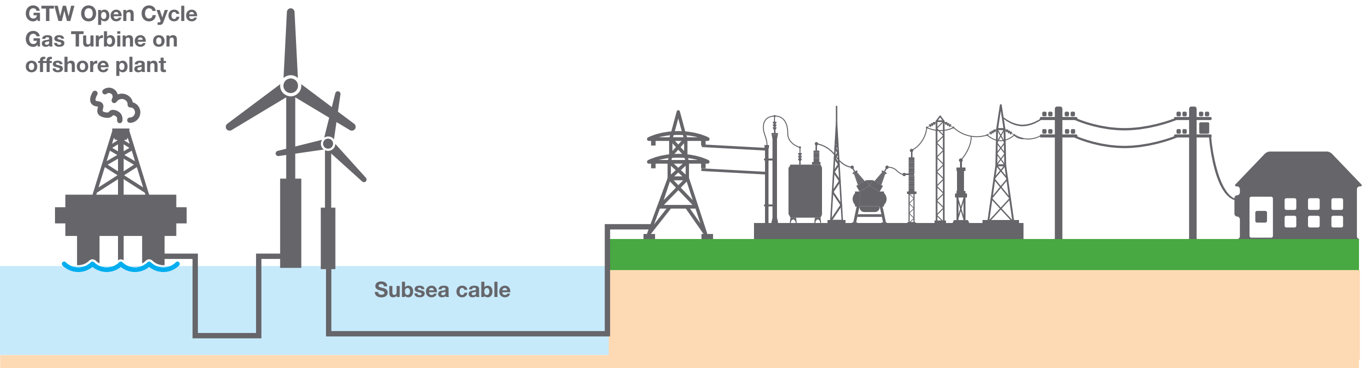
The gas-to-wire (GTW) concept refers to the burning of gas offshore (in power generation facilities local to gas fields) with the electricity transmitted to shore via subsea cable. Existing hubs could be fully converted (such that all gas produced would be converted to power) or partially converted (such that the existing gas export route would be retained in conjunction with the new power export route).

Figure 1 - Development Options



In the overall concept, power generated from an offshore GTW facility would be routed to shore via the export cable installed for the nearby offshore windfarms. As a relatively flexible and fast-responding form of power generation, it could play a useful role in balancing the electricity grid as supply and demand fluctuates.

Figure 2 - GTW - overall concept



2.3 Alternatives

Whilst this document exclusively refers to GTW, alternative gas-renewables integration opportunities also exist. With the Netherlands offshore sector facing similar challenges to those in the UK SNS, the OGA has established a dialogue with the Netherlands Organisation for Applied Scientific Research (TNO) to support knowledge-sharing and to investigate future opportunities for trans-boundary infrastructure development. In the Netherlands, short, medium and long-term energy integration strategies are under consideration (Reference 3).

2.3.1 Platform Electrification

Typically, offshore oil and gas platforms burn fuel gas in turbines to meet their own power requirements, be that mechanical (to drive large rotating equipment) or electrical. The unit costs and emissions of such offshore power generation schemes are relatively high compared to an onshore equivalent.

The opportunity now exists for platforms to import electricity from offshore wind power facilities which have been installed nearby. Operators of offshore gas compression hubs in the Dutch sector are currently investigating power import options from windfarms. If the power export cable is bi-directional, platforms can import power from the onshore grid when windfarm output is low (Reference 4).

2.3.2 Power-to-Gas

Whilst GTW converts gas molecules into electricity for export via cable, the power-to-gas (PTG) concept refers to the reverse. In PTG, offshore windfarm power is used to generate hydrogen via electrolysis of seawater which can be exported to shore via existing gas pipelines. This creates a more flexible form of renewable energy which can be supplied to shore (for use in power generation, transportation and petrochemicals) via existing gas export infrastructure. In the Netherlands, research is under way investigating the feasibility of conversion of offshore gas infrastructure to hydrogen (Reference 5).

2.3.3 Other

Beyond the physical integration of offshore gas and wind in the SNS and EIS, there also exists an opportunity to create synergies between the two sectors, such as the development of common standards and marine / aviation logistics sharing. The OGA will actively promote such synergies with the potential to drive increasing cost efficiency across the SNS and EIS.

2.4 Activity to Date

Several UKCS operators have contacted the OGA in recent years to discuss their interest in integration with windfarm operations.

In early 2018, the East of England Energy Group (EEEGR), with support from the OGA, established an industry-led work group intended to assess the opportunity for integration between the oil and gas and renewable sectors. Three key strands of activity have been defined:

- **Activity integration:** sharing of ‘day to day’ operations (including offshore logistics) to improve efficiency and reduce area operating costs
- **Co-existence:** ensuring co-ordination of key activities in both sectors e.g. aviation, and shipping routes, cable and pipeline installation
- **Energy integration:** technology-driven full-scale integration of operations, such as GTW and PTG

Participants include leading operators and members of the supply chain from the oil and gas and renewable sectors.

3. Technical Assessment

Whilst individual elements of offshore GTW are already proven separately (e.g. offshore gas production, gas-fired power generation, subsea power transmission), the overall concept is yet to be commercialised. Further technical considerations in a development concept are likely to be field-specific, a number of which are noted below.

3.1 Gas Turbine

Gas turbine concepts considered consist chiefly of:

- Combined-Cycle Gas Turbines (CCGT)
- Open-Cycle Gas Turbines (OCGT)

3.1.1 CCGT

The bulk of onshore UK gas-fired power generation capacity is CCGT. Consisting of a gas turbine and a secondary steam turbine (for the recovery of further energy from waste heat), CCGT can achieve high thermal efficiencies. Whilst more operationally-flexible than coal and nuclear generation, its efficiency is nevertheless reduced when operating at fluctuating output such as when called upon to compensate for intermittent wind generators.

3.1.2 OCGT

OCGT, consisting solely of a gas turbine (with no waste heat recovery) has a lower efficiency than CCGT but is more operationally-flexible whether from a ‘black start’ i.e. from cold or as a ‘spinning reserve’.

Furthermore, with a much smaller ‘footprint’, OCGT, especially using aero-derivative machinery already commonly used offshore, is well-suited to applications where the available ‘real estate’ can be restricted.

The key advantages of aero-derivative OCGTs over larger ‘frame’-type OCGTs, aside from lower space and weight requirements, are higher efficiency and operational flexibility.

3.2 Processing

3.2.1 Gas Treatment

The entry specifications to the UK National Transmission System (NTS) are defined in the Gas Safety (Management) Regulations 1996. Key elements are noted in the following Table 1:

Table 1 - NTS Entry Specifications

Parameter	Unit	Value
Wobbe Number	MJ/m^3	≥ 47.20 to ≤ 51.41
Incomplete Combustion Factor		≤ 0.48
Soot Index		≤ 0.60
Impurities		"shall not contain solid or liquid material which may interfere with the integrity or operation of pipes or any gas appliance (within the meaning of regulation 2(1) of the 1994 Regulations) which a consumer could reasonably be expected to operate;"
Hydrocarbon dewpoint and water dewpoint		"shall be at such levels that they do not interfere with the integrity or operation of pipes or any gas appliance (within the meaning of regulation 2(1) of the 1994 Regulations) which a consumer could reasonably be expected to operate;"
Operating Pressure	barg	operating pressures for entry into the NTS can be as high as 85 barg for which onshore compression is often required.

A potential advantage of GTW applications is that gas produced offshore need not be conditioned to the above-mentioned UK NTS entry specifications thus reducing or even eliminating the complex processing (offshore and onshore) currently required. As such, GTW applications could be pertinent for the development of off-spec fields. Note that in 'partial' GTW conversions (where some gas is still routed to the NTS) such processing equipment would still be retained either offshore or at the onshore receiving terminal.

The level of conditioning required for a GTW application is dependent upon the gas turbine selected but is typically limited to:

- 25 barg inlet pressure to fuel gas compressor upstream of OCGT
- 28°C superheat to ensure the inlet gas remains liquid-free

3.2.2 Liquid Handling

For fields generating low volumes of condensate, this could be used as a co-fuel in the OCGT noting any possible impact on efficient burner operation and emissions.

3.3 Platform

3.3.1 Design Considerations

In specifying a GTW facility, adjacent to or on a gas production installation, there are a number of design options to be considered. Both safety and environmental design considerations are out with the scope of this document.

3.3.2 Retrofit to existing platforms

Retrofit of GTW facilities to existing platforms includes the following:

- **Normally Unattended Installations (NUIs):** the relatively small size and weight of a typical SNS NUI could present challenges for a GTW conversion. Remaining gas volumes would also need to be considered. More importantly, without permanent manning, reliable operation (especially start-stop in response to market demand) could prove difficult to ensure

- **Manned Platforms:** multi-platform hubs in the SNS and EIS could have sufficient space and weight capacity for a GTW application. For instance where compression is no longer required, a dedicated compression platform could offer sufficient footprint and weight capacity, especially with current equipment removed. This option could also deliver more efficient operations by using the GTW facility to provide power to the hub itself and reduce the need for any existing power generation facilities

3.3.3 Retrofit of mobile platforms

A more practical option for the location of power generation facilities could be the use of a mobile platform, such as a converted jack-up drilling rig, bridge-linked to an existing production platform, be that an NUI or a manned installation. This concept offers the most commercial flexibility; both the rig (and the OCGTs on-board) could be leased by a field operator. Once the current field is depleted, the facility could be relocated to its next target.

3.3.4 New, fixed platforms

Newly-built, fixed power-generation platforms can be connected to gas production platforms via pipeline or bridge-link. Whilst these can be specified with 'bespoke' facilities and dimensions, early assessment by industry has concluded that the high associated CAPEX would likely make such applications uneconomic.

3.4 Power Export System

The power export system consists of three main elements:

- the power cable from the GTW facility to the windfarm's offshore sub-station
- the offshore sub-station
- the windfarm's offshore power export cable to shore

3.4.1 Power Cable to Offshore Sub-station

The power cable linking the GTW facility to the existing offshore sub-station would be manufactured and installed in a similar manner to the windfarm export cable. At the GTW facility, the cable would be pulled through a J-tube from the seabed to topside. Once secured, the lay barge would install the cable by unspooling it and placing it in a trench (typically 1m deep) being dug as the vessel moves along.

Current practice is to abandon cables in-situ. If, however, it is proposed to relocate the GTW facility after a number of years, options for cable recovery could be investigated at the design stage.

3.4.2 Offshore Sub-station

Offshore windfarms contain two types of power cable:

- **Array cables:** up to 6 km in length, these typically operate at 33 kV and connect several wind turbines (25-30 MW capacity) to the offshore sub-station

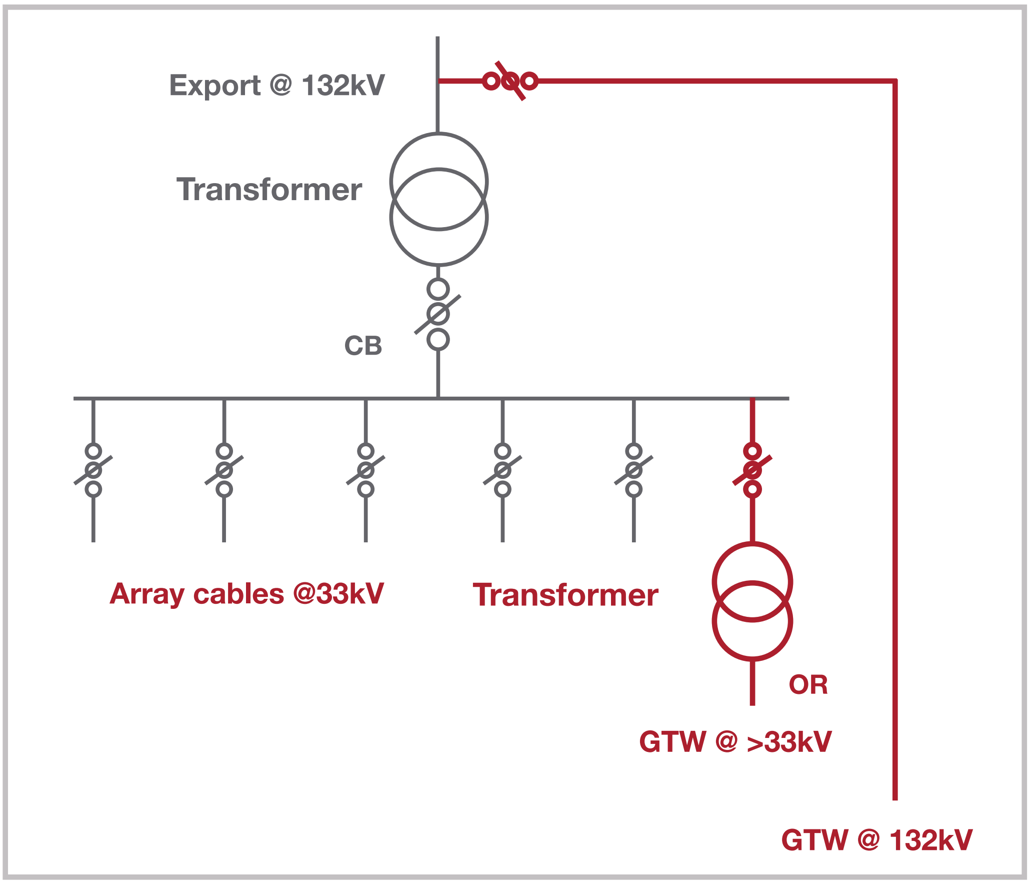
- **Export cable:** this typically operates at 132 kV High Voltage Alternating Current (HVAC) and connects the offshore sub-station to shore. Proposed new windfarms to be located further from shore could use higher voltages possibly with High Voltage Direct Current (HVDC) to reduce losses

The simplest means of connecting GTW output into an existing offshore windfarm sub-station would be at 33 kV via the same switchboard as the windfarm's array cables. It should be noted, however, that 33 kV is a distribution voltage best suited to small loads and short distances; for GTW applications where output exceeds 50 MW and 'tie-back' distances exceed 10 km, losses could be excessive.

Such losses could be reduced were the GTW to export power at a higher voltage, such as the 132 kV typically used in the windfarm export cable; this could carry up to 200 MW over 60 km without losses exceeding 3.5%. At the offshore sub-station, GTW power would be tied-in to the windfarm export cable 'downstream' of the transformer used to raise windfarm power from 33 kV to 132 kV.

Where the export cable operates at HVDC (as proposed for new, more distant windfarms), the GTW facility could nevertheless export at HVAC with transformation to array cable voltage taking place on the offshore sub-station. This eliminates the requirement for expensive DC rectification at the GTW facility.

Figure 4 – Offshore Transformer Station, GTW tie-in options



3.4.3 Windfarm Power Cable to Shore

Electrical power from the GTW scheme would be exported from the offshore sub-station by sharing the power cable installed for (and used by) the offshore windfarm. Although typically constructed by the windfarm operator, ownership of the operational export cable must be transferred to a separate entity, known as the Offshore Transmission Network Owner (OFTO).

It is assumed that wind power (with its low marginal cost and zero emissions) would always take priority; the GTW scheme would be entitled to export power only within the 'ullage' available in the export cable at any given time.

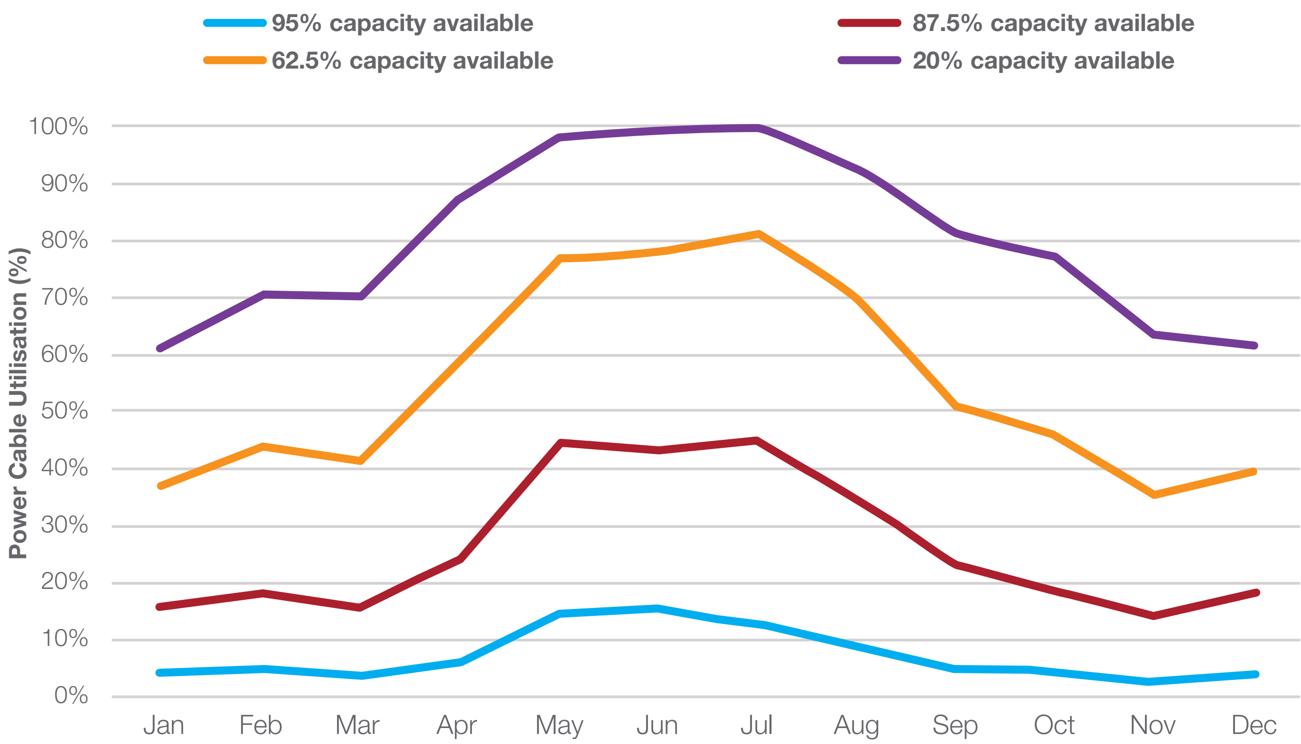
Historic data of UK windfarms demonstrate an annual utilisation of 40% thus leaving 60% of capacity available for GTW use. Key caveats are noted:

- The 40% utilisation is an annualised value; much more capacity is available in summer than in winter. As illustrated in Figure 5, a windfarm with an annual average utilisation of 40% uses 75% (or more) of its export cable capacity for just 20% of the time

- At very low windfarm throughputs, the export cable is not fully energised. GTW power exported under such conditions could be subject to proportionately higher transmission losses

- New windfarms (currently under construction or in the planning stage) are located further from shore and feature larger turbines. Their utilisation is anticipated to increase towards 50%, thus reducing the operating window for GTW schemes

Figure 5 – Windfarm Power Cable Capacity Availability



4. GTW Locations

SNS and EIS gas-producing hubs have been matched up against nearby windfarm infrastructure to identify possible locations for GTW developments. In most cases, a suitable offshore windfarm has been identified, but for those closest to shore, a short, dedicated power export cable could be more appropriate.

Where GTW operating life is small (typically below ten years), developers may wish to consider leased equipment i.e. OCGTs, jack-up platform. For longer duration developments, purchased equipment may be more appropriate.

Table 2 - Potential GTW developments, SNS & EIS

	Hub	Nearest Windfarm (existing and planned)	Windfarm Capacity[1] (MWe) (indicative)	Distance (km, approx.)
1	CMS	Hornsea Project Three or Hornsea 1 (East)	4,000	50
2	Sole Pit	Dudgeon	402	35
3	Leman E	Norfolk Vanguard	1,800	20
4	Leman W	Norfolk Vanguard	1,800	35
5	West Sole	Triton Knoll	900	35
6	Amethyst	Triton Knoll	900	20
7	Cleeton & Ravenspurn	Hornsea Project Four	1,000	50
8	Trent	Hornsea Project Four	1,218	40
9	Cygnus	Dogger Bank - Creyke Beck A	1,200	35

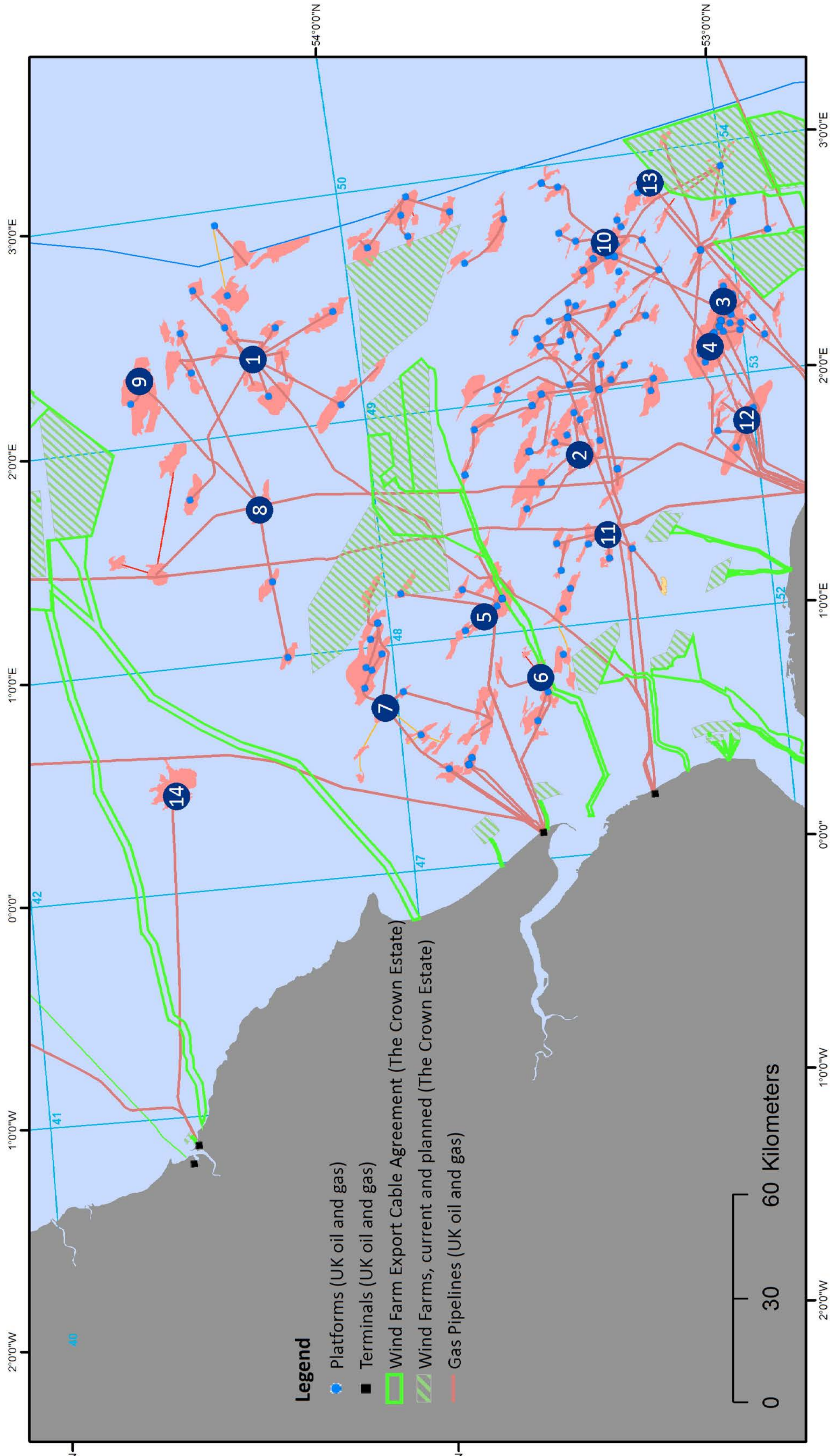
Notes
1. Windfarm capacity: LR Study for OGA, 10 October 2017 (Reference 4)

Table 2 – Potential GTW Developments, SNS & EIS

	Hub	Nearest Windfarm (existing and planned)	Windfarm Capacity[1] (MWe) (indicative)	Distance (km, approx.)
10	Indefatigable	East Anglia North Tranche 2	580 to 800	40
11	LAPS	Dudgeon	402	20
12	Hewett	N/A - closest option: direct power export to shore	N/A	30
13	Sean	East Anglia North Tranche 2	580 to 800	20
14	Breagh	N/A - closest option: direct power export to shore	N/A	65
15	Douglas	Gwynt y Mor	576	10
16	South Morecambe	West of Duddon Sands	389	20

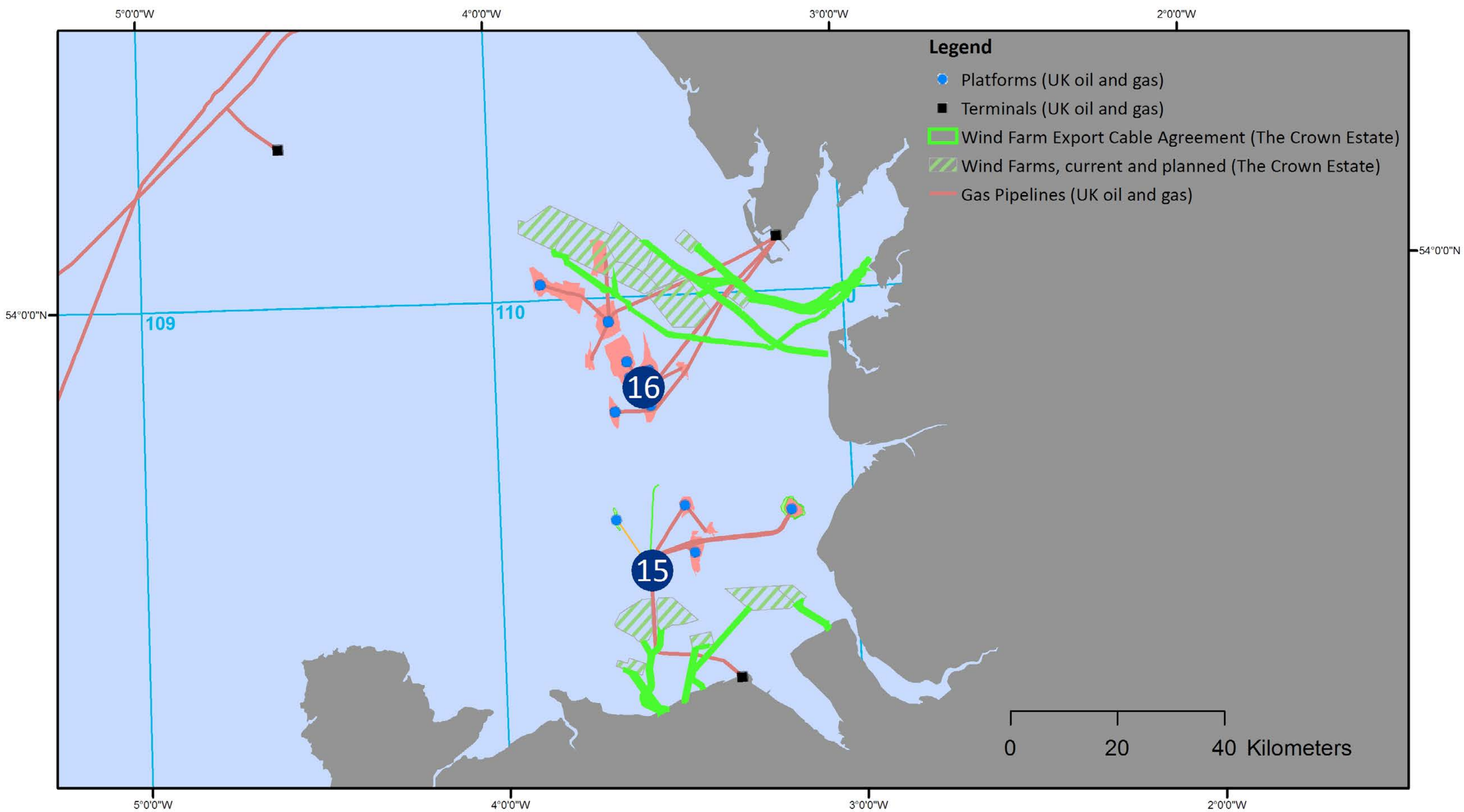
Notes
1. Windfarm capacity: LR Study for OGA, 10 October 2017 (Reference 4)

Figure 6 - SNS Infrastructure - Gas and Renewables



Reference: Pipeline and Platform data sourced from CDA and UKOilandGasData, downloaded July 2018

Figure 7 - EIS Infrastructure - Gas and Renewables



Reference: Windfarm information sourced from The Crown Estate, downloaded July 2018, © Crown Copyright (2018)

5. Next Steps

Today's UK SNS and EIS sectors offer two, parallel energy systems (offshore gas fields and windfarms) in overlapping proximity. Integration of these creates an opportunity to enhance economic recovery from gas fields (new and existing) whilst remaining consistent with UK power generation demand. The OGA will seek to maintain an active role and further promote the integration between the gas and renewables sectors in the SNS and EIS, with the following next steps:

1. The OGA will continue to support and allocate resource to the EEEGR cross-industry work group commissioning to address the synergies between offshore gas and renewables in the SNS. The work group has the current priorities with specific deliverables:

    - Operational synergies: to understand how sectors can collaborate to improve cost and operational efficiency

    - Area co-existence: to understand how parallel operations, including shipping, helicopter movements and seismic surveys, etc., can best be coordinated without detriment to each other

    - Development synergies: to understand how infrastructure can be shared via concepts such as GTW and PTG

2. The OGA will seek to identify and realise opportunities for cross-border collaboration on energy integration with TNO. Working in conjunction with the ECN (Energy Research Centre of the Netherlands), TNO is investigating gas-renewables integration as part of the Dutch energy transition.

3. The OGA will continue to work directly with oil and gas operators as well as the supply chain where there is an express interest in energy integration opportunities. To date, both prospective developers and infrastructure operators continue to approach the OGA for further insights on GTW in particular.

6 References

1. Global Wind Energy Council, Global Wind Report – Annual Market Update 2017
2. OGA's UK Oil and Gas Reserves and Resources - as at end 2016
3. TNO, System Integration Offshore Energy: Innovation Project North Sea Energy
4. LR, Gas to Wire, UK SNS and EIS, Rev4, 10 October 2017
5. Energy Delta Institute, On the Economics of Offshore Energy Conversion: Smart Combinations

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