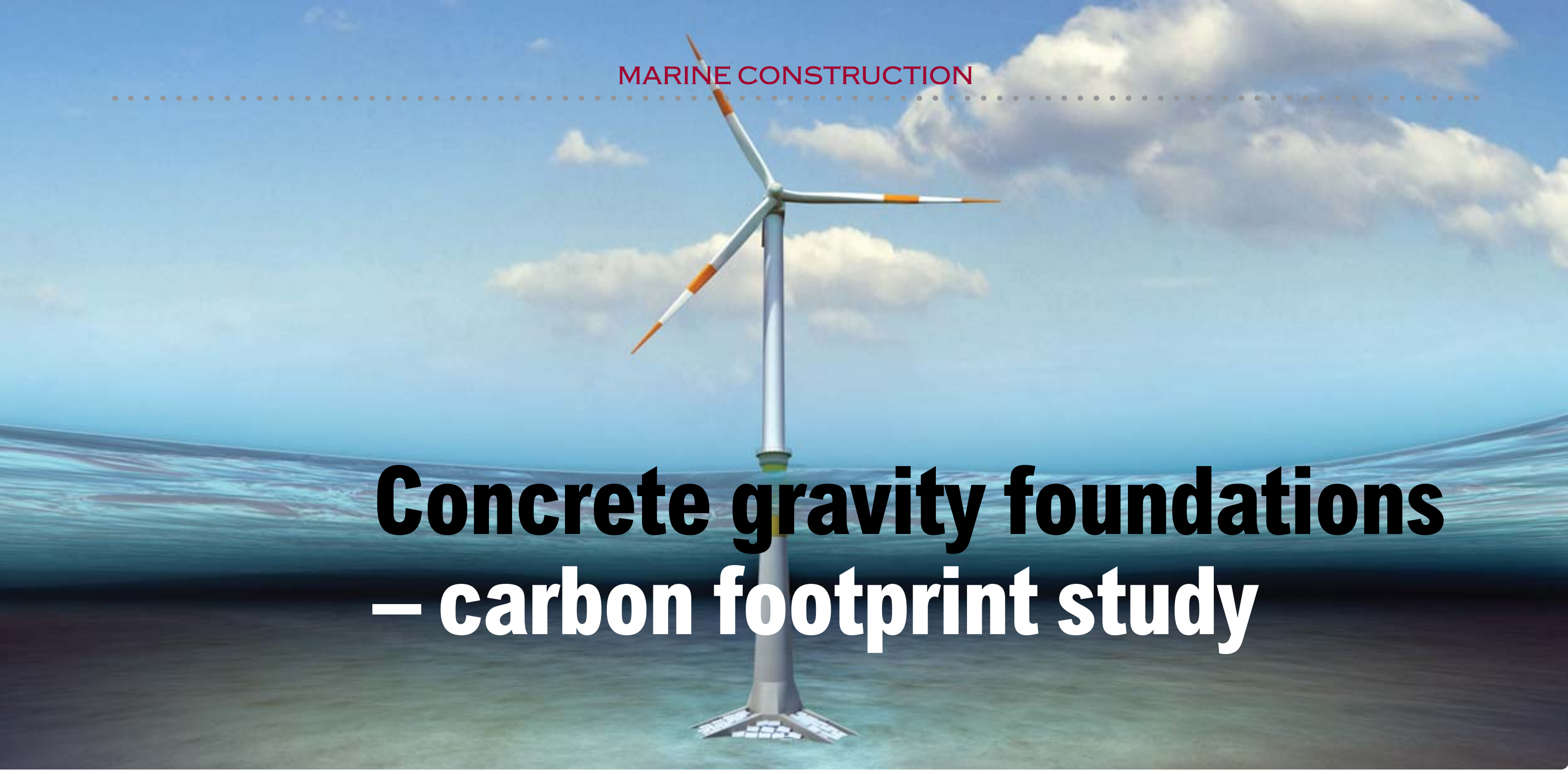

Concrete gravity foundations – carbon footprint study

Given that the purpose of offshore windfarms is to generate low carbon, renewable energy, the greenhouse gases emitted during the construction and operation of offshore windfarms is an important consideration. Henrietta Ridgeon and Helen Dingle of Arup, Steve Hunt of Vinci Construction and Andrew Minson of MPA–The Concrete Centre outline the findings of a preliminary carbon footprint study carried out by the Interest Group for offshore wind gravity foundations organised by The Concrete Centre.

The priority for the study was to estimate the carbon footprint of the raw materials and other resources to be used in the construction of a concrete gravity foundation to support a 5MW turbine in 42m-deep water. However, the study also included consideration of:

- transportation of materials to a manufacturing/construction facility
- resources used in the construction of the manufacturing facility
- resources used in the manufacture of any bespoke vessels used for installation
- resources used during installation of the foundations
- resources used during maintenance of the foundations
- resources used during deconstruction of the foundations.

The study only considered the concrete gravity foundation. It did not consider the other parts of the offshore windfarm, such as the turbine blades, nacelle, tower, cables, substations, etc.

Methods and assumptions

A number of assumptions were made in order to ensure that carbon footprint estimates for different concrete foundation solutions would be comparable. The following assumptions were made:

- Average road distance for transport of materials to the manufacturing facility of 160km.
- Average distance from port to offshore wind site of 50km.
- Manufacturing facility to build a batch of 200 units at a rate of 50 per year. (This is a low figure; facilities are expected to produce a minimum of 100 per year and to manufacture in excess of seven years, hence the CO_2e per unit will be less and this study will give an over-estimate.)
- For installation, five units per visit for ballasting, scour and seabed preparation (where required).
- Maintenance visits numbering eight in a 25-year lifetime with four units visited in each trip. (Once again this is a very onerous schedule for such a durable solution.)
- Deconstruction included both removal and breaking up of units.

In further support of comparability, a template carbon footprint schedule was prepared, which included a list of carbon factors to be applied to different resources. Many of the carbon factors were drawn from the *Inventory of Carbon and Energy*[1] published by the University of Bath. Other sources included the *2011 Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting*[2].

The template was issued to the members of the Interest Group to complete. The Interest Group also conducted a preliminary carbon footprint estimate for an alternative to concrete gravity foundations, namely a steel jacket solution based upon the steel jackets used in the Beatrice Windfarm for a 5MW turbine in 42m-deep water.

Results: foundation only

The 'foundation only' results include raw materials

> The total amount of greenhouse gases produced as a consequence of an activity is known as a 'carbon footprint' and is usually expressed in equivalent tonnes of carbon dioxide (CO_2e).
>
> A carbon footprint includes emissions from other greenhouse gases as well as carbon dioxide. However, all emissions are expressed in the form of carbon dioxide equivalents. For example, 1 unit of methane is equivalent to 21 units of carbon dioxide.

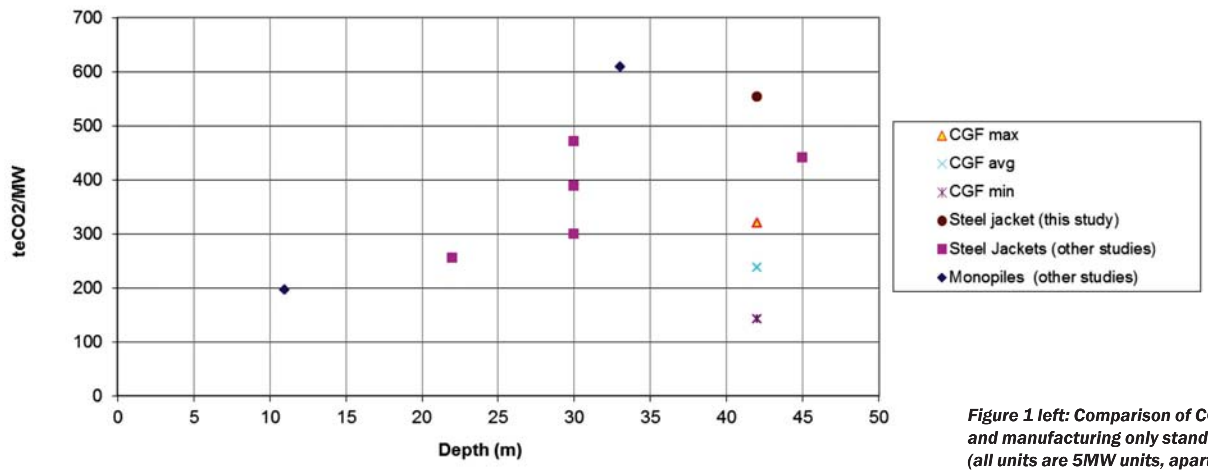

Figure 1 left: Comparison of CO_2e for materials and manufacturing only standardised to per MW (all units are 5MW units, apart from monopiles which support 3.6MW unit).

and other resources to be used in the construction of the foundation but exclude the manufacturing facility, bespoke vessels, installation, maintenance and deconstruction.

The average carbon footprint for six different concrete gravity foundation (CGF) solutions was estimated to be 1190 tonnes CO_2e per 5MW unit (with a range of 708–1597 tonnes CO_2e per 5MW unit). This compared with an estimated carbon footprint for a steel jacket solution of 2770 tonnes of CO_2e per 5MW unit.

The key driver for the difference in the carbon footprints was the quantum and type of steel within the different solutions. The concrete foundations incorporate significantly less steel than the steel jacket solution. Moreover, reinforcement steel is used in the concrete solutions, which in Europe is produced almost entirely from recycled materials, while this study assumed that steel plate would be used for a steel jacket.

Steel plate is manufactured principally from virgin materials. The assumed carbon factors for the two materials, as derived from the *Inventory of Carbon and Energy*, are:

- steel (bar and rod based on UK average recycled content) – 0.45kg CO_2e/kg
- steel (plate based on world average recycled content) – 2.21kg CO_2e/kg.

Some of the concrete solutions also included a significant proportion of cement replacement products such as GGBS (ground-granulated blast-furnace slag). Cement is a significant contributor to the carbon footprint of concrete and hence replacement of cement with recycled materials such as fly ash and GGBS is a potential means of lowering the carbon footprint of concrete.

The findings are plotted in Figure 1, together with other data that have been sourced but unfortunately is not otherwise in the public domain.

Results: total carbon footprint

The total carbon footprint results include raw materials and other resources to be used in the construction of the foundation and the manufacturing facility, bespoke vessels, installation, maintenance and deconstruction.

Combining all the resources used in the manufacture, installation, maintenance and deconstruction of concrete foundations gave an estimated average carbon footprint for four different concrete gravity foundation solutions of 2480 tonnes CO_2e per 5MW unit. Some of these aspects are more uncertain than the raw materials used in the foundations themselves and hence the estimated total carbon footprint of 2480 tonnes CO_2e should be considered as an indicative figure only.

Table 1 – Comparison of CO_2e per 5MW unit for materials and manufacturing only

Average for concrete gravity foundation (CGF) solutions (5MW turbine)	1190 tonnes CO_2e per unit	237 tonnes CO_2e/MW
Steel jacket (5MW turbine)	2770 tonnes CO_2e per unit	554 tonnes CO_2e/MW

The proportional contributions to the total carbon footprint of concrete foundations solutions were approximately as follows:

- 43% resources used in the raw materials and manufacture of a concrete base
- 8% resources used in the construction of the manufacturing facility and any bespoke vessels used for installation
- 26% resources used during installation of the foundations
- 6% resources used during maintenance of the foundations
- 17% resources used during deconstruction of the foundations.

Lower carbon footprint

This preliminary study conducted by the Interest Group indicates that concrete solutions are not likely to be any worse than a steel jacket solution in terms of its carbon footprint. Indeed, concrete solutions appear to have a significantly lower carbon footprint compared with a steel jacket.

The Interest Group would like to thank all those organisations who provided information in support of this study. ●

● Further information:

Greenhouse gas emissions were calculated by the Interest Group for Concrete Gravity Base Foundations in accordance with PAS 2050[3], self-declared.

References

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