

**A3/B3 Colloquium 2023**  
**Preferential Subject (PS1, PS2, PS3)**  
**Study Committee (B3)**

**The Influence of Embodied Carbon on Management of High Voltage Substations in a UK Net Zero Environment**

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**Abstract**

Having declared a global climate emergency, the UK government alongside numerous worldwide governments are calling for urgent action to be taken to reduce or stop the change in climate and avoid irreversible environmental damage. In 2019, the phrase ‘net zero’ was coined by the UK government when legislation was passed, committing to the lower greenhouse gas emissions, and aiming for net zero by 2050.

In a UK context, the demand for sustainability is paving the way for a significant increase in renewable energy, and significant transmission network upgrades are required to accommodate the additional renewable energy.

High voltage substations are a critical element of the electricity transmission network and significant investments will be undertaken on substation projects in the move towards net zero.

With increased focus on sustainability, embodied carbon from the substation projects will be the scene of greater scrutiny. Embodied carbon refers to emissions emitted from the lifecycle of the asset; from product supply, construction, use and end of life phases. The topic of embodied carbon in substations is under-researched in the UK and previous publications do not consider large scale input from industry participants.

This paper presents a mono-method quantitative study undertaken on the industry participants involved in the life cycle management of high voltage substations in the UK on the existing and future influence of embodied carbon on management of high voltage substations in a UK net zero context. The sample size for this first type of study in the UK was 35; i.e., individuals employed by an asset owner or supply chain in manufacturing, construction, maintenance or decommissioning of high voltage substations rated at 132kV and above in the UK.

The objective of the study was multiple fold, from gaining an understanding of embodied carbon by the industry participants, understanding the current role of embodied carbon in project decision making, to examine the attitudes and barriers preventing incorporation of embodied carbon considerations in the lifecycle, and to understand the future role that embodied carbon could play in the project lifecycle stages.

It is anticipated that outputs from this first-off prototype study will be used by the substations industry in the UK to formulate focus groups and conduct large scale research.

## **Keywords**

Substations, HV Equipment, Net Zero, Embodied Carbon, Sustainability

## **1 Introduction**

The topic of embodied carbon in substations is under-researched in the UK. The only two UK publications from Harrison *et al.* (2010) and Daniels *et al.* (2016), and overseas contributions from Wei *et al.* (2017, 2018, 2020, 2021) do not consider large scale input from industry participants. This paper presents data collected via mono-method survey. The survey consisted predominantly of closed quantitative questions with a selection of open qualitative questions. Determining the research questions was equally challenging as the industry has different views about changes required for achieving Net Zero in the UK (Wills, 2020; Melton, 2018). The survey was carefully designed to capture current position and knowledge in terms of embodied carbon, and future trends in the industry. Care was taken to ensure individuals involved in the substation life cycle management were targeted for the survey.

A post positivism standpoint has been adopted for this research, while the data was collected using a convenience sampling relying on non-probabilistic sampling method (Given, 2008), as the research focused on views of participants working on substations in any stage of the life cycle. Only responses from participants involved in substations rated at 132kV or greater were considered as these substations are complex in size and configuration. A total of 35 responses from individuals employed by an asset owner or supply chain in manufacturing, construction, maintenance or decommissioning of high voltage substations rated at 132kV and above in the UK are analysed.

## **2 Survey Results**

### **2.1 Embodied Carbon Understanding**

The participants were initially queried if they understood the phrase embodied carbon. 71.4% or 25 respondents understand embodied carbon; however, 28.6% or 10 respondents have heard about embodied carbon but do not possess detailed knowledge.

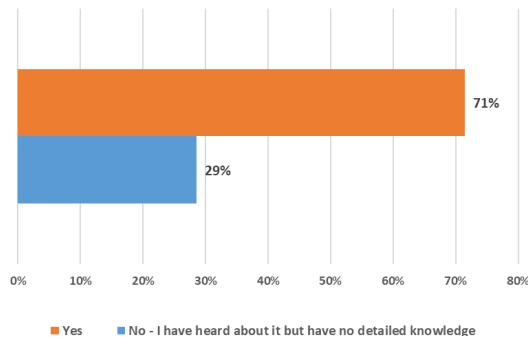


Figure 1 - Responses on understanding of embodied carbon

A comparison of participants' understanding of embodied carbon against personal embodied carbon footprint monitoring indicates that 8 responses or 22.8% monitor embodied carbon occasionally but do not have a detailed knowledge on what embodied carbon refers to. This is an interesting finding as either respondents did not consider they had comprehensive knowledge of embodied carbon, or they are not aware of what they are monitoring occasionally.

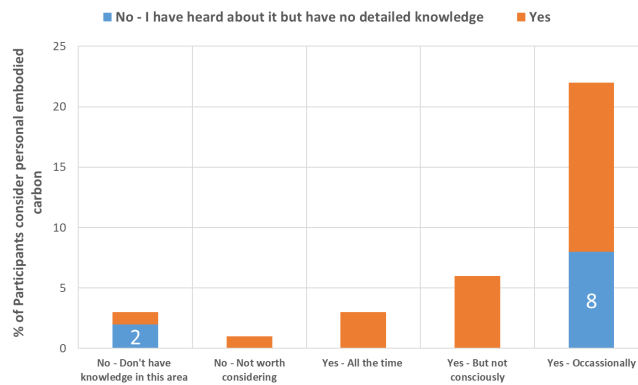


Figure 2 - Participants considering personal footprint against understanding of embodied carbon

Instead of giving a definition, the participants were requested to qualitatively describe the term embodied carbon. The finding suggests that participants have a good understanding of the phases the embodied carbon, this is despite 22.8% of participants previously noting they do not have detailed understanding of the phrase.

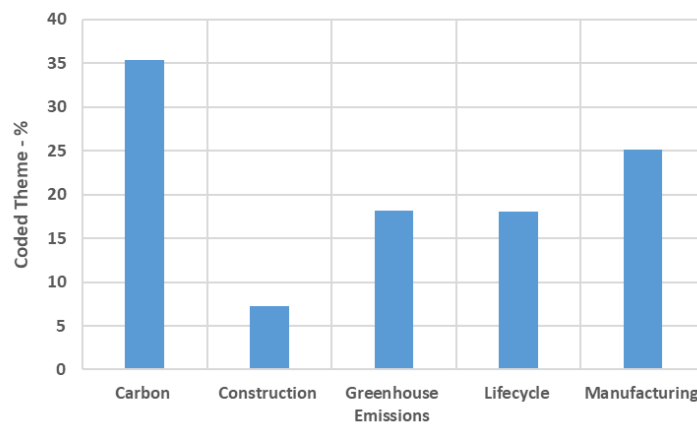


Figure 3 - Coded theme from respondents understanding of embodied carbon

The participants recorded a mixed response in terms of what phase contributes to the highest amount of embodied carbon in substations. 37.1% consider product manufacturing to be the highest phase,

and this is followed by 28.5% view construction and installation at the highest phase. The responses are interesting primarily due to the fact that there is no publicly available information on the phase determination and outcome depends on the size and application of the substation.

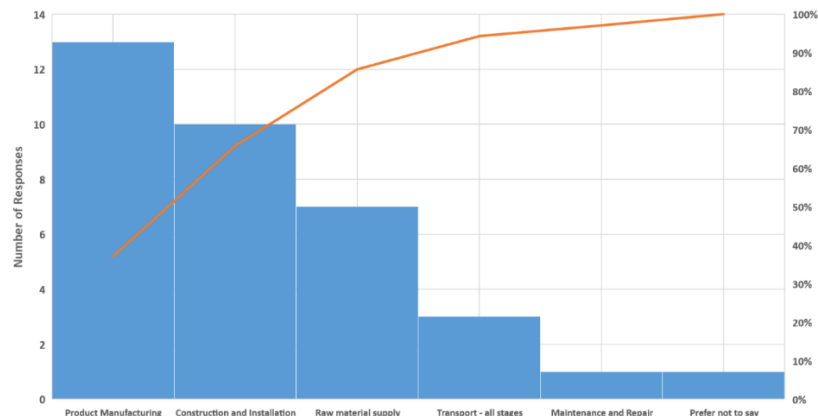


Figure 4 - Participants view of highest phase associated with embodied carbon in high voltage substations

## 2.2 Embodied Carbon Influence

Nearly half of the participants (46%) are ‘extremely concerned’ with the embodied carbon emitted from the substations. The mean rating was 4.34 with an observed standard deviation of 0.684. With no participants indicating ‘not concerned’ suggests that the high voltage substations industry in the UK is worried with embodied carbon emissions.

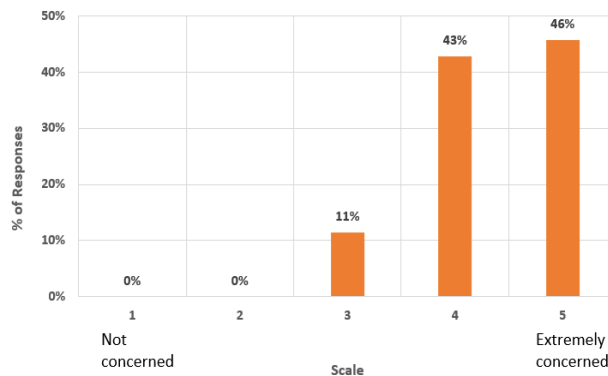


Figure 5 - Participants concerned with the embodied carbon emitted from substations in the UK

Interestingly, although the participants are concerned with the embodied carbon from substations in the UK, there isn’t the same level of consideration given to undertaking assessment or reduction in embodied carbon and its impact on decision making in any phase of the project. The participants rated from 1 (no influence) to 5 (significant influence) on impact of embodied carbon on project decision making. The mean calculated is central around 3.03 with a standard deviation of 1.248.

The 95% confidence level for mean has lower and upper bound values of 2.60 and 3.46 with a median of 3. Negative kurtosis value (platykurtosis) of -1.108 is more than the threshold of -1 indicating a distribution that is flattened when compared to the normal distribution.

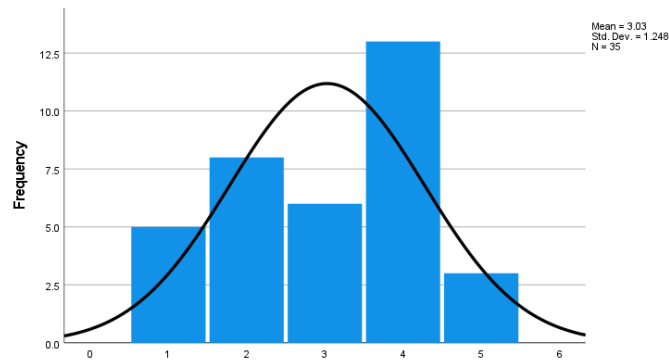


Figure 6 - Responses on influence of embodied carbon on project decision making; scale ranging from 1 indicating no influence on 5 with significant impact

The box plot supports the distribution as it shows a rather even spread across the rating scale. The upper and lower quartile values are evenly distributed at 2 and 4, with whiskers also spread by 1 rating. The finding supports that there isn't a strong influence of embodied carbon on project decision making.

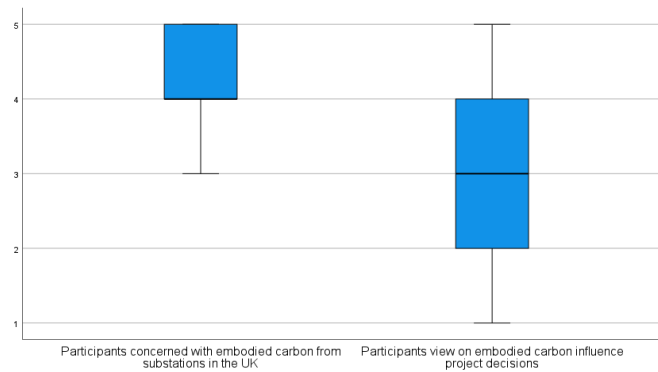


Figure 7 - Stem and leaf plot comparing two variables

### 2.3 Embodied Carbon Embedment

The survey attempted to understand if international standards and best practice guides related to embodied carbon are utilised in substations. A large proportion of circa. 40% did not prefer to say if BS EN Sustainability of Construction works in the UK and/or PAS2080 Carbon Management in Infrastructure by the industry; this may be due to participants being unclear on content of these standards and perhaps indicates lack of technical understanding of the topic.

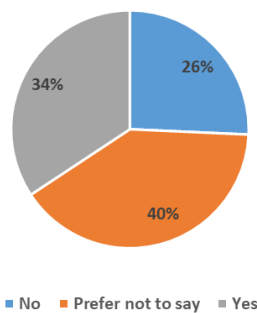


Figure 8 - Use of international standards and best practice guide associated with embodied carbon on substation projects

47% of the participants belong to organisations that are aligned with targets set in the Science Based Targets. Science Based Targets initiative drives climate change action in the private sector by setting science-based reduction targets (World Resources Institute, 2022). It is encouraging to note that 11% recommend that a sign-up by the organisation is recommended.

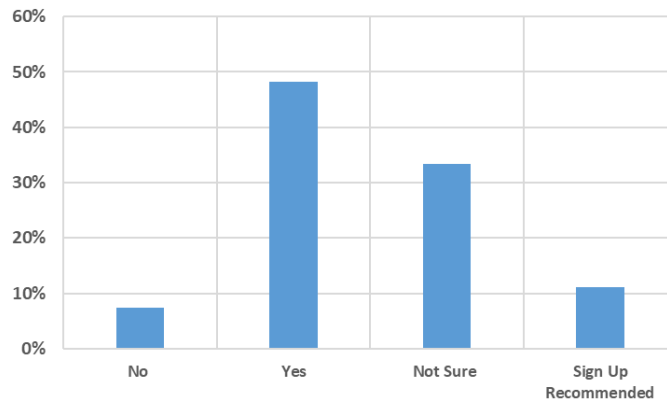


Figure 9 - Organisation's alignment with Science Based Targets

The respondents overwhelmingly at 86% consider that embodied carbon will play a greater role in the electricity industry as the industry strives towards net zero.

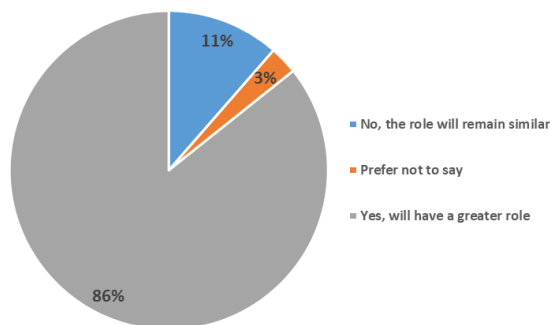


Figure 10 - Participants view on future role of embodied carbon

Furthermore, a significant majority of the industry participants at 91% consider that measurement and reporting of embodied carbon should be legislated in the UK. The above findings indicate that the industry is not only concerned with the current levels of embodied carbon from substations, but also view that it will play a greater role in the future and consider that legislation is one way to enforce this.

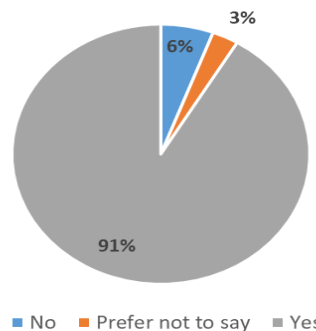


Figure 11 - Participants view on legislative measures for measurement and reporting of embodied carbon

According to the industry participants the highest contribution of embodied carbon on substation projects in the UK is from procurement of materials (14.62%) which includes civil and steel procurement, followed by construction activities (8.55%). The code analysis is based on key words and only the prominent categories observed are trended.

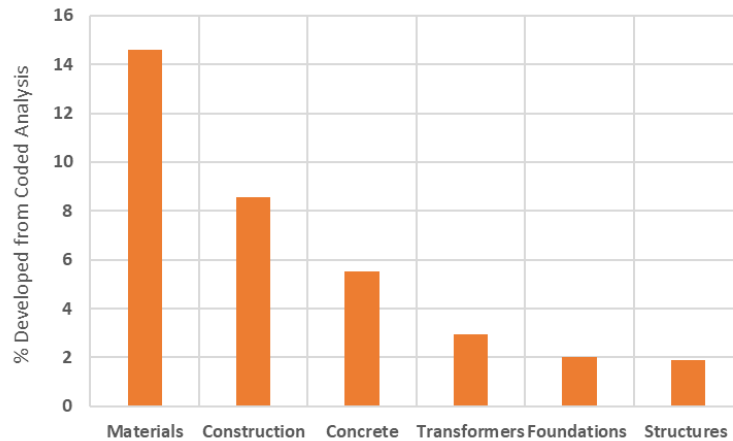


Figure 12 - Highest contribution of embodied carbon on substation projects

To understand if there was any correlation between project management and attitudes towards embodied carbon, the participants were queried on items that has the highest influence on project management. Scope was overall rated as having the greatest influence (44.4%), followed by budget (31.7%) and then project time allocation (23.8%). The value of chi-square statistic between concern over embodied carbon and project management approach is 64.531 and the  $p$  value (asymptotic significance 2-sided) is 0.528, which is greater than the designated alpha level of 0.05. The result confirms that concern over embodied carbon is independent from influence on project management.

### 3 Results Outcome

The survey has found that there is no strong evidence to suggest that reduction or assessment of embodied carbon is involved in high voltage substation decision making. However, the study has observed that nearly half of the participants at 46% are concerned with embodied carbon from high voltage substations in the UK. Furthermore, the majority proportion at 71.4% have an understanding of embodied carbon. According to the industry participants, there is a high expectation at 86% that embodied carbon will play a greater role in the future. In addition, an overwhelming population of 91% are of the view that measurement and reporting of embodied carbon should be legislated.

As the sample size was only 35, it is suggested that a wider industry study is continued that extends the sampling criteria to policy makers and regulators to further understand barriers that prevent embedment of embodied carbon on substation projects. It is important to gain an idea of the future direction of embodied carbon from individuals and organisation's perspective.

The survey data was collected primarily via social media and there is a probability that some experienced individuals from the substations industry may not be active on these channels. To capture a wider pool of audience with varying industry experiences, as this study was completed by 83% of participants who had over 10 years of experience in the substations industry, attendees of UK electricity industry conferences could be requested to complete the survey as part of conference registration. As a number of internationally based original equipment manufacturers who supply

substations equipment to UK also exhibit at these conferences, representatives from these organisations could also be captured at these industry conferences. UK based electricity network companies could also be directly approached to complete the survey as it is likely that only technical biased project members attend the conferences, and views from environmental and sustainability representatives may not be captured.

This study is the first of its type dedicated to investigating role of embodied carbon on high voltage substations in the UK. Historic literature has evaluated substations in a wider context and there has been no previous study as a reference in the UK or internationally that has taken views of substation industry participants on embodied carbon. The stakeholders of this study include network asset owners, equipment manufacturers, installation contractors and policy makers in the UK.

## **4 Recommendations**

The primary recommendation from this study is for the policy makers to develop a consistent measurement and reporting technique for embodied carbon on substations in the UK. The study found that despite having a number of recent publications and standards on sustainability and carbon reporting, there isn't a significant uptake by the industry members. Only 26% of the study respondents using British Standards and PAS reporting guidelines.

The electricity network operators in the UK are recommended to further investigate barriers that prevent adoption of embodied carbon for substations into project decision making. The study found that scope has the highest influence on substation project management. Inclusion of measurement and reporting of embodied carbon could be included in the technical specifications, and it will ensure inclusion in the project decision making. To further improve adoption of embodied carbon on projects, the network operators are recommended to establish training on embodied carbon as a core module, similar to site inductions for project staff.

Whilst measurement and reporting can be captured in project specifications, significant steps need to be taken to reduce embodied carbon on substation projects. The electricity network operators are recommended to give increased tender weightings to substation equipment with low embodied carbon over alternative options. This will not only ensure deployment of sustainable products but encourage the supply chain and equipment suppliers to source and manufacture environmentally conscious products.

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## Bibliography

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