Contribution ID: **86** Type: **Oral Presentation**

Carbon life cycle modelling of scientific computing

Thursday, 28 March 2024 16:40 (20 minutes)

Summary: We propose a model to estimate and minimise full life cycle emissions of scientific computing centres based on server embodied carbon, PUE, projected next-generation performance-per-Watt improvements and actual/projected carbon intensity of the location.

In this paper we present a model for the assessment of the replacement cycle of a compute cluster as a function of the carbon intensity of the region where it is deployed and the embodied carbon in the manufacturing of the server. The model allows to take into account facility PUE or cooling emissions, server load and energy efficiency gains through replacement by the latest models.

The embodied carbon in the manufacturing of the server is estimated based on public historical data reported by manufacturers for some models, together with average transport emissions. These carbon emissions for acquiring new hardware is weighed against the ongoing emissions for running older hardware, and we provide a model to optimize replacement cycles for minimal carbon footprint given that newer equipment will have greater energy efficiency for equivalent scientific compute work.

We show the results of this model for several real world sites to provide an equivalent scientific computing capacity, using actual conditions for their power and cooling emissions, which gives us a tailored strategy for the site on replacement cycle for hardware to minimize carbon footprint.

For instance, the model shows that with current estimates for embodied carbon, to minimise the full life cycle emissions, clusters in countries with moderate electricity carbon intensity (<200 gCO2e/kWh) should ideally be kept in operation for several decades.

Since running computers for several decades provide practical and financial challenges, we also discuss limits to the applicability of the model outcomes to practical site operations and procurements. In a addition we also come with some community and industry recommendations that from our work indicate they would be helpful to lower the total carbon emissions from scientific computing.

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Session Classification: Network, Security, Infrastructure & Operations

Track Classification: Track 7: Network, Security, Infrastructure & Operations