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Literature Review on LCA methodologies to Estimate CO2 Emission of the SMR

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1. Introduction

According to 2030 NDC (Nationally Determined Contribution), the industry field needs to reduce CO2 emission more than 14.5% until 2030, and it aims to CO2 net neutralization by 2050 [1]. Renewable energy has been attention as the representative power source for carbon free, however, it has a critical defect of intermittency such as duck curve. SMR has the potential to supply a flexible baseload by utilizing the multi-purpose, such as electricity, heat, hydrogen and desalination. For this reason, SMR (Small Modular Reactor) is emerging as a technology to compensate the renewable energy. Also, an increase in the dispersed generation and the replacement demand of diesel generation accelerates SMR technology development.

After Covid-19, the global warming threat and the Green New Deal have become more prominent. Above all the international community requires companies gradually to extend the disclosure of carbon emission information from Scope 1 to Scope 2 and 3. Fig. 1 shows an overview of each scope and emissions across the value chain. The GHG (Greenhouse Gas) Protocol defines each scope as the below:

- Scope 1 emissions: direct emissions from sources owned or controlled by a company
- Scope 2 emissions: indirect emissions from purchased electricity, steam, heat and cooling
- Scope 3 emissions: all other emissions associated with a company's activities

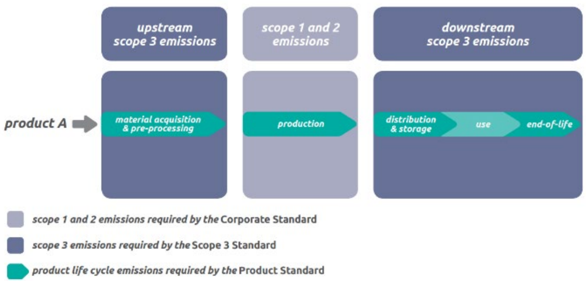

Fig. 1. Overview of GHG Protocol scopes and emissions across the value chain [2]

Due to the steadily reinforced GHG Protocol, companies need to know how much CO2 their products emit. Thus, this study aims to evaluate the CO2 emission for SMR life cycle. As first step, the existing research on CO2 emission assessment will be reviewed in this paper. In the next step, items and ranges in upstream and downstream will be defined for CO2 emission assessment. Finally, the difference in CO2 emissions will be evaluated when applying the steam cycle and the sCO2 cycle.

2. Literature review

The LCA (Life Cycle Assessment) is a technique analyzing a target product or system from raw material extraction through manufacture and use to its final disposal. According to ISO-14040, the LCA work consists of analysis goal and scope definition, life cycle invert analysis and life cycle impact assessment. It is good to analyze each process, material and energy in detail, but there is a disadvantage that very wide range of data and a lot of time are spent. Therefore, it is necessary to establish a proper goal and derive indicators through appropriate assumptions.

In this section, it is described that some of the cases of CO2 emission assessment research conducted in Korea. There are few cases of LCA for NPP (Nuclear Power Plant). The following chapters cover the research cases of KAERI (Korea Atomic Energy Research Institute) and Inha University, which conducted the LCA research systematically.

2.1 Life Cycle Assessment (KAERI, 2002)

KAERI conducted LCA work based on the ISO-14040 framework. To assess the environmental burden of target NPPs, system boundaries and data availability have to be firstly defined. They proposed the meaning of nodes such as system boundary, process, intermediate feedstock and material as Fig. 2.

KAERI report concluded that environmental burdens are generally heavier in power generation process than in upstream and fabrication processes. Although various data was used to present, it is quite limited because it does not include the construction stage, the back-end fuel cycle, and the decommissioning stage.

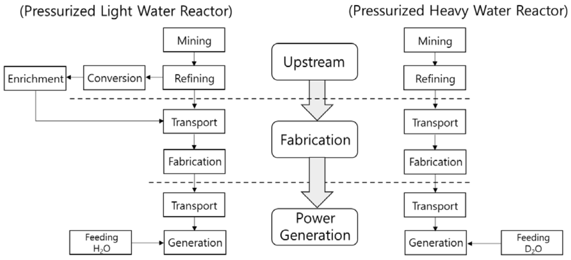

Fig. 2. Process aggregation chart of KAERI LCA [3]

2.2 Life Cycle Assessment (Inha Univ., 2003)

Inha university conducted LCA between the NPP and the coal thermal power plant. The report includes the complex environmental assessment for radiological impact assessment as well as the CO2 emissions. Fig. 3 describes the analysis scope, which covers from construction and decommissioning process.

The CO2 emissions of the coal thermal power plants were estimated at about 90 times of that of NPPs. However, there is a limit that radioactive waste emissions from NPPs do not try being estimated as carbon dioxide emissions. Nevertheless, it is meaningful that it systematically dealt with CO2 emissions for the NPPs in Korea.

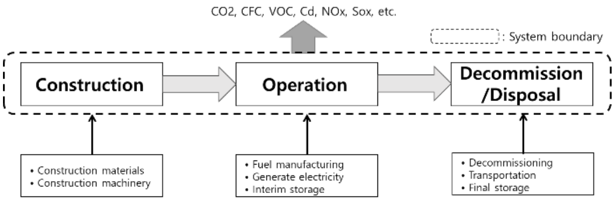

Fig. 3. Evaluation scope of Inha university LCA [4]

3. Summary and future works

This paper overviewed main results of KAERI and Inha University. The results of the KAERI systematically reported CO2 emissions that may occur in the manufacture and use of fuels. However, there was a limitation in not including CO2 emissions from the construction and the decommissioning of NPPs. On the other hand, Inha University's results better evaluated CO2 emissions over the whole life cycle of NPPs. However, there was a limitation that radioactive waste emissions from NPPs do not try being estimated as carbon dioxide emissions.

As future works, items and ranges in upstream and downstream will be defined for LCA of SMR as following the methodology of Inha university. There is no case of decommissioning of nuclear power plants in Korea. Therefore, the evaluation of the decommissioning phase will utilize the Japanese case referred by Inha university and the research of Koltun [5].

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