Life cycle assessment, life cycle costing, risk assessment and multi criteria decision analysis of alkaline fuel cells for large scale stationary power application.

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Abstract

With the increasing relevance of sustainability and energy independence in the energy sector in the world, fuel cells have emerged as one of the many technologies capable of achieving these goals. The POWER-UP system is an alkaline fuel cell based system being developed under the aegis of the POWER-UP consortium [3]. It will be capable of generating 500 kWe and 400 kW of heat, fuelled by hydrogen generated as a by-product of the chlor-alkali electrolysis process. In this thesis the environmental impacts, costs and accident risk assessment are conducted together with a Multi Criteria Decision Analysis (MCDA) for the POWER-UP system. A Life Cycle Assessment (LCA) for the production, operation and the End-of-Life (EoL) of the system is conducted to quantify environmental impacts and identify the environmental impact hotspots of the system, which can be improved upon, as the project is in design phase. The effects of an important methodological issue of allocating environmental impacts in case of multi-functional processes are also analysed. Levelized Cost of Electricity (LCOE) is calculated to analyse the economic performance of the system and also identify the major cost contributors. Scenarios involving alternate hydrogen production pathways, with the chlor-alkali process as the reference, are analysed by comparing their environmental and cost impacts. An accident based risk assessment is conducted for the system in order to include the social aspect of the effect on human health in the decision-making process. The LCA, costing and risk assessment culminate with the generation of indicators for the MCDA. The latter is conducted to assess the performance of the system by ranking it against 13 other electricity generation technologies on the dimensions of sustainability and security of supply. The weights for the MCDA are simulated using generic weighting schemes and a Laboratory for Energy Analysis (LEA) survey. It is found that hydrogen production dominates the environmental impacts during operation of the system. Significant improvements in the cost and environmental impact reduction are achieved by improving the cell efficiency, lifetime and recycling/refurbishment rates. While, reduction in stack production costs leads to improvement in economic performance of the system. It has been found that the allocation procedure used has significant effects on the quantification of environmental impact values of the system. A framework for accident risk assessment for the POWER-UP system is developed, which is based on approximations and assumptions due to lack of relevant data. Based on this preliminary work, a comparative risk assessment of the system shows that it performs better than the fossil fuelled and renewable plants. The MCDA shows that the POWER-UP system with current assumptions regarding lifetime, costs, efficiency and EoL treatment performs worse than the renewable and fossil based plants. The future system on the other hand performs better than the fossil based and some of the renewable plants depending on the weights selected by the decision maker.

[3] http://www.afcenergy.com/projects/powerup.aspx