capital cost requirements for the CNT-PFR and CNT-FBR process models. The net present value (NPV) for the CNT-PFR process was $462.5 million, whereas the net present value (NPV) for the CNT-FBR process was $740.5 million. The net present values for the CNT-PFR and CNT-FBR production processes were both positive, and proposed investment in the production of 5,000 metric tons of carbon nanotubes per year, based on the CNT-PFR and the CNT-FBR production technologies were economically feasible and viable.

The raw materials, products, energy requirements and the emissions from the CNT-PFR and CNT-FBR production processes were obtained The total flow rate of raw materials, which consisted of the feed and other reactants, into the CNT-PFR and CNT-FBR processes, was 3,772 kg/hr and 4,234 kg/hr respectively. The total flow rate of carbon nanotube product and other emissions from the CNT-PFR and CNT-FBR production processes was 3,772 kg/hr and 4,234 kg/hr respectively. The energy consumed by the CNT-PFR and CNT-FBR production processes was in form of steam and electricity. The steam consumed by the CNT-PFR and CNT-FBR processes was 13,746 kg/hr and 18,298 kg/hr respectively. The electrical energy consumed by the CNT-PFR and CNT-FBR production processes was 107 MW and 13 MW respectively. The electrical energy consumed by the CNT-PFR process was significantly higher than the electrical energy consumed by the CNT-FBR process because of the higher operating pressure of the CNT-PFR process (450 psi) compared to the operating pressure of the CNT-FBR process (150 psi).

In summary, the chemical vapor deposition technique offered a more promising route to the commercial production of carbon nanotubes using either a plug flow reactor using iron carbonyl and carbon monoxide or a fluidized bed reactor using carbon monoxide and a cobalt molybdenum catalyst. These reactors were used as a basis for the conceptual design of two commercial–scale plants with a capacity of 5,000 metric tons of carbon nanotubes per year. The plants were designed with recycling unconverted carbon monoxide reactant and purifying the carbon nanotubes. The profitability analysis for both processes showed that both production technologies were economically viable. The economic price for the CNT-PFR process was $38 per kg of carbon nanotubes using a minimum attractive rate of return (MARR) of 25% and an economic life of 10 years. The economic price for the CNT-FBR process was $25 per kg. Based on these results, the route to multi-ton production of high purity carbon nanotubes at affordable prices could become a reality if an environmental impact analysis is positive.

An environmental impact analysis was conducted for both of the CNT processes. Two scenarios were considered: All CO2 released into the environment, and all CO2 reused as raw material. The environmental impact analyses for both the processes were based on the following:

Media for release of CO2, CO and H2 – Air
Water release not accounted for as it is reused: CW/SSS/SST
Efficiency of all heat exchangers: 75%
Only Natural Gas used as fuel
Electricity/Other energy consuming utility was not evaluated

Case 1: All CO2 Released into the Environment: The contribution of each of both the processes in relevant impact categories was determined where quantitative data gives an idea of the magnitude of contribution of each process in various impact categories.

Case 2. All CO2 Reused As Raw Material: The contribution of each of both the processes in relevant impact categories i was determined where quantitative data gives an idea of the magnitude of contribution of each process in various impact categories.

In summary the environmental impact analysis used two scenarios, and in both it was observed that the water and fossil fuel usage was more in CNT-FBR Process compared to CNT-PFR Process. Moreover, the CNT-FBR Process even contributes to photochemical smog due to the CO released in the environment. Finally, if the carbon dioxide is recycled, the contribution to global warming is eliminated.

In order to provide a more comprehensive impact analysis of these processes, power consumption can be developed for each unit which can be used to back calculate the fuel used for producing it. Most of the streams come out pure (water, product. etc.). In order to provide a more realistic analysis of the CNT production processes, it is necessary to estimate the composition of impurities that would need to be treated before disposal. In the conceptual design, perfect separation was used, and equilibrium composition calculations are needed to improve the results of the environmental impact analysis. Future research

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Future Activities: None

Supplemental Keywords: Carbon Nanotubes, Life Cycle Assessment

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