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Future Possibility of Carbon Sequestration by Biomass-Fusion Hybrid Systems & Economic Performance of Fusion Power Plant on Future Deregulated Electricity Market & Techno-economic analysis of biodiesel and hydrogen production via Fusion-Biomass Hybrid Model

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A. This paper proposes a new and innovative fusion energy application in the emissions trading market based on the combination with biomass processing. An endothermic biomass conversion reaction of charcoal making process, or dry distillation;
($CH_{1.6}O_{0.6}$) = C+0.4H_2+0.6H_2O-451kJ (where biomass is assumed to be woody including large fraction of lignin.) can convert fusion energy obtained as high grade heat into carbon.
The product solid char is separated and can be stored as it is or sintered. This biomass-fusion hybrid system will provide an innovative carbon sequestration method that originally is recovered from atmosphere by the photosynthesis by plants. What this system provides is the isolation of CO2 from the earth cycle including fossil combustion, and stabilizes it as solid carbon, and "sells"in the emissions trade market. If the values of the electricity and emission credits are similar to those currently observed, total sales, i.e. chance to return the investment for fusion would be similar. While competition in the clean electricity market in the future is anticipated to be tough, CCS market can provide significantly larger capacity because no other alternative technologies are known other than the underground storage. In this emissions credit market, fusion has fewer competitors that may have limiting siting and environmental constraint.
Because transport, some industrial and residential heat sectors unavoidably release CO2, net negative emission by human activity with biomass is inevitable. This new fusion-biomass hybrid can provide net negative emission not only for electricity, but for all kinds of CO2 sources, and suggests the solution to return the CO2 concentration to the age before the industrial revolution. This study proposes an innovative option of fusion application that could potentially be larger and more important than electricity generation, and justifies the investment of fusion development that could be recovered from the future market.

B. The economic performance of steady-state fusion power plants on future deregulated electricity markets was quantitatively analyzed for the first time with a newly constructed Simplified PJM Market Model. The results showed that (i) discussions based on simple levelised cost of electricity are insufficient for deregulated markets and (ii) the unplanned outage frequency target should be lowered to 0.3 times/year on deregulated market to achieve economic rationality of fusion power plants.

Conventionally, the development strategies for fusion power plants came from extrapolation of past fission plant installation trends. However, due to the rapid transformations of the markets around the world, the future electricity markets will be significantly different from that of half a century ago. The fusion development strategies shall be revised accordingly: conventional measures such as levelised cost of electricity (LCOE) may no longer be applicable to future fusion power plants.

To quantitatively analyze the economic performance of steady-state fusion power plants on future deregulated electricity markets, Simplified PJM Market Model that incorporates three Energy Market, Imbalance Fee and Ancillary Service Market was constructed. A steady-state fusion power plant with 1,200 MW electrical output (2,801 MW fusion) was assumed. The net present values (NPVs) of 40 years of plant operation were calculated with the discount rate of 1.7%. A sensitivity analyses were conducted for the unplanned outage frequency from 0.001 to 0.00001 times/hours.

The economic performance of fusion power plant showed higher sensitivity to the unplanned outage frequency on deregulated market. The NPV of fusion plant on deregulated market would be devaluated from +368 million USD to -741 million USD when the unplanned outage frequency rises from 10-5 per hour to 10-4 per hour, while on conventional market, the devaluation would be only from 370 to 285 million USD.

This study pioneered a vital new area for the economic assessment of fusion power plant: the economic performance on the deregulated electricity market. Results show that discussions based on simple LCOE would be inapplicable to deregulated markets, and the unplanned outage frequency target should be lowered on deregulated market.

C. This paper aims to investigate techno-economic analysis of fusion-biomass hybrid model based on previously proposed technical and chemical concept. Fusion-biomass hybrid model, which takes no value of waste biomass from municipal, agricultural, and forestry areas as feedstock, produces synthetic gas generated by endothermic pyrolytic gasification using high temperature of fusion heat. Several blanket designs based on LiPb and SiC technology such as Dual Coolant Lithium Lead (DCLL) would be available for the heat over 700oC. Its technical extension is possible to perform biomass gasification of ($C_6H_{10}O_5$ + H_2O ⟶ $6H_2$+ 6CO -814 kJ) to produce chemical energy, synthetic gas. Produced synthetic gas can be converted into two different products; diesel and hydrogen. First, synthetic gas that contains hydrogen (H_2) and carbon monoxide (CO) can be converted into diesel which is regarded as "carbon-neutral biofuel"by Fischer-Tropsch process ($2H_2$+ CO ⟶ -CH_2-+ H_2O + 160kJ). The other is to produce hydrogen by water-gas shift reaction process (CO + H_2O ↔ H_2+ CO_2 + 32 kJ). Carbon dioxide from water-gas shift reaction can be managed by carbon capture and sequestration technology. Underlying the technical and chemical process of fusion-biomass hybrid model, levelized cost of fuel for diesel and hydrogen is calculated as USD0.41/kg and USD1.21/kg, respectively. Breakeven price is USD0.73/kg for diesel and USD2.65/kg for hydrogen under the assumption of 1,000ton/day of fusion-biomass hybrid plant with 30-year lifetime. Sensitivity analysis is performed applying total capital investment, operation & maintenance cost, fuel production amount, operating time and fusion heat cost to understand the correlations between variables and fuel price. In addition to that, net present value after 30-year operation is calculated according to the change in fusion heat cost and fuel price, because technical structure and advancement highly affect fusion heat cost. Fusion-biomass hybrid model benefits in terms of environmental aspect by decreasing both waste biomass and CO_2 emission. This study can provide guideline in targeting which fuel could be economically justified in the circumstances of variable environmental policy under different market demand and economical situations that would have a significant impacts on the designing of the fusion commercial reactors.

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