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Emergy evaluation of combined heat and power plant processes

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ABSTRACT

An energy-focused environmental accounting method based on the embodied solar energy (emergy) principle was used for evaluating biomass and coal-based combined heat and power (CHP) cogeneration processes. The emergy method expresses all the resources needed (fuel, investment, labor etc.) as solar energy equivalents. The method looks at sustainability from the point of view of the biosphere. In fact, emergy aims to be a 'memory' of how much work the biosphere has done to provide a product.

Biomass and coal-based CHP alternatives were compared with independent production of heat & power. It was found that biomass-based cogeneration is 3.3 times more emergy-efficient than coal-based independent production; i.e. the biosphere needed to work 77% less for biomass CHP produced heat & power compared to that produced independently from coal.

Cogeneration from the same fuel was in all cases 0.3 times more emergy-efficient than independent production. In general heat and power production from biomass is 2.3 times more emergy-efficient than that from coal in a similar process. The emergy sustainability index shows a similar trend, e.g. the sustainability index of a biomass CHP plant is 15 times higher than that of a coal CHP plant.

The fuel, its transport, and the oxygen in air used for burning account for over 80% of the emergy in biomass CHP, whereas in a coal-based process the share is over 90%. The share of capital is quite small in terms of total emergy.

1. Introduction

Sustainable development, reduction of greenhouse gas emissions, and the availability of fossil energy resources are matters of great concern. These concerns are justified, since heat and power are the essential driving forces of industrial processes and communities. Nevertheless, unsustainable technology is currently dominant in electricity and heat production. Fossil fuels supply 86% of the world's commercial energy [1]. Despite concerns over biomass availability, it is claimed that biomass is more flexible and reliable as an energy source to replace fossil fuels than others, such as sunlight, wind, geothermal heat etc [2]. At the moment most electricity is produced in independent production, where heat is lost. The advantages of biomass CHP include a higher total efficiency than in conventional power plants and consequent reduction of greenhouse gas and other pollutants, provided the heat can be utilized as a by-product. From the local point of view, the application of biomass energy can contribute to sustainable development in multiple regards, not only from the environmental aspect but also in social ways, and by enhancing the local economy due to the demand for biomass in the proximity of the power plant [3]. In general, biomass fired CHP systems are considered to have a great market potential [4]. The moisture levels of pine wood chips can be reduced by water heat from process, which is satisfactory for using as a fuel for combustion in the energy generation process, at a higher efficiency [5]. Pine wood chips are applied as the biomass input for CHP plant in this study.

Earlier emergy based evaluations of CHP processes have used fossil-based fuels, typically coal: Caruso et al. [6] compared a number of cogeneration technologies with conventional power plant technology by using several fossil fuels. The transformities were calculated for the energy produced. Brown and Ulgiati [7] compared in detail three renewable electricity production methods (wind, geothermal, hydro) with three fossil fuel fired power plants. However, these were neither CHP processes nor biomass fired. Mirandola and Stoppato [8] evaluated five power production technologies on several levels. Technologies included oil fired thermoelectric, natural gas CHP, geo–thermoelectric, gas turbine CHP, and hydroelectric processes. Feng et al. [9] compared a conventional coal-fired process with two designs of waste incineration CHP plants. Al-Sulaiman et al. [10] studied an integrated organic rankine cycle (ORC) with a biomass combustor for

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