2.4. Transportation Systems

To avoid additional costs and energy required to dry and transport the seaweed to the conversion system, the optimal situation would be to establish all drying, energy conversion, and by-product processing facilities integrated together, near the shorelines. It was assumed that the drying equipment is installed near the shore, so that the harvested seaweeds are delivered directly into the dryer equipment. Dried seaweed was then transferred by trucks to the conversion plants. Transportation costs for a 25 tonne truck were 2.6, 1.45, and 1.27 $/km for a 40, 160, and 320 km transportation radius, respectively [27]. The average distance of transportation between the dryer and final product conversion equipment was considered to be 40 km (25 miles). Also it was assumed that the labor demand for the transportation and drying steps were equal to the labor demand in the ethanol plant [25].

2.5. Conversion Systems

After delivery, two energy conversion methods were considered, as follows:

1. AD (anaerobic digestion) integrated with the CHP system: Biogas produced in an AD is burned in a CHP system to produce electricity. The waste product (digestate) from AD was used as fertilizer.
2. Ethanol production through fermentation: Ethanol is the main product in this method, and fermentation by-products are used as animal feed, digestate, or electricity production, based on the selected process method. Fermentation residuals can be converted into animal feed or can be digested to produce biogas and thus electricity. Specifically, the by-products in this method were animal feed or electricity and digestate as bio fertilizer, or the combination of these three products. According to [5], the rate of animal feed per liter of ethanol production is 1.21 kg. The amount of digestate production in residual fermentation followed by AD was equal to the amount of fresh seaweed fermentation in AD, but electricity production was reduced to 64% compared to scenario 1 (based on [10]).

2.5.1. Fermentation

Potentially, the production of liquid biofuels from brown algae is high, due to the unique content of laminarin, mannitol, and alginate [8,16]. These structural polysaccharides and sugar alcohols should be broken down into their fundamental monomers before fermentation [14]. *Saccharomyces cerevisiae*, *Zymomonas mobilis*, glucanases, mannitol dehydrogenize, laminarinase, and cellulase are relatively common microorganisms and enzymes which are used for industrial fermentations [3,11,28–30]. To date, seaweed-based ethanol has been produced only on an experimental scale, so data for these processes must be estimated for large scale [5]. We assumed that the process of ethanol production from seaweeds may be similar to the process for corn ethanol conversion [5]. Therefore, with few exceptions, data of these processes, including energy and labor demand, equipment, by-products processing, and so on, were taken from [25].

2.5.2. Anaerobic Digestion (AD)

Because of the typically low lignin content in macroalgae, it may be suitable for production of biogas in an anaerobic digester [10,14,31]. The overall conversion efficiency could be improved by integrating the methane production system with a CHP unit [10]. Therefore, it was assumed that the AD was integrated with a CHP unit. The inputs for anaerobic digestion, in addition to seaweed slurry (seaweed + water), included electricity (mainly for pumping) and heat (to heat the slurry from ambient temperature to the desired temperature). Electricity was supplied by the output electricity of gas engines. Recovered heat from the gas engine was more than the AD requirement [4,10]. However, because of the variability of AD requirements in different locations and seasons, it was assumed that all the produced heat was used to fulfill the AD requirement. Therefore the outputs of AD with CHP