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# Logistics issues of biomass: The storage problem and the multi-biomass supply chain

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**Abstract**

Biomass is a renewable energy source with increasing importance. The larger fraction of cost in biomass energy generation originates from the logistics operations. A major issue concerning biomass logistics is its storage, especially when it is characterized by seasonal availability. The biomass energy exploitation literature has rarely investigated the issue of biomass storage. Rather, researchers usually choose arbitrarily the lowest cost storage method available, ignoring the effects this choice may have on the total system efficiency. In this work, the three most frequently used biomass storage methods are analyzed and are applied to a case study to come up with tangible comparative results. Furthermore, the issue of combining multiple biomass supply chains, aiming at reducing the storage space requirements, is introduced. An application of this innovative concept is also performed for the case study examined. The most important results of the case study are that the lowest cost storage method indeed constitutes the system-wide most efficient solution, and that the multi-biomass approach is more advantageous when combined with relatively expensive storage methods. However, low cost biomass storage methods bear increased health, safety and technological risks that should always be taken into account.


*Keywords:* Logistics; Biomass storage; Multi-biomass; Biomass supply chain; Energy exploitation; Agricultural biomass

**Contents**



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## 1. Introduction

Biomass is one of the renewable energy sources on which policy makers are greatly based upon to reduce the greenhouse gas emissions. One of its main advantages is that it is a very versatile energy source, generating not only electricity but also heat and biofuels to be used in the transportation sector. It is also one of the few renewable energy sources that may be stored and can generate energy on-demand. The academic community has also been very interested in the energy exploitation of biomass. Several studies have been performed to forecast the contribution of biomass in the future energy supply, both at a regional and at a global level [1–3]. All of these studies conclude to the fact that biomass usage will be increased significantly in the years to come. Nonetheless, there is no consensus on the maximum level biomass exploitation could achieve.

One of the most important barriers in increased biomass utilization in energy supply is the cost of the respective supply chain and the technology to convert biomass into useful forms of energy. It is therefore natural that many attempts have been made to date to simulate and optimize a specific biomass supply chain on the understanding that significant cost reductions could originate from more efficient logistics operations. Most of the research work performed concerns simulation models of the biomass supply chain, focusing on various aspects of the logistics operations.

The cost of producing short rotation forestry was investigated by using spreadsheet models in ref. [4], focusing mainly on the operations of biomass production, collection and storage. An analytic supply chain modeling for 5 biomass types was performed in ref. [5], concluding that 20–50% of biomass delivered cost is due to transportation and handling activities. Similarly, very analytical supply chain simulation models for forest [6], cotton [7] and *Miscanthus giganteus* biomass [8] have been developed. GIS has also been employed in several studies [9,10] to calculate the exact transportation distances for supplying specific amounts of energy crop feedstock across a state, taking into account the spatial variability in their yield.

## 2. Previous literature on biomass storage

The stage of biomass storage is a very critical link on the respective supply chain. In most cases of the relevant research work low cost storage solutions are chosen, without examining the positive effect that more sophisticated (and more costly) solutions may have. Many researchers assume on-field biomass storage [5,8,11]. Both ambient and covered on-field storage has also been examined [12]. The method of on-field storage has the advantage of low cost but on the other hand, biomass material loss is significant and biomass moisture cannot be controlled and reduced to a desired level, thus leading to potential problems in the power plant technological devices. Furthermore, health and safety issues exist, such as the danger of spores and fungus formation [5,13] and self-ignition due to increased moisture. Finally, the farmers may not allow on-farm storage of the biomass for a significant time period, as they may want to prepare the land for the next crop [11].

Several authors consider the use of intermediate storage locations between the fields and the power plant [5,14,15]. For all biomass fuels in which the use of intermediate storage has been modelled, the fuel has to be transported twice by road transport vehicles (first from farm/forest to the intermediate storage facility and then from storage to the power station). This fact will result in a higher delivered cost than a system in which there is only one road transport movement (directly from farm/forest to power station). Using an intermediate storage stage may add in the region of 10–20% to the delivered costs, as a result of the additional transportation and handling costs incurred [5].

Finally, the option of settling the storage facility next to the biomass power plant has also been examined in the relevant literature [15,16]. On the latter case, an innovative storage layout with biomass drying capability using dumped heat from the power plant was presented. This concept aims at reducing faster the biomass moisture content and prevents material decomposition as well as fungus and spores formation. Using storage facilities attached to the power plant is the only viable case of accelerating the drying process of the biomass, as dumped heat may be used without need for extra energy consumption.

It is obvious that the biomass supply chain literature has not paid to the issue of biomass storage the attention it deserves. In most cases the lowest possible cost solution is adopted, without examining the effect this solution may have on the total system cost. This work aims at comparing three biomass storage solutions found in the literature, in terms of total system cost. The concept of multi-biomass is also adopted in its simplest form: two locally available biomass types are considered, as this concept may lead to significant system cost reduction [14]. The analysis is performed by examining a case study, in order to come up with some tangible results.

## 3. The biomass supply chain

### 3.1. Typical layout

A typical biomass supply chain is comprised of several discrete processes. These processes may include ground preparation and planting, cultivation, harvesting, handling, storage, in-field/forest transportation, road transportation and utilization of the fuel at the power station.

Considering the typical locations of biomass fuel sources (i.e. in farms or forests) the transport infrastructure is usually such that road transport will be the only potential mode for collection and transportation of the fuel. Other factors that favour the use of road transport include the relatively short distances over which the fuel is transported and the greater flexibility that road transport can offer in comparison with other modes. Other transportation means, such as ship or train may be considered when long distance biomass transport is examined [17]. However, this is not the case in this work, where emphasis is placed on locally existing biomass types.