

Analysing terminal facilities for biomass operations

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Introduction

The use of solid biomass (e.g. wood pellets) has been boosted by the recent development in bioenergy and EU directives. For instance, some power stations are in the process of a conversion to co-firing with sustainable biomass. The worldwide growing demand promotes the international biomass trade because the supply potential is unevenly spread out and shipping is and will continue to be the main method for transporting solid biomass.ⁱ Bulk terminals around the world have been dealing with solid biomass for some time on a small scale. However, with the expectation of the use of bioenergy growing (see Figure 1) and consequently the international solid biomass trade market. It is necessary to address comprehensive analyses of the terminal facilities for solid biomass operations.^{ii,iii}

Several ports already have appropriate handling facilities but the storage and inland transportation will require additional investment. Various aspects should be taken into account to provide a thorough picture of solid biomass operations: the significant material types for large-scale handling; the physical/flow properties of solid biomass; a comparison between handling of solid biomass and other common bulk material; and the effects caused by the stochastic parameters (e.g. vessel arrival patterns) to the storage capacity and storage time of solid biomass operations. These aspects are further discussed in the following sections.

Material type and properties

There are various kinds of solid biomass, but not every type is suitable for being transported over long distances and handled in dry bulk terminals. Selection criteria such as potential availability, the application preference/possibility by major users and logistical concerns were used to estimate which materials will

be commonly handled. Based on these criteria, the types of solid biomass to be expected by dry bulk terminals are: wood pellets, wood chips and torrefied pellets.

It is essential to understand the material properties of these selected solid biomass types, in order to know how to handle and store them properly. Selection and design of handling and storage equipment for solid biomass types strongly depends on their physical material properties/flow properties. Furthermore, the flow properties may also affect the operational process.

Although some handling properties of wood pellets and wood chips have been obtained by various studies, a completely range of their flow properties was not very clear. As a newly developed material, there is no information available yet for the flow behaviour of torrefied pellets. Various experiments such as density testing, large-scale linear annular shear testing, and linear wall friction tests were performed recently to determine the handling characteristics of wood pellets, wood chips and torrefied pellets.^v (see Figures 2, 3 & 4) For a better understanding regarding equipment it is important to make further interpretations: to compare these solid biomass properties with other bulk materials that have been handled and

studied frequently, such as coal. Table 1 shows an overview of the flow properties of some solid biomass types and coal.

Comparison between biomass and coal

The following points can be made on the similarities and differences between the selected solid biomass and coal (see Table 1):

- Wood pellets have better flow-ability among the selected solid biomass materials and coal. The flow behaviour of torrefied pellets is more resembling to the flow behaviour of coal. Wood chips have the poorest flow ability among these materials.
- Values of bulk density and lower heating value (LHV) together show that up to eight times more volume of solid biomass is required for the same energy input.
- Similar to coal, solid biomass properties vary in a wide range. Equipment designed for the handling solid biomass should take this fact into account.

In terms of handling and storage equipment, the following conclusions can be made for solid biomass:

- Sensitive towards material degradation. Therefore the storage

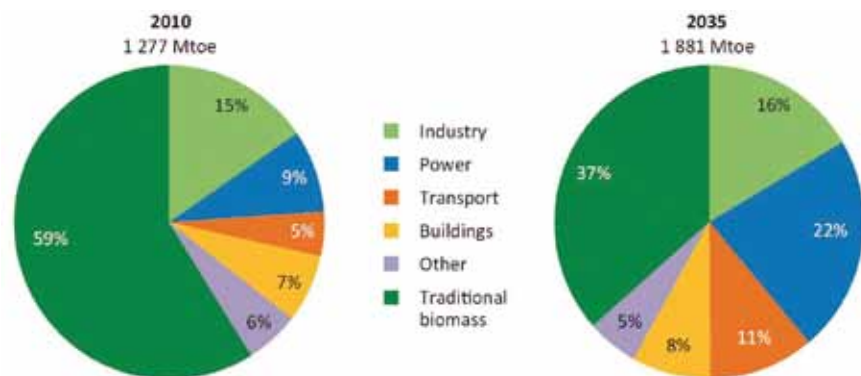


Figure 1: World bioenergy use by sector in the New Policies Scenario, 2010 and 2035.^{iv}



Figure 2: Wood pellets - 6 mm (left), Figure 3: Wood chips - 0-100 mm (top right), Figure 4: Torrefied pellets - 6 mm (bottom right).

- time should be shorter than for coal.
- Equipment designed for coal can be used for solid biomass. However, the number or capacity of equipment has to increase (three to four times more due to bulk density) for same tonnage performance requirement.
- Enclosed or covered equipment is required (e.g. flat storage, covered belt conveyors).
- Handling methods should be adjusted to cope with biomass material properties for un-wanted effects (e.g. against self-heating).

Storage facilities and time

Storage facilities for solid biomass require large areas as a result of their low bulk density and energy content (see Table 2), and such provisions can be realised either

at the waterside terminals or more inland, at the premises of the power station (end user). To have the same energy output as coal, up to eight times more volume of solid biomass is required. A common demand figure for a power station unit will be about three million tonnes of wood pellets per year and when the choice comes to wood chips even 4-4.5 million tonnes may be required. Due to the low bulk density, the lower energy content, and the need for an uninterrupted supply, power stations typically ask for storage capacities of about 100,000 tonnes which requires a covered storage around 200,000 cubic metres (wood pellets). In addition, because of their lower bulk density, more volume of solid biomass needs to be stored. With the same stacking method, 1.3 times more land is needed (lower volumetric performances for biomass).

Supply chain characteristics e.g. vessel sizes, strategic decisions, reliability, and availability of inland transportation and costs will determine which location should be preferred to realise a large-scale storage facility. The stochastic nature of supply chains, for example arrivals/departures of incoming and outgoing material flows, size composition of vessels/inland transportation, and the number of influencing parameters for example supply seasonality, make it difficult to simply calculate the best alternative. That's why simulations are increasingly applied to analyse the biomass supply chain, including a sensitivity analysis for parameters difficult to estimate over a long period of time (terminal operation disruptions such as rainfall, changes in vessel charter policies), see Figure 5 for an example.

		Torrefied pellets	Wood pellets	Wood chips	Coal
Physical properties	Particle Density (kg/m ³)	1225 - 1251	1174 - 1820	N/A	1100 - 1800
	Bulk Density (kg/m ³)	633 - 651	506 - 629	223 - 263	640 - 920
	Moisture Content (%)	4	8 - 11	42 - 49	15 - 65
	Effective angle of internal friction (°)	48	40 - 43	48 - 53	55
	Angle of repose (°)	38 - 44	34 - 40	43 - 47	27 - 38
Equipment in contact with biomass: wall friction angle	PE (°)	12	9 - 11	15 - 19	10 - 15
	Concrete (°)	29	29 - 32	32 - 36	30
	Mild Steel (°)	15	16 - 17	25 - 29	24 - 34
	Stainless Steel (°)	26	17 - 19	29 - 30	25 - 35

Table 1: Summary of the experimental results.^v

	Torrefied pellets	Wood pellets	Wood chips	Coal
Lower heating value (LHV) (GJ/ton)	8 - 21	16 - 18	14 - 17	30

Table 2: Comparison of lower heating value between solid biomass and coal.

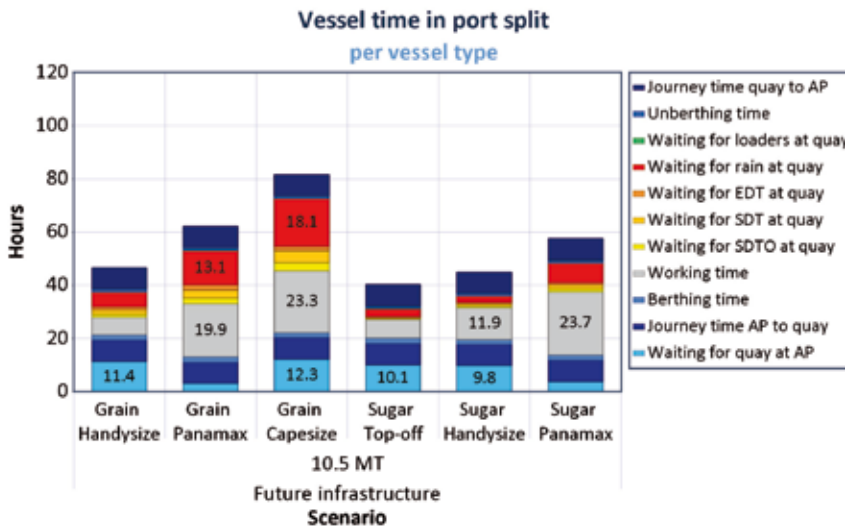


Figure 5: An example of vessel handling time in detailed status.

Several enclosed/covered storage options can be used to store solid biomass. Some power stations/bulk terminals have selected silos (ensuring a first-in/first-out material flow); others chose wide sheds or domes (with a circular stacking/reclaiming system). The following recommendations apply to all storage options:

- Measures against dry matter loss and material degradation, such as a good ventilation system and pre-drying before storage, should be applied.
- Measures against self-heating should be applied. Such measures can be

having homogeneous storage piles (in terms of material particle size distribution), taking the geometry of storage piles into account, avoiding compacted storage piles etc.

- The storage time of solid biomass should be controlled. Depending on the moisture content of the material, the recommended storage time varies from three weeks (for fresh wood chips) to three months (wood pellets).
- Both storage capacity and storage time are sensitive to arrival and departure patterns. Good logistic control is required.

In conclusion

The international biomass trade market is expected to have a significant increase for the predicted future growth in the use of bio-energy fuels. Among the large variety of biomass wood chips, wood pellets, and torrefied pellets are identified to be the most preferable and possible materials.

The material characteristics of solid biomass imply that volumetric performance is the recommended main benchmark rather than tonnage performance. The number of equipment increases for equal tonnage performance requirements (three to four times more, due to bulk density). Equipment designed for coal can be used for handling solid biomass. However, storage methods, storage time and handling processes should cope with solid biomass material properties (e.g. enclosed storage).

The low bulk density of solid biomass results in the requirement for a larger storage land size and faster stock turnaround time. An analysis with the help of a simulation model is recommended as it allows investigating the impact of stochastic events (e.g. material arrival and departure patterns, operational disruptions) and will result in a better terminal design in terms of berth capacity, equipment utilisation, storage capacity and storage time.

References

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^vM R Wu, 'A large-scale biomass bulk terminal', Delft University of Technology, 2012. ISBN 978-94-6186-076-7.

About the author



Dr Mi-Rong Wu is a consultant for TBA, a leading terminal design and simulation company in The Netherlands. Her primary responsibility is managing projects for design and performance assessment in the bulk sector. She has five years' bulk sector research experience focused on subjects such as bulk terminal design, bulk material handling, and the development of a simulation model for bulk terminal design. Dr Mi-Rong Wu holds a PhD titled: 'A large-scale biomass bulk terminal' from Delft University of Technology. The research explores the possibility of a large-scale bulk terminal in West Europe dedicated to handle solid and liquid biomass materials.

About the organisation

Netherlands-based TBA is a leading international provider of consultancy and software. Its product and service portfolio concentrates on marine terminals and intermodal container terminals. TBA's clients include all major terminal operators worldwide and many local port operators. TBA has completed over 200 terminal projects with varied scope; from design review to complete master planning. TBA supports a terminal operator during all stages from concept to realisation and thereafter in operations. TBA is specialised in ensuring that the planning is realised and targeted performance levels are achieved.

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