

## SOURCES OF FOREST BIOMASS FOR BIOREFINING IN FINLAND

*There is a growing need to increase the use of forest biomasses as a source of renewable, green energy. Also new bio-based products replacing those of fossil origin are to be promoted in order to decrease the carbon footprint and oil-dependency of industrial production. Goals to achieve a bio-based economy on a national level are ambitious and will require a significant enhancement or reallocation of the utilization of the existing forest resources. To realise these plans, the raw material demand of increasing forest energy production and biorefining must be addressed and fulfilled.*

### POSSIBLE SOURCES OF RAW MATERIAL

Currently, stem volume growth of the Finnish forests exceeds drain by about 30 million m<sup>3</sup> per year. 90% of the raw wood used annually (ca. 70 mill m<sup>3</sup> in 2010) is allocated to the wood product and pulp industries and the rest is directed to energy production in small-scale housing and heating plants. Wood energy is also produced from logging residues and stumps from clear-cuts as well as small-diameter thinning wood. Part of the by-products of wood and pulp industries, such as bark, sawdust and chips, are utilized in energy production. New biorefining facilities would be competing for raw material supply with these current users of woody biomasses. Although on a national level, there is a wide margin between the amount of wood assortments harvested today and the maximum amount that could be sustainably harvested, it is not self-evident that there is enough desired raw material for every purpose of use in every location.

Without specifying exact forest-derived raw material types needed for a biorefinery, potentially the raw material demand could be met by reallocating the current biomass flows. This could mean redirecting pulpwood, energy wood or industrial by-product flows into new processes. Trade cycles and changes in the production capacity of forest industry are reflected in the volume of harvested roundwood. This can lead to a temporary or even permanent free potential of harvestable roundwood, namely pulpwood that could be utilized in a new biorefining facility. However, redirecting the current energy wood and industrial by-product flows would create a respective deficiency in the raw material supply for energy production, which should be compensated in one way or another. In principle, moving renewable raw material from energy production to biorefining and replacing it by fossil materials, such as coal, does not sound very appealing. Therefore, another option to satisfy the raw material demand of biorefining would be to enhance the utilization of existing biomass resources. This supply would only be limited by the economic and ecological sustainability of forest management and, naturally, the quantity of the biomass reserves.

### QUALITY DEMANDS AND FEEDSTOCK PROPERTIES

The biorefineries' quality demands for raw material may differ from the ones of the current forest industries. The feedstock quality is defined by the processes used in refining as well as the variety of the desired end-products. For instance, gasification and pyrolysis are more sensitive to impurities, such as

rocks, sand or metals than fermentation. Furthermore, feedstock homogeneity is more important in gasification than in fermentation. Although these are robust generalizations, it is clear that all biomass types are not suitable for every refining process. The chemical composition and physical properties of stem wood, crown components or stumps are divergent, hence the intended purpose of use for all raw materials should be known prior to making estimates on feedstock availability.

The tree stem, excluding bark, is a relatively homogeneous material and its chemical and physical properties are well known. For many refining processes, one could argue that stem wood is the easiest production material. On the other hand, bark and crown components are more diverse in terms of chemical composition. As stem wood constitutes mainly of cellulose, hemicelluloses and lignin with small amounts of extractives, the ratios of these compound groups change from biomass component to another, as well as between tree species. Crown components contain much more extractives and other compounds than stem wood, which is a significant factor in determining the suitable feedstock materials for biorefining processes. Stump wood is quite similar to stem wood, with the exception of a somewhat higher concentration of extractives. However, there is a possible negative aspect in using stump and root biomass as a feedstock. Harvested stumps always contain some soil residue, such as sand or rocks, and these impurities could cause problems in some refining processes.

The chemical and physical properties of tree biomass components are unique to every tree species. Furthermore, so are the proportions of each biomass component of the whole tree biomass. For example, the crown components i.e. branches and needles are more dominant in spruce (ca. 20-30% of total biomass) compared to pine or birches (15-25%). Tree size is also a significant determinant of the ratios of biomass components. Proportions of stem wood and roots are increased as trees grow larger, and respectively proportions of the crown components, bark and stumps are decreased. These ratios affect the yield of desired biomasses, and should be taken into account in biomass potential estimations.

## **BIOMASS POTENTIALS**

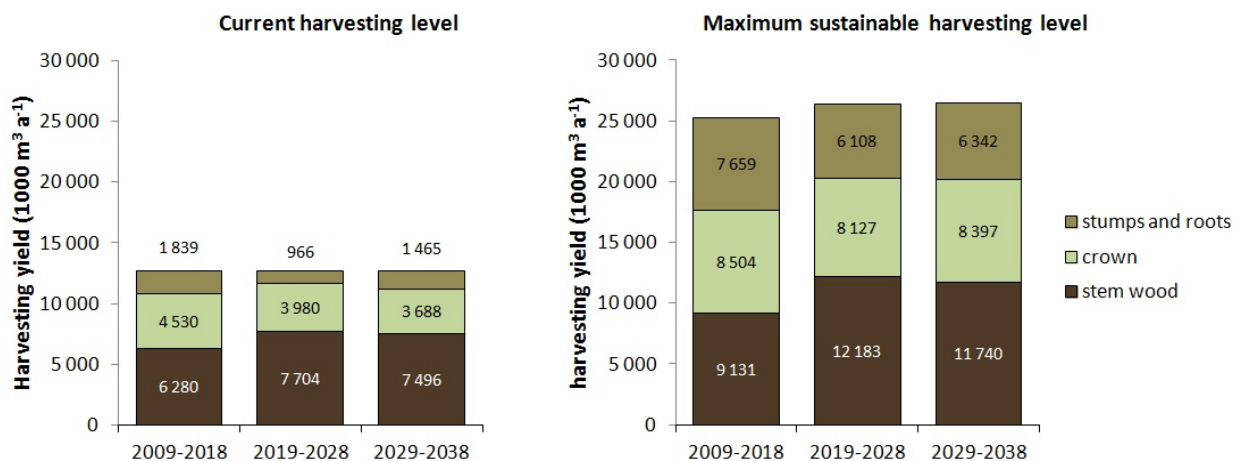
In order to evaluate the potential of harvestable forest biomasses, harvesting restrictions must be considered. Stem wood harvesting is not restricted any other way than by the limits of sustainability of forest management and nature values, but when harvesting tree crowns and stumps, possible nutrient loss or damage to the remaining or future tree population needs to be considered. According to the current guidelines for whole-tree harvesting, it is suitable only in pine and broadleaf-dominated thinning stands with fertility class better than or equal to sub-xeric heath land or corresponding peatland type. Logging residues from clear-cuts can also be harvested from corresponding sites. Stump lifting is accepted from these sites, excluding certain groundwater areas.

It has been estimated that in Finland the gross annual potential of forest chips from logging residues, stumps and small-diameter thinning wood is ca. 48 million m<sup>3</sup>. However, most of this potential is unusable due to ecological, economic or technical restrictions, so the practical potential of forest chips is around 14-20 million m<sup>3</sup> annually. Compared to the current use (in 2011) of forest chips, 6.8 million m<sup>3</sup>, there certainly is room for improvement in the utilization of non-roundwood forest biomasses.



At the same time, over 9.9 million m<sup>3</sup> of forest biomass-derived industrial by-products were used in energy production. Most of this, 6.6 million m<sup>3</sup>, was bark, and the rest consisted of wood residue chips, sawdust, recycled wood, and pellets and briquettes. There are no exact numbers on the quantities of the by-product reserves, but most likely they are extensively utilized already in energy production. For instance, the annual use of raw wood is ca. 70 million m<sup>3</sup>, of which a maximum of 10% could be bark. This would amount to roughly 7 million m<sup>3</sup> of bark, which is almost the quantity already used in combustion. Hence, utilizing these by-products in biorefining processes could be in direct competition with energy generation.

The development of the biomass resources and corresponding biomass harvesting potentials has been estimated with MELA-simulations for the following three decades (Figure 1). On the basis of current harvesting levels, the annual harvesting yields are not expected to increase very much in the future. Nonetheless, compared to the maximum sustainable harvesting levels there is quite a lot of unused potential, especially in the case of stumps. The nationwide MELA-simulations also point to a significant free potential of pulpwood. The difference in annual pulpwood harvesting yields between the current harvesting level and maximum sustainable is calculated to be ca. 7.7 million m<sup>3</sup> for years 2009-2018. It probably is not economically feasible to harvest all of this potential, but these figures indicate that there could be significant raw material reserves for new wood users.

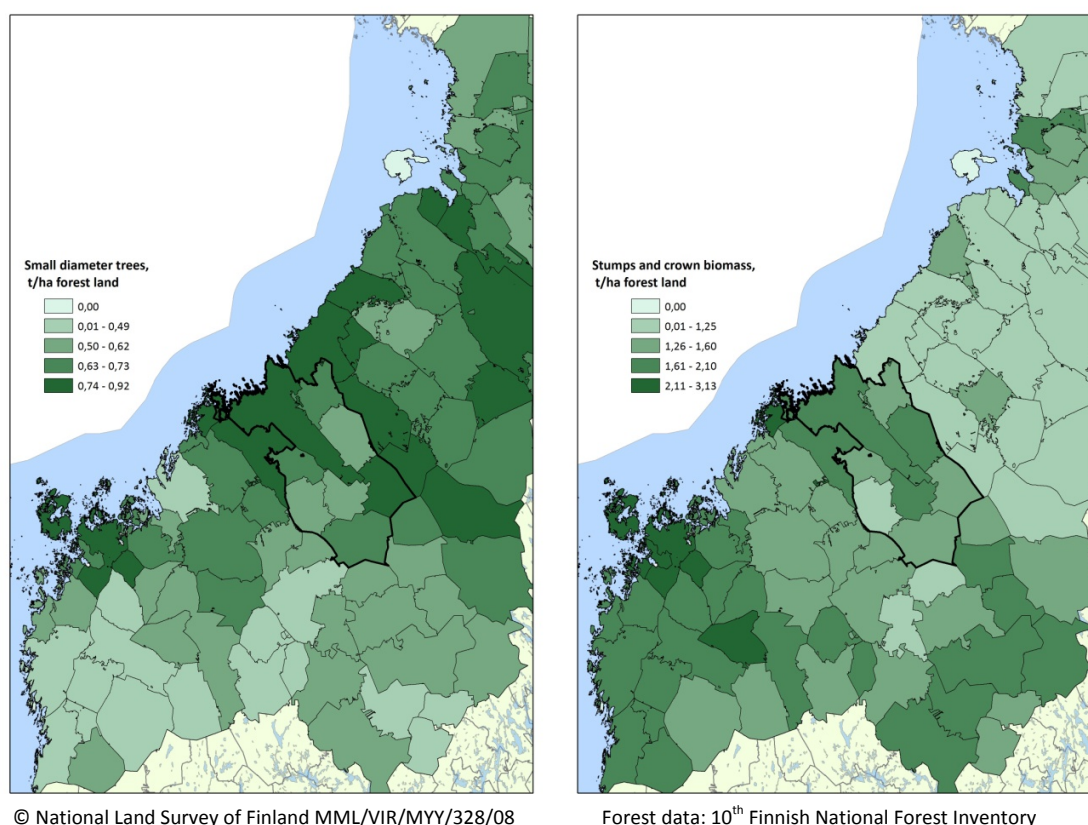


**Figure 1.** Annual harvesting yields of biomass components (non-roundwood) for three simulation periods using two harvesting scenarios. Source: Metla / MELA-group, June 19 2012.

## CONCLUSIONS

Reviewing national scale figures on forest biomass potentials leads to the impression that there is plenty of raw material available for new biorefining facilities. However, forest reserves are not evenly distributed throughout the country (Figure 2), and competition for raw material can be more intense in some regions. Additionally, the availability of different forest biomass assortments is partly dependent on roundwood loggings. The quantity of logging residues i.e. crown biomass from clear-cuts is directly related to the amount of final fellings (the same applies to stumps). Currently, the profitability of harvesting small-diameter trees is in some cases related to roundwood yield in the same felling, although it is not necessary to harvest roundwood if the yields of other biomass assortments are large enough.

The location and capacity of a biorefining facility are of key importance when the availability of raw material is considered. The location should be optimal in respect to the raw material reserves within a realistic procurement area. Also the type of the raw material reserves available should match the demands set by the refining processes. Ultimately, the capacity to pay for the raw material defines the eventual availability of forest biomasses for biorefining.



**Figure 2.** Municipal potentials of small-diameter trees (whole-tree biomass) and stumps and logging residues in Central Ostrobothnia (thick black line) and surrounding areas.

## LITERATURE

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