High Quality Wood Chips for Gasification

Ulf-Peter Granö

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To ensure the best possible end products, the energy wood collected from forests must be high quality. The same applies to the rest of the chain: all the work and equipment used in harvesting, handling, and processing of bioenergy feedstock must be also high quality.

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Introduction

The quality development of small-scale production and processing of biomass for local and regional consumers requires research and monitoring. Small-scale solutions improve employment prospects for rural workers in energy production and processing. Active small businesses and energy cooperatives are needed in the harvesting, handling, and processing of local energy commodities for local and regional consumers.

To successfully produce high-quality final products, a few aspects should be considered across the entire value chain:

- Choose good-quality energy wood to ensure low amounts of bark
- Properly utilize the natural drying process to save drying costs
- Use powerful, well-built equipment that can provide high-quality energy wood
- Integrate activities with processes such as gasification of biomass and small-scale CHP units
- Cooperate with local energy cooperatives and entrepreneurs
- Prefer customers in the local area and the local region

The appropriate combinations and good application of the elements listed above can help achieve a higher utilization rate of energy wood and side products. A higher rate then contributes to the reduction of waste and unused by-products while also reducing environmental impact.

Figure 1. Smooth and fine wood chips

Uneven and poor wood chips.

Quality of energy wood important for gasification

Recently there has been a significant increase of interest in procuring the best quality wood chips for processing. Getting the best raw material requires that each stage and instance of handling in the process be carried out with the best practice available.

There are two basic methods for managing energy wood from the forest.

1. Handling fresh chips by chipping recently delimbed trees next to a forest road.
2. Handling the delimbed wood and chipping after natural drying in the field.

Forest machine harvesting and natural drying

Harvesting energy wood is performed with efficient machinery, which is nowadays often equipped with a multi-tree handling (MTH) unit for multi-stem handling and multi-stem delimbing.

Figure 2. The MTH unit for multi-stem delimbing. *Photo, John Deere (www.deere.se)*

Connecting weighing equipment to an energy-harvesting unit can facilitate the calculation of the amount of harvested energy wood. Crane-tip mounted scales make it possible to determine the amount of energy wood that is harvested or forwarded with a forest tractor, a harvester, a forwarder or a harwarder.

Figure 3. A crane-tip mounted scale for weighing of energy wood.

Chipping fresh wood chips

The handling chain for chipping green wood chips requires that fresh wood material be used within a limited time, especially during the warm season. Microorganisms directly trigger the degradation process, resulting in temperature rise, humidity increase, and unhealthy mold dust (fungal spores).

For the production of quality chips, all branches and green parts should be left in the forest. After chipping, the material should be dried by an efficient drying process and then temporarily stored under a roof before the chips go to further processing.

Drying fresh chips

Drying fresh wood chips directly after harvesting, when the moisture content is between 45% and 55%, means that a very large amount of water must be removed to reach a moisture content below 15% to 25%, as many of the gasification plants may require. There are many different types of wood dryers to choose from. Effective options for better drying quality include rotary drum dryers, bin dryers, tower dryers, and belt dryers.

Figure 4. Natural drying in the field in an open area. The energy wood must be covered before the autumn rains begin.

Final drying of field-dried wood

After chipping, naturally field-dried energy wood has a moisture content between 25% and 40%. Drying should achieve a moisture content below 15% to 20%, therefore the final drying process must be performed correctly.

In order to achieve moisture content below 20%, preheated air needs to be used. It requires an efficient dryer that can utilize waste heat to keep the drying costs down. For a small chip producer it often means that the drying plant will be built adjacent to a local district heating plant.

Quality energy wood requires quality throughout the handling chain

To achieve and maintain a sufficient supply of high-quality wood chips, the various work and management, from harvest to processing, must be carried out in a satisfactory manner. The quality of the energy wood that reaches the processing plant depends on the quality of the wood materials, as well as on the quality of work in different parts of the handling chain of the biomass.

General guidelines

Some general guidelines for the management of energy wood materials from harvesting to processing:

- Prevent the energy wood material from contamination by soil, dust, and other contaminants during harvest and transport.
- Remove the nutrient-rich green parts during harvest (e.g., branches, needles, and leaves).
- Sort the energy wood materials by quality at an early stage.
- Choose a good location for the natural drying and storage, where contamination can be avoided and drying can be done in the best way.
- Cover energy wood stacks stored for natural drying before the autumn rains.
- Avoid making large quantities of damp wood chips for long-term storage. Moist wood chips easily get moldy. In addition to degradation of the chips' energy potential, mold spores easily spread into the environment.
- Minimize the risk of mold in damp wood chips by starting the final drying early.
- Protect dried energy source from precipitation by storing it under a roof.
- Minimize the potential for soil moisture to moisten an already dried wood material.

A well-prepared storage location provides good conditions for effective drying of energy wood.

Figure 5. MTH multi-stem delimbed downy birch provides excellent energy wood for quality chips.

Chipping energy wood

The effective coordination of the chipping process for energy materials requires a careful driver and effective chipping equipment. Substandard or poor quality material should be sorted out before chipping.

Figure 6. Large, tractor-driven chippers operated by an experienced entrepreneur often produce better chip quality..

Transportation

Avoid exposure to impurities at all handling stages: during the transport of energy wood materials from the forest to the field drying location, during transport of wood chips to the storage location, and during transport to final drying from the chipping location. Contamination and unwanted contact with the ground can easily occur during loading and from tractor tires.

Logistics and final drying

Well-planned loading and removal of wood from the chip dryer improves the handling. Final drying is accomplished with minimal energy losses and achieves uniform moisture content of the dry wood chips, which ensures higher quality.

Storage of dried chips

After the wood chips are dried, they must be stored under a roof in a dry place where water cannot enter. If drying is done in batches, a larger buffer silo for wood chips is needed before transportation to the processing plant. Otherwise, there can be problems when a steady supply of wood chips exists.

Effective field drying

Experience and knowledge show that field drying can reduce moisture content to 25%–30% with the right choice and extra effort. Here are some guidelines:

- Choose an open, airy space for drying and storage.
- Ensure that air can circulate under the stack of energy wood, supported by the right size logs.
- Cover the woodstack before the autumn rains.
- Utilize the dry weather during the summer season for efficient drying.
- Do not let snow and water get into the stack during the removal of energy wood and chipping.
- Old and overyear wood material should be burned as wood chips. It should not be used for further processing.

Some examples of logistics for biomass

To ensure the availability of good biomass for the gasification of wood chips, smooth logistics and efficient supply chain management are needed. Good logistics depends on the type and quality of wood materials used in the gasification. The general guideline to follow is as follows: the cleaner and more homogeneous the wood material is, the easier the purification process after gasification will be.

During start-up, the following must be considered: the availability of wood materials and the main purpose of the producer gas or biosyngas (bio-SNG). If the product gas is directly burned in the local combined heat and power (CHP) unit, the requirements for the purification of the gas are lower. Other uses of the product gas increase the demands for purity and gas quality.

Harvesting, handling, and pre-treatment or processing of the biomass from forests can be done in many different ways, depending on the seller and the buyer. The biggest differences in the handling chain often depend on who the customer is. Customers can be major ones, such as power plants, or local ones, such as energy co-operatives.

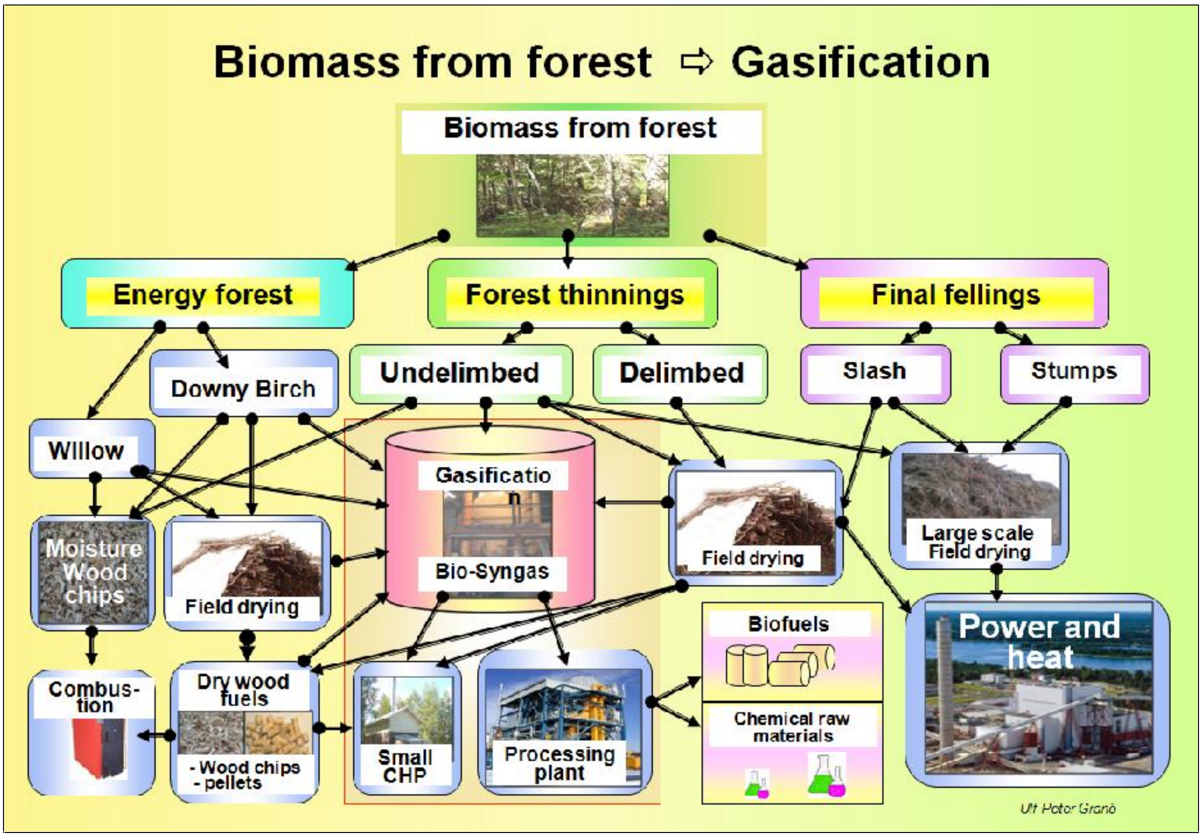

Figure 7. Simplified overview of the routes biomass can take: from, energy forest, forest thinnings and final fellings.

For small-scale gasification in rural areas, the primary question is choosing the right way to combine the gasification plant with the local CHP unit for producing both heat and electricity to make most of biosyngas (i.e., wood gas) from the gasification. Depending on the type of gasification facility and the technology, the biomass more or less requires final drying before the wood chips can be used for gasification after chipping and drying.

Biomass from forest thinnings

Final fellings often require larger equipment because the wood is thicker and a high amount of larger trees are included. In contrast, harvesting and processing biomass from thinnings requires only the smallest harvester models.

The quality of biomass feedstock deteriorates quickly if degrading fungi, bacteria, and insects are allowed to rapidly proliferate during storage. The risk of degradation can be reduced by pre-drying and proper storage.

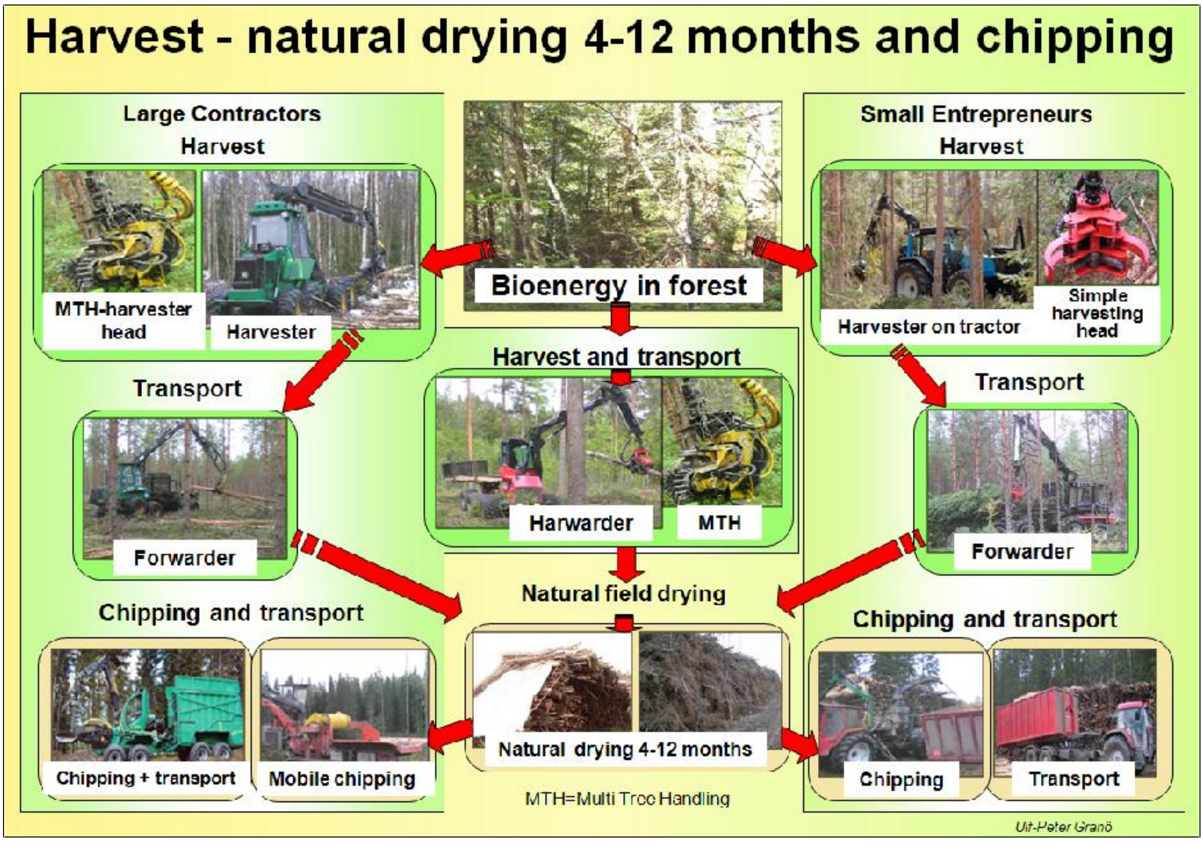

Figure 8. Examples of machines and equipment in the forest harvesting chain.

Natural drying of energy wood

Natural air drying is the best option to eliminate the high humidity in the energy wood material.

Figure 9. A well-made coverage for energy feedstock produces drier end product. Depending on the conditions, the moisture content of the energy wood can be below 30% (moisture).

By ensuring that the material is properly protected before the autumn rains, the material stays drier and at least 5% lower humidity of the wood material can be achieved compared to an uncovered stack of energy wood.

Equipment for chipping and crushing biomass

To use biomass from forests for small-scale heating or small CHP units, the material has to be chipped or crushed. For small users, the wood fuel is normally in the form of wood chips.

Small or large energy entrepreneurs?

Development in rural areas has shown that a range of machine work services are increasingly delivered by contractors. This also involves the large-scale forestry machine work. Harvesting and transportation of roundwood and energy wood, slash bundling, chipping, and other actions are performed by small and large contractors. The small contractors are often local one-man businesses.

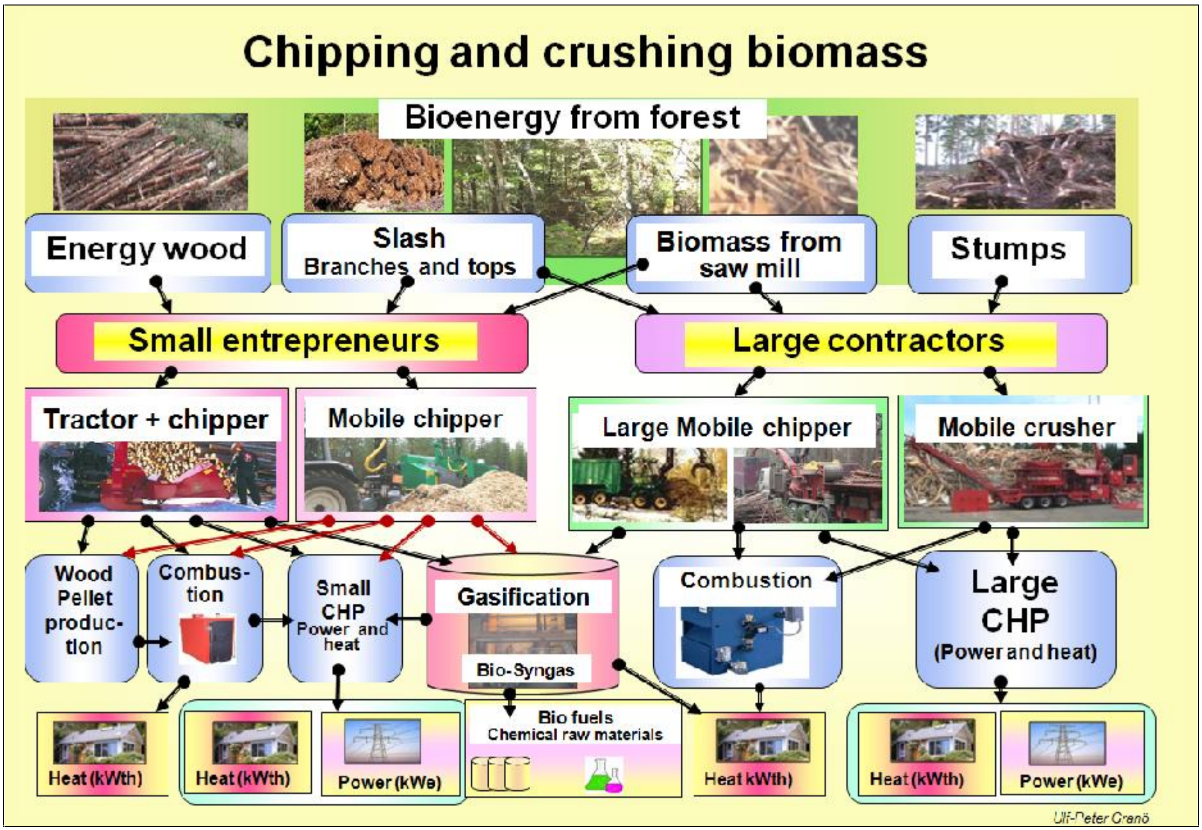

Figure 10. Overview of alternative routes for biomass from forest, through chipping / crushing, and processing. Bioenergy for heat or for electric power and heat. Bioenergy, as feedstock for biofuel or the chemical industry.

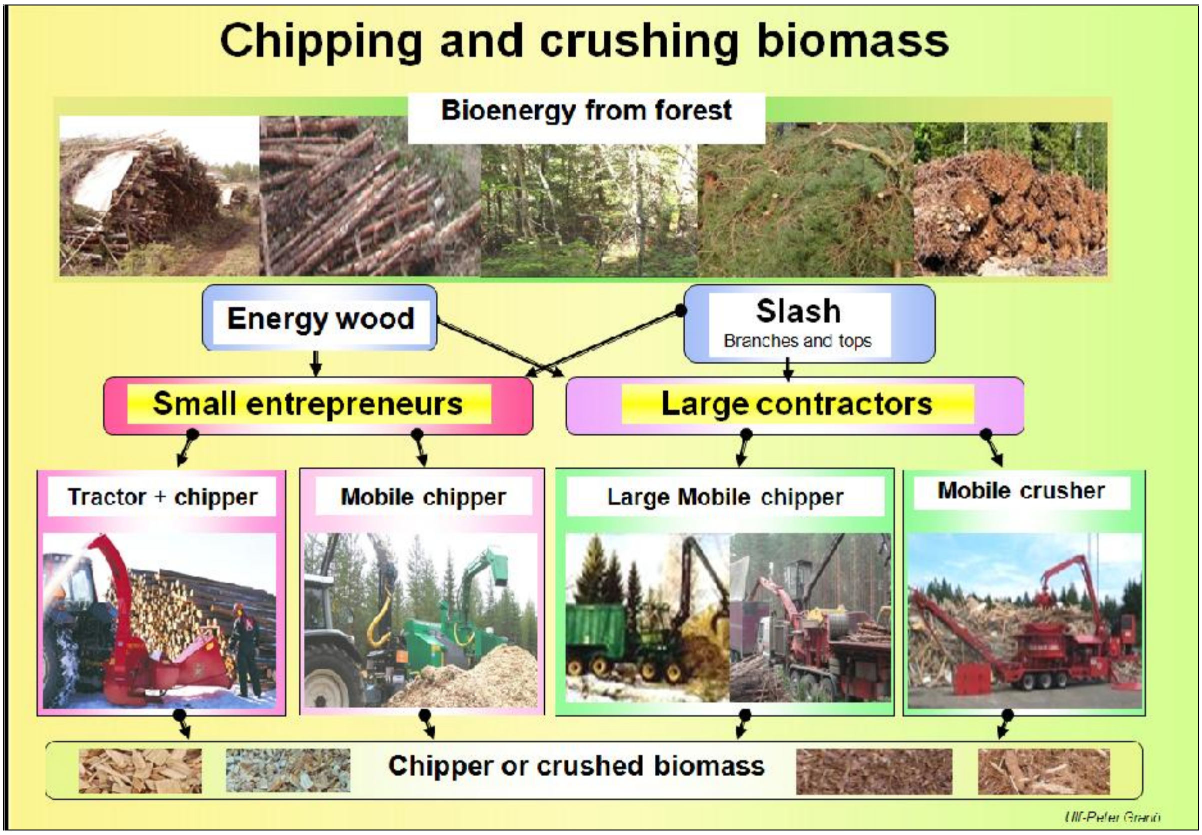

Figure 11. Examples of differences between small and large contractors. Large contractors have often chips equipment with capacities of over 150 m^3/h. Large mobile crushers are mainly used in connection with large power plants to, for example, crush stumps and demolish wood.

Examples of the ways for producing biofuels from wood

Type of action	*Biofuel raw materials*		*Handling*		*Type of wood fuel*
Final fellings *(for regeneration of forest)*	Slash *(Branches and tops)*	Fresh	Harvesting - Collecting	Chipping	*Green* wood chips
			Harvesting - Bundling	Chipping	*Green* wood chips
				Field drying + chipping	*Brown* wood chips
		Harvesting - Field dried	Collecting	Chipping	*Brown* wood chips
			Bundling	Chipping	*Brown* wood chips
Thinning and clearing in young forest stands	Energy wood , whole trees	Fresh	Harvest -Direct chipping	at harvest	*Green* wood chips
			Harvesting -forwarding	Chipping	*Green* wood chips
			Harvesting -forwarding	Field drying + chipping	*Brown* wood chips
			Harvesting - Bundling	Field drying + chipping	*Brown* wood chips
	MTH delimbing	Fresh	Harvesting -forwarding	Field drying + chipping	Quality wood chips
	Energy wood		Harvesting -forwarding	Field drying + combi-splitter	Firewood
Short rotation Energy forest *(downy birch)*	Energy wood	Fresh , whole energy woods	Harvest -Direct chipping	at harvesting	*Green* wood chips
			Harvesting -forwarding	Chipping	Green wood chips
				Field drying + chipping	Brown wood chips
	MTH delimbing	Fresh	Harvesting -forwarding	Field drying + chipping	Quality wood chips
	Energy wood		Harvesting - Bundling	Field drying + chipping	*Brown* wood chips
Bioenergy forest, Growing willow	Energy fuels	Fresh	Harvesting - Collecting	Chipping	*Green* wood chips
			Harvesting - Bundling	Field drying + chipping	*Brown* wood chips
Stumps	Energy fuels	Fresh	Collecting stumps	Field drying and crushing	*Brown* crushed wood

MTH = Multi Tree Handling *MTH delimbing = MTH for multi-stem delimbed* Ulf-Peter Granö

Figure 12. Different fuel qualities can be produced from various materials by a range of methods in the subsequent handling.

Good quality energy wood makes it easier to achieve a high-quality final product. The most important guideline for energy wood is to utilize natural air drying and prevent bacteria and fungi from attacking the wood material. By properly protecting the stack of energy wood before the autumn rains, material that is at least 5 percentage points drier can be achieved.

Final drying of wood chips for gasification

For the gasification of biomass, most types of small-scale gasifiers need some kind of drying of wood chips to achieve a moisture content below 20% to 25%. However, there is some promising research on new gasification reactors that use wood chips with moisture levels of 25% or higher.

Utilizing natural field drying

To achieve high-quality energy wood, the natural drying process should be favored. The best drying period is during the summer months because of higher temperatures and lower humidity.

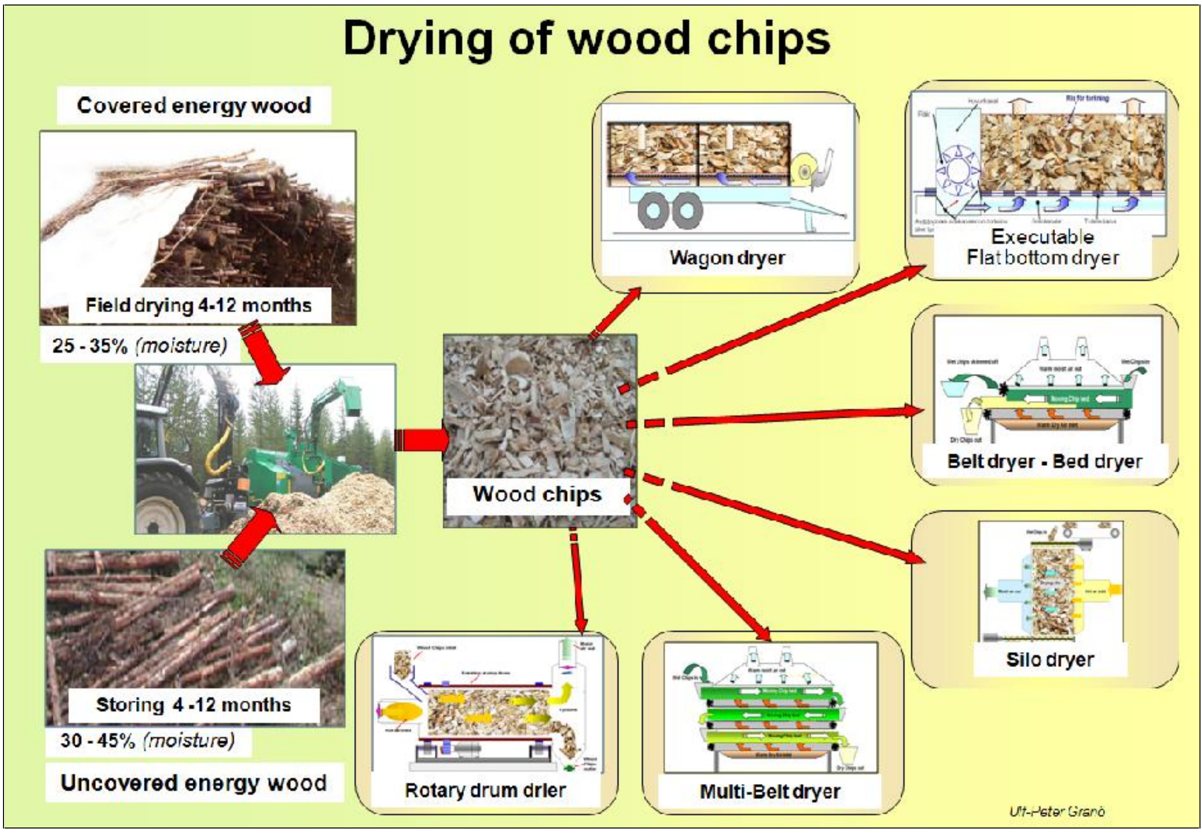

Figure 13. Overview of different dryers for small-scale drying small-scale, carried out by smaller entrepreneurs or energy co-operatives (energy co-op).

The worst period for drying is the rainy autumn months when the humidity is high. Especially if the energy wood stack is uncovered, several percentage points of dryness are easily lost to higher moisture content.

Different types of materials are used to cover the wood. They range from tarps that can be used for several years to covers made of kraft paper. The use of kraft paper covers has increased because they are easy to handle and can be fed into the chipper at chipping.

Experiments have shown that a well-made cover for energy wood decreases the moisture content by 5 to 10 percentage points compared to wood without a cover. A poorly covered stack of energy wood and a stack without a cover after drying can have a moisture content of 35% to 45%, while a covered stack of energy wood after the end of drying time can have a moisture content of 30% to 35%. With optimal storage and covering conditions, the moisture content can be decreased below 30%, therefore resulting in high-quality energy wood.

Small CHP plants for wood biomass

The technology of small power plants (CHP) is currently undergoing rapid development. It is now possible to utilize forests as a bioenergy source in different types of small and medium-sized power plants. The basic fuel can be wood chips or pellets. In Central Europe there is significant interest in small CHP plants using biomass as a fuel. Small CHP units are between 30 kWe and 500 kWe in size (kWe = kilowatts of electricity). The development of small CHP plants is based on several principles, some of which will be briefly discussed in the following sections.

Main technologies for small CHP units

Small- and medium-sized co-generation technology is primarily based on the following:

- **ORC technology**
- **Stirling engines**
- **IC engines** (gas engines) - *requires biomass gasification*
- **Microturbines** - *requires biomass gasification*
- **Fuel cells** - *requires biomass gasification*

Organic Rankine Cycle (ORC) units manufactured in Europe

The Italian firm Turboden is among the leading manufacturers of ORC units. For the past 30 years, they have worked with ORC systems for small power plants .They have built over 250 ORC units in Central Europe and several are currently under construction. The Turboden ORC units range in size from 200 kWe to 2.5 MWe.

Figure 14. *Turboden ORC plants are factory installed on the platforms, and during the assembly in the CHP plant they are connected together and to the boiler. The ORC-CHP plant in the picture is in Toholampi, Finland, and the power output is 1.3 MWe. Photo: Turboden.it*

Stirling engines mainly in use for small CHP installations

Stirling engines are developed, for example, in sizes ranging from 9 kWe to 75 kWe.

Figure 15. Stirling engine 35 kWe, before assembly. The heat transfer device is visible on the cylinder head.

Photo, Stirling.dk

These Stirling engines are mainly for boilers, with the size range between 100 kW and 800 kW. For good heat transfer and high efficiency, the Stirling engine's heat transfer surfaces should be kept clean. To make cleaning easy, only product gas (biosyngas) from gasified wood fuel should be burned in the boiler. During the burning of biosyngas, the soot formation is low compared to wood chip combustion.

Microturbine

In the last ten years, the development of microturbines for biogas and wood gas biofuels has taken off. Different sizes of microturbines are available and have been in use for many years for natural gas, especially in remote locations where no power lines for electricity exists. As an example, ISET in Germany has been working on development projects to follow up Capstones microturbines in sizes from 30 kWe to 500 kWe.

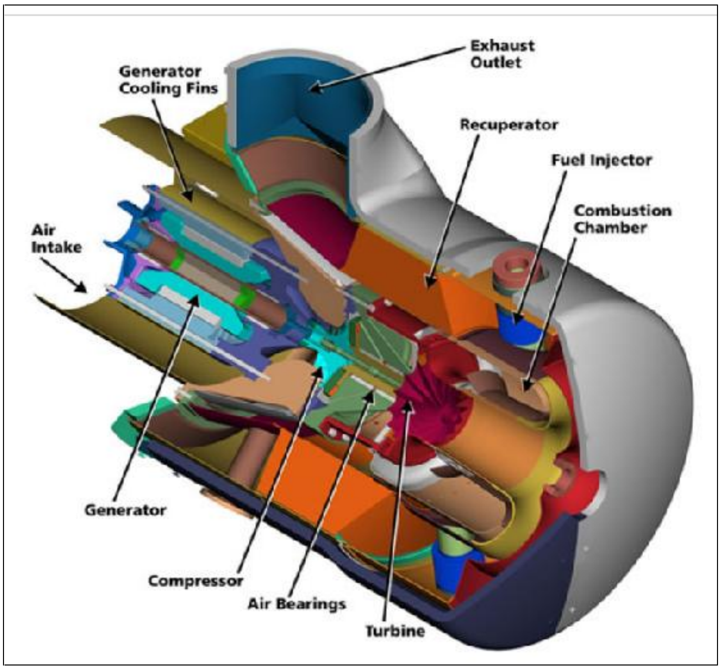

Figure 16. *Microturbine equipped with a generator from Capstone, which can use purified biogas or wood gas. Microturbine units are usually below 200 kWe in size.*

Photo by, Capstoneturbine.com

Some advantages of microturbines:

- Compact with smooth execution
- Low maintenance costs
- Low noise level
- Easy to install, requires no strong foundation

Biogas and biosyngas used in microturbines must be purified well, also of moisture, and the gas needs to be compressed. A microturbine can withstand hydrogen sulfide (H2S) better than the piston engines.

IC gas engine *(piston engines)*

Large IC gas engines for natural gas have been used in power generation for some time, including as reserve units for hospitals and other buildings. Small CHP units with gas piston engines fueled with natural gas or biogas have been used in several areas where electricity is not otherwise available. It is possible to modify and install different types of IC gas engines so they can utilize biogas or biosyngas fuels.

Figure 17. *IC gas engine (piston engines). Example of a piston engine in a CHP unit, a 20-cylinder Jenbacher gas engine.*

Photo: ge-energy.com (Jenbacher)

Future promises fuel cells for biosyngas

In the near future, biosyngas from gasified wood chips can be used as fuel for CHP units with fuel cells. The company MTU CFC Solutions GmbH in Germany manufactures fuel cells that can use biogas and biosyngas after thorough purification. CHP units with fuel cells in sizes around 250 kWe are already in operation, but mainly for natural gas.

Figure 18. *Installation of a fuel cell stack at a MTU CFC plant in Germany.*

Photo: www.mtu-online.com

Many different development opportunities available

Development of small-scale processing of biomass will continue in many different ways. The most important starting point for small-scale processing is to process and refine bioenergy feedstock near the place where it is available for local and regional customers.

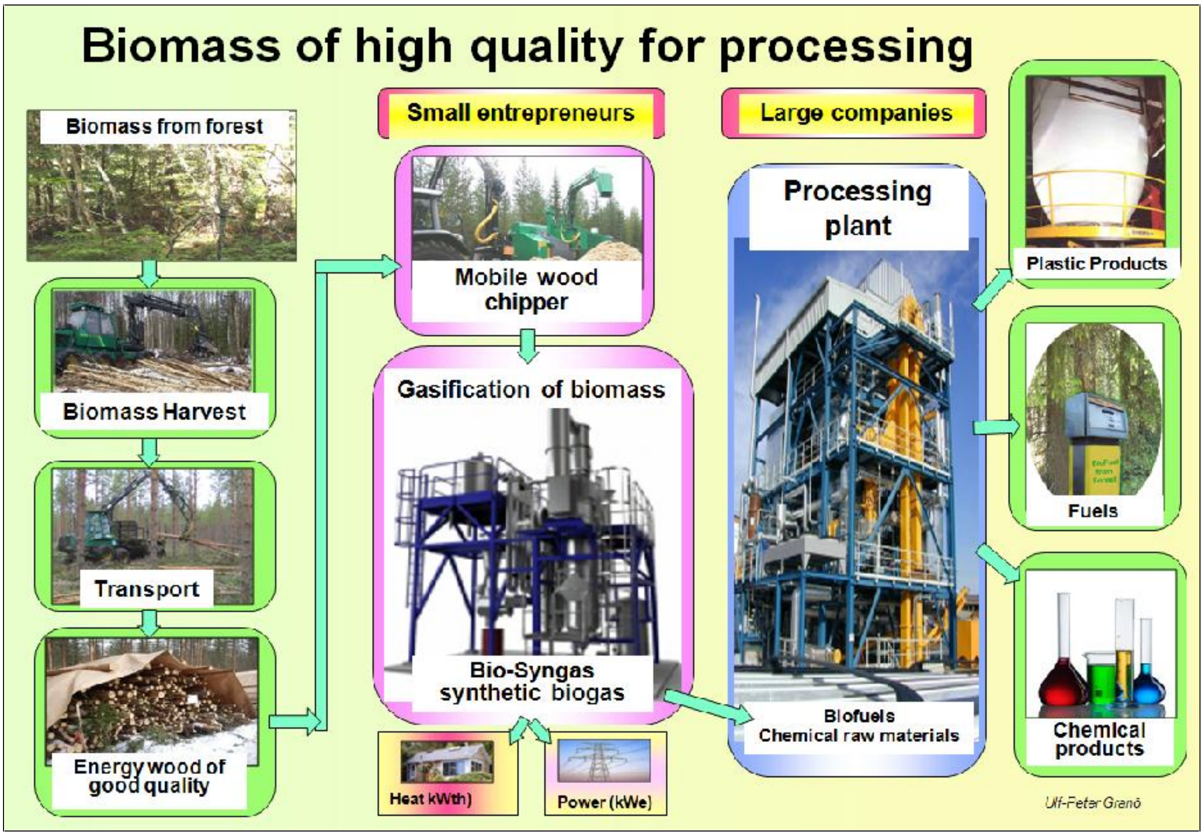

Figure 19. *Final high-quality products are more easily obtained from high-quality biomass.*

The better the cooperation between different local actors, such as energy co-operatives, the easier it is to achieve the objectives of biomass processing for energy. An excellent gateway to start cooperation might be a local heating unit for a few farms, businesses, schools, or a local heating unit in the village. The next step in development may be to simultaneously produce electricity but also to integrate with other biomass processing activities.

The goal should always be to strive for as good quality of wood biomass feedstock as it is possible to procure from the forest. Lower quality wood biomass as well as logging residues and logging slash can be advantageously transported to large consumers who have custom boilers that can utilize material with high bark and small branch content. In addition, these large consumers also often have a flue gas purification process. In the future, biomass gasification in small-scale units will make it possible to produce raw materials in gas and liquid form for further processing by the fuel and chemical industries.

To ensure the best possible end products, the energy wood collected from forests must be high quality. The same applies to the rest of the chain: all the work and equipment used in harvesting, handling, and processing of bioenergy feedstock must be also high quality.

References

Bain, R. Overend, R., and Craig, K., *Biomass-Fired Power Generation, National Renewable Energy Laboratory, Golden CO,* ***1996****.*

Craig, K. and Mann, M., *Cost and Performance Analysis of Three Integrated Biomass Combined Cycle Power Systems, National Renewable Energy Laboratory, Golden, CO,* ***2002****.*

Granö, U.-P., *Small-scale processing of bioenergy, Scribd.com,* ***2013****.*

Granö, U.-P., *Utlokaliserad energiproduktion, Förgasning av biomassa, Scribd.com,* ***2010****.*

Granö, U.-P., *CHP - Grön Kemi - Bioenergi från skogen, Scribd.com,* ***2010****.*

Granö, U.-P., *Nyttja bioenergin från skogen, Scribd.com,* ***2008****.*

Knoef, H.A.M., *Handbook on Biomass Gasification, BTG biomass technology group B.V. Enschede, the Netherlands,* ***2005****.*

Johansson, T. B., Kelly, H., Reddy, A. K. N., and Williams, R. H., *Renewable Energy, Sources for fuels and electricity, ISBN 1-55963-139-2,* ***1993****.*

Laitila, J. and Asikainen, A., *Koneellinen energiapuun korjuu harvennusmetsistä, PuuEnergia 3(****2002****), 8–9.*