

FEEDSTOCK FOR BIOFUEL PRODUCTION:

Energy crops from agriculture

Energy crops are crops produced with the objective to be used in the energy system. The energy crops presented here are not suitable as food. They include the species willow, reed canary-grass, poplar and aspen. These crops can be used to produce a variety of biofuels using different processes according to the flowchart below. By gasification and further treatment they can be used to produce e.g. methanol, DME, hydrogen gas, Fischer-Tropsch diesel and substitute natural gas (SNG). By fermentation they can be used to produce ethanol, and by anaerobic digestion to produce biogas, although some pre-treatment is be required.

Willow

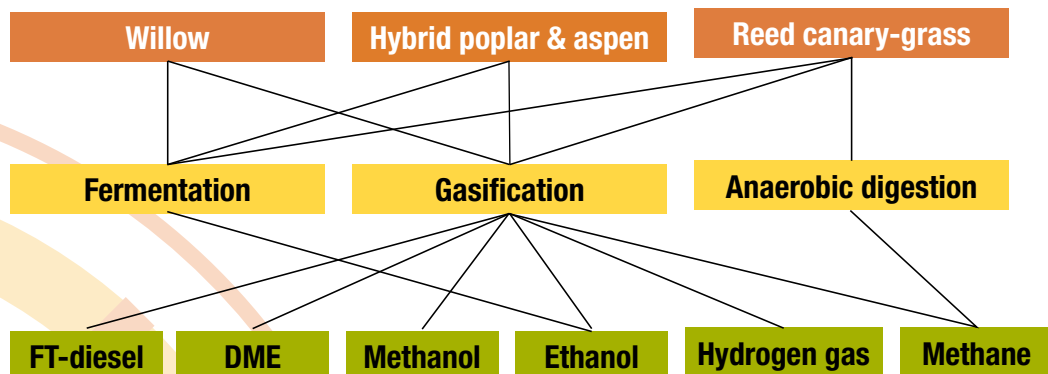
The genus *Salix* includes a large amount of species and is found wild in all continents except Australia. In Sweden a few species have been selected for breeding programs to form new varieties suitable for growing in different climates. Energy willow can

be grown up to the southern parts of northern Sweden. It needs nutrient rich soil with a pH above 6 and a good supply of water and light to grow well. Clay soils to fine sand soils are appropriate.

After preparation of soil, planting is done from cuttings, and is performed from end of April to middle of June. About 13 000 cuttings per hectare are planted in rows, with more space between every second row to facilitate harvesting. Weed control is very important during the establishment since the weeds compete with the willow plants for light, water and nutrients. Both mechanical and chemical weed killing is needed during the planting year. In Sweden, about 11 580 hectares willow was cultivated in 2010.

Use of fertilizers, mainly nitrogen, increase growth significantly. Ideally fertilizing should be done every year, but due to practical problem it is mainly done the first and second year in each rotation, when the plants are small enough to give access for the spreader. In soils with low pH lime or ash can be applied.

Harvesting is done during winter every 3-5 years. It is time for harvest when the biggest stems are 7-10 cm in diameter at the base. The output is 20-25 dry tonnes/hectare during first harvest and 30-35 dry tonnes/hectare onwards. Common harvesting systems include direct chipping at harvest and harvesting of whole stems. The economic lifetime of a plantation is 20-25 years.



Reed canary-grass

Reed canary-grass is a perennial grass that grows wild in wetlands in most of the northern hemisphere and can be grown in all parts of Sweden, even in the north. It can be grown in most kinds of soils, but grows best in wet soils with high organic matter content. When grown in bog soils, spreading of lime or ash may be needed to increase the pH value. Different kinds of soils give the grass different properties. For example the ash content in the grass is higher when grown in clay soils. In 2010, about 800 hectares of reed canary-grass were cultivated in Sweden.

Preparation of the land includes ploughing and weed killing before sowing. Weed killing during the first year of growth may also be necessary. Sowing is done in early spring for the grass to establish properly before autumn.

Harvesting is done either in spring or autumn. The first harvest is done in the second year, and then every year onwards. The output is 4-6 dry tonnes/hectare. Harvesting in the spring gives a brittle grass with low moisture content, and no further drying is needed. The amount of potassium, chlorine, phosphorus and nitrogen is also lower in the spring, resulting in lower ash content and higher ash melting point. Harvesting in the autumn gives a higher yield, but the moisture content is also higher, this would e.g. be more appropriate for biogas production.

The need for fertilizing is largest the first two years. Autumn harvesting removes a lot of nutrients together with the grass while if the harvesting is done in the spring, most of the nutrients are in the roots and are left on the field. Therefore less fertilizing is needed if a system with spring harvesting is used.

Hybrid aspen and poplar

The genus *Populus* includes about 30 species and grows wild in most of the northern hemisphere. They are commercially interesting since they grow fast and can reproduce from cuttings. As energy crops, different kinds of hybrid varieties are used. They grow best on farmland or fertile forest land, in soils with a pH between 5.5 and 7.5. Nutrient rich light clay soils are suitable. Locations that are frost exposed during the establishment period should be avoided and there need to be a good supply of water.

Preparation of the soil includes loosening to allow the roots to grow deeper, and weed killing. Weeds can compete with the plants and reduce growth but also constitute a favourable environment for voles, which can cause significant damage to the plants. Especially aspen is also very popular to deer, and fencing is often necessary.

Planting is made from rooted cuttings in May or June. The amount of plants and the management during the growing period is determined by the intended use of the biomass (energy, pulp and/or timber). Suggested rotation time for energy use is 15-25 years and felling is done with traditional forestry techniques. Growth is 7-9 dry tonnes/hectare and year.

After felling, shoots develop in large amounts, which can be used to establish a second generation plantation, either by keeping all the shoots and after a few years harvest, similar to a willow plantation, or by continuous thinning to establish a new plantation with sparser stems. The latter however is very labour intensive. Another alternative is to pull the stumps and make a new planting with rooted cuttings. However, experience of poplar and aspen growing in Sweden is limited and more research is needed. About 490 hectares poplar and 240 hectares aspen were cultivated in Sweden during 2010.

Chemical properties

These are the chemical properties of the selected energy crops, their mean value and range. (Source: Phyllis database)

	Willow	Reed canary-grass	Hybrid aspen and poplar
Lower heating value (MJ/kg _{dm})*	18 (18-19)	17 (15-18)	19 (18-20)
Ash content (%)	1.8 (0.5-4.6)	6 (1.4-13)	1.2 (0.2-2.7)
Lignin (%)	26 (25-26)	4.6 (4.0-5.3)	23 (16-32)

* dm = Dry Matter.