Turku University of Applied Sciences
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TURKU UNIVERSITY OF APPLIED SCIENCES

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# SUMMARY

As part of the three-year Interreg IIIA EU project ”Reed strategy in Finland and in Estonia” administered by the Southwest Finland Regional Environment Centre, the possibilities of utilising the Common Reed as an energy resource were examined. The project charted the amount of harvestable reed beds, compared various harvesting and pre-processing methods, implemented combustion tests of reed material processed in different ways and drew up various reports on the logistics and costs involved in using reed crops for energy generation.

The reed beds on the coasts of Southern Finland, estimated to cover ca. 30 000 hectares, form a bioenergy potential which could, when implemented as a carefully planned harvesting-production chain, be a significant addition as a mixed fuel for the incineration plants and farmhouse furnaces using peat and chip, and at the same time bring opportunities for extra earnings, employment and benefits also to the water systems. Also, processing the reed into pellets and burning reed bales in furnaces suited to burning bales offer new uses for reed energy. Also the use of reeds for biogas is an uncharted territory. This combined with the nutrient decreasing effect of the summer harvesting of the reed mass, which also reduces the load to water systems, opens up interesting views worth further research. Furthermore, the sludge produced in the digestion is a good fertilizer, since the majority of the nutrients produced by the decomposition process are in an immediately utilisable form for plants.

Before a large scale use of reed energy is possible, more study and development work is needed. Especially, cost-effective harvesting is one of the bottle-necks in the reed energy chain. Also the incineration technology, pre-processing and biogas use present open questions. As immediate development measures, also other harvestable reed resources on the coast and in the inland regions bar the ones mentioned in this report should be mapped, reed energy harvesting methods and chains should be developed with the help of investment and development funding, and the best methods for harvesting and burning all straw-like bio fuels (reed, straw and Reed Canary Grass) should be examined.

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# FOREWORD

The abundantly growing Common Reed which has taken over seaside bays and lake shores forms a local hitherto unused bioenergy potential. The various phases of its production chain need technological and financial surveys before the potential can be made use of. As part of the three-year EU Interreg IIIA project ”Reed strategy in Finland and in Estonia” administered by the Southwest Finland Regional Environment Centre, the possibilities of utilising the Common Reed as an energy resource were examined. The bioenergy sub-project charted the amount of harvestable reed beds, compared various harvesting and pre-processing methods, implemented combustion tests of reed material processed in different ways and drew up various reports on the logistics and costs involved in using reed crops for energy generation.

A significant part of the surveys on the energy use of the Common Reed were implemented as Bachelor's theses at Turku University of Applied Sciences, in the degree programmes in Mechanical Engineering, Automotive Engineering, and in the degree programme in Sustainable Development. The Bachelor's theses examined the burning properties of the Common Reed (Virko, 2007; Kelkka, 2007), the harvesting possibilities (Silen, 2007), pre-processing methods for energy use (Vuorma, 2006), harvesting technology and machinery (Valo, 2007) (Himanen, 2007), transportation logistics (Puolakanaho, 2007) and the entire energy generation chain and the cost-effectiveness of the energy use of the Common Reed (Simi, 2007). In addition, a Master's thesis is being prepared on the biogas use of the Common Reed in the degree programme in Environmental Technology.

This report is composed of the theses completed on the energy use of the Common Reed. As an additional source other literature on the energy use of renewable and straw-like plants were used. The report describes the various phases in the Common Reed energy production chain from harvesting to incineration. The goal is to trace the preconditions of using the Common Reed for energy in Southern Finland, and also to point out gaps in our knowledge and further development needs. In an earlier publication, ”The Common Reed as an energy plant – estimated production yield, technical possibilities and environmental protection ” (Isotalo et al, 1981), the possibilities of using the Common Reed for energy were explored in diverse ways from the amount of reed resources to harvesting methods and costs. Since then, the interest in and expectations of renewable energy sources have only grown. We now know more about using the Reed Canary Grass, comparable with the Common Reed in many ways, as an energy plant. Also, the project ”Reed strategy in Finland and in Estonia” has generated a wealth of new knowledge. Thus there is a distinct need for updating knowledge about reed energy.

Utilising reed energy is, on the overall, an interesting and challenging equation, in which the variables are the many interests in using reed beds, environmental issues, the development work for harvesting technology, logistics, incineration technology, the attitude of landowners and the energy politics, and agricultural aid and employment politics. The incentive for seeking solutions to the multi-variable equation is offered by the great potential connected to the Common Reed: the under-utilised and in places so overgrown reed beds that they are a menace, and the image and possibilities of “green energy”.

The climate change and the exhaustion of fossil energy set great expectations for renewable energy sources. Responding to the challenge of climate change presupposes, not just restrictions but also a “policy of possibilities” (Suomen Kuvalehti 26.10.2007), which generates new kinds of innovations and employment from sustainable energy solutions. The eutrophication of water systems, climate change and the decrease in the use of shores as pastures have boosted the growth of the Common Reed, which in the future can be a local, employment generating, ecologically sustainable energy solution in which energy production will be accompanied with other uses and environmental benefits such as protection of the water systems.

The writers of this publication want to extend their thanks to all the people who were part of this venture, and who with an open mind and courage joined us in the promotion of the energy use of the Common Reed. Special thanks go to Ülo Kask and Markku Riihimäki, and all the private persons who allowed us to use their incinerators and furnaces – not to forget the students who made their contribution by hard work on their theses.

Turku 1.2.2008

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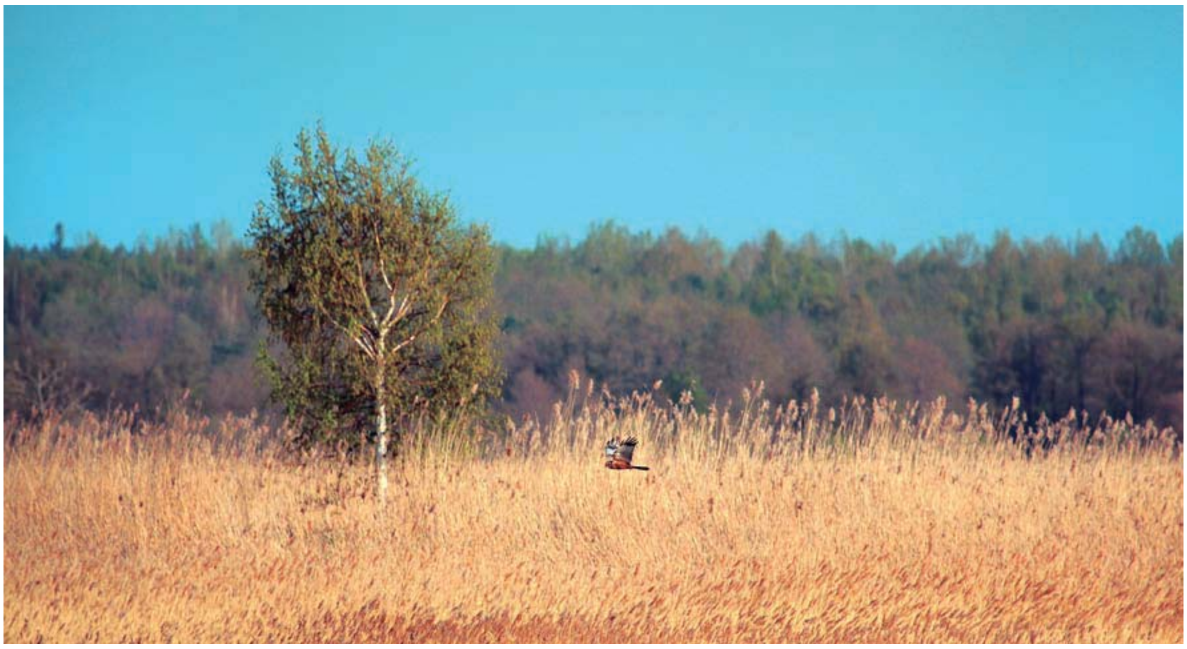


*Photo: Sami Lyytinen.*

# 1 INTRODUCTION

## 1.1 Background

There are great expectations involved in increasing the use of bioenergy. Increased renewable bioenergy is sought 1) to ensure energy self-sufficiency and energy maintenance security, 2) to diminish the use of fossil fuels which are being exhausted, 3) to mitigate the climate change 4) for other environmental benefits, like diminishing the load of nutrients to the water systems from agriculture and 5) in order to honour our commitment to various international agreements.

Bioenergy is generated from biomass, such as logging residue, and from energy plants grown in the fields, for instance the Reed Canary Grass. For its energy use possibilities, the Common Reed can be compared to field biomass. Reed energy can be generated in the same manner as energy from other biomass forms, either by burning the dry biomass or by generating biogas from the green, summer harvested reed through anaerobic digestion process or use it as the source of second generation of bio fuels (bio ethanol, bio-diesel, bio-hydrogen).

Bioenergy sources add diversity to our energy sources, and often they can also add to the operational security of the local energy distribution, and increase self-sufficiency in energy production. Not only the reliability of energy distribution and local self-sufficiency but also shorter transportation distances and the energy and environmental conservation that come in its wake are important factors in favour of increasing the use of bio fuels.

Bioenergy is also seen as a potential factor in securing the livelihood of the rural areas, as a development field for new kinds of energy technology innovations and as an opportunity to increase employment related to the bioenergy production chain. Additional weight to the idea of increasing the use of bioenergy sources is given by the fact that they can be used in the production of transport fuels, bio ethanol and biogas. Decreasing the amount of green house gases like carbon dioxide, which accelerate climate change, is a central argument for increasing the use of renewable energy sources. If we count out the load due to harvest and transport, and the biomass used is replaced by new, carbon dioxide binding growth, biomass energy sources are carbon dioxide neutral sources of energy. The energy produced by the use of biomass diminishes carbon dioxide emissions if it is used to replace the use of fossil fuels. By favouring local bioenergy sources the distance of transports and thus also the costs of transport and the environmental emissions will be smaller.

In Finland, the use of renewable energy resources is influenced by national energy policy guidelines and international agreements. In the national climate and energy strategy (Near future guidelines in climate and energy policy – national strategy for implementing the Kioto agreement. Government report to the parliament on November 25th, 2005) the stated goal is to increase the amount of renewable energy sources in Finland to 29 percent by the year 2010. In 2006, the part of renewable energy in the overall energy production in Finland was ca. 24 percent, which mainly consisted of bioenergy (84 percent of the renewable energy resources).

On the international level, the Finnish energy political solutions and the status of renewable energy resources are influenced by for instance the emissions trade directive of the EU, aiming at diminishing green house gas emissions, and other EU level agreements. In Finland, the green house gas emissions trade system affects incineration plants with capacity over 20 MW, and thus increases their interest in biomass energy. Carbon dioxide neutral bioenergy sources diminish the emissions from the plants and thus bring cost savings in the form of transferable emission rights.

On the EU level, the goals of increasing renewable energy are connected to, besides the climate change aspect, also to decreasing the dependency on imported energy because of the higher price of oil and because of the political instability in some oil producer countries. In the "energy package" agreed on at the beginning of 2007, the EU has set as its goal to increase the share of renewable energy sources to 20 percent by the year 2020. In the division of the burden between the Union countries, this has been understood to mean that in Finland, the share of renewable energy sources should be increased from the current 24 percent to even more than 40 percent. In many comments this has been labelled an unrealistic target. However, the goal is to significantly increase the production of renewable energy.

In Finland, the greatest possibilities of significantly adding to the share of renewable energy resources lie in bioenergy. It has been estimated that it is possible to increase the use of bioenergy with as much as 50 percent from the current situation by the year 2015 (Evaluation of the long-term utilisation possibilities of biomass in Finland. An expert work group report). The bioenergy production is mainly based on wood fuels both now and in the future: logging residue and the sludge from forest industry, and bark and sawdust. In addition to wood fuels, great opportunities arise within the use of field biomass, such as straw and Reed Canary Grass. The Finnish Bioenergy Association Finbio has estimated that ca. one fifth of the need for renewable energy can be covered by field biomass. So far, Finland has invested in the use of wood energy, but according to the long-term scenario to the year 2050 presented by VTT (The State Technical Research Institute), the increase in the use of domestic energy sources will come to a halt after 2030 due to scarcity of wood. In case the scarcity of wood in the future becomes a factor limiting its use, the significance of mixed fuels such as field biomass will grow.

In order to increase the use of bioenergy suggestions have been made towards drafting a specific promotion plan for the use of bioenergy, investments into research and development, removal of administrative hindrances ( for instance, efficient transfer of bioenergy in the power network), tax subsidies (for instance, return of electricity tax for energy produced with biomass), feed-in tariff to ensure viable producer price independent of market price, education and a "Green Certificate" for biomass energy. Especially the poor price competitiveness and the development needs in production and business operations models seem to be restricting factors in increasing the use of bioenergy.

The multiple use possibilities of biomass enhance its competitiveness in the energy market (Dornburg and others, 2005). In multiple use raw materials, the raw material can also be used for other things besides energy generation, such as for food, fodder, building material, fertilizer or for chemical production. Heat, electricity and fertilizer can be produced even from the same batch of raw material. The Common Reed, which grows in abundance in the bays on the coast of Southern Finland, is a prime example of a multiple use raw material which can, in addition to energy production, be used e.g. in waster water treatment and also for building material. (See Ikonen and Hagelberg, 2007).

## 1.2 Using straw-like plants as an energy resource

By its characteristics as an energy plant, the Common Reed can be compared with Reed Canary Grass, which is a field-grown grass. The energy mass farming of Reed Canary Grass in fields and former peat production areas has been developed as a co-operation of research institutes and enterprises for more than a decade. The Reed Canary Grass has proven to be both a winter-hardy and a high-yielding energy plant (in spring harvest, 6–8 tons per hectare), which stays productive for 10–12 years (Pahkala and others, 2005). The Reed Canary Grass is deemed the energy plant best suited for Northern European conditions. In addition to energy generation, the Reed Canary Grass is also suitable as raw material for paper.

The cultivation area of the Reed Canary Grass has increased strongly in recent years. In 2004, the cultivation area was 4 500 hectares, and in 2006 the Reed Canary Grass was cultivated on more than 17 000 hectares of contract cultivation. Interest in the cultivation of the Reed Canary Grass is still growing, and its use as a mixed fuel in heating plants using peat or chip can be a factor bringing added energy self-sufficiency locally, and it can also be a source of added income.

The Ministry of Agriculture and Forestry has set as a national cultivation target 100 000 hectares of Reed Canary Grass by the year 2015. The spring harvested Reed Canary Grass has an energy content of ca. 4,5 MWh/t in its use humidity. The energy potential of the crops according to the cultivation area of 2006 was thus ca 460 GWh, and the cultivation target in 2015 is equal to ca 2700 GWh of energy. Power plants using fluidized bed furnace technology can receive and utilise Reed Canary Grass, but because of its lightness the straw mass is mixed with other fuels such as peat and chip, at a maximum 10 percent mix ratio.

There are many environmental benefits to cultivating Reed Canary Grass besides its use for energy. The cultivation of the perennial Reed Canary Grass as opposed to cultivation of annual grain crops decreases the carbon dioxide emissions from the fields. A group of researchers in biogeochemistry at the University of Kuopio have observed that in peat production areas, the Reed Canary Grass cultivations can even act as carbon sinks, reducing the amount of carbon dioxide emissions to the atmosphere (Kuopion yliopistolehti 2/2006). Reed Canary Grass cultivations in the protective zones of rivers and lakes or in the filter areas of residential wastewaters also reduce erosion and nutrient flows (Börjesson, 1999; Partala and Turtola, 2000).

Cost-effectiveness of the entire production chain is a prerequisite for making use of the field biomass as raw material for energy. Behind the great enthusiasm for Reed Canary Grass are the low cultivation costs, and the applicability of modern farming equipment and machinery also for the cultivation of the Reed Canary Grass. The cultivation of Reed Canary Grass is, with the help of agricultural support (support for farms, environmental and energy plant aid) more profitable than farming barley for animal feed (Pahkala and others, 2005). The profitability is, however, affected by the form of the produced material (bales/chip), its quality, transportation distances and the ability of power plants to receive and handle Reed Canary Grass. For instance, from the point of transportation an economical distance is 90–120 km depending on the quality of the material: in loose material haulage the economical distance is shorter than in bale haulage (Flyktman and Paappanen, 2005). The interest in Reed Canary Grass by the power plant companies has to do with emissions trade (over 20 MW incineration plants): fossil fuels can be replaced by the carbon dioxide neutral Reed Canary Grass and thus the emissions load can be reduced.

In the energy use of Reed Canary Grass, important development objects include the development of higher-yielding subspecies (the current subspecies are developed for fodder use), minimizing harvest losses by developing harvesting techniques (the dry and brittle Reed Canary Grass crumbles easily) and developing the mixing techniques for Reed Canary Grass and other bio fuels, such as peat and wood chip, and further development of bale crushing methods (Flyktman and Paappanen, 2005).


*A Reed Canary Grass bale. Photo: Teemu Kettunen*

Of other straw-like materials, also a certain amount of straw, in addition to Reed Canary Grass, is used as an energy resource. The arable field area in Finland, one million hectares, annually generates approximately 3 million tons of straw, the energy potential of which is ca. 10 TWh (VAPO). In 2002, straw was used for the generation of ca. 67.5 GWh of energy (ca. 7000 tons of straw mass). In Finland the reasons to the modest use of straw are the difficulty in harvesting the dry straw, lack of competent harvesting methods, the lack of space for storage and the small supply of good domestic incinerators. As with Reed Canary Grass, the grain straw is a renewable, carbon dioxide neutral energy source. The grain species affect the burning properties: the best one is wheat and the toughest one oat when comparing their cinder melting behaviour. There are similar problems in the uses of straw and Reed Canary Grass. Bottle-neck factors are the development of harvesting and combustion techniques. In incineration, problems are caused by for instance the fuel feeding systems of power plants which have not been designed for the use of straw-like materials. In Denmark, straw has been used in energy generation for a long time, and many farms have furnaces suited to burning straw.

The Finnish Bioenergy Association (FINBIO) has set a goal of raising the energy production from straw and Reed Canary Grass to approximately 2.5 TWh by the year 2010, which would mean straw harvesting from about 60 000 hectares, and the cultivation of some 60 000 hectares of Reed Canary Grass.

### 1.3 Various aspects in using and maintaining reed beds

The Common Reed is a pest and a blessing. As a fast-growing and abundantly productive plant, the reed has spread efficiently on the lake shores and the coastal areas of the Baltic Sea in the wake of the eutrophication of water systems and climate change, and as a result of the decreasing use of shore areas for pastures. Around Finland and also elsewhere in Europe the Common Reed is viewed as a menace, which closes up waterfront vies, diminishes the living space of other shoreline and water plants and prevents the leisure use of lakes, rivers and seashores. On the other hand, many different species are dependent on the reed, and the reed can be made use of in many different ways.

There are many, partly conflicting interest bound with the reed beds. When calculating the costs and profits of using the reed for energy uses, other interests and possible environmental benefits connected with the use of the reed beds should be taken into account.

The net impact of the Common Reed on **the water quality and environmental emissions** is difficult to assess. The impact is both direct and indirect (Huhta, 2007). The Common Reed, like also the other big plants in water environments, binds solid matter and the bottom sediment. The stems oxygenate the roots and also the bottom sediment, and prevent the phosphor in the bottom from being released.

A reed dominated shoreline zone also emits significant amounts of methane which is a powerful greenhouse gas (more than 20 times more effective than carbon dioxide). The methane emissions can be much bigger than from e.g. peaty bottom areas (for instance Kankaala and others, 2004), which have traditionally been considered significant sources of methane.

Planning the use and maintenance of reed beds has an impact on the environmental load. By mowing the reed beds biodiversity can be increased and the landscape can be preserved. Badly planned mowing can, however, add to the methane emission from the reed bed area, and summer harvesting can, if disturbing it, release nutrients from the bottom. Also damaged plants, especially in early summer, release nutrients to the water. The effects of different maintenance and utilisation methods are, however, not well known.

The quickly growing reed ties up in its growth nutrients that are possible to eliminate from the water system together with harvesting. While assessing the water system impact of the reed harvesting the time of the harvesting must be taken into account. Harvesting at the end of July is the most effective way of eliminating nutrients since the nutrient resources in the rootstock are mobilised for efficient growth. In the summer, the dry material of the reed contains approximately 1 percent of nitrogen (Kask, 2007) which means that one hectare of mowed reed eliminates some 50 kg of nitrogen. Phosphor elimination is 0.9 g per one kilogram of dry matter (Hansson and others, 2004), so it is possible to eliminate ca. 4.5 kg per hectare in the harvest. On the other hand, the mechanism of the nutrient flow from the mowed reed is not well known. Later, at the end of August, the nutrients are transferred into the rootstock to secure growth during the next season, and the nutrient diminishing effect of the removal of the sprout mass in late summer is smaller. The removed growth should always be shifted further away from the shoreline to prevent nutrient flow. In case the growth of the reed bed is not to be weakened, the reed must be cut above the water level.

Winter harvesting removes organic matter which when decomposing would use up the oxygen supply of the water and form a nutrient source. On the other hand, the nutrient content of the winter reed is low since most of the nutrients have transferred into the rootstock, and the amount of nutrients removed by harvest is thus relatively low (Granéli and others, 1992).

The Common Reed is the basic plant used in rootstock purification plants. The use of the Common Reed in rootstock purification plants is based on the extensive filtering effect of the rootstock and on the microbe activity in the rootstock. A rootstock purification plant reduces the solid matter and nutrient load to the water systems, but the purification effect in Finnish conditions has not yet been precisely studied. On the basis of a few studies, the purifying effect of a rootstock purification plants for organic matter is 20–90 percent, for phosphor and nitrogen 10-80 percent and for solid matter and chemical oxygen binding 60–80 percent. In Finland, small-scale rootstock purification plants have been tested in the treatment of wastewater in scarcely populated areas and in the treatment of seep waters from landfills. The use of wetlands in wastewater treatment is developed in several projects around the world. In Holland, an extensive project has been launched on treating waters with high nutrient content with the help of artificially created reed bed areas combined with the energy use of reed mass (Adrie van der Werf, a paper presented at the final seminar of the project ”Reed strategy in Finland and in Estonia” on August 8th, 2007 in Estonia).

The growth of reed beds can also have an indirect impact on water quality. The reed beds offer suitable living environments for carnivorous fish having an impact on the regulation of fish stocks in the family Cypridinae, which release nutrients from the sediment (Huhta, 2007).

*The Bearded Tit. Photo: Antti Below.*

*The building of a reed roof was introduced on a course organised by the project "Reed Strategy in Finland and in Estonia" in Turku in the autumn of 2006. Photo: Martti Komulainen.*

*In January 2006, The Tallinn University of Technology organised an information exchange seminar for the Finnish and Estonian experts interested in the energy use of the Common Reed. In connection with the seminar, the participants were introduced to the Thermal Engineering Department laboratories at the University. Photo: Eija Hagelberg.*

Reed beds have a significant impact on the **biodiversity** of the water and wetland environments. Generally speaking the wide, Common Reed dominated plant societies are very scarce in species (Ekstam, 2007). This is true of also other species with high stems. As the reed beds have spread out and the pasture use of shores has decreased, many meadow species in the coastal areas have regressed.

There are several reed bed specialists among birds, such as the Bearded Tit, the Reed Warbler and the Great Reed Warbler. Also many others, such as the Marsh Harrier and the Great Bittern, are dependent on reed beds. Reed bed areas offer the birds nesting and living environments but also resting places during migration. Several of the large reed bed areas are included in the Ramsar agreement on international wetland preservation.

The drying up of reed beds and wetlands growing impenetrable reduce the bird species. The mosaic structure of a reed bed area, where water and unbroken reed beds alternate, is good for the diversity of the bird species. The damp meadows, sludge shores and bushes joined with the reed bed add to diversity. Thus it should be a goal to strengthen and maintain the mosaic structure in the plans for the use and maintenance of the reed beds, instead of single-minded mowing of the entire reed bed area (Below and Mikkola-Roos, 2007).

The Common Reed has been traditionally used as a **building** and especially **roofing** material. The reed is also used in handicrafts and decoration (see for details Ikonen and Hagelberg, 2007).

The reed can also be used as **fodder plant, decking material for plant cultivation and as fertilizer.** Its use for mere fertilizer is uneconomical, but combined with its other uses (such as energy generation) and its environmental benefits (landscape preservation and reduction of nutrients causing eutrophication of water systems by mowing), even that can be profitable (Hansson, 2004).

### 1.4 Description and goals of the project

The use and maintenance of reed beds presuppose research based, careful regional planning in which a suitable balance is sought between the maintaining, removal, utilisation and the upkeep of reed beds. The objective of the project ”Reed strategy in Finland and in Estonia” is to create a strategy for the sustainable use of reed beds in Finland and in Estonia. The basis for the Reed strategy is created by co-operation between experts, by the existing research knowledge and by practical measures. The strategy can later be utilised elsewhere in the Baltic Sea area in addition to Finland and Estonia.

In addition to the Southwest Finland Regional Environment Centre which acted as administrator and co-ordinator in the project, participants in the implementation of the project were The Tallinn University of Technology, Turku University of Applied Sciences,
Cursor Oy, Southeast Finland Forest Centre, and the Cities of Turku and Salo.
Pilot areas for the project were chosen from Southern Finland and Estonia. The reed beds in the project were observed in a cross-disciplinary manner from five different angles:

1. water protection
2. bioenergy
3. building (construction)
4. biodiversity
5. landscape, culture, leisure use and agriculture.

In addition to the planning of the use and maintenance of reed beds, the project added to the exchange of knowledge and experiences, and brought Estonian reed construction expertise to Finland. The central outcomes of the venture have been presented in the publication ”Read Up on Reed” (Ikonen and Hagelberg, 2007).

The part ”The energy use of reed beds” introduces surveys of existing knowledge about the use of the Common Reed and generally the use of straw-like plants as sources of energy, charts the amount of utilisable reed resources in Southern Finland and in Estonia and different harvesting methods, reports on implemented combustion tests with reed fuels in different forms and discusses different reed energy production models and assesses the costs connected with them.

# 2 THE COMMON REED AS A SOURCE OF ENERGY

## 2.1 The utilisable reed resources

The Common Reed (*Phragmites australis*) is one of the most widely spread vascular plant species in the world. The Common Reed which belongs to grasses has often commonly been called grassweed, which however is its own species and belongs to a different plant family, Cyperaceae. The Common Reed grows rapidly reaching up to 1–4 meters during the growth season, in some places even as high as 7 meters. The growth speed is influenced by temperature, humidity and the nutrient content, and its utilisation and maintenance measures.

The sexual, seed production based reproduction of the Common Reed is very modest. Mainly the reed growth spreads through a rootstock. The Common Reed is a strong competitor in the plant society: the high and dense growths of it decrease the light on the bottom and thus diminish the survival possibilities of other species. The dead parts of the plant form a thick mulch layer and prevent the seeds of other species from sprouting, and its aggressively spreading roots create a hindrance to the spreading of other species (Roosaluste, 2007).

*The Common Reed. Photo: Helena Särkijärvi.*

One of the most important variables describing the energy use possibilities of biomass is the annual biomass yield, irrespective of whether biomass is used for incineration or in biogas production. Translated into dry matter, the Common Reed yield on the coast areas of Finland has been assessed to be some 5 tons per hectare per year (4.6–7.4 t/ha) (Isotalo and others, 1981). The reed thrives on eutrophication, and in nutrient rich areas the height of the growth and the yield per hectare can be clearly bigger than the above mentioned numbers. Cultivated in favourable conditions, the reed may even reach the yield of 30 tons of dry matter per hectare (Adrie van der Werf, a paper presented at the final seminar of the project ”Reed strategy in Finland and in Estonia” on August 8$^{th}$, 2007 in Estonia).

In the Reed strategy project survey, the yield per hectare varies between 4–12.6 tons while the average amount was 7.6 tons (Silén, 2007). The biomass utilisable in summer is bigger than in winter, since part of the leaves fall during the winter, and the snow layer raises the cutting height (Kask, 2007).

The reed harvest varies yearly, due not only to growth conditions but also to autumn storms and ice conditions in winter: strong winds cause the crop to flatten, and the moving ice can cut the reed stems causing diminished amounts of harvestable crop.

The extent of the reed bed areas in Southern Finland was charted on the southern coast of Finland (from Virolahti to Pyhämaa, counting out Åland) and in western Estonia by using the Landsat satellite image interpretation. The method enables the charting of wide areas in a short time, even though the resolution of the material sets its own limits (the smallest unit being 30 m x 30 m) (Pitkänen, 2006; Pitkänen ja muut, 2007).

The total area of reed beds in the survey was estimated to be 30 000 hectares in Southern Finland which is one percent of the land area of coastal municipalities. The biggest unified reed bed areas in the survey were found in Southern Finland, in the sheltered seashore bays of Southwest Finland, Eastern Uusimaa and Kymenlaakso. On the less sheltered and steep shores of the archipelago, the reed beds were smaller and narrower. Data per municipality is shown in table 1.

The total area of reed beds multiplied by yield per hectare gives an assessment of the harvest potential. Thus, the reed resources in Southern Finland would be approximately 150 000 tons per annum.

The possibilities of harvesting and utilising the Common Reed are defined, in addition to the extent of the reed beds, by the quality of the harvested material, its location, ownership relations, the attitude of the water area owners and nature preservation considerations (Silén, 2007). The permissions and attitude issues connected with harvesting are discussed in chapter 3.1.

TABLE 1. *Reed bed areas in the coastal municipalities of Southern Finland.*

| Municipality | Reed bed area (ha) | Share of reed beds in the municipal area (%) |
|---|---|---|
| Askainen | 755,04 | 7,92 % |
| Dragsfjärd | 398,54 | 0,18 % |
| Espoo | 296,60 | 0,58 % |
| Halikko | 476,21 | 1,24 % |
| Hamina | 168,07 | 4,57 % |
| Hanko | 97,26 | 0,12 % |
| Helsinki | 390,95 | 0,57 % |
| Houtskari | 745,71 | 1,28 % |
| Iniö | 393,69 | 1,17 % |
| Inkoo | 562,60 | 0,59 % |
| Kaarina | 272,13 | 3,66 % |
| Kemiö | 526,77 | 1,29 % |
| Kirkkonummi | 710,30 | 0,69 % |
| Korppoo | 624,50 | 0,34 % |
| Kotka | 307,01 | 0,32 % |
| Kustavi | 824,59 | 1,55 % |
| Lemu | 455,58 | 8,33 % |
| Loviisa | 175,10 | 1,88 % |
| Masku | 285,21 | 3,07 % |
| Merimasku | 640,36 | 7,25 % |
| Mietoinen | 194,18 | 2,55 % |
| Naantali | 534,26 | 6,46 % |
| Nauvo | 1437,86 | 0,85 % |
| Paimio | 141,44 | 0,58 % |
| Parainen | 1611,87 | 3,40 % |
| Pernaja | 2124,62 | 1,92 % |
| Perniö | 109,59 | 0,26 % |
| Piikkiö | 215,54 | 1,95 % |
| Pohja | 172,25 | 0,65 % |
| Porvoo | 2123,99 | 0,99 % |
| Pyhäranta | 127,52 | 0,17 % |
| Pyhtää | 882,97 | 1,19 % |
| Raisio | 57,35 | 1,15 % |
| Ruotsinpyhtää | 717,48 | 1,52 % |
| Rymättylä | 981,18 | 2,92 % |
| Salo | 95,08 | 0,64 % |
| Sauvo | 623,66 | 2,08 % |
| Sipoo | 436,46 | 0,60 % |
| Siuntio | 72,87 | 0,27 % |
| Särkisalo | 418,22 | 2,76 % |
| Taivassalo | 1321,28 | 5,99 % |
| Tammisaari | 1742,23 | 0,93 % |
| Turku | 679,09 | 2,23 % |
| Uusikaupunki | 1103,96 | 0,85 % |
| Vantaa | 5,32 | 0,02 % |
| Vehkalahti | 470,76 | 0,42 % |
| Vehmaa | 313,13 | 1,55 % |
| Velkua | 400,04 | 3,18 % |
| Virolahti | 499,56 | 0,89 % |
| Västanfjärd | 220,09 | 1,52 % |

**Sum total (ha)** 28940,07

**Average percentage of the municipality area** 1,03 %

## 2.2 Energy content and quality as a fuel

Factors affecting the usability of the Common Reed as a energy source when burning it are the moisture of the reed mass, its heating value, its bulk density, ash content and the ash properties. As the moisture percentage increases, the heating value decreases as the vaporization of water consumes energy, the amount of combustion gases increase and the burning process is hindered. The moisture percentage varies according to the time of year (15–60%): the moisture suitable for combustion, ca. 18–20 % is reached between January and March (Kask, 2007).

To its energy content, the Common Reed is almost equal to wood chips (table 2). Measured by bomb calorimeter, the so-called calorific heating value in high pressure pure oxygen for the Common Reed is ca. 18–19 MJ/kg and its effective heating value at 15–20 % operating moisture content approximately 14–15 MJ/kg (3.9–4.2 MWh/t) (Isotalo and others, 1981; Kask, 2007). The heating value is bigger for winter harvested material than for material harvested in the summer (Kask, 2007). By its heating value, the Common Reed is comparable to Reed Canary Grass and straw, the effective heating value of which at 14–15 % operating moisture content is approximately 4.1–4.2 MWh/t.

When the energy content (the heating value) of winter harvested Common Reed is ca. 15 MJ/kg (4.2 MWh/t) at operating moisture content, the energy content of a reed bed of one hectare can be approximately 21 MWh (in case the dry matter yield is 5 t/ha). This is the equivalent of the energy consumption of one detached house per year. In their entirety, the reed beds on the coasts of Southern Finland (ca. 30 000 ha) could yield the calculatory amount of 630 GWh energy. As a comparison we could assess the energy produced by the annual growth of forests. In Southern Finland, the annual forest growth is approximately 6 solid cubic metres per hectare. Translated into chip cubic metres it is 15 chip cubic metres/ha. If the energy density of whole tree chips depending on the wood species when dry (at 40 percent moisture) is approximately 0.84 MWh/ bulk m3, 15 bulk cubic metres give 12.6 MWh energy.

There are also other combustion technical properties involved in the quality of fuel, such as bulk density and its effect on the fuel feeding into the incineration plant, possible need of pre-processing, the ash that the fuel contains and the number of agents in the ash that possibly corrode the incinerator equipment. The bulk density of the Common Reed harvested and chopped in the spring is ca. 32 kg/ bulk cubic metre (chapter 3.2) which is lower than that of, for instance, the Reed Canary Grass, and one order lower than that of peat and chips at operating moisture content (sod peat: 389 kg/ bulk $m^3$; long beam chips: 250–350 kg/bulk $m^3$). Because of its low bulk density, chopped reed straw cannot be burned as such in chip furnaces but it must be mixed with peat or chip. Burned as such, the dry and light chopped reed raises the combustion temperature of the furnaces, which are designed to burn much heavier material, very high. Also the transport systems are not necessarily designed for straw-like and light materials, and thus the furnace efficiency might be reduced when the transport equipment cannot feed in the chopped reed at a sufficient speed.

Due to its very low bulk density, the energy density in the chopped reed is also low, approximately 0.13 MWh/bulk cubic meter (cf. Reed Canary Grass 0.3–0.4 MWh/ bulk $m^3$ and

TABLE 2. *Qualities of different fuels.*

| Fuels | % Moisture | % Volatiles | % Ash | MJ/kg, Calorific value of dry matter | Elemental composition | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | C, % | H, % | N, % | O, % | S, % | Cl, % |
| | | | | | | | | | | |
| Reed | 15-20 | 81,8 | 2,1-4,4 | 18,92 | 47,5 | 5,6 | 0,3 | 43,3 | 0,04 | 0,11 |
| Yellow straw | 15 | 70 | 4 | 14,4 | 42 | 5 | 0,35 | 37 | 0,16 | 0,75 |
| Green straw | 15 | 73 | 3 | 15 | 43 | 5,2 | 0,41 | 38 | 0,13 | 0,2 |
| Flax | 10,3 | | 4,62 | 18,81 | 46,5 | 6,08 | 0,4 | | 0,25 | 0,27 |
| Hemp | 18 | | 3,7 | 17,35 | 45,92 | 5,47 | 1,07 | | 0,09 | |
| Grain straw | 20 | | 5 | 17,4 | 46 | 5,9 | 0,5 | 40 | 0,08 | 0,31 |
| Rapeseed | | | 4,6 | 23,9 | 58,6 | 8,5 | 3,7 | | | 0,5 |
| Rape straw | 25 | 79,2 | 2,4-2,8 | 19,33 | 46-48 | 5,7-5,9 | 0,8 | 39-42,1 | 0,17-0,21 | 0,22-0,1 |
| Reed Canary Grass | 10-15 | 74 | 5,5 | 17,6 | 46 | 5,5 | 0,9 | | 0,10 | 0,09 |
| Sawdust | 45-60 | | 0,4-0,5 | 19-19,2 | | 6,2-6,4 | 0,1-0,5 | | <0,05 | |
| Cutting residues | 50-60 | | 1-3 | 18,5-20 | | 6-6,2 | 0,3-0,5 | | <0,05 | |
| Wood pellet | 8-10 | 83,6 | 0,4-0,5 | 19-19,2 | 49-50 | 6,0-6,1 | <0,16 | | <0,007 | 0,01-0,03 |
| Wood+reed pellet | 7,4 | 82,7 | 0,7 | 19,9 | | | | | | |
| Straw briquette | 13,8 | | 6,2 | 18,5 | | | | | | |
| Meadow hay briquette | 12,3 | | 4,9 | 19,5 | | | | | | |
| Peat | 45 | 78,5 | 5 | 20,8 | 55 | 5,5 | 1,7 | 32,6 | 0,2 | |
| | | | | | | | | | | |
| Heavy fuel oil | - | | | 40,6-41,1 | 88,4 | 10,1 | 0,3-0,4 | | 0,8-0,95 | |
| Light fuel oil | - | | | 42,4 | 86,2 | 13,7 | 0,01-0,03 | | 0,1 | |
| Natural gas | - | | | 33,1-34 MJ/$m^3$ | | | 0,8 | | | |

long-beam chips 0.7–0.9 MWh/ bulk $m^3$). This again increases the storage and transport costs of the chopped reed and on longer distances sets a requirement of increasing the bulk density for instance by baling or pelletizing or in some other way densifying the chopped reed (see chapter 3.2).

The sulphur content of the reed mass is small (less than 0.1 %), so it does not form a significant sulphur emission source, and burning the reed does not promote the corrosion of incinerator or combustion gas surfaces. The reed contains a small amount of corrosion promoting chlorine. The amount of chlorine is markedly bigger in the biomass harvested in summer (Kask, 2007), since most of the chlorine is in the leaves which fall in late autumn. The effect of the chlorine can be prevented by adding hydrated lime into the combustion reaction.

The high ash content of the Common Reed (ca. 4 %, cf. wood 0.4–0.7 %) is a problem for the incineration both in small and big furnace constructions. The ash lowers the heat value, hinders the combustion and carried by the combustion gases soils the incinerator surfaces and flues, and presents an environmental problem. The ash content and the chemical properties of ash are different in summer and in winter. The ash content is at its lowest in winter (2–4 %, in the summer 4–6 %; (Kask, 2007), when the leaves containing a wealth of ash have fallen. The amount of silicon oxide in the ash is significantly greater in winter and the amount of potassium oxide smaller. This has an impact on e.g. the melting point of the reed ash. The melting point of the ash is lowered as the content of alkali metals, such as potassium, increases. This is the reason to the ash melting point varying according to the time of year the reed material was harvested: in the summer harvested material, the ash softens at under 1 000 °C, whereas the ash in the winter reed didn't melt even at 1350 °C (Kask, 2007).

The high melting point of the reed ash prevents the building of solid slag impeding the combustion process, but the great amount of ash creates its own demands to the furnaces.

*Reed ashes. Photo: Ülo Kask.*

# 3 REED ENERGY PRODUCTION CHAIN

## 3.1 Harvesting

### The time and conditions of harvesting

The Common Reed can be harvested for energy use both in winter and in summer. The dry reed harvested in winter is used for burning and the summer harvested green mass is used for biogas production. The harvesting time should be tailored according to the weather conditions, the quality properties of the material and other values and utilisation interests regarding reed beds.

When the reed is used for burning, an important factor is the moisture in the reed mass. The moisture percentage is at its lowest in spring winter, March – April (chapter 2.2). Even then the harvesting should be done at midday when the morning moisture has evaporated. Even rain during the harvesting does not necessarily hinder the harvest, since even after a longer period of rain the standing reed dries up in a few days to its pre-rain moisture levels.

The annually varying weather conditions set limits to the harvesting. The breaking ice can destroy the reed beds and hard winds flatten the reed beds. The success of winter harvesting is essentially tied to the snow situation and the thickness of the ice on the water. If the freezing takes place in the fall while the water level is high and the levels drop after that, the thin ice clinging to the reed straws becomes an insulation layer which slows down the freezing. In this case also the air pockets between the layers of ice can break under the weight of the harvesting machines. If furthermore there is snowfall on the ice coating, the formation of the bearing ice is weakened. During some years, poor ice conditions can prevent almost all winter harvest of the reed. In the future the climate warming can make winter harvesting which is done on the ice much harder as the ice winter gets shorter and the ice thinner.

The ice in the reed bed areas is generally weaker than in the open water areas, since the reed beds and the "reed peat" formed by the dead read matter conserve heat energy. Also, the dead material increases the anaerobic methane digestion of the reed. It can be assumed that if the reed could be gathered by yearly harvest, the decomposing matter would decrease and the ice would thicken so it could also better carry the harvesting machines.

The green reed mass for biogas production is harvested in the late summer, after the most sensitive phases of the nesting of reed bed bird species. Harvesting done in the early summer can make the growth stop and damage the rootstock. The choice of cutting height is fundamental: cutting the reed under the water level makes the growth stop, whereas harvesting by cutting above the water level and especially in the late summer does not jeopardize the growth of the reed in summers to come. The summer reed mass harvested for biogas production also decreases the nutrient load to the water systems, since late summer harvesting, before the nutrients are transferred to the rootstock to ensure the growth in the next season, is the most efficient way of removing nutrients from the water systems.

### The permits for harvesting

At best, the use of reed as an energy source is beneficial to the interests of the owners of land and water areas in connection with using the water areas for leisure activities, with keeping the landscape open and with water preservation. In the small-scale attitude survey implemented together with the project ”Reed strategy in Finland and in Estonia” the attitudes towards utilisation of reed beds were mainly positive (Silén, 2007), even though it currently isn't possible to reimburse the land or water area owners for the reed harvested for energy incineration or biogas production.

The permits required for the harvesting of the Common Reed are dependent on whether the reed harvested grows on the shores or on water areas. For harvesting the reed growing on land areas, the permit of the landowner is needed. The owner of the land area can utilise the reed growing on it relatively freely, provided that the area isn't located on a nature conservation area or belong to the Natura 2000 network or any other nature protection programme.

The harvesting on water areas is regulated by water legislation. In theory, removing a hindrance caused by water plants for instance by mowing reed beds is possible to do without permission even in water areas owned by someone else, if it does not present a significant inconvenience to the owner of the water area (Water Law, chapter 1, § 30). In jointly owned water areas, the shareholder has a right to utilise the common areas in such a way that the right of other shareholders to such utilisation is not jeopardized (law of common areas 28 a). It is important to notice, that in the first mentioned case the issue is the removal of water vegetation as a maintenance and preservation measure. If the main focus is on utilising the Common Reed, and especially if the mowing is done as a means of earning, one must have the permission of the water area owner or the owning shareholders of the area. It is wise to enter into a written agreement on the use of the reed bed with the owner, irrespective of whether the reed bed is located on land or in water. It is also wise to write down particulars regarding the use of the roads leading to the reed bed in the agreement.

In case the mowing covers more than 0.1 hectares manually, or more than 1 hectare by using machinery, the mowing is considered ”larger than insignificant” and the situation changes. In such cases, the owner of the water area or the group of shareholders administering common water areas must be notified of the measure at least one month in advance, and the local environmental centre must be informed.

A significant part of the biggest reed beds on the southern coast of Finland belong to the Natura 2000 network. A part of them are protected by Nature Protection Act, and a part of them belong to the wetlands or bird waters protection programmes. In areas covered by nature protection programmes, the regional environmental centre must always be contacted before harvesting reed beds; the environmental centre assesses whether the harvesting is possible without endangering natural preserves. In some cases, protection regulations or the preservation of the living environments of endangered species prevent the harvesting altogether. However, small-scale harvesting often adds to the mosaic structure of the area which also increases biodiversity.

At best, the harvesting of reed benefits the preservation of biodiversity since the harvesting can increase the living possibilities of many species in the shore meadows such as those of waders. On the other hand, many ”reed bed specialists” presuppose large areas of reed beds (see chapter 1.3). Harvesting should not be done before the end of July, when the most sensitive phases of the birds' nesting are over.

**Reed energy from the Natura area**

In a EU Iniative 2 -project, administered by the Turku University of Applied Sciences, ” Nutrients to good use – the use of biomass for energy in Vakka-Suomi”, a regional model is created for the use of biomass of the non-cultivated areas in the region of Vakka-Suomi, a group of coastal municipalities in Southwest Finland. The reed beds chosen as the pilot area for the project are located on a Natura 2000 area in Kolkanaukko, Taivassalo. The project aims at studying the conditions for operating in a Natura area. A significant part of Finland's largest reed beds are located in similar natural conservation areas.

There is an attempt to find solutions to the balance between preserving the Natura values and the utilisation of reed beds. When implemented purposefully, reed bed harvesting can even add to an area's value for birdlife, and improve the state of the water system and the leisure use value of the area. While utilising the reed beds, the water systems in the area will be benefiting from the reduction of nutrients. As a basis for the reed bed use and management planning, the projects surveyed the pilot area in terms of natural values, ownership of land and water areas and the interests of the landowners. As the project progresses, potential farmers or sub-contractors are sought for the harvesting of the reed beds in the pilot area.

### Harvesting equipment and machinery

The reed grows in very different places ranging from water areas to dryer shore areas. The different growth places and harvesting times (summer/winter) presuppose differing harvesting equipment. In the choice of equipment, the defining factors are the technical requirements in harvesting and the overall cost-effectiveness. The cost-effectiveness depends on e.g. harvesting and transport costs and the work yield and harvesting losses, which in the case of the Reed Canary Grass have been deemed a central development goal (harvesting loss 20–30 percent with the field chopper – round baler combination).

The essential technical factor in the harvesting of reed is the weight of the machine and the surface pressure it directs against the ground and the ice. Machinery on wheels is the most cost-effective in light of the transportation between work sites, even though also chain track structure decreases surface pressure. Also extra wide tyres for tractors decrease the surface pressure.

The varying water level sets limits to winter harvesting, since it hinders the formation of dense ice. Also snow piling up on the growth slows down the formation of the ice layer bearing the weight of the harvesting machinery and also otherwise makes the harvesting more difficult, and decreases the amount of the harvestable reed mass. The essential requirement for winter harvesting is small surface pressure, so that the harvesting machine with a full load stays on the surface of the ice or the mud bottom without sinking. In the winter, it is possible to harvest the reed with existing farming machinery.

In winter, the mowing can be done with a disc mower and the harvesting with self-loading wagon or a baler. The baling can be done using a round baler, a square baler or a hard baler. The most cost-effective alternative would be large square baling, but at the moment the price of the square baler is still high, and the ice cannot bear the weight of the machine, 7–9 tons. The more commonly used round baler is more economical and the machine lighter. The chopper commonly used in a round baler produces 5–10 centimetres long chopped straw which is tied with a net. The hard baler that has been used the longest produces smaller bales which raise the transportation costs, but instead the machine itself is light. The harvested reed can be transported to the shore with a self-loading wagon. A chopping self-loading wagon produces ca. 5 cm long chopped straw which can be used for burning. The bulk density of the chopped straw is significantly smaller than that of a bale, and here the decisive factor is the transportation cost.

In case one wants to reduce the amount of equipment and runs, a precision chopper can be attached to the tractor. The chopper feeds the chopped straw directly into the wagon behind it. Another alternative is to attach a round baler to a tractor equipped with a disc mower.

The Reed strategy project also charted the applicability of different methods, on the basis of mowing tests, to the harvesting of the reed in winter and in summer (Valo, 2007). So far, there's no actual reed thresher on the market even though even such a machine is being developed; instead, the local entrepreneurs and machine subcontractors implemented the harvesting either by using existing farm machinery or with improvements to them. Harvesting was also done with a machine designed for the collection of reed building material. The harvesting was very experimental and was implemented on the basis of invitations to tender. There was a shortage of tenders, since going out on the ice with their own machinery was not very enticing to the machine entrepreneurs. The winters during which the experiments were implemented, 2006–2007, were also very mild with bad ice conditions.

In the harvesting experiments in Askainen in late winter 2006, the harvesting was done with a field chopper. In practice the work was done in such a manner that connected to one tractor there was a field chopper, from where the chopped Common Reed was blown directly into a wagon connected to a tractor driving alongside. The wheels of the chopper had been replaced by runners to prevent the equipment from sinking into the snow (Valo 2007).

In the experiments implemented at Salmilahti in Southeastern Finland, the reed bed was mowed by a disc mower, after which the mowed windrow was collected with a self-loading wagon. The ice breaking underneath the harvesting machinery a few times created some problems. The surface pressure of the self-loading wagon could be lowered by equipping the tandem axle of the wagon with caterpillar band (Valo, 2007).

In earlier harvesting experiments of the Common Reed by TTS (Work Efficiency Institute) (Isotalo ja muut, 1981), the machinery used was hay harvesting equipment (mower, chain rake, baler), and the harvesting succeeded well in early winter when the ice was solid. Snow was not a significant hindrance in the experiments.

The Danish manufactured Seiga machine with a cutting blade is used in harvesting the Common Reed for building material. In Estonia, the reed is collected for domestic building needs, but in normal years there is enough of material for export also. Wide flywheels keep the surface pressure of the machine low and the cutter bundles the reed for further processing. On a good day the Seiga BCS cuts about 6000 bundles a day, but requires a crew of 3–5 people and two adjacent blades. The normal work yield per day is ca. 4000 bundles. Even though the machine operates blamelessly, an even greater volume would be needed to harvest reed for bioenergy raw material, and from the point of view of bioenergy, the bundling is unnecessary.

Also available is a Polish caterpillar band machine especially designed for cutting reeds, based on a German light tractor and an Italian BCS cutter. The cutting capacity is ca 1000 bundles per hour, depending on the reed bed, and the machine requires a crew of 2–3 persons. The equipment weighs 2500 kg and can easily be transported on a chassis or pallet. The reed harvester still requires development work to be applicable precisely for bioenergy harvesting. For instance, the BCS cutter should be replaced with a chopping blade and the walls built higher (Hanhikari 8.6.2007).

A machine which so far is untested in Finland is the Wetland Harvester developed the British Loglogic. It has been developed for harvesting especially in areas that require small surface pressure from the equipment. After mowing, the reed mass is directed into a chopper making chaff of 1–4 cm. The chaff is blown into a silo of 8 cubic metres at the back of the machine. The manufactures announces the hour capacity of 10 tons of ready chaff, which equals the harvest of ca 2 hectares. The problem is the high price of the machine.

A specific reed thresher has also been developed in Finland for the harvesting of the Common Reed. The advantage of the thresher is that the reed can be harvested, baled and transported to intermediate storage close to the shore using just one machine. The built-up reed thresher usually consists of the cutting table of an ordinary farm thresher, a bull chain conveyor, round baler and a hind wagon with which the bales are transported to the shore. The equipment is promising in its operational principle, but has proven not to work very well in reed harvesting


*Continuous track machines have a low surface pressure which is a definite help in damp and soft-bottomed reed beds. The thresher in the picture is small and narrow enough to fit onto a trailer which makes it quick and easy to transport on highways. Photo: Pekka Poutanen.*

*The windrow of harvested reed can also be collected by tractor on a hard bottom or thick ice. In the picture, a disc mower attached to a tractor and a self-loading wagon behind it. A better solution would be a thresher which would also collect the material so only one trip to the reed bed would be necessary. Photo: Teemu Kettunen.*

*The wide-tyred Seiga was originally designed for rice farming, but it is commonly used for harvesting reed beds in different parts of Europe. In the picture you can see an demonstration of harvesting reed with a Seiga in Halikonlahti, March 2006. Photo: Eija Hagelberg.*

*A harvester which would mow and bale the reed on one run could be the most functional solution in the energy harvesting of reed beds. In Vehmaa, a reed thresher the planning of which is still halfway is under construction and has been brought out of storage for photography. Photo: Eija Hagelberg.*

*Reed bed threshing and harvesting experiments in Mietoistenlahti in June 2007. Photo: Kimmo Härjämäki.*

*In southern France, reed is collected for building use also from a pontoon moving between two points with the help of a wire. This does not upset the water bottom and stops the bottom nutrients from dissolving into the water. Photo: Brigitte Poulin.*

since it is too heavy. In a Bachelor's thesis in Automotive Engineering degree programme at Turku University of Applied Sciences (Himanen, 2007), improvements to the built-up reed thresher were sought with the help of prototyping. Central development areas were minimizing the surface pressure of the machine, and designing pontoons which would support the machine in case the ice breaks underneath it.

The Common Reed, which will grow in southern Finland to heights of even 3–4 metres, may require for its cutting gear something quite different from the equipment used in hay harvesting. Possible models for the equipment could be the gear used for corn and Miscanthus sinensis (Porcupine Grass) harvesting.

Summer time harvesting of reed from water areas is quite a different problem since it takes place in water that can be as deep as 2 metres. The harvesting machine should float and preferably it could also run on land. It would also be a benefit if the transfer trips could be done without expensive arrangements and special transports. One of the options for summer harvest is a floating tractor (Hitsacon Oy). The tractor floats on big tyres and pontoons and can be used for instance for water systems conservation work. In principle, the floating tractor could be fitted with cutting equipment, and the cut material could be guided to a floating trailer. The floating tractor could be used in winter reed harvesting just as an ordinary tractor.

On the market there are also machines designed for clearing out vegetation from eutrophic waters. In a survey connected with the fertilizer use of reed , which was implemented in Sweden, the Finnish manufactured Aquatic Plant Harvester designed for removing aquatic plants was used in water about 0.5–2.5 metres deep. Others are for instance Truxor, a caterpillar band based mower built on pontoons, which can mow the reed from 1.5 meters water depth all the way to the shore, and another one similar to it, the Finnish manufactured Pandora mower, which collects the mowed reed into an attached barge.

Also a piste (prepared ski trail) maker with additional equipment could be applicable for both summer and winter harvesting. The chain track operated piste maker has low surface pressure. Also a track driven wheel buggy equipped with finger beam thresher has been tested in the summer harvesting of reed beds.
The work yield of the harvesting chains

When assessing the cost-effectiveness of harvesting the Common Reed for energy generation, it is important to know the work yield, which means how much reed can be harvested by using the different harvesting alternatives per time unit. Even if the work would be done with well-known farming equipment, the efficiency of which is known, the shoreline circumstances can bring surprises. In a Bachelor's thesis at TUAS, in the degree programme in Mechanical and Production Engineering (Valo, 2007) the work yield of different harvesting chains were assessed in winter harvesting. The calculations were based on values and comparisons with the work yield of the equipment in farm use.

TABLE 3. *The work yield of different harvesting chains (Valo 2007, 31)*

| Work phase | Work yield ha/h |
|---|---|
| Mowing with a disc mower (300 cm) | 2 |
| Gathering with a self-loading wagon, vol. 27 $m^3$ | 1 |
| Round baling | 2 |
| Square baling | 2 |
| Gathering of bales | 1,5 |

When we get more experience of the gathering work, the work yield will be more precise to calculate. If it is possible to harvest a familiar shore again during new winters, and the weaknesses and hardships of the harvest areas are known, the harvest will become more routine and more effective, and the performance cost-effective.

In summer harvesting, the work yield is smaller than in winter. The work yield of the floating tractor has been estimated at 0.5 ha per hour. Also moving in open water consumes significantly more energy than working on ice.


*One of the problems on the Common Reed's way from the reed bed into the furnace can be in the pre-processing of the material, where the reed must be chopped short enough to move well in conveyors and transfer equipment. A bale chopper intended for normal agricultural use works well in the chopping. With it, the chopped reed comes out with even quality and short enough. Photo: Arki Virko.*

## 3.2 Pre-processing

The reed mass can be used for energy generation in different forms: Both chopped short and mixed with chips, peat or grain, and as pellets, briquettes or as biogas. Mixed with for instance chips the reed can be burned in the furnaces currently used. From the point of view of overall cost-effectiveness, the energy density of the reed is the most important factor. The energy density of reed is bigger than that of straw, but clearly smaller than that of wood. The transport and storage of fuel with low energy density is expensive. So from the point of view of cost-effectiveness, the energy density of the reed material should be increased by baling or producing pellets. It is possible to use various kinds of hydraulic presses, but there is no experience of these in connection with the Common Reed.

### Chopping

In experiments done on chopping loose reed with a chopper intended for wood chips, the chaff was mainly composed of 3–10 cm long straws but there were also 20–30 cm long straws in it. (Vuorma, 2007) The bulk density was estimated at 32,5 kg/bulk cubic metre (compare with straw 30–40 kg/bulk $m^3$ and Reed Canary Grass 63 kg/bulk $m^3$). In another experiment, a tractor operated chopper which can chop tree trunks up to 25 cm diameter was used. The problem with chopping proved to be its varying quality. The dry Common Reed turned out to be tough since it either didn't crush or the outcome was pieces of reed 20–500 mm long. By adjustments the cutting outcome became a little better. Also the feeding speed played a role. When feeding large amounts of reed, the material came out chopped smaller. Chopping the moist Common Reed gave better results. The moist Common Reed came out of the chopper with an even quality, with size variation between 20–50 mm (Virko, 2006).

At the Vahala Garden chips storage in Halikko, the Common Reed was chopped with a branch chopper for a combustion test. The dry Common Reed and the flower panicles dusted excessively and the reed stem was left in pieces about 10–15 cm long. The bundle strings were cut off with a knife so they wouldn't stick in the conveyor. Feeding the chopper is hand work which causes costs and is very slow.

### Bales and bale crushing

The benefits of baling compared with bulk chopped reed are the greater density of the material in transport and the accessibility of existing baling equipment. Also the space needed for storage decreases compared to bulk material. Almost all round balers are equipped with a chopper which means that the bales consist of chips about 5–10 cm in length. For successful burning the Common Reed should be chopped into bits less than 5 cm in length, so it wouldn't present problems for conveyors, unless the bales are used as such in furnaces suited to burning bales. With bale crushers, however, the bale strings can present a problem.

In the experiment of hard baling the Common Reed (Vuorma, 2006) carried out within the Reed strategy the baling succeeded well once the adjustments of the baler were right. The average density of the bales was ca. 163 kg/$m^3$, which is comparable to the density of a hay

*A reed bale. Photo: Eija Hagelberg.*

*Experimental Common Reed pelletizing on the equipment of Biottori Oy in Jämijärvi. It is possible to press Common Reed into pellets even with small-scale pelletizing machines. When chopped short enough the Common Reed, the right adjustments and a pinch of for instance Turnip Rape pressing waste guarantee a first-class pellet. Photo: Sami Lyytinen.*

bale and bigger than the density of a straw bale. The density was in the same class as previously mentioned in the experiments on hard baling the Common Reed (Isotalo and others, 1981). In the round baler experiment, there was no problem with the baling of the material, but because of the slippery reed the bales didn't stay intact very well when tied by string – this could be avoided by using a baling net. (Funck, report on June 15th, 2007). Problems related to the slippery quality of the reed have also been reported earlier (Isotalo and others, 1981).

In the reed bale crushing experiments (Vuorma, 2007), both hammer and rotor crushers were used. The crushing experiments resulted in 1–2 cm long, standard quality chopped reed.

#### Pelletizing

Pellet heating is becoming more common in small houses as a heating form replacing oil heating. On the size scale of power plants, the use of pellets is restricted by their high price. Pelletized winter reed is easy to store and to transport, but the pelletizing itself adds to the costs. The pellet is manufactured from ground biomass, with or without a binder, into cylinder formed pieces with the average length of 5-30 mm.

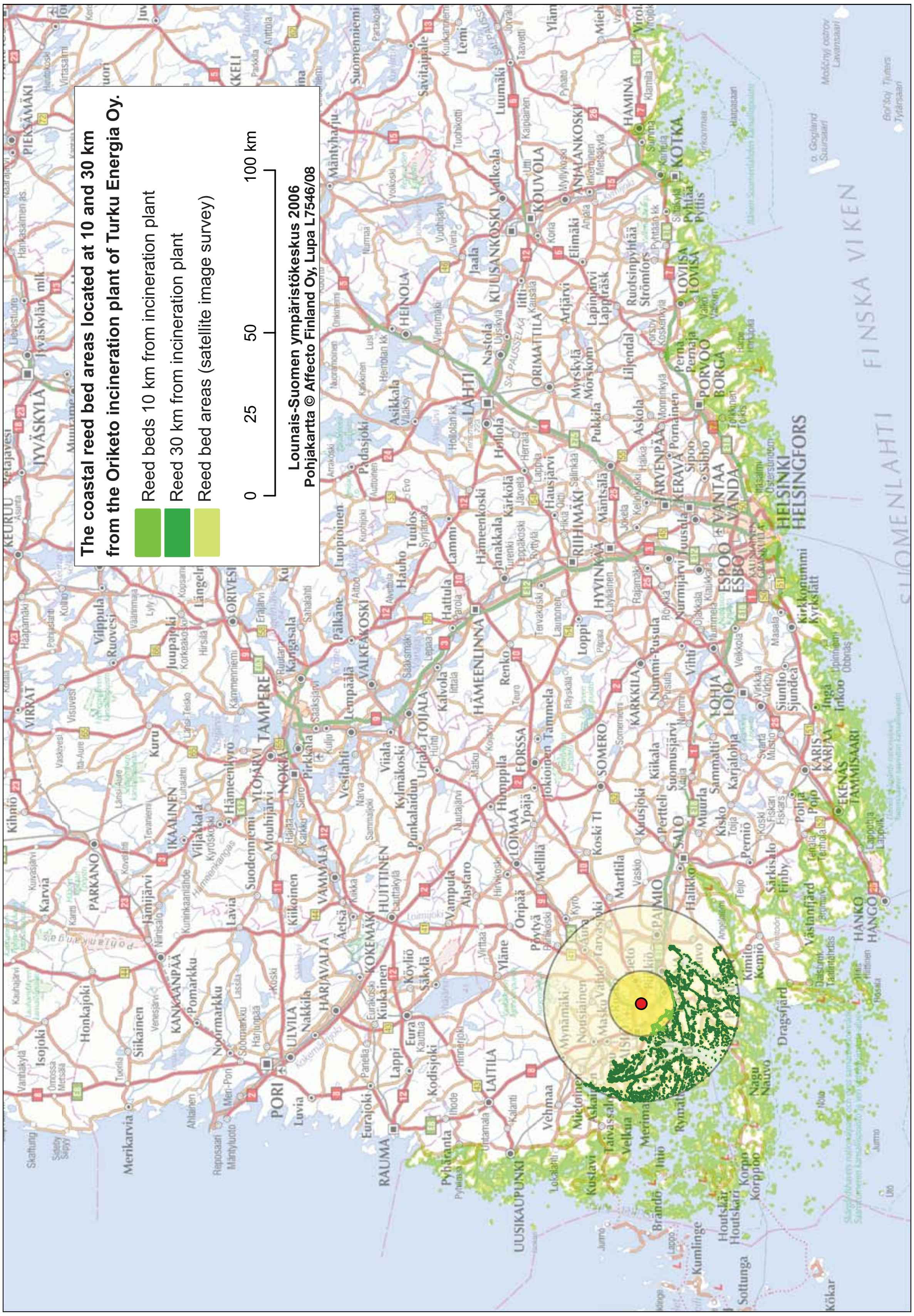
The pelletizing experiments of the Reed Canary Grass show that the pellitization succeeds best when the straw mass is mixed with for instance peat. This way the pellet gains durability. At the same time, its incineration properties are enhanced. Vapo, the leading wood pellet manufacturer in Finland, intends to increase the use of Reed Canary Grass in the manufacture of pellets in the future. In the Vapo pellet factories, promising tests have been carried out on using the Reed Canary Grass in the manufacture of mixed pellets, by mixing it in sawdust. Amongst others, the Vöyri pellet plant tests show that Reed Canary Grass can be used up to 50 percent in the pellets using modern technology (Vapo Bulletin May 19th, 2006).

Like Reed Canary Grass, the Common Reed which shares many qualities with it is also suitable for pelletizing. The Reed strategy project carried out a pelletizing experiment with the Common Reed on a small-scale pellet machine at Jämijärvi in November 2006. The chopped reed, which was of uneven quality, caused a blockage in the machine. Without a binder the dry reed mass would also not stay solid. Moisturizing the mass and adding a binder (Turnip Rape powder and grain dust) improved the result (Vuorma, 2007).

The Tallinn University of Technology has also done pellet tests. The research shows that it is good to add ca. 5 percent of other raw material, for instance Turnip Rape, to the reed material in order to make the pellet solid (Kask 2007, at the final seminar of the project "Reed strategy in Finland and in Estonia" on August 31st, 2007 in Estonia).

#### Briquetting

A briquette is a cubic or cylindrical piece of bio fuel made by pressing or densifying from ground biomass, with or without a binding material. Briquettes are mostly used in regional heating plants and district heating plants, and in industrial plants.




*The coastal reed bed areas located at 10 and 30 km from the Oriketo incineration plant of Turku Energia Oy.*

Experiments on briquetting the Common Reed were carried out in May 2006 at the Kuortane energy cooperative plant which uses sawdust and Reed Canary Grass briquettes as a fuel for their regional heating plants. The experiments on the Common Reed failed because of the high moisture content in the reed bales used as raw material.

### 3.3 Transport and storage

An economical transport distance for straw-like bio fuels is dependent on the quality of the material. For instance, economical transport distance for Reed Canary Grass is at maximum 90-120 km depending on the quality of the material: in bulk unit transport the distance is shorter than in bale transport (Flyktman and Paappanen, 2005). In bulk harvesting, the chopped material can easily be mixed with peat or chips at the incineration plants, but the low energy density increases the transport costs. In order to increase density, the reed should be baled or transformed into an even denser form such as a briquette or pellet. Also the volume weight of bulk chopped reed can be increased with various pressing devices. The density of a round or square reed bale is approximately 140–170 kg/m3 (cf. bulk chaff ca. 30 kg/$m^3$) and thus its economical transport distance is longer.

One of the objectives of the satellite charting commissioned by the project ”Reed strategy in Finland and Estonia” was to survey, using location databases, the distance between the reed beds and possible power plants to minimize transport costs. When analysing the results, it was found that there were 272 hectares of reed bed areas at a radius of 10 km from the Oriketo heat power plant of Turku Energia Oy, and at a radius of 30 km, already 6433 hectares. This already equals to an energy potential of 135 GWh, which is significant considering the fact that the total energy output of the Oriketo heat power plant in 2005 was 331 GWh.

In a Bachelor's thesis at TUAS degree programme in Automotive Engineering (Puolakanaho, 2007), logistic operational calculations were drawn up for the transport of the Common Reed. For all distances in the transport of light bulk material, such as chopped reed, briquettes, pellets or bales, the most cost-effective transportation form was a combination vehicle. In transports less than 50 km long the shorter loading time of a truck compensated its lesser transportation capacity. When the maximum harvesting area is 4.4 hectares, also a truck could be used for the pellet or briquette transportation in the light of the operational calculations.

In the logistics chain of using the Common Reed for energy generation it is important to note the storage of the reed material also. Even here the form of the material (chopped reed / bale / pellet) is decisive: the storage of the chopped reed presupposes large storage facilities and is also uneconomical (need of large storage facilities/ energy content). Chopped reed bulk equalling 1 MWh of energy requires some 7,6 $m^3$ of storage, while it only requires 1,5 $m^3$ as a hard bale. In Finland there is not yet much experience of storing the Common Reed, but in Estonia the storage of the reed which is collected for building use can well be done in old, unused cowsheds that were left after the collapse of collective farming. Once it is dry the reed stays intact for years but the storage room must have ventilation.

In the harvesting experiments in Finland the reed was baled, and the hard bales were left outdoors on forklift platforms covered with light covers. During the storage time some moisture managed to get under the tarpaulins and the bales sucked in the moisture, which hindered for instance the carrying out of the briquetting tests.

At the Paimio district heating plant the fuel is stored outdoors. Moisture in the fuel does not impede the incineration, since in the burning process a flue gas scrubber is used after the electric filter; with the help of the flue gas scrubber the moisture coming in with the fuel can be used directly as heat in the district heating network (Vuorma 2007, 29).

Round bales of Reed Canary Grass are stored in an outdoor shelter because of the room they need, or in any roofed storage space the farm has to spare. The round bales are stored in a roofed pillar store or piled horizontally in stacks under cover, insulated from the ground by for instance forklift platforms. Bulk harvested chopped Reed Canary Grass is stored near the harvest area in shelters that are packed and covered in the same manner as silage storages (Pahkala ym. 2005, 17.).

### 3.4 Incineration

In the project ”Reed strategy in Finland and in Estonia” incineration tests were conducted in various types of furnaces. Power plant scale tests were conducted at Paimion Lämpölaitos Oy and Perniön Hakelämpö Oy, and also by the Forest Centre of Southeast Finland at the power plant of Kotka Energia (Virko, 2007). On the farm scale incineration tests were conducted at the Joensuu Manor in Halikko, at the Lindö Manor in Tammisaari and at the Vahala Garden in Halikko Halikossa (Kelkka, 2007). In the incineration tests, observations were made about the transport of the wood chip – chopped reed mix through the conveyor equipment and about the combustion properties of the material.

The most common ways of burning solid fuels are flat grid burning and fluidized bed burning. In fluidized bed burning, air is blown from underneath and thus the fuel can be made to float and to burn effectively. The flat grid technology is typically common in small furnaces with a maximum effect of 15 MW and fluidized bed burning in furnaces of bigger effect scale. Furnaces with moving grids, where even burning can be ensured, are best suited burning straw-like materials. Essential issues in burning straw-like biomass seem to be the length of the chopped straw and the treatment of the ash formed in the combustion process. In small furnaces, the maximum length of the chopped straw seems to be 30–40 mm since longer straws cause problems in the fuel conveyors even though there is also alternative conveyor equipment on the market where the straw length is not a problem. In experiments conducted with Reed Canary Grass in which chopped straw was burned in a fluidized bed furnace of a district heating plant, the longer straws caused blockage in the conveyor equipment (Martikainen, 2002).

Straw-like materials can be used in furnaces as chaff mixed with other biomass (in about 10 % ratio) and as bales, pellets and briquettes, either as such or mixed with other biomass.

Usually the bales are crushed before incineration, but there are also so called "cigar" type furnaces which can be used for burning round or square bales as whole. Bale furnaces, however, are still rare in Finland.

Bulk dried chopped reed raises the burning temperature very high. The burning effect of the furnace is reduced when bulk matter cannot be fed with sufficient speed in furnaces designed for burning peat and chips, i.e. denser material with higher moisture. Thus it is not wise to burn the Common Reed as bulk material but instead it is a fuel to be added as a mixture to peat or chips. The amount of ash creates problems in the incineration in small furnaces. In small furnaces the removal of ashes should be automated, or a large enough ash space be provided so that the removal of ash is not a problem. As such, the ash is not a problem but can be used as fertilizer.

In the farm scale incineration tests of the Reed strategy project, chopped reed (3–10 cm, with also 20–30 cm long stem particles in it )was used in 1/3 volume ration mixed with chips, and hard baled reed as such. It was conceded that the Common Reed is suitable for burning with minor equipment alterations as long as adequate air supply is ensured and the reed is chopped short enough (less than 10 cm, preferably ca, 4 cm).

The test incineration at heat plants using chips (30 percent reed, the rest wood chips) showed that in one test there were problems due to the high moisture percentage of the reed (70 %) and in another, problems due to the arching of the fuel. The problems can be avoided by making sure of the quality of the material both concerning the moisture and the length of the chopped reed.

It was not possible within the project to test the burning of the Common Reed in the big power plants at Fortum in Naantali or the Oriketo incineration plant in Turku because of shortage of material. In the incineration test at Kotka energy plant, implemented by the Forest Centre of Southeast Finland, the outcome was that the Common Reed could be burned even in bigger furnaces without problems.

A certain amount of heat furnaces burning gas are also in use. In carburation, the fuel is gasified before burning. Carburation needs less supervision than flat grid burning. A carburation plant is in use for instance at Björkboda Manor in Dragsfjärd, where chips are used as a fuel. Also chopped reed has been experimentally used in the manor heat plant as a 10 percent mixture with chips.

A representative of more modern furnace technology is the Cmr furnace, which also burns gasified fuel. There is not much experience of working the new kind of furnace.

*Experimental combustion of the Common Reed in the carburation furnace of Björkboda Manor. The Common Reed burns without problems together with the main fuel which is wood chips, only the amount of the ash generated differentiates it from pure wood fuel. Photo: Sami Lyytinen.*

**Straw bale furnace – a new opportunity for burning the Common Reed**

In December 2007, a wholly new kind of straw bale furnace in Finland was taken into use in Kemiö. Some 15 years ago, a few straw bale furnaces were brought from Denmark, the spearhead in using straw bales for energy generation, but after this the import has grinded to a halt. During that time, the technology has been significantly improved and the technical problems of the old straw bale furnaces have been minimized. The straw bale furnace should also be suitable for burning Common Reed as it is suitable for burning Reed Canary Grass. Burning Common Reed in the new type of furnace has not yet been tested.

During 2006–2007 the Reed strategy project implemented an incineration test in an old type straw bale furnace (Kelkka, 2007). In the experiment, Common Reed was burned as square bales. One of the problems was the ash which lay down on the surface of the straw bale, and the incineration was neither clean nor optimal. In the new straw furnaces this problems has been removed by adding automated fans into the furnace.

In Denmark, straw burning furnaces have been used for years; in Denmark straw makes up a significant part of the entire energy production of the country. Modern straw burning technology has been adopted during the last year also in Sweden, and the technology is finally arriving in Finland also. In Estonia there are no experiences of it so far.

At the moment, there are dealerships in Finland for two Danish straw burning furnaces: Overdahl and Faust. Overdahl manufactures straw furnaces in the size class 120–850 kW. In Sweden, the biggest model has produced power of one MW at best. In Finland, the price range for furnaces in the biggest size class is currently ca. 110 000–120 000 euros. The price covers the finished construction including the furnace, the smoke stack and the accumulator (Gröning 2007).

The incineration chamber length of the Overdahl 850 kW straw furnace is 4.2 metres and the diameter 2.05 m (round chamber). It can burn several different materials: wood ( even timber up to 4.2 metres long), construction wood and waste, platforms, cardboard and paper – and in addition to these also bales of straw, Reed Canary Grass and probably also bales of Common Reed. The furnace holds three round bales at one time. Big square bales also fit into the incineration oven, and smaller square bales can be stacked in even greater numbers. In addition to the above mentioned, the furnace can burn also other bio material. In Sweden it is permissible for farmers to use the furnace for burning up carcasses in chicken farms. In Finland there are no experiences of this so far. (Gröning, 2007).

One of the good sides of the furnace is that materials can be burned in it whole; there is no need for chopping. At times when maximum power is not needed, the furnace can burn stuff like twigs and forest clearing waste. Several diverse fuel materials give this kind of furnace several good utilisation possibilities.

In case only straw (and/or Reed Canary Grass and Common Reed) is burned in the furnace, the amount of ash is greater than in wood burning. However, in Denmark it has been observed that by burning wood after the straw, the amount of ash from the straw can be reduced further while it burns with the wood. A ladle which is the size and form of the bottom of the oven has been designed for easy collection and removal of the ashes from the oven (Gröning, 2007). The ash of clean straw, Reed Canary Grass and Common Reed can still be spread out on the fields as a fertilizer, so the ash is by no means a hazardous waste.

The amount of straw (or reed, or other energy source) burned depends on the energy need. For instance, a Swedish chicken plant farm uses the biggest straw furnace of 850 kW. On a cold winter's day with several minus grades the furnace is filled twice, both times feeding the furnace with three round bales of straw.

The biggest straw furnace gives enough of heating power for big scale farms (such as greenhouse cultivation, chicken production) or for instance for the needs of a small village. A good example of this could be a village in an agricultural area, close to big reed bed areas, in which one inhabitant (entrepreneur in farming) could start a small heating plant, whose furnace would burn material gathered from the close environment, and the entrepreneur could sell locally generated energy to the entire village population.

A straw furnace might be applicable to the energy use of the Common Reed. This way, the harvesting could be simplified, and the material wouldn't need to be chopped small since the chopping has proved to be a problematic and cumbersome phase. Thus a straw furnace could be recommended for acquisition at least in areas where there are large reed beds nearby. The Common Reed could act as an additional energy source to any other type of energy source suitable for the above mentioned furnace type.

**Lihula town will soon be heated by the Matsalu reed**
Margus Källe, development advisor, Lihula Municipality

On the coastal area of Matsalu there is one of the largest reed bed clusters on the Baltic Sea, some 3000 hectares of reed beds. The independence of Estonia in 1991 and the ensuing collapse of the collective farming – and, at the same time the number of cows – led to discussions about the use of hay biomass for energy. The idea of using hay biomass in Lihula at the end of the 1990's was strongly suggested by the Matsalu natural park since at the end of the 1990's there was not enough of use for the hay harvested in farming in the Matsalu.

Research on the combustion properties of reed beds and meadow hay has really only got going by the activity of The Tallinn University of Technology, with the help of the Phare financing in 2005-2006. The research results published in 2006 supported the use of hay biomass, and the planning of building projects for incineration plants using biomass was started in 2007 supported by the European regional development fund. The concrete building and restoration project for decreasing greenhouse gases found as its financiers Norway and the financing mechanisms of the European economic area. (The EU and of the EFTA countries Iceland, Liechtenstein and Norway form the European economic area.) Margus Källe states that there is no final financing decision from Norway but that it is very likely. The project is called "Reduction of greenhouse gas emissions by of adopting renewable bio fuels at the Lihula Soojus OÜ heating plant". In case there is a positive decision on the financing, the construction work starts already at the beginning of 2008. Lihula Municipality currently has ca 2900 inhabitants, and the town of Lihula 1600.

Two more furnaces will be built, one of 800kW (hay biomass; hay and reed bales) and the other 1MW (wood chips). The new furnaces will be in use continually from here on and will mainly produce heat (80–90 %). The third furnace, a coal slate oil furnace in use even now, would in the future be used only when it is very cold and while the other furnaces are being repaired. The biomass of the hay grasses is planned to be at the most 20 percent of the total energy production of the Lihula power plants. Also storage room will be built in conjunction with the incineration plant for drying the reed and hay bales. If the reed is gathered in late winter, there is no reason why it couldn't be burnt at once: the moisture percentage must be less than 20.

Lihula plans to invite tenders from hay biomass suppliers and draw up contracts for several years. The essential aspect is that in addition to the reed beds, also the hay of the great shore and flood fields of Matsalu can be used. Reed beds can, after all, be quite flattened out during some years. Also the surplus material from the Matsalu area gathering of reed for building material can be used for furnace energy. A local entrepreneur has also sold chopped reed on a small scale for cover material to gardens.

*Reed bed in summer. Photo: Eija Hagelberg.*

### 3.5 Biogas use

The fresh reed mass harvested in the summer can be used for production of biogas. One the one hand, the winter reed is too dry, and the reed does not contain enough of nutrients needed by the bacteria taking care of the methane digestion, either. Biogas is produced in digestion which is an anaerobic decomposition process generating methane and carbon dioxide. The excess sludge can be used as a fertilizer. Biogas can be utilised for both electricity and heat production.

There is not much experience of using the Common Reed for biogas generation. In the experiments carried out by the Technical University of Tallin, biogas has been produced from green reed mass (methane content 55–60 percent) with the ratio of 0.4–0.5 $m^3$/kg (Ülo Kask, email report on November 12th, 2007). The tests were small-scale and more research is needed.

There is more research information on the biogas use of the Reed Canary Grass, which is similar to the Common Reed as an energy plant (Lehtomäki, 2006). The study charted the biogas yield, the pre-processing and storage of different kinds of field biomass. In the biogas use of biomass, the material should preferably be chopped before use. This gives more reactive surface and it boosts the decomposition of difficult polymer compounds such as lignocellulose. Also the storage has an effect on the biogas production: the preservation of the Reed Canary Grass and other grass plants without any preservative chemicals lowers the yield of biogas. Of the researched energy plants (for instance Timothy-grass, Lupin, the stinging nettle) and crop waste (sugar beet leaves, straw) the Reed Canary Grass belonged to the group of plants with the highest biogas potential, varying on levels of 2 900–5 400 $m^3$ methane per hectare, the equivalent of 28–53 MWh/ha of energy. In all probability the biogas potential of the Common Reed is somewhere in that area, but this will require further testing.

In the above mentioned study, when Reed Canary Grass was mixed with manure, the biogas yield was significantly bigger than by using plain manure. At best, Turku University of Applied Sciences is doing a survey together with the Development Centre in Vakka-Suomi on the biogas production possibilities of the Common Reed mixed with manure sludge.

**Vakka-Suomi in the forefront of bioenergy development - next step utilisation of the Common Reed**

Vakka-Suomi has come a long way in developing bioenergy. One of the motors for the development work has since long been the Development Centre of Vakka-Suomi, with the help of which local entrepreneurs in 2003 established Biovakka Oy, which produces electricity to the national power network, and heat for the next door property, from the manure sludge of nearby pig farms by anaerobic digestion. Now all eyes in the development centre are on the province's uncultivated green masses and their use for bioenergy. A focal point of interest is the Common Reed. There are about 3000 hectares of reed in our region. That is far more than would be possible to separate for bioenergy plant cultivation from the arable area according to any plan, says **Markku Riihimäki** at the Development Centre of Vakka-Suomi.

A pilot project to create a basis for utilising reed beds was decided to be undertaken in the area of Vakka-Suomi in the beginning of 2007, financed by the Southwest Finland Environment Centre and the municipalities in the area and lead by Turku University of Applied Sciences.

During the project, an example model for the bioenergy use of the reed beds in the surroundings of Kolkanaukko is produced. According to Riihimäki, the project is already well under way: local landowners and future harvesting entrepreneurs have become interested in the venture and during the summer, the charting of the natural values of the reed bed area belonging to the Natura 2000 network has been completed during the summer. On the basis of the surveys completed it is already clear where the reed can and is permitted to be harvested. Also a site for utilising the reed is being developed close to the reed bed area, in the centre of Taivassalo. – One of the rapidly realizable ways of utilising the reed is to burn the winter harvested, dry reed mixed with wood chips in the regional heating plant planned in Taivassalo, states Riihimäki and continues: - Also smaller, farm-sized chip heat plants in the close environment can be considered for the burning of winter harvested reed.

Riihimäki thinks that generating biogas out of the reed biomass is an alternative more interesting than burning. – We can create biogas from using reed as a mixture material with manure sludge, for instance. In such a case, a biogas plant like Biovakka could be considered. Another alternative is a pure "green digestion plant", in which also other green biomass types could be used in addition to the Common Reed.

There are several green digestion plants around the world, says Riihimäki. Of the German, roughly 4000 working biogas plants already 80 percent are plants using green bio mass. The operational experiences have been encouraging, and the development centre has been working towards bringing home expertise from them for the use of the home province.

It can be estimated that the hectare yield of harvested Common Reed in its energy content equals to the annual electricity need of 1.5 -2 electrically heated small houses. Since there are more than 3800 hectares of reed all in all in the province, it would be enough to guarantee the electricity and heating of 5400 electrically heated small houses.

The production of biogas would bring even other positive effects besides the generation of energy to the area. As a local energy source it would be one of the factors impacting the growth of a new kind of energy entrepreneurship, and thus would have an effect on the local employment and activity. From the environmental point of view, the use of the Common Reed would decrease greenhouse gas emissions, improve the quality of water and create a possibility to retrieve the nutrients dissolved in the waters back on the fields. – In the cultivation experiments implemented together with MTT Agrifood Research Finland it has been observed that digested pig farm sludge is at least as effective as artificial fertilizers, and even better. Of the cultivated plant nutrients only magnesium is missing, says Riihimäki. Bringing the Common Reed into fertilizing would cover even that. – So, we must consider the utilisability of the Common Reed from several points of view. Harvesting is one; energy is another and the end product the third. Therefore the benefits of it should be calculated as a totality, not only by counting the price of energy, Riihimäki continues.

Calculating solely by the gross price of energy, the use of the Common Reed is not sensible. But the same is true of many other digested matters. According to Riihimäki, the digestion of the Common Reed needs an auxiliary pull from two directions. The first would be an energy subsidy for the Common Reed. The reed beds in energy use should be allocated the same energy plant subsidy as to the fields in energy cultivation use. This, according to Riihimäki, would suffice to cover the costs of harvesting and would make the utilisation of the reed bed into a realistic alternative. Another is a feed tariff for electricity produced by biogas, something the Ministry of Employment and the Economy is already working on. With it, biogas generated electricity could have a stable, guaranteed price which is higher than the gross price. How high the price would be is an open question. In Germany, it is about three times the gross price. – Something like that should be implemented in Finland if the large scale utilisation of green mass is really an objective.

# 4 THE ENVIRONMENTAL BALANCE IN REED ENERGY

The overall environmental balance in reed energy is based on the energy consumption and emissions of the various production phases and the indirect environmental effects of energy use.

The carbon dioxide released in the use of bioenergy sources binds with the new biomass. Retaining carbon dioxide balance presupposes that new biomass is formed equalling the amount of biomass reduced in energy use. The Common Reed used as an energy source, just as other bioenergy sources, also reduces the carbon dioxide emissions warming the climate if used to replace fossil fuels. If the yield of one hectare of reed beds replaces ca. 2000 litres of heating oil, it equals to ca. 6 tons reduction in carbon dioxide emission. Utilization of the entire reed bed resources of Southern Finland in energy production to replace fossil fuels would then equal to an emissions reduction of 180 000 tons of carbon dioxide. In addition, emissions connected to fuel transport must be considered: when favouring local bio fuels, the production and use of energy take place close to one another and long transports can be avoided. Calculating the greenhouse gas balance for biomass, counting in all greenhouse gases and the emissions of production (for instance, the manufacture and use of fertilizers) and transport is difficult (see Adler and others, 2007), and it has not been determined for the energy use of the Common Reed.

The environmental effects of the actual burning of the reed are not well known. Incomplete burning produces small particle emissions and emissions of incombustible gases. This may be a problem, especially in small-scale incineration.

In all the studied domestic bioenergy sources the energy balance is positive meaning that the production consumes less energy than is the energy content of the product itself. For the Reed Canary Grass, the production chain energy consumption is about 5.8 percent of the energy produced by the Reed Canary Grass (Wihersaari, 1996). The energy balance in the use of energy plants depends a lot on the fertilization. With the Reed Canary Grass, the production of fertilizers is the biggest energy consumption factor in the production chain (4.4 % of the energy produced by the Reed Canary Grass). In this respect the Common Reed is competitive since it doesn't require fertilization in its natural habitat. The energy balance of the energy use of the Common Reed has not been studied much. In Sweden a survey was done to study the prerequisites of using the Common Reed as a fertilizer in organic cultivation, and the energy balances of different alternatives were assessed in conjunction with it (Per-Anders Hansson, 2004). Of the studied alternatives (fresh Common Reed chopped and spread directly on the fields, composted Common Reed and the sludge which is a by-product of biogas production spread on the fields) the most economical by its energy balance turned out to be biogas production with energy balance of about + 4 MJ/kg.

Also other environmental gains should be calculated in the environmental balance of the energy use of the Common Reed. The net benefits for water quality discussed in chapter 1.3 can be tricky to determine. However, on the general level in can be said that the Common Reed binds nutrients to the bottom sediment and in its growth thus decreasing the load to water systems. The nutrient amount removed from the cycle by harvesting depends on the harvesting time: the summer green mass contains more nutrients. In summer harvest, it is possible to remove some 50 kg of nitrogen and 4.5 kg phosphor per hectare when the harvest yield is 5 tons of dry matter per hectare (see chapter 1.2). Agriculture produces a flow of nutrients to the Archipelago Sea on the scale of approximately 253 tons of phosphor and 3058 tons of nitrogen per year (the numbers do not include natural flow; source Southwest Finland's Environmental Centre). There are approximately 15 000 hectares of reed beds in Southwest Finland, and at least a half of this area, 6250 hectares, can be assessed as harvestable. Thus the annual summer harvest would remove 28 tons of phosphor, which is more than 10 percent of the annual load of phosphor to the Archipelago Sea from agriculture. In other words, the impact would be significant. The use of green reed mass in biogas production is thus connected with potentially significant gains for water protection.

In addition to the ecological viewpoints, the use of the Common Reed for bioenergy can also be observed from the point of view of social and ethical sustainability. At best, the entire reed energy production chain from harvesting to pre-processing to incineration and biogas use brings employment and added earning possibilities to the rural areas, and increases its livelihood. It can also be thought that it is ethically more just to produce fuel from plants growing spontaneously on the shores than to cultivate energy plants on fields that are suitable for food production.

*Photo: Sami Lyytinen.*

# 5 PRODUCTION COSTS AND ECONOMIC COST-EFFECTIVENESS OF REED ENERGY

The production costs for reed energy are based on the harvesting, storage, transport and incineration costs or the pre-processing costs for biogas use. In the Reed strategy project, a Bachelor's thesis was completed at Turku University of Applied Sciences in the degree programme in Sustainable Development (Simi, 2007) discussing the use of winter mowed Common Reed for bioenergy, its economic cost-effectiveness and its competitiveness in Finland compared with especially the similar Reed Canary Grass but also with other energy products. The study focused on the harvesting tests carried out in the project and the author had contact with the sub contractors and other agents who had conducted the tests. The objective was to gather information of the costs accrued by the harvesting.

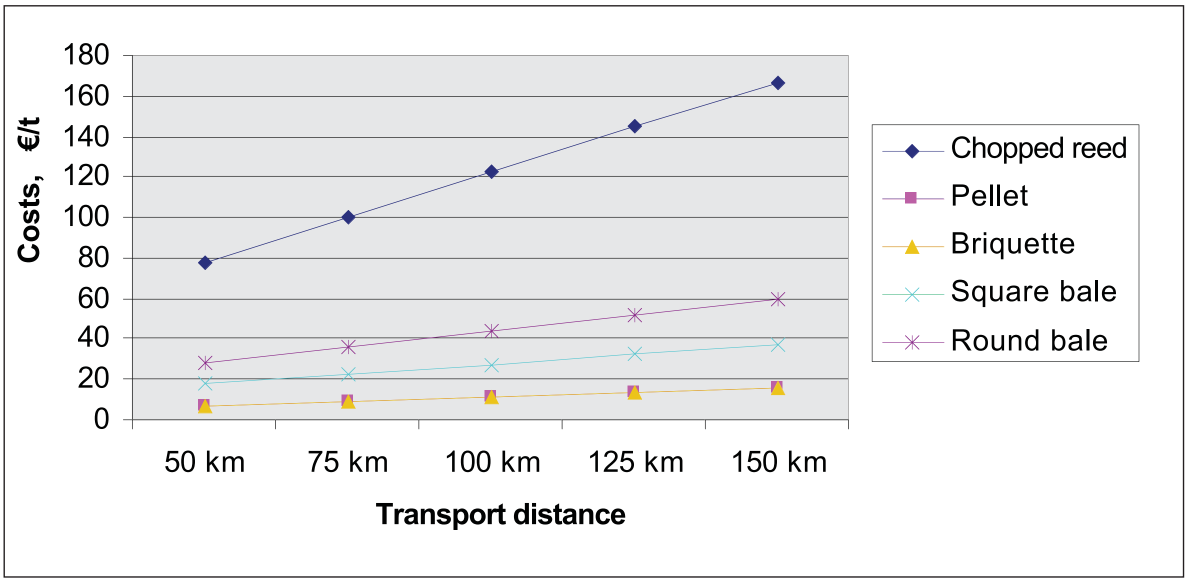
It is hard to assess the production costs in connection with the Common Reed concerning work accessibility, working hours and the costs due to these in the separate phases of the harvesting-production chain, since the harvesting at current still takes more or less trial and error. The reed beds differ, can be located in tough places, there can be rocks etc. in the midst of the growth. Also the bearing of the ice is always a risk factor to the entrepreneur. There are not many experiences in Finland of harvesting the common reef, and since the work outcome and costs of the experimental harvesting have not been evaluated in detail, the calculations were based on a TTS Work Efficiency Institute study on the costs of mechanical labour and statistical contracting prices on the production chains of hay and/or straw.

**The harvesting** costs of the Reed Canary Grass can give direction and comparative basis, even though the harvesting of the Common Reed sets extra requirements for the harvesting equipment, and challenges depending on the varying ice conditions. Table 4 shows the harvesting work costs for Reed Canary Grass on sub-contracting level machinery, when the mowing result is baled into round bales (Pahkala ja muut, 2005). Thus the sub-contractor harvesting costs are ca. 75 euros/ha. In comparison, the harvesting costs with farm-size machinery (mowing with a chopper – baling – transfer of bales into interim storage) when done as one's own work were assessed to be ca 110 euros/ha. In bulk harvesting the costs were assessed at 84–100/ha depending on the equipment used. The latest costs of machine work and statistical sub-contracting prices were published in July 2007. According to these the price level is now approximately 15 % higher than that reported in an earlier publication on the cultivation and production costs of the Reed Canary Grass (Pahkala and others, 2005). According to the updated information the harvesting costs of the Reed Canary Grass would thus be ca. 86 e/ha as a sub-contracting job. The costs of bulk harvesting are in the same class when the crushing of the bales is not counted in (Paappanen ja muut, 2006).

TABLE 4. *The machinery, the work they require and the pricing of the work done with them used in the production cost calculations for the Reed Canary Grass. (Pahkala ym. 2005, 29).*

| **Round baling. Harvesting with contractor scale machinery.** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Work phase | Work machine | Acquisition price VAT 0% | Use h/ year | Write-off period years | Machine labour h/ha | Human labour h/ha | Cost €/h | €/ha |
| Field chopping | Towable, 3,2m | 14700 | 140 | 6 | 0,43 | 0,64 | 39,5 | 25,1 |
| Baling | bale netting | 25400 | 215 | 6 | 0, 64 | 0,98 | 42,65 | 41,59 |
| Transfer of bales into interim storage | Front loader, bale clamp | 1500 | 85 | 8 | 0,36 | 0,50 | 17,63 | 8,82 |
| Sum total | | | | | 1,43 | 2,11 | 99,75 | 75,47 |

The producer price for Reed Canary Grass depends on the transport distance to the end use destination. This is naturally the case also for the Common Reed. The increase in **transport costs** according to transport distance for bioenergy products of different densities is shown in figure below (Puolakanaho, 2007). Bulk material (chips/chaff) cost increase, related to the distance, is much steeper than that of dense material (for instance, pellets). On short distances, bulk transport of chopped material is also possible, and comparing with the cost of crushing bales it is also economical, but when the distance grows it is important to increase the energy density. If the vehicle is fitted with a load pressing device, the bulk transport of the chopped reed becomes significantly more economical.




*Transport costs (euros/h) by truck according to the transport distance for bioenergy products differing in density*

The **producer price** for the Reed Canary Grass (power plant price) is in the same class with the price paid for other bioenergy products as well, ca. 12–20 e/MWh. The producer price formation for the Reed Canary Grass is influenced by quality (e.g. moisture, you get the best price if the moisture is under 20 percent), by the grade of processing / form of delivery (chopped/ baled/pelletized) and the readiness of the power plant to handle and crush the bales. In some cases, chopped straw should be mixed with peat before delivery to the incineration plant. The incineration length (ca. 4 cm) chopped material can readily be mixed with peat or chips, and the price paid is thus higher, but also the transportation costs are higher. There is no one answer to the question of which is more economical, bulk harvesting or baling, since the utilisation of the Reed Canary Grass in incineration plants is only starting (Pahkala, 2005).

On the current price level, the energy cultivation of the Reed Canary Grass is not viable without subsidies. According to Pahkala and others (2005) the production costs for the Reed Canary Grass are about 560 e/ha. When the price for the bales at the edge of the field is 144 e/ha, we can conclude that the cultivation is strongly cost-negative without subsidies. It has been estimated that the cultivation is not cost-effective even when environmental benefits are included in the cost-result calculation. If one includes the subsidies (cultivation aid, environmental and energy plant subsidies) the cultivation is cost-effective, even more so than the cultivation of barley for fodder (Pahkala, 2005).

If the same price was paid for the Common Reed as for other bioenergy products, the producer price for one hectare of reed beds would be ca. 190 euros (9–10 e/MWh, yield 5 t/ha, Common Reed energy content 4,2 MWh/ ton). If the harvesting costs are in the class for the Reed Canary Grass, i.e. contractor baled ca. 86 e/ha, or harvested with farm-size machinery ca 110-120 e/ha, or the same size class as bulk harvest, the energy use of the reed could be just about cost-effective on short transport distances. So far, there are too many unknown or insufficiently known factors in the cost-effectiveness equation for a more precise assessment of the cost-effectiveness. In the production costs of the Reed Canary Grass, a significant part is made up by the starting and maintenance costs. In this respect, the Common Reed is cost-effective, since growing in its natural habitat the Common Reed does not require fertilizing or any other tending. Cost-effectiveness without investment subsidies also presupposes that the current farming equipment can be used.

The interest towards the Common Reed by the bigger incineration plants is also due to the **emissions trade aspect**. The Common Reed, like wood and the Reed Canary Grass, is a so called carbon dioxide neutral fuel which for power plants impacted by the emissions trade (plants with nominal output over 20 MW) means clear savings. In 2008 the price of the emissions right will be ca 20–22 e / ton of carbon dioxide. One reed bed hectare equals ca 2000 litres of light fuel oil, the carbon dioxide emissions of which are ca. 6 tons, which in emissions rights equals to approximately 120 euros.

In addition to private economic cost-effectiveness bioenergy can also be viewed from the point of view of **social cost-effectiveness,** in which also other social yields and indirect benefits like environmental effects will be considered. (For Reed Canary Grass, see Suomalainen, 2006). For the Common Reed, the yield calculation should also cover for instance climate benefits, water protection benefits and its impact on employment in the rural areas.

# 6 UTILISATION MODELS

The combination of the harvesting and production alternatives and the form of the energy use are dependent on the actual intention: is it to remove reeds from the shore, with energy use just contingent to this, or is the actual goal to produce energy? Also the accessible equipment, the time of harvesting and form of use (chaff/bale/pellet) determine the utilisation model.

In the following some questions with alternative answers are introduced for defining the harvesting – production chain.

1. Who is planning the energy use of the reed?
   1) An agricultural entrepreneur or a machine contractor living near the reed bed area
   2) A business specialised in mowing water plants, in dredging, in gathering wood chips or other materials
   3) The municipality or the state
   4) A private citizen living on the shore or a summer house owner
   5) An entrepreneur specialised or specialising in harvesting the Common Reed
   6) Some other party, what?

2. In what kinds of places is the reed going to be gathered?
   1) On one's own shore
   2) On the neighbours' shores
   3) On municipal land
   4) On state land
   5) On jointly ownded land
   6) As a commissioned service in a place the customer has pointed out
   7) close to a suitable heat plant

3. What is the purpose of the harvest?
   1) Generation of energy
   2) Improving the reed bed quality (for instance for gathering roofing material during the coming few years)
   3) Clearing the shore, opening up a landscape
   4) Water protection (removing nutrients and digesting plant mass)
   5) Promotion of biodiversity
   6) Something else, what?

4. What kind of equipment is used for the harvesting?
   1) Farming machinery (especially equipment used for hay harvesting and applications to it)
   2) Reed harvesting machinery
   3) Hand tools (scythe, sickle, and snow plow)
   4) By boat with a mowing blade attached
   5) Something else, what?

5. When is the gathering done?
   1) Early summer
   2) Late summer
   3) Autumn
   4) Winter

6. From what kind of a surface?
    1) From the water
    2) Dry and hard land
    3) Between the two previous one, a soft uncertain bottom, a little water
    4) From the ice

7. How is the reed transported from the shore?
    1) On a trailer attached to one's own car
    2) On a tractor trailer
    3) With harvesting equipment
    4) By one's own truck
    5) By someone else's truck
    6) By boat
    7) By something else, what?

8. How is the reed processed?
    1) Chopping
    2) Baling
    3) Whole, no processing
    4) Crushing
    5) Other, what?

9. The end product?
    1) Bale
    2) Chips or chaff (a mixed fuel with chips, waste wood, grain dust, peat or coal)
    3) Pellet
    4) Briquette
    5) Whole
    6) Other, which?

10. Use?
    1) Bale furnace
    2) Chip furnace
    3) Power plant
    4) Pellet furnace
    5) Pellet open fireplace
    6) Sauna oven
    7) A carburator furnace
    8) Biogas plant
    9) Other, which?

11. Is it possible to generate sales income?
    1) Yes
    2) No
    3) Maybe
    4) Unknown

12. Owner of the furnace?
    1) One self
    2) A neighbour
    3) A farming entrepreneur in the nearby area
    4) A summer house owner in the nearby area
    5) A village heat plant or one nearby
    6) Municipal or an external entrepreneur's heat plant
    7) Other, which?

After answering the above 12 questions from their own point of view, the party interested in the harvesting can trace out the entire needed chain. With certain alternatives, a part of the follow-up questions are screened out. For instance, reed gathered in the winter is not suitable for biogas use. If energy use is planned, the requirements set for the different options should be clarified.

In the following, there are some examples of different harvesting – production chains and utilisation models for reed energy that even with the current technology could be feasible. In this context, the cost-efficiency or viability have not been considered, since that requires further investigation.

*Photo: Eija Hagelberg.*

*Photo: Sami Lyytinen.*

## MODEL EXAMPLE 1: REED FOR THE PELLET FURNACES OF SMALL HOUSES AND THE PELLET OPEN FIRES OF SUMMER HOUSES

**Chain: mowing in winter – chopping – pelletizing – storage – delivery to pellet furnaces and pellet open fireplaces**

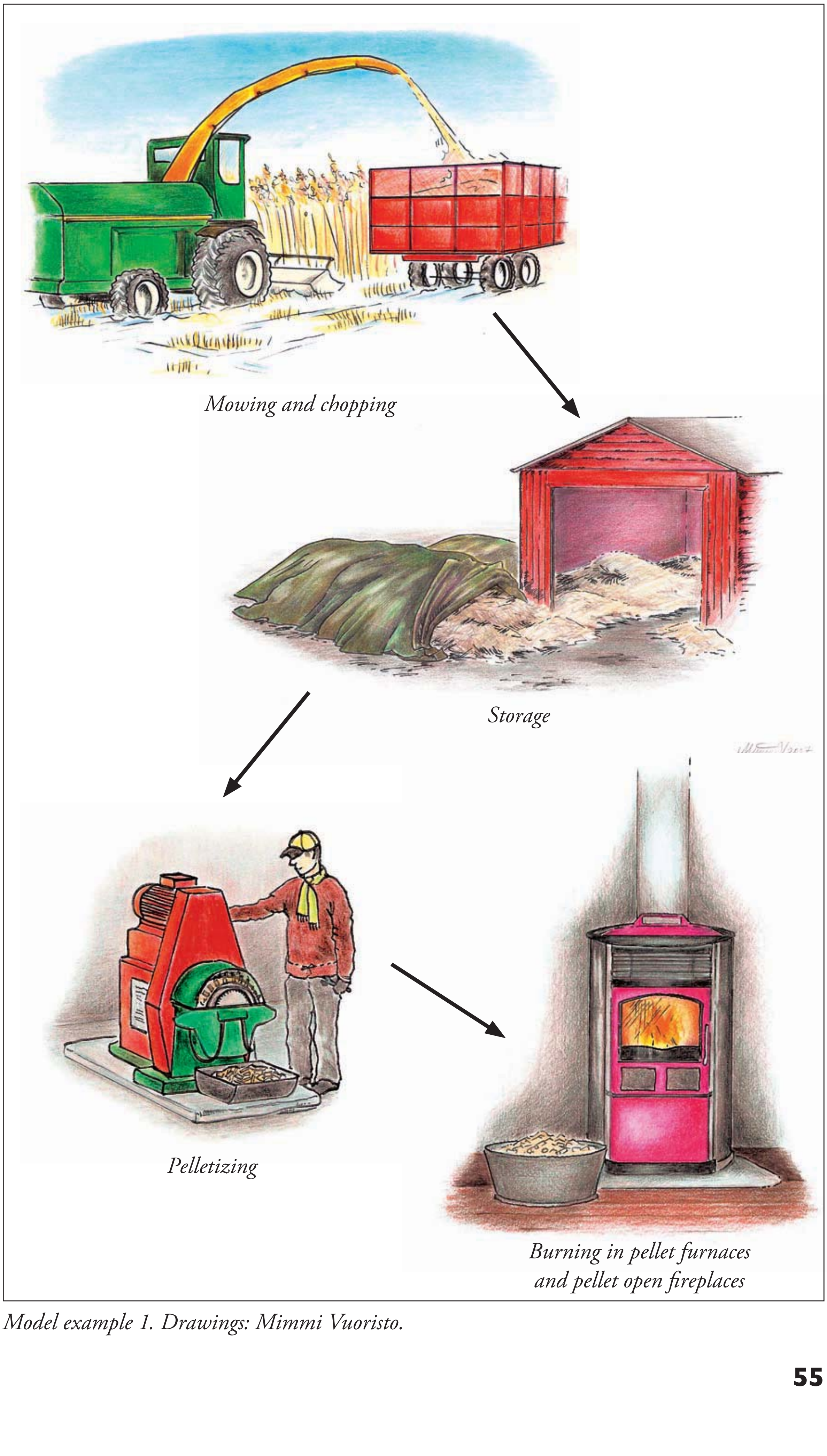
A farmer, who in the winter mainly focuses on maintenance of equipment and forest work, could utilise their existing diverse farming equipment also during the winter. Possible they need to acquire some additional gear to implement the entire chain. A farming entrepreneur living close to wide reed bed areas sets out, when the ice is thick enough, to the nearby reed beds to mow them with for instance a tractor equipped with cutting blades, and to gather the material. They have in advance agreed in writing with the owners of the water and land areas about the harvest. The lion part of the landowners is the private summer house owners, but the area is also connected to a large, undivided common area, the shareholders of which by joint decision have given permission for the harvest. The inhabitants and the summer cottage owners are just pleased when the foul-smelling rotting plant mass is collected from the shores. The summer dwellers hope that they no longer have to set out in the spring and clear the shores from the old reed floating in the shore water. A precise map has been drawn on the harvesting areas in which the permitted harvesting places, rocks and dangerous places are clearly marked. In the best case the data has also been fed into the contractor's GPS, so they have no trouble staying in the right areas following it while doing the harvesting.

The farmer collects the reed in such a way that he or she chops it either in the gathering phase or on the shore. They transport it with their own haulage equipment (a truck or a tractor with trailer) into an old barn they have standing empty. The chopped reed is stored in a dry and well ventilated place until the pelletizing entrepreneur arrives to the farm with their mobile pelletizing machine. The reeds are crushed into small crumbs and pelletized. The pellets are then sacked and still stored in the barn.

The farm entrepreneur sells the pellets to the small houses in the area with pellet heating. In the spring, the summer cottage dwellers also come to buy reed pellets for their summer house pellet-burning open fireplaces. The pellets are used both for heating the cottage and the water.

This model also includes visions of the future which may well come true when there are more of functioning pellet-burning open fireplaces on the market. Pellet heating of small houses is becoming more and more common, and that could well be where the reed pellet finds its niche. Some entrepreneurs have already shown interest in acquiring mobile pelletizing machines. The existence of one would make it possible to implement the pelletizing near the shore.

Without surveys it is hard to assess whether summer cottage owners would be ready to pay the slightly higher price for reed pellets (instead of firewood) if they knew the reed was gathered from their own shores. It is surely not an impossible thought. Even though wood chopping for many summer cottage dwellers is an important vacation therapy, people still want more comfort in their summer cottages. The easy and clean pellet heating could well be suitable for many summer cottages.




*Model example 1. Drawings: Mimmi Vuoristo.*

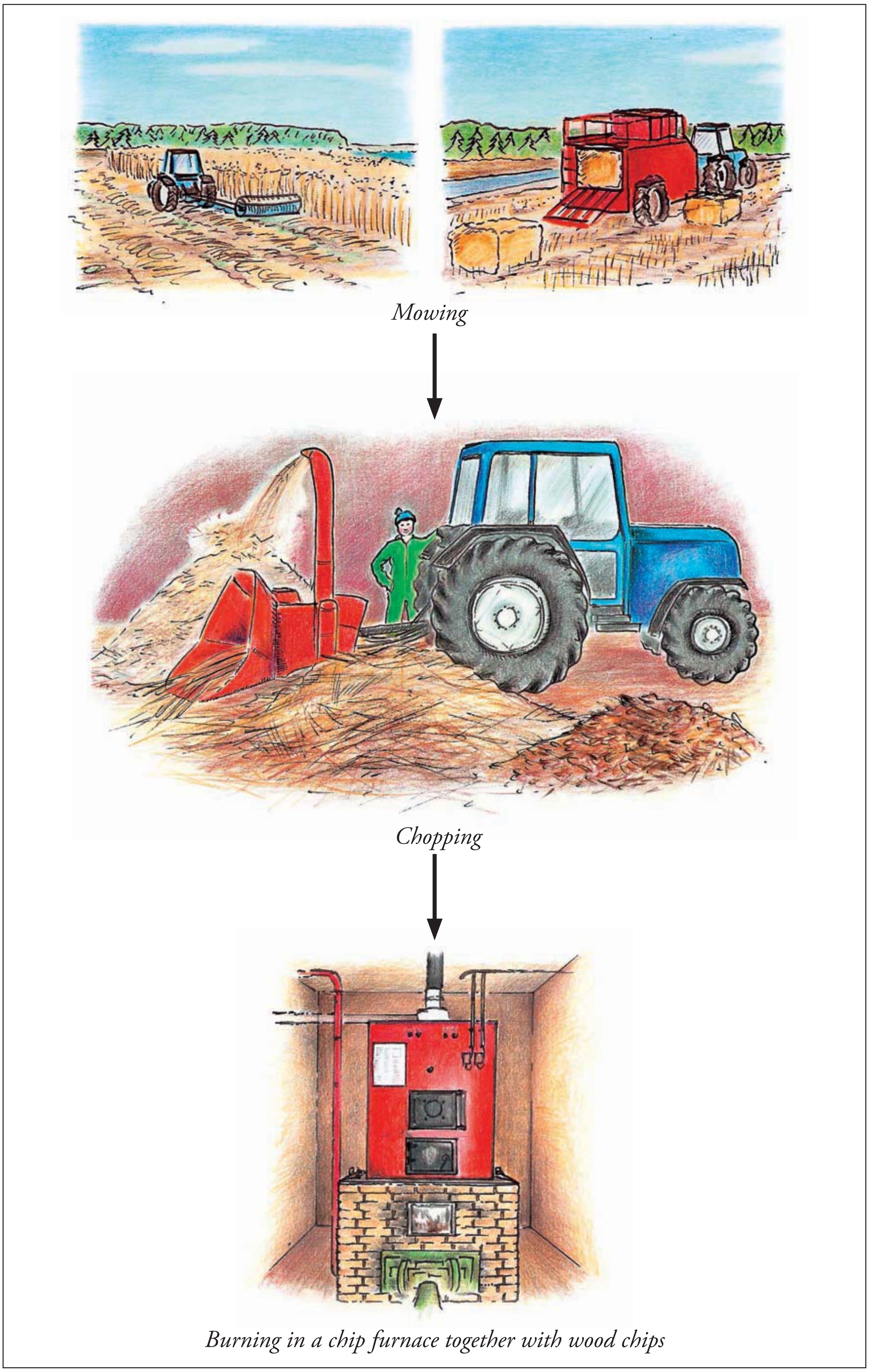
## MODEL EXAMPLE 2: USE OF CHOPPED REED MIXED WITH WOOD CHIPS

**Chain: mowing in winter – chopping – storage – use in a chip furnace together with wood chips**

A farm entrepreneur collects reed from the shores with their own equipment, as in the earlier model. They chop the reed either in the gathering phase or on the shore to ca. 5 cm in length. They use the reed in their own chip furnace for additional heat (mixed with wood chips, 10 percent reed, 90 percent wood chips).

If the harvesting area is big and the ice is strong enough, the agricultural entrepreneur can gather reed also from a larger area, chop it and sell it to the neighbouring farm as fuel for their chip furnace. If the amount is even bigger, the chopped reed can be sold to heat plants in the close area with a method comparable to treating the Reed Canary Grass.

Alternatively, and especially if the distance to the heating plant is longer, the cut reed can be baled and then crushed at the heating plant to suit the incineration.




*Model example 2. Drawings: Mimmi Vuoristo.*

## MODEL EXAMPLE 3: WHOLE BALES

**Chain: mowing in winter – baling – storage – incineration in a bale furnace**

An agricultural entrepreneur, who has the equipment for making round bales, big square bales or smaller square bales, acquires or builds himself a machine suited to reed harvesting, for instance a track chain machine or a flywheel machine.

A modern straw furnace taking care of the heating of most of the village houses has just been built in the neighbouring village.

The agricultural entrepreneur starts to gather reed on the shore from reed shores close to the heating plant. He transports the reed he has gathered to the shore where he makes the bales. From here, he transports the reeds with his own truck or tractor to the storage of the heating plant. The entrepreneur makes sales income from the reed bales. Part of the reed bales he sells to a nearby livestock farm to be used as straw for the animals. A local gardening entrepreneur again comes to collect some of the bulk reed from the shore and pays the farmer for it. The gardening entrepreneur uses the reed as cover material and makes protective mats out of it, selling them in the shop of his own nursery.

In the above described model, the basis is local networking which means that the agents in the area work in close collaboration. Because the Common Reed is light material and the transport costs thus can easily become too high, it is necessary to use the material close to the harvesting area. This is also necessary in all the other models.

*Mowing and baling*

*Incineration in a bale furnace*

*Model example 3. Drawings: Mimmi Vuoristo.*

## MODEL EXAMPLE 4: LARGE SCALE REED BED REMOVAL IN LEISURE AREAS OR FOR LANDSCAPING REASONS – INCINERATION IN A POWER PLANT TOGETHER WITH OTHER BIOMASS

**Chain: mowing in winter – baled or chopped to the municipal heating plant – storage – use with wood chips and peat**

A municipality has realised that the use of the most important leisure time area in the municipality has decreased in the last years since the area is surrounded by a thick reed bed. The view out to open water has narrowed down year by year. In addition, in summer there is an unpleasant odour on the beach coming from the rotting reed beds.

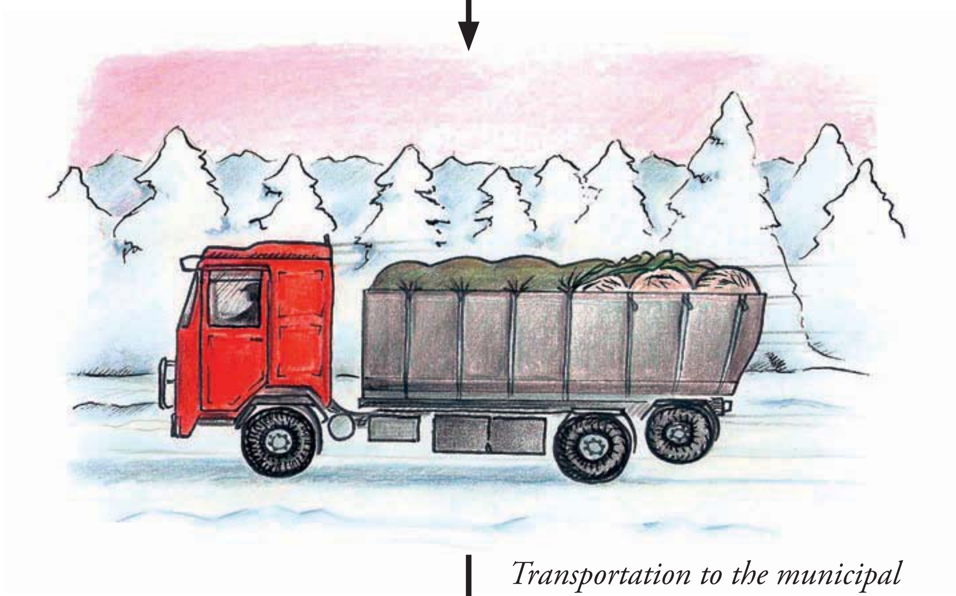
The municipal board has decided that the leisure time area is to be conserved with small costs. There is no willingness nor are there economic resources for a large scale dredging to remove the thick rootstock of the Common Reed, and the rotting reed peat, to reopen the closed up shore. The municipality is aware of the fact that dredging also disturbs the shallow water, and some unwanted nutrients can also be released into the water from the bottom sediment.

There is also a regional heating plant in the municipality, which mainly burns wood chips and peat, and some Reed Canary Grass and other materials. The municipality send outs invitations to tender with the purpose of finding a constructor for the winter harvesting of the Common Reed. The contractor is found and an agreement is entered into on the annual removal of the reed (with the additional condition that the reed is standing up in the late winter; if autumn or winter storms have flattened the crops, the contractor will not be refunded for the harvest). The municipality draws up a clear contract with the entrepreneur on the harvesting area in such a way that it is acceptable to both parties. The contractor should carefully consider what kind of an agreement to sign so they won't have to perform the work risking their expensive harvesting machinery and their own health by having to do the harvesting for instance on thin ice. Also the quality of the reed gathered should be agreed on: wet reed collected in sleet weather is not necessarily suitable to all furnaces, so the commissioner of the work should be precise on this point.

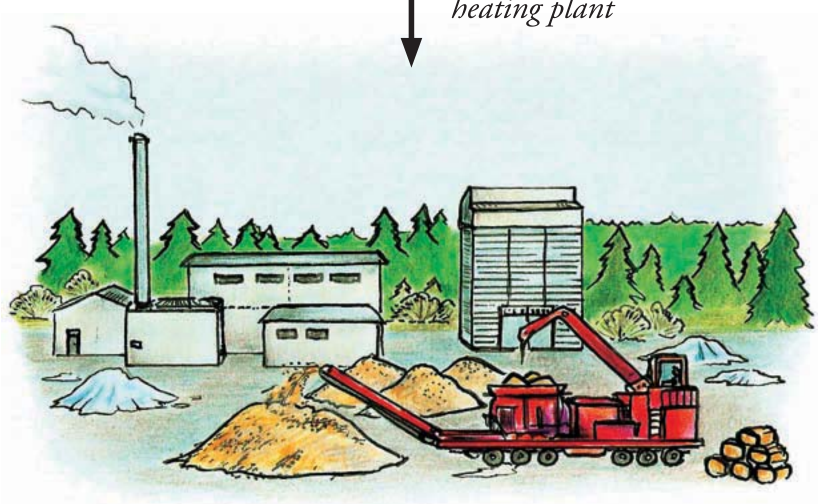
The harvesting of the reed is begun in mid-winter as soon as the surface is suitable for the harvesting equipment. The contractor bales the reed into round bales or gathers it as bulk material and transports it to the regional heating plant also making an income on it. In the regional heating plant the bales are crushed and the chaff is mixed with for instance wood chips and burned. The municipality can offer the contractor help for the harvesting and the baling in the form of persons employed with the help of wages subsidy, in which case the price of the harvesting can be decreased a little.

The regional heating plants operated by heating entrepreneurs and other places are potential users for the Common Reed as a mixed fuel together with chips or peat. A good example of heating business in Southern Finland is Perniön Hakelämpö Oy that produces heat for a small rural area of 40 households. The plant has a 3 MW bio furnace and two 2 MW oil furnaces. Some 800 $m^3$ of light fuel oil per annum has been replaced by chips equalling to a 2000 tons per year reduction in carbon dioxide emissions. In the fall the bio furnace is used on a capacity of

*Mowing and baling*



*Transportation to the municipal heating plant*



*Incineration in a power plant together with other biomas*

*Model example 4. Drawings: Mimmi Vuoristo.*

1.5 MW using 50 cubic metres of chips per day. The plant has also experimented with burning sod peat and sawdust. The heating plant has also made a commitment to buy the Reed Canary Grass harvest of some 30 hectares in the area. The plant is a municipal investment, and the heating contractor takes care of acquiring the fuel and producing heat for the district heating system. The compensation is paid according to the produced MWh. Approximately 12 000 MWh/year of energy is produced for the district heating network, of which 95 percent is by wood that is mainly forestry waste, birch fiber and dry rotted wood. The plant employs 3–6 people annually in the local economy and the same number elsewhere in Finland (Somerpalo, 2006).

## MODEL EXAMPLE 5: BIOGAS

### Chain: mowing in summer – use for biogas production mixed with the manure produced by livestock farms

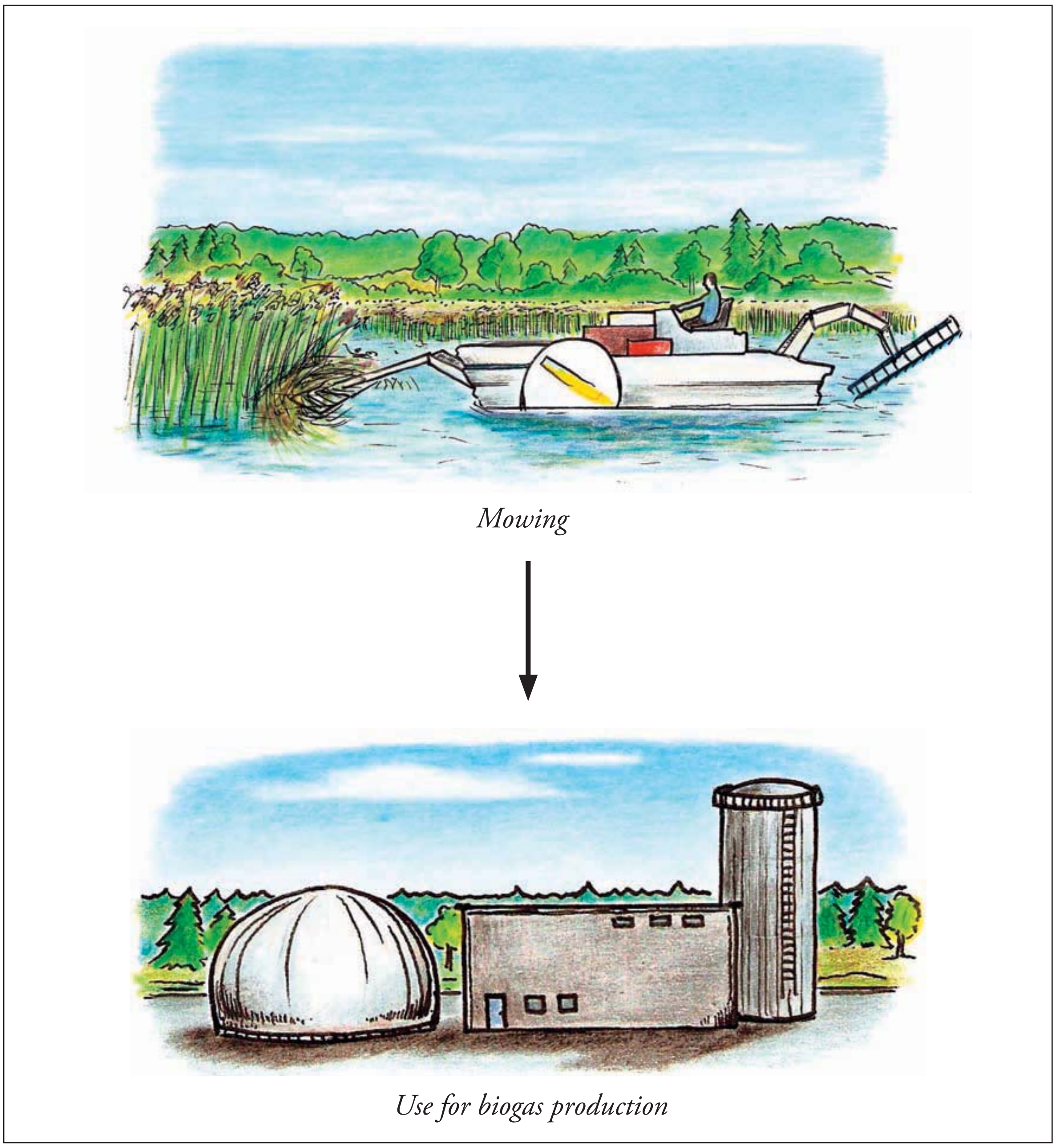
This model works in its initial phases as the model above, but instead of a chip furnace in the nearby area there is a biogas plant generating biogas from the manure produced by the livestock farms in the area. The municipality together with the biogas plant has researched the possibility of the plant being able, with small alterations, to also receive Common Reed which harvested in the summer is a very suitable material for gasification.

The municipality invites tenders on the summer harvest which should be undertaken in July – August. In June harvesting is avoided because of the birds' nesting season. By postponing the harvest from early summer to July a high nutrient spike of a few days can be avoided in the bay. This could result from cutting the reed under the water in early summer, when the underwater stem left standing would still be pumping nutrients from the bottom sediment to the water for a few days. Mowing done in the middle or at the end of the summer is the most efficient way of removing nutrients from the sediments since at that time, the stem and the leaves of the plant are full of nutrients. Towards autumn, the plant transfers its nutrients back to the rootstock again.

A contractor with the suitable equipment for mowing will mow and gather the reed in big stacks on the shore. A municipal truck driver will transport the reed from the shore to the biogas plant. The municipality and the biogas plant agree on the price of the material. The municipality pays the mowing contractor the agreed price on the completed work.

This will be repeated also the next summer, when the amount of reed will be much less than the first summer. The third summer the municipality will assess whether harvesting is needed. Sometimes the reed beds vanish quickly already after two years' harvesting, but the bottom and the amount of nutrients in the sediment have an effect on how quickly the summer harvesting will reduce the reed beds.

During the couple of next summers the harvesting can be skipped at this location and then repeated again according to need during the coming years. If the municipality reserves resources in its budget for annual harvesting, which would be wise, the reed could be mowed in some other location during the years that the primary site does not need to be mowed. This would also secure regular material for the biogas plant.




*Model example 5. Drawings: Mimmi Vuoristo.*

The constructor who arrives to do the harvesting work commissioned by the municipality would probably also do the mowing of reed beds for other owners in the area. If the municipality is active and publishes information on the matter, both private owners and others could benefit from the presence of the mower in their vicinity. This way the transportation costs of the machine could be shared.

Harvesting taking place in late summer is an efficient means of removing nutrients from the cycle and thus the production of biogas energy also brings water protection benefits. Also in this model the harvesting phase is critical: in order to reach water protection gains it must be made sure that the bottom is not disturbed.

**Energy use possibilities of the Common Reed in Estonia**

(The views of Ülo Kask, a researcher at the Thermal Engineering Department at the Tallinn University of Technology)

**What kinds of fuels produced from the Common Reed would be best for use in the modern energy equipment?**

As with all grasses, it is possible to manufacture solid, liquid and gaseous bio fuels out of the Common Reed. In the manufacture of solid fuels it is best and most cost-effective to us reed harvested in the winter and early spring, and the waste from building materials made out of reed. Liquid and gaseous bio fuels are best manufactured from the green reed harvested in the summer and early autumn.

The choice of fuel is decided whether it is used in small furnaces (maximum power 300 kW) or bigger ones with capacity over 300 kW. In small furnaces solid fuel pressed to great density should be used, meaning reed pellets or briquettes – in the bigger furnaces also pure dry chopped reed can be used, preferably with wood fuels. In district heating plants also reed bales can be used (round bales max 250 kg and big square bales max 450 kg), which are normally crushed before placing in the furnace. Some furnace types can also burn whole reed bales.

In furnaces, which simultaneously produce both heat and electricity, it would be most effective to burn biogas (preserved fodder is manufactured of the reed, it is wrapped in anaerobic conditions and with the generated methane based gas (60 percent) a combustion engine is started to produce heat and electricity in the same plant). Liquid bio fuels (bio ethanol, bio diesel) are best to use as engine fuel in transport vehicles.

**Why is reed still not used as fuel in Estonia? Why is the Common Reed more popular in building use?**

In Estonia, building material waste is used as fuel in the heating plant of Orissaari in the province of Saare county. 5–10 cm long straw is added to wood waste or sod peat and they are burned as a mix. The straws add volume to the burning mass, the air has better access to the burning particles and the burning process is more efficient. A more common use for the reed as a fuel has not yet been found, since technically and economically motivated harvesting technology nor equipment applicable to it have not yet been developed. In the heating plant using green biomass which will be completed in 2009 in Lihula, there are plans to start using reed bales as one of the fuel types.

The raw material price of the Common Reed as a building material is higher than what heat producers could pay for it. Heat producers (district heating plants) would be able to pay a maximum of 10–12 €/MWh for the reed as a fuel.

**How much of harvesting subsidies would be needed to make the use of reed as a fuel viable?**

Calculations have not been made as yet, but on an estimate the harvesting subsidy should be at least 2 000 kr/ha (130 e). If the harvest per one hectare in the winter is an average of 6.5 tons, the subsidy should be ca. 300 kr/ton (20 e) and 75 kr/MWh (~5 €/MWh).

**Have there been any experiments in Estonia to use the Common Reed for biogas generation?**

Anaerobic decomposition tests on the green reed have been implemented in Estonia at the Chemistry Institute of the Tallinn University of Technology (*TTÜ Keemia instituut*). An average of 0.5 $m^3$/kg dry matter was generated. The biogas experiments will continue.

*Photo: Sami Lyytinen.*

# 7 SWOT ANALYSIS

The SWOT analysis (strengths – weaknesses – opportunities – threats) of the Common Reed, as an energy source in general and when processed for fuel, was discussed at the international final seminar of the reed bed project, in a workshop on bioenergy, in Matsalu in 2007. There were participants from Finland, Estonia, Sweden and Holland who all have slightly different interests concerning their reed beds. The SWOT table introduced here shows observations of the Common Reed's energy source properties from the point of view of Finland.

Conclusions can be drawn on the basis of the analysis on how the strengths should be benefited from, how the weaknesses can be turned into strengths, how the future opportunities can be used and how the threats can be avoided.

**Strengths**

The Common Reed is a renewable, domestic, versatile energy source, the material production costs of which are next to nothing. Several environmental benefits are connected to the burning of the reed, such as water protection. The energy use of the reed is carbon dioxide neutral (the carbon dioxide released in the burning is bound up by new growth), so it doesn't promote climate warming.

Reed energy has the image of ”green energy” and it can safely be assumed that it will be received positively. This makes the marketing of it easier. Additionally there are great expectations of bioenergy in general, which can facilitate the obtaining various sorts of development funding for the reed energy production chain.

The Common Reed compares in many respects to the popular field energy plant Reed Canary Grass, which helps in the process of making use of the Common Reed. There is research material on the Reed Canary Grass on more than 10 years now. Even though the Common Reed sets different requirements to the harvesting, the experiences of pre-processing and burning the Reed Canary Grass are largely applicable to the Common Reed also.

**Weaknesses**

The many diverse interests connected with the reed beds – landscape preservation, environmental protection, leisure time use, utilisation for practical uses – makes the planning and implementation of also the reed energy utilisation chains challenging. What is needed is holistic strategic planning to make sure the different viewpoints will be considered.

There are still many aspects to be studied further in the harvesting – production chain. The most problematic one of these is the harvesting phase. Reed energy still demands more research and development. Obtaining energy plant subsidy and other subsidies for the reed bed areas would be an incentive for the use of the reed beds, and treating the Common Reed as an equal energy plant with the Reed Canary Grass would encourage the ”cultivation” of shores.

**Opportunities**

Reed energy offers great opportunities as a local and socially and ecologically sustainable energy solution. The utilisation degree of farming equipment and machinery can be increased when it is used for reed harvesting outside of the cultivation season. At its best reed energy is the new ”ground winner” in the rural areas creating new boost and employment in the countryside, together with the utilisation of other bioenergy sources.

There have not been many studies in Finland about how the reed areas could be used in the reduction of nutrient loads to the water system. Small scale rootstock cleaning plants have been implemented, but their water cleaning effect is not known. In Holland, interesting views are opened by extensive plans of using man-made reed beds – wetlands to treat waste waters and also connecting energy use with them. Similar experiments could also be implemented in Finland, where the main problem in water systems is the nutrient load from agriculture and other sources.

**Threats**

Threats are fought off by adding the consciousness of the general public and by alerting the decision-makers, and this way adding financing for product development and for decisive action.

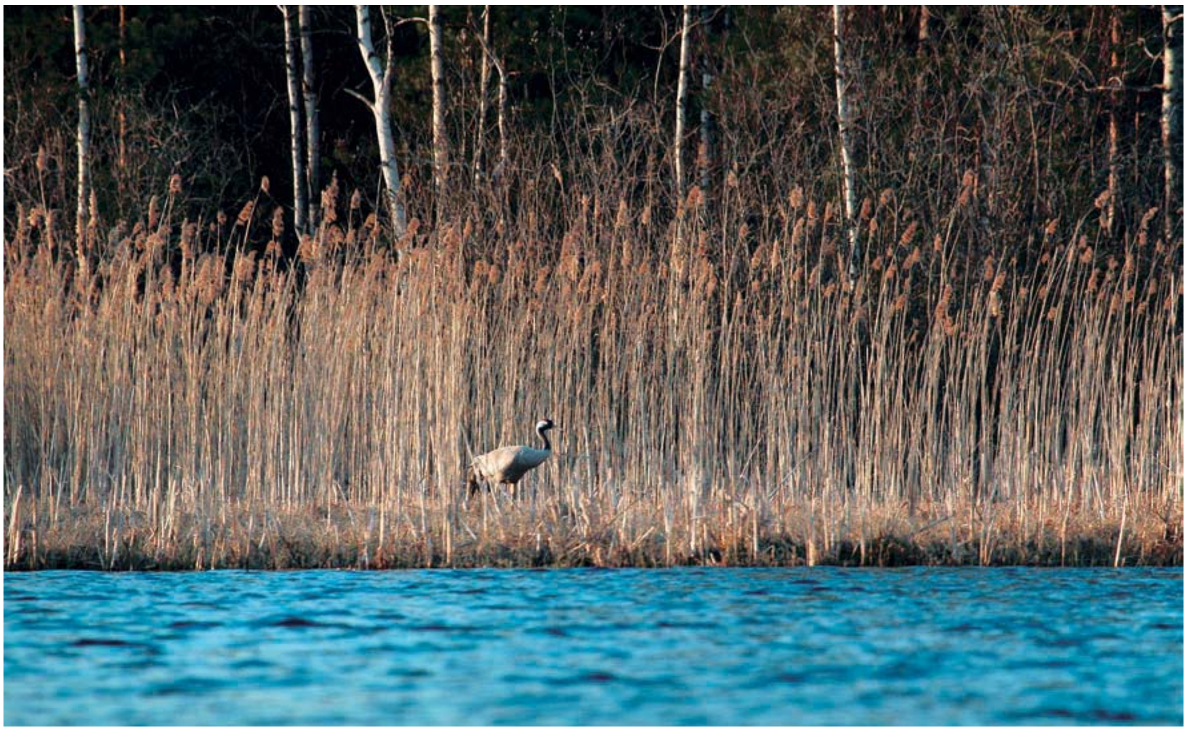


*Photo: Sami Lyytinen.*

## SWOT - The Common Reed as an energy source

| STRENGTHS | WEAKNESSES |
|---|---|
| • renewability, quick growth, good yield<br>• potentially great areas of utilisation<br>• no fertilizers or pesticides needed<br>• offers employment<br>• several utilisation possibilities, e.g. use in water protection and building<br>• a non-food crop<br>• climate neutral, denitrification<br>• positive expectation and image - ”green energy”<br>• a versatile energy source (solid, liquid or gas)<br>• there is available technology<br>• many potential producers<br>• many potential users<br>• a good mixed fuel<br>• in many respects comparable with the Reed Canary Grass which has been studied a great deal | • many different uses – compromise between different interests and administration of the reed resources can be challenging<br>• getting harvesting permits can be difficult<br>• the yearly crops are dependent on the climate and ice conditions<br>• economically hard to predict<br>• no ready market<br>• no suitable harvesting gear<br>• harvesting and transport expensive<br>• incineration produces great amounts of ash<br>• emissions from incineration have not been studied |
| OPPORTUNITIES | THREATS |
| • treatment of waste water<br>• creates jobs<br>• regional impact<br>• more efficient use of farming equipment<br>• national and international co-operation<br>• green energy certificates<br>• a new ground winner for farmers<br>• does not threaten food production<br>• technological development<br>• the image of ”green energy”<br>• the ash waste can be used as fertilizer<br>• opportunities in export | • entrepreneur opinion<br>• decision-maker opinion<br>• climate effect on the crops – climate warming makes harvesting more difficult<br>• emissions from small-scale incineration<br>• changes in legislation<br>• legislation too slow<br>• lack of funds for product development |

# 8 CONCLUSION AND SUGGESTIONS FOR MEASURES

**Vision**

The Common Reed is used as a source of additional energy in areas where there are large reed beds and which are located at an economical transport distance from regional heating plants and the heating centres of farms. The utilisation of the reed beds takes place according to a well-planned management strategy. The strategy takes into account natural preservation aspects, landscape maintenance, leisure use, water protection and other needs for use, such as collection of building material.

The harvesting of the reed is implemented by harvesting chains formed by local entrepreneurs, who outside the cultivation and hay harvesting seasons utilise the farm equipment in the harvesting of the Common Reed. With the help of investment and development subsidies specifically targeted to promotion of bioenergy, harvesting chains and methods have been developed, and a special reed harvester, which on one run both harvests and transports the reed bales it produces to interim storage, has been taken into use.

Reed energy is made use of locally, in versatile forms and cost-effectively: the use of the reed as an energy plant is energy plant subsidised. Regional heating plants use reed as a mixed fuel together with wood chips. The material to the plants is delivered as bales which are crushed at the plant and mixed with the main fuel. There are also plants that can burn bales as whole. Local farms and greenhouses also use the reed as a mixed fuel in chip furnaces. To these furnaces the reed fuel is delivered from nearby seaside also as chopped directly down to the size they can use. Some farms that comprise forests and water areas are energy self-sufficient by using the energy generated from winter reed and logging residue.

Part of the annually harvested reed is processed into pellets which are sold to small houses. Natural and man-made reed bed areas are used for treatment of the drainage water and cleansed waste waters from housing areas and rivers that bring nutrient loads to the water systems. From these reed beds, regularly alternating the harvesting areas, green reed mass is gathered by summer harvest into a joint biogas plant of livestock farms where the reed mass is mixed with manure.

The Common Reed, as a result of different experimental and development projects and demonstration sites for the energy use of the reed, has gained a credible position as a local ”green”, carbon dioxide neutral source of additional energy, where the energy use is combined with other benefits such as the improvement of water quality, landscape maintenance and employment.

There are great expectations of bioenergy. In addition to wood fuel which holds first place among bioenergy sources, attention is now also being paid to field energy: to energy plants and straw. Use of straw is sensible but its low energy density is a challenge. In a survey implemented by the Ministry of Agriculture and Forestry (Vainio-Mattila and others, 2005) a significant increase of energy plant cultivation on the fields has been suggested. The survey suggests that by 2012 the surplus fields not needed for food production, some 500 000 ha (25 % of the current arable area) would be reallocated to energy plant production.

Instead of significant investment in altering cultured fields suitable to energy plant production, it would be wise to first examine the possibilities of using other, hitherto unused biomass reserves. Reed beds area such a hitherto unused source of energy. Despite the above described vision, reed resources are not the answer to the expectations of significant increase in the use of renewable energy sources. The role of wood fuels will still be central among the renewable bioenergy sources. Instead, on the coastal regions of Southern Finland, where the use of wood energy is more modest, the reed resources can have a significant role. In 2003, of the energy consumption in Southwest Finland, 26 350 GWh, the share of wood fuels was 3 % (750 GWh: The Energy Office of Southwest Finland). If the energy potential of the usable reed resources in the coastal areas of Southwest Finland is about 315 GWh (15 000 ha), taken to use it would make up for 1.2 percent of the total energy consumption.

The strength of reed energy lies in its **locality**. Locally, reed energy can offer a significant addition to the bioenergy source selection. The reed beds on the coast of Southern Finland are estimated to cover ca. 30 000 hectares and form a bioenergy potential which as a carefully planned harvesting-production chain would be a substantial addition as a fuel mix in plants using chips and peat, and in the furnaces of farms. At the same time it could bring in extra income opportunities and employment and also benefit the water systems. The Common Reed is a bioenergy source which brings a lesser load to the environment compared to the popular and as such environmentally cost-effective Reed Canary Grass. The use of the Common Reed in energy generation does not presuppose fertilizing and thus does not cause nutrient emissions, and does not add to the emissions due to fertilizer production. Compared to the Reed Canary Grass, the Common Reed is also an "ethically sustainable" energy source since it does not diminish the arable area used for food production.

The harvesting, pre-processing and incineration tests presented in this report and implemented within the "Reed strategy in Finland and Estonia" project are of a pilot study nature. More research is needed on harvesting techniques, pre-processing, incineration and the economy of the reed energy production chain. Experiments carried out both earlier and by the project with the Common Reed do show, however, that the reed has potential: by its energy content the Common Reed can be compared to the most commonly used bioenergy source, chips. Also its hectare yield is big, ca. 5 tons of dry matter, and when cultivated under good conditions probably much bigger than that.

In Finland, there have as yet not been many proposals or plans to add the amount of reed or its cultivation. In Central Europe, retreating reed beds are being preserved for natural preservation goals, and man-made wetland areas are created in order to cleanse waters with high nutrient content. As we in Finland think the major problem is reed beds running wild, talk of cultivating the reed can be ridiculed.  But in view of the challenges presented by the large scale eutrophication of water systems even this should be discussed: could it be possible to implement reed bed cultivations at the river mouths or by housing areas, wide reed cleaning plants or **multifunctional wetland areas**, in which the rootstocks holding back nutrient flows are doing the water protection work? By annually alternating between the harvesting areas, the removed nutrient-rich green mass would further remove nutrients from the cycle and from the water systems, and could at the same time be utilised for biogas production in digestion plants. Such ventures are under way for instance in Holland. If the reed beds are also implemented as nature-like and diverse wetlands, the above mentioned benefits will be added to by enriching biodiversity and the landscape.

The cost-effective **harvesting** of the Common Reed is the bottle-neck in the whole reed energy chain. Also in an earlier survey on reed energy (Isotalo et al., 1981), the energy use opportunities of the Common Reed were stated but the ”bottle-neck factor” was found to be the harvesting phase. Unstable ice conditions in winter hinder the later winter harvesting of material for incineration use. The harvesting methods of the Reed Canary Grass which is cultivated in fields cannot as such be directly applied to the harvesting of the Common Reed growing on shores and water areas, since the fickle ice conditions in the reed beds bring an added challenge to the winter harvesting of the reed. The weight of the harvesting machinery and the surface pressure of it is the threshold factor. Decreasing the surface pressure with wide tyres or caterpillar bands could be an answer. Many alternatives have not yet been tested.  There is the ”Wetland Harvester” on the market, but its high price does not encourage experimenting.

In an Bachelor’s thesis at Turku University of Applied Sciences (Valo, 2007) dealing with harvesting machinery, the conclusion was to recommend a combination of a reed mower with a trailer which mows, bales and transports the harvest on one run. Also other machines designed for collection reed for building material could be useful. Summer harvesting is another chapter. The machine should be floating and preferably also run on land. In addition, the machine should leave the bottom undisturbed so the nutrients in it would not be released to the water. The harvesters in commercial production have been designed for removing reed growth, not for sustainable harvesting of it for energy use. So, there is still much to be studied and developed in the harvesting techniques.

The practical implementation of the harvesting and the transport presupposes organisation, starting from the local readiness. Which is the most cost-effective way to harvest, handle and transport the reed should be decided case by case. In this respect pilot surveys should be made in which the reed beds, harvesting chains and the readiness of the receiving incineration plants should be charted. (See surveys on local production models for the Reed Canary Grass: Paappanen and others, 2006).

The central factor in cost-effectivenss is the **energy density** of the bioenergy material. The processing of the reed mowed as long straw or chopped with a field chopper to a more transport economical bale, or further crushing to pellets which can also be used in small house furnaces, raises the costs in one part of the production chain but lowers them in another. What the most overall cost-effective harvesting – production alternative is depends on the case. Different production models have been sketched in chapter 6.

In the **baling tests** of the project there were no major problems but keeping the bales whole probably presupposes bale netting. The **pelletizing tests** showed that a binder material promotes the solidity of the pellet. On the other hand, the briquetting tests failed because of the dampness of the material. Pellet heating is on the rise all the time and in the future, the interest will probably grow also on the power plant sector when coal combustion power plants start looking for energy sources with low emissions. Then the availability of wood material can become a restrictive factor for pellet production, and new pellet raw materials can find a new market.

In the **incineration tests** of the Common Reed it was discovered that the length of the chopped straw is an important factor, just as it is in the incineration of the Reed Canary Grass. The chopped straw should be shorter than 5 cm. Also otherwise the quality of the reed, for instance moisture, should be optimal. The use of sufficiently dry and short chopped reed as a mixed fuel with peat and chips has turned out to be functional in combustion tests. Also promising results were had from bale burning. However, more incineration tests are needed. Also the **biogas use** is almost an uncharted territory. The latter combined with the nutrient removing effect, thus diminishing the load to water systems (see chapter 1.3.), of the summer harvested reed mass opens up interesting views worth further investigation. Also the sludge generated by digestion is an exceptionally good fertilizer since most of the nutrients that result from the decomposition process are in a form directly usable to plants.

Reed energy shows itself as an environment friendly, ”green” enegry, which it of course compared to for instance fossil fuels is, to the greatest possible extent. There are, however, no studies about the environmental balance in reed energy. When assessing the **environmental impact** also the indirect impact on water quality, landscape and biodiversity of reed energy should be taken into account.

To be a realistic alternative reed energy must, in addition to its ”greenness”, also be cost-effective irrespective of in which form it is used – as a bale in a bale furnace, as a pellet in a small house furnace, chopped and mixed with wood chips and incinerated in a regional heating plant or a farm, or as biogas produced in a digestion plant. It is difficult to assess the economic viability of the Common Reed since there are no experiences of large scale harvesting experiments over several years. Only when the harvesting chain of the Common Reed from the field to the furnace has been optimized will we know what the overall costs of the entire chain are.

As a summary it can be concluded that the Common Reed is a potential, local source of additional energy for furnaces and heating plants using peat and chips. It is possibly also suitable for bale incinerators as such, and processed to a pellet also suitable for small house furnaces and pellet-burning ovens. Before reed energy can be utilised on a larger scale, more studies and development work is needed. In many respects, the Reed Canary Grass is of help since there is more experience of using if for energy, and which in incineration behaves like the Common Reed. When it comes to harvesting, the experiences with the Reed Canary Grass cannot be applied to the Common Reed, which again requires more development work on the part of the harvesting machinery.

The central development areas in reed energy are:

**Reed bed management plans**

- opportunities to improve the hectare yield of the Common Reed by cultivation and the allocation of separate areas for bioenergy production
- management plans for reed bed areas taking into consideration the bioenergy use possibilities, nature preservation and landscape values and other utilisation needs

**Bioenergy use combined with the treatment of waste waters and drainage waters**

- cleaning waste waters, drainage waters and flows from agriculture in natural or man-made multi-effect wetlands and the bioenergy use connected to this

**Harvesting techniques and chains**

- harvesting technological development work focusing attention on the lowering of the surface pressure of the harvesting equipment, the cost-effectiveness of the harvest and the pre-processing (chopping, baling)
- charting of the harvesting chains
- implementing the harvesting in conjunction with landscaping work in rural areas using the so-called rural area service agreement models and co-organising agents

**The processing of energy products**

- processing the reed into pellets and briquettes: the quality requirements to the material, use of binders

**Combustion techniques**

- developing furnace techniques to better apply to burning straw-like materials
- large scale combustion tests on burning bales

**Environmental impact**

- the environmental balance in reed energy: the energy balance, effect on environmental emissions (environmental emissions from incineration, indirec environmental impact), evaluation of other environmental benefits (water production, leisure use, landscape maintenance, use as fertilizer

**Economical viability**

- the cost-effectiveness of the harvesting – production chain: calculating the work yield, the needed work hours and the costs
- calculation models in which social yields, environmental benefits, and regional and employment impact are accounted for
- various subsidy and funding alternatives for promoting the energy use of the

Common Reed: energy plant subsidy, feed tariff systems to promote electricity production from bioenergy, investment aids for the development of harvesting equipment, development subsidies for methods and harvesting chains planning, employment subsidy to enable reed energy experiments, environmental subsidies to locations where the work is landscape maintenance and bioenergy use is an attachment.

**Guidance and education**

- guidance and education about the energy use possibilities of the Common Reed
- demonstration locations and production chains

**The immediate development measures are:**

- to map the harvestable reed resources and draw up management plans for the reed areas on the coast and inland which were not presented in this report
- to start development work on reed energy harvesting methods and chains with the help of investment and development funding, in which best regional solutions are sought in addition to methodological development by bringing together the available reed resources, harvesting chains and the plants utilising the fuel and other consumers
- to launch an extensive project to find the best methods for the harvesting and incineration of all straw-like bio fuels (the Common Reed, straw and the Reed Canary Grass)

The Finnish rural area overall policy published in 2004 for the years 2005–2008 sees the production of bioenergy and the promotion of its use as a good tool to add to the enterprising opportunities in rural areas. One of the objectives is that the use, collection and processing of renewable energy forms ( e.g. field bioenergy, wood chips, bio fuel liquids and biogas) is promoted in the countryside by creating opportunities for the founding and operations of small businesses utilising them and developing their usability.

One of the implementation models for the scattered jobs like landscape maintenance and also the harvesting of reed could be so-called **agreement basis and co-organising agents.** The agreement basis (also rural area agreement, rural area service agreement) stands for bringing together rural activities by using a flexible co-organisation mechanism for work and commodities. In the action model, the co-organising agents bring together the parties, the service providers and buyers, and help them in drawing up service agreements.

The success of the Common Reed as a bioenergy source presupposes fearless entrepreneurs and courageous innovators. Also communication and publicity supporting business operations, education, consulting, politics and joint effort between the agents in the branch are needed. What is also needed is bold and successful pilot solutions which act as examples for new ventures and give basis for entrepreneur networks.

**Guidance, education and information** are also needed to raise the status of the Common Reed. The goal should be for the reed to soon have the same status and reverence as an energy plant as other energy plants, and for it to be eligible for the same energy plant subsidies as other energy plants. Also an important goal is that heating plants realise that the reed is an emission trade product which could lower their carbon dioxide emissions.

In respect to its energy content, its yield and its energy use together with the indirect environmental benefits it brings, the Common Reed is a "green" energy source full of potential just waiting to be utilised.

# LITERATURE

Adler, P., S. Del Grosso, and W. Parton. 2007. Life-cycle assessment of net greenhouse-gas flux for bioenergy cropping systems. Ecological Applications 17(3):675–691.

Evaluation of the long-term utilisation possibilities of biomass in Finland. An expert work group report. 12.2.2007. (in Finnish)

Below, A. and Mikkola-Roos, M. 2007. Reed bed birds. In I. Ikonen and E. Hagelberg, (eds.). Read Up on Reed! Southwest Finland Regional Environment Centre.

Börjesson, P. 1999. Environmental effects of energy crop cultivation in Sweden–I: Identification and quantification. Biomass and Bioenergy 16:137.

Dornburg, V., G. Termeer, and A. P. C. Faaij. 2005. Economic and greenhouse gas emission analysis of bioenergy production using multi-product crop-case studies for the Netherlands and Poland. Biomass and Bioenergy 28:454–474.

Ekstam, B. 2007. Reed bed biodiversity. In I. Ikonen and E. Hagelberg, (eds). Read Up on Reed. Southwest Finland Regional Environment Centre.

Flyktman, M. and Paappanen, T. 2005. Use capacity survey of the Reed Canary Grass. Report on the study VTT. (in Finnish)

Granéli, W., Weisner, S.E.B., Sytsma, M.D., 1992. Rhizome dynamics and resource storage in Phragmites australis. Wetlands Ecol. Manage. 1, 239–247.

Hansson, P-A. 2004. Use of summer harvested common reed (*Phragmites australis*) as nutrient source for organic crop production in Sweden. Agriculture, Ecosystems & Environment 102(3):365.

Himanen, T. 2007. Reed mower prototyping. Bachelor's thesis at Turku University of Applied Sciences, Automotive Engineering. (in Finnish)

Huhta, A. 2007. To cut or not to cut? The relationship between Common Reed, mowing and water quality. In I. Ikonen and E. Hagelberg, (eds.). Read Up on Reed! Southwest Finland Regional Environment Centre.

Ikonen, I. and Hagelberg E. (eds.) 2007. Read Up on Reed! Southwest Finland Regional Environment Centre.

Isotalo, I., Kauppi, P., Ojanen, T., Puttonen, P. and Toivonen, H. 1981. The common reed as an energy plant. Assessed yield, technical possibilities and environmental protection. Bulleting 210. Water Administration. (in Finnish)

Kankaala, P., Ojala, A. and Käki, T. 2004. Temporal and spatial variation in methane emissions from a flooded transgression shore of a boreal lake. Biogeochemistry 68: 297-311.

Kask, Ü. 2007. Reed as energy resource in Estonia. In I. Ikonen and E. Hagelberg, (eds). Read Up on Reed! Southwest Finland Regional Environment Centre.

Kelkka, J. 2007. The applicability to small-scale burning of the common reed. Bachelor's thesis, Turku University of Applied Sciences, Mechanical and Production Engineering.(in Finnish)

Lehtomäki, A. 2006. Biogas production from energy crops and crop residues. University of Jyväskylä.

Near future guidelines in climate and energy policy – national strategy for implementing the Kioto agreement. Government report to the parliament on November 25th, 2005. (in Finnish )

Martikainen, E. 2002. The Reed Canary Grass as a raw material for bio energy at the Saarijärvi district heating plant. Jyväskylä University of Applied Sciences, Natural Resources Institute. (in Finnish)

Paappanen, T., Kallio, E., Kirjalainen, T. and Lindh, T. 2006. Developing the Jahtavisneva producer circle in the production of the Reed Canary Grass, interim report I. Project report, VTT processes. (in Finnish)

Pahkala, K., Isolahti, M., Partala, A., Suokannas, A., Kirkkari, A., Peltonen, M., Sahramaa, M., Lindh, T., Paappanen, T., Kallio, E. and Flyktman, M. 2005. Cultivation and harvesting of the Reed Canary Grass for energy production. Second corrected edition. Agriculture and food economy 1. MTT. ( in Finnish)

Partala, A., and E. Turtola. 2000. Biomass grass is an efficient measure in stopping nitrogen flow. Experimental activities and practice 57(6). (in Finnish)

Pitkänen, T. 2006. Where does the reed grow? – Satellite charting of Common Reed areas on the coasts of Southern Finland and the Estonian Väinämeri. Comments from Turku University of Applied Sciences 29. Turku University of Applied Sciences. (in Finnish)

Pitkänen, T., Meriste, M., Kikas, T. and Kask, Ü. 2007. Reed resource mapping in Finland and Estonia. In I. Ikonen and E. Hagelberg, (toim.). Read Up on Reed! Southwest Finland Regional Environment Centre.

Puolakanaho, K. 2007. Logistics and operations calculation in the transport of the Common Reed. Turku University of Applied Sciences, Automotive and Transportation Engineering. (in Finnish)

Riihimäki M. 2006. Bioenergy strategy in Vakka-Suomi. Vakka-Suomi regional municipality cluster. (in Finnish)

Roosaluste, E. 2007. The reed itself. In I. Ikonen and E. Hagelberg, (eds.). Read Up on Reed! Southwest Finland Regional Environment Centre.

Silén, H. 2007. The possibilities of harvesting the Common Reed for bio energy and construction use on the coastal area of Southern Finland. Bachelor's thesis, Turku University of Applied Sciences, Sustainable Development. ( in Finnish)

Simi, P. 2007. The Common Reed as bio energy and its economic viability. Bachelor's thesis, Turku University of Applied Sciences, degree programme in Sustainable Development. (in Finnish)

Suomalainen, S. 2006. Bioenergy from the fields: the possibilities of the Reed Canary Grass in energy production. Master's thesis, University of Helsinki, Dept. of Economy, environmental economy. (in Finnish)

Valo, A. 2007. Common Reed harvesting for energy use. Bachelor's thesis, Turku University of Applied Sciences, Mechanical and Production Engineering. (in Finnish)

Virko, A. 2007. Burning the Common Reed in power plant scale furnaces. Bachelor's thesis, Turku University of Applied Sciences, Mechanical and Production Engineering. (in Finnish)

Vuorma, J. 2006. Preprocessing the Common Reed for energy use. Bachelor's thesis, Turku University of Applied Sciences, Mechanical and Production Engineering. (in Finnish)

*The Common Reed.*
*Drawing: Mimmi Vuoristo.*