DEVELOPMENT OF R&D SERVICES IN THE BIOMASS FUEL-PELLET SECTOR

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ABSTRACT: Central Finland is home to a multi-faceted pellet-related business sector but local pellet research has been primarily of a short-term subscribed nature. This has meant that long-term planning and pellet research collaboration has remained at a modest level. A study was conducted in which the level and needs of research and development (R&D) services were evaluated and an assessment was made for expected research needs in coming years. The scope of the evaluation included: basic international research regarding pelletisation of raw materials, a mapping of prominent research partners, facilities and apparatus, and current and past supporting research from local institutions. From the findings, a development agenda for local pellet research has been drawn up and areas of research in which investment should be made are identified. This paper describes important aspects of the study and summarises the findings. The following areas of basic pellet research are proposed: pelletisation (fundamental processing phenomena), new upgrading technologies for biomass raw materials (torrefaction), diversification of pellet raw material types and biomass storage issues. The main objective of the study is the forming of competitive pellet research clusters in Central Finland among relevant companies and research organisations.

Key words: biomass pellet research services, wood pellets, Central Finland

1 INTRODUCTION

1.1 Background

In 2008, the global production of wood pellets was roughly ten million tons of which some six million tons were produced in Europe [1]. At present, the global industry uses mostly dry sawdust and cutter shavings, from spruce and pine species, to make its pellets [2]. These conventional wood pellets can be seen as a special case within biomass utilisation. They are unique in that their raw materials are by-products of large wood-processing industries and fairly homogeneous with regard to physical properties. Indeed, it is for this reason that they have been easily utilised. Due to the characteristics of wood fuel, conventional wood pellets are also suitable for small and large-scale consumption alike. Pellet production, consequently, has a strong reliance on the productivity of the wood-processing sector.

Present European energy policy aims to significantly increase the use of biomass in energy generation and biomass pellets can play an important role. But as the clean and dry by-products of the wood-processing sector approach full utilisation in Europe, new raw materials are needed for fuel pellets; materials which are expected to fulfil the same quality and efficiency demands as those of wood.

1.2 Objective

The Finnish Centre of Expertise Programme (OSKE) funded a pellet research and development project consisting of two phases. The aim of the first phase was to make a survey of current pellet research activities in Finland and abroad and to draw-up a development agenda for the pellet R&D sector in Central Finland. The agenda identified areas of investment whose strengthening would lead to more permanent and long-term R&D services in the region. The project's second phase will take place in future months during which time competitive research clusters would be formed in Central Finland.

1.3 Scope

The first phase of the project had duration of seven months and the survey encompassed regional players in Central Finland who have been active in pellet-related research and development. Compiled national information was mostly limited to past regional activities. A survey of recent international pellet-related research was conducted based mostly on journal publications and national institutional reports. The main focus of the survey was research and development activities related to wood pellets produced from wood-processing by-products but it also investigated a diverse set of raw materials and processes which could become relevant as the industry expands in future years.

1.4 Methodology

The project had a steering committee which consisted of members from the following organisations: the University of Jyväskylä (JYU), the Technical Research Centre of Finland (VTT), Jyväskylä Innovation Oy and Vapo Oy. The main tasks within the first phase of the project were realised by JYU and VTT. Personnel from VTT compiled research findings from previous pellet-related studies of recent decades and identified present production technologies and possible partners for regional collaboration. Jyväskylä University acted as the project coordinator and was responsible for a review of pellet-related research activities outside of Finland, identifying key technologies and institutions in the field and compiling information regarding past and present complementary research at the university. Together JYU and VTT compiled a development agenda through discussion with businesses and organisational partners. The steering committee met twice during the four-month task phase of the project in addition to informal meetings among local company and other organisational representatives.

A pellet-related publication database was one product of the first project phase. It was created at the University of Jyväskylä using a web browser-based environment. Scientific and internal project publications are organised in the system and can be accessed by the Sustainable Bioenergy Group at JYU for future pellet activities. A large amount of pellet publications, both internal and public dating from the 1980s onward, from VTT were also scanned into portable document format (PDF) and stored in the database.

Findings from the project have been reported in Finnish among steering committee members and OSKE and, in English, selected findings are reported in this paper. Project activities were also strengthened through organised graduate-level courses at the University of Jyväskylä which included pellet production lectures, a visit to a standards laboratory (for pellets norms) and economic evaluation of pellet-related enterprises (torrefaction). A publication at the upcoming EFORWOOD conference in Uppsala, Sweden, in September 2009 also utilises findings from the project.

2 CHALLENGES AND OUTLOOK FOR THE FUEL-PELLET SECTOR

Based on pellet production statistics and scientific literature, it is clear that the pellet industry is set to evolve into a more global entity with more diversity in raw materials and also in the technology it employs. For this to happen, local players need to understand possible avenues for future growth while also investing in refinement of existing production methods.

2.1 General challenges in energy use of biomass

In order to expand the raw material base of fuel pellets and make the sector less dependent on the wood-processing industry, other forms of biomass besides spruce and pine wood will need to be utilised. For example, agricultural and forest residues are abundant in Europe [3] but the problem is to utilise these materials in a cost effective manner. In general, non-woody, biomass is not without its challenges which mainly are derived from a few properties. Firstly, green biomass has a relatively low mass, high water content and poor energy density. Secondly it requires storage facilities and readily undergoes biodegradation. Thirdly, non-woody biomass also shows a wide variance with regards to its combustion properties, depending on its origin, when compared to wood and fossil fuels.

As with current use of biomass in co-firing applications, the first two challenges can be somewhat overcome if using some methods of harvest, densification and drying of biomass which is economically feasible and if transport distances to users are short [4]. Wide variance in combustion characteristics, however, makes small-scale use of the fuel impractical due to factors such as: emissions of volatile compounds, high ash-content of fuel, low ash-melting temperature, corrosion problems and technical solutions which would enable burning these fuels in domestic settings. Therefore, as has been suggested [5] it seems probable that at least two classes of fuel pellets, for large-scale and small-scale users, will be a reality if utilising these fuels.

2.2 Current research trends

2.2.1 Raw materials and pelletisation

Pelletisation of biomass for fuel has been a topic of interest for decades. In Finland, pellets began to be a subject of interest in the late 1970s. Physical and chemical processes during pellet formation are of interest because of factors such as pellet durability, mass density, and energy consumption in pellet making and lifetime of equipment. A good summary of Finnish pellet research and also a good description of the numerous process variables encountered in pelletisation of wood materials have been given [6]. Pelletisation is only the final step of a series of processes in which raw materials are prepared for pressing. Depending on the material these usually include crushing, grinding, drying, mixing and pre-compaction. For a given raw material, there are optimal values to achieve in pelletisation in order to balance pellet quality with economics. Consequently, theory and modelling of the process is important in research and a common tool has been the use of a single pellet press with which dynamic process parameters can be better understood. Single pellet presses have been uses to study the applicability of powder compaction models to biomass materials; particles of wheat and barley straw, switchgrass and maize residues [7]. A slightly more advanced press, with removable dies, was also used for studying pellets made from mixtures of wood, bark and coal [8]. Researchers have also been able to study the forces within the matrix channels of commercial pellet presses by sequential loading of their single press; this essentially models the real process by dividing it into finite steps [9]. The same study applied the theory to both softwoods (pine, spruce and fir) and hardwoods (beech) pellets.

Important sources of biomass raw materials are determined by local resources and industry and may be relevant only at a local level of production. Research in several countries continues to focus on their possible utilisation in future fuel-pellet production. For example, North America has vast supplies of agricultural residues, mostly straw, which, in Canada, have been assessed for collection and use for other economic purposes [10] and specific studies encompass the mechanical properties of pelletised straw, maize residues and switchgrass [11]. In countries where both the forest and pellet industry are well-developed, the intent has been to begin utilising logging residues and bark material in pellet making [12]. Likewise, researchers have conducted applied research with regards to several materials including: exhaust gases analysis from combustion of mixed straw-peat pellets [13], pelletisation of Icelandic larch and reed canary grass which seems a promising crop for pelletisation in unused agricultural land in northern Sweden [14].

2.2.2 Torrefaction

With the general challenges of biomass utilisation in mind, torrefaction, a process consisting of the mild heat treatment (200–300 ºC) of biomass in the absence of oxygen, seems a promising technology because a more homogenous fuel is obtained from a range of raw materials. This thermo chemical process can be used to pre-treat biomass (both wood and non-wood) in order to improve both its mass and energy density. The end product is also more brittle, which significantly reduces the energy required for milling the material, and hydrophobic, meaning it requires no dedicated storage facilities, and is no longer susceptible to biological degradation [15, 16].

During the process light volatile components in the biomass are “burnt off” and these combustible gases, so called *torgas*, can be recycled and used as a supplementary fuel in the drying phase. The resulting torrefied biomass has more “coal-like” properties and can be used directly in co-firing or gasification applications or as a feedstock for fuel pellets. Torrefied biomass has a higher mass density and much improved energy density because typically 70 per cent of the original mass is retained yet this contains 90 per cent of the original energy content. The moisture content of the product is very low; only a few per cent.

When combined with pelletisation, torrefaction greatly improves the economics of transporting the fuel. In fact, given a raw material of wet sawdust it has been shown that the production of torrefied wood pellets is a markedly better economic investment than that of conventional wood pellets [17]. In this case, the benefits stem from three aspects of the process; the utilisation of torgas, the reduced energy requirements of milling and the improved economics of transportation (due to greater energy density). For comparison, conventional wood pellets have a bulk energy density of 10 GJ/m^3 whereas the value for torrefied pellets is 14 GJ/m^3 [17]. Additionally, this economic analysis does not include the additional savings for the end-user who no longer requires dedicated storage facilities for the fuel since torrefied biomass can be handled in much the same manner as coal. It is worth noting that torrefaction technology challenges one of the primary assumptions of biomass utilisation; namely that it only makes economic sense to use biomass resources near the place of their origin. Torrefaction, and a similar thermal process of carbonisation, are currently entering the commercial phase at three facilities in Europe and at least two in North America [18].

2.2.3 Optimising wood pellet quality and production

A large part of recent research addresses current production challenges in the pellet sector. Producers, of course, would like to produce the best quality fuel-pellets for their customers with minimum cost. Methods of increasing process automation at pellet mills are then desirable if cost savings result from their use.

Some of the variables in pellet production include the blended proportion of spruce and pine sawdust, moisture content, drying temperature and energy consumption of pellet press. As an example, it has been shown that near infrared (NIR) spectroscopy can be a tool in automation by analysing the spectral data of process sawdust. The research demonstrates that such a system is capable of predicting power consumption within 91 per cent accuracy in addition to the optimal blends of pine and spruce sawdust after system calibration [19].

The maturity or age of sawdust is of practical importance in pellet production. Sawdust of a proper maturity is required so that pellets do not off-gas while in storage. Such emissions can cause odour problems, are health risks for workers and users, especially for materials in a confined storage space [20]. Some research regarding emissions of volatile organic compounds (VOC) has been carried out and it was found that pellets made from Norway spruce emitted fewer VOCs than those made from Scots pine [21]. The same study suggests that lipid content of sawdust could be used as an indicator of sawdust maturity and that drying temperatures affect the composition of emitted compounds.

Some method of controlled aging of sawdust would then be desirable for pellet producers. A recent paper describes the treatment of Scots pine sawdust using electron beam irradiation [22]. Although results were mixed and technology employed somewhat exotic, the work demonstrated that some level of maturation of sawdust was possible by decreasing the amount of free fatty and resin acid content in the treated sawdust.

2.3 Specific needs in local pellet sector

Through discussion with Finnish pellet producers several specific needs and challenges were identified in the existing production chain. Some of these issues have already been documented in research.

2.3.1 Expanding raw material base

Finnish producers would like to expand the selection of raw materials used in pellet production. Ideally, this would include forest residues, bark and wet sawdust. Cost of raw material acquisition was stated as being the greatest barrier to pellet production. In addition, controlled blending of raw materials, in order to achieve good quality pellets, was said to be difficult to control even with present materials (pine and spruce). Consequently, optimisation of drying, milling and blending processes will be increasingly important as new raw materials are utilised. Methods of material acquisition will need to be revisited in order to minimise costs and innovate more efficient harvesting techniques.

2.3.2 Self-heating of sawdust and wood pellets

The self-heating, or spontaneous heating, of both wood pellets and sawdust, especially pine, has been identified as a problem in production. It was described that self-heating has been observed in wet piles of softwood sawdust kept outdoors as well as in piles of dry pellets during sea transportation to the end-user. It was discussed that industry does have some general guidelines for handling materials. For example, some producers say a four-month maturation period for sawdust stores is a good rule of thumb in avoiding problems. Self-heating of any materials is considered a health risk, due to possible emissions (CO, CO_2), as well as a fire hazard and therefore the conditions leading to it need to be understood in order to minimise and prevent such risks.

2.3.3 Dust reduction from peat-based pellets

In terms of product quality, a means of dust reduction from peat-based pellets at power plants was identified as problematic in the Finnish pellet industry. Peat dust is generally problematic due to work safety precautions and general worksite maintenance. Although not indicated in discussions, explosions due to dust accumulation are a hazard in confined spaces where any source of ignition is present.

2.3.4 Lifecycle analysis of wood-peat pellets versus fossil fuels

This topic of study into the lifecycle of wood and peat pellets was raised by a local producer. The origin and pre-handling of wood raw material influence the environmental performance of the product. A pellet product made of a mixture of both peat and wood could however solve some production specific problems originating from non-uniform wood raw materials in addition to providing a technical advantage for both corrosion and emission control. Peat fuels, however, generally have a bad reputation outside of a few countries with significant peat resources. Lifecycle analysis of these fuels compared to those of fossil fuels (coal and oil) was identified as desirable information with regards to product reputation and public image. For example, many countries classify peat as a fossil fuel due to its slow formation even if consumption is considerable less than its rate of growth. Additionally, a good lifecycle description of globally traded fuels like coal was seen as important in terms of informed comparisons of fuel types.

2.3.5 Information and technical support for domestic pellet users

Pellet producers recognised that technical support for their customers was lacking, at least in the Finnish market, which could be attributed to the recent emergence of pellet systems. Often customers invest in pellet heating systems without a good understanding of the product. In some cases, perhaps due to zealous marketing claims, customer expectation of the technology is too high. For example, specifications for combustion efficiency may state maximum values for a system operating at a certain heating level. But the total annual efficiency of the device is much lower due to variance in heating needs throughout the seasons. This was identified as an important issue for future development of the pellet sector since negative attitudes towards the technology could develop due to misinformation. It has been stated that there has been a general lack of confidence in pellet technology due to its association with traditional wood heating and this may yet be a valid argument in Finland [2].

3 PROPOSALS FOR AREAS OF LOCAL RESEARCH INVESTMENT

3.1 Research collaboration

A local research and development network is vital for promoting innovation in the biomass fuel-pellet sector. Biomass resources have traditionally been important to industry in Central Finland and therefore, the necessary components for networking already exist in the region. What is lacking is a more lasting strategy between key entities which would enable long-term research project investment and business development.

The University of Jyväskylä together with VTT are seen as key coordinators in the region due to their facilities and equipment, various departments and good contacts with the business sector and other research institutions. VTT in Jyväskylä has a long tradition of biomass research, skilful personnel, suitable laboratory facilities as well as processing equipment (crushers, conveyors, hammer-mills and pellet presses &c.) VTT has also been active in quality classification and standardisation of European biofuels.

Jyväskylä University's Renewable Energy Programme is multidisciplinary and has access to important facilities one of which is a new pellet research laboratory located in Vaajakoski. The laboratory houses a prototype pellet furnace coupled with a Stirling engine for production of heat and electricity. The pellet burner and combustion segments of the device are well-suited for combustion experiments of biomass fuel-pellets and experimental measurement associated with emissions. For example, it is possible to utilise the equipment and services of the aerosol laboratory for combustion particle and nano-safety research. At present, the department of biological and environmental science also has use of a laboratory and test hall, located at the Jyväskylä region landfill site Mustankorkea. Furthermore, fruitful discussions regarding pellet research cooperation between the Jyväskylä and Joensuu region has taken place during the project.

The following table identifies some important members of the pellet R&D industry in Central Finland and summarises their key strengths as it relates to the industry.

Name	**Type of Organisation**	**Key facilities and/or services**
University of Jyväskylä (JYU) www.jyu.fi	Educational and Research Institution	• Renewable Energy Programme • Sustainable Bioenergy Group • Vaajakoski pellet laboratory • Natural science laboratories (physics, chemistry, environmental science) • Mustankorkea laboratory and test hall
Jyväskylä University of Applied Sciences (JAMK) www.jamk.fi		• Institute of Natural Resources, Saarijärvi • Bioenergy Development Centre
Technical Research Centre of Finland (VTT) www.vtt.fi	Research Institution	• History of working with standardisation of quality classification for European biofuel • Combustion research facilities • Pellet presses • Milling equipment
Vapo Oy www.vapo.fi	Company	• Baltic region's largest pellet producer • Access to biomass raw materials
Ariterm Oy www.ariterm.fi		• Manufacturer of boilers for biomass fuels & heating systems
Enas Oy www.enas.fi		• Fuel analysis services • Pellet standard testing
Jyväskylä Innovation Oy www.jklinnovation.fi		• Promotion of regional development between research and business

Table I. Identified key members of Central Finland's pellet research and development community.

3.2 Proposed basic research

From the development agenda, which was the product from the first phase of the project, the following main research and development themes were among those seen as important for future of the industry. Based on the general findings, these topics warrant promotion and investment in the Finnish pellet sector at present and they strengthen collaboration between existing institutions.

3.2.1 Pelletisation

Basic research involves the study of physical and chemical mechanisms in pelletisation of biomass materials. Areas of investigation include: modelling of forces and pressures in pellet presses, energy balances of formation, properties of additives, investigation of optimal blends of raw materials. Research can begin with use of single pellet press and progress to larger commercial units. Accurate experimental measurement techniques are to be employed to quantities results which will have practical implications in industry. The work will allow production of sample batches of novel pellets for durability and combustion-related testing.

3.2.2 Torrefaction

Research of thermo chemical processes would best begin with a laboratory-scale torrefaction set-up for small biomass samples (less than 1kg). Batch-type experiments appear rather straightforward and have been described elsewhere [23]. Such experiments should allow heat-treatment of wood and non-wood biomass and the measurement of temperature, pressure, mass variations, mass flow of exhaust gases and analysis of exhaust gas constituents and properties. The information obtained from these experiments would then allow analysis of energy and mass balance of the process. In turn, an initial economic evaluation of the process would be possible and allow comparison of results with those documented in literature. The feasibility of a continuous pilot-scale plant in the Finnish operating environment could then be determined. Pelletisation trials and analysis of available raw materials, greenhouse gas emissions, logistics and markets would follow pilot-scale research. Torrefaction has the potential for marketing a whole new chain of technologies which require design and manufacture.

3.2.3 Raw material diversification

To help alleviate the fuel-pellet sector's strong dependence on the wood-processing industry, research is needed in utilisation of new raw materials. In Finland, the most obvious choices, and also those indicated by pellet producers, are forest-based materials such as whole trees obtained from thinning operations, trees used for fibre content and forest residues (needles and branches). In order to be economically viable, feasible production chains need to be established for new materials. In some case, existing equipment or methods may be suitable. For example, harvesting of such materials may be possible with present machinery but milling may require more attention in order to achieve a desired blend of bark. Natural drying of materials in the field may be necessary to reduce costs.

3.2.4 Storage and self-heating of biomass fuels

This topic is an important area of research for all biomass in general but will focus on those used for fuel. Research areas would include the following: emission of volatile organic compounds from biomass fuels, self-heating mechanisms and methods of prevention, health and safety aspects of fuels storage and transport, effects of storage on fuel quality and storage and packaging technology for solid biofuels. There are also related subjects of study including: suitable maturity indicators for sawdust, experimental determination of torrefied biomass durability while stored under a variety of unfavourable conditions and economic assessment of storage costs for different types of biomass fuels (a significant cost-savings factor in torrefied biomass production).

4 CONCLUSIONS

The global biomass fuel-pellet industry is expected to continue the expansion seen in recent years. This will no doubt lead to more optimisation by pellet producers in order to effectively utilise the high-quality by-products of the wood-processing industry. New technologies for quality control, such as automation and control techniques, and expansion of raw material use, such as upgrading using torrefaction, are expected to be important in this growth and producers will increasingly look to utilising other raw materials which may depend on local conditions.

Central Finland is home to several key research and development entities whose collaboration could lead to long-term R&D activities in the region; the University of Jyväskylä is in a key position in this regard. Raw material resources are abundant in the form of forest industry by-products and pellet-related companies already exist and can assist in bringing new technologies to domestic and global markets. Additionally, several production challenges have been identified in local industry and solutions to these is desirable.

In short, research collaboration ideas have been formulated and the following areas of basic pellet research are proposed for regional cooperation, and especially for JYU: pelletisation (fundamental processing phenomena), new upgrading technologies for biomass raw materials (torrefaction), diversification of pellet raw material types and biomass storage issues.

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