Journal of Industrial Information Integration 6 (2017) 11–21

Contents lists available at ScienceDirect

Journal of Industrial Information Integration

journal homepage: www.elsevier.com/locate/jii

Suitability of papiNet-standard for straw biomass logistics

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ARTICLE INFO

Article history:
Received 24 March 2017
Accepted 15 April 2017
Available online 17 April 2017

Keywords:
Multi-fuel supply chain
Supply chain
papiNet
Straw logistics
Bioenergy ecosystem
Logistics chain

ABSTRACT

Multi-fuel solutions are an increasingly common set-up in CHP (Combined Heat and Power) plants. Many plants use different types of biofuels, such as wood or agricultural products. In Finland, the most prominent type of biofuel in CHP are forestry products, with agricultural biofuel playing a marginal part. This work investigates the use of the papiNet standard, originally designed for the forestry supply chain, as a possible data exchange format for a multi-fuel supply chain where forestry products are the dominant type of fuel. Two data models are described in this work: a data exchange model between different actors in the supply chain, and a data model for storing the required information. Furthermore, the application of the papiNet standard with these data models is explored. As a result, the papiNet standard is found to be suitable for use with some provisions.

1. Introduction

Combined Heat and Power, or CHP power plants, are an important part of the electricity and heat generation infrastructure. They are especially important in colder climates, where buildings require heating for a large part of the year. One current trend in energy production in CHP plants is increasing the use of biomass and reduction in the use of fossil fuels. This is part of the general trend of increased use of renewable energy in recent years. For example, in the European Union the average annual growth of renewable energy between 1990 and 2014 was +4.28% [6]. In 2014 the highest share of gross electricity production in EU was produced using renewable energy sources (28.2%), followed by nuclear (27.5%) and coal (25.3%) [5]. However, it should be noted that when heat production is taken into account, nuclear power produces more total energy than renewable sources [6]. It should also be noted that this comparison includes only energy produced by power plants, and thus excludes important areas of energy consumption, such as transportation.

Biomass-using CHP plants sometimes use one specific type of biomass, such as wood, but often the systems are designed as multi-fuel systems capable of using a range of different kinds of fuel. Common are also solutions where biomass is co-fired together with fossil fuels such as coal [25]. The types of biomass used in energy production can be characterized in several ways. McKendry divides the material by type into *woody plants, grasses, aquatic plants*, and *manure*, with grasses further subdivided according to moisture content [14]. Another way to categorize biomass is to divide it into crops and wastes, with waste coming from three sources: *forests, agriculture*, and *municipal waste* [16]. The latter categorization is more suitable for the purposes of this paper, as many biomasses used in CHP energy production are created as by-product or waste product of some other process. Examples of wastes and by-products include felling waste, sawdust, and straw residue. There are also biomasses grown for use in CHP energy production, such as reed canary grass [3,11] and willow [4,29,30]. However, despite research and development efforts, cultivation of such energy crops is currently not a particularly wide-spread phenomenon [4,10]. In 2007 the total estimated area for energy crop cultivation in the whole EU was approximately 2.5 million [1,8] to 5.5 million [21] hectares out of approximately 109 million hectares. The majority of these fields were used to grow crops for biofuel production, such as rape [8,21]. Thus, in order to use agricultural biomass in any significant degree in CHP power plants, by-products such as straw need to be utilized.

Forest biomass, as well as solid agricultural biomass such as straw or reed canary grass, can be directly used in common CHP plants. In case of co-firing plants, different types of fuels are typically mixed together with each other. Such multi-fuel power plants require the management of multiple different fuel sources, and thus have a need for sophisticated information systems to manage the different supply chains and ensure the availability of fuel. In Finland the most common type of biomass in energy production is forest biomass. However, there is significant interest in exploring the potential of other sources of biomass in energy production. Also of interest is how these sources could be easily integrated to the current supply chain, which is focused on forest products.

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http://dx.doi.org/10.1016/j.jii.2017.04.004

This paper concentrates on the information management of the supply chain logistics of straw biomass in a multi-fuel environment in Finland. The main focus is in investigating suitable means for the different actors involved in the supply chain to be able to exchange data in a machine readable and standard manner. Appropriate data management models for the supply chain are also explored. In Finland the forestry supply chain, which includes the supply of forest biomass for energy production, uses the papiNet standard [22] for data exchange. The main goal of this work was thus to investigate whether papiNet could be used to also handle the data exchange needs of the straw biomass supply chain, or if another data exchange format is needed. The primary research question in this work is "*How feasible it is to use forestry data exchange standards to handle straw supply chain information management for multi-fuel biomass power plants*".

The rest of this publication is arranged as follows. Section 2 contains the general background, theory, and methods related to this work, and it is followed by Section 3, which describes the previous work the results described here are based on. Section 4 contains the main results of the work, and is followed by discussion in Section 5. Finally, Section 6 contains the conclusions.

2. Materials and methods

Forests are a very important part of the geography and the economy of the Nordic countries, especially Finland and Sweden. Approximately 78% of Finland and 53% of Sweden is covered by forest. Meanwhile nearly 9% of Finnish and approximately 6% of Swedish land area is used for agriculture. The numbers are a bit lower in Norway, with approximately 38% of the land covered by forests, and 3% by agriculture. In Denmark land is mostly used for agriculture (62% of the land area), and in Iceland both forests and agricultural land are marginal [2].

Thus, while this work concentrates on the situation in Finland, the findings may be directly applicable also for Sweden and Norway, where the forestry and wood production are dominant parts of the local bioeconomy ecosystem. For other areas, direct application of these results should be done with care.

The forestry supply chain is an area of bioeconomy where the integration of software systems and automatic data exchange between different actors is well-developed. In the Nordic countries one reason for the high level of development is that the supply chain is dominated by a relatively small number of large forest industry companies.[1] Their central market position gives these companies the ability to make industry standards for the supply chain. However, it also gives these companies the ability to ensure that the supply chain serves their best interests.

Forestry logistics has at least two important, internationally supported standards that are in wide-spread use in the Nordic forestry industry: StanForD and papiNet. The StanForD (**Stan**dard for **For**est machine **D**ata and Communication) standard maintained by Forestry Research Institute of Sweden is meant for data storage and exchange between computers in forestry machines [27], whereas the papiNet standard maintained by the papiNet initiative[2] is meant for data exchange between actors in the forest and paper products supply chain [22]. In addition to these two, there are other standards used in various nations for a number of different purposes, such as buying and selling timber, or maintaining forest resource maps. As an example, the various national forestry standards used in Finland can be found on a single web page[3].

The current versions of the StanForD and papiNet standards have been implemented using XML, which is currently a very common method in business to business interoperability [9,18,19]. The papiNet standard attempts to cover the supply chain of forestry products as well as possible, and has been adopted for use in several countries [7,15,17]. The standard covers data transfer needs for different parts of the supply chain from business activities, such as requests for availability or complaints, to measuring, storing and moving the products. The standard also explicitly covers eight forestry product categories ranging from forest wood to book manufacturing and pulp [22].

Currently, the use of straw in energy production in Finland is marginal [10] despite active research on the topic [26]. However, there is significant potential in energy production with straw, and in Nordic countries there are existing power plants using straw, such as the Fyn Power Station in Denmark [26]. Fyn creates 24.5 MW of electricity and 84 MW of heat annually by using 170,000 tons of straw as fuel. Total annual straw harvest in Denmark is 5.5 million tons [1]. At the time of the writing of this text, the most ambitious straw power project in Finland is a bio–ethanol production plant under construction at Kouvola, Finland, which would consume 330,000 tons of straw to produce 72,000 tons of ethanol.[4] The Kouvola power-plant is to start ethanol production in summer 2019.

Typically in straw supply chain it is assumed that the straw is baled upon harvest and the supply chain will handle bales. There have been attempts at transporting unbaled straw in Finland, but experiments showed it to be a worse option than using bales. Typical Finnish balers produce round bales. Rectangular balers, which would produce bales more suitable for the supply chain due to their shape, are rare due to high price and weight, as well as low demand. However, with rectangular bales there would be less wasted space during transport [20].

This work was conducted as part of the Finnish strategic research project BEST - Sustainable Bioenergy Solutions for Tomorrow.[5] Part of the BEST project was the development of a *biomass virtual terminal*, an integrated software solution for managing lots of biomass stored in various locations ranging from large, permanent storage stacks to small, transient roadside piles. The initial goal of the virtual terminal was to be able to meet the future requirements of forestry biomass supply chain in Finland. However, there was a strong need to expand the terminal to also include other types of biomass. Straw was selected as the first case for the expansion of the concept.

3. Previous research: forestry supply chain in Finland

The basis of the work described here was the work done in the BEST project regarding bioenergy supply chains for forest products [24]. Based on the work described in [24] a series of data communication models were developed. These models corresponded to the different means used in Finnish forestry industry for handling the logistics of using felling waste for energy production. The models covered delivery of felling waste directly from roadside storages to the power plant, delivery through a central storage, as well as delivery through external fuel terminal attached to the power plant. Detailed description of this further forestry–related work is out of scope of this paper. However, in order to show the basis of the main results described here, a brief overview of the model for direct delivery of felling waste to the power plant will now be described [23].

In the direct delivery case the felling waste is stored at a roadside storage near the logging area, chipped on-site and delivered

[1] Metsä group, UPM, and Stora-Enso in Finland.
[2] http://www.papinet.org/.
[3] http://metsatietostandardit.wm.fi/en.
[4] http://www.sbe.fi.
[5] http://clicinnovation.fi/activity/best/.