Application of the papiNet-Standard for the Logistics of Straw Biomass in Energy Production

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Abstract. Multi-fuel solutions are an increasingly common set-up in CHP (Combined Heat and Power) plants. Many use also 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 only 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. In the work a model for the data exchange between different actors in the supply chain is described, and the application of papiNet in it is explored. As a result, the papiNet standard is found to be suitable for use with some provisions.

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

1 Introduction

One current trend in energy production is the use of biomass in CHP (Combined Heat and Power) power plants. Such systems sometimes use one specific type of biomass, such as wood, but often the systems are designed multi-fuel systems. Common are also solutions where biomass is co-fired together with fossil fuels such as coal [18]. 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 [10]. Another way to categorize biomass is to divide it into crops and wastes, with waste coming from three sources: *forests*, *agriculture*, and *municipal waste* [12]. 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, such as felling waste or sawdust. There are, however, agricultural biomasses that are grown for use in CHP energy production, such as reed canary grass [2, 7]. However, despite research and development efforts, cultivation of such energy crops is currently not a particularly wide-spread phenomenon [6]. In 2007 the total estimated area for energy crop cultivation in the whole EU was approximately 2.5 million [1, 4] to 5.5 million [16] hectares out of approximately 109 million hectares. The majority of this area was used to grow crop for biofuel production, such as rape [4, 16]. Thus, in order to 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 fuel are typically mixed together with each other. Such multi-fuel power plant requires the management of multiple different fuel sources, and thus has 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, and how these sources could be easily integrated to the current supply chain, which is focused on forest products.

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. In Finland, the forestry supply chain, which includes the supply of forest biomass for energy production, uses the papiNet standard [17] for data exchange. The 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 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*".

2 Materials and Methods

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 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 puts these companies in a position to make industry standards for the supply chain. Forestry logistics has at least two important, internationally supported standards: 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 [20], whereas the papiNet standard maintained by the papiNet initiative is meant for data exchange between actors in the forest and paper products supply chain [17]. 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[2].

[1] Metsä group, UPM, and Stora-Enso in Finland
[2] http://metsatietostandardit.wm.fi/en

The current versions of the StanForD and papiNet standards have been implemented using XML, which is currently a very commonly used method in business to business interoperability [5, 14, 15]. 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 [3, 11, 13]. 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 product categories ranging from forest wood to book manufacturing and pulp [17].

Currently, the use of straw in energy production in Finland is marginal [6] despite active research on the topic [19]. 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 [19]. Fyn creates 24.5 MW of electricity and 84MW of heat annually by using 170 000 tons of straw as fuel. Total annual straw harvest in Denmark is 5.5 million tons [1]. Currently in Finland, the most ambitious straw power project is the bio–ethanol production plant under construction at Kouvola, Finland, which would consume 330 000 tons of straw to produce 72 000 tons of ethanol[3].

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 price, weight, and low demand. However, with rectangular bales there would be less wasted space during transport.

This work was conducted as part of the Finnish strategic research project BEST - Sustainable Bioenergy Solutions for Tomorrow[4]. 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.

As part of the research on the virtual terminal concept, the flows of data between different forest supply chain actors in the Finnish biomass logistics chain were modeled. The constructed model was then reviewed and refined in workshops. This forest biomass model was used as the basis for the inclusion of straw in the virtual terminal. In addition, previous work on the use of straw in energy production was mapped using a literature review and expert interviews. This work acted as basis on the development of a data model for straw supply chain.

[3] http://www.sbe.fi

[4] http://clicinnovation.fi/activity/best/

Based on the information gained from the forest biomass data model and the expert interviews, the forestry model was modified for handling straw biomass. The straw model was then reviewed and refined using expert opinions, and the information that needed to be transferred between different actors, systems and processes was extracted from the model. The result of the extraction was then used to further review and develop the model. Finally, examples of the data messages included in the model were constructed using the papiNet standard.

The papiNet examples constructed were compared against the model and the information exchange needs in order to analyze the suitability of the papiNet standard for the task. In the analysis, special emphasis was placed on the coverage of the standard, mainly can it be used to depict all the information required, and the suitability of the standard, mainly can all the information required be expressed in a concise and useful manner.

3 Results

The main result of this work is the model of the communication between different actors and processes in the straw supply chain for energy production, and the analysis of this model. Based on the model and the defined data transfer needs, examples of communication messages using the papiNet standard have been developed. The model has been analyzed using expert reviewers, and its suitability for purpose has been assessed. The model is depicted in Figures 1 and 2. The notation in the figures is inherited from the related forestry model, and it has been implemented using the Altova UModel diagram tool.

The black rectangles in the Figures depict the actors and systems involved in the model. There are three primary actors: the *energy company*, the *supply chain*, and the *farmer*. The energy company's *ERP system* and farmer's *Farm Management Information System* are also depicted separately in the Figures. The goal of the energy company is to procure fuel for their power stations in order to ensure that the stations can always produce the desired amount of energy, both electricity and heat. The supply chain has been hired by the energy company to transport straw from the farmers to the power stations. The farmers have been contracted by the energy company to cultivate cereals and sell their straw for energy. In a typical situation there is one energy company and numerous farmers involved in the process. The number of supply chain actors is at least one, but can be more. Different actors can, for example, be responsible for different geographical areas.

The different systems and processes in Figures 1 and 2 are depicted using two elements that represent different processes in the model. The yellow rectangles are processes that communicate with other processes in the model, and blue rectangles are data management systems or processes that do not directly communicate with other parts of the model. There is one such detached process in Figure 2: the process of cultivating a farm. The numbered steps in the Figures depict various stages of the straw supply management. The arrows in the model depict communication from one process to another, where each arrow depicts one exchange of data. Finally, both the farmer and the energy company have their own information systems that interact with their processes.

3.1 Making a Farming Contract

The making of the farming contract and the harvest notification are shown in detail in Figure 1. The process starts with the farmer making a preliminary agreement with the energy company for selling them straw. Based on this agreement, the energy company can create in their ERP farmer database an entry for the farmer, which they then use to store all information about the farmer that they need. Similarly, the farmer can store the details of the agreement to the software system they use to store the farm data. The preliminary agreement acts as a basis for the actual farming contract between the energy company and the farmer. In the farming contract, the farmer and the energy company agree on the approximate amount of straw the farmer is willing to sell. At harvest the farmer will find out how much straw they actually have, and can inform the energy company about how much straw they are capable of selling.

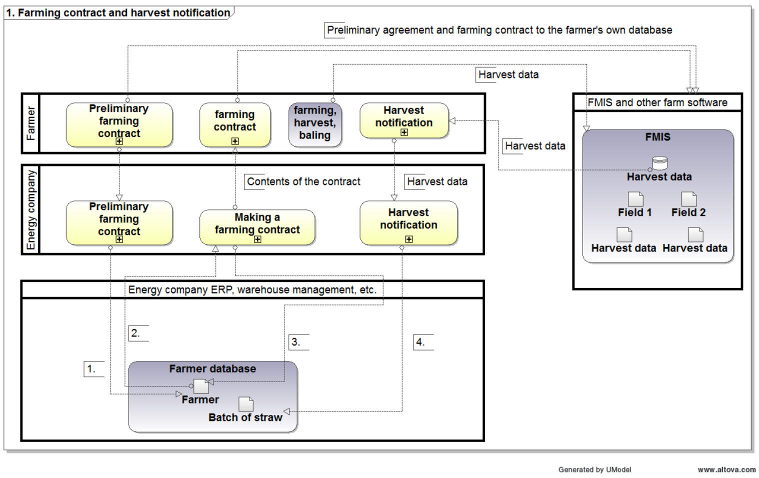

Fig. 1. The straw supply chain model from making of the farming contract until the harvest notification

The process of making a farming contract will most likely be done primarily using means that are not directly machine readable, i.e. paper contracts. While electronic contracts are possible, the paper contract tradition is still extremely strong and therefore likely to persist for quite a while. From the point of view of the information management, the most important details for the farmer and energy company to agree during the contract making process is the approximate amount and location of straw the farmer is willing to sell. Using this information, the energy company can make preliminary plans for arranging their supply chain to provide them with straw until the next harvest period.

Typically, the machine-readable data transfer in the model starts with the farmer sending harvest report to the energy company (step number 4). Previous communication is likely to be primarily on human-readable documents. The harvest report is a report on *amounts* and *locations*, and possibly also *moisture percentage* of the harvest. Assumption is that the straw will be baled for transport, and thus the basic unit of measurement that needs to be transmitted is the number of bales available. If the baler can also measure the weight and moisture of a bale, further information can also be transmitted. Location is assumed to be either a street address, or GPS coordinates.

3.2 Order for New Fuel

The more detailed description of the model continues in Figure 2. The left side of the Figure covers the model from the creation of a new order for fuel to the sending of a notification of straw retrieval to the farmer, while the right side covers the model from straw pickup to the fulfillment of the fuel order. The communication depicted by steps 6 through 8 within Figure 2 happens inside the energy company's organization. The activity begins when the warehouse management determines a need for more fuel (step 5) and sends a order for fuel (step 6) that starts a new *fuel procurement* process. The most important things given to the new process are the *amount of fuel*, the *delivery location*, and *deadline for delivery*.

The fuel procurement process forwards the order for fuel to the energy company's *farmer database* to select the loads of straw that would fulfill the order (step 7). If needed, the loss of straw between the harvest and the current time can be estimated using loss modeling, if such is available. Currently, no loss models are in use. The farmer database will send the fuel procurement process information how fulfill the order (step 8). This message contains information regarding straw lots to be retrieved, including the *location* and *owner* of each lot, as well as information on the *amount* of straw.

After the fuel procurement process has gained information on what to deliver to the power station, it can forward the information to the *supply chain*, which will create a new *straw delivery* process to handle the pickup, transport, and delivery of the straw. The fuel order that the fuel procurement process transmits to the straw delivery process (step 9) in Figure 2 is a combination of the fuel order (step 6) and the straw data (step 8). The supply chain then accepts the order (step 10). Should the order be rejected, the fuel procurement process needs to react. Possible actions include contacting another supply chain operator, adjusting the order, or advising the power station that new fuel order cannot fulfilled given the criteria.

After the straw delivery process has accepted the order, the next action is sending the farmer an advance notification of straw retrieval (step 11). This message informs the farmer about the *location* and the *amount* of straw to be taken, as well as the estimated *time* when it will happen.

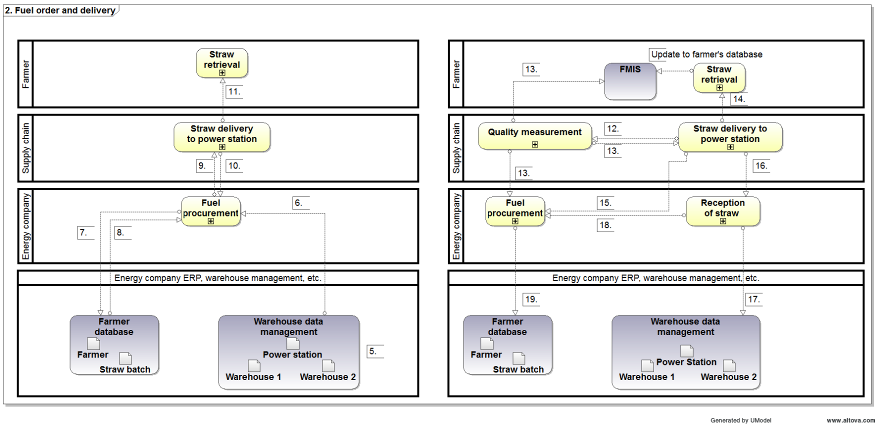

Fig. 2. The straw supply chain model from the creation of an order for new fuel, until the delivery of straw to the power station

3.3 Fuel Delivery

The right side of Figure 2 covers the model from straw pickup to the fulfillment of the fuel order. In the model as part of the straw pickup, the supply chain actor makes a *quality measurement*, where the weight and moisture of each bale of straw is measured. In case quality measurement cannot be made, the model skips to the retrieval of straw.

The quality measurement process is starts with the straw retrieval process making a quality measurement order (step 12). The important information transmitted in the order is the *location*, the *time*, and the *type* of measurement to be done. If needed, the order can be accepted in a manner similar to step 10. The acceptance procedure is not included in the model). When the measurement has been done, the quality measurement results can be sent to the straw retrieval process, the fuel procurement process, and the farmer (step 13). The measurement results should contain the *weight* and *moisture* of each straw bale included in the delivery.

When a lot of straw is picked up from a specific farmer, the straw delivery process sends the farmer a message, which contains information about the *location*, the *time* and the *amount* of straw that has been picked up (step 14). At the same time, the straw delivery process also sends this information to the fuel procurement process (step 15) as well as to the power station (step 16).

When a load of straw arrives at the power station, the supply chain actor will hand it over to the *straw reception* process. Upon receiving the load, the reception process will send a message to the warehouse (step 17) and to the fuel procurement process (step 18), informing them on the arrival of the new batch of fuel. The message to the warehouse includes the *amount* of new fuel delivered, while the message to the fuel procurement process informs this process that a specific shipment has arrived. The fuel procurement process updates the farmer database (step 19). If the arrival of straw concludes a specific fuel procurement, the fuel procurement process, and with it the order for fuel, end. Otherwise the fuel procurement process will continue to wait for confirmations regarding the rest of the fuel order.

4 Discussion

Based on the model described in section 3 and the example papiNet messages created in the work, the usefulness of the standard on the problem of straw supply chain was analyzed using a standard SWOT analysis. Results of the analysis can be found in Table 1. The table is arranged to separately list all the four aspects of SWOT analysis in order to give the reader a quick overview of the advantages and disadvantages of the papiNet standard. More detailed discussion regarding each element can be found in Sections 4.1–4.3

Table 1. Strengths, Weaknesses, Opportunities, and Threats on the use of papiNet for straw logistics in bionenergy context

strenghts	**weaknesses**
Mature, robust technology	Relative identifiers for many elements are cumbersome
Contains all required message types	No support for describing agricultural concepts
Capable of expressing the required information	Weak support for identifying non-forestry actors and concepts
Sufficient ability to cross-reference information	
Opportunities	**Threats**
Significant support in forest industry	May be unsuitable for environments where forestry products are not dominant
Supported in several countries	Poor profitability of the sector
Existing platforms make it easier to expand the scope of the solution	In Finland, the lack of appropriate machinery

4.1 Strengths

The papiNet standard includes message types that can be used to deliver all the information the messages require in the process of fuel delivery. Table 2 shows which papiNet message type is used in each step of the process. As can be seen on the table, six different types of papiNet messages have been employed. However, some steps could be handled also by other messages, such as using a *DeliveryMessage* in step 18. Thus, this is not the only means to implement the model using papiNet. In an implementation of the virtual terminal concept, the message types to be used then need to be decided.

An important part of the data exchange, is the identification of each actor in the process, as well as cross-referencing to all relevant messages in the process. In papiNet all actors are called parties, and each of them needs to have an unique *identifier*. The standard includes a large number of different types of identifiers, such as the global *papiNetGlobalPartyIdentifier* and *VATIdentificationNumber*. The global identifier is an IANA Private Enterprise Number (PEN)[5], whereas VATIdentificationNumber is the VAT number of the actor. Both are well-suited to act as unique identifiers in the process.

Cross-referencing messages is required for example due to how a single order for fuel may be divided into a large number of deliveries that can be done by different supply chain actors. Thus there must be means to link each delivery instruction to a specific order. In papiNet messages allow for references to other messages, which include all the different message types in the model, and thus the model offers sufficient supporst maintaining cross–referencing. However, in some cases references require an authority to be assigned to them. Many possible authorities are relative to the message, which can make it difficult to pass references along.

As can be seen, the papiNet standard includes data elements that can be used to depict the required information for the supply chain to work. Thus there are rather low barriers for including straw supply chains in the same information system as forestry product supply chains and with papiNet it is possible to create a multi-fuel supply chain information management system.

Table 2. The papiNet message types used in each step of the model. Natural language stands for unstructured text documents in natural language, and N/A stands for steps that are not associated with data exchange

step	**message**	**step**	**message**	**step**	**message**
1 .	natural language	8.	DeliveryInstruction	15.	DeliveryMessage
2.	natural language	9.	DeliveryInstruction	16.	DeliveryMessage
3.	natural language	10.	BusinessAcceptance	17.	DeliveryMessage
4.	MeasuringTicket	11.	DeliveryMessage	18.	ShipmentStatus
5.	N/A	12.	PurchaseOrder	19.	DeliveryMessage
6.	PurchaseOrder	13.	MeasuringTicket		
7.	PurchaseOrder	14.	DeliveryMessage		

4.2 Weaknesses

A possible problem with using the standard is the use of relative identifiers in many messages. For example, many elements in the standard require defining

[5] http://pen.iana.org/pen/PenApplication.page

the actor responsible for assigning the value, such as a message reference. Such are needed, for example, when papiNet is used to send messages between different actors in the same organization. In such case it may not possible to use the PEN or VAT identifiers, as these can be identical for both the sender and the receiver. In such messages, it is possible to use for example the papiNet AssignedBySender identifier, which allows for the use of arbitrary identifiers. However, AssignedBySender is a relative ID, and thus cannot easily be passed along a message chain. The same problem with relative identifiers is also found elsewhere in the standard.

Another problem with the use of papiNet is that the standard does not have any in–built means of describing agricultural concepts or products. The standard has a product description element called <product>, under which different types of products can be described in detail. However, the <product> element supports seven categories of forestry products. Everything else must be described using the *other products* category, which it is very generic and thus cumbersome to use.

The standard is originally designed for forestry products, and thus the handling of non-forest biomass can, in general, be cumbersome when using it. The values of many attributes in the standard are forestry-related, such as the itemType -attribute in the <itemInfo> element, which describes the type of item being measured. Many of the possible attribute values are directly related to forestry, such as *Log*. <ItemInfo> has some general values, such as *box*, or *pallet*. However, as these values are very generic, their usefulness is somewhat limited. Some of the values can actually be deceptive in the context of agriculture. One possible value of <ItemInfo>is *baleItem*, but in the standard this is assumed to be a bale of pulp or paper. Thus using this value for straw bales is, at least in principle, misusing the standard and can lead to confusion in an implementation.

Therefore, while the papiNet standard is a good choice for supply chain data exchange in a business ecosystem where forestry products have a significant presence, other solutions should be considered in cases where forestry products are either not present at all, or have only a minor role.

4.3 Opportunities and Threats

The papiNet has significant international support in the forestry industry. The papiNet initiative has over 40 member companies from both Europe and North America, giving the standard a wide-spread and stable industry support. This, in turn, translates to significant geographical coverage in the use of the standard. Therefore papiNet is a safe decision in the sense that there is a strong organization behind the standard that guarantees its future use.

Furthermore, the widespread support fo the standard also translates into platforms that support the use of papiNet. Thus there are both existing platforms in production use where papiNet is supported, as well as people who have experience in working with the standard and implementing it in actual production environments. Thus it is easier to take the papiNet standard into use than try and apply technology which is not as robust or widely used.

However, the dilemmas of what data exchange standard to use, or how to apply them, are relatively minor compared to the problem of making the straw ecosystem in bioenergy production attractive to the various actors. Straw supply chains have been successfully created, as shown by the Fyn Power Station in Denmark, and, in principle, there is interest among Finnish farmers to sell straw for energy [19]. However, the amount of income a farmer can get from straw is quite small, as typical price the farmer might get is under 20€ per ton, which is a fraction of the current low Finnish grain price of approximately 140€ per ton [21]. In practice, this makes many farmers think the income is not worth the effort. Unfortunately the straw price given to the producer cannot be increased, or straw would become uneconomical source of energy compared to other fuels [19].

Furthermore, an efficient supply chain would require the weight and moisture of the straw to be measured during baling, in order to to give the energy company information about the quality of the harvest. However, current balers in Finland typically cannot do this and the low profit potential of selling straw does not make new investments attractive.

Bale weight is relatively simple to measure even after baling, as this can be done with any tractor which has a scale attached to the front loader. Measuring the moisture of the bale after baling is can be more difficult, however, as it is recommended that bales are wrapped in plastic for storage [8]. Penetration of the wrap for measuring the moisture would aversely affect the storage characteristics of the bale. There is a similar problem if the moisture content is measured during bale retrieval, if the plan is to store the bales at the power station premises for an extended period of time.

A relatively significant problem in the supply chain is also the fact that most balers in Finland produce round bales. The round shape is problematic in logistics, as it leads to relatively large amount of wasted space between bales. For efficient logistics, large rectangular bales would be better than round ones. However, rectangular balers are rare in Finland, and their large weight can be a problem on Finnish fields.

Thus, the problems in setting up the information systems required are relatively minor ones compared to the other practical problems in using straw for energy.

4.4 The biomass Virtual Terminal

The communication model described in this paper is intended to be used as part of a *biomass virtual terminal*, an integrated software solution for managing lots of biomass stored in various locations. The goal of the terminal is to make it possible to have a single system that can be used to manage all biomass an energy company has intended to use in their power plants. By its very nature, such system requires a large number of independent actors to cooperate and share data. From the point of view of energy company, the situation is a relatively traditional cooperative venture together with a large number of subcontractors. The number of subcontractors required can be large, but there are only rather few different types of actors involved in the process.

The straw logistics process described in this paper contains two types of subcontractors: the farmers and the supply chain actors. The virtual terminal will also require two other types of subcontractors in order to handle forest biomass, the forest harvester contractors and forestry companies. The forestry companies manage and handle the primary forest biomass trade, and sell felling waste and other such products to the energy company. The contractors do the actual forest harvesting. The subcontractors are typically managed either by the energy company directly, or by a specific party the energy company has outsourced their fuel acquisition to. In the straw model the assumption is that the energy company directly manages the subcontractors, as there currently are no actors who would provide such service in Finland. However, should the straw biomass market increase, such actors would most likely appear. Or, alternatively, companies that currently manage forest biomass acquisition would expand their business to cover also straw.

The whole production and supply chain for a co-fired CHP plant can, in reality, grow large and complex. Thus it might be useful to approach the problem as a whole using a virtual enterprise model, or similar [9]. So far, such overview of the whole process chain has not been made, but could be done in the future.

Similarly, the different types of fuel included in such supply chain can be extremely heterogeneous. Thus, if the biomass virtual terminal would be extended into a complete fuel virtual terminal encompassing all fuel used by an energy company, the papiNet standard in its current form would quickly become inadequate. The element types, possible values, and especially the whole <product> element would need to be expanded further and generalized.

5 Conclusions

From information technology point of view it is relatively simple to adapt the papiNet standard for the use of agricultural bioenergy chains. The usability of papiNet for straw has been demonstrated in this paper, and similar means can be used for other agricultural biomasses. This is an advantage in an environment similar to the current bioenergy business ecosystem in Finland, where the business is concentrated mainly on forestry biomass. Thus existing logistics systems already use forestry-related standards, such as papiNet. In an environment, where this external motivation for the use of forestry standards does not exist, a new assessment of the existing standards should be done, and some other standard may well be more suited for the task.

Similarly, should the number of different types of fuel handled grow very large, the limitations of the papiNet standard in its current form, will soon be encountered. The standard is designed primarily to handle logistics and business transactions in forestry, and not the energy industry. Therefore other standards may be more suited in such case, or alternatively the papiNet standard would require significant amount of further work.

However, the real barrier for the use of agricultural biomass in energy production is not the technology, but the business. For the farmer, the amount of compensation they get from selling straw for energy is very small compared to the amount of resources and time required for harvesting and storing the product. Furthermore, the additional income gained from this needs to be used to cover the additional need for fertilizers, as straw is no longer used to improve the soil.

Thus, we can relatively easily develop the technological means for including agricultural biomasses in the bioenergy ecosystem, but at least in the case of Finland, it is difficult to make it into a profitable business that attracts farmers.

References

1. E. Alakangas and M. Virkkunen. Biomass fuel supply chains for solid biofuels. *The publication produced in EUBIONET2 project (EIE/04/065/S07. 38628)*, 2007.
2. J. Burvall. Influence of harvest time and soil type on fuel quality in reed canary grass (phalaris arundinacea l.). *Biomass and bioenergy*, 12(3):149–154, 1997.
3. C. Ginet. Standardised electronic data exchange in the french wood supply chain. In *The Proceedings of the Precision Forestry Symposium 2014: The anchor of your value chain*, 2014.
4. T. Laitinen and T. Lötjönen. Energy from field energy crops - a handbook for energy producers. Technical report, Intelligent Energy Europe, 2009.
5. F. Lampathaki, S. Mouzakitis, G. Gionis, Y. Charalabidis, and D. Askounis. Business to business interoperability: A current review of {XML} data integration standards. *Computer Standards & Interfaces*, 31(6):1045 – 1055, 2009.
6. T. Lindh, T. Paappanen, E. Kallio, M. Flyktman, V. Kyhk, P. Selin, and J. Huotari. Production of reed canary grass and straw as blended fuel in finland. Technical report, VTT Technical Research Centre of Finland Ltd, 2005.
7. R. Lord. Reed canarygrass (phalaris arundinacea) outperforms miscanthus or willow on marginal soils, brownfield and non-agricultural sites for local, sustainable energy crop production. *Biomass and Bioenergy*, 78:110 – 125, 2015.
8. T. Lötjönen and V. Joutsjoki. Harvest and storage of moist cereal straw. best research report no 2.1.5. Technical report, Cleen Ltd, 2015.
9. M. Martinez, P. Fouletier, K. Park, and J. Favrel. Virtual enterprise organisation, evolution and control. *International Journal of Production Economics*, 74(13):225 – 238, 2001. Poductive Systems: Strategy, Control, and Management.
10. P. McKendry. Energy production from biomass (part 1): overview of biomass. *Bioresource Technology*, 83(1):37 – 46, 2002. Reviews Issue.
11. F. Mtibaa, A. Chaabane, I. Abdellatif, and Y. Li. Towards a traceability solution in the canadian forest sector. In *1st International Physical Internet Conference*, 2014.
12. S. Naik, V. V. Goud, P. K. Rout, and A. K. Dalai. Production of first and second generation biofuels: A comprehensive review. *Renewable and Sustainable Energy Reviews*, 14(2):578 – 597, 2010.
13. D. Naslund and S. A. Williamson. Supply chain integration: barriers and driving forces in an action research-based industry intervention. In *Supply Chain Forum: An International Journal*, volume 9, pages 70–80. Taylor & Francis, 2008.
14. M. L. Nelson, M. J. Shaw, and W. Qualls. Interorganizational system standards development in vertical industries. *Electronic Markets*, 15(4):378–392, 2005.

15. J.-M. Nurmilaakso, P. Kotinurmi, and H. Laesvuori. Xml-based e-business frameworks and standardization. *Computer Standards & Interfaces*, 28(5):585 – 599, 2006.
16. C. Panoutsou, B. Elbersen, and H. Bttcher. Energy crops in the european context. Technical report, Biomass Futures, 2011.
17. papiNet. the papinet standard v2r40. Technical report, The papiNet initiative, 2015.
18. M. Sami, K. Annamalai, and M. Wooldridge. Co-firing of coal and biomass fuel blends. *Progress in Energy and Combustion Science*, 27(2):171 – 214, 2001.
19. Satafood. Biotaloudella lisarvoa maataloustuotannolle (additional value to agricultural production through bioeconomy). Technical report, Satafood Oy, 2014.
20. Skogforsk. troduction to stanford 2010. Technical report, Skogforsk, 2010.
21. F. F. Statistics. `http://www.maataloustilastot.fi/en/uusi-etusivu` Accessed on July 7th, 2016.