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Biomass Supply Chain Framework for a Decision Management of Biomass Power Plant: A Case Study in Suphan Buri Province

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Abstract

Biomass to produce electricity has been promoted as one of a potential resource of renewable energy in Thailand. However, sustainable supply at competitive price of biomass feedstock is a common issue facing by many biomass power plants around the world including Thailand. A systematic framework to analyze biomass supply chain (BSC) for improving BSC is needed due to very complex relationship of BSC components. Therefore, in this research the Supply Chain Operation Reference model (SCOR) well recognized as strategic framework to manage a supply chain has been adopted and proposed as a systematic tool to analyze BSC. The biomass power plant in Supan Buri province was selected as a case study of this research. The result showed that the adapted SCOR model at SCOR level 1 to 3 has been developed for the case study industry and found that the adapted SCOR model can be used to represent, mapping and improve an understanding of complex relationships between actor and entities involving in the BSC for further analysis of BSC management.

Keywords: Biomass, Biomass supply chain (BSC), Supply Chain Operation Reference model (SCOR)

1 Introduction

Biomass to produce electricity has been promoted as one of a potential resource of renewable energy in Thailand. By year 2030, the national power plan foresees that solar shall have the largest share with 30% (6,000 MW), followed by biomass with 28% (5,570 MW), and wind with 15% (3,002 MW) (AEDP, 2012). Nevertheless, the current status of biomass power plant installed capacity is at 2,815 MW in year 2016 (EPPO, 2015) which is still far beyond the target set by the Alternative Energy Development Plan (AEDP). Thailand is an agricultural country which is rich in biomass resources. Papong *et al*. (2004) provided an overview of biomass utilization in Thailand and addressed that the major limitations of utilizing biomass in Thailand is difficulty in assessment of resources, inconsistent production, inappropriate properties (e.g. low bulk density and high moisture content), problem of collection, transportation and storage as well as uncertainty regarding to availability and reliability the resources. Prasertsan and Sajjakulnukit (2006) concluded that the barriers to the success of implementation bioenergy policy in Thailand are poor coordination among government agencies with private sectors; bias government policy toward small power producers (SPPs) with lower production cost(bidding process); lacking of standards bioenergy systems and equipment; high-financial risk of bioenergy projects; limited information regarding to the successful cases of bioenergy applications; as well as insufficient awareness and confidence in technologies for biomass energy. Raychaudhuri and Ghosh (2016) stated that the biomass power industries were currently making a small profit (suffering losses due to high cost of fuel procurement and generation) and the entire biomass supply chain does not function well which posed a challenge for stable operations and the development of biomass power industries. Future development in a field of cost, strategic planning and policy implication was recommended.

Typical characteristics of biomass-to-bioenergy supply chains are various relationships between activities and actors involved in the supply chain and they vary from place to place leading to the complexity and difficulty to manage the supply chain. Three main segments can be classified for biomass-to-bioenergy supply chains (De Meyer *et al*., 2014); an upstream segment involves related operations from biomass production to deliver at the gate of conversion facility; a midstream segment involves related operations at conversion facility; and a downstream segment entails activities related to storage and distribution bioenergy to customers.

To manage the supply chain, systematic method which views supply chain as a whole system to facilitate a decision making involving different components enclosed in the supply chain is needed. Many researchers developed mathematical programming models as a design and analysis tools for better efficiently and effectively manage their supply chain (De Mayer *el al.*, 2014; Mafakher and Nasiri, 2014; Atashbar et al., 2016). Most of them come up with different ideas to identify complex characteristic of their supply chains.

Even though, mathematical programming models are a powerful tool to design and analyze a supply chain system; nevertheless, applicants should be skillful in mathematic subjects which sometimes limit their uses. Due to this fact, therefore, this research work aims to propose a unified standard framework which helps to analyze the whole biomass-to-electricity generation supply chain based on Supply Chain Operation Reference (SCOR) model. This idea will be implemented to the case study of the biomass power plant located in Suphan Buri province.

SCOR model is process reference model developed by the Supply Chain Council (SCC) which provided a unified framework serving as a diagnostic tool for supply chain management and it has been widely adapted in many companies due to different culture and operation environments (Georgise *et al.*, 2013). Georgise *et al.* (2016) stated that currently companies started to adopt and adapt SCOR model to map, evaluate and to address their improvement needs for disjoints process. SCOR model is a strategic planning tool that allows senior managers to simplify the complexity of supply chain management (Huan *et al.*, 2004).

In the following section, first, the characteristic of biomass-to-electricity generation supply chain related to the case study in Suphan Buri province will be described. Then, adapted SCOR model was proposed to a case study as a standard framework to analyze the biomass supply chain (BSC) at Level 1, 2 and 3 and finally the conclusion of this work will be provided.

2 Biomass Supply Chain of Case Study

As stated earlier, biomass supply chain (BSC) is made up of a range of different activities vary from place to place. This work selected the power plant located in Suphan Buri province to study biomass-to-electricity generation supply chain. The power plant registered in a program of Small Power Provider (SPP) issued by EGAT with the total installed capacity of 91.4 MW. From the field study survey, its supply chain is comprised of 7 main activities: harvest, collection, pre-treatment, storage, transportation, biomass-to-electricity generation and electric power distribution. Harvesting accounts for gathering-related activities of biomass crops in agricultural area. Collection accounts for gathering-related activities of biomass from its origin either industrial or agricultural area. Pre-treatment or sometimes called pre-processing accounts for a treatment that converts biomass into a denser or looser form for carriers which facilitate handling, storage and transportation (e.g., baling, chipping and palletiza- tion). Storage site is required as a buffer between discontinuous supply of feedstock and a year-round production of the power plant. The storage site can be located either at the fields, intermediate storage sites or at the power station. Transportation accounts for any movement or flow of biomass from one place to another place including loading/unloading activities. Transportation can be in a field, in the power plant, from a field or an intermediate storage site to the power plant, etc. Biomass-to-electricity generation accounts for related activities of converting a biomass to electricity. Converting biomass to electricity at the power plant also involves pre-treatment, storage and transportation activities. For example, the power plant moves the baled sugarcane trash from the storage site to loosen the baled leaves at the de-baling machine before conveying it to the boiler. Electric power distribution accounts for a distribution of electric power to a transmission system provided by EGAT to further distribute to end-users. Figure 1 represents all possible material flow diagram related to each activities of biomass-to-electricity generation supply chain of the case study adapted from De Meyer *et al.* (2014)

To efficiently manage the supply chain, complexity arises at the upstream segment due to different kind of biomass types are utilized at the power plant. Bagasse which is the residue left from sugar mill located nearby the power plant has been used as main feedstock. Therefore, a huge amount of bagasse is required to produce electricity. However, its availability is limited which depend on actual sugarcane production capacity of the nearby sugar mill, weather condition and harvesting season.

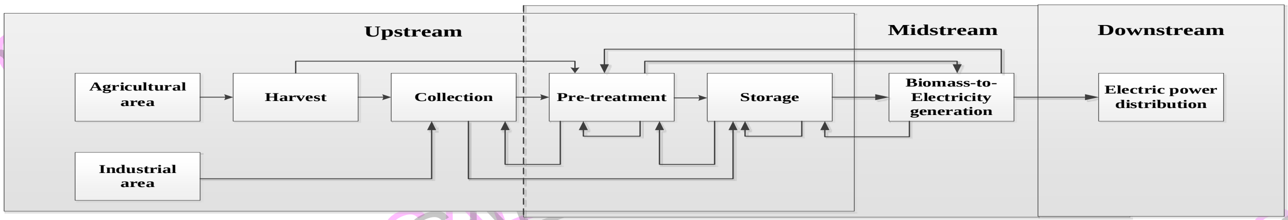

Figure 1 Material flow of biomass supply chain (adapted from De Meyer *et al*., 2014)

In addition, bagasse is an organic material subject to deterioration leading to the material loss during storage. As a result, sometimes, its sources are delivered from alliance sugarcane mills located in other provinces of Thailand. Moreover, to ensure availability of sufficient feedstock, procurement team of company currently utilized woodchip, sugarcane trash, rice husk, rice straw and sawdust as alterative feedstocks to generate electricity and this encompass different actors, relationships, as well as availability of each biomass and its price issues, into the management of supply chain. At the midstream, the management challenge is mainly about how to find sufficient feedstocks and smooth the flow of multi-type feedstocks to generate electricity while keeping the operation and feedstock cost as lowest as possible. Undoubtedly, the effectiveness of management at the midstream segment will result in the success of distribution electric power to the power line regulated by the Power Purchase Agreement (PPA) signed with EGAT.

3 Adapted biomass-to-electricity generation supply chain

All the data provided in this section were collected and analyzed from literature and a field study survey at the power plant. In this section, the process of developing the adapted SCOR model for the case study at each Level of SCOR model will be elaborated. First, we will start with the concept of basic elements of SCOR model and then explain how SCOR model is adapted. Next, SCOR model Level 1, 2 and 3 for the biomass supply chain will be represented.

SCOR model is unique framework that links business process, metrics, best practices and technology into a unified structure to support communication among supply chain partners and to improve the effectiveness of supply chain management and related supply improvement activities (SCC, 2012). The model can be used to describe supply chains that are very simple or very complex using a common set of definition. SCOR model first launched in 1996 and revision 11.0 is the latest version of SCOR model. The model contains 4 major sections: performance, processes, practices and people.

Performance has two element types: performance attribute and performance metrics; a performance attribute is a group of metrics used to evaluate the supply chain. Five attributes were classified in the model: reliability, responsiveness, agility, cost and asset management. For the process, three levels of SCOR processes are provided in the scope of the model. Level 1 defines scope and content of the core management processes of the supply chain. Six core business management processes of Plan, Source, Make, Deliver, Return and Enable are in Level 1. Level 2 describes the process characteristics associated within the core processes at Level 1. Level 3 provides detailed process element information related to each Level 2 process. Inputs, Outputs, description and the basic flow of process elements are captured at Level 3 (Thakkar *et al*., 2009). Please note that to implement the SCOR model, it need to extend the model at least to Level 4 using industry-specific processes, systems and practices (SCC, 2012).

3.1. Adapted SCOR model Level 1

From the data gathered from a field study at the power plant, Table 1 represented the adapted SCOR model Level 1 process and their definitions which relevant to the main activities of the biomass supply chain. Please note that Enable process which is management practice for better improving the performance of supply chain was not included here because the clear picture of the company's management process for better improving the performance of supply chain still intangible and difficult to clearly define their stage of this practice.

Also, Figure 2 showed the mapping of existing activities of the supply chain within the scope of SCOR process putting them into categories of main segments related to the biomass supply chain (i.e., biomass suppliers, biomass power plant, and EGAT), availability area (i.e., agricultural residue types and industrial residue types) and domain of suppliers (i.e., farmers, middle man, sugar mill, and primary wood products and wood-based facilities)

Table 1 Adapted SCOR model Process Level 1 definitions

SCOR process	Definitions
Plan	The processes activities associated with gathering of requirements, gathering of information on available biomass resources, balancing requirements and resources to determine planned capabilities and gaps in demand or resources and identify actions to correct these gaps. Related processes are procurement planning, planning of electricity generate and planning of power transmission and distribution.
Source	The processes activities associated with the issuance of purchase orders or scheduling deliveries, receiving, validation and storage of biomass and accepting the invoice from the supplier. Related processes are harvest, collection, procurement and storage.
Make	The processes activities associated with the transformation or conversion of biomass. Related processes are pre-treatment and electricity generation.
Deliver	The processes activities associated with validate and creation of customer orders, scheduling order delivery truck, pick, pack, shipment, invoicing the customer as well as distribution of electricity to the power line. Related processes are loading and unloading, transportation, storage and electric power distribution.
Return	The processes activities associated with the reverse flow of biomass. Related process is return of defective biomass.

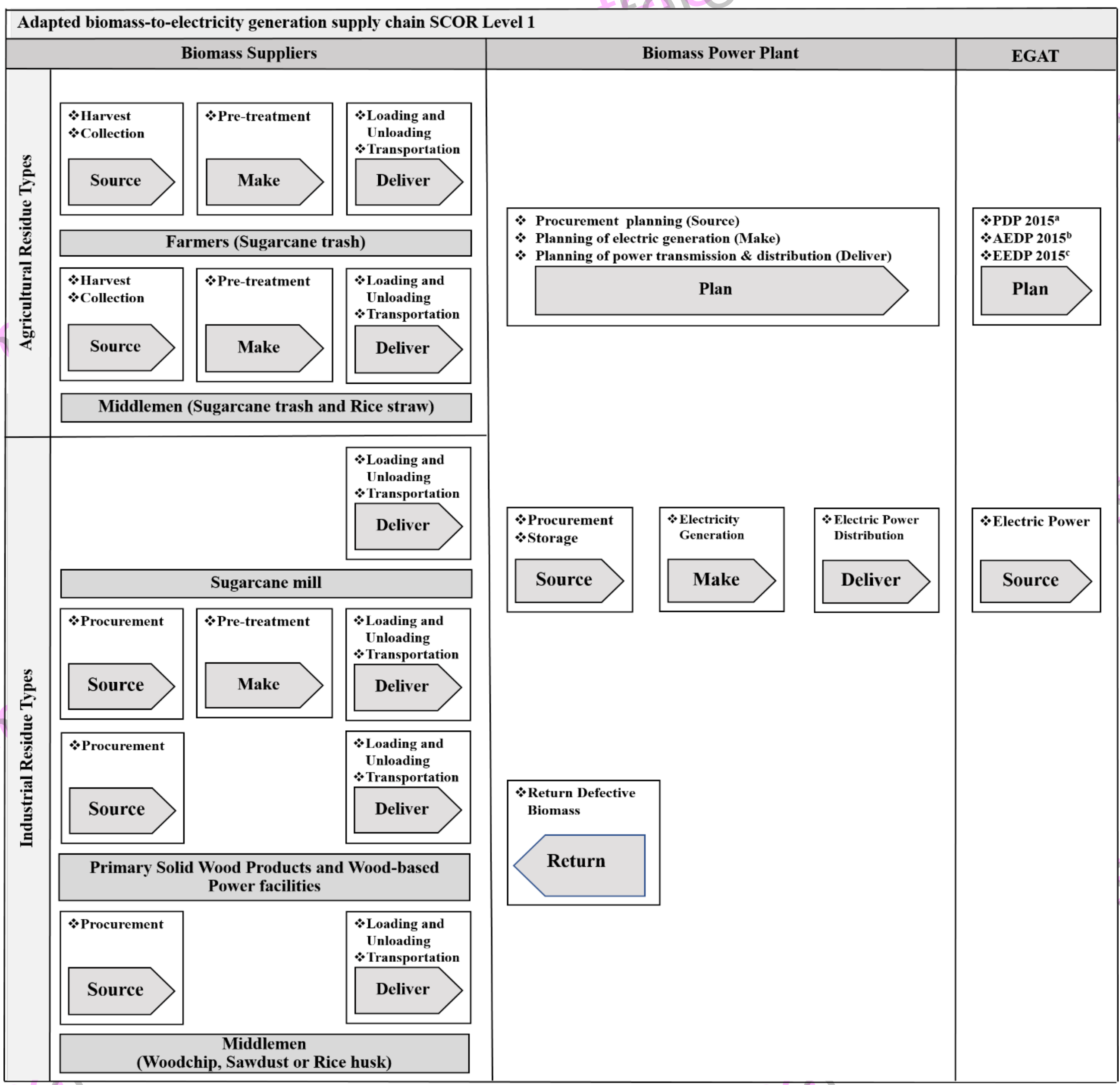

Figure 2 Mapping process SCOR model Level 1 with activities in BSC (aPDP2015: Thailand Power Development Plan, 2015; bAEDP2015: Energy Efficiency Development Plan, 2015 and cEEDP2015: Thailand Energy Efficiency Development Plan ,2015)

3.2. Adapted SCOR model Level

From the data gathered from a field study at the power plant, Table 2 represented the process categories of adapted SCOR model Level 2 which is relevant to process Level 1 defined in Table 1. Figure 3 showed the Adapted SCOR model Level 2 presenting in a same way as shown in Figure 2.

However, scope of Adapted SCOR level 2 did not include the segment of EGAT due to lack of data on how EGAT manages its organization

Table 2 Adapted SCOR model Process Level 2 definitions

SCOR process	Definitions
Plan	
Plan Source	The development and establishment of courses of action over specified time periods that represent a projected appropriation of biomass resources to meet supply chain requirements.
Plan Make	The development and establishment of courses of action over specified time periods that represent a projected appropriation of biomass production to meet electricity generation requirements regulated by Power Purchase Agreement (PPA).
Plan Deliver	The development and establishment of courses of action over specified time periods that represent a projected appropriation of delivery biomass or electricity to meet delivery requirement.
Source	
Source Stocked Biomass	The process of harvest, collection, ordering and receiving biomass based on aggregated demand requirements with the intention to maintain a pre-determined volume of biomass in the inventory.
Source Make-to-Order Biomass	The processes of harvest, collection of the power plant ordering and receiving biomass which is ordered only when required by specifications of the power plant.
Source Make-to-Power Purchase Agreement	The process of identifying and selecting sources of supply, negotiating, ordering, receiving and transferring biomass to manage the inventory volume of biomass feedstock in accordance with Plan Source established along with the regulation of PPA issued by EGAT.
Make	
Make-to-Stock Biomass	The process of pre-treatment biomass based on aggregated demand requirements with the intention to maintain a pre-determined volume of biomass in the inventory.
Make-to-Order Biomass	The process of pre-treatment of biomass which is ordered only when required by specifications of the power plant.
Make-to-Power Purchase Agreement	The process of conversion biomass to electricity in accordance with the regulation of PPA issued by EGAT.
Deliver	
Deliver Stocked Biomass	The process of delivering stocked biomass in response to requirement of the power plant.
Deliver Make-to-Order Biomass	The processes of delivering quantified biomass which is sourced and prepared in response to the qualification of the power plant.
Deliver Make -to-Power Purchase Agreement	The processes of transmission and distribution electricity to the power lines in accordance with regulations of PPA issued by EGAT.
Return	
Product Return Defective Biomass	The return of defective biomass not conforming to specifications (e.g.; % moisture content, size, weight and foreign matter).

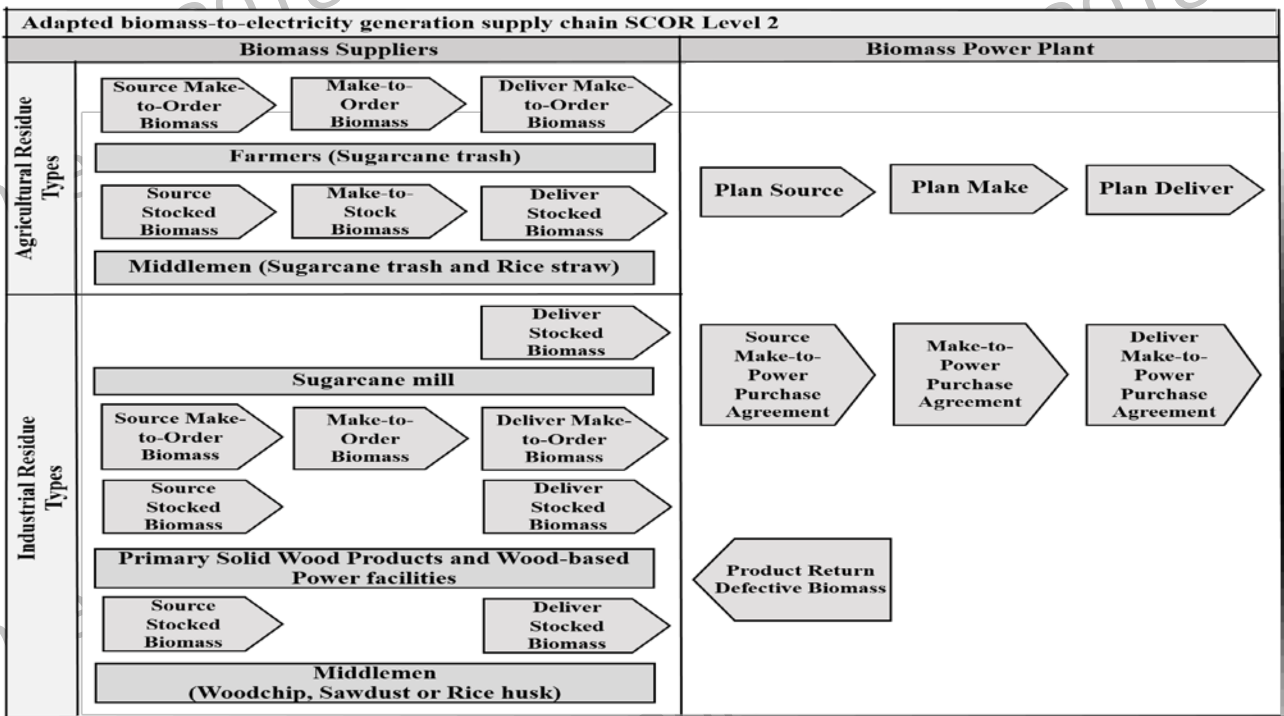

Figure 3 Adapting SCOR Model Level 2

3.3 Adapted SCOR model Level 3

At SCOR model Level 3, a detailed analysis of Inputs, Outputs, description and the basic flow of process elements was needed at the power plant. Accordingly, in-depth interviews with the power plant operators were conducted and this is time consuming process. Therefore, Source Make-to-Power Purchase Agreement which was a very important process regarding to the procurement of feedstock supply was selected into the analysis.

Table 3 showed the process elements of selected SCOR model Level 3 and their definitions.

Moreover, at Level 3, performance metrics can be applied to the related processes. The actual performance metrics utilized at the power plant were represented and defined in Table 4 separated by each performance attributes. Note that it is normal that performance metrics of SCOR Level 2 become a part of process Level 3 because they are related.

Last but not least, Figure 4 represents relationship of Input, Output process of each process elements at Level 3 along with the relevant information flow and their performance metrics.

Table 3 Adapted SCOR model process Level 3 of Source Make-to-Power Purchase Agreement

SCOR process	Definitions
Identify Source of Supply	The identification and qualification of potential biomass suppliers capable of delivering biomass which will meet all of the required biomass specifications.
Select Final Supplier and Negotiate	The identification of the final biomass suppliers based on the evaluation of RFQs (request for quotation), supplier qualifications, and the generation of a mutual agreement defining costs and terms and conditions of biomass availability.
Schedule Biomass Deliveries	Scheduling and managing the execution of biomass deliveries based on the details in the sourcing plan.
Receive Biomass	The process and associated activities of receiving biomass.
Verify Biomass	Verify received with the biomass specifications (% moisture content, size, weight and foreign matter).
Transfer Biomass	The transfer of accepted biomass to the appropriate process lines or storage location at the power plant.
Authorize Supplier Payment	The process of authorizing payments and paying suppliers for their accepted-delivered biomass.

Table 4 Performance metric definitions

Performance metric	Definitions	Related process of performance metric
Reliability		
Perfect Order Fulfillment	The percentage of delivered biomass which are correct and accurate quantities, conditions, documentation as well as time and location of delivery.	Source Make-to-Power Purchase Agreement (Level 2)
% Biomass Received Defect Free	The percentage of received biomass without foreign matter such as sand and stone.	Verify Biomass (Level 3)
% Biomass received with correct content	The percentage of received biomass with correct specification.	Verify Biomass (Level 3)
Responsiveness		
Queuing and Waiting Cycle Time	A time associated with queuing and waiting processes of a truck when arrive at the gate power plant.	Schedule Biomass Deliveries (Level 3)
Receiving Biomass Cycle Time	A time associated with receiving biomass starting from the time a truck get into the power plant, weighting, loading and unloading, till a truck leaves the power plant.	Receive Biomass (Level 3)
Agility		
Additional biomass volumes obtained in 30 days	The additional volumes of required biomass in each month.	Source Make-to-Power Purchase Agreement (Level 2)
Current Biomass Volume	Amount of purchased biomass	Source Make-to-Power Purchase Agreement (Level 2)
Safety Stock	A level of extra biomass stock which is maintained to mitigate a risk of biomass stockout.	Source Make-to-Power Purchase Agreement (Level 2)
Cost		
Sourcing Cost	The total cost associated with managing the ordering, receiving, transferring, inspection and warehousing of biomass.	Source Make-to-Power Purchase Agreement (Level 2)
Purchased Biomass Cost	The total cost of biomass purchased to produce electricity.	Source Make-to-Power Purchase Agreement (Level 2)
Asset Management Efficiency		
Days Payable Outstanding	The length of time from purchasing biomass until cash payment must be made expressed in days.	Source Make-to-Power Purchase Agreement (Level 2)

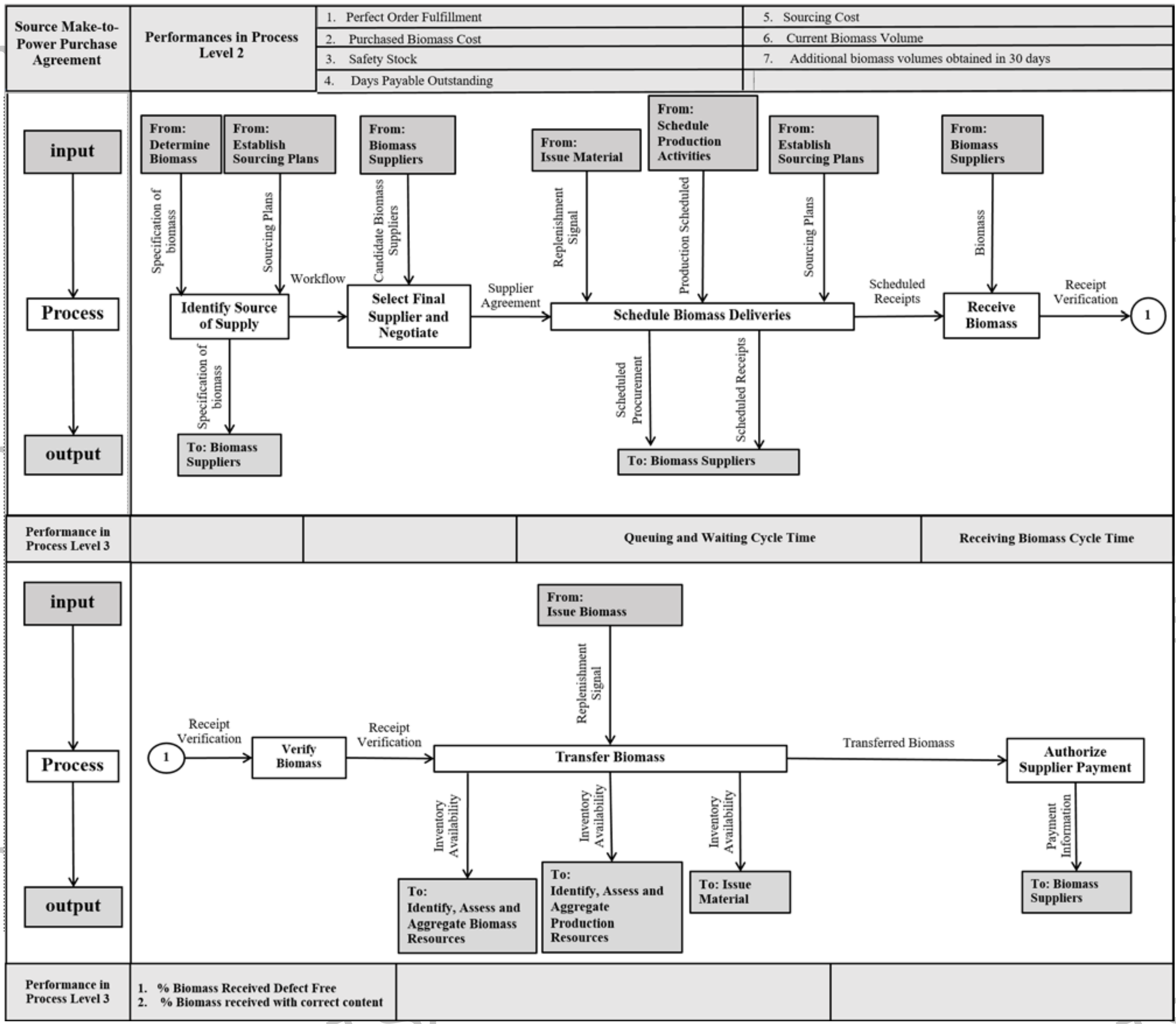

Figure 4 Process SCOR model Level 3

4 Conclusions

In this work, adapted SCOR model of process Level 1, 2 and 3 were developed and proposed to represent a framework for biomass supply chain by analyzing data gathered from the selected case study. The results showed that the adapted SCOR model is very helpful to represent, mapping, and improve an understanding of complex relationships between actors and entities involving in the biomass supply chain. However, based on our knowledge from literature review and our work, SCOR model itself could not guide on which methods should be employed to better manage and improve the supply chain. A person at an executive level related to the BSC should be participated and take action for further analysis of BSC management in real practices.

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