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An Impact Analysis of Circular Economy Strategy on Global Shipping of Woody Biomass

By
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Acknowledgement

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Studying Maritime Economics and Logistics (MEL) at Erasmus University, Rotterdam is one of the most important decisions in my life and the whole learning phase sheds some light on the link between trading and global cargo flow via shipping. I am grateful for all the arrangements and efforts made by Renee Slater, Martha Tjhin, and Felicia de Jong of the MEL department during the COV-19 pandemic period. It would have been a tougher and depressing experience without their support throughout the course.

Furthermore, as a world citizen and an enthusiastic actor in the shipping industry, I strongly believe that the circular economy transition for the world sustainable evolution is meaningful for the whole planet and the better vision of future changes in global cargo flow can lead to a more clear picture of shipping industry.

Abstract

Although the implementation of the circular economy for more sustainable development has gained more attention over the last decade, woody biomass which is a representative of an important sustainable energy source and core achievement of circular economy has seldom been investigated to envisage its connection with shipping demand in the academic literature. With this thesis, we attempt to envisage the impact of the circular economy on the trade and shipping demand of woody biomass. To our surprise, the increasing implementation of the circular economy in the next decades is unlikely to have a significant impact on the shipping demand for woody biomass, as total woody biomass cargo flow accounts for only 3% percentage of global sea traffic. However, there will be a significant decline in round wood shipping demands in the North American and Middle Eastern regions, but a boom in shipping demand within Africa and from Asia to Africa may occur in the coming decades as the global circular economy matures. For non-recyclable wastepaper, the shipping demand is expected to skyrocket in the Middle East, while it will remain stable in the Far East & Asia Pacific and South America regions for Chips, while sawdust, wood waste, and scrap from the European Union to North America will see a slight increase in shipping demand.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

CE Circular Economy

CDCP Product Design and Cleaner Production

CICERONE Circular Economy Platform for European Priorities Startegic Agenda

EC European Commission

EU European Union

IE Industrial Ecology

IRENA The International Renewable Energy Agency

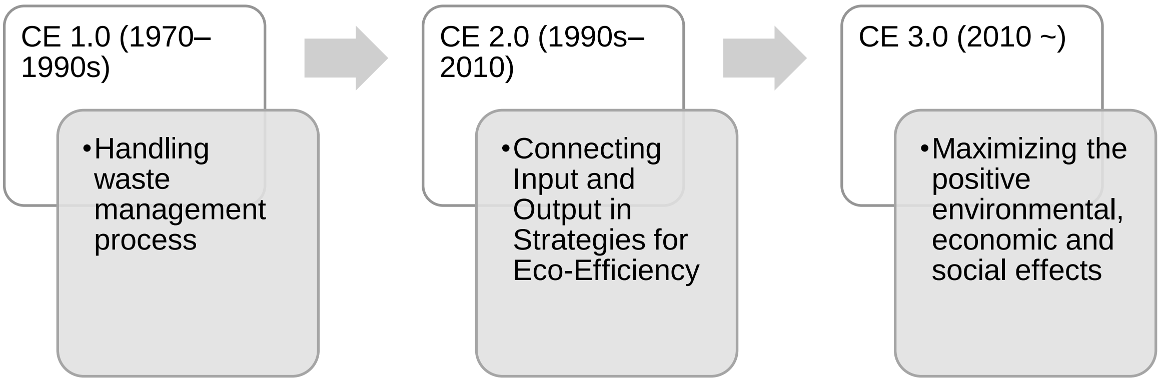
RL/CLSC Reverse Logistics and Closed-Loop Supply Chain Management

WM Waste Management and Environmental Sciences

1. Introduction

1.1 Background

Back to 1758, Quesnay's "Tableau Economique" brought forward the earliest concept of circular economy with the surplus value from cyclical inputs (Murray et al., 2015). Later in the 19th century(1814–1897), P.L. Simmonds set up the examples of closing material loops. (Cooper,2011) Evaluation for waste usage in economic activities can often be observed (Ayres and Ayres, 1996) but the global economy advances at the cost of increasing problems in waste management due to the lack of integrative waste management approaches after World War II (Carter, 2001). Then the publication of the Club of Rome (1972) leads to a shift to the next three phases. (Reike et al., 2018)



The first phase represented as CE 1.0 is from 1970 to 1990 and the concept was about the implementation of a waste management system based on the circular economy. The second phase as CE 2.0 is from 1990 to 2010 and it is about limiting negative environmental impacts in economic expansion and in 2010, the final phase of CE 3.0 began, and the circularity principle was deemed to be the best solution because except for economic gains sustainability challenges are linked to population growth and lead to great attention on resource depletion and retainment of the value. (Reike et al., 2018) Long-term design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling can all contribute to CE which reveals that some pivotal elements like Industrial Ecology (IE) and merchandise Design and Cleaner Production (CDCP) principles are re-emphasized. (Geissdoerfer et al., 2017) Besides, scientific literature regarding circular economy grows steadily with time, addressing higher maturity in waste management and a more competent conceptual framework for recycling, separation, collection and etc.

During the circular economy transition(CE 3.0), European Parliamentary Research Service 2017 published a study towards a circular economy. It examines waste management, challenges of waste management, and waste streams, such as municipal waste, packaging waste, food waste, and bio-waste, in the EU's Circular Economy Action Plan. Wastage valorization is the process of converting organic waste components into more valuable products which has a high probability of helping achieve circular economy goals.

1.2 The Impetus for this Research Study

Global container shipping is estimated to account for around 60 percent of all seaborne trade, which was valued at around 14 trillion U.S. dollars in 2019 and with the percentage being even higher in developing countries according to UNCTAD and Statista Research Department. Given the trend for circular economy transformation and environmental protection to combat global warming, we can expect a growing number of sustainable business models to be implemented and later reshape global trade and shipping as production and consumption patterns must undergo a wide range of structural changes. However, as explained before, the consequences in shipping demand with the implementation of the circular economy are full of uncertainties. Since the circular economy transition is inevitable but new changes in the amount and the type of cargoes traded and shipped can be massive, we thus choose to narrow the scope and study the change of seaborne trade woody biomass which is representative of an important bioenergy source and core achievement of the circular economy but seldom investigated and quantified within a feasible timeline to envisage its connection with shipping demand in the academic literature. Since IRENE REmap 2030 estimates that about two-thirds of global bioenergy use is traditional, nearly 40% of the world's population relies on traditional biomass for cooking and heating and growing international trade and final use of traditional biomass can be expected as energy demand in developing countries rises over the next two decades with limited access to modern energy, we hereby choose the woody biomass to conduct this meaningful research study and expect to understand what new changes it might make in the maritime sector.

1.3 Research Question and Objectives

The main research question that needed to be answered in this research study is, What is the trade and transport impact of the implementation of the circular economy (CE) on global shipping?

To answer the main research question, the following sub-research questions need to be solved.

What is the conceptual framework of circular economy?

How can we derive insight into the demand for shipping?

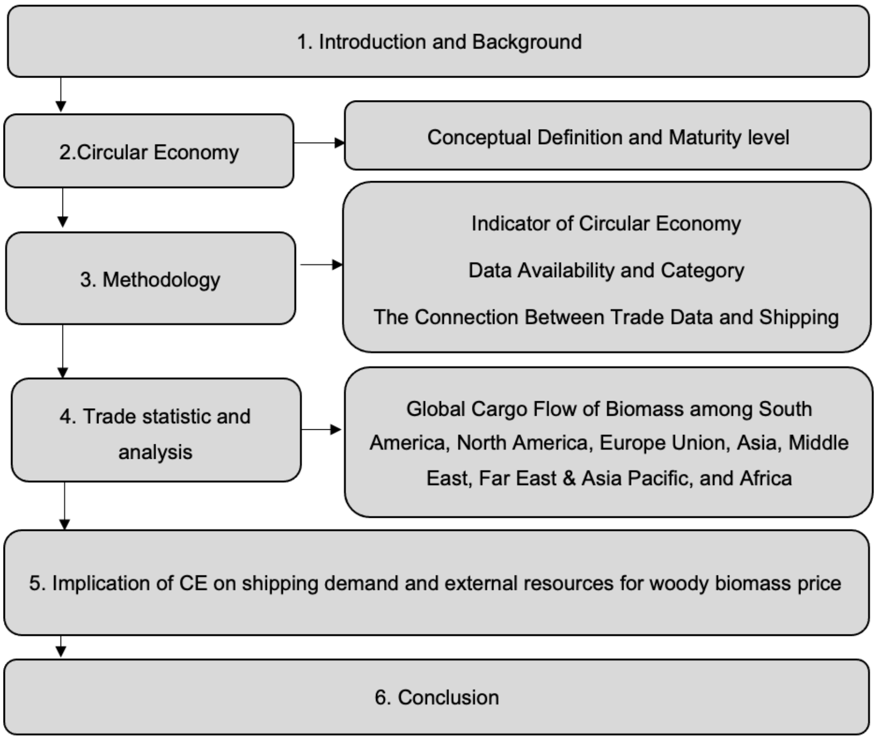
What is the global cargo flow of woody biomass?

The objective of the paper is to investigate the implementation of circular economy and its impacts on the global shipping demand of woody biomass. In order to achieve the objective, it is essential to define the concept of circular economy, maturity level, indicators, historic trade development. After that, the changes in trade can be assessed according to new production and consumption patterns incurred by the circular economy at different maturity levels

1.4 Relevance of this Study

As a strategic decision, the circular economy has been mentioned massively and drawn intensive attention globally. According to OECD Resource Efficiency & Circular Economy Project, new structural changes to the economy will be brought by the implementation of circular economy and it will have great impacts on trade flows of biomass. New production and consumption patterns can reshape different country’s demand for biomass and influence the volume of biomass seaborne trade. In this thesis, the detailed trade and transportation impact analysis of woody biomass will be of interest to the governments, shipping lines, port authorities, traders, NGOs, press & media, and academic institutions.

1.5 Thesis Structure



Chapter 1 introduces the background of the circular economy and the research impetus for the impact of the circular economy on global seaborne trade of biomass. Research questions and objectives are presented in this chapter together with explanations on research relevance.

Chapter 2 presents the conceptual background through an in-depth literature review on the refurbished concept of the circular economy. Firstly, we have a close look at the concept of the circular economy and its evolution over the years. To make a clear definition of circular economy, relevant works of literature are studied and reviewed with the defined most important disciplines of the circular economy. After that, we conclude with a matrix containing the highly cited literature from all continents and explain the core foundation for developing the conceptual framework on the circular economy and framing the circular maturity level to study its impact on biomass global trade.

Chapter 3 is target to elaborate the methodology approach of the study with biomass trade analysis and introduction of the connection between trade data and shipping to answer the research question. It starts with explaining the amount of biomass traded and shipped for energy production that can be considered as the core achievement of circular economy and introducing the available type of data and category for the analysis. With a comprehensive process for the data analysis, the connection between trade data and shipping will be brought out with proper consideration of the limitations of trade data and reliability.

Chapter 4 is about the results and analysis of the outcome in the previous chapter - trading analysis and summary. It illustrates the results of the trade analysis performed for biomass through aggregated trade data at the regional level. Together with the consideration on circular economy maturity level at each region and future transition, all data results are compiled and visualized to answer the research question - what is the cargo flow of biomass, and how is the trade flow aligned with circularity implemented in selected regions.

Chapter 5 will carry out the topic on the implication from external recourses for price fluctuation - the ratio of value per volume from all available resources and its related historical development - which projects the most interesting part of this thesis. Though the real market is more diverse and dynamic and the external resources might consist of dynamic factors from the political, economic, legal, geographical perspective, we mainly focus on the upstream supply of woody biomass.

Chapter 6 will discuss the implication of the circular economy on the shipping demand of biomass. It is noticeable that under the right conditions, biomass can serve as a bridging solution towards a carbon-neutral economy when there are not enough alternative products but more sustainable technologies available. Thus, the demand for biomass either from domestic resources or from external resources via shipping or aviation is indispensable not only in the implementation of the circular economy but also during the transition of the circular economy.

Chapter 7 will conclude all of the key findings to answer the research questions and outline the limitations of the current study and make suggestions for further research in the context of circular economy implication on the global trade of biomass via shipping.

2. Circular Economy

2.1 Circular Economy Definition

The circular economy is a refurbished concept and there is no clear conceptual framework visible over the years. (Yuan et al., 2008; Lieder and Rashid, 2015). Confusion on the concept of the waste hierarchy and the meaning of R's-imperative in value retention has existed for a long time. (Kirchherr et al. 2017) We assume CE as a transformative concept required a closer look at its historic and geographic evolution to define the characterization of the concept in terms of maturity. To overcome this conceptual uncertainty, I concluded 72 literature contributions based on what was analyzed in Reike et al., 2018 for the main principles of the circular economy. In brief, waste management and environmental sciences, reverse logistics and closed-loop supply chain management, product design and cleaner production, industrial ecology, and circular economy 2010+ are all derived from these contributions. Authors who have been cited more than 50 times are bolded, while papers that have been cited less than five times are not counted. Except for the most recent papers (2010-2020) and a few papers from Asia, in Table 1 literature review of circular economy and five main disciplines, all relevant perspectives have been covered.

Table 1 Literature Review of Circular Economy and Five Main Disciplines

Main Disciplines	**Literature Review of Circular Economy**
1. Waste Management and Environmental Sciences (WM)	**Peng et al. 1997**; Price & Joseph 2000; **King et al., 2006**; Gerrard & Kandlikar 2007; Miller et al., 2002; Yoshida et al., 2007; **Allwood et al. 2011**; Kazerooni Sadi et al. 2011; Hultman & Corvellec 2012; Jones et al. 2013; Rusjanto 2010; Xin et al. 2014; Diener & Tillmann 2015; Worrell & Reuter 2014;
2. Reverse Logistics and Closed-Loop Supply Chain Management (RL/CLSC)	**Thierry 1995**; **Fleischmann et al. 1997**; **Guide et al. 2003**; De Brito & Dekker 2003; **Blackburn et al. 2004**; **Mitra 2007**; **Srivastava 2008**; Fernández & Kekaele 2005; Amelia et al. 2009; **Defee et al. 2009**; **Jayal et al. 2010**; Badurdeen et al. ,2009; **Wang & Hsu 2010**; Kuik et al. 2011; Rahman & Subramanian 2012; García-Rodriguez et al 2013; Hazen et al. 2012; **Hassini 2012;** Loomba & Nakkashimi 2012; Nagalingam et al. 2013; Romero & Molina 2013; Agrawal et al. 2015; Sihvonen & Ritola 2015; Silva et al. 2013; **Govindan et al. 2014**; Van Buren et al. 2016; Fercoq et al. 2016; Sinha et al. 2016;
3. Product Design and Cleaner Production (CDCP)	**Jawahir et al. 2006**; Rahman et al. 2009; **Gehin et al. 2008**; Ingarao et al. 2011; Yan & Wu 2011; Xing & Luong 2009; Bakker et al. 2014; Yan & Feng 2014; Go et al. 2015; Den Hollander & Bakker 2012

4. Industrial Ecology (IE)	**Ayres & Ayres 1996**; Kazazian 2003; Roine & Brattebo 2003; Francis 2003; Cohen-Rosenthal & Musnikow 2003; Stahel 2003; Li 2011; **Stahel 2010**; **Graedel et al. 2011**; Liu et al. 2016; Stahel & Clift 2016
5. Circular Economy 2010+ (CE2010+)	**Geng et al. 2012**; Bilitewski, 2012; **Su et al. 2013**; **Ghisellini et al.** 2014; Lieder & Rashid 2015; **Stahel & Clift 2016; Reike et al. 2018; Korhonen et al. 2018;**

Adapted from source: Reike et al., 2018

This thesis presents 10R's hierarchy of circular economy value retention options, which was developed by Vermeulen et al in 2018. Produce and use, as well as concept and design, are two product life cycles and have their own hierarchies, which can be further divided and grouped into three loops according to a span of time (short, medium-long, long). In the 'produce and use' life cycle, resources are used to produce and consume a product, and also to recycle or dispose of it after use while the other lifecycle 'concept and design' means evolution from original design to a more sustainable design including prototyping and adjustments through production process optimization and better application (Kuik et al., 2011; Nagalingam et al., 2013) (Reike et al., 2018)

Table 2 Final 10R Hierarchies and Value Retention Options

Loops	R- Hierarchy	Value retention option
Short	R0	Refuse
	R1	Reduce
	R2	Resell/ Re-use
	R3	Repair
Medium Long	R4	Refurbish
	R5	Remanufacture
	R6	Repurpose
Long	R7	Recycle Materials
	R8	Recover (energy)
	R9	Re-mine

Source: (Vermeulen et al., 2018)

Table 3 R-imperatives for Circular Economy in Targeted Academic Literature

#Rs	WM	RL/CLSC	CDCP	IE	CE2010+
3Rs	4	3	2	0	6

4Rs	2	6	0	6	0
5Rs	6	6	3	4	0
6Rs	1	7	4	0	0
7Rs	0	2	0	2	0
8Rs	0	1	0	0	1
9Rs	0	3	0	0	0
10Rs	1	0	1	0	0

Source: (Reike et al., 2018)

Surprisingly, according to our observation, CE2010+ literature is dominated by the 3Rs - namely reduce, reuse, and recycle which are the major concepts for eco-friendly processing of products - while in waste management that 5Rs clearly triumph. 4Rs, 5Rs, or 6Rs are frequently use in RL/CLSC but in general 5 R's are usually given in a clear hierarchy and best defined across all principles, and 7Rs- 10Rs are far less used. (Vermeulen et al. 2018) In this thesis, we hereby consider 3Rs as a standard benchmark during the period from 2000 to 2030 as it is a widely recognized principle of sustainability. Detailed conceptual explanations on the 3Rs are as below:

'Reduce' is used in three different ways: consumer-focused, producer-focused, and as a generic term. As Francis (2003) points out, it is about eliminating product waste, while others believe it is about all stages of the product life cycle. (Ghisellini et al., 2014) We can get some hints by observing desired consumer behaviors, such as using purchased products with more care and less frequency, or making repairs to prolong the life of purchased products in repair shops. Den Hollander and Bakker (2012) included participation in the 'sharing economy' as they expect more effective product use through pooling while in most cases, however, 'reduce' is explicitly linked to producers and their role in the 'concept and design' life cycle, meaning using less material per unit of production.(Jayal et al., 2010)(Lieder and Rashid, 2015)(Roine & Brattebo, 2003) (Sihvonen and Ritola, 2015)(Worrell and Reuter, 2014).

A second consumer of an item that requires little or no adaptation and functions as a new item for the same purpose is considered to be a 'reuse'. This means that the item does not require any refurbishment, reworking, or repair. (De Brito and Dekker, 2003)(Bakker et al., 2014; Ghisellini et al., 2014) As for the consumer, it means buying a nearly new or never-used second-hand product, possibly after some minor quality improvements. Such reuse can also happen in economic activity through collectors and retailers. (Agrawal et al., 2015) Direct re-use of unsold or returned products as well as products with damaged packaging can also be included in this category. (Romero and Molina, 2013)

Nevertheless, when it comes to usage frequency and confusing usage, 'recycling' is at the top. 'Recycling' represents the processing of shredding, melting, and other methods to separate pure materials from mixed streams of post-consumer products or post-producer waste streams. (Graedel et al., 2011). Essentially, recycled materials do not retain any of the original product structure and can be re-applied anywhere as secondary materials, according to the concept. (Worrell and Reuter, 2014) Stahel (2010) emphasizes that recycling of production wastes from end producers or component producers can also occur in business-to-business relationships. This is so-called primary recycling, which is opposite to secondary recycling, where materials are not mixed and waste collectors are able to collect products that have reached the end of their lifespan.

Considering the scope of this study is about examining the impact of circular economy development on global shipping of biomass, we need to have a comprehensive understanding of the connection between circular economy at defined ten different R Hierarchies and globally traded biomass. As we move into the next chapter, we will take a look at the big picture and then narrow down the scope of circular economy adoption at fragmented 3Rs within a feasible timeline to assess its impact on the sea transportation demand. We will explore historical global trade data and price fluctuations of generic woody biomass cargo flow and its main components after the next chapter because international trade is the driving force behind the shipping industry.

2.3 The Connection Between Circular Economy and Global Traded Biomass

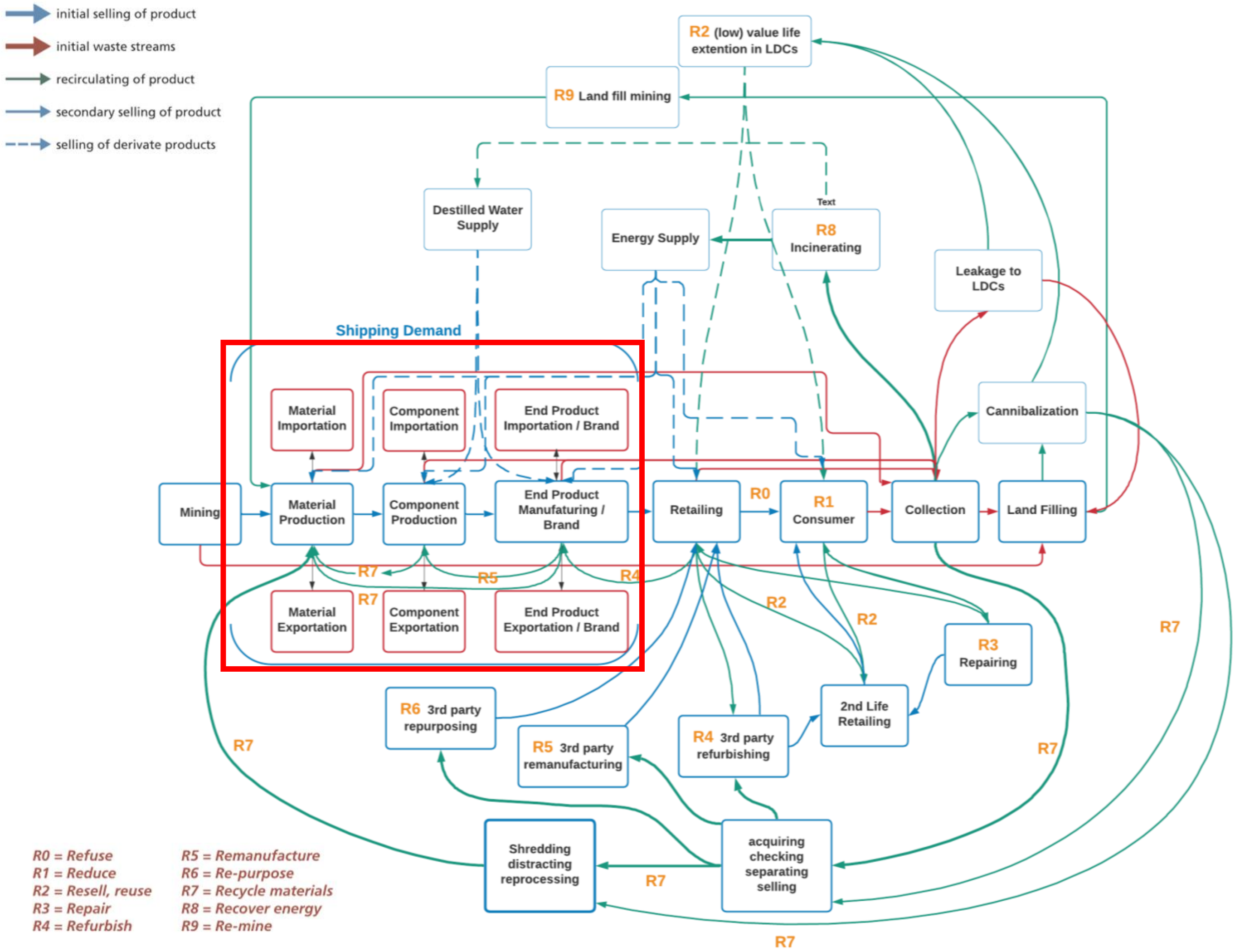


Figure 1 Circular Economy Retention Options in the Product Produce and Use Life Cycle

Adapted from source: Reike et al., 2018

The above flow chart shown in Figure 1 describes the circular economy retention options in the product production and use life cycle in which blue arrows showed the initial selling of products, green arrows indicated the possible recirculating of products and red arrows represented the initial waste streams. Moreover, possible connections between global seaborne trade and circular economy at different R Hierarchy are marked within the red square area. Outsides the red square area and mainline from mining to landfilling are the connections between secondary selling of products and selling of derivative products that are linked by the blue dotted line and green dotted line.

Generally speaking, the selling of products begins at mining and ends with the filing of used end products, which consist of different components that are made from various raw materials. Given the possibility of resource scarcity and technical bottlenecks in the manufacturing of materials, components, and end products, shipping demand may arise in countries with comparative advantage or that require products from other countries to meet their domestic demand. When there are more possibilities to recycle raw materials and end products and remanufacture end products from recycled components at a reasonable cost during product production and use life cycle as shown by the green arrows within the red square area in the flow chart, shipping demand might fluctuate in line with the new changes in demand under the impact of CE implementation. In other words, when the demand for new materials and components reduces via more recycling, we might expect the reduction of import quantity for those linked materials and components.

Besides, links among material production, material import and export, and material recycle or among the end producer, component manufacturers, represented multiple new stakeholder groups' interests will be under the impact of CE and fluctuations of shipping demand. Except for direct importers and exporters, third parties such as terminal operators engaged in transportation and some recirculation activities, for instance, might suffer from the reduction of cargo flow. All these mentioned factors exist in the evolvement of a circular economy and study its separate impact on global shipping demand indicating complex interactions between different parties and each social actor will have its own perspectives, capabilities, and constraints, as well as its own strategic strategy development.

As a renewable energy source, biomass is one of the world's most important ones. Biomass can be used as a feedstock for a range of different liquid and solid fuels in addition to just being burned directly for energy (biofuels). Instead of relying on intermittent sources such as wind or solar power to generate heat and power, biofuels can be transported and stored. Global interest in bioenergy development is increasing due to biomass's many advantages, as well as the need to curb climate change, reduce dependence on fossil fuels, and implement the circular economy. (Proskurina et al., 2017) With the principle to embrace simplicity in complexity, I customize the flows in Figure 2 to better illustrate the supply and demand framework of biomass. Biomass energy comes from two different sources: primary bioenergy, which is produced on agricultural land or in forests, and biomass residue, which is produced as a by-product of food and wood products throughout their supply-and-demand chains.

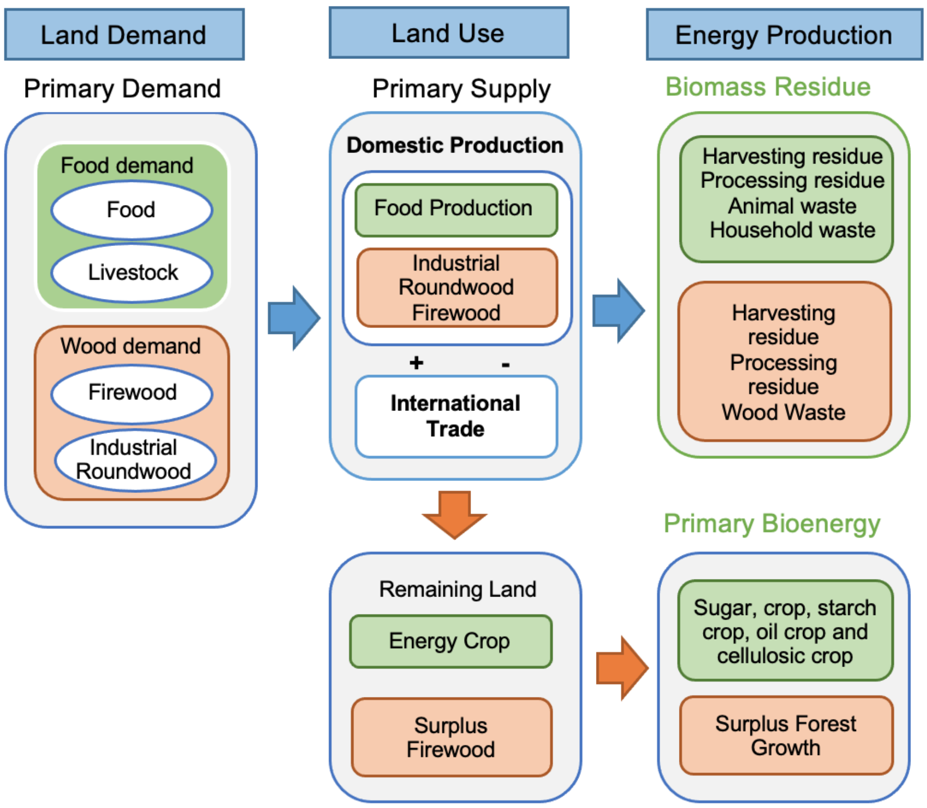


Figure 2 Cycles for Land Demand and Energy Production

Adapted from source: Global Bioenergy Supply and Demand Projections - A Working Paper for REmap 2030

Primary bioenergy production from agricultural resources is constrained because energy and food crops share the same land resources. Crop production determines the amount of land cultivated, the food crops raised, and the yields. According to the demand-supply cycles for land demand and energy production, each component mentioned in the chart can transmit messages to the market to either increase or decrease their prices. Thus, as raw materials for energy and food, the price of agricultural commodities are linked to the price of end product bioenergy and biomass. Besides, It is also important to note that the allocation of land is dynamic and influenced by factors such as favorable agricultural policies and investments, as well as modern technology and management techniques to increase crop yield. However, to meet their food and energy needs, not all countries have sufficient land resources or advanced technologies. Hence the inherent land resources of each country will determine its original demand for wood import and export and the implementation of a circular economy that increases energy efficiency from waste has either an increasing or decreasing impact on biomass shipping demand. Biomass will be imported from other countries if domestic resources are not sufficient to meet bioenergy demand. The reverse is also true: If a country has excess land after it has met all of its domestic food and bioenergy needs, it is assumed that its remaining resources could be used for export to other countries. There are a number of examples of industrialized countries such as the EU, the United States, and Japan which domestic biomass production cannot meet the demand and count on import. In the meantime, some regions of Sub-Saharan Africa and Latin America have biomass production potential that exceeds local demand. When fossil fuels can be replaced by local biomass fuels, local use of biomass is often more cost-effective than exporting. As a result, biomass imports will only account for a small portion of global energy consumption.

In the later assessment of this thesis, woody biomass is prioritized in data analysis to study its implications on seaborne trade because it accounts for nearly half of biomass energy (44 percent). In addition to woody biomass, liquid biomass, herbaceous and agro-biomass, fruit-based biofuels, new commodities, and other biodegradable wastes can also be included in seaborne trade biomass but they are excluded from this thesis study scope. (Alakangas et al., 2011) Similarly, cycles for land demand and woody biomass production as Figure 3 can explain the connection between land resources and woody biomass production. International trade of woody biomass components can either increase or decrease as a result of the circular economy, which represents an increase in the reuse of wood waste for energy production.

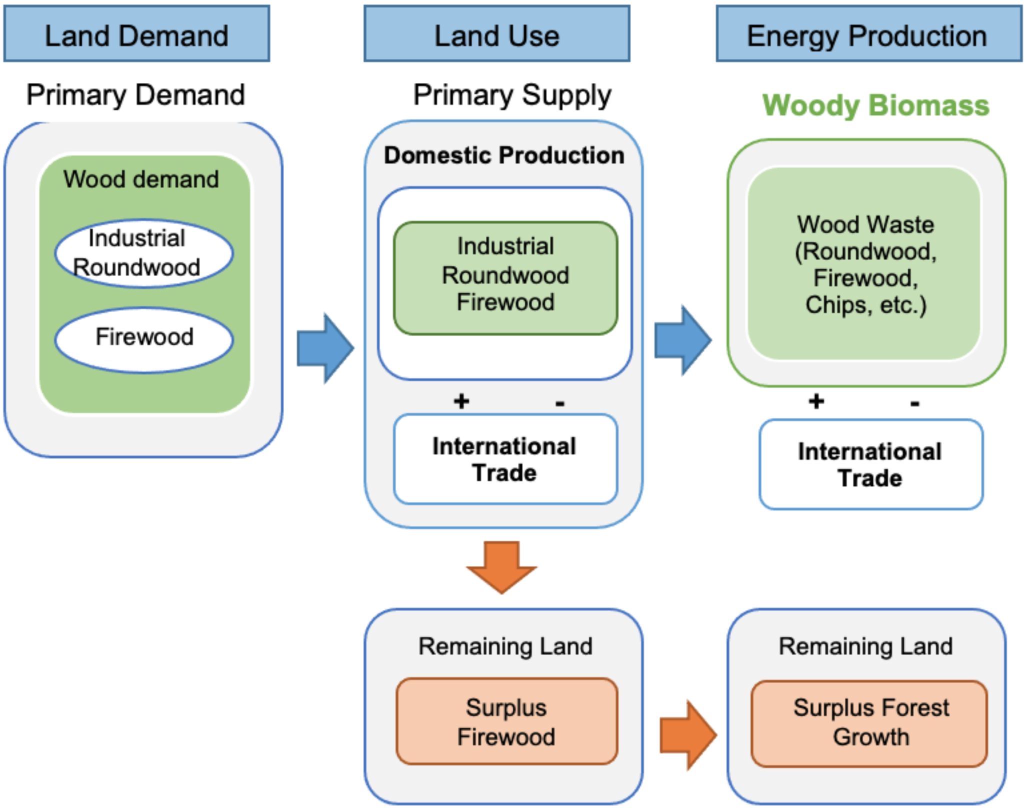


Figure 3 Cycles for Land Demand and Woody Biomass Production

Adapted from source: Global Bioenergy Supply and Demand Projections - A Working Paper for REmap 2030

2.4 Classification of Maturity Level and Alignment of Circular Economy

After using the synthesized typology of ROs as a starting point to understand their own possibilities in CE and connections with biomass shipping demand, we try to classify the maturity level of the circular economy and define the alignment of circular economy among different international organizations' objectives. Thus, we established maturity levels based on the different engagement of CE contributions in table 4.

Table 4 Maturity Level of CE Contribution

Maturity Level	Concept	Description
1	Non or Hardly attention	Failure or great gap in CE contribution
2	Isolated initiatives	Isolated project and initiatives for CE contribution
3	Multiple coordination initiatives	Inconsisiteny in the management of CE model
4	Standard contribution	Standard CE business model implemented throughout the organization
5	Ambition to contribute	Company is the ambassador in all processes with prominent focus on CE business and continuous improvement on CE business model implementation

Adapted from source: Tuinstra et al., 2020

As each maturity level is based on the different engagement of CE contributions, we follow the below principles to define its value (Tuinstra et al., 2020)

Maturity Level 1: The delivered value of circular economy depends on a small number of individuals and no formal structure or plans. Within the organization, there is no clear focus on contributing to making the more circular value chains and no running projects or attention to circularity is included in the business strategy.

Maturity Level 2: Different tactics and approaches are used inconsistently and hence there is no coordination and different tactics and approached are used as different individuals' initiatives. However, the company in isolated places in the organization are in general more active in circular activities.

Maturity Level 3: Best practice examples are evident and their delivered value is more visible and can be tracked more easily. There is attention for circularity within the management team, initiatives are increasingly being coordinated and more talk of the development of a certain degree of standard in thinking and acting. Some pilot projects have been completed.

Maturity Level 4: An unambiguous community approach has been adopted and the organization has fully embraced thinking and contributing to circular value chains. The R hierarchies have been initiated and shaped in all layers of the organization. Contributing to circular value chains is part of company strategy and more visible efforts and delivered values are embed throughout the organization strategy.

Maturity Level 5: The framework of continuous improvement for contributing to the circular business model has already been successfully implemented with positive outcomes and values. All R hierarchies have been developed in such a way that growing the circularity of value chains has become the core competence of the organization. Besides, the organization and its employees serve as a model for other companies in and outside the value chains where it is active and support others in the further development of their contributions.

Additionally, it is important to have a discussion on various scales, such as the global economic system and national economic system; value chains of interconnected companies; international organization objectives; individual business firms; and product scale.

In this context, we can find the objectives of the international organizations who support circular economy have some different inclinations (shown in Table 5) according to CICERONE Horizon 2020 but they all considered a very high level of alignment with CE definition and broad involvement of policymakers, industry, education and other stakeholders from local to global. Despite the fact that all international organizations hope to create a circular society, only the G7/G20 outlines all of the project's objectives. Only half of the organizations mention three objectives, including reducing resource consumption or sustainable production, supporting economic growth, and protecting the environment, while the G7/G20 and PACE consider improving waste management as the primary objective. (Renault et al., 2019)

There is no standard benchmark to quantify CE maturity and measure alignment at a national level, as we discussed earlier. Numerous factors and scales have been employed in various academic publications, but no final conclusion can be drawn at this time. The links among material production, material import and export, and material recycle or among the end producer, component manufacturers, and intermediate component import and export are explained briefly in chapter 2.3. These relationships involved multiple new stakeholder groups with dynamic and complex interrelationships which are different to define and quantify. And that's not even mentioning connections between unrelated third parties involved in terminal transportation and byproduct recirculation. Further research is needed to fill in the gaps. What we can do is to focus on the keywords that international organizations have provided in order to get a sense of where the maturity and alignment of CE stand at a regional level and what might be going on.

Table 5 The Objectives of The International Organizations and CE Alignment

Objectives	Improve waste management	Reduce resources consumption/ sustainable production	Climate protection	Support economic growth	Protect the environment	Establish a Circular society/Education/Dialogue
G7/G20	✔	✔	✔	✔	✔	✔
OECD				✔		✔
UN Environment		✔			✔	✔
PACE	✔	✔				✔
UNIDO				✔	✔	✔
WRFA						✔

Adapted from source: (Renault et al., 2019)

3. Methodology Approach

The trade data from WITS and UN COMTRADE sources with 6 digit HS code was used to determine the import and export volume of biomass. Overall trend analysis was based on each 5-year period from 2000 to 2020. Obtaining reliable data to quantify biomass seaborne trade flows can be problematic as biomass in various forms can be found in a large number of cross-border streams. Due to the fact that our focus is on shipping demand, while it is difficult to determine whether these streams of biomass are raw materials to be processed or finished products themselves, we still can standardize the trade volume into metric tons and measure the price in US Dollars per ton.

When it comes to the measurement of woody biomass components, the trade quantities are recorded in different units such as cubic meters, kilograms, and liters. Considering trade statistics shall be based on numbers within the same unit, we use conversion factors in Table 6 to standardize different units.

Table 6 Wood Unit Conversion Factor

Previous Unit	Conversion factor	Standard Unit
1 kilogram	0,001	0,001 metric ton
1 liter wood charcoal	0,0003	0,0003 metric ton
1 cubic meter roundwood	0,746	0,746 metric ton

Adapted from source: Forest Research 2021

Moreover, a multi-regional generalized RAS technique is applied for shipping demand estimation on some specific origin-destination (O-D) matrix as international trade streams mostly happen at the regional level. The O-D matrix we established consists of seven regions - South America, North America, European Union, Africa, Middle East, Asia, Far East, and the Asia Pacific – and the future implications are based on the latest trade data in 2019. In other words, this RAS method is based on total import and export quantities of seven regions mentioned before, and the overall container flow per biomass product-subcategory was calculated by summing the flows of every regional aggregated import and export data with a starting matrix that reflects the latest existing connections in 2019.

Obviously, to determine the most realistic and detailed trade flows, we must categorize woody biomass into six subcategories according to different component resources to study their generic trade development and outstanding implications on shipping demand. Besides, the specific ratio of price fluctuation with all available resources such as comparative advantages, favorable political issues, and so forth will be discussed.

3.1 Indicator of Circular Economy

The European Commission provided us with a list of possible indications (EC, 2018a) to illustrate macro-scale indicators of the circular economy. EC's proposal for measuring CE progress in EU member states is the CE monitoring framework which is considered as a suggestion for macro-scale indicators. (EC, 2018a) The 'CE monitoring framework' is divided into four sections: production and consumption, waste management, secondary raw materials, and competitiveness and innovation and all of these sections are associated with the priority areas from the CE Action Plan in Europe: plastics, garbage, critical raw materials, construction and demolition, and biomass and bio-based products (EC, 2015a). The EC proposal presents ten indicators that are supported by existing information from Eurostat, the Raw Materials scoreboard, and also the resource efficiency scoreboard (EC, 2018a). (Moraga et al., 2019)

Table 7 Indicator of Circular Economy

Indicator	Sub-indicator	Measurement Type
1. Self-sufficiency for raw materials	-	Indirect CE
2. Green public procurement	-	Direct CE
3. Waste generation	Generation of municipal waste per capita Generation of waste per GDP Generation of waste per DMC	Direct CE
4. Food waste	-	Direct CE
5. Recycling rates	Recycling rate of municipal waste Recycling rate of all waste	Direct CE
6. Recycling / recovery for specific waste streams	Recycling rate of overall packaging Recycling rate of packaging waste by type Recycling rate of wooden packaging Recycling rate of e-waste Recycling of biowaste Recovery rate of C&D waste	Direct CE
7. Contribution of recycled materials to raw materials demand	End-of-life recycling input rates Circular material use rate	Direct CE

8. Trade in recyclable raw materials	Imports from non-EU countries Exports to non-EU countries Imports from EU countries Exports to EU countries	Indirect CE
9. Private investments, jobs and gross value added	Gross investment in tangible goods Number of persons employed Value added at factor cost	Indirect CE
10. Patents related to recycling and secondary raw materials	Patents of recycling and secondary materials	Indirect CE

Source: Moraga et al., 2019

As the criterias in this thesis are all about seaborne trade, we only focus on the trade in recyclable raw materials as the CE indicator in Table 7, which means the trade flow within EU countries and among non-EU countries will be studied further in the following chapter.

3.2 Data Availability and Category

Earlier studies have shown that limited statistics on the global trade of biomass (Heinimö, 2008; Heinimö et al., 2013) while the markets for biomass are developing as it is one of potential future energy source – for example, In 2004, the direct trade of biomass accounted for less than a fourth of the total global bioenergy trade but in 2011 it had increased to 45% (Heinimö et al., 2013) – and in some EU countries the bioenergy use has already been largely based on imported biomass, and some countries are planning to make a major increase in biomass import for energy purposes. But determining the international trade volumes of biomass has been problematic for a variety of factors, including:

First, trade statistics do not distinguish between energy and raw material as the end use of the materials. Biomass components, for example, are traded for their material value, but they might ultimately be used in energy production. Second, biomass streams can be used in a variety of ways and there is no way to tracking them directly. Third, some biomass fuels, such as bio-ETBE, are recorded in aggregate form by different trade statistics which causes data ambiguity. Forth, there are some new commodities, such as which will be soon internationally traded but has no clear CN code. As an example, torrefied biomass (pellets or briquettes) can be classified separately under CN codes 4401 31 and 1213 000 which makes it much more difficult to collect and analyze trade data and statistics. (Alakangas et al., 2011)

Heinimö and Junginger carried out the first analysis of the global status of direct and indirect energy biomass trade within the IEA Bioenergy Task 40 from 2004 to 2006 and other comprehensive biofuel market analyses have been published by Lamers et al. for liquid and solid biofuels. However, they focused only on direct international trade of solid and liquid biofuels without including indirect trade and measuring the impact of biomass international trade on shipping. (Heinimö et al., 2013)

Considering that we are analyzing shipping demand, we concentrate on the trade volumes for woody biomass and its components as subcategories in order to capture all direct and indirect flows of trade. This is possible and feasible because CN codes include categories for all types of products and biomass-related cargoes are transported by containers in seaborne trade no matter directly or indirectly. In Table 8 we can find the main CN codes for woody biomass and wood fuels based on 6 digit CN code.

Table 8 Woody Biomass Components and CN Codes

Woody Biomass Components	**CN code(s)**
Round wood	440320, 440399, 440410
Chips	440121, 440122
Sawdust, Wood waste and scrap	440130
Fuel wood	440110
Charcoal	440200
Wastepaper (not recyclable)	470790

Adapted from source: (Alakangas et al., 2011)

Furthermore, we acknowledge that cross-continental trade is the most common form of seaborne trade in the methodology. To study trade impacts on container shipping patterns, we divide global cargo flow of biomass among seven regions - South America, North America, European Union, Africa, Middle East, Asia, Far East and Asia Pacific.

3.3 The Connection Between Data and Shipping

International trade volume and price is driven by the demand of different countries and influenced by several external factors such as national comparative advantage, political issues, economic growth, technological innovation, social and environmental development, currency rate, legal terms and regulations and etc but only international trade is the deep-rooted reason for shipping. Thus, we build up the direct connection between aggregated import and export volume in metric tons at the regional level with shipping demand across continents.

With the help of WITS and UN COMTRADE database for import and export quantity and trade value per product category per year, we are able to create an international framework for demand and supply at the country's level for the past 20 years. Given the fact that cargo shipping flows of international trade generally cross continents, each country's international trade supply and demand represented by import and export volume can also link the main generic shipping flow of biomass-related cargoes by aggregating national import and export quantity into a regional level. The connection between country and region can be found in the appendix at the end of the thesis. On the basis of the number of tons of biomass-related components that are imported and exported per region, and the assumption that all biomass-related cargoes are shipped by sea as it is the most cost-effective method compare to air, and each region is equally connected to other regions via shipping, we can deploy RAS method to envisage shipping demand fluctuations. In other words, we assume there is no existence of any region in the world without shipping connection and international trade with other regions. Also, there is trade and shipping demand within each region. Since all regional connections are treated equally, even if some are more important than others, we assign the same weight to all of them. We must admit that on a smaller scale (country level) this might lead to an overestimation of cargo flows, but the deviation in our study can be ignored as the estimation of connections is on a larger scale (regional level).

As described before in the methodology introduction, the overall cargo flow was calculated by summing the flows of every regional aggregated import and export data under defined product categories with a starting matrix that reflects the latest existing connections in 2019. The basic quantity unit of container flow is measured in metric ton which can be easily converted into the number of containers TEU - unit of measurement can be used to determine cargo capacity for container ships and terminals - according to the relevant container type and TEU ratio. Apart from that, the total value of trade which measures cargo value in USD per ton can also reveal the sensitivity of container shipping costs on trade. Shippers are still motivated to export despite skyrocketing freight costs in situations where the cost of container transportation is very low relative to the total cargo value and the international market is growing. On the contrary, in situations where the cost of container transportation makes up a large portion of the cargo value and alternative products can be found in the local market, this type of product's globalization level will lag behind. Thus, the data of import and export quantity and regional product price on average can be inferred to the panorama of biomass seaborne trade and its impact on cargo container shipping flow.

4. Trading analysis and summary

Since the trade value and quantity data of national import and export can be aggregated to reflect the global biomass seaborne trade among regions, we set each 5-year period from 2000 to 2020 as a benchmark timepoint and study the generic trade trend for aggregated biomass components which includes seven main category - round wood, chips, sawdust, wood waste and scrap, fuelwood, charcoal, non-recyclable wastepaper.

Trade statistics for aggregated biomass components enable us to understand the trade pattern and its shipping scale in a big picture over the past 20 years but it might be too generic for specific components. In order to complete the structured analysis of biomass and foresee specific components' impact on shipping, we deploy the RAS method for each biomass component and summarize these components that have the most outstanding impacts on shipping in terms of volume and interpret the price fluctuations with external resources to gain more insights on future trend. The following sections will firstly make generic trade statistics and analysis and then discuss the specific cargo flow component by component.

4.1 The Generic Trade Analysis for Aggregated Biomass Components

According to the statistic of WITS and UN COMTRADE database, the percentage of regional aggregated biomass components export in the total global export volume is listed in Figure 4. Given that the data for trade quantities is incomplete, we have to make some estimations and fulfill the missing data by calculating the average product price per region and then dividing the total trade value of each country by its regional average price to find the estimated quantities.

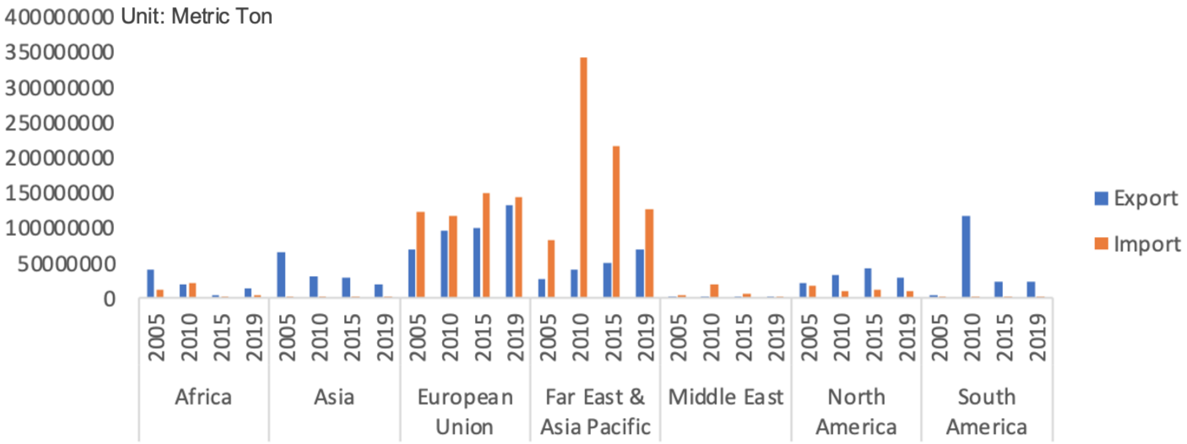


Figure 4 The Overview of Generic Trade Trend for Aggregated Woody Biomass Components

Source: WITS and UN COMTRADE database and own analysis

We can observe from the above Figure 4 that export of biomass-related components have grown rapidly in the Far East and Asia Pacific over the past 20 years, with an export volume share of the world total in 2019 nearly doubling those of 2005, while the European Union continues to be the world's top exporter, increasing its share of global exports from 30 percent to 46 percent. From Asia and Africa in general, the export of biomass-related components dropped dramatically from 28 percent and 17 percent respectively to only 7 percent and 4 percent during the same period. Furthermore, the sudden increase of South American exports in 2010 and North American exports in 2015 is also notable, indicating that these two regions have the capacity (massive land and abundant wood resources) to meet further demand. Especially South America, which in general export less than 10 percent of total world biomass export, was able to support one-third of the global market in 2010. Except for North America's 2015 export boom, the Middle East and North America's export volumes have steadily increased, but their relative share of world export volume is approximately at the same level.

Table 9 The Percentage of Regional Export Volume for Aggregated Biomass Components of Global Export Volume of Selected Regions and Years

% World Export	Africa	Asia	European Union	Far East & Asia Pacific	Middle East	North America	South America
2005	17,65%	28,13%	30,23%	12,18%	0,13%	9,58%	2,09%
2010	5,85%	9,17%	28,19%	12,10%	0,13%	9,73%	34,83%
2015	1,88%	11,47%	40,06%	20,18%	0,37%	16,56%	9,48%
2019	4,49%	7,02%	46,08%	24,22%	0,20%	9,82%	8,17%

Source: WITS and UN COMTRADE database and own analysis

Table 10 The Percentage of Regional Import Volume for Aggregated Biomass Components of Global Import Volume of selected regions and years

% World Import	Africa	Asia	European Union	Far East & Asia Pacific	Middle East	North America	South America
2005	5,06%	1,31%	49,93%	34,21%	1,86%	7,40%	0,24%
2010	4,01%	0,55%	22,73%	66,60%	3,78%	2,08%	0,24%
2015	0,63%	0,72%	38,41%	55,44%	1,65%	2,94%	0,21%
2019	1,37%	0,29%	49,45%	44,40%	0,87%	3,51%	0,10%

Source: WITS and UN COMTRADE database and own analysis

Although there were some fluctuations in 2010 and 2015 when imports from the Far East and Asia Pacific exceeded the European Union, the European Union remained the world's largest importer of biomass-related components in 2019. According to the trade statistics shown in

Table 9 and Table 10, over 60% of the biomass in the past 10 years is imported and exported from the European Union and Asia Pacific regions. The import volume from the Far East and Asia Pacific region is at least twice of export in terms of quantity with export grew stepwise while imports surged in 2010 but reduced dramatically in the last decade. On the other hand, the change in the volume of imports and exports of the European Union is relatively small, but both increase steadily over the past 20 years. Meanwhile, the import volumes have declined in Africa, Asia, the Middle East, North America, and South America in the same period, with the drop in North America being nearly twice as large as the initial volume in 2005. Furthermore, the data on imports and exports reveals the direction of cargo shipping flows, with the European Union and the Far East and Asia Pacific regions being the major biomass shipping cargo destinations that might receive cargoes mainly from the European Union, Asia, South America and the Far East and Asia Pacific regions.

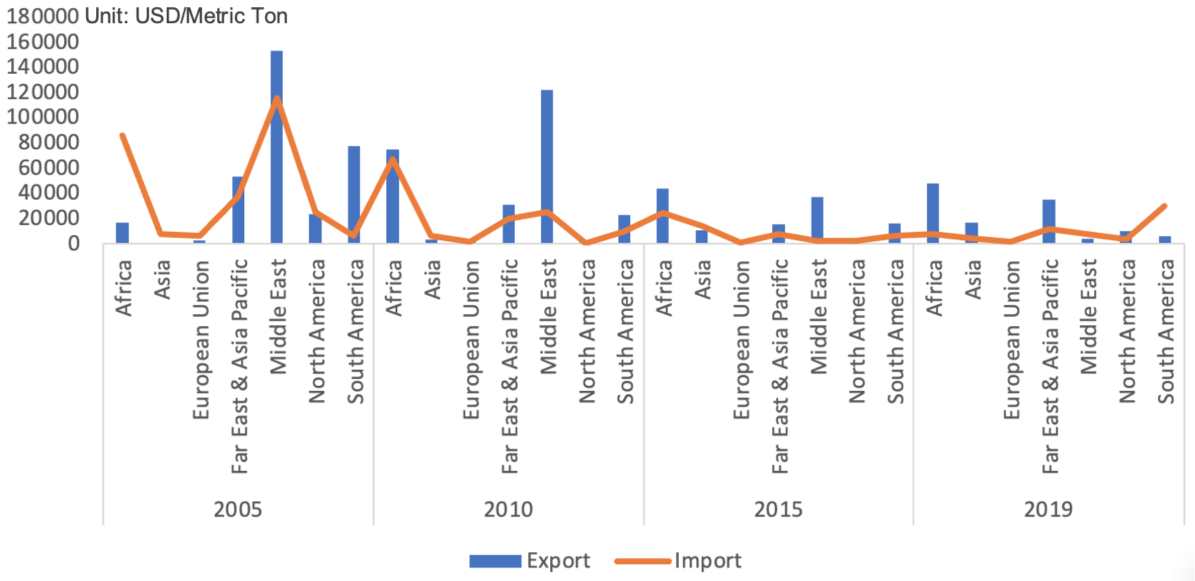


Figure 5 The Overview of Generic Average Price for Aggregated Woody Biomass Components

Source: WITS and UN COMTRADE database and own analysis

Beyond the change in trade volume, the trade value and price fluctuations of aggregated biomass components over the last twenty years are on a path to becoming a global commodity. Import and export price fluctuations in 2019 across regions are clearly much smaller than what they were in 2005, even the gap of import and export price follows the same pattern, as can be seen from Figure 5. Since both import and export prices have fallen in recent 10 years and there remained a gap of production costs among regions, biomass cargoes are more likely to be traded and transported on a larger scale by container ship. Consequently, when the trend described above continues, biomass trade activities and shipping connections between regions in 2019 and onward must be more widely linked, and the new cargo flow can move to alternative regions at a similar price to open the new market when the regional market signal indicates the demand is on the upswing.

However, regardless of whether it is about imports or exports, the container is the only mode of transportation for seaborne trade and regional shipping demand will be affected by the total volume of imports and exports. Thus, for the aggregated biomass components and some specific components that are important in the global seaborne trade, we will study OD pairs further in the chapter that follows to shield some light on their impact on shipping.

In order to further forecast the generic CE implementation impact on biomass related cargo shipping, we firstly use the RAS method to estimate an origin-destination (O-D) matrix and related cargo flow among these seven defined regions. The global cargo flows of aggregated biomass components among regions are expressed in metric tons and summarized in Table 11 and Table 12.

Surprisingly, even the sum of total aggregated woody biomass components cargo flow in Table 11 (587,9 million metric ton) accounted for a small percentage of global sea traffic (about 3%) based on UNCTAD statistic that 811 million TEUs of containers were handled in ports across the globe during the year of 2019 and our estimation that 24 metric tons of cargo normally loaded up in one TEU. (Hari Menon, 2021)

However, we still can expect large cargo flow circulated within European Union and Far East & Asia Pacific with the higher implementation of circular economy and these two regions are still the major exporters to other regions with dominant advantage in terms of trade volume. The Middle East and Africa are relatively inactive actors in both import and export activities compare to South America and North America.

Table 11 The Estimated Future Global Cargo Flow of Aggregated Woody Biomass Components of Selected Regions

Unit: Metric Ton	Africa	Asia	European Union	Far East & Asia Pacific	Middle East	North America	South America
Africa	178.730	123.321	6.433.840	5.691.701	112.831	456.325	13.644
Asia	279.224	192.660	10.051.381	8.891.961	176.272	712.902	21.316
European Union	1.832.161	1.264.161	65.953.346	58.345.675	1.156.632	4.677.794	139.868

Far East & Asia Pacific	962.836	664.341	34.659.769	30.661.789	607.833	2.458.272	73.504
Middle East	7.777	5.366	279.961	247.668	4.910	19.856	594
North America	390.675	269.559	14.063.344	12.441.148	246.631	997.454	29.824
South America	324.942	224.205	11.697.134	10.347.878	205.134	829.629	24.806

Source: WITS and UN COMTRADE for 2019 trade data and own RAS analysis

As biomass utilization is central to circular economy implementation, it's still interesting to see how the growth of biomass-related trade and its subsequent new changes in the shipping sector explains how mature circular economy is. For this reason, we focus on detailed biomass components shipping flow in and out percentages across regions rather than absolute quantity numbers when analyzing main components. To determine which product categories as biomass components are the most important in terms of total import and export volumes as well as which product categories have the greatest growth potential based on historic trade patterns over the last twenty years, we will analyze trade statistics in Figure 6 and discuss this in detail.

Figure 6 Components Share of Global Woody Biomass Total Trade Volume of Selected Regions and Years

Source: WITS and UN COMTRADE database and own analysis

Although the raw data of trade quantity is incomplete and we adjusted it based on some estimations, round wood still made the largest contribution to the global trade in terms of trade quantity and value from 2000 to 2019, according to the world trade statistics shown in Figure 6 based on WITS and UN COMTRADE database. However, round woods share of the world's biomass cargo trade volume rather than value, on the other hand, has been in decline. Correspondingly, the global biomass market had more space for the new increasing cargo flows from chips, sawdust, wood waste and scrap, non-recyclable wastepaper, etc. Wastepaper's upward trend in the Middle East's trading volume and mild development in Europe can be clearly noticed when looking at global trade share over time but its share in North America seems to be relatively stable in the last decade. The trade volume of sawdust, wood waste, and scrap experienced a similar rise happened in the European Union, Asia, and North America regions while the trade value fluctuation in the region of European Union grows more significantly than the region of North America and the change of total trade value in Asia, in general, is too subtle to be observed on a global scale. The regional trade volume development pattern of chips is not smooth and seems to be full of uncertainties, but it is undeniable that chips are the second-largest contributor to the global biomass trade volume, and Africa, South America, and Middle East regions have great potentials based on their historical performance and relatively low total trade value compared to the Europe Union and the Far East & Asia Pacific.

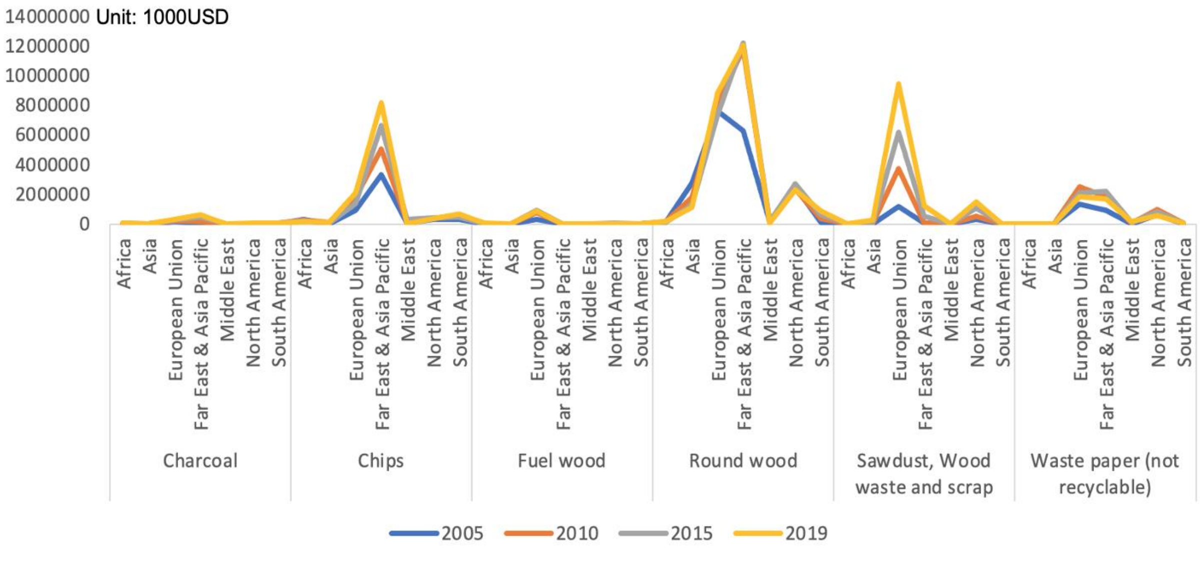


Figure 7 Trade Value Fluctuations of Woody Biomass Components in Selected Regions and Years

Source: WITS and UN COMTRADE database and own analysis

4.2 The Trade Analysis for Round Wood

Round wood's history of trade development over the past two decades appears to be undergoing major shifts in import and export volume of developing regions such as the Far East & Asia Pacific and South America. As clearly indicated by Figure 8, the import volume of round wood in the Far East & Asia Pacific region had been cut down dramatically since 2010 while stable development with mild fluctuations in imports of the European Union can be concluded. South America, Africa, and Asia regions followed the same decreasing trend in their export volume during the same period. Moreover, the import volume except for European Union and the Far East & Asia Pacific regions, in general, fluctuates on a smaller scale with gentle falling in Arica, Middle East, and North America regions and stable development in Asia and South America regions compared to the regional changes in export volume.

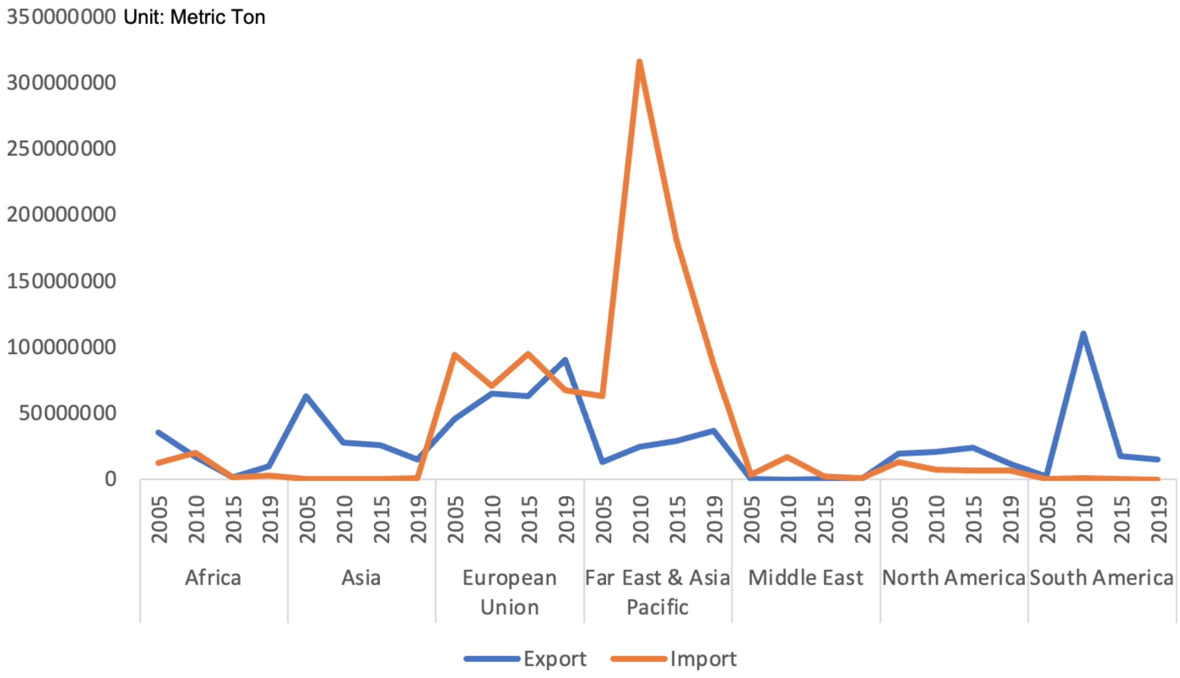


Figure 8 The Overview of Round Wood Trade Volume of Selected Regions and Years

Source: WITS and UN COMTRADE database and own analysis

Africa: The overall decline trend in import and export volume of round wood can be observed in the region of Africa where has dropped by nearly 15% in export share and 5% import share of world trade from 2005 to 2019, though Africa import and export volume rebounded about 4% and 1% separately in 2019 compared to 2015. We here assume that those countries with the largest aggregated trade value in recent years will undergo the major shock of declining demand in the coming years. We found South Africa (42,3 million USD), Congo Republic (26,5 million USD), and Mozambique (24,9 million USD) in terms of export value, and Morocco (11,2 million USD) in terms of import value, are most likely to continue shrinking in total trade values in the coming years, according to our analysis of trade data in 2019.

Asia: From nearly 35 percent to only 8,4 percent of the global market, Asia round wood export has been declining over the last two decades, but Asian import share has remained at a similar level which is roughly 0,4% share of global import volume since 2010 even though their share declined from 0,87% to 0,27% during 2005 and 2010. Given the same assumption that those countries with the largest aggregate trade value in recent years will undergo the major shock of variable demands during the CE transition, we found Russian (about 1 billion USD in 2019) in terms of export value will keep diminishing, while Kazakhstan import value (about 8,87 million USD in 2019) has a good chance of increasing moderately in the long term.

European Union: Compared to the percentage in 2005, the share of European Union round wood export volume in 2019 has more than doubled and reaching 50 percent of the global total export volume. With continuous growth in the share of export volume and rapid recovery in the share of import volume in recent 10 years after a significant drop in 2010, we can still expect major cargo flows in and out to happen within the region as it remains the largest regional exporter and second-largest importer simultaneously. According to our analysis of trade data in 2019, the Czech Republic (0,76 billion USD), and Germany (0,64 billion USD) in terms of export value might keep their upward trend, while Sweden (0,597 billion USD), Austria (0,594 billion USD) and Germany (0,455 billion USD) import value are likely to fluctuate in the coming years. Despite the fact that the share of import volume of the European Union seems to be in turmoil, the share of exports is keeping increasing robustly.

Far East & Asia Pacific: The upward trend for the export volume of round wood and moderately decrease in import volume during the last decade can be seen in the region of the Far East & Asia Pacific but this region is still the largest importer that accounted for 52% of total global import volume and second-largest regional exporter that has more than 20% world share. For the same reason we explained in the European Union region, significant cargo flows in and out of the region can be expected. Furthermore, we notice that with trade record in 2019, New Zealand (2,2 billion USD), Australia (0,43 billion USD), and Japan (0,134 billion USD) in terms of export value have great possibilities of keep growing, while China (6,86 billion USD), Indian (0,58 billion USD) and Vietnam (0,42 billion USD) in terms of import trade value, are most likely to remain at the current level or decrease mildly in the coming years given it has stopped growing since 2010 or 2015. However, Japan's round wood imports, which are the second largest in the region, have been declining for the past 20 years and have not seen a similar increase as other countries during 2005 and 2010.

Middle East: Contrary to other regional changes, the overall trend of both import and export volume of round wood in the Middle East is relatively plain and stagnant. Slight decrease with only 1%~ 2% decrease in the share of global import volume and close to 0,03% share of global export volume. This might be due to the geographic characters of limited forest resources and abundant alternative fuel energy in the region. We still can see Turkey and United Arab Emirates are major exporters of round wood in 2019 with separately 5 million and 2 million trade value. When we cast a look at import value, Egypt Arab Republic (46,7 million USD), the United Arab Emirates (7,5 million USD), and Turkey (4,7 million USD) are the main contributors. Some cargo flows in and out of the United Arab Emirates as it is on the list of both major importer countries and exporter countries.

North America: The overall decline trend of export volume of round wood can be observed with a 4% decrease in global export share from 2005 to 2019 and the regional share of global import volume rebounded about 2,3% in 2019 compared to 2010. We found the within the region United States (1,3 billion USD in 2019) in terms of export value is back to its 2005 record after the fall of total trade value in the last 5 years and the United States (0,12 billion USD) and Canada (0,26 billion USD) in terms of import value, are most likely to continue shrinking in the following years, according to our analysis of trade data in 2019.

South America: The overall increasing trend of export volume of round wood from merely 1,5% to 8,4% share of world total exports in 2019 can be observed in the region of South America but the import volume and share in the global market are limited (less than 0,1% in 2019). However, according to our trade statistics, we found Uruguay (0,67 billion USD) in terms of export value, and Peru (1,58 billion USD) and Jamaica (683,365 million USD) in terms of import value, might keep on the upswing and grow exponentially given its sudden surge of trade values from 2005 to 2020. Moreover, the region of South America made up at least 40% of world export volume in 2010 indicated its potential capacity.

The summary of the historical changes in the regional share of global round wood import and export volume according to the defined CN codes and timeline can be seen in Table 11 and Table 12.

Table 12 The Percentage of Round Wood Export of Total Woody Biomass World Export Volume of Selected Regions and Years

Region	2005	2010	2015	2019
Africa	19,67%	6,34%	1,05%	5,69%
Asia	35,31%	10,61%	15,99%	8,40%
European Union	25,35%	24,49%	39,00%	50,43%
Far East & Asia Pacific	7,42%	9,18%	18,16%	20,49%
Middle East	0,03%	0,00%	0,08%	0,03%
North America	10,78%	7,88%	14,91%	6,56%
South America	1,44%	41,50%	10,81%	8,39%

Source: WITS and UN COMTRADE database and own analysis

Table 13 The Percentage of Round Wood Import of Total Woody Biomass World Import Volume of Selected Regions and Years

Region	2005	2010	2015	2019
Africa	6,60%	4,65%	0,67%	1,69%
Asia	0,87%	0,27%	0,44%	0,47%
European Union	50,52%	16,37%	32,94%	40,86%
Far East & Asia Pacific	33,04%	72,89%	62,55%	52,46%
Middle East	1,73%	3,96%	0,87%	0,44%
North America	7,12%	1,70%	2,37%	4,03%
South America	0,13%	0,16%	0,17%	0,05%

Source: WITS and UN COMTRADE database and own analysis

4.3 The Trade Analysis for Chips

Trade patterns for chips in the Far East & Asia Pacific and the European Union appear to be evolving rapidly. As shown in Figure 9, the volume of chips imported and exported in both regions has increased dramatically since 2005, with minor fluctuations in between. South America regions follows the same increasing trend in their export volume between while its import volume has remained flat since 2005. North America witnessed a drop in exports in the past 5 years while its development of imports seems to be stable. Middle East export volume and Africa import volume have both stagnated since 2005 while Chips export volume has fallen slightly in the African region over the past two decades.

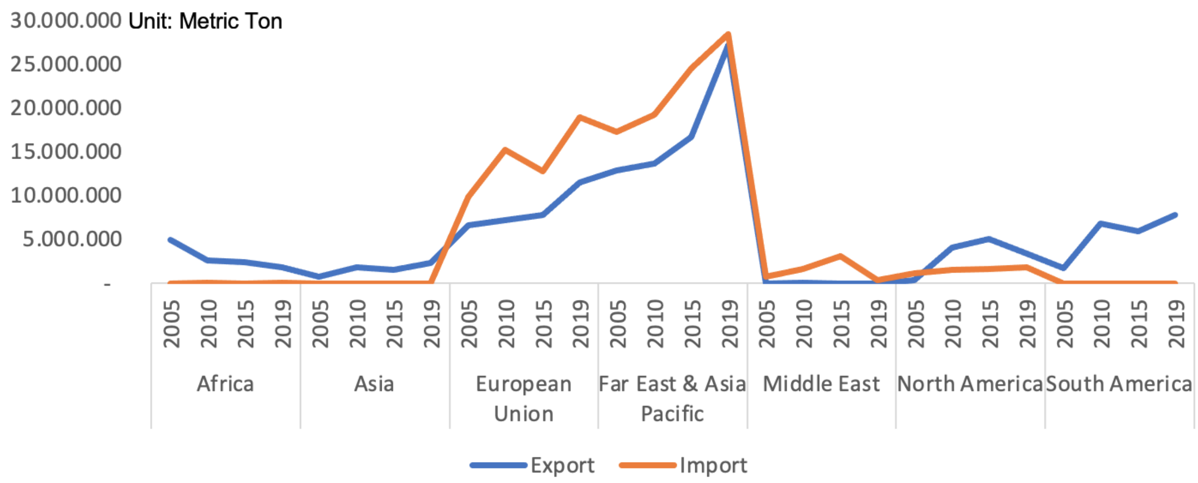


Figure 9 The Overview of Chips Trade Volume of Selected Regions and Years

Source: WITS and UN COMTRADE database and own analysis

Africa: The overall decline trend of chips export volume can be observed in the region of Africa which decreased from nearly 17% export share of the world total in 2005 to only 4,5% share in 2019. As for the import volume, though changes are subtle, its import share grew from merely 0,2‰ of the world total to 0,2% between 2005 and 2019. Given the projected development of Africa, we might have the chance to witness its growth in imports continuously. Thus, we apply the same assumption that those countries with the largest aggregated trade value in recent years will be under the shock of great changes in trade and find South Africa (0,18 billion USD), Eswatini (2,6 million USD), and Gambia (2,3 million USD) in terms of 2019 export value, are most likely to continue shrinking but South Africa (3,3 million USD) and Botswana (2,32 million USD) in terms of 2019 import value might keep its upward trend in the coming years.

Asia: Falling From 28 percent of the global market to 7 percent, Chips export volume has been expanded slightly in volume, but it keeps losing its global market share over the last two decades. During the same period Asian import share of the world, trade has declined from 4,7 percent to almost 0 percent. Besides, according to our analysis of trade data in 2019, we found Russian Federation (1,15 billion USD) in terms of export value will keep diminishing, while Kazakhstan (9 million USD) on the contrary has a great chance to keep rapid growth in export value. Regarding the imports value, Russian Federation (about 2,4 million USD) will boost moderately in a long term.

European Union: Compared to the percentage in 2005, the share of European Union chips in 2019 has increased at least 15% of the global total export volume and 5 percent of the global total import volume and now ranked the largest regional exporter with 46,08% share of world total exports and second-largest importer with 38,07% world share. With the continuous growth in volume and share of the world market, we can still expect major cargo flows in and out within the region and strong interaction with other regions. Based on trade data in 2019, Germany (1,17 billion USD), Czech Republic (0,9 billion USD), and Latvia (0,8 billion USD), in terms of export value are on the top 3 and hence have a higher possibility to follow the upward trend, while Finland (0,18 billion USD) and Portugal (0,15 billion USD) in terms of import value are more likely to grow with fluctuations in the coming years. Even though the share of Chip import in world total seems to be with some slight fluctuations, chips import and export volume is keeping increasing robustly.

Far East & Asia Pacific: The increase in import and export volume during the last two decades can be seen in the region of the Far East & Asia Pacific where the export volume has experienced rapid growth since 2005 and doubled in 2019 to an almost equivalent quantity of imports. Back to the start point year 2005, the import volume of Chips in this region is much larger and now the gap is almost invisible in Figure 9. Still, the largest importer belongs to the Far East & Asia Pacific which accounted for 57% of total global import volume. Meanwhile, it also ranked as the second-largest regional exporter with more than 24% world share. For the same reason we explained in the European Union region, significant cargo flows in and out of the region can be expected. Furthermore, with trade record in 2019, we conclude that New Zealand (2,3 billion USD), Vietnam (2,03 billion USD), and Australia (1,15 billion USD) in terms of export value are on the top and have more chance to follow the generic regional upward trend and keep growing in future, while China (2,39 billion USD) and Japan (2,38 billion USD) in terms of import trade value, the first one will keep strong growth in trade value while the second one is likely to make mild development in the coming years given their historic pattern.

Middle East: Chip exports to the Middle East have remained relatively low compared to other regions. Slight fluctuation with 0,1% changes in the share of global export volume from 2005 to 2019 and sudden drop from 7% to only 0,8% share of global import volume during 2015 and 2019 can be seen in the historic trade development. Possible reasons include the limited forest resources, abundance of alternative fuels, and technical innovation in the area. According to our analysis of trade data in 2019, the United Arab Emirates and Turkey are major exporters of chips in 2019 with separately 54 million and 30 million trade value. When we have a look at imports, United Arab Emirates (5 million USD), and Turkey (35 million USD) are again the main importers in terms of value. Regional main chips cargo flows in and out of the United Arab Emirates and Turkey are predictable.

North America: The import and export North America region overall seems to be constant, though export volume has greater increase during 2010 to 2015 and later declined in the latest 5 years. The regional share of global export volume rebounded to 16% in 2015 but later in 2019 back to its historic regular 9% share while the regional share of global import volume remained steadily at 4% share of the world total for the past 20 years. The United States (2,98 billion USD) and Canada (1,09 billion USD) in terms of export value are growing steadily while the top 1 regional importer Canada (100 million USD) in terms of import value is far larger than the second-largest importer - The United States (with only 15 million USD) - and will increase at a stable pace, according to our analysis of trade data in 2019. Furthermore, the import value of The United States is most likely to continue shrinking in the following years, given its historic trend.

South America: The overall increasing trend of export volume of chips can be observed in the region of South America and its export share increased from merely 2% in 2015 to 8% in 2019 but almost no changes in the import volume and limited decline in import share of world total (decreased from 0,08% to 0,01% in 2019). However, according to our trade analysis, we found Uruguay (0,78 billion USD), Chile (0,42 billion USD), and Peru (0,28 billion USD) in terms of export value, had gained more weight in this region with a continuous increase during the last 20 years. Argentina (2,4 million USD) and Chile (2,3 million USD) in terms of import value, might keep on the upswing and grow slightly given its constant trade volume from 2005 to 2020. Moreover, we notice that the South American region once accounted for at least 34% of the world's export volume in 2010, demonstrating its potential.

In the following Table 13 and Table 14, we can take a glance at historical changes in the regional share of global chips import and export volume according to the defined CN codes and timeline.

Table 14 The Percentage of Chips Export of Total Woody Biomass World Export Volume of Selected Regions and Years

Region	**2005**	**2010**	**2015**	**2019**
Africa	17,65%	5,85%	1,88%	4,49%
Asia	28,13%	9,17%	11,47%	7,02%
European Union	30,23%	28,19%	40,06%	46,08%
Far East & Asia Pacific	12,18%	12,10%	20,18%	24,22%
Middle East	0,13%	0,13%	0,37%	0,20%
North America	9,58%	9,73%	16,56%	9,82%
South America	2,09%	34,83%	9,48%	8,17%

Source: WITS and UN COMTRADE database and own

Table 15 The Percentage of Chips Import of Total Woody Biomass World Import Volume of Selected Regions and Years

Region	2005	2010	2015	2019
Africa	0,00%	0,09%	0,03%	0,20%
Asia	4,71%	4,01%	3,25%	0,01%
European Union	33,85%	40,30%	30,40%	38,07%
Far East & Asia Pacific	54,76%	47,11%	54,84%	57,19%
Middle East	2,64%	4,25%	7,42%	0,81%
North America	3,96%	4,18%	4,01%	3,71%
South America	0,08%	0,05%	0,04%	0,01%

Source: WITS and UN COMTRADE database and own analysis

4.4 The Trade Analysis for Sawdust, Wood Waste and Scrap

The trade volume of sawdust, wood waste, and scrap over the past two decades appears to be quite low and stagnate in several regions including Africa, Asia, Middle East, and South America as clearly can be seen in Figure 10. Across the European Union region, the import volume of sawdust, wood waste, and scrap has skyrocketed since 2015, and the export volume has jumped on the bandwagon, though on a smaller scale. With steady growth since 2005, the import and export volumes for wood wastes and scrap across the Far East and Asia Pacific region are also trending upward. A significant increase in the export volume from North America in 2015, which appears to be the second-largest export region till 2019, has also been noted.

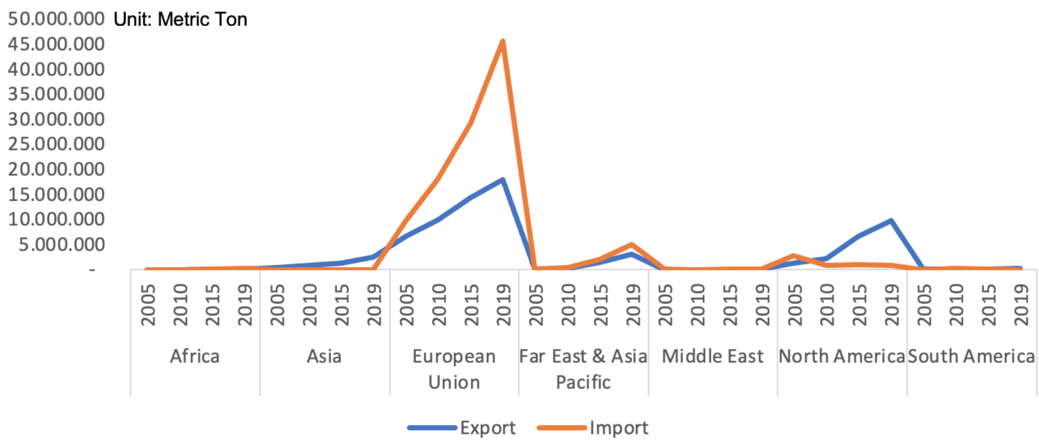


Figure 10 The Overview of Sawdust, Wood Waste and Scrap Trade Volume of Selected Regions and Years

Source: WITS and UN COMTRADE database and own analysis

Africa: The overall import and export volume of sawdust, wood waste, and scrap is small, but we noticed the upward trend of Africa regional import share of world total import volume, increased from 0,2 ‰ to 0,9 ‰ during 2005 and 2019 while export share remains at 15‰ of world trade during the last two decades though it once jumped to 1,6 ‰ in 2015 later in 2019 has returned to its historic regular number. Within this region, Tunisia (2,6 million USD), Benin (2,96 million USD) and South Africa (1,86 million USD) are the main exporting countries and in terms of export value, they have a great chance to keep increasing while Ghana (nearly 10 billion USD), Botswana (1,17 billion USD) and South Africa (about 1 billion USD) in terms of import value, are most likely to continue rising in the coming years, according to our analysis on historic trade development and recent trade value in 2019.

Asia: From only 3 percent to almost 8 percent of the total global export volume, Asia sawdust, wood waste, and scrap have been growing constantly over the last two decades, but Asian import share in 2019 remains at the similar level of 2015 which is roughly 0,1% share of global import volume even though it declined from 0,07% to 0,03% between 2005 and 2010. Russian is the main importer and exporter in this region with exports (about 0,3 billion USD in 2019) and imports (about 1,57 million USD in 2019) both expected to grow rapidly based on historic trade value development.

European Union: Compared to the percentage in 2005, the share of European Union sawdust, wood waste, and scrap export in 2019 surprisingly has declined more than 25 percent of the global total volume though we can clearly see the total quantity of exports have risen robustly. Even after twenty years of import volume growth, we still find that the European Union's share of global import volume has only risen by 3%. As this region remains the world's largest exporter and importer simultaneously, we can expect major cargo flows in and out to happen inside the region. According to our analysis of trade data in 2019, Latvia (0,35 billion USD) and Germany (0,3 billion USD) in terms of export value will keep its strong upward trend, while United Kingdom (1,6 billion USD), Italy (0,6 billion USD) and Denmark (0,57 billion USD) import value are likely to have mild growth in the coming years. Despite the fact that strong increase in import and export volume of the European Union, the share of export in the global market might keep decreasing.

Far East & Asia Pacific: The upward trend for sawdust, wood waste, and scrap can be seen in both import and export volume and moderately increase in the regional share of world total import and export quantities. The Far East & Asia Pacific is still the second-largest importer in terms of volume with a 9% share of total global import volume and the third-largest regional exporter with a 6% world share in 2019. For the same reason we explained in the European

Union region, significant cargo flows in and out of the region can be expected. Furthermore, we notice that with trade record in 2019, Vietnam (0,34 billion USD) and Malaysia (0,1 billion USD) in terms of export value, and Korea Republic (close to 0,4 billion USD), and Japan (0,29 billion USD) in terms of import trade value, both have great possibilities of keep growing. On top of that, we notice that Vietnam's exports and Korea's imports of 2019 have grown in value by a staggering 332 and 443 times as of 2005.

Middle East: Import and export volumes of sawdust, wood waste, and scrap wood in the Middle East have remained relatively flat and stagnant, like what happened in Africa. We find the same upward trend of the Middle East regional share of world total import volume, which increased from 0,1 ‰ to 1,3 ‰ during 2005 and 2019 and similarly export share rose from 0,8 ‰ to 1,2 ‰ between 2005 and 2019 with subtle downward fluctuations in 2010. We observe Occ, Pal, Terr, and Turkey are major exporters of sawdust, wood waste, and scrap wood in 2019 with separately 4,5 million USD and 2,6 million USD trade value in 2019. When we look at total import value in 2019, Qatar (1,82 million USD) and Israel (1,84 million USD) are the main contributors. Exports and imports from the countries mentioned are more likely to see a significant increase in total trade value based on their historical trends.

North America: The great rise of sawdust, wood waste, and scrap wood export volume can be observed in this region with a 15% increase in global export share from 2005 to 2019, while the regional share of global import volume once jumped to 21% in 2010 but dropped significantly to only 3% in the last decade, although the changes in import volume seem to be flat in Figure 10. We found the United States (nearly 1 billion USD in 2019) export value is 48 times larger than the 2005 trade value record but in terms of import value the United States (0,1 billion USD) is slightly lower than that of 2005 and Canada (23 million USD) has doubled its import trade value as of 2005 and has great chance to keep rising in the following years based on our trade data analysis.

South America: The import and export volume of sawdust, wood waste, and scrap wood seems to be stagnated and the import and export share of world total trade is limited (both less than 1% in 2019). However, the regional import share of total world volume has recovered from 0,2% in 2015 to 0,4% in 2019 while the regional export share continues to decline. According to our trade statistics, we found Brazil (37 million USD in 2019) in terms of export value and quantity are the top one contributor, and Uruguay (2,2 million USD in 2019) in terms of import value is the highest in 2019 but as of import quantity is the third – lower than Peru and Brazil. We also find out a staggering 26- and 34-fold appreciation in the value of total trade in Brazil and Uruguay from 2005 to 2019.

Table 15 and Table 16 summarize the historical changes in the regional share of global sawdust, wood waste, and scrap import and export volume according to the defined CN codes and timeline.

Table 16 The Percentage of Sawdust, Wood Waste and Scrap Export of Total Woody Biomass World Export Volume of Selected Regions and Years

Region	**2005**	**2010**	**2015**	**2019**
Africa	0,15%	0,03%	0,16%	0,14%
Asia	3,86%	5,89%	5,39%	7,38%
European Union	78,15%	75,10%	60,33%	53,32%
Far East & Asia Pacific	1,67%	2,38%	6,18%	9,22%
Middle East	0,01%	0,16%	0,02%	0,13%
North America	14,97%	15,99%	27,68%	29,08%
South America	1,21%	0,44%	0,23%	0,73%

Source: WITS and UN COMTRADE database and own analysis

Table 17 The Percentage of Sawdust, Wood Waste and Scrap Import of Total Woody Biomass World Import Volume of Selected Regions and Years

Region	**2005**	**2010**	**2015**	**2019**
Africa	0,02%	0,03%	0,08%	0,09%
Asia	0,19%	0,07%	0,03%	0,10%
European Union	87,75%	77,33%	92,37%	90,12%
Far East & Asia Pacific	2,55%	0,55%	1,90%	6,16%
Middle East	0,08%	0,46%	0,08%	0,12%
North America	8,89%	21,37%	4,60%	2,98%
South America	0,51%	0,19%	0,94%	0,43%

Source: WITS and UN COMTRADE database and own analysis

4.5 The Trade Analysis for Non-Recyclable Wastepaper

The trade volume of non-recyclable wastepaper over the past two decades appears to be quite low and stagnated in several regions including Africa, Asia, Middle East, Middle East, and South America, though small fluctuations in the Middle East. Import and export volumes of non-recyclable wastepaper in the European Union region have been steadily increasing since 2005, though imports have grown at a slower rate than exports. Regarding the Far East and Asia Pacific region, it has been on trending upward until 2015 in imports and exports, but both experienced a decline in the last five years. In North America, which appears to be the second largest, exports increased until 2010, remained at a similar level in the next five years but declined in 2019 to less than half of what they had been in 2015.

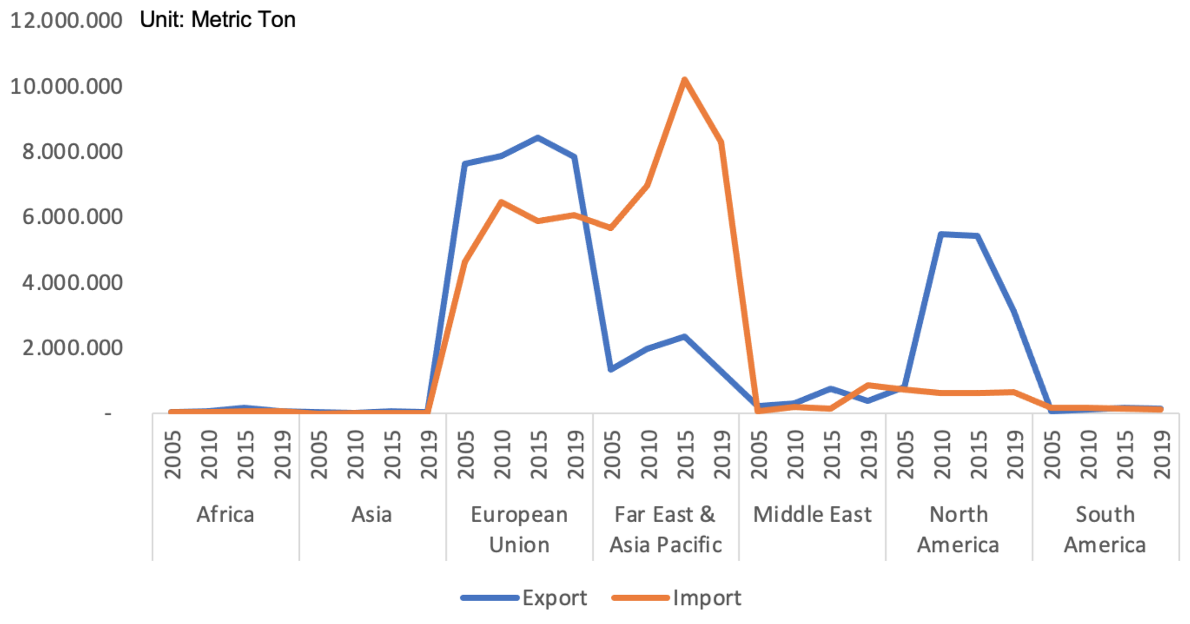


Figure 11 The Overview of Non-Recyclable Wastepaper Trade Volume of Selected Regions and Years

Source: WITS and UN COMTRADE database and own analysis

Africa: Even though Africa's overall import and export volume of non-recyclable wastepaper is relatively insignificant and appears to have a flat trend, we've observed a steady upward trend in the region's export share of the world's total export volume, which increased from 3,6% to 5% between 2005 and 2019, while the import share decreased from 9,6 percent to 3,3% during that same period. Within this region, Honduras (3,2 million USD), Morocco (1,72 million USD), and Mauritius (1,06 million USD) are the main exporting countries with the highest export value and they have a great chance to follow the increasing trend while Tunisia (nearly 6,1 million USD), South Africa (1,84 million USD) and Nigeria (about 1,35 million USD) are those with highest import value in 2019 and most likely to continue rising in the coming years, though the moderate decline of trade value might be seen in South Africa, according to our analysis on historic trade development.

Asia: From 8% to merely 3,3 ‰ of the total global import volume, Asia's non-recyclable wastepaper has been trending downward constantly over the last two decades, but Asian export share in 2019 remains at the similar level of 2005 with a 2 ‰ increase in the share of global export volume. No matter in terms of trade value or volume, Russian is the main importer and exporter in this region with exports (about 7,87 million USD in 2019) and imports (about 1,8 million USD in 2019) both expected to grow moderately based on historic trade value development.

European Union: The share of European Union non-recyclable wastepaper import seems to be stable in volume in the last decade but surprisingly it declined more than 20 percent share of the global total imports between 2005 and 2019. The export volume and share of world total also jumped on the bandwagon of the same trend in imports, though on a larger scale in volumes and relatively lower decreasing rates in its shares (only 15% reduction during the same period). Even though both imports and exports seem to be in mild turmoil, we still can conclude this region remains the world's largest exporter and second-largest importer for twenty years with major cargo flows in and out of the region. According to our analysis of historic trade data, the United Kingdom (0,19 billion USD) and the Netherlands (0,18 billion USD) in terms of export value in 2019 might keep being in the turmoil, while Germany (0,23 billion USD) and the Netherlands (0,18 billion USD) in terms of import value in 2019 are likely to go down further in the coming years. Besides, the share of European Union export and import in the global market might keep decreasing.

Far East & Asia Pacific: The upward trend for non-recyclable wastepaper can be seen in the regional share of world total imports in Table 17 and Table 18, which increased from 26% in 2005 to nearly 60% share of total global import volume in 2019, but its import volume keeps going down. Although the export share of the world total is with only a 2% loss between 2005 and 2019 and made up 10% of the world share in 2019, the obvious decreasing trend can be noticed in export volume. Since 2010 Far East & Asia Pacific has become the largest importer and the third-largest regional exporter in terms of volume and world share, significant cargo flows in and out of the region can be expected. Furthermore, we notice that with trade record in 2019, Australia (52,3 million USD) and Japan (41,2 million USD) in terms of export value, and Korea Republic (close to 51 million USD) in terms of import trade value, have great possibilities of keep going down. However, the trade value of Indian imports (about 1,2 billion USD) is on the top and exceptional with the general regional trend and seems to grow further, according to our analysis on historic trade development.

Middle East: Import and export volumes of non-recyclable wastepaper in the Middle East have remained relatively flat with some fluctuations in the last decade. We noticed the Middle East regional share of world total export volume experienced a minor 1% increase in 2019 compared to the level of 2005, though once doubled world share in 2015 as of 2005 but later went down 1% share in 2019. Similarly, the export share rose from 8,5 ‰ to 14,4 ‰ between

2005 and 2015 but later had a 5‰ drop in 2019. We observe the United Arab Emirates and Turkey are the top exporters and importers of non-recyclable wastepaper in 2019 with separately 40 million USD and 17 million USD trade value in exports and 14 million USD and 76,5 million USD trade value in imports. Those countries mentioned are more likely to witness a strong increase in total trade value in the coming years based on our predictions on their historical trends.

North America: The great rise of non-recyclable wastepaper export volume can be observed in 2010 and in 2019 it is with 24% global export share, while the regional share of world total export volume once jumped to 25% in 2010 but kept falling in the last decade. Although the changes in import volume and share of world total imports seems to be flat, similar ups and downs in terms of world share can be found in 2010 and next ten years. The United States (nearly 0,37 billion USD in 2019) export value is lower than 2005 trade value record (0,41 billion USD) while Canada (69,2 million USD in 2019) has slight increase in trade value as of 2005 but in terms of import value the United States (25 million USD) is almost half of that in 2005 and Canada (28 million USD) is nearly one third the value in 2005. Based on our trade data analysis, there is great chance for these two countries' trade value keep falling in the following years.

South America: Import and export volumes of non-recyclable wastepaper in South America have remained relatively flat and stagnant, like what happened in Africa and Asia, and the import and export share of world total trade is limited (both nearly 1% in 2019). However, the regional import share of total world volume decreased from 6,8% in 2005 to 0,89% in 2019 while the regional export share was keeping rising from 6,8‰ to 11,4‰. According to our trade analysis, we found Guatemala (8,1 million USD) and Costa Rica (5,3 million USD) are the top regional actors in terms of export value and quantity in 2019, while Guatemala (16,2 million USD in 2019) in terms of import value and quantity are also the highest and El Salvador (13 million USD in 2019) is the second-largest regional actor in this region.

Import and export volumes of non-recyclable wastepaper from defined regions, CN codes, and timelines are summarized in the following Table 17 and Table 18.

Table 18 The Percentage of Non-Recyclable Wastepaper Export of Total Woody Biomass World Export Volume of Selected Regions and Years

Region	**2005**	**2010**	**2015**	**2019**
Africa	0,36%	0,48%	1,02%	0,50%
Asia	0,51%	0,27%	0,41%	0,33%
European Union	75,32%	49,62%	48,56%	60,81%
Far East & Asia Pacific	12,98%	12,38%	13,37%	10,06%
Middle East	2,11%	1,97%	4,38%	2,99%
North America	8,03%	34,58%	31,24%	24,18%
South America	0,68%	0,70%	1,02%	1,14%

Source: WITS and UN COMTRADE database and own analysis

Table 19 The Percentage of Non-Recyclable Wastepaper Import of Total Woody Biomass World Import Volume of Selected Regions and Years

Region	**2005**	**2010**	**2015**	**2019**
Africa	0,96%	0,30%	0,30%	0,33%
Asia	8,16%	1,33%	0,68%	0,33%
European Union	55,03%	40,93%	44,61%	34,44%
Far East & Asia Pacific	25,81%	48,74%	47,51%	59,54%
Middle East	0,85%	0,63%	1,44%	0,89%
North America	2,40%	6,53%	4,23%	3,58%
South America	6,79%	1,53%	1,23%	0,89%

Source: WITS and UN COMTRADE database and own analysis

5. Implication from External Resources for Price Fluctuation

The allocation of land is dynamic and influenced by factors such as favorable policies and investments, as well as modern technology and management techniques to increase annual net gain in the forest areas. Considering woody biomass is the byproduct of forest resources, the inherent land and forest resources of each region will play a critical role in determining its import and export demand for woody biomass components when the global price becomes stable. Thus, we firstly looked at the regional forest area and deforestation rate provided in the Global Forest Resources Assessment 2020 to understand the forest area availability and regional deforestation rate to understand the upstream of wood-related products and the implication from forest and land resources to regional woody biomass products price fluctuations. This is because that forest area availability and supply for roundwood and woodfuel are important indicators for woody biomass, even though not all wood removals come from forests and the volume of wood removals in 2018 was less than 1 percent of the forest growing stock according to Global Forest Resources Assessment.

Based on Global Forest Resources Assessment 2020, we found Russia, Brazil, Canada, United States, and China can represent more than half of the world's forest area (54%) and over two thirds (66%) of the world's forests in 2020 are found in the top ten countries which mainly concentrate in North America, South America, Far East & Asia Pacific and Asia regions.

Table 20 Historic Deforestation Rate (1000 ha/year) of Selected Regions and Years

Region	**2000~2010**	**2010~2015**	**2015~2020**
Africa	4.314	4.444	4.414
Middle East	99	96	107
Far East & Asia Pacific	3.207	3.287	2.107
Europe	92	201	69
North America	475	253	263
South Amercia	6.891	3.519	3.126
World Total	15.117	11.801	10.150

Source: Data from Global Forest Resources Assessment 2020 with own calculation

Moreover, global deforestation rates shown in Table 20 indicate the conversion of forest to other land uses such as agriculture have been declining for the past two decades except for Africa and Middle East, even though not uniformly across regions.

The most long-term growth in wood supply occurs in countries that have established forest plantations in the past few years (especially in the Far East & Asia Pacific and Latin America)

Removals in the European Union and Asia region have increased significantly since 2000, where forest industries and demand for wood are growing rapidly, according to the Global Forest Resources Assessment.

There has been a steady increase in wood removals in the region of Africa between 2000 and 2018. African wood removals increased by 2% per year on average during that time, which was in line with population growth. For both industrial roundwood and wood fuel, the number of removals increased.

Wood removals in the Far East and Asia Pacific region remained stable between 1990 and 2018, with industrial Roundwood supplies increasing and wood fuel removals declining. Particularly in East Asia and Southeast Asia, this trend was driven by the rapid development of forest-based industries (for example, more demand for industrial Roundwood) and an improvement in living standards as available alternative energy sources reduce the demand for wood fuel. As a result of an increased supply of wood from forest plantations in Australia and New Zealand, the total wood removal of Australia, New Zealand, Papua New Guinea, and the Solomon Islands reached 87 million m3 in 2018.

Removals in North America declined sharply in 2018 due to the global financial crisis, which had negative impacts on the housing sector and consequently on wood demand, especially in Canada and the United States of America. In addition to increasing removals of industrial Roundwood, wood fuel removals have been growing in the region to meet increasing export demand for wood pellets. It is also worth noting that between 2000 and 2018, the amount of wood removed in South America increased steadily to 429 million cubic meters, thanks to a growing supply of industrial Roundwood from forest plantations (mostly in Argentina and Brazil)

Globally, wood removals, in general, are on the rise as the demand for, and consumption of, wood products rises in tandem with rising populations and income levels. According to these predictions, this trend will continue in the coming decades.

One important conclusion is that when deforestation rate plummet while wood removal increase in specific regions with abundant forest resources such as South America and Asia Far East & Asia Pacific the world will receive the signal that the unit price for wood related exports from these regions might go down as the overall supply is increasing. On the demand side, woody biomass is used primarily for bioenergy production in downstream markets. There's no doubt that woody biomass price fluctuations must be influenced by wood-based bioenergy, but we're unable to conduct further research due to time constraints and high complexity to distinguish both direct and indirect trade.

6. Implication of Circular Economy on Shipping Demand of Woody Biomass

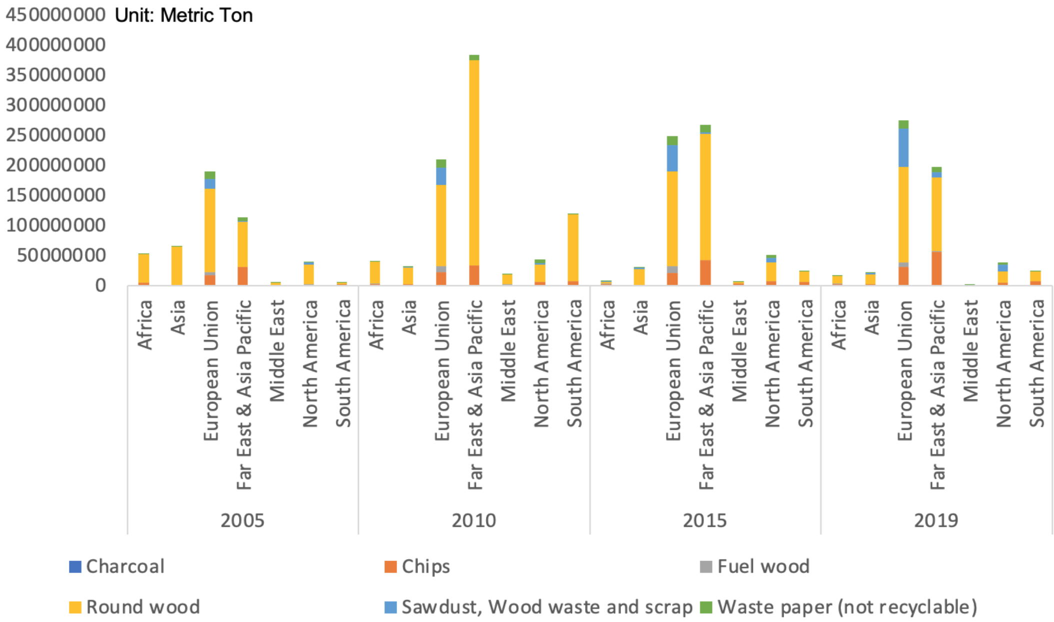
The increasing implementation of the circular economy in the next decades is unlikely to have a significant impact on the real world's shipping demand for woody biomass, despite the fact that governments, especially in Europe, and international environmental organizations have discussed woody biomass as an alternative sustainable energy source extensively.

Table 21 Import and Export Volume of Aggregated Woody Biomass Components of Selected Regions and Years

Region	2005	2010	2015	2019
Africa	52.950.918	40.320.154	7.190.272	16.935.671
Asia	64.981.257	31.101.120	29.443.226	21.053.508
European Union	191.456.030	211.801.252	250.189.365	276.563.634
Far East & Asia Pacific	114.453.529	385.047.060	268.781.756	198.952.199
Middle East	4.835.591	19.848.714	7.360.853	3.087.363
North America	40.096.462	43.556.290	53.029.588	38.487.499
South America	5.398.206	118.945.965	24.636.089	23.825.293
Grand Total	474.171.994	850.620.556	640.631.149	578.905.167

Source: WITS and UN COMTRADE database and own analysis

Figure 12 The Comparison of Each Woody Biomass Component Total Import and Export Trade Volume of Selected Regions and Years



Source: WITS and UN COMTRADE database and own analysis

This is because total aggregated woody biomass components cargo flow (578,9 million metric tons in 2019) shown in Table 21 accounts for only 3% percentage of global sea traffic based on UNCTAD statistic that 811 million TEUs of containers were handled in ports across the globe during the year of 2019 and estimation that 24 metric tons of cargo normally loaded up in one TEU (Hari Menon, 2021). However, we apply the same RAS methodology to round wood, chips, sawdust, wood waste, and scrap and wastepaper (not recyclable), which are identified in trade analysis and Figure 12 as either woody biomass main components or have great growth potentials, to calculate their share in estimated global cargo flow of aggregated woody biomass and forecast fluctuations in shipping demand at regional or even country's level.

Round wood: Considering the historic major cargo flow in aggregated woody biomass components is round wood, even on the trend of decreasing, we notice the cargo flow of round wood to North America region decline greatly and there is almost less than 10% imports in Middle East region. On the contrary, the cargo flow within Africa and from the Far East & Asia Pacific to Africa will increase its share in aggregated total volume to over 90% which indicates there will be a significant increase in cargo flow of round wood and more shipping demand might occur from New Zealand or Australia to South Africa, as well as from major export countries in Africa such as the Congo Republic to major import countries like South Africa. A slight increase in the share of aggregated cargo flow (over 80%) might be seen from Africa to Asia, Far East & Asia Pacific to Asia, and North America to Africa and Asia. Together with historic trade development and analysis shown in Table 22, it is also predictable that increasing shipping demand from Far East countries to Kazakhstan and Mozambique.

Table 22 The Estimated Percentage of Round Wood in The Aggregated Woody Biomass Future Cargo Flow

Region	Africa	Asia	European Union	Far East & Asia Pacific	Middle East	North America	South America
Africa	93%	37%	62%	91%	39%	87%	38%
Asia	88%	35%	59%	86%	36%	82%	36%
European Union	80%	32%	54%	78%	33%	75%	33%
Far East & Asia Pacific	62%	25%	42%	60%	26%	58%	25%
Middle East	10%	4%	7%	10%	4%	10%	4%

North America	49%	20%	33%	48%	20%	46%	20%
South America	75%	30%	51%	73%	31%	70%	31%

Source: WITS and UN COMTRADE for 2019 trade data and own RAS analysis

Chips: According to the chart for historic shipping demand, the second-largest cargo flow in aggregated woody biomass components is Chips and it brought major cargo flow to South America and the Far East & Asia Pacific. In the next decade, the largest cargo flow of chips can be expected within the Far East & Asia Pacific which accounted for nearly 50% volume of aggregated biomass components and the second-largest will be from the Far East & Asia Pacific to South America. Based on these predictions and trade analyses we made before, New Zealand and Vietnam might witness more shipping demand from chips to China, Japan, and Argentina as larger demand always can be seen in countries' historic trade development. To our surprise, the cargo of chips from the Middle East and North America to the Far East & Asia Pacific accounted for more than 35% volume of aggregated biomass components, which indicated strong growing potentials in chips' shipping demand from the United Arab Emirates, Turkey, USA and Canada to countries in the Far East & Asia Pacific region.

Table 23 The Estimated Percentage of Chips in The Aggregated Woody Biomass Future Cargo Flow

Region	Africa	Asia	European Union	Far East & Asia Pacific	Middle East	North America	South America
Africa	2%	0%	10%	17%	12%	14%	1%
Asia	2%	0%	9%	15%	10%	12%	1%
European Union	1%	0%	6%	11%	8%	9%	1%
Far East & Asia Pacific	5%	1%	29%	49%	35%	39%	3%
Middle East	0%	0%	0%	1%	0%	0%	0%
North America	2%	0%	9%	15%	11%	12%	1%
South America	5%	0%	24%	42%	29%	34%	2%

Source: WITS and UN COMTRADE for 2019 trade data and own RAS analysis

Sawdust, Wood Waste and Scrap: The historic cargo flow of sawdust, wood waste, and scrap in aggregated woody biomass components seem to be outstanding in European Union only, but with a detailed review of historical data and RAS analysis we can predict that the major cargo flow from European Union to North America, which is up to 78% share of aggregated biomass cargos flow, and sawdust, wood waste and scrap might also circulate within the European Union and the moderate rise of shipping demand can be expected as a result. This might benefit major EU exporters includes Latvia and Germany and importers such as the United Kingdom, Canada, and the United States in terms of trade volume. Furthermore, it is worth noting that there are almost no cargo flows in Africa and South America countries and limited cargo flows out to North America. This might be partially due to abundant forest resources in Africa and South America as we explained before and large cargo flow from European Union and more circulation within North America as circular economy maturity grows.

Table 24 The Estimated Percentage of Sawdust, Wood Waste and Scrap in The Aggregated Woody Biomass Future Cargo Flow

Region	Africa	Asia	European Union	Far East & Asia Pacific	Middle East	North America	South America
Africa	0%	0%	1%	0%	0%	0%	0%
Asia	4%	0%	28%	3%	1%	7%	3%
European Union	5%	0%	30%	4%	1%	8%	3%
Far East & Asia Pacific	2%	0%	10%	1%	0%	3%	1%
Middle East	3%	0%	17%	2%	1%	5%	2%
North America	12%	1%	78%	10%	4%	20%	9%
South America	0%	0%	2%	0%	0%	1%	0%

Source: WITS and UN COMTRADE for 2019 trade data and own RAS analysis

Non-Recyclable Wastepaper: Based on Table 21 and Figure 12, the cargo flow for all woody biomass components is quite low. However, according to our RAS analysis, we might witness the staggering growth in shipping demand for non-recyclable wastepaper within the Middle East and from South America to the Middle, which is almost 5 to 6 times larger than the regional volume of aggregated biomass cargo flow. Turkey and the United Arab Emirates might be the biggest winners whose import and export volume and value will increase significantly. Moreover, mild growth in North America and the Far East & Asia Pacific exports to the Middle East is predictable which also contributes to the regional shipping demand. However, there will be less than 10% cargo flow for non-recyclable wastepaper in other regions. This might be partially due to the low trade volume of non-recyclable wastepaper for some regions in the starting matrix of RAS.

Table 25 The Estimated Percentage of Non-Recyclable Wastepaper in The Aggregated Woody Biomass Future Cargo Flow

Region	Africa	Asia	European Union	Far East & Asia Pacific	Middle East	North America	South America
Africa	0%	0%	0%	1%	3%	1%	4%
Asia	0%	0%	0%	0%	1%	0%	2%
European Union	2%	1%	5%	8%	41%	8%	52%
Far East & Asia Pacific	1%	0%	2%	2%	13%	2%	16%
Middle East	19%	8%	58%	90%	479%	90%	604%
North America	3%	1%	9%	15%	77%	14%	97%
South America	0%	0%	1%	1%	4%	1%	5%

Source: WITS and UN COMTRADE for 2019 trade data and own RAS analysis

7. Conclusion

7.1 Chapter Summary

From the first chapter, the background of the circular economy and the research impetus for the impact of the circular economy on the global seaborne trade of biomass is introduced with explanations on the research questions, objectives, and research relevance.

In the second chapter, the conceptual framework of circular economy is presented through an in-depth literature review on the refurbished concept of circular economy as our answer for the first sub-research question. To make a clear definition of the conceptual framework, we conclude with a matrix containing the highly cited literature from all continents and explain the core foundation for developing the conceptual framework with 3R and framing the circular maturity level to study the impact of circular economy implementation on biomass global trade.

The methodology approach of the study with biomass trade analysis and introduction of the connection between trade data and shipping are presented in chapter three to answer the second sub-research question. We derive insight into the demand for shipping by explaining the amount of biomass consumed and shipped can be considered as the core achievement of the circular economy and international trade is the deep-rooted reason for shipping. With a comprehensive process for the data analysis through the well-known RAS method, the connection between trade data and shipping is brought out with proper consideration on the limitations of data and model reliability.

In chapter four we present the results and analysis of the outcome in the previous chapter - trading analysis and summary and answered the third sub-research question about what is the global cargo flow of woody biomass. We notice the sum of total aggregated woody biomass components cargo flow (578,9 million metric tons in 2019) accounts for a small percentage of global sea traffic (about 3%) and large cargo flow circulates within the European Union and the Far East & Asia Pacific with the higher implementation of circular economy and these two regions are still the major exporters to other regions with dominant advantage in terms of trade volume. The Middle East and Africa are relatively inactive actors in both import and export activities compare to South America and North America

From chapter five we collect external recourses from the upstream of woody biomass to figure out the price fluctuation and summarize that when deforestation rate plummet while wood removal increase in specific regions with abundant forest resources such as South America and Asia Far East & Asia Pacific the world will receive the signal that the unit price for wood related exports from these regions might go down as the overall supply is increasing.

In chapter six we conclude that the increasing implementation of the circular economy in the next decades is unlikely to have a significant impact on the global shipping demand for woody biomass and calculation for important components of woody biomass are made to predict their share in estimated global cargo flow and forecast fluctuations in shipping demand at regional or even country's level. In short, there will be a significant decline in round wood shipping demands in the North American and Middle Eastern regions, but a boom in shipping demand within Africa and from Asia to Africa may occur in the coming decades as the global circular economy matures. Moreover, the shipping demand might rise dramatically within the Middle East for non-recyclable wastepaper, remain at a similar level within the Far East & Asia Pacific and South America regions for Chips while experiencing a slight increase for sawdust, wood waste, and scrap from European Union to North America. The main research question about what is the trade and transport impact of the implementation of the circular economy (CE) on global shipping demand so far has been introduced thoroughly.

7.2 Research questions and answers

To answer the main research question what is the trade and transport impact of the implementation of the circular economy (CE) on global shipping, the following sub-research questions are answered first.

What is the conceptual framework of circular economy? In our study, the circular economy conceptual framework with 3R (reduce, reuse, recycle) is used as a standard benchmark because it is a widely recognized sustainability principle and dominates CE 2010+ literature reviews.

How can we derive insight into the demand for shipping? The amount of biomass traded and consumed for energy production can be considered as the core achievement of the circular economy and international trade is the deep-rooted reason for shipping. Thus, the fluctuations of regional demand for wood biomass components that come with the implementation of the circular economy will drive the flow of cargoes.

What is the global cargo flow of woody biomass? We notice large cargo flows of woody biomass circulate within European Union and the Far East & Asia Pacific and these two regions are still the major exporters to other regions with dominant advantage in terms of trade volume. The Middle East and Africa are relatively inactive actors in both import and export activities compare to South America and North America.

After answering all these sub-questions, we can answer our main research question regarding the trade and transport impact of the implementation of the circular economy (CE) on global shipping. We conclude the sum of total aggregated woody biomass components cargo flow (578,9 million metric tons in 2019) only accounts for a small percentage of global sea traffic (about 3%) and hence the higher implementation of circular economy in terms of woody biomass is unlikely to have a great impact on the global shipping demand. In addition, we predict that there will be a significant decline in round wood shipping demands in the North American and Middle Eastern regions, but a boom in shipping demand within Africa and from Asia to Africa may occur in coming decades as the global circular economy matures. Moreover, For non-recyclable wastepaper, the shipping demand is expected to skyrocket in the Middle East, while it will remain stable in the Far East & Asia Pacific and South America regions for Chips, while sawdust, wood waste, and scrap from the European Union to North America will see a slight increase in demand.

7.3 Limitations of the study

Firstly, there is a limited amount of relevant literature, as there is a large amount of literature in the context of circular economy, which has led to different interpretations on the definition of the circular economy across regions and actors in the industry.

It's important to note that there is no standard benchmark for measuring circular economy maturity and alignment at a national level. To get a sense of where CE maturity and alignment are at a regional level, we can only focus on keywords provided by international organizations. To fill in the gaps, more research is needed.

The last limitation is about the trade data availability and regional shipping connections. We have to make estimation by dividing the total trade value with the regional average price when some countries' trade quantity is missing, and all regional connections are treated equally, even if some are more important than others, we assign the same weight to all of them. Moreover, due to time constraints and the difficulty of distinguishing between direct and indirect trade of biomass, further research on the price implications of woody biomass has not been completed.

7.4 Suggestions for further research

Since the circular economy transition is significant and inevitable but new changes in the amount and the type of cargoes traded and shipped can be massive, we suggest more research on the new changes in shipping demand of critical global commodities which might be under the impact of circular economy transition. Furthermore, a clear objective and standard benchmark to quantify CE maturity and measure alignment at a regional or national level will be favorable for stakeholder groups' interests.

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9. Appendix

The list of region and related countries

Region	Country
Africa	Algeria
Africa	Angola
Africa	Benin
Africa	Botswana
Africa	Burkina Faso
Africa	Burundi
Africa	Cameroon
Africa	Cape Verde
Africa	Central African Republic
Africa	Comoros
Africa	Congo Dem, Rep,
Africa	Congo Rep,
Africa	Cote d'Ivoire
Africa	Eswatini
Africa	Ethiopia(excludes Eritrea)
Africa	Fm Sudan
Africa	Gabon
Africa	Gambia The
Africa	Ghana
Africa	Guinea
Africa	Guinea-Bissau
Africa	Honduras
Africa	Kenya
Africa	Lesotho
Africa	Libya
Africa	Madagascar
Africa	Malawi
Africa	Mali
Africa	Mauritius
Africa	Mayotte
Africa	Morocco
Africa	Mozambique
Africa	Namibia
Africa	Niger
Africa	Nigeria
Africa	Rwanda
Africa	Sao Tome and Principe

Africa	Senegal
Africa	Seychelles
Africa	Sierra Leone
Africa	South Africa
Africa	Syrian Arab Republic
Africa	Tanzania
Africa	Togo
Africa	Tunisia
Africa	Uganda
Africa	Zambia
Africa	Zimbabwe
Asia	Azerbaijan
Asia	French Polynesia
Asia	Georgia
Asia	Kazakhstan
Asia	Kyrgyz Republic
Asia	New Caledonia
Asia	Russian Federation
Asia	Samoa
Asia	Sudan
Asia	Uzbekistan
European Union	Albania
European Union	Andorra
European Union	Austria
European Union	Belarus
European Union	Belgium
European Union	Bosnia and Herzegovina
European Union	Bulgaria
European Union	Croatia
European Union	Czech Republic
European Union	Denmark
European Union	Estonia
European Union	European Union
European Union	Faeroe Islands
European Union	Finland
European Union	France
European Union	Germany
European Union	Greece
European Union	Greenland
European Union	Hungary
European Union	Iceland
European Union	Ireland

European Union	Italy
European Union	Latvia
European Union	Lithuania
European Union	Luxembourg
European Union	Malta
European Union	Moldova
European Union	Montenegro
European Union	Netherlands
European Union	North Macedonia
European Union	Norway
European Union	Poland
European Union	Portugal
European Union	Romania
European Union	Serbia FR(Serbia/Montenegro)
European Union	Slovak Republic
European Union	Slovenia
European Union	Spain
European Union	Sweden
European Union	Switzerland
European Union	Ukraine
European Union	United Kingdom
Far East & Asia Pacific	Australia
Far East & Asia Pacific	Bangladesh
Far East & Asia Pacific	Bhutan
Far East & Asia Pacific	Brunei
Far East & Asia Pacific	Cambodia
Far East & Asia Pacific	China
Far East & Asia Pacific	Cook Islands
Far East & Asia Pacific	East Timor
Far East & Asia Pacific	Fiji
Far East & Asia Pacific	Hong Kong China
Far East & Asia Pacific	India
Far East & Asia Pacific	Indonesia
Far East & Asia Pacific	Japan
Far East & Asia Pacific	Kiribati
Far East & Asia Pacific	Korea Rep,
Far East & Asia Pacific	Lao PDR
Far East & Asia Pacific	Macao
Far East & Asia Pacific	Malaysia
Far East & Asia Pacific	Maldives
Far East & Asia Pacific	Mauritania
Far East & Asia Pacific	Micronesia Fed, Sts,

Far East & Asia Pacific	Mongolia
Far East & Asia Pacific	Myanmar
Far East & Asia Pacific	Nepal
Far East & Asia Pacific	New Zealand
Far East & Asia Pacific	Other Asia nes
Far East & Asia Pacific	Pakistan
Far East & Asia Pacific	Palau
Far East & Asia Pacific	Papua New Guinea
Far East & Asia Pacific	Philippines
Far East & Asia Pacific	Singapore
Far East & Asia Pacific	Solomon Islands
Far East & Asia Pacific	Sri Lanka
Far East & Asia Pacific	Thailand
Far East & Asia Pacific	Tonga
Far East & Asia Pacific	Tuvalu
Far East & Asia Pacific	Vanuatu
Far East & Asia Pacific	Vietnam
Far East & Asia Pacific	Wallis and Futura Isl,
Middle East	Afghanistan
Middle East	Armenia
Middle East	Bahrain
Middle East	Cyprus
Middle East	Egypt Arab Rep,
Middle East	Iran Islamic Rep,
Middle East	Israel
Middle East	Jordan
Middle East	Kuwait
Middle East	Lebanon
Middle East	Occ,Pal,Terr
Middle East	Oman
Middle East	Qatar
Middle East	Saudi Arabia
Middle East	Turkey
Middle East	Turkmenistan
Middle East	United Arab Emirates
Middle East	Yemen
North America	Bermuda
North America	Canada
North America	Mexico
North America	United States
South America	Anguila
South America	Antigua and Barbuda

South America	Argentina
South America	Aruba
South America	Bahamas The
South America	Barbados
South America	Belize
South America	Bolivia
South America	Brazil
South America	Chile
South America	Colombia
South America	Costa Rica
South America	Cuba
South America	Dominica
South America	Dominican Republic
South America	Ecuador
South America	El Salvador
South America	Grenada
South America	Guatemala
South America	Guyana
South America	Jamaica
South America	Montserrat
South America	Netherlands Antilles
South America	Nicaragua
South America	Panama
South America	Paraguay
South America	Peru
South America	St, Kitts and Nevis
South America	St, Lucia
South America	St, Vincent and the Grenadines
South America	Suriname
South America	Trinidad and Tobago
South America	Uruguay
South America	Venezuela