University of Natural Resources and Life Sciences
Department of Water, Atmosphere and Environment
Institute of Waste Management

Market situation, collection and treatment of plastic waste in Lao PDR and Vietnam

Master Thesis
Submitted in partial fulfilment of the requirements for the degree of Graduate Engineer of Master of Science

submitted by
Elisabeth Bundschuh, BSc
Stud Kennz.:/ Matr. Nr.: 00740632 / 427

Vienna, 21 August 2020

Acknowledgement

First and foremost, I would like to express my sincere gratitude to my supervisor Ao.Univ.Prof. Dipl.-Ing. Dr.nat.techn. Stefan Petrus Salhofer. This master thesis was quite challenging straight from the beginning and I am grateful for the support, guidance and constructive comments.

Special thanks to Pepsi for her insight information about Laos, especially in the beginning of the writing process.

Finally, I am thankful to my family and friends for providing me with their everlasting support, encouragement and sometimes volitional distractions throughout my years of study and the process of writing this thesis. I could not have accomplished that without them. Danke!

Statutory declaration

I hereby declare that I am sole author of this work. No assistance other than that which is permitted has been used. Ideas and quotes taken directly or indirectly from other sources are identified as such. This written work has not yet been submitted in any part.

This work has not been submitted in the same or similar form to any other examiners as a form of examination. I am aware that offenders may be punished (‘use of unauthorized assistance’) and that further legal action may ensue.

Abstract

The production and consumption of plastics is steadily increasing over the last decades. Concurrently the amount and complexity of plastic waste is increasing and requires proper collection, treatment and disposal methods. This thesis aims to give an overview of the plastic market, plastic consumption, recycling industries and waste management systems in Laos and Vietnam.
To examine the plastic market, foreign trade and domestic production data was processed. For a comprehensive survey of the waste management and the recycling industry, in a first step the management of municipal solid waste was investigated. In a second step a closer look was taken on the specifics of plastic waste and the current collection and treatment. Furthermore, this thesis examines the challenges and gaps of the current plastic waste management and recycling industry and gives options for improvements, along with recommendations for future data collection.

Keywords: plastic consumption, plastic market, Plastic recycling Laos, Vietnam

Kurzfassung

Auf globaler Ebene sind die Produktion und der Konsum von Kunststoffen in den letzten Jahrzehnten stetig gestiegen. Gleichzeitig haben die Menge und Komplexität der Kunststoffabfälle zugenommen und es bedarf einer geordneten Sammlung, Behandlung und Entsorgung, um negative Umweltauswirkungen und nachteilige Einflüsse auf den Menschen zu reduzieren. Diese Masterarbeit gibt für Laos und Vietnam einen Überblick über den Kunststoffmarkt, den Einsatz von Kunststoffen und die Verwertung. Weiters werden die Sammlung, Behandlung und Entsorgung von Siedlungsabfällen in Laos und Vietnam untersucht. Zur Analyse des Kunststoffmarktes wurden Außenhandelsstatistiken und Daten zu Produktionsmengen ausgewertet. Die Abfallwirtschaft wurde mit Fokus auf Siedlungsabfälle betrachtet, um ein Bild der vorhandenen Infrastruktur zu erhalten. Die Sammlung, Behandlung und Entsorgung von Kunststoffabfällen wurden in einem zweiten Schritt genauer untersucht, um Hemmnisse und Schwachstellen aufzudecken. Basierend darauf werden Vorschläge für die Weiterentwicklung und Optimierung der Sammel- und Behandlungsprozesse Prozesse erarbeitet. Dabei werden die Bereiche Regelungen und Kapazitäten, Infrastruktur und Technologie sowie Partizipation betrachtet.

Schlüsselwörter: Kunststoffkonsum, Kunststoffmarkt, Kunststoffrecycling, Laos, Vietnam

Table of Contents

List of Figures

List of Tables

List of Abbreviations

BAT	Best available technology
BOPP	Biaxially oriented polypropylene
CC	Commodity Code
DONRE	Department of Natural Resources Environment (Vietnam)
DOP	Dioctyl phthalate
EPR	Extended Producer Responsibility
HCMC	Ho Chi Minh City
HIC	High Income Country
HSW	Household solid waste
IRS	Informal Recycling Sector
JICA	Japan International Cooperation Agency
Kt	Kilo tons
Mt	Million tons
LMI	Lower middle income
MFA	Material Flow Analysis
MOIC	Ministry of Industry and Commerce (Lao)
MONRE	Ministry of Natural Resources and Environment (Vietnam)
MRF	Material Recovery Facility
MSW	Municipal solid waste
NDIR	Nondispersive infrared sensor
PA	Polyacetals
PC	People’s Committee
PC	Polycarbonate
PDR	People’s Democratic Republic
PE	Polyethylene
PET	Polyethylenterephthalat
PP	Polypropylene
PS	Polystyrene
PSW	Plastic solid waste
PVC	Polyvinylchloride
RDF	Refuse Derived Fuel
SW	Solid Waste
UDAA	Urban Development Administration Authority
UMI	Upper Middle Income

WMS	Waste Management System

1. Introduction

The invention of plastics in the beginning of the 19th century was a huge step for the economy. Especially the packaging industry was in favour of the introduction of plastic material. Since the 1960s plastic manufacturing was growing significantly (Allwood et al., 2011). The positive aspects of the material, e.g. transparent, can easily be coloured, light-weighted, flexible or hard, waterproof, can be blown into foam with good heat isolating properties, as well as the relatively cheap production costs, are the main reasons why plastic is such a handy material. Due to its versatility and the features described above, plastics replaced other materials which were heavier, less resistant and pricier. On one hand durability is one of the main desirable features of plastics, but on the other it causes environmental problems, as it is degrading slowly and takes hundreds of years to photodegrade. By this process plastics slowly break down into small particles (micro and nano-plastics) which can be assimilated by living creatures (Akenji et al., 2019).

In industrialized countries, as well as emerging economies and developing countries, the rising amount of plastic waste, which comes along with increasing consumption of plastic products, is a major problem for the waste management sector. The huge variety of plastic products on the market is an issue and challenge for the recycling industry. The composition of plastic products is not always stated on the product and hence not comprehensible. Especially the amount of plastic packaging and plastic containers is growing in line with the increasing population and adaption of lifestyle. As plastics are bulky and decomposition takes hundreds of years it shortens the lifetime of landfills (Kawai et al., 2012a). Especially developing countries and fast-growing economies struggle with their waste management and changing composition of waste. Due to lack of public awareness and limited investments into infrastructure MSW is still disposed of in surrounding living areas or non-sanitary landfills (Luong et al., 2013).

According to the World Bank (2018a), Vietnam's economy grew rapidly in the last 30 years. The country transformed of one of the poorest countries, to a lower-middle income country (LMI) with a GDP-growth rate of 6.8% in 2019. Population also increased rapidly since 1986 from 60 Mio. people to 96.46 Mio. Urban population in Vietnam is approximately 37%.

Laos economy was changing in the late 1980s from a central planning system to a decentralized economy. The share of agriculture of the total economic value started to decline in the beginning of the 1990s. Agriculture accounted for more than 60% in 1990 and fell to a share of less than 30% in 2011. The largest share of the economy is industry followed by services (Menon and Warr, 2013). The Laotian population is mainly living on the countryside, 36% of the total population live in cities, as mentioned in Tab. 1 (United Nations, 2019; World Bank, 2019).

Municipal solid waste generation in Laos with 252 kg/cap/yr is still low compared to Austria with 579 kg/cap/year. In both southeast Asian countries MSW generation per capita and day is less than 1 kg. As shown in Tab. 1 the per capita waste generation in Vietnam was 255 kg/cap in 2011. MSW data for Myanmar is from 2014 and relates to Yangon and data for Cambodia is from Phnom Penh in 2013. In rural areas the waste generation is lower than in cities, due to little industry and commercial activities and more impecunious lifestyle (World Bank et al., 2005).

Tab. 1: Overview of country data (Eurostat, 2015; Hoornweg and Bhada-Tata, 2012; Phoungthong, 2017; Spoann et al., 2019; UNDP, 2020; United Nations, 2020a, 2020c, 2020d, 2020e, 2020b; World Bank, 2020b, 2020c, 2020a)

Country information (2019)	**Laos**	**Vietnam**	**Cambodia**	**Myanmar**	**Thailand**	**Austria**
Population (Mio)	7.17	96.46	16.25	54.05	69.62	8.95
Urban population	36%	37%	24%	31%	51%	59%
Surface area [km²]	236,800	330,967	181,035	676,600	513,100	83,871
GDP growth rate	6.9%	6.8%	7.5%	6.8%	3.9%	2.6%
GDP per capita (USD)	2,457	2,342	1,382	1,257	6,595	47,717
HDI	0.60	0.69	0.58	0.58	0.77	0.91
Income Group	LMI	LMI	LMI	LMI	UMI	HIC
MSW [kg/cap/yr]	252	255	278	146	412	579

The purpose of this thesis is to answer the following research questions:

- What is the average consumption of plastics and which types of plastic are consumed most in Laos and Vietnam?
- How is the waste management sector dealing with plastic waste and how can the current collection and treatment systems be improved?

2. Methods

Data for this thesis was collected by desk research. Secondary data from UN Comtrade, scientific papers, reports, websites, and questionnaires was processed. This data was chosen, as there is no official data available for Laos and Vietnam provided by the governments.

UN Comtrade is the United Nations International Trade Statistics Database, which is the largest database worldwide. This database helps to compare trade information of different countries. The data is reported by countries voluntarily. The United Nations Statistics Division (UNSD) processes annual international trade statistics data from 170 different countries or areas into the UNSD standard format. Values are converted into US-Dollar and quantities into metric units. Different categories are split into commodity codes according to the Harmonized System (United Nations, 2016), which is a six-digit code system to classify traded goods. As it is an international system, countries use it for reporting of customs purposes. Approximately 5,300 different products are classified into three different levels, chapters and grouping within chapters and specifications. For example, chapter 39 covers ‘Plastics and articles thereof’. One grouping within this chapter is ‘Polymers of ethylene, in primary forms’ (3901). On the next level one specification is ‘Ethylene polymers; in primary forms, polyethylene having a specific gravity of less than 0.94’ (390110) (United Nations, 2017).

For Vietnam export and import data from 2000 to 2016 was available. Categories with the commodity code 39, namely 'Plastics and articles thereof' including its subcategories were evaluated. In total 26 subcategories, with 4-digit commodity codes were identified, hence not all of them were filled with data. In most years, not more than two subcategories had missing data, therefore the years are included into the evaluation. The missing categories are either one or two out of these three Commodity Codes: 3911, 3913, 3914. All calculations were done with trade quantities.

Data for Laos was available for the years 2010 to 2016. The same CC and subcategories were reviewed.

As a second step, a questionnaire was prepared and sent out in April 2019 to four partners of the project 'South East Asia-Europe Network for building training and education capacities in Plastic Recycling in Laos and Vietnam with emphasis on quality, safety and resource efficiency', to gather more information about the market and the waste management of plastics in Laos and Vietnam. Three questionnaires were filled out and returned, two for Vietnam and one for Laos. Vietnamese questionnaires referred to the same sources for trade data and domestic production as found by desk research. Not all the questions were answered due to lack of information or answers were not given without any given reason. Especially questions regarding recycling activities and foreign trade of plastic waste did not give any new information.

One part of this thesis should have been a MFA to show the flows and quantities of different plastic types. Due to lack of data it was not possible to perform a MFA. Nonetheless it helped to identify missing data and indicated possible approaches for future field studies.

In this thesis following terminologies are used in the way explained below:

Municipal solid waste: UNEP defines MSW as follows: "waste consisting of everyday items, used and then thrown away, such as products packaging, bottles, food scraps and newspapers which comes from homes, schools, hospitals and businesses." MSW can be divided into three categories, which usually only includes non-hazardous waste: household, commercial and industrial waste (Rudolph et al., 2017).

Household Solid Waste: waste from single- and multiple-family-homes, hotels and day-use recreation areas are taken into account of household waste (Rudolph et al., 2017).

Informal sector: The informal sector includes all income-generating economic activities not authorized or regulated by the state, besides similar authorized and monitored activities. Informal activities are small-scale and labour-intensive (Castells and Portes, 1989). Workers in the informal sector are not covered or insufficiently covered by law and don't pay taxes (OECD/ILO, 2019). For this thesis informal activities are only related to MSW management.

Secondary raw materials: Materials, which are produced through recycling processes are called secondary raw materials. They can be used in manufacturing processes instead of or alongside virgin raw materials (European Parliament, 2019). The quality of secondary raw materials highly depend on the quality of the input materials (Neidel and Jakobsen, 2013).

3. Plastic Market Situation

Rapid industrialization of emerging and developing countries led to a rising demand of raw plastic material worldwide. Due to globalization, trade flows are expanding but are accompanied by volatile market prices. Recycling rates started to increase but the market for secondary raw material remains volatile. The lack of sorted and uncontaminated plastic waste, along with insufficient and outdated recycling processes is an obstacle for Laos and Vietnam. Transboundary waste shipments have increased in the last decade. Industrialized countries send their plastic waste to developing countries, because recycling processes are labour-intensive and workforce in developing countries is still cheap (Hammerschmied, 2019). According to the UN, Asia represents the major global recycling market, not only for plastics, but also for e.g. metals or paper (Wilson et al., 2015).

Plastic packaging is the main production sector for plastic products and is the fastest growing sector. The main polymers used for plastic packaging are PET for bottles, PP and HDPE together with LDPE, as listed in Tab. 2.

Tab. 2: Most Common Polymers Used in Packaging Applications (Rudolph et al., 2017)

Application	**Most Common Polymers Used**
Bottles, flasks	PET (65.6%), HDPE (28%), PP (3%), PVC (3%), LDPE (0.4%)
Closure items, bottle caps	PP (73%), HDPE (20%), LDPE (5%), PVC (2%)
Films	LDPE (76%), PP (20%), PVC (3%), PET (1%)
Bags, sacks	LDPE (61%), HDPE (31%), PP (8%)
Jars, boxes, tubes	PP (73%), HDPE (20%), LDPE (5%), PVC (2%)

Plastics consist of a variety of components to be suitable for different areas of application. Additives are important to give plastics their specific attributes. Chemical resistance, heat-proof or flexible features are some examples for their variety of attributes. Trade statistics and production information do not include the content of additives and fillers, as plastic composition is corporate secret. Therefore Mutha et al. (2006) estimated the share of additives by application. As a basis for the estimation they used the book ‘Additives for Plastics Handbook’ by Murphy (1996). The required quantity of additives is rather small, as production is expensive. The amount is increasing for technical plastics as they need to meet higher standards for i.e. heat-resistance or rigidity (Lindner and Hoffmann, 2015; Stoifl et al., 2017).

Tab. 3: Fractions of additives by application (Mutha et al., 2006)

Application	**Additives and fillers [%]**
Films	4–5
Injection moulding	6–10
Blow moulding	15
Pipes and conduits	20

Wire and cable	8–20
Woven sacks	12
Extrusion coating	7
Profiles	25
Rotomoulding	10
Monofilaments	10
Footwear	25
Sheets	15
Hoses and tubes	15
Appliances	10
Others/rest	5–15

Additives influence the service life of plastics. According to PlasticsEurope (2019) 60% of plastics have a durability of less than 50 years, depending on the type of plastic and usage. Plastic packaging reaches its end of life in one year, which is far sooner than pipes, therefore generated plastic waste does not necessarily correlate with plastic consumption and waste generation in the year of interest. The classification of plastic products by consumer sectors of Van Eygen et al. (2017) was adapted and extended by service life as shown in Tab. 4.

Tab. 4: Consumption sectors, some product examples and their service life (Mutha et al., 2006; Van Eygen et al., 2017)

Consumer Sector	**Product examples**	**Service life [yr]**
Packaging	Foils, bottles, carrier bags, containers	1
Building & construction	Pipes, floor coverings, window profile, coatings for cables	35
Technical	Cars, trucks, bicycles, electronic equipment	20
Consumer	Household appliances, cutlery, kitchen utilities, clothing, yarns, toys, furniture	5-15

3.1 Market situation in Laos

Laos is a landlocked country bordering China in the north, Vietnam in the northeast and east, Cambodia in the south, Thailand in the west and Myanmar in the northwest. Laos main trading partner are Thailand, China and Vietnam (Bannister et al., 2017; Lafont and Silverstein, 2020). The economic situation of Laos is improving but still it is one of the poorest countries in Asia (Menon and Warr, 2013).

3.1.1 Production

Plastic production takes place in Laos, hence no specific information nor quantities of production of plastic goods and primary material is available. However, Laos is in the

beginning of starting a statistical database. In the statistical yearbook of 2018, a value of total production of plastic goods in 2017 and 2018 was published. According to the statistical yearbook in 2017 plastic goods with a value of 817 Mio Kips were produced. In 2018 the value increased to 886 Mio Kips (Ministry of Planning and Investment and Lao Statistics Bureau, 2019). Without quantities or specification to different plastic types these numbers cannot be further processed or used.

3.1.2 External trade

In a 2017 study of Bannister et al., different trade statistics were assessed and showed that there is a gap between national reporting and international trade statistics. Data from UN Comtrade is collected as a mirror statistic. Mirror statistics use the import and export data of trading partners to gain information about the country in demand. Regarding plastics, data from Comtrade showed that there was significantly more export of plastic than data of the Lao Ministry of Industry and Commerce (MOIC) revealed. Data of MOIC could not be found for further processing.

In Laos around 17,000 tons of plastic polymers and products were imported in 2016. The export of plastics compared to the import is rather low with approx. 2,300 tons in 2016.

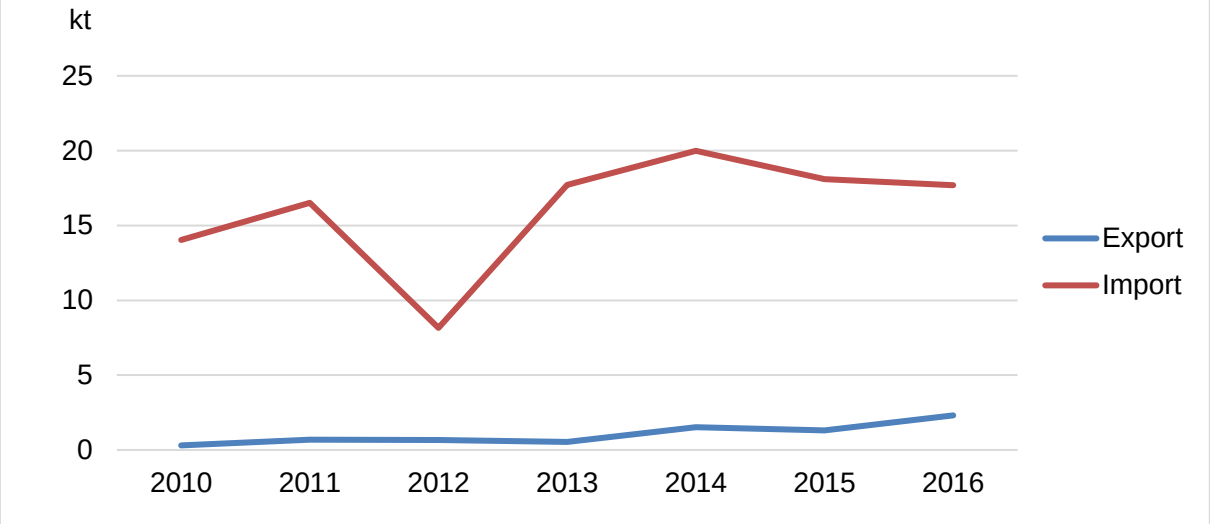

Figure 1: Laos foreign trade of plastic materials, products and waste (DESA/UNSD United Nations Comtrade database, 2018)

Import and export, as shown in Figure 1 is slightly increasing. The lowest import quantity in 2012 cannot be explained, but it is assumed that insufficient data is the main reason. According to the most recent Comtrade data from 2016 the five most important polymers imported in Laos are PVC, PS, PP, PE and PA. PVC import represents the biggest share, with a great margin. For the high amount of PVC imported, no reason could be found during the desk study. The export of PVC declined from around 6 tons in 2014 to around 200 kg in 2015 and 2016, according to UN Comtrade. Import of PVC is steadily growing since 2012.

According to data from UN Comtrade the export of plastic waste, parings and scrap grew significantly since 2010 as shown in Figure 2. Rising consumption and the fact, that there is only one recycling plant operating explains the high amount of exporting plastics waste. As there is no additional data on foreign trade, it cannot be confirmed that the Comtrade data is entirely correct. Due to time-lag in importing and exporting, different reporting tools and categories, there is a bilateral discrepancy in mirror

statistics (Javorsek, 2016). Illegal trade of plastic material should also be taken into account when looking at trade statistics (Kellenberg, 2015).

Import of plastic waste, parings and scrap is volatile according to Comtrade data. With the peak of import in 2013 and then slowly decreasing import quantities, as shown in Figure 2.

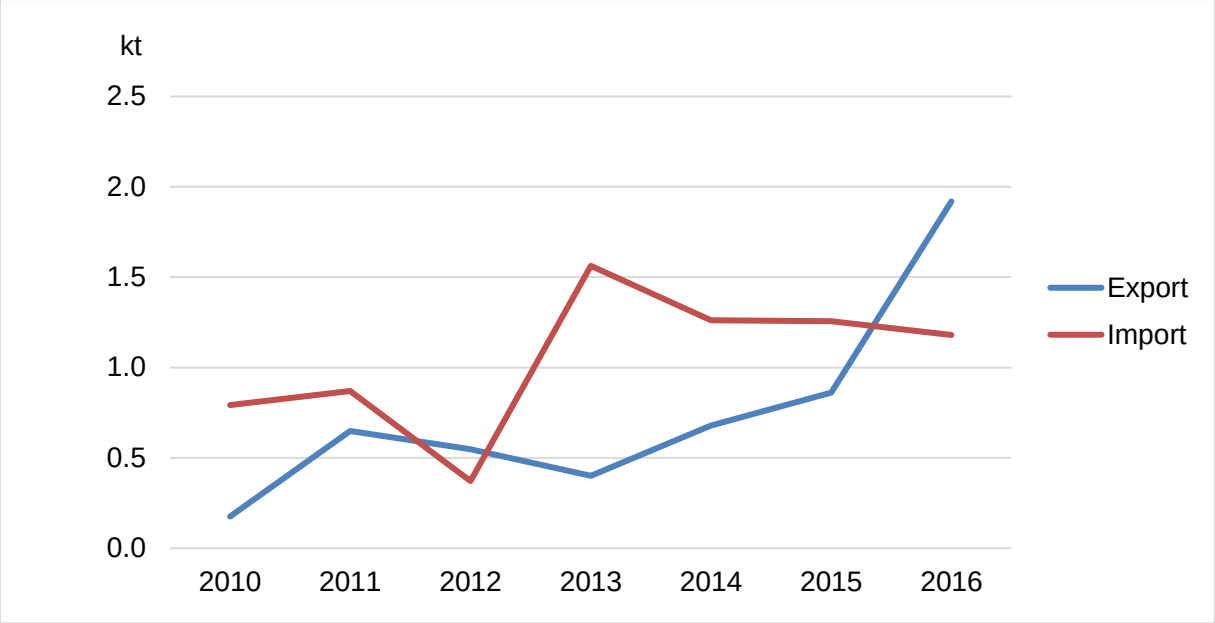

Figure 2: Laos foreign trade of waste, parings and scrap of plastic (DESA/UNSD United Nations Comtrade database, 2018)

3.1.3 Domestic Consumption

In Cambodia and Myanmar the domestic plastic consumption in 2010 was 25.5 kg/cap/yr according to a study of Jambeck et al. (2015). As these two countries have a comparable economic state it is assumed that the domestic consumption of plastic in Laos is the same. Further information or other sources could not be found.

In Laos data of plastic production is not available. Neither information about the types of plastic produced nor quantities could be found. Foreign trade is insignificant with an import of 17,000 t of plastic in 2016 and export less than 2,300 t. It is assumed that this is a result of a small and underdeveloped plastic industry along with illegal import and export activities and lack of recording. Especially in regard of waste trade, it is assumed that it is done illegally. Foreign trade of plastic waste is low, with 1,900 t in 2016, as shown in Figure 2. However, export of plastic waste is increasing. The estimated domestic plastic consumption is 25.5 kg/cap/yr.

3.2 Market situation in Vietnam

The plastic industry in Vietnam is a relatively new sector compared to other industry sectors, as the textile industry. In the early 1990s plastic production started to increase slowly. In 2016 approximately 2,000 plastic manufacturing sites were established (StoxPlus, 2017; Tran, 2019; VPA, n.d.).

Domestic production sites for primary material are not able to meet the demand of plastic manufacturing industry, therefore the Vietnamese government passed decision 2992/QD-BCT in 2011 to strengthen the plastic industry. This decision includes targets till 2020 and an outlook till 2025 to achieve higher production quotas. Plastic

manufacturing companies receive tax and capital incentives to increase their output. According to this decision, plastic production shall reach 12.5 Mio tons in 2020 and shall have a yearly growth rate of 15% (Vietcombank Securities, 2016). In 2013 the domestic production was 5.2 Mio tons, as shown in Figure 3. Between 2012 and 2018 the plastic industry had an annual growth rate of 16 to 18%. In 2018 the production quantity rose to 8.3 Mio tons.

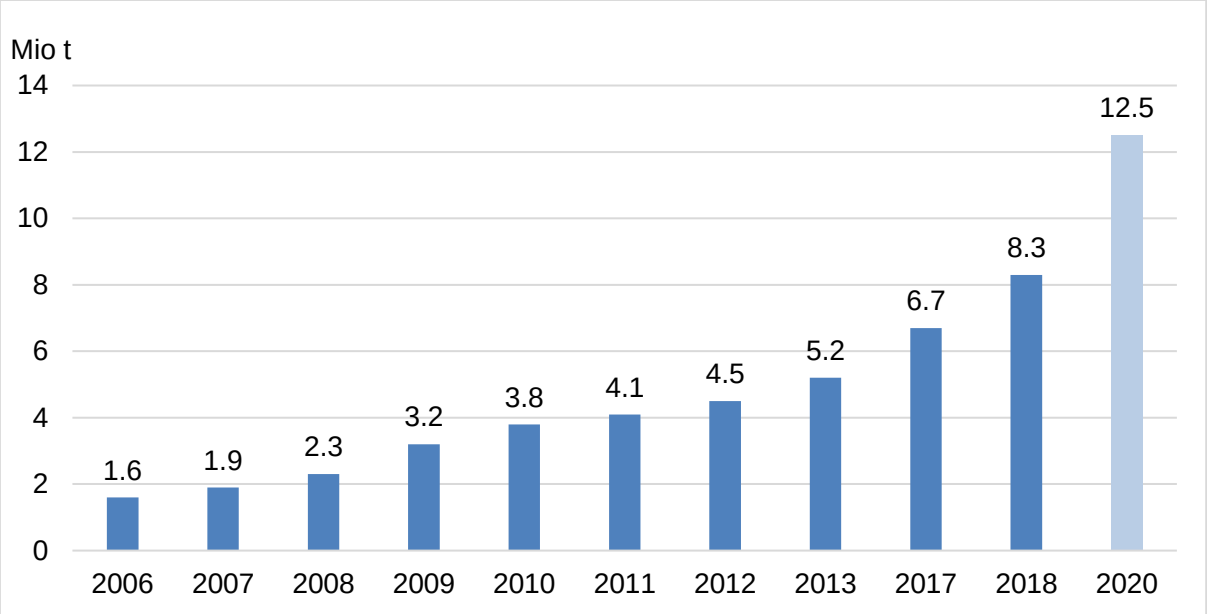

Figure 3: Vietnamese plastic production output in Mio t (British Plastics Federation, n.d.; Tran, 2019; Vietnam Business Council for Sustainable Development, 2019)

Between 80% and 90% of primary plastic material is imported due to an underdeveloped petrochemical industry. The demand for PE and PP resins is high and growing every year (Vietcombank Securities, 2016).

3.2.1 Production

Vietnam Plastic Association (VPA) divides the plastic industry into four main segments, namely consumer, construction, packaging and technical sector. The consumer sector includes single use products as straws, tableware and furniture. Pipes, isolation for cables and water tanks are part of the construction sector. Parts for machinery, electronic equipment and cars are summarized as technical products (Vietcombank Securities, 2016). The packaging industry is the largest segment, with app. 38% of total production in 2015, as shown in Figure 4 (Deutsche Gesellschaft für Internationale Zusammenarbeit GIZ, 2018; StoxPlus, 2017; VPA, n.d.). According to the governmental plastic development plan, construction and technical sectors shall increase their proportion of plastic production compared to the packaging and consumer sectors.

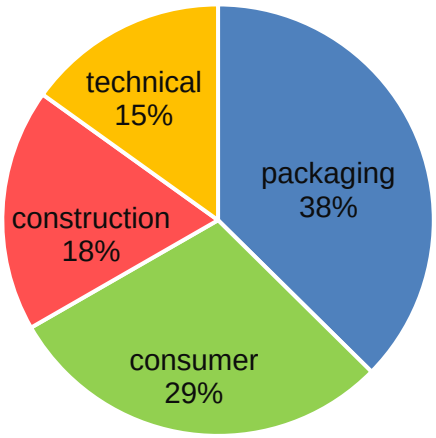

Figure 4: Production share of plastic industry sectors in 2015 (VPA, n.d.)

According to StoxPlus (2017), there are seven manufacturing sites, which produce primary polymers. Tab. 5 shows the output capacity of domestic production of primary materials. The highest amount of domestically produced plastics is PP. According to VPA (n.d.) two companies are producing a total amount of 420,000 t of PVC per year. In the report of StoxPlus (2017) domestic production of PE is not mentioned. It is not clear, if there is no PE production in Vietnam or if there is no available data on it. The petrochemical industry in Vietnam is rather new and small. Currently there are less than 30 oilfields and two refineries (British Plastics Federation, n.d.). The total domestic production of primary material is approx. 1,700,000 t/yr, which accounts for approx. 20% of the take up in plastic processing production. In autumn 2018 Nghi Son oil refinery started with a new production facility with a capacity of 370,000 tons of PP per year, which will meet nearly 50% of the domestic PP demand. At the same time production of 400,000 tons of PET plastic pellets started (Vietnam Business Council for Sustainable Development, 2019).

Tab. 5 production of primary material in Vietnam (StoxPlus, 2017; Vietnam Business Council for Sustainable Development, 2019; VPA, n.d.)

Raw material	**Output capacity [t/yr]**
PP	622,000
PET	545,000
PVC	420,000
PS	48,000
EBS	38,000
DOP	40,000
Total production	1,700,000 t/yr

Vietnam mainly imports plastic resins from Saudi Arabia, South Korea, Taiwan, China and Thailand (VPA, n.d.).

The main proportion of additives is also imported, as production facilities are small to medium size companies which cannot meet the demand (British Plastics Federation, n.d.).

The report “Vietnam Plastic Industry” of Concetti (2013) claims that most of all household and packaging products that are sold in supermarkets are manufactured domestically. Neither specific data, nor an explanatory statement is given in the report. The statement could not be verified or proven wrong by other sources.

Machinery is mainly imported from other Asian countries and Europe. The equipment is not state of the art, exceptions are major factories who need to stay competitive to the international market. Small businesses mainly use outdated machinery and often second-hand equipment (British Plastics Federation, n.d.; Concetti, 2013).

Primary domestic production quantities are collected from VPA, StoxPlus and the Vietnam Business Council for Sustainable Development as shown in Tab. 5. Other papers and reports also refer to data of VPA, therefore no other sources for verification could be found. Data of domestically manufactured semi-products and products could not be found specifically for any plastic type.

According to Vietnam Business Council for Sustainable Development (2019) in 2018 a total of 8.3 Mio tons of semi-finished and finished plastic products were manufactured in Vietnam. These products were manufactured from 6.9 Mio tons of resins and approx. 1.4 Mio tons of recycled plastic scrap (Vietnam Business Council for Sustainable Development, 2019). In the case of PP it is assumed that 3.3 Mio tons of final products are domestically manufactured.

With the current information available and lack of specific data of external trade of plastic scrap and waste it was not possible to gain information about the share of domestic recycling activities. It is not certain, to which extent imported plastic waste is re-exported or processed within the country.

3.2.2 External trade

The Vietnamese plastic industry highly relies on importing plastic resins in primary form. The market price for primary material correlates with the international oil price. Due to this correlation, domestic businesses are dependent on foreign exchange rates (VPA, n.d.). The UN Comtrade data reaffirms this demand for plastic in primary forms as seen in Figure 5. The main five primary polymers which are imported are PE, PP, PS, PVC and PA and PC. The latter including other polyethers and epoxide resins, in primary forms; polycarbonates, alkyd resins, polyallyl esters and other polyesters, in primary forms. Polymers of the last category are mainly used in technical industry, because of their high mechanical strength, stiffness, hardness, and low coefficient of friction. A VPA report states that in 2015 a total of 1.07 Mio tons of PE in primary form and 0.89 Mio tons of PP in primary form were imported (VPA, n.d.). This is coherent with the data evaluated from UN Comtrade.

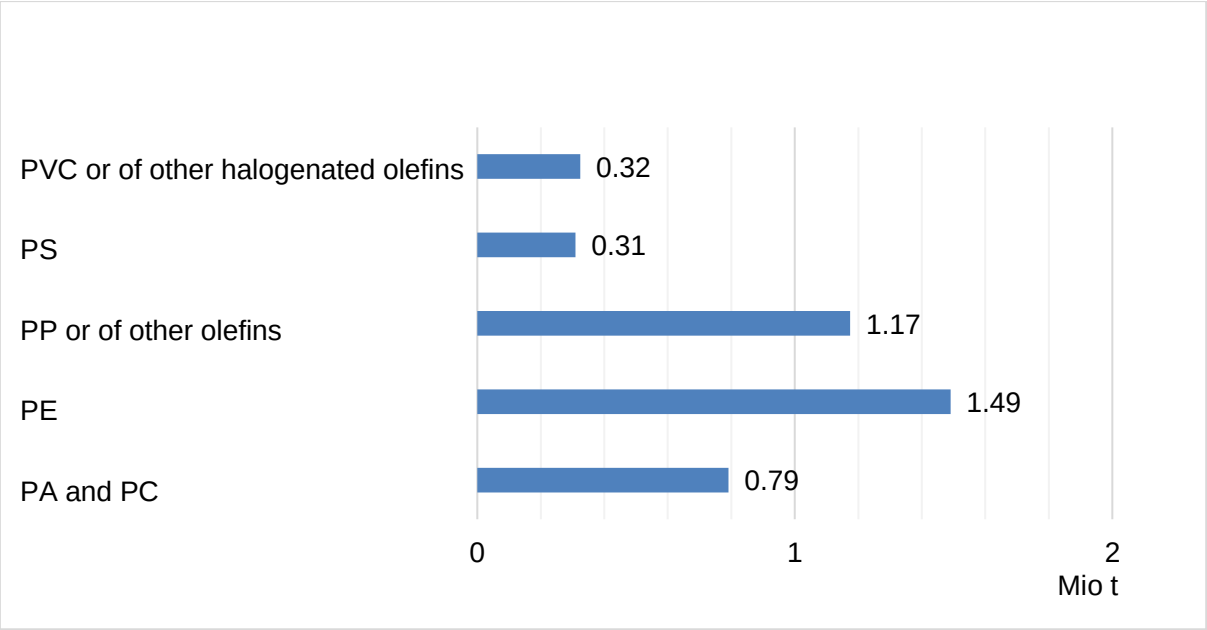

Figure 5: Top 5 import quantities of plastics in primary form in Vietnam in 2016 (DESA/UNSD United Nations Comtrade database, 2018)

The import of plastic material grew from 1.2 Mio. tons in 2000 to 10.5 Mio. tons in 2016 (DESA/UNSD United Nations Comtrade database, 2018) as shown in Figure 6. This statistic contains imports of plastic primary material, plastic products as well as plastic waste.

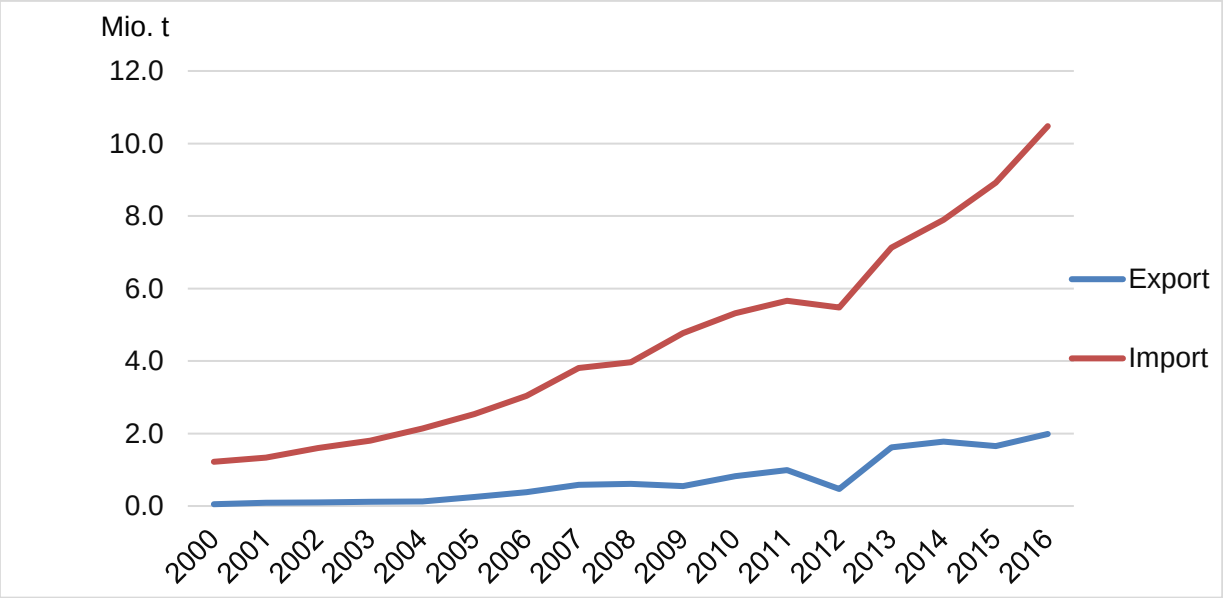

Figure 6: Vietnam foreign trade of plastic material and products (DESA/UNSD United Nations Comtrade database, 2018)

The two biggest fractions of primary material are PE and PP. It can be explained due to a high demand on the market and strengthening of the plastic industry sector by the government. Due to lifestyle changes the demand of plastic products rose in general. The import of PE also shows a rapid growth since 2000. The export of PE stays at low level as pictured in Figure 7, since there is hardly any production of primary material within the country and the domestic produced PE is used by Vietnamese companies. This is also applicable for PP export and import, as shown in Figure 8. 51% of total volume of plastics imported, are PE and PP, being further processed by packaging

industry. The import of approx. 1.1 Mio. tons of PP resins are in the same range as Vietcombank Securities (2016) stated in their report.

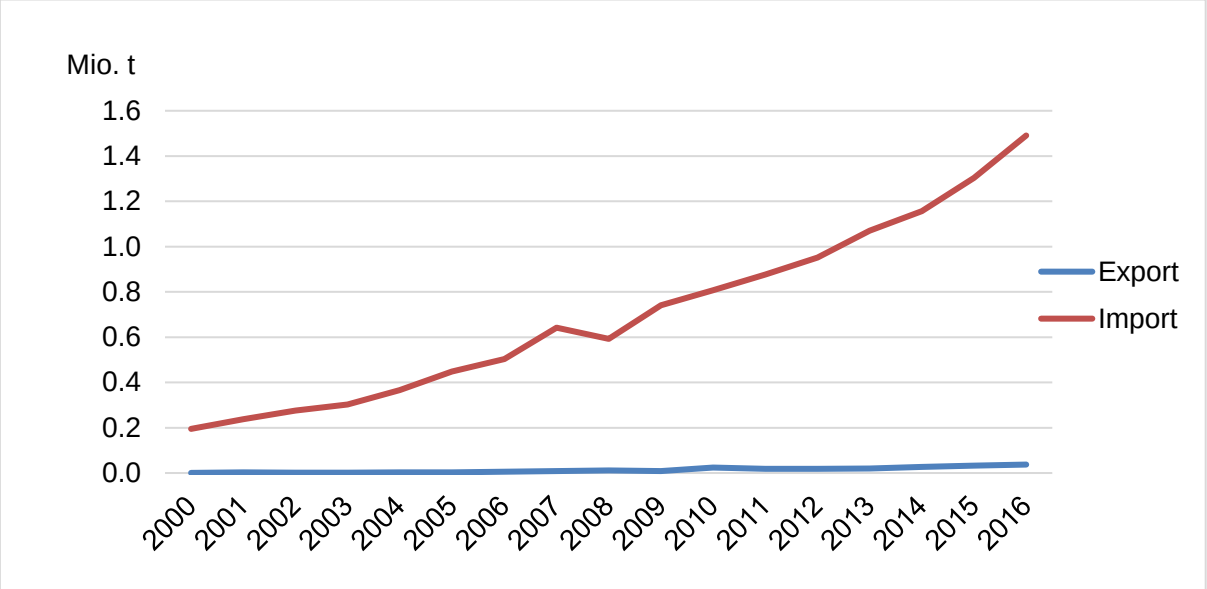

Figure 7: Vietnam foreign trade with polymers of ethylene in primary forms (DESA/UNSD United Nations Comtrade database, 2018)

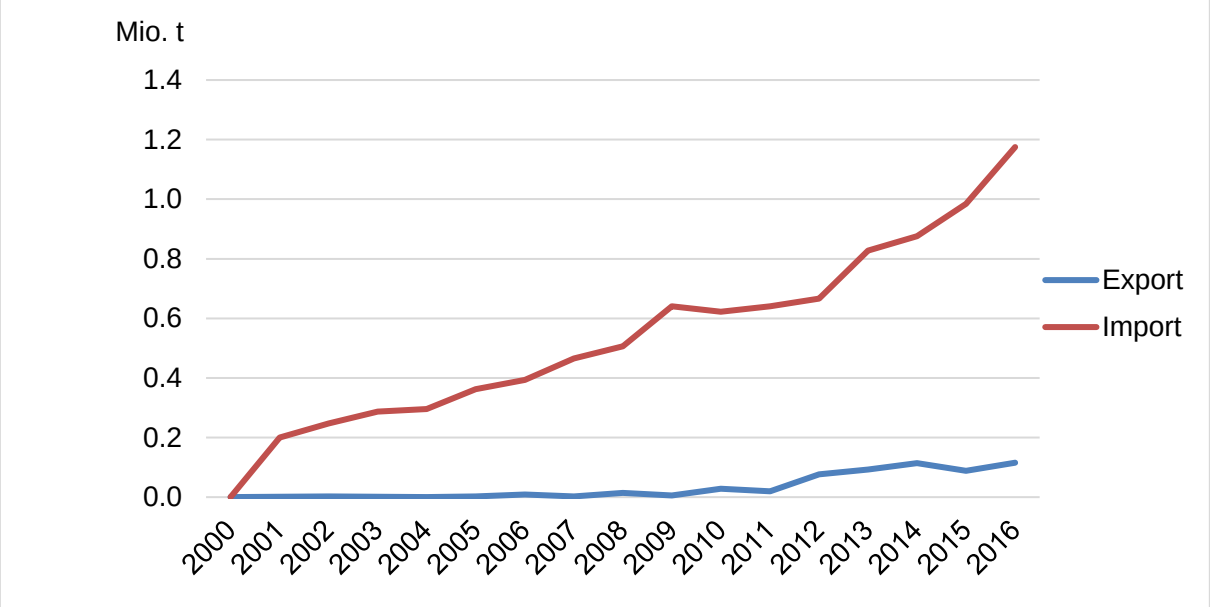

Figure 8: Vietnam foreign trade with polymers of propylene, or of other olefins in primary forms (DESA/UNSD United Nations Comtrade database, 2018)

Vietnam also trades plastic waste, although there is no official data or statement of the Ministry of Industry and Trade, UN Comtrade shows external trade with plastic waste. Several other sources also refer to trading quantities of UN Comtrade. According to which, the import and export of plastic waste increased since 2005. For 2012 there was no data available, therefore the average of 2011 and 2013 was taken. Beginning of 2011 the export exceeded the import of plastic waste as shown in Figure 9. In 2015 the amount of waste parings and scrap of plastic exported was 119,000 tons, which was lower than in previous years. An explanation for the reduced amount could not be

found. Other sources than Comtrade to receive information or data about external trading amounts of plastic waste could not be found.

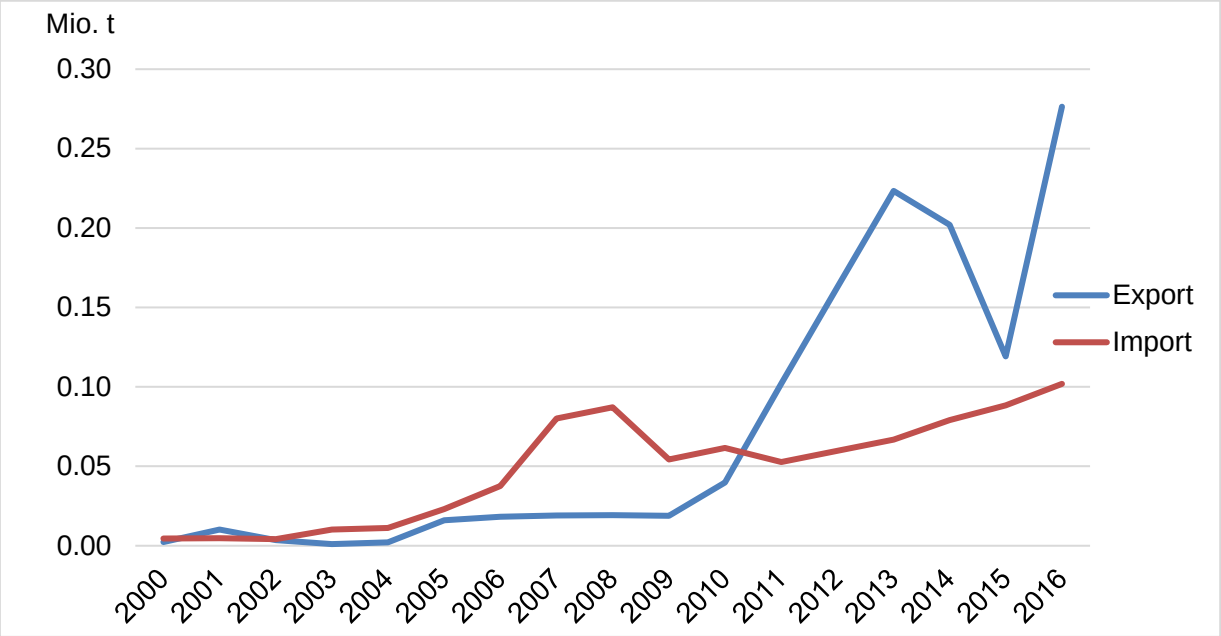

Figure 9: Vietnam foreign trade with waste, parings and scrap (DESA/UNSD United Nations Comtrade database, 2018)

In 2017 China banned plastic waste scrap with low quality and unsorted MSW from import, starting January 1St 2018, which led to an increased amount of scrap import into Vietnam. Especially plastic waste of low quality is an issue for the recycling industry, the government feared environmental disadvantages, therefore no new licenses for the import of plastic waste were issued beginning of July 2018. Illegal shipments of waste are also at the centre of attention of government officials to avoid environmental issues (Das, 2018; Thong, 2018; Vu, 2018).

In 2016 Japan has been the largest importer of plastic consumer products made in Vietnam. Especially the demand for plastic bags was high (Vietcombank Securities, 2016).

Statistics show that export of plastics mainly takes place in the form of products. Comtrade data was used to give an overview of the top five exported products. For some categories the quantities were missing. To give an overall picture and include all data available, Comtrade data was processed. The trade value of each CC by each year known, was divided by trade quantity of the same category and year to calculate the value of one ton of plastic in this category. These calculations were done for each of the five categories. The result is value per ton. Due to yearly fluctuation the average value per ton was used to calculate the missing quantities (quantity of CC of year x = value of year x/calculated average value per ton). 27 out of 85 quantities needed to be calculated. The top five export categories have the commodity codes 3920, 3921, 3923, 3924 and 3926. In Tab. 6 the description of these CC is given. The full list of CC including plastics and related commodity names can be found in Annex I.

The most important products exported are packaging plastics. Figure 10 shows that the exported quantity of plastic articles for the conveyance or packing of goods; stoppers, lids, caps and other closures of plastics (3923) was increasing tremendously. With more than 200,000 tons exported in 2016 it is the most important category for plastic industry with a revenue of 840 Mio USD. Articles of plastics and articles of other materials of heading no. 3901 to 3914, n.e.c. in chapter 39 (3926) also has a big

revenue with 770 Mio USD, but with less quantity compared to packaging products. 3926 includes articles of apparel and clothing, fitting for furniture and coachwork, statuettes and ornaments as well as office and school supplies (DESA/UNSD United Nations Comtrade database, 2018). Since Vietnam imports about 80-90% of primary material, it is obvious that there is hardly any export of primary material, as the domestic production is low and the domestic demand is high.

Tab. 6: Commodity codes and name of top 5 export categories (DESA/UNSD United Nations Comtrade database, 2018)

CC	**Commodity Name**
3920	Plastics; plates, sheets, film, foil and strip (not self-adhesive); non-cellular and not reinforced, laminated, supported or similarly combined with other materials, n.e.c. in chapter 39
3921	Plastic plates, sheets, film, foil and strip n.e.c. in chapter 39
3923	Plastic articles for the conveyance or packing of goods; stoppers, lids, caps and other closures of plastics
3924	Tableware, kitchenware, other household articles and hygienic or toilet articles, of plastics
3926	Articles of plastics and articles of other materials of heading no. 3901 to 3914, n.e.c. in chapter 39

In 2017 a total of 6.7 Mio tons of plastic was produced in Vietnam, as shown in Figure 1. Approximately 1.7 Mio tons of the total plastic produced is primary material. According to UN Comtrade the sum of top 5 commodities exported was approximately 0.4 Mio tons in 2016. Which accounts for around 4.6 Mio tons of domestic plastic consumption.

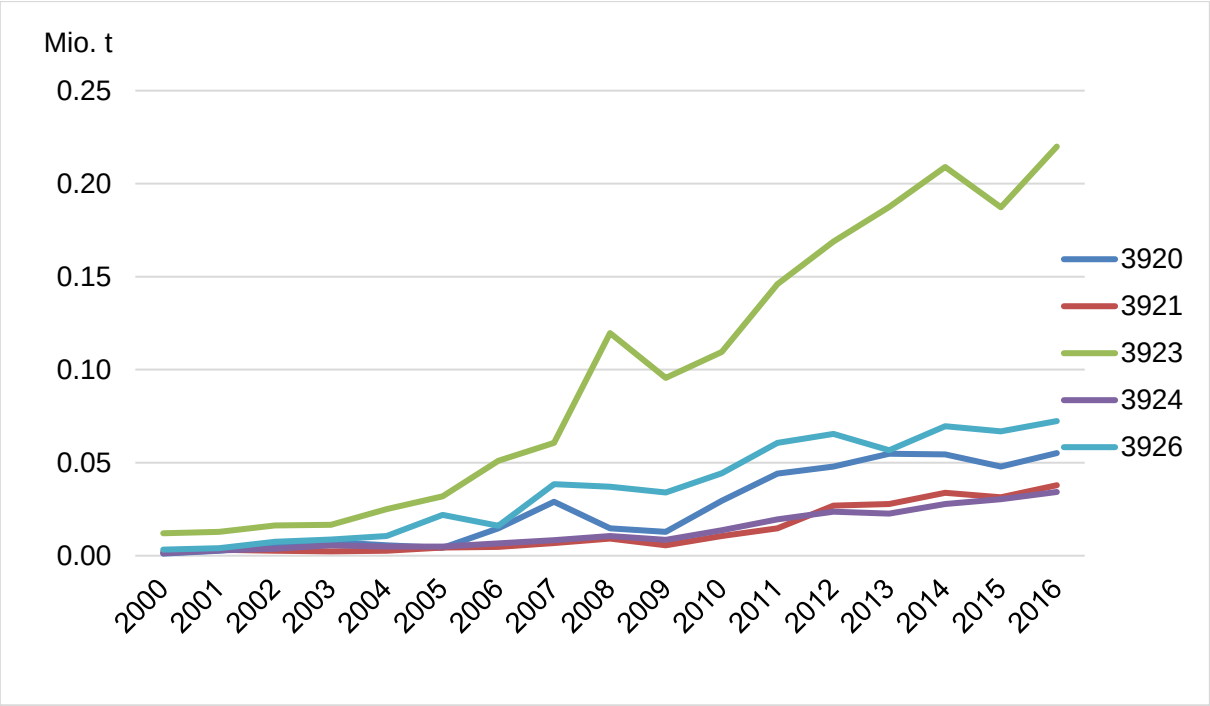

Figure 10: Top 5 categories of plastic products exported from Vietnam, by quantity (DESA/UNSD United Nations Comtrade database, 2018)

3.2.3 Domestic consumption

Plastic consumption is defined as imported polymers, plastics, plastic products plus domestically produced plastics, polymers and products minus exported plastics within a given time period. It includes primary material, additives and fillers for manufacturing, plastic products as well as products which contain a fair amount of plastics.

Mutha et al. (2006) states that approximately 60% of total plastics consumed in India are polyolefins. Whereas Kunststoff-Deutschland (s.a.) states that in Europe approx. 48% of the total plastic consumption are polyolefins. Polyolefins include PP, PE, LDPE, HDPE, LLDPE (Kunststoff-Deutschland, n.d.; Plastics Europe, n.d.). It is assumed that the share of polyolefins in Vietnam is comparable to India, therefore calculations were made with 60% polyolefins consumed of total domestic plastic consumption.

The per capita plastic consumption in Vietnam is still low compared to other Asian countries. The consumption is rising due to changing lifestyle and higher income. The per capita consumption of plastic products was 40 kg in 2012 (British Plastics Federation, n.d.). In 2015 the per capita consumption rose up to 55 kg as shown in Figure 11. Calculated with the numbers of the previous chapter 3.1.2 of 4.6 Mio tons of total domestic consumption divided by the total population of 96.46 Mio the result is 47 kg/cap in 2017, which is in a similar range as the number of Heinrich Böll Foundation (2019) with 41.3 kg/cap in 2018 and the number of British Plastics Federation. The graph shows a comparison of the per capita plastic consumption to Laos, Thailand, Austria and Germany. Due to lack of data, the consumption refers to different years. The Vietnamese consumption is of 2015, the Austrian, Laotian and Thai data of 2010. In Germany the consumption of plastics was 103 kg/cap in 2016, for post-consumer plastics. If only plastic packaging of HSW is considered the consumption in Germany was 25 kg/cap in 2016 (Federal Ministry for the Enviornment Nature Conservation and Nuclear Safety, 2018). In 2017 the per capita consumption of plastic packaging rose to 38.5 kg (Schüler, 2019).

In both countries domestic plastic consumption is low compared to industrialized countries like Austria and Germany. However, the consumption is comparable to countries with a similar economic state. Laos can be compared to Myanmar and Cambodia. Vietnam is similar to Thailand, although Thailand's economic development and infrastructure is more advanced.

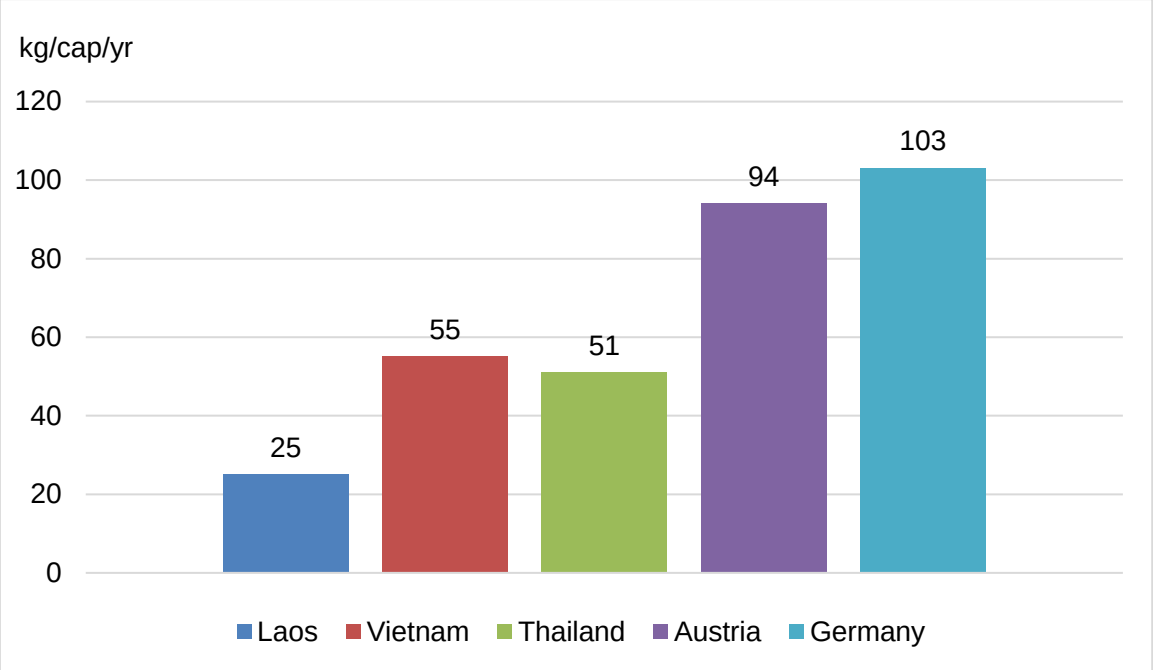

Figure 11: plastic consumption (British Plastics Federation, n.d.; Federal Ministry for the Enviornment Nature Conservation and Nuclear Safety, 2018; Jambeck et al., 2015; Stoifl et al., 2017)

For Vietnam, it is not stated if this data only includes urban areas, therefore it is assumed as data representative for the whole country. In developing countries there is a gap between consumption in urban and rural areas. In urban areas the per capita consumption of plastics, especially plastic packaging is comparable to other Asian cities. In rural areas people grow food on their own, so there is little demand on extra packaging (Guerrero et al., 2013; Marshall and Farahbakhsh, 2013; The World Bank, 2012).

4. Waste Management Systems

In lower middle-income countries as well as developing countries MSW generation is approx. 233 kg/cap/yr as shown in Tab. 1. Collection of MSW is executed in urban area, whereas in rural areas often no waste management system exists. It is common practice to litter or to burn waste in order to reduce the amount.

Waste management systems operate on low standards and are often not efficient, due to financial constraints and social perception. They show some similarities regarding their socio – economic conditions. Open dumping or landfilling without prior treatment are the main disposal methods. Sanitary landfills are rare and do not fulfil western standards (Aparcana and Salhofer, 2013; Wilson et al., 2006).

Informal workers are essential to recycling plastics and other valuable materials. They provide a valuable service to the society by collecting waste from the streets and consequently reducing the amount of waste taken to the landfill. Municipalities do not have enough resources to build an integrated waste management system (Sakai et al,

2013). Not only financial constraints are limiting new technologies and landfills, but also population growth and land scarcity (Kawai et al., 2012a). In ASEAN countries there is a lack of technically trained employees. Handling waste and especially hazardous waste is not properly managed. Innovative processes are not implemented, hence to low capacity for innovation which comes along with little courage (Lewis and Bengtsson, 2019). Recycling businesses operate at low organization levels, with little capital. Usually the whole family is running a small unregistered enterprise without rules and regulations. Health and safety regulations, laws and taxes are avoided and not payed (Gunsilius et al., 2011a; Wilson et al., 2006).

Kawai et al. (2012b) compared data of MSW collection in Vietnam with data from Japan and came to the conclusion that fundamental and reliable data on a local level is available, which is also comparable to data from Japan. This data is also within the range Shekdar (2009) stated for MSW composition in developing countries. Nevertheless, improvements in keeping records need to be made. Human errors and lack of weighbridges lead to defectiveness of collection amounts. It is recommended to develop methods for estimating collection amounts (Kawai et al., 2012b).

In developing countries people have little income and there is no social security system in place therefore people are working in informal sectors. Materials which can be sold, e.g. metals or plastic are a source of income for waste pickers, junk buyers and small recycling businesses (Truong, 2018). Formal waste management systems started to rely on informal waste pickers, as they reduce the volume and amount of waste by collecting recyclable materials.

The generation of municipal solid waste is still lower than in western countries. As shown in Figure 12 the per capita MSW generation in Vietnam is 1.46 kg per day and in Laos 0.7 kg. In comparison in Austria 2.23 kg are generated per capita and day.

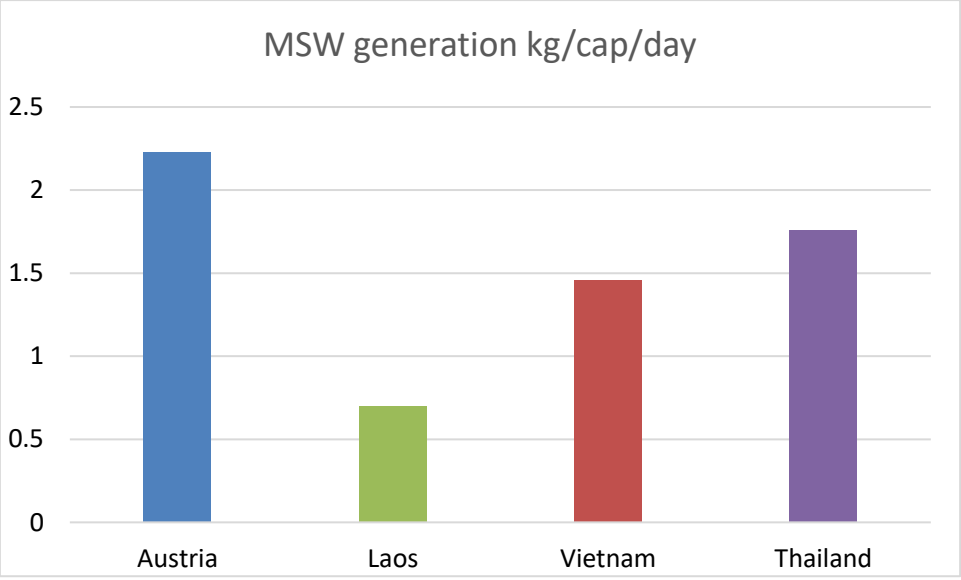

Figure 12: MSW generation rate in 2012 (Hoornweg and Bhada-Tata, 2012)

4.1 Waste Management System in Laos

In Laos there are several authorities involved in waste management and recycling. On a national level the ministry for Natural Resources and Environment (MoNRE) and the Ministry of Public Works and Transport (MPWT), as well as the Ministry of Planning and Investment (MPI) specifically for plastics are responsible for these tasks. In the provinces the Urban Development Administrative Authorities (UDDAs) are responsible for waste management issues (Akenji et al., 2019; MoNRE, 2019).

According to Sato et al. (2019) MSW is defined as waste produced by households, commercial enterprises and industries. Industrial hazardous waste is collected separately in Vientiane and Luang Prabang and disposed of in designated compartments of the landfill (Science Technology and Environmental Agency Lao PDR, n.d.).

In Vientiane the capital city of Laos, approximately 30 to 50% of generated solid waste is collected by Vientiane City Office for Management and Service (VCOMS) or one of its contractors (Akenji et al., 2019; Global Green Growth Institute, 2018). In total around 8.7% of the waste is recycled. The recycling rate is calculated as following: (collected recyclable waste)/(estimated generation of waste). Laos faced a fast-growing urbanization. Between 1990 and 2014 the share of urban population increased from 15.4% to 37.6% (Curea, 2017; MoNRE, 2019).

The average MSW generation rate in urban areas is 275 kg/cap/yr. Whereas in Vientiane and in four secondary cities, Luang Prabang, Thakhek, Savannakhet and Pakse, the per capita generation is between 292 kg and 511 kg per year. These four cities are using landfills, without any sanitation, for the disposal of MSW. Other cities and rural areas dump MSW openly or burn waste. Industrial and hazardous waste are often disposed of in the same areas. Local authorities are in charge for collection and disposal activities. (Ministry of Public Works and Transport and Ministry of Natural Resources and Environment, 2013).

In Savannakhet approximately 40-50% of solid waste is collected. Recycling material is mainly collected at curb side by waste buyers and then sold to junkyards and dealers. Approximately 5% to 10% of the total waste stream is recycled. Presumably, this not only includes plastics but also glass, metals, and organic waste. A simple MRF is operated by a private contractor (Curea, 2017; Ministry of Public Works and Transport and Ministry of Natural Resources and Environment, 2013).

In four major cities of Laos the waste composition was analysed by Sang-Arun and Pasomsouk (2012). Plastic waste has a share between 6% in Pakse and 15% in Savannakhet of the total solid waste generation in each city. The share of organic waste (food and vegetables, wood, grass, trees, leaves) in Vientiane with 49% is lower than in the three major cities with a share ranging between 70 to 83% but in all four cities it is the largest fraction. According to the Global Waste Management Outlook in middle- and low-income countries the share of organic waste is averaging 46 to 53% (Wilson et al., 2015). The report states further that the share of plastic is ranging from 7 to 12% without any connection to the income level. No study could be found about the waste composition in rural areas. Studies in other countries show that waste generation typically is lower than in cities. The share of organic waste is higher, while the share of plastics is lower compared to cities.

Tab. 7: Waste composition of four major cities in Laos (Sang-Arun and Pasomsouk, 2012)

Waste fraction [%]	Vientiane	Luang Prabang	Savannakhet	Pakse
Food, Vegetables	30	51	54	62
Wood/Grass/Trees /Leaves	19	23	16	21
Paper	6	8	9	4
Plastic	13	9	15	6
Glass	6	6	2	2
Metal	3	1	1	1
Textile	2	1	1	1
Other	21	1	2	3
Total	100	100	100	100

4.1.1 Legal Framework

On a national level MPWT is the main ministry regulating the solid waste management sector. Preparation of environmental laws and regulations on the other hand, is one of the responsibilities of MoNRE. In 2017 the ministry issued Lao PDR's national environmental standard, which regulates the emission of several substances and consequently the waste management sector (Global Green Growth Institute, 2018). The basis for SWM in each city is regulated by provincial decrees (Ministry of Public Works and Transport and Ministry of Natural Resources and Environment, 2013).

The Environment Protection Law No. 29/NA from 2012 and the National Action Plan (2016-2021) on Solid Waste Management are the main instruments to encourage citizens and private companies to reduce waste at source by following the 3Rs concept (Reduce, Reuse, Recycle) (Global Green Growth Institute, 2018; MoNRE, 2019).

4.1.2 Collection

In all major cities, there is a collection system implemented, but there is no separate collection of specific waste fractions. Around 71% of the area is covered by collection of MSW. The Urban Development Administration Authority of Luang Prabang and local private contractors are handling MSW collection and disposal. The per capita MSW generation is 239 kg/cap/yr. in 2011. Approximately 3% of MSW generated, was recycled (Ministry of Public Works and Transport and Ministry of Natural Resources and Environment, 2013). In Pakse and in the Greater Pakse areas, which includes 42 villages, around 21% of HSW is collected. In the urban area the coverage is around 44%. Recyclables are collected by junk buyers and sold to recycling shops which mainly export the material to Thailand and Vietnam. Waste pickers collect approximately 50% of plastic waste generated. Workers of UDAA also segregate

recyclables directly during collection. Valuable materials are collected in bags which hang form the trucks (GHK International, 2012).

In the capital city Vientiane approx. 50% of HSW generated is collected by the formal sector. The per capita generation rate for HSW was 277kg per year. The other half is dumped openly or burned (Souksavath et al., 2005). Souksavath et al. (2005) do not define HSW in their paper, it is assumed that that the definition of Rudolph (2017), stated in chapter 2 is applicable. Sato (2019) states that around 32% of generated solid waste in Vientiane is collected and disposed of in a dumpsite. According to the questionnaire filled out by Prof. Vatthanamixay Chansomphou (2019) of the National University of Laos, there is no separate collection done by the formal sector. Khanal and Souksavath (2005) state that in 2003 in Vientiane there were 30 recycling banks operating in either schools or in communities. In 2017 a waste bank at the National University of Laos started to operate and is still running (World Bank, 2020d). People sell their valuable waste to recycling banks which are then further sold to a private company. The private company brings these recyclables to either Vietnam or Thailand (Khanal and Souksavath, 2005).

In most cities UDAA is responsible for waste collection. In Luang Prabang it is a private contractor. In most cases these private contractors are SMEs (Curea, 2017).

Recycling activities are executed in both, formal and informal sector. Waste pickers and VCOMS workers, who collect and sell recyclables to formal contestants. Recycling buying centres, recycling workshops and processing companies are licensed and hence operate in the formal sector (GHK International, 2012; Global Green Growth Institute, 2018; Sato et al., 2019).

4.1.3 Treatment

A formal waste separation system at source is not in place, except for valuable materials, which are sold directly by households (Curea, 2017). In Luang Prabang a pilot project for recycling of organic material was implemented. Two ways of recycling biodegradable material are realised, on-site recycling and off-site recycling. On the one hand on-site recycling is performed directly by households through composting and on the other hand off-site recycling is performed by waste pickers and recycling shops or the community (Ministry of Public Works and Transport and Ministry of Natural Resources and Environment, 2013; Sato et al., 2019). In Vientiane valuable materials are either brought to waste banks or are collected by mobile traders directly at households. Then recyclables are sold to junk shops and dealers who sell these valuables to recycling factories or exporters, as depicted in Figure 13.

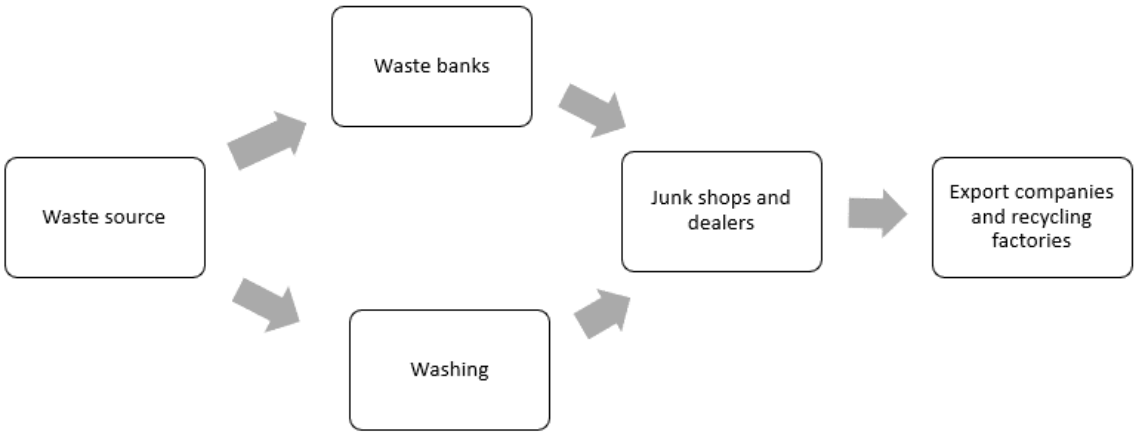

Figure 13: Recyclables waste management structure Vientiane (Chansomphou, 2019)

To strengthen the recycling industry the ministry of Public Work and Transport, MONRE, Vientiane City Office for Management and Service are currently working on formulating a program for integrated waste management with the target to improve the solid waste management practices, preparation of guidelines on sustainable cities and the promotion of environmentally sustainable community-based waste management. A pilot project, with the name LPPE (Laos Pilot Program for Narrowing the Development Gap towards ASEAN Integration, Environmental Management Component) has been implemented in Vientiane, Luang Prabang and Xayabouri to promote environmentally sustainable cities (Japan International Cooperation Agency (JICA), 2015). One of the goals of this pilot project was to improve the waste management systems in the pilot cities. In Vientiane the collection coverage of MSW in selected areas increased from 33 to 56%. The collection systems in all three cities were extended to additional areas. Source separation for recyclables was promoted along with avoidance of excessive packaging. These activities were implemented jointly with several other actions (Japan International Cooperation Agency (JICA), 2015).

4.1.4 Disposal

MSW is disposed of in a designated area, which can be defined by the main landfilling management practises as shown in Tab. 8. Besides these classified landfills, open or uncontrolled dumping is practised in low and middle-income countries, i.e. disposal of waste without any control parameters in any place possible.

Landfills in Laos are mainly non-engineered. These non-engineered landfills are semi-controlled dumps or controlled dumps. The operation is cheap and management is easy, but they comprise health, safety and environmental hazards therefore engineered landfills and sanitary landfills are preferred (Hoornweg and Bhada-Tata, 2012; Idowu et al., 2019; Idris et al., 2004). Collected solid waste is mainly disposed of at designated open dumpsites, without lining, leachate collection, or treatment systems (Sang-Arun and Pasomsouk, 2012).

Tab. 8: Landfill classifications (Hoornweg and Bhada-Tata, 2012)

	Operation and Engineering Measures	Leachate Management	Landfill Gas Management
Semi-controlled Dumps	Few controls; some directed placement of waste; informal waste picking; no engineering measures	Unrestricted contaminant release	None
Controlled Dump	Registration and placement/compaction of waste; surface water monitoring; no engineering measures	Unrestricted contaminant release	None
Engineered Landfill/ Controlled Landfill	Registration and placement/compaction of waste; uses daily cover material; surface and ground water monitoring; infrastructure and liner in place	Containment and some level of leachate treatment; reduced leachate volume through waste cover	Passive ventilation or flaring
Sanitary Landfill	Registration and placement/compaction of waste; uses daily cover; measures for final top cover and closure; proper siting, infrastructure; liner and leachate treatment in place and post-closure plan	Containment and leachate treatment (often biological and physico-chemical treatment)	Flaring with or without energy recovery

In Vientiane there is one landfill located 32km outside the city centre. It can be considered as a semi-controlled dump. MSW is discharged without prior treatment, leachate is treated but gas is not captured. The landfill is owned and operated by VCOMS. Informal waste pickers are collecting recyclables on site and sell them directly to the recycling buying centre, as they are not allowed to take valuables outside the landfill's premise (Global Green Growth Institute, 2018). The landfill in Vientiane has an incinerator which is used to burn medical waste, hence it is cost intensive only a portion of medical waste is incinerated (Chansomphou, 2019). In Luang Prabang a new landfill has been established in 2014, since the prior one was full. Luang Prabang's landfill has a section for windrow composting for biodegradable waste from hotels and restaurants and an area for sludge disposal (Japan International Cooperation Agency (JICA), 2015; Vacha, 2019). In rural areas community dumps have been established, but they are poorly managed.

4.2 Waste Management System in Vietnam

This chapter states the status quo of MSW in Vietnam. If not specifically mentioned industrial waste is not included, as no information could be found on management of industrial waste. Hazardous waste from hospitals which operate an incineration plant is incinerated. Medical waste from hospitals without an incineration plant is mostly mixed with household waste during collection and disposed of on a landfill (World Bank, 2004). According to Tran (2019) industrial waste is collected separately from MSW. It is likely that plastic waste from plastic manufacturing sites is collected by the informal sector for recycling purpose, but no official information could be found. In Vietnam no formal separate collection for the recyclable fraction is implemented. There is no segregation of different waste streams at source, except collection of recyclable materials by the informal sector. Several sources state that in Vietnam approximately 16% of the MSW is plastic waste (Reichenbach et al., 2018; The World Bank, 2012).

In 2011 a case study about the collection and the disposal behaviour of people living in Can Tho, the capital city of Can Tho region, in the south of Vietnam, located in the Mekong Delta was published. The case study focused on plastics in household waste. The main purpose was to give an overview of waste generation rate and the composition, especially with regard to plastics. The study was performed in four central districts of Can Tho City. The authors chose sampling points in parts of the city with and without waste collection services. The household waste was sorted by 10 categories, according to prior studies. The case study also included a survey about disposal behaviour and waste composition. Recycling junk buyers and recycling depots were also included in the survey. The average generation of HSW was 102 kg/capita/yr, which is low compared to HCMC with 281 kg/cap/yr. In the paper no reason was given for the low generation. The discrepancy could be explained due to the fact that the study was executed directly at households and not during or after the collection service. Hence waste from small businesses, commercial buildings or markets are not included. According to the study 11% of the total waste generation was recyclable, of which approximately 59% was plastic waste. Plastic packaging waste is the preponderance of total recyclable plastics in HSW in Can Tho City. The share of plastic bottles seems rather low with 13% of the total recyclable plastics (Thanh et al., 2011, 2010).

In Hanoi the average share of recyclables, such as paper, plastic, metal and glass is 20% according to a report of World Bank in 2005 (World Bank et al., 2005). It is not explained why there is a 10% gap between the generation share of recyclables in Can Tho City and the rest of Vietnam. It could be that the valuable materials in Can Tho City are separately collected and directly sold to a junk buyer.

In another city, Thu Dau Mot city, close to HCMC the average HSW generation in 2017 281 kg/cap/yr. A waste composition study in Thu Dau Mot city with 300 sample households was done. The waste was separated into organic, plastic, PET, paper, glass and others. As Figure 14 indicates the average share of plastic was 11% of the total HSW generated (Trang et al., 2017).

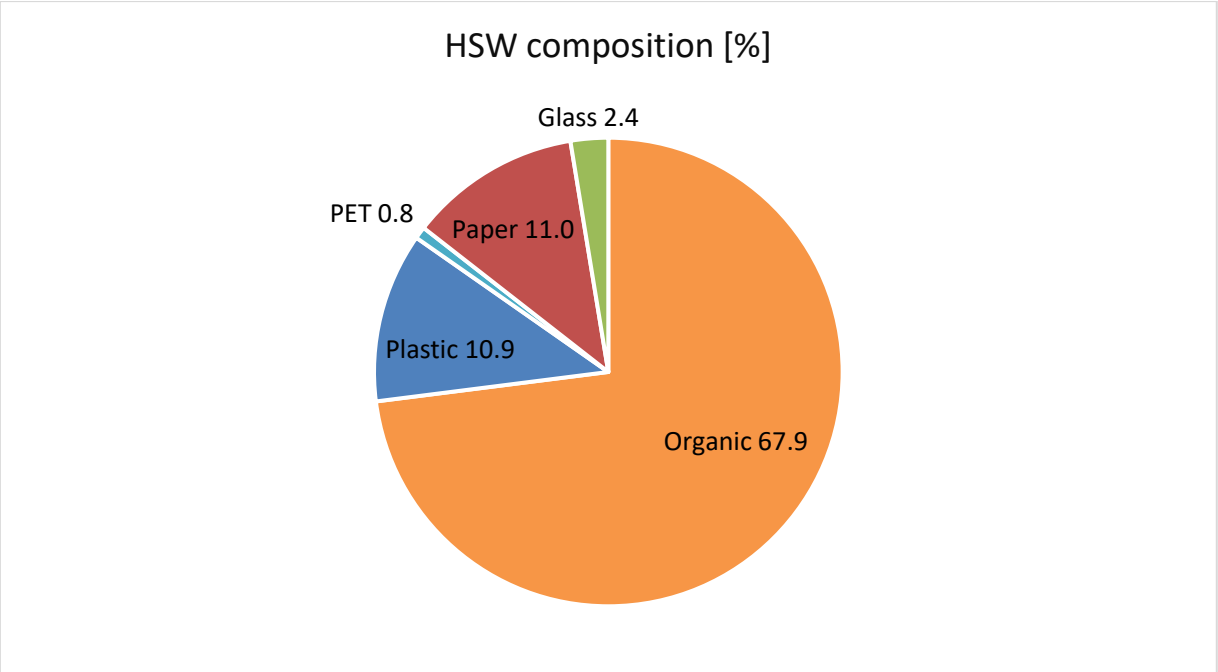

Figure 14: HSW composition in Thau Dau Mot city (Trang et al., 2017)

In 2015 the average generation of MSW in big urban areas of Vietnam was between 0,9 and 1,3 kg/cap/d. In rural areas the average waste generation per person and day was 0,4 kg (Schneider et al., 2017). According to the World Bank the average waste generation in East Asia and Pacific was 0,95 kg/cap/d in 2005 (World Bank, 2012).

According to CITENCO approx. 500 tons of plastic waste were disposed of every day in 2017. These 500 tons are part of the MSW collected at the two biggest transfer stations (Ahmad M.A., 2019).

4.2.1 Legal framework

In Vietnam legislation comprises of constitution, laws and ordinances and by-law documents, such as decrees, circulars and Prime Ministerial decisions.

Terms regarding waste management and 3R are defined by law on environmental protection 2014 (LEP 2014), decree 38/2015/ND-CP on waste and scrap management, decision 16/2015/QD-TTg on take-back and treatment of discarded products, circular 36/2015/TT-BTNMT on management of hazardous waste and inter-ministerial circular 58/2015/BYT-BTNMT on medical waste management.

In 1993 the first law on Environmental Protection and waste management was passed.

The National Strategy on Waste Management in Urban and Industrial Areas with scope of 2020 was passed in 1999. In 2005 the 3R concept and principles were integrated into the Law on Environmental Protection, with regulations on waste segregation at-source, reuse and recycling and the concept of extended producer responsibility (EPR). The National Strategy on Integrated Solid Waste Management from 2009 to 2025, and furthermore to 2050 was enabled. Objectives and solutions to achieve the targets were defined. In 2014 the Law on Environmental Protection was revised to better understand the role allocation and functions of authorities in waste management (Thang, 2017).

According to Schneider et al. (2017) the recycling targets of the National Waste Management Strategy and the focus on a complete waste collection system by 2025 are sufficient basis for a circular economy framework.

4.2.2 Collection

In Vietnam an average 71% of MSW is collected, steadily increasing since 2000. In larger cities the collection rate is approx. 76% and in smaller cities approx. 70% whereas in rural areas only around 20% of MSW is collected. In poor neighbourhoods there is no collection service at all (World Bank et al., 2005).The collection of MSW in Vietnam is in responsibility of the People's Committee in cooperation with DONRE and MONRE. In Hanoi, HCMC and surrounding provinces collection and treatment of MSW is outsourced to private companies. These private companies need to have a license which is issued by VEA (Vietnam Environment Association) and they have formal contracts with the local authorities. MSW is usually not separated at source. Households collect MSW with plastic bags or plastic containers in front of the houses. HSW is collected by waste carts and then brought to trucks. The waste is furthermore either brought to a transfer station, or discarded directly at a treatment plant or dumpsite or landfill (Truong, 2018).

It is common practice that recyclables are picked up directly at the households by waste buyers, but also along the way to the disposal site, there are waste pickers who collect valuable materials. More than two third of the waste pickers in Vietnam are women and approx. 9% are children. Traditionally they live close to the landfills and are exposed to environmental, health and safety hazards (World Bank et al., 2005). Plastic bottles and other plastics which are not highly contaminated, are often sold to waste collectors or small recycling businesses. Before MSW is discharged at the treatment plant or disposal site, recyclable plastics are separated by waste pickers (Indochine Engineering, n.d.; Nguyen, 2006).

In the capital city Hanoi waste pickers collect valuable materials, such as plastics. They either collect it directly at the place of generation, at collection cards, trucks or at the landfill (Ishigaki et al., 2008). In HCMC 30% of waste collectors are public institutions, the remaining 70% is private. In 2015 approximately 85% of MSW generated was collected in the urban area (Schneider et al., 2017). According to Nguyen (2006) the amount of recycled waste is high, but there are no official numbers due to the fact, that most of the recyclables is collected by informal waste pickers. In Hanoi approximately 1/5 of MSW is recycled.

Recyclables from industrial waste are sorted at the place of origin for instantaneous reuse and recycling. Plastic scrap, which cannot be lead back directly into the process could be used for secondary production and is therefore sold to recycling units (Vietnam Business Council for Sustainable Development, 2019)**.**

4.2.3 Treatment

According to The Global Plastic Action Partnership (2020) around 10 to 15% of the total plastic waste is collected for recycling. Reuse and recycling activities are conducted by the informal sector, a network of waste pickers at landfills, informal waste collectors, and waste buyers (World Bank et al., 2005). In HCMC there are more than 270 small recyclers located in the residential area and approximately 10 recycling businesses in the industrial zone. 80% of these small recyclers are specialized in plastics (Vietnam Plastics Association, 2014). In Vietnam recycling is mainly done in approx. 3000 craft villages. These villages are mainly located in the north of Vietnam, close to major cities. Vietnam craft villages are working in various business sectors, but the recycling business is an unique domestic specialization (Netherlands Enterprise Agency, 2018). In 2004, 90 of these 3000 craft villages were doing business

in waste recycling and 5 out of these 90 were specialized into plastics recycling (Trung et al., 2010).

In the 2012 study of Kawai et al. the results of an interview survey of households in Hanoi show that the majority stores recyclables for sale or donation to junk buyers. Approximately 76% of plastic waste is sold. The largest share of plastics in HW was plastic bags with 27.1g/cap/day. The informal sector doesn't buy these bags, as the amount is too small and it would take a long time to collect sufficient amounts to sell. Therefore most households discard them along with MSW (Kawai et al., 2012a).

4.2.4 Disposal

In Vietnam MSW is predominantly disposed of without prior treatment. There are approx. 96 open dump sides and landfills across the country and only 16 of these are sanitary landfills (Christensen and Tho, 2015; Truong, 2018). Self-disposal methods, as burning, burying waste, disposing it off into the landscape and dumping into rivers, canals and lakes is common in many areas. Open dumping and poorly operated landfills cause environmental problems for the surrounding communities. Untreated leachate contaminates ground and surface water, airborne pollutants have effects on respiratory system of humans and animals and can cause skin or digestive diseases. Odours attract flies and mosquitos, which can spread numerous diseases into large areas (World Bank et al., 2005). Building sanitary landfills is one of the priorities of the Vietnamese government, but due to lack of funding, the development is slow and financed by developmental funds (Jain, 2017).

5. Plastic Waste Management

In extension to the previous chapter about waste management, specific activities in plastic waste management in Laos, Vietnam and Europe are elaborated in this chapter.

5.1 Plastic Waste Management Laos

In Vientiane the capital city operates a recycling buying centre on the landfill site. This recycling buying centre takes recyclables from waste pickers in exchange for money. They then sort, wash and bundle the plastic for further sale. As stated in chapter 4.1.4 Informal workers are not allowed to take recyclables outside the landfill site, therefore waste pickers are employed by this recycling centre. Along the way from place of generation to the landfill recyclables are also collected. At transfer stations, workers are allowed to collect and sell valuable material. One private company also allows their workers to collect and sell recyclables along the collection chain as shown in Figure 15. Recycling buying centres sell valuable materials to recycling facilities, which are mostly located in China and Vietnam. Waste banks are in need of cleaning machinery to improve the purity of the recyclable and to increase the value and hence the revenue (Global Green Growth Institute, 2018). As mentioned in section 4.1.2 30 waste banks were established during a pilot project of JICA (Khanal and Souksavath, 2005). In 2020 there is one waste bank operating in the National University of Laos (World Bank, 2020d).

Lantieng Recycling Company is a recycling company which washes, crushes and shreds recyclables into smaller pieces. Mainly PET, PP and OPP are the plastic types conditioned. The final products are raw materials which are sold to other industries to manufacture bags for fertilizers or foams for upholstered furniture. Recycling

processes and manufacturing processes are rudimentary. Therefore only a small amount of recyclables is used for production, due to low quality of the recycled plastics (Global Green Growth Institute, 2018).

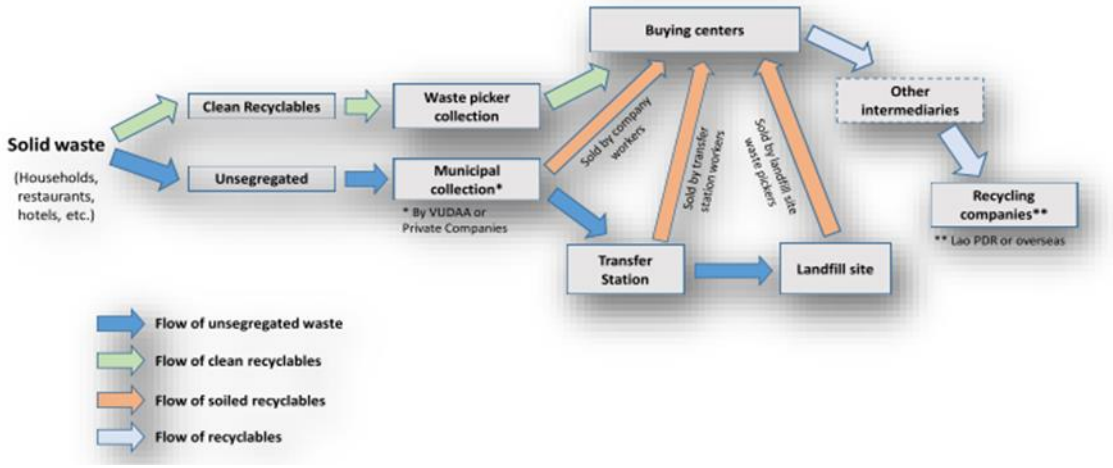

Figure 15: MSW flow in Vientiane (Global Green Growth Institute, 2018)

5.2 Plastic Waste Management Vietnam

Vietnam discharges an estimated amount of 1.8 Mio tonnes of plastic waste per year. According to an article of Tuyen (2019) a report from MONRE states, that 27% of the total discharged plastics is recycled. The same article claims that according to MONRE, each household consumes 35 plastic bags per week and following 1 kg of plastic bags per month (Tuyen, 2019).

In 2003 a study shows that the share of plastics discharged in the now closed GÈ Cát landfill in HCMC was around 16%. The main fraction was nylon with 13,8% (Schneider et al., 2017). Within the paper the category nylon is not further explained, hence it is assumed that the author writes about polyamides. It is assumed that mostly plastic bags and foils are disposed of at landfills, as they are difficult to sell to waste buyers or recycling businesses due to pollution and low market prices (Kawai et al., 2012a).

Recyclable plastic waste is brought to craft villages and small-scale recycling businesses. Families in craft villages buy recyclables of junk buyers or waste pickers. Approx. 4% of these craft villages are in the recycling business. The small recycling businesses are run by families, who are specialized in different types of plastic or in a specific step of the recycling process. Most workers are self-employed or small enterprises have less than 10 employees. Recyclables are washed and shredded into plastic scrap (Ministry of Natural Resources and Environment, 2008; Pearse, 2010).

Craft Villages

Craft villages are villages where a minimum of 30% of the inhabitants are working in craft production. Production and commercial activities need to be stable for the last two years and follow regulation and legislation (Ministry of Natural Resources and Environment, 2008). These regulations and legislations are hardly monitored by the authorities and not executed.

Families started to find other sources of income besides agricultural activities in seasons when there was no harvesting or little farming activities. Craft villages produce a variety of different crafts, e.g. pottery, carving, silk waving and recycling of materials

as paper, metals and plastics (Sakata, 2013). Craft villages can be divided into six different categories: (1) food processing, including animal husbandry and butchery, (2) textile production including dyeing, silk production and leather processing, (3) the production of construction material and masonry, (4) recycling, (5) handicraft production and (6) others (Trung et al., 2010). In this thesis the term craft village is only used regarding recycling craft villages.

Some villages started by manufacturing souvenirs and changed their business to recyclables due to the demand of the industry. They are an important source of income in neighbouring villages as there is a lot of workforce in need. Families operate as small businesses and specialize in a particular recycling step or on a specific type of plastic (Ministry of Natural Resources and Environment, 2008; Pearse, 2010; Trung et al., 2010).

A basic model for plastic recycling in craft villages is as follows: Recyclable plastics such as PE, PP and PVC are collected either by waste pickers or directly by junk buyers. Waste pickers sell plastics to junk buyers who then sell the plastic waste to craft villages. In these craft villages plastic waste is sorted, washed, grinded and heated to melted. Eithers pellets or plastic films are produced and again sold to manufacturing industries. In Figure 16 a basic process is diagrammed, depending on the craft village the process steps can vary (Ministry of Natural Resources and Environment, 2008; Trung et al., 2010).

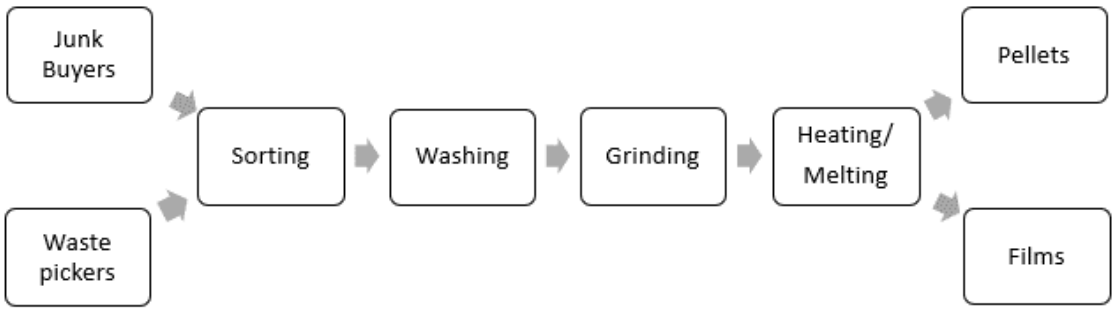

Figure 16: Basic process of plastic recycling at craft villages

One of these recycling craft villages is Trieu Khuc. The inhabitants of Trieu Khuc changed their business from papermaking to recycling plastic. Recycling businesses in Trieu Khuc mainly produce chips and flakes to sell it to industries as input material. Some households manufacture products locally, as coat hangers or furniture (Ministry of Natural Resources and Environment, 2008; Pearse, 2010).

Phano Boi is a craft village working on plastic recycling 40 km from Hanoi. Packaging, cans, pipes, brass, pots and other plastic items are used as raw materials to produce plastic granulate and plastic goods. The material is mostly from domestic origin (80-90%). In recent years, the share of imported material was rising. Approximately 90% of plastics are segregated before brought to the craft village where the plastic scrap is classified, shredded, washed, filtered, compressed, extruded into filaments and finally cut into plastic granulates. Wastewater is discharged without prior treatment, although some families installed an accumulation tank, national standards are not met. The remaining solid waste is disposed of in a landfill nearby (UNIDO, 2018).

Another one of these craft villages is Minh Khai, where plastic bags, plastic granulates, thin films, plastic pipes, nets, wires, cans and boxes for food are produced as well as plastic pellets and films. Approximately 600-650 t/day of raw material is used for production. Around 25-30% of these raw materials for production is plastic scrap made from plastic waste. The most limiting factor is the quality of the collected recyclables. Due to the import ban of the Vietnamese government on plastic waste with poor quality it is expected that the quality of the raw material is rising. A major issue is the amount of solid waste generated, as a lot of plastic is recycled, between 15 - 20% are discharged and dumped in the dumpsite located next to the village. The little capacity of the dumpsite leads to uncontrolled open burning (Retamal et al., 2019; UNIDO, 2018).

Recycling activities in craft villages are often done with outdated machineries and without any safety regulations for workers or for the environment. PVC is heated till it melts without any safety precautions although it contains hazardous materials and toxins which are volatile and can cause health issues for workers and local residents. Wastewater from washing processes is disposed of without filtering it, so macro- and microplastics are transferred into the environment (Ministry of Natural Resources and Environment, 2008; Sakata, 2013; Trung et al., 2010). Workers and inhabitants are confronted with health threats and the surroundings are facing heavy environmental pollution (Sakata, 2013; Salhofer, 2018). 90 per cent of craft villages exceed the levels of pollution set by the national environmental protection law. Noise, odour, wastewater, toxicity, sludge, solid waste and air pollution are typically an issue close by the craft villages. The surroundings are affected directly, hence health and safety for workers and residents are in danger. Respiratory disease, skin disease, digestive, skin, throat and eye diseases are common diseases for workers in recycling craft villages as well as mental illness and cancer. Water is also often polluted and not only impacting local areas but also downstream areas with toxins, oil and small particles of plastic. Toxic gases, Hydrogen Chloride (HCL), Hydrogen Cyanide (HCN), Chlorine (Cl_2) and Carbon Monoxide (CO) are released during heating and melting processes. The level of pollution is related to quality of input materials (Ministry of Natural Resources and Environment, 2008; Trung et al., 2010).

Figure 17: plastic flakes drying in the sun after washing (DesRoberts, 2017)

Besides these craft villages the plastic recycling sector is growing. Private investments are increasing. In 2012 Thanh Tai Gas Company invested in a new PET recycling plant with a capacity of 1.5 billion bottles per year (Schroeder et al., 2016).

5.3 Plastic Waste Management Europe

The European Union's key principle is to prevent waste generation in the first place. A hierarchy with five principles to manage waste, as shown in Figure 18 was created to obtain a sustainable WM system. The most favourable principle is on the top and the least at the bottom. Besides that, circular economy also plays an important role in the European way of approaching WM. Circular economy implies to maintain resource value in the economic cycle as far as possible, along with preventing and reducing negative effects of obtaining primary resources on the environment and society (European Environment Agency, 2019).

Figure 18: EU Waste Hierarchy (European Commission, 2008)

The EU aims to improve recycling rates for MSW and packaging waste and makes them comparable between member states. The first target rate for 2001 and 2008 for packaging recycling was introduced in 1994. Currently every country has its own calculation for recycling rates. For meeting the targeted rates in 2025, 2030 and 2035 new harmonised calculation rules were adopted in 2019 (European Environment Agency, 2019). Recycling targets are set by the European Commission in various directives for specific waste streams.

According to the Waste Framework Directive (2008/98/EC) 50% by weight of household derived paper, metal, plastic & glass needs to be prepared for reuse and recycling by December 2020. Reference year is 2017. The directive was revised and set reuse and recycling targets of 55% by 2025, 60% by 2030 and 65% by 2035. In order to stay on track to meet these targets, studies are conducted to detect gaps and consequently set actions for improvement (European Commission, 2018).

Reuse and recycling of packaging waste is regulated by the Packaging Directive (94/62/EC). The directive was revised to introduce more ambitious recycling targets of 65 % in 2025 and 70 % in 2030. The material-specific target for plastic is 55 % in 2030.

The packaging waste recycling rate is calculated by dividing the amount of packaging waste recycled by the amount of packaging waste generated for each respective year (European Environment Agency, 2019).

The harmonised calculation method will result in lower recycling rates per country. Austria and Germany are committed to increasing recycling rates in the future to meet the targets. The point, where the recycling rate is calculated is fixed. According to

decision 2019/1004 of the European Commission (2019) the point of calculation is ‘Plastic separated by polymers that does not undergo further processing before entering pelletisation, extrusion, or moulding operations. Plastic flakes that do not undergo further processing before their use in a final product’. In other words, the recycling rate is calculated on the basis of the amount of waste that enters the recycling facility. Waste which is rejected through the sorting process is not included (D’Amato et al., 2019).

5.3.1 Plastic Waste Management in Austria

Since 2009 it is not allowed to landfill waste without prior treatment. Waste is either treated in a mechanical-biological or thermal treatment plant to minimise the release of leachate and landfill gas and render it inert (DVO, 2008). The landfilling of untreated organic waste has been banned since mid-2005 Therefore, different routes for e.g. plastic recycling and treatment were established. Along with the global trend, the quantity and complexity of plastic waste in Austria is rising.

In Austria there is a separate collection for lightweight packaging waste, which includes among others, plastic packaging. For the collection of packaging waste, there is an extended producer responsibility scheme implemented. Companies putting packaging on the market need to pay a licence fee for the collection of the packaging waste. Depending on the region there are different collection systems implemented. After collection, impurities are segregated, and plastic packaging is sorted into different plastic types. Subsequently depending on the type of plastic following steps vary. Plastic waste is shredded, washed, dried, melted, and as a last step processed into granulate, which then can further be used for manufacturing (Bundesministerium für Nachhaltigkeit und Tourismus, 2017). Unsorted packaging plastics is crushed and agglomerated coarse granulates in order to either produce tubes or other simple shapes or use it as RDF. According to Friedrich et al. (2019) there is an oversupply of low quality plastic waste, which is not favoured by the recycling industry. Their study also shows that the demand for plastic recyclates is higher than the supply of the recycling market.

PET-bottle recycling reaches high standards in Austria. PET-bottles are segregated by colour and pass through a special cleaning process, to then be recycled to a PET-bottle (Bundesministerium für Nachhaltigkeit und Tourismus, 2017). In Austria there are discussions to implement a deposit system for plastic bottles for beverages, since a study from Hauer et al. (2020) came to the conclusion that this is the best option to meet the future EU collection targets.

The collection targets are set in the Directive on Single-Use Plastic (SUP Directive) along with 4 other measures to reduce consumption and improve the recycling of plastic beverage bottles and containers. The SUP directive includes market restriction, product design, marking/labelling requirements, awareness raising measures, EPR schemes, and separate collection. In 2025 the target for separate collection of beverage bottles is 77% and 90% by 2029 for all bottles with a maximum capacity of 3 litres. By 2025 PET-bottles need to consist of 25% recycled plastic, by 2030 30% of all types of beverage bottles. EPR schemes to cover the costs of collection, transport and treatment of waste need to be implemented and raising awareness for reusable alternatives is also a key action along with market restrictions of expanded polystyrene for beverage containers (Copello de Souza, 2019). The current collection rate for plastic beverage bottles is 70% and for plastic packaging 58% (Hauer et al., 2020).

In 2017 65.6% of total packaging waste was recycled. In the same year 33.4% of plastic packaging was recycled (Eurostat, 2020). According to the report of Hauer et al. (2020) the recycling rate of plastic packaging from households is approx. 25%.

5.3.2 Plastic Waste Management in Germany

Germany is the largest producer of plastic products in Europe with a quantity of 19.3 Mio t in 2018 (PlasticsEurope Deutschland e.V., 2019). Since the early 1990s the government enforces plastic recycling, hence Germany is also one of the largest markets for plastic recycling in Europe. An EPR was implemented. In 1991 an ordinance on packaging waste was adopted and a privately operated dual system was implemented, called the 'DSD' (German: Duales System Deutschland). Besides the public waste collection of packaging waste a second system (dual) was established for sales packaging (Grüner Punkt, n.d.). Households collect their packaging waste into yellow bins or bags, which are provided by the dual system. Manufacturing companies of plastic packaging and vendors pay a licence fee to the dual system, so their packaging is collected. The population pays a fee for the municipal waste collection and treatment. The separate collection of packaging waste is financed through EPR. For one-way plastic bottles, a deposit system was installed in 2003. This system facilitates a recycling of clean bottles, which then can be easily recycled into bottles again. A side effect of this deposit system is that littering is not a big issue in Germany. People tend to collect bottles to receive the deposit. In 2005 Deutsche Pfandsystem GmbH (DPG) was established to provide the legal and organizational framework for the deposit system. Since the same year shops with a certain size of sales area are obliged to take back beverage bottles made out of the same material they sell (DPG Deutsches Pfand System GmbH, n.d.; Žmak and Hartmann, 2017).

According to Consultic Marketing & Industrieberatung GmbH (2016) 99% of all plastic waste in Germany was recovered in 2015. 45% was mechanically recycled and 53% was recovered energetically. Feedstock recycling plays a minor role with approx. 1% of the total recycling. In 2017 69.6% of packaging was recycled. The recycling rate for plastic packaging was 48% in the same year (Eurostat, 2020).

5.3.3 Best available technology

The following descriptions of best available technology was picked with the main target to receive high quality recyclables. Figure 19 displays the stream of plastic waste with different treatment methods and their output material, such as monomers through

chemical recycling.

Figure 19: plastic treatment streams (PlasticsEurope, 2019a)

To reprocess post-consumer plastic scrap typically following steps are followed:

- Sorting
- Shredding
- Metal separation (ferrous and non-ferrous)
- Secondary crushing
- Washing
- Sorting based on particle level (e.g. density, colour)
- Drying
- Agglomeration
- Granulation
- Compounding

5.3.3.1 Collection of plastic packaging waste

The primary target of separate collection of plastic waste is to reach a high coverage and high quality along with little effort. Depending on technical and financial support, as well as public awareness, there are different options to create a sufficient collection system. The best option for the highest possible quality of collected plastic packaging is to implement a separate collection system. Plastic packaging waste which is collected separately shows little contamination. A separate collection of PET from other plastic packaging has the advantage that the PET recycling process is easy compared to the recycling of plastic packaging with different compounds and additives. Different behaviours of waste separation in urban and rural areas need to be taken into account, hence a different collection system in cities and rural areas is reasonable (Blum, 2017; Salhofer, 2001).

5.3.3.2 Separation of plastic packaging waste

According to the CEO of ARA (Altstoff Recycling Austria), the main player in Austria for collection of plastic packaging waste, separation of plastic packaging waste is the major challenge, stated in Blum (2017). Separation processes can be divided in sorting of valuable material (positive) and separating of contaminants (negative).

Typical steps of separation are:

- Pre-treatment – grinding and classifying
- Manual sorting
- mechanical sorting
- sensor-directed sorting

Manual sorting is a cheap, but labour-intensive sorting method, which is suitable for emerging and developing countries. Visual identification of plastic types is done by operators using the resin identification code, shape, colour, appearance, and trademarks of plastic. Manual sorting is usually combined with an automated sorting process, to reduce the possibility of human error. Automated sorting can be done with a float-and-sink sorting, hence there is a variation of density of plastic types. Froth-Floating sorting, near-infrared sorting, x-ray fluorescence, laser-aided identification and marker systems are various automated sorting methods (Rudolph et al., 2017). Every single method has its advantages and disadvantages therefore a combination of methods leads to the best outcome.

5.3.3.3 Treatment of plastic packaging waste

According to Eriksen et al. (2018) there are three different quality levels for recyclables. For products in contact with food the high-quality-level is required. Medium quality is applicable for toys, pharmaceuticals, electronics, and electronical equipment. The third level is low-quality for e.g. pipes. Plastic recycling processes can be divided into four main routes: re-extrusion (primary), mechanical (secondary), chemical (tertiary) and energy recovery (quaternary) (Brems et al., 2012; Ignatyev et al., 2014). For post-consumer plastics secondary recycling methods are the main option, with the exception of PET bottle recycling. Pre-Consumer plastics and PET bottles are recycled primarily.

Primary Recycling (Re-extrusion)

The aim of this process is to gain plastics with the same, or similar characteristics as the primary product (i.e. closed-loop recycling). The main challenge is to receive plastics with high quality and little contamination. Due to the cleanliness mainly plastic material from manufacturing processes are recycled with this process. The other major source is PSW from households (Al-Salem et al., 2009). Manufacturing scrap is used for re-extrusion, due to its high quality and cleanliness. The main challenge to recycle post-consumer plastics is the cleanliness and the requirement of single plastic types. Mixed materials are not suitable for recycling processes as the strength and resistance of the material is reduced after processing a material-mix. Plastic polymers generally keep their molecule structure, but during the melting process polymer chains are damaged therefor products usually do not exist 100% of recyclables but are a mix of virgin and recyclable plastics (Rudolph et al., 2017). Bottle-to-bottle recycling of PET bottles for beverages is one example of primary recycling.

Secondary Recycling (Mechanical recycling)

Open-loop recycling means to produce products with lower quality requirements. PET bottles can be recycled into fibres. Single-polymer plastics can be recycled mechanically, other more complex material mixtures are not suitable for this process. It is essential that plastic waste is sorted and washed before the beginning of the mechanical recycling. Several daily used plastics are products of mechanical recycling, such as plastic bags, pipes, window and door profiles (Al-Salem et al., 2009). Secondary recycling involves sorting and reprocessing steps to produce single-polymer pellets, granulates or flakes for use in new plastic products. Recycled plastics is mainly used in building, construction, packaging, and agriculture, depending on the quality of the material. A closed loop recycling, e.g. bottle to bottle is not always possible due to high product specifications and strict regulations, therefore other recycling paths were invented (PlasticsEurope, 2019b).

Primary and secondary recycling can be summarized to mechanical recycling, which can be found in a various of scientific papers (Al-Salem et al., 2009; Gintenreiter-Kögl, 2001; Van Eygen, 2018). Hence for this thesis primary and secondary recycling is looked at individually, as they differ referring to the quality of input and output material.

Tertiary Recycling (Chemical recycling)

Also known as feedstock recycling, with technologies as pyrolysis and hydrolysis to recycle cross-linked polymers and thermoplastic polymers with low quality, which are not suitable for mechanical recycling (Faraca et al., 2019). Polymer chains are converted into low molecular weight compounds or broken down into plastic monomers. Plastic monomers can be used to create polymer chains again. Low molecular weight compounds are used as feedstock for the petrochemical industry. Common processes are hydrolysis, hydrocracking and depolymerization. Large energy and chemical consumption hinder this recycling process to become more common. In the past there were some successful experiments for recycling of polyolefins, but only in a small-scale (Rudolph et al., 2017).

Since 2018 there is a pilot plant in Austria, which produces synthetic crude in a pyrolysis process by using up to 100 kg of mixed plastic waste per hour. Subsequently the recycled crude oil can be processed either into feedstock for the plastics industry or fuel. The essence of the process is thermal cracking. Long-chain hydrocarbons are cracked into shorter-chain light hydrocarbons by using a solvent to decrease the viscosity of the plastics and to increase the heat transfer (Borealis AG, 2019; OMV, 2018; Sharma, 2020).

Quarterly Recycling (Energy recovery)

For energy recovery of plastics there are two options. Either plastic is incinerated along with MSW or it is conditioned as RDF. Incineration of MSW is common practise in Austria and other developed countries to obtain energy and heating and to reduce the amount of waste landfilled.

RDFs is pelletized fuel produced out of SW through shredding, drying, and densifying. In the beginning of the process solid waste is separated into combustible and non-combustible components. The former is crushed and shredded, dried, and then compacted into pellets. RDFs are typically used in the cement industry or brick kilns (Global Green Growth Institute, 2018). They are used to save costs for fuels, to reduce consumption of primary resources and to decrease the amount of greenhouse gas emissions. RDF has to meet certain requirements, especially due to the varying composition. Depending on the waste utilized (i.e. commercial, industrial or MSW)

variations can easily appear. Waste collection schemes, or seasonal variations also influence the composition of RDFs. In order to uphold the quality (e.g. calorific value, biomass content, heavy metal contents) of RDFs with respect to their composition a reliable quality assurance is essential (Schwarzböck et al., 2018). Regardless of the type of plant, general quality standards must be fulfilled:

- well defined calorific value
- low chlorine content
- quality controlled composition (few impurities)
- defined grain size
- defined bulk density and
- availability of sufficient quantities with required specification.

In Austria there are legal requirements for certain parameters (Sarc and Lorber, 2013). Additionally the supplier and user of RDFs reach an agreement on further specifications, such as grain or particle size, net calorific value, chlorine content, sulfur content, fluorine content, ash content, water content, biogenic car-bon content, as well as bulk density and restrictions for heavy metals content like: As, Sb, Pb, Cd, Cr, Co, Cu, Zn, Ni, Hg, Tl, V, Sn and Mn. These further specifications are at the same time limiting factors for RDF as they cause heavy corrosion. PVC is a major contributor of chlorine in RDF and can be sorted out by NDIR-sensor (Lorber et al., 2011; Sarc and Lorber, 2013). A multi-stage separation process within unit operation steps is necessary to reach higher qualities. Separation of ferrous and non-ferrous materials and unwanted inert materials, such as stones or glass need to be sorted out. The material needs to be crushed and sieved several times, depending on the input material (Sarc and Lorber, 2013).

6. Conclusion and Outlook

The examination of the plastic market and the plastic waste management systems in Laos and Vietnam was a challenging task due to insufficient data and little information given in English. Production and trade data are not sufficiently recorded and publicly available. Case studies and pilot projects are rare, however they are good methods to obtain more reliable data and to cover the lack of data. In the following section obstacles and recommendations are provided.

6.1 Plastic Market

The plastic industry in both countries has been growing in the last decades, especially in Laos the industry is small and uses outdated machinery. Laos highly relies on import of primary material and plastic products.

In Vietnam the plastic market is increasing, notwithstanding improvements for already operating production sites are needed, especially in regard to pollution control. The Vietnamese government sees the need to reinforce primary production to be independent on external trade and the fluctuation of the crude oil price. The domestic production in 2019 only meets 10 - 20% of the demand for primary polymers. In Vietnam the government tries to strengthen the plastic industry and global investors are setting foot. To strengthen the domestic production, investments are needed to upgrade existing facilities or build new ones. However, a market analysis to attain

specific information about the demand and the plastic types produced is essential before any investment.

For examining foreign trade data, UN Comtrade was used, as there were no other available sources for primary data or to verify data. For Laos and Vietnam, the same obstacle occurred.

Plastic consumption in Laos with 25 kg/cap/yr in 2010 was estimated due to similarities of economic state to Myanmar and Cambodia. The lion's share of plastic demand is presumably covered by imports. In 2015 the Vietnamese per capita plastic consumption was 55 kg, which is comparable to the consumption in Thailand. Since the packaging industry is the biggest producer and plastic packaging reaches its end of life within a year, the waste management sector needs to handle a significant amount of plastics. The amount of plastic packaging waste is expected to grow in the future.

6.2 Plastic Waste Management

Plastic waste management in Laos is only done by the informal sector. No separation is done by official waste collectors. Hence valuable materials are either collected directly at households or sorted out at transfer stations. In Vientiane remaining plastics in MSW are sorted out at the landfill by informal collectors and are then sold to the recycling centre on site. In the capital city separate collected recyclables can also be brought to a waste bank. Information about waste banks in Laos are scarce but comparable systems are already in place in Thailand and in Indonesia.

According to Domonyik (2020) waste banks in Indonesia take valuable and clean material from private persons as well as from junk buyers or waste pickers. Waste banks have been implemented to formalise the informal sector workers. They are community-run facilities which take recyclables in exchange for money or a deposit in a savings account. Such models can be either operated by communities or by informal workers who can establish their own waste bank and provide door-to-door collection. These informal workers can work together to become stronger stakeholders in the recycling business and hence earn more money. On the other hand implementing waste banks also includes risks for the informal workers, such as benefits for reorganising in groups or cooperatives are not perceived, lack of funding to initiate waste banks or that buying centres and recycling companies have too much bargaining power over the waste banks (Global Green Growth Institute, 2018).

The Laotian waste bank sells recyclables to recycling businesses which mainly export it to Thailand and Vietnam. This system helps to minimize the total amount of waste disposed of (Global Green Growth Institute, 2018; World Bank, 2020d). Other than that, there is no data or specific information about the plastic recycling sector. Except that there is investment from Thailand for a new recycling plant, besides one existing recycling plant. It is assumed that within the recycling plant of a brewery PET is recycled, hence bottles are produced for beer. Information about the recycling technology or machinery could not be found.

In Vientiane little recycling activities exist along the value chain. Although these activities are informal, the coexistence with the formal waste management is working properly. For recovering plastics it is recommended to do it through a door-to-door collection, as the material is less polluted and the collection, transport and disposal costs for MSW management systems are lower compared to plastic picking at disposal sites (Scheinberg et al., 2011). Irrespective of formal or informal recycling activities.

The system of waste banks could be a good option for collection of valuable materials. Best practise is the waste bank in the National University of Laos.

In Vietnam plastic waste management is also done by the informal sector workers. There is a lack of infrastructure and investment to improve collection, sorting and recycling techniques. Besides small recycling companies, plastic recycling is mainly done by craft villages without any health, safety, or environmental precautions. Stakeholders are aware of the pollution craft villages are emitting, but the MSW management system relies on these informal recycling processes. Local, regional, and national authorities do not monitor or fine these villages. Another reason for not intervening with recycling villages is that the government knows about the advantages and revenue they are creating. The government saves money for not formalising craft villages. Nonetheless in long term formalisation is beneficial for both sides.

6.3 Proposals

Improving existing plastic WMSs is complex and needs to be considered at its best. In this section proposals for both countries are formulated. In general recommendations for improvements in plastic waste management and recycling shall include the following three categories: community participation and capacity building, infrastructure and technology provision as well as regulatory improvements. As the focus of this thesis is on plastic waste, landfill technologies, composting of organic material and management of hazardous waste are not considered.

6.3.1 Raising awareness and training

For implementing a sustainable waste management system in particular a plastic waste management system or even a circular economy strategy an active engagement of citizens in changing consumption patterns is required. Campaigns for raising awareness for waste segregation, especially recyclables are an option to easily apply. Waste prevention, reduction and separation plays a major part in reducing the amount of waste and improving the quality of recyclables. Consequently, it takes longer to reach the limits of landfill capacities. Conferences, workshops, community meetings and awareness campaigns organized as bottom-up activities are effective in increasing the participation of various stakeholders, such as schools, businesses, environmental organizations and waste pickers (Gutberlet and Baeder, 2008; Ojeda-Benitez et al., 2002).

For efficient waste separation at source, citizens need to be trained about different waste streams. At first, it is necessary to raise awareness for environmental issues. It is recommended to inform and train the population about the disadvantages of plastic waste and the advantages of plastic recycling. Not only the reduction of waste, but also the creation of a cleaner environment and creation of workplaces in the waste management sector are beneficial. Raising awareness for the merit of recycling activities also plays an important role. Socio-economic advantages along with environmental improvements goes hand in hand with improvement of this sector.

A transition towards circular economy with eco-design and clear declaration of plastic products not only reduces the amount of primary resources used for production but has a positive effect on the recyclability. Potential hazardous materials are not used for manufacturing anymore, with a proper circular economy package installed.

Political decision-makers also need to be aware of the contributions and positive impact the informal sector has on the current system and furthermore they need to

consider the benefits of integrating the informal workers into the MSW management system (Gunsilius et al., 2011b).

Universities can organize workshops regarding occupational health and safety, pollution control and recycling of different types of plastics. As universities have a good international network, lecturers from abroad can also teach about best practise examples of waste separation and plastic recycling. The European Commission is currently funding a project which aims to improve the dialogue between research and practice in Laos and Vietnam. Regional training hubs to improve knowledge transfer are established to address the specific needs of higher education in plastic recycling and waste management and to connect the industry with the academic world (SEA-PLASTIC-EDU, n.d.). In spring 2019 UNESCO launched its 'Plastic Initiative'. Representatives from Lao, Vietnam, Cambodia and Thailand identified and discussed plastic pollution, with the aim to tackle this issue together and find possible solutions. A network was established, with representatives from the ASEAN countries, along with UNESCO's Plastic Initiative team, to identify and tackle plastic pollution in the ASEAN countries (UNESCO, 2019).

Laos

Population in Laos, especially in low income areas have limited knowledge about the advantages of reducing plastic waste and waste separation. However, workshops in schools are recommended to further strengthen this mindset as well as information campaigns.

Vietnam

In Vietnam educated people are also aware of the impact of plastic waste on the environment and health. Citizens with little education and rural inhabitants need to have a better understanding for these issues. Especially workers in craft villages need to be trained about occupational health and safety precautions. They are not properly trained in differentiating types of plastic and they do not know about their different properties. Along with that, they are not fully aware of health and environmental risks along the recycling process, due to hazardous chemicals and substances.

Nguyen et al. (2003) found in their study of Cat Que commune in Ha Tay that, village communities and local mass organizations made a significant contribution to local environmental management. As already mentioned, the role of the district and provincial environmental authorities were limited and unclear. Several studies underline, that an increase in environmental awareness through information campaigns, education and trainings need to be incorporated into village norms and empower decision makers (Ministry of Natural Resources and Environment, 2008; Trung Dinh Dang, Sango Mahnty, 2010)

6.3.2 Formalisation of the informal recycling sector (IRS)

Sasaki et al. (2014) published a study that shows notable benefits for cooperation between informal and formal MSW management, notwithstanding that additional costs are an essential problem in developing and emerging countries.

For improving the current plastic WMS one solution could be the integration of IRS into the formal WMS. Gunsilius et al. (2011) state that the integration of the informal sector also has benefits for the formal sector since informal workers are experienced in identifying materials and have knowledge in marketing and using the materials in various ways. An increase of recovery rates and an overall decrease of SWM costs

are major benefits of regularising and integrating the informal sector into the formal SWM system.

For successfully integrating an IRS, regulations and legislation, financial and institutional support are indispensable. Gunsilius (2010) states that legalising the activities by contracts for collection and recycling, preparing educational toolkits, creating social support programmes, giving strategic advice and guidance, improving technical and management practices, and developing secondary material markets are crucial for an integration of the informal sector.

An example for successfully integrating the informal sector in the formal WMS, is Brazil. In the beginning there was conflict and mistrust on both sides, but the tide had turned and there exist a variety of functioning models. Cooperation and partnerships between the official stakeholders and informal workers evolved (Gunsilius, 2010).

According to Ezeah et al. (2013) six crucial aspects need to be implemented: social acceptance, political will, mobilisation of cooperatives, partnerships with private enterprises, management and technical skills, as well as legal protection measures. The level of implementation needs to be flexible because every country has its own specifications due to different financial, physical, human, public and social capital available. In any case, the practical experiences of the informal sector are an asset for establishing a sustainable WMS (Ezeah et al., 2013).

Laos

In Laos the informal sector can be implemented into the formal one through waste banks. There is already a functioning waste bank at the National University of Laos. People who work there can advertise the system and bring it to other cities or regions. It is recommended to establish more waste banks with the support of informal waste pickers. A good example for integrating informal workers into the formal WMS is a waste bank in Indonesia, to be specific Bank Sampah Induk Gesit in Jakarta. The waste bank employs former customers of the waste bank. These employees have a good knowledge about recyclables as they used to be waste pickers. As informal waste pickers they sometimes had a higher income, nonetheless working for the waste bank has the advantage of a secure and regular income (Domonyik, 2020). The poor economic situation of informal workers, their social rejection, lack of education and health issues and working conditions is expected to improve (Aparcana and Salhofer, 2013).

Vietnam

The value of waste pickers in Vietnam is already seen by authorities, nonetheless they are working in the informal sector. In the long term it is advantageous to integrate these waste pickers into the formal WMS, as the government receives revenue and taxes from the sale of valuable materials.

6.3.3 Data

A legally binding harmonised reporting system for all manufacturing, importing, and exporting companies is recommended. This is to be implemented along with an official statistical database, openly available.

On the waste management side, a database for the amount of waste generation, source and composition is essential. Monitoring the material flow of plastic waste, including formal and informal routes is essential to gain information about the quantities and types of plastic waste. This supports the improvement of collection, sorting and recycling structures where needed.

Laos

The main important issue for future research is to close the gap of lacking data. Especially in Laos data is rare and official databases are not fully instated, at the time this thesis is finished. For a closer examination of the plastic consumption in Laos it is recommended to study the MSW composition more closely, especially in regard of different plastic types. This should be done in urban and in rural areas, as waste composition varies. Post-consumer plastic waste generation could be assessed through waste characterization studies in different cities and rural areas directly at households.

Vietnam

For Vietnam also a central database for market and waste related data is necessary. It is recommended that the General Statistics Office of Vietnam gathers data about the plastic market, waste composition and generation. Basic information, e.g. the production of plastic packaging is available, but more categories are necessary to gain an overview of the total market and waste management sector.

At sanitary landfills it is recommended to install weighbridges and do waste sorting analysis to receive information about the amount and composition of MSW.

6.3.4 Infrastructure and technology

The implementation of incineration plants to gain energy out of MSW is a useful option, if organic waste is segregated from residual waste. As the share of organic waste is between 46% and 53% in developing countries, MSW is too wet for incineration and the calorific value is too low (Shekdar, 2009; Wilson et al., 2015).

It should be considered to replace existing collection schemes, by a source separation collection scheme, investments for bins and collection vehicle are necessary.

Material recovery facilities (MRFs), where incoming waste (mixed waste) is sorted, plays a role in preparation for material recycling. A basic MRF can consist of a sorting table and a weighing scale where workers segregate the waste manually (Global Green Growth Institute, 2018).

Laos

On the landfill site of Vientiane the recycling business already sorts out fractions with a market value. This concept can be introduced to other landfills as well. Depending on the possible investment larger, automated MRFs with payloaders or forklifts, conveyor belts, magnetic separators, trommel screens or balers can be constructed (Asian Development Bank, 2013; Global Green Growth Institute, 2018).

Vietnam

The relocation of polluting enterprises, such as craft villages to designated industrial zones should be a priority for commune, district and provincial levels of government. However, such relocations need to be effectively managed by the relevant bodies to avoid merely shifting the pollution problem elsewhere. To upgrade craft villages with cleaner technologies research is needed on site of the craft villages. The status quo needs to be examined for specific solutions. The improvement of recycling techniques could result in a reduction of the amount of waste disposed of. Which goes along with the reduction of disposal costs. Establishing sanitary landfill close to these craft villages also reduces emissions (Ministry of Natural Resources and Environment and Resources, 2008; World Bank et al., 2005). In Vietnam craft villages require wastewater treatment facilities and solid waste management. As craft villages have a

limited capital, they rely on the support of the government to finance adequate infrastructure. Another issue is the limitation of available space for this infrastructure (Fanchette and Stedman, 2016; Ministry of Natural Resources and Environment, 2008; Sakata, 2013).

6.3.5 Regulations

This thesis does not focus on regulations, decrees, or any policies, but for improving plastic waste management and recycling it is inevitable. Mechanisms, such as incentives or penalties can be introduced to reassure the population and large generators of waste to separate valuable materials from the residual waste (Global Green Growth Institute, 2018).

To strengthen the recycling sector in general it is essential to set standards to protect people from hazardous substances as well as the environment and formalize the informal sector.

Laos

Laos has to implement further regulations on plastic waste management and also has to specify, enforce and monitor the already implemented laws and regulations.

Vietnam

In Vietnam responsibilities and the role allocation of authorities are not always clear, which causes issues in executing regulations. Furthermore, monitoring activities are not carried out properly. To strengthen governmental capacity, a Korean study suggests that Vietnam should increase environmental awareness in government, build capacity on policy development, prepare workable management plans, and implement monitoring and evaluation systems. In addition, it is essential to improve institutional structures to enable efficient implementation of policies and incentive systems at provincial and district levels (Asian Development Bank, 2013; Hoang and Fogarassy, 2020; Scheinberg et al., 2011).

The existing legal system on environmental protection needs to be improved. The regulatory framework in which enterprises operate is weak and civil society and local authorities have limited power to address environmental concerns. Responsible environmental authorities and agencies need to be strengthened, especially at local or district level. It is easier to execute regulations on a smaller scale and reinforcing environmental protection around craft villages.

Literature

Ahmad M.A., 2019. Plastic waste in CITENCO activities 2017 6, 5–9.

Akenji, L., Bengtsson, M., Kato, M., Hengesbaugh, M., Hotta, Y., Aoki-Suzuki, C., Gamaralalage, P.J.D., Liu, C., 2019. Circular Economy and Plastics: A Gap-Analysis in ASEAN Member States. Jakarta.

Al-Salem, S.M., Lettieri, P., Baeyens, J., 2009. Recycling and recovery routes of plastic solid waste (PSW): A review. Waste Manag. 29, 2625–2643. https://doi.org/10.1016/j.wasman.2009.06.004

Allwood, J.M., Ashby, M.F., Gutowski, T.G., Worrell, E., 2011. Material efficiency: A white paper. Resour. Conserv. Recycl. 55, 362–381. https://doi.org/10.1016/j.resconrec.2010.11.002

Aparcana, S., Salhofer, S., 2013. Development of a social impact assessment methodology for recycling systems in low-income countries. Int. J. Life Cycle Assess. 18, 1–10. https://doi.org/10.1007/s11367-013-0546-8

Asian Development Bank, 2013. Materials recovery facility tool kit. Mandaluyong City.

Bannister, G., Ghazanchyan, M., Bikoi, T., 2017. LAO P.D.R.: Assessing the Quality of Trade Statistics, IMF Working Papers. https://doi.org/10.5089/9781484325742.001

Blum, L.B., 2017. Kunststoffabfälle aus Haushalten - Stand der Technik bei der Sammlung und Verwertung in Europa. Universität für Bodenkultur.

Borealis AG, 2019. OMV ReOil project: OMV and Borealis extend their partnership at the industrial site in Schwechat.

British Plastics Federation, n.d. Vietnam Plastics Market [WWW Document]. URL http://www.bpf.co.uk/events/Vietnam_Plastics_Market.aspx (accessed 1.5.18a).

British Plastics Federation, n.d. Plastics in Vietnam.

Bundesministerium für Nachhaltigkeit und Tourismus, 2017. BUNDES-ABFALLWIRTSCHAFTSPLAN 2017. Vienna.

Castells, M., Portes, A., 1989. The informal economy: Studies in advanced and less developed countries, in: World underneath: Origins, Dynamics, and Effects of the Informal Economy. Johns Hopkins University Press, Baltimore, pp. 11–37.

Chansomphou, V., 2019. Questionnaire.

Christensen, D., Tho, L., 2015. Resources , Conservation and Recycling A Danish – Vietnamese partnership for business and technology development in solid waste management. "Resources, Conserv. Recycl. 105, 123–133. https://doi.org/10.1016/j.resconrec.2015.10.019

Concetti, 2013. Vietnam plastic industry.

Consultic Marketing & Industrieberatung GmbH, 2016. Produktion, Verarbeitung und Verwertung von Kunststoffen in Deutschland 2015.

Copello de Souza, L., 2019. Unfolding the Single-Use Plastics Directive.

Curea, C., 2017. Sustainable Societies and Municipal Solid Waste Management in Southeast Asia, in: Sustainable Asia. WORLD SCIENTIFIC, pp. 391–415. https://doi.org/10.1142/9789814730914_0015

D'Amato, A., Paleari, S., Pohjakallio, M., Vanderreydt, I., Zoboli, R., 2019. Plastics waste trade and the environment.

Das, K., 2018. Vietnam to Restrict Surging Scrap Imports [WWW Document]. URL https://www.vietnam-briefing.com/news/vietnam-to-restrict-surging-scrap-imports.html/

DESA/UNSD United Nations Comtrade database, 2018. Foreign Trade Vietnam and Laos.

DesRoberts, E., 2017. 72 Hours in Vietnam: Observations from Craft Recycling Villages - Ocean Conservancy [WWW Document]. URL https://oceanconservancy.org/blog/2017/08/04/72-hours-vietnam-observations-craft-recycling-villages/ (accessed 4.3.20).

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), 2018. Country profile Viet Nam.

Domonyik, A.M., 2020. ANALYSIS OF WASTE BANKS IN INDONESIAN FOR PLASTIC. University of Applied Life Science.

DPG Deutsches Pfand System GmbH, n.d. Function of Deposit Scheme [WWW Document]. URL https://dpg-pfandsystem.de/index.php/de/ (accessed 6.9.20).

DVO, 2008. Ordinance govering the dumping of waste - Verordnung des Bundesministers für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft über Deponien (Deponieverordnung 2008 – DVO 2008).

European Commission, 2019. Decision (EU) 2019/1004.

European Commission, 2018. REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS on the implementation of EU waste legislation, including the early warning report for Member States at risk of. Brussels.

European Commission, 2008. Waste Hierarchy.

European Environment Agency, 2019. Waste recycling. Copenhagen.

European Parliament, 2019. STRATEGY for SECONDARY RAW MATERIALS [WWW Document]. URL https://www.europarl.europa.eu/legislative-train/theme-new-boost-for-jobs-growth-and-investment/file-strategy-for-secondary-raw-materials (accessed 6.30.20).

Eurostat, 2020. Recycling rates for packaging waste.

Eurostat, 2015. Environment in the EU.

Ezeah, C., Fazakerley, J.A., Roberts, C.L., 2013. Emerging trends in informal sector recycling in developing and transition countries. Waste Manag. 33, 2509–2519. https://doi.org/10.1016/j.wasman.2013.06.020

Fanchette, S., Stedman, N., 2016. Discovering Craft Villages in Vietnam, Discovering Craft Villages in Vietnam. IRD Éditions, Marseille. https://doi.org/10.4000/books.irdeditions.26049

Faraca, G., Martinez-Sanchez, V., Astrup, T.F., 2019. Environmental life cycle cost assessment: Recycling of hard plastic waste collected at Danish recycling centres. Resour. Conserv. Recycl. 143, 299–309. https://doi.org/10.1016/j.resconrec.2019.01.014

Federal Ministry for the Enviornment Nature Conservation and Nuclear Safety, 2018. Waste Management in Germany 2018: Facts, data, diagrams, Waste Management in Germany. Berlin. https://doi.org/10.1167/12.6.3.Introduction

Friedrich, K., Möllnitz, S., Holzschuster, S., Pomberger, R., Vollprecht, D., Sarc, R., 2019. Benchmark Analysis for Plastic Recyclates in Austrian Waste Management. Detritus 09, 105–112. https://doi.org/10.31025/2611-4135/2019.13869

GHK International, 2012. Pakse Urban Environmental Improvement Project - Updated Technical Report on Pakse Solid Waste Management.

Gintenreiter-Kögl, S., 2001. Recycling von Kunststoff-Verpackungsabfällen. Johannes Kepler Universität Linz.

Global Green Growth Institute, 2018. Solid Waste Management in Vientiane - Situation assessment and opportunities for waste-to-resource. Seoul.

Grüner Punkt, n.d. About us [WWW Document]. URL https://www.gruener-punkt.de/en/company/about-us.html (accessed 6.9.20).

Guerrero, L.A., Maas, G., Hogland, W., 2013. Solid waste management challenges for cities in developing countries. Waste Manag. 33, 220–232. https://doi.org/10.1016/j.wasman.2012.09.008

Gunsilius, E., 2010. Role of informal sector in solid waste management and enabling conditions for its integration. Experiences from GTZ. Ger. Tech. Coop. Agency (GTZ), ….

Gunsilius, E., Chaturvedi, B., Scheinberg, A., 2011a. The Economics of the Informal Sector in Solid Waste Management.

Gunsilius, E., Spies, S., García-Cortés, S., Medina, M., Dias, S., Scheinberg, A., Sabry, W., Abdel-Hady, N., Santos, A.-L.F. dos, Ruiz, S., 2011b. Recovering resources, creating opportunities: Integrating the informal sector into Solid Waste Managment, Deutsche Gesellschaft für …. Eschborn.

Gutberlet, J., Baeder, A.M., 2008. Informal recycling and occupational health in Santo André, Brazil. Int. J. Environ. Health Res. 18, 1–15. https://doi.org/10.1080/09603120701844258

Hammerschmied, F., 2019. Secondary Raw Material Markets and Recycling Technologies in Low- and Middle-Income Countries. University of Natural Ressources and Life Sciences.

Hauer, W., Wellacher, Michael, Allesch, A., Beigl, P., Happenhofer, A., Huber-Humer, M., Obersteiner, G., Wellacher, Martin, 2020. Möglichkeiten zur Umsetzung der EU- Vorgaben betreffend Getränkegebinde, Pfandsysteme und mehrweg. Vienna.

Hoang, N.H., Fogarassy, C., 2020. Sustainability evaluation of municipal solid waste management system for hanoi (Vietnam)-why to choose the 'waste-to-energy' concept. Sustain. 12, 1–20. https://doi.org/10.3390/su12031085

Hoornweg, D., Bhada-Tata, P., 2012. What a Waste: A global review of solid waste management, Urban Development Series Knowledge Papers. Washington. https://doi.org/10.1111/febs.13058

Idowu, I.A., Atherton, W., Hashim, K., Kot, P., Alkhaddar, R., Alo, B.I., Shaw, A., 2019. An analyses of the status of landfill classification systems in developing countries: Sub Saharan Africa landfill experiences. Waste Manag. 87, 761–771. https://doi.org/10.1016/j.wasman.2019.03.011

Idris, A., Inanc, B., Hassan, M.N., 2004. Overview of waste disposal and landfills/dumps in Asian countries. J. Mater. Cycles Waste Manag. 6, 104–110. https://doi.org/10.1007/s10163-004-0117-y

Indochine Engineering, n.d. Vietnam's Solid Waste Sector Outlook and Engineering Opportunities.

Ishigaki, T., Chung, C. Van, Sang, N.N., Ike, M., Otsuka, K., Yamada, M., Inoue, Y., 2008. Estimation and field measurement of methane emission from waste landfills in Hanoi, Vietnam. J. Mater. Cycles Waste Manag. 10, 165–172. https://doi.org/10.1007/s10163-008-0202-8

Jain, A., 2017. Waste Management in Asean Countries.

Jambeck, J., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science (80-.). 347, 3–6. https://doi.org/10.1126/science.1260352

Japan International Cooperation Agency (JICA), 2015. Laos Pilot Program for Narrowing the Development Gap towards ASEAN Integration - Environmental Management Component.

Javorsek, M., 2016. Asymmetries in international merchandise trade statistics: A case study of selected countries in Asia and the Pacific. Bangkok.

Kawai, K., Osako, M., Matsui, S., Dong, N.T., 2012a. Identification of junk buyers' contribution to recycling of household waste in Hanoi, Vietnam, through a physical composition analysis. Waste Manag. Res. 30, 681–688. https://doi.org/10.1177/0734242X12444895

Kawai, K., Thi, L., Huong, M., Osako, M., 2012b. Accumulation and Reliability of Data on Municipal Solid Waste Management in Urban Areas of Vietnam 68, 465–471.

Kellenberg, D., 2015. The Economics of the International Trade of Waste. Annu. Rev. Resour. Econ. 7, 109–125. https://doi.org/10.1146/annurev-resource-100913-012639

Khanal, B.R., Souksavath, B., 2005. Environmental Management Measures and Current Practices in Solid Waste Management: A Case Study from Vientiane, Lao People's Democratic Republic, Journal of GMS Development Studies, Vol. 2, pp. 69-89. J. GMS Dev. Stud. 2, 69–89.

Kunststoff-Deutschland, n.d. Polyolefine [WWW Document]. URL https://www.kunststoff-deutschland.com/html/polyolefine.html (accessed 4.21.20).

Lafont, P.-B., Silverstein, J., 2020. Laos [WWW Document]. Encycl. Br. URL https://www.britannica.com/place/Laos/People#ref52501 (accessed 6.20.20).

Lewis, A., Bengtsson, M., 2019. Circular Economy and Plastics: A Gap-Analysis in ASEAN Member States. Jakarta.

Lindner, C., Hoffmann, O., 2015. Analyse/Beschreibung der derzeitigen Situation der stofflichen und energetischen Verwertung von Kunststoffabfällen in Deutschland.

Lorber, K.E., Sarc, R., Pomberger, R., 2011. Österreichische Erfahrungen zum Einsatz verschiedener Abfälle als Ersatzbrennstoffe (EBS) und mögliche Anwendungsprobleme, in: Wissenschaftskongress Abfall- Und Ressourcenwirtschaft. pp. 1–18.

Luong, N.D., Giang, H.M., Thanh, B.X., Hung, N.T., 2013. Challenges for municipal solid waste management practices in Vietnam. Waste Technol. 1, 17–21. https://doi.org/Municipal solid waste; open dumping,; landfill; composting; incineration; recycling; Vietnam

Marshall, R.E., Farahbakhsh, K., 2013. Systems approaches to integrated solid waste management in developing countries. Waste Manag. 33, 988–1003. https://doi.org/10.1016/j.wasman.2012.12.023

Menon, J., Warr, P., 2013. Lao economy: Capitalizing on natural resource exports. Asian Econ. Policy Rev. 8, 70–89. https://doi.org/10.1111/aepr.12006

Ministry of Natural Resources and Environment, 2008. National state of environment 2008 - Vietnam Craft Village Environment. Hanoi.

Ministry of Natural Resources and Environment, Resources, 2008. National State of Environment 2008 - Vietnam Craft Village 120.

Ministry of Planning and Investment, Lao Statistics Bureau, 2019. Statistical Yearbook 2018. Vientiane.

Ministry of Public Works and Transport, Ministry of Natural Resources and Environment, 2013. Brief Country Analysis Paper - Lao PDR. Hanoi.

MoNRE, 2019. Country 3R Progress Report: Lao People's Democratic Republic, Ninth Regional 3R Forum in Asia and the Pacific. Bangkok.

Murphy, J., 1996. Additives for Plastics Handbook.

Mutha, N.H., Patel, M., Premnath, V., 2006. Plastics materials flow analysis for India. Resour. Conserv. Recycl. 47, 222–244. https://doi.org/10.1016/j.resconrec.2005.09.003

Neidel, T.L., Jakobsen, J.B., 2013. Report on assessment of relevant recycling technologies. Lyngby.

Netherlands Enterprise Agency, 2018. Circular Economy Vietnam - Waste Management & Recycling.

Nguyen, K.Q., Tran, V.T., Le, V.L., 2003. Assessing Participatory Rural Environmental Management in the Craft Villages (Cat Que commune , Hoai Duc district , Ha Tay province).

Nguyen, T., 2006. Solid Waste Management in Vietnam, School of Internaional and Public Affairs, Columbia Univeersity.

OECD/ILO, 2019. Definitions of informal economy, informal sector and informal employment [WWW Document]. Tackling Vulnerability Informal Econ. URL https://www.oecd-ilibrary.org/development/tackling-vulnerability-in-the-informal-economy_103bf23e-en (accessed 3.27.20).

Ojeda-Benitez, S., Armijo-de-Vega, C., Ramírez-Barreto, M.E., 2002. Formal and informal recovery of recyclables in Mexicali, Mexico: Handling alternatives. Resour. Conserv. Recycl. 34, 273–288. https://doi.org/10.1016/S0921-3449(01)00105-7

OMV, 2018. ReOil - Raw Material Recycling of Used Plastics [WWW Document]. URL https://www.omv.com/en/sustainability/innovation/circular-economy-re-oil (accessed 6.8.20).

Pearse, W., 2010. A Look at Vietnam's Plastic Craft Villages [WWW Document]. URL

https://ourworld.unu.edu/en/a-look-at-vietnams-plastic-craft-villages (accessed 10.10.19).

Phoungthong, K., 2017. Municipal solid waste management in Thailand. Curr. Sci. 112, 674. https://doi.org/10.18520/cs/v112/i04/674-674

Plastics Europe, n.d. Polyolefine [WWW Document]. URL http://www.plasticseurope.de/das-ist-kunststoff/kunststoffsorten/polyolefine.aspx (accessed 1.4.18).

PlasticsEurope, 2019a. The Circular Economy for Plastics - A European Overview. Brussels.

PlasticsEurope, 2019b. Plastics - the Facts 2019.

PlasticsEurope Deutschland e.V., 2019. Geschäftsbericht 2018. Frankfurt.

Retamal, M., Dominish, E., Xuan Thinh, L., Nguyen, A.T., Sharpe, S., 2019. Here's what happens to our plastic recycling when it goes offshore [WWW Document]. URL http://theconversation.com/heres-what-happens-to-our-plastic-recycling-when-it-goes-offshore-110356 (accessed 4.15.19).

Rudolph, N., Kiesel, R., Aumnate, C., 2017. Understanding Plastics Recycling: Economic, Ecological, and Technical Aspects of Plastic Waste Handling. Hanser Publishers, Munich.

Sakata, S., 2013. Rural Industries in Northern Vietnam: Strategies of small-scale Business establishments in the formation of craft villages, in: Sakata, S. (Ed.), Vietnam's Economic Entities in Transition. Ide-Jetro, pp. 204–227. https://doi.org/10.1057/9781137297143

Salhofer, S., 2001. Kommunale Entsorgungslogistik. Erich Schmidt Verlag GmbH & Co., Berlin.

Salhofer, S.P., 2018. Source Separation and Recycling, in: Maletz, R., Dornack, C., Ziyang, L. (Eds.), The Handbook of Environmental Chemistry. Springer, Cham, pp. 227–246.

Sang-Arun, J., Pasomsouk, K., 2012. A guide for improving municipal solid waste management and promoting urban organic waste utilization in Lao PDR. Kanagawa.

Sarc, R., Lorber, K.E., 2013. Production, quality and quality assurance of Refuse Derived Fuels (RDFs). Waste Manag. 33, 1825–1834. https://doi.org/10.1016/j.wasman.2013.05.004

Sasaki, S., Araki, T., Tambunan, A.H., Prasadja, H., 2014. Household income, living and working conditions of dumpsite waste pickers in Bantar Gebang: Toward integrated waste management in Indonesia. Resour. Conserv. Recycl. https://doi.org/10.1016/j.resconrec.2014.05.006

Sato, N., Phonvisai, P., Sonthavy, P., Ogawa, R., 2019. CURRENT CONDITION AND ISSUES OF MUNICIPAL SOLID WASTE MANAGEMENT IN VIENTIANE CAPITAL , LUANG PRABANG DISTRICT AND XAYABOURI DISTRICT IN LAOS PEOPLE ' S DEMOCRATIC REPUBLIC CURRENT CONDITION AND ISSUES OF MUNICIPAL SOLID WASTE MANAGEMENT IN VIENTIANE CAPI, in: APLAS TOKYO 2018 The 10th Asia-Pacific Landfill Symposium. Tokyo, pp. 1–8.

Scheinberg, A., Spies, S., Simpson, M.H., Mol, A.P.J., 2011. Assessing urban recycling in low- and middle-income countries: Building on modernised mixtures.

Habitat Int. 35, 188–198. https://doi.org/10.1016/j.habitatint.2010.08.004

Schneider, P., Anh, L., Wagner, J., Reichenbach, J., Hebner, A., 2017. Solid Waste Management in Ho Chi Minh City, Vietnam: Moving towards a Circular Economy? Sustainability 9, 286. https://doi.org/10.3390/su9020286

Schroeder, P., Anggraeni, K., Sartori, S., Weber, U., 2016. Sustainable asia: Supporting the transition to sustainable consumption and production in asian developing countries, Sustainable Asia: Supporting the Transition to Sustainable Consumption and Production in Asian Developing Countries. World Scientific Publishing Co. Pte. Ltd. https://doi.org/10.1142/9862

Schüler, K., 2019. Aufkommen und Verwertung von Verpackungsabfällen in Deutschland im Jahr 2017. Mainz.

Schwarzböck, T., Aschenbrenner, P., Spacek, S., Szidat, S., Rechberger, H., Fellner, J., 2018. An alternative method to determine the share of fossil carbon in solid refuse-derived fuels – Validation and comparison with three standardized methods. Fuel 220, 916–930. https://doi.org/10.1016/j.fuel.2017.12.076

Science Technology and Environmental Agency Lao PDR, n.d. Lao PDR National Environmental Performance Assessment (EPA) Report.

SEA-PLASTIC-EDU, n.d. Project Info [WWW Document]. URL http://plastic-edu.com/en/project-info/ (accessed 7.26.20).

Sharma, G., 2020. Austria's OMV Wants To Dominate $50B Global Market For Synthetic Oil Made From Plastic Waste [WWW Document]. Forbes. URL https://www.forbes.com/sites/gauravsharma/2020/02/20/austrias-omv-wants-to-dominate-50b-global-market-for-synthetic-oil-from-plastic-waste/#1a8fe8452758 (accessed 6.8.20).

Shekdar, A. V., 2009. Sustainable solid waste management: An integrated approach for Asian countries. Waste Manag. 29, 1438–1448. https://doi.org/10.1016/j.wasman.2008.08.025

Souksavath, S., Sidlakone, S., Qian, X., Haruna, M., 2005. Study on Facility Planning for Encouraging the Integrated Solid Waste Management in Vientiane Capital , Laos 1–3.

Spoann, V., Fujiwara, T., Seng, B., Lay, C., Yim, M., 2019. Assessment of public-private partnership in municipal solid waste management in Phnom Penh, Cambodia. Sustain. 11. https://doi.org/10.3390/su11051228

Stoifl, B., Bernhardt, A., Karigl, B., Lampert, C., Neubauer, M., Thaler, P., 2017. Kunststoffabfälle in Österreich - Aufkommen und Behandlung. Vienna.

StoxPlus, 2017. Vietnam Plastics and Plastic Packaging Industries : Opportunities and Challenges. Ho Chi Minh City.

Thang, N.T., 2017. State of 3Rs in Asia and the Pacific - The Socialist Republic of Viet Nam. Unitetd Nation.

Thanh, N.P., Matsui, Y., Fujiwara, T., 2011. Assessment of plastic waste generation and its potential recycling of household solid waste in Can Tho City, Vietnam. Environ. Monit. Assess. 175, 23–35. https://doi.org/10.1007/s10661-010-1490-8

Thanh, N.P., Matsui, Y., Fujiwara, T., 2010. Household solid waste generation and characteristic in a Mekong Delta city, Vietnam. J. Environ. Manage. 91, 2307–2321. https://doi.org/10.1016/j.jenvman.2010.06.016

The Global Plastic Action Partnership, 2020. Viet Nam - Reshaping the plastics sector to deliver a more sustainable marine economy by 2030 [WWW Document]. URL https://globalplasticaction.org/countries/vietnam/ (accessed 6.30.20).

The World Bank, 2012. What a waste: a global review of solid waste management. Urban Dev. Ser. Knowl. Pap. 16–21. https://doi.org/10.1111/febs.13058

Thong, V., 2018. Plastic industry hit hard by abrupt scrap import ban [WWW Document]. URL https://e.vnexpress.net/news/business/industries/plastic-industry-hit-hard-by-abrupt-scrap-import-ban-3792774.html

Tran, D.T., 2019. Questionnaire.

Trang, P.T.T., Hanh, N.T.X., Toan, D.Q., Dong, H.Q., Thu, N.T., 2017. The Effects of Socio-economic Factors on Household Solid Waste Generation and Composition: A Case Study in Thu Dau Mot, Vietnam. Energy Procedia 107, 253–258. https://doi.org/10.1016/j.egypro.2016.12.144

Trung, D.D., Mahnty, S., Nguyen, T. Van, 2010. Vietnam ' s Craft villages and water pollution: A review of previous research. Canberra.

Trung Dinh Dang, Sango Mahnty, N.T. Van, 2010. Vietnam ' s Craft villages and water pollution : A review of previous research Trung Dinh Dang , Sango Mahanty and Nguyen Thanh Van March 2010 1–22.

Truong, N., 2018. Solid Waste Management in Vietnam: Current situation, challenges and strategies for development. Metropolia University of Applied Sciences.

Tuyen, L.D., 2019. Plastic Wastes Pose Threats on Vietnam's Environment [WWW Document]. Heinrich Böll Found. URL https://th.boell.org/en/2019/11/06/plastic-wastes-pose-threats-vietnams-environment (accessed 4.30.20).

UNDP, 2020. 2019 Human Development Index Ranking [WWW Document]. URL http://hdr.undp.org/en/content/2019-human-development-index-ranking (accessed 5.25.20).

UNESCO, 2019. The Plastic Initiative launches! [WWW Document]. URL https://theplasticinitiative.org/the-plastic-initiative-launches/ (accessed 8.1.20).

UNIDO, 2018. Terms of Reference - For the provition of Services and Equipment (Turnkey) for two pilot facilities to be located at Phan Boi and Minh Khai Craft Villages - Vietnam.

United Nations, 2020a. UNData Lao [WWW Document]. URL http://data.un.org/en/iso/la.html (accessed 5.25.20).

United Nations, 2020b. UNData Austria [WWW Document]. URL http://data.un.org/en/iso/at.html (accessed 5.25.20).

United Nations, 2020c. UNData Myanmar [WWW Document]. URL http://data.un.org/en/iso/mm.html (accessed 5.25.20).

United Nations, 2020d. UNData Thailand [WWW Document]. URL http://data.un.org/en/iso/th.html (accessed 5.25.20).

United Nations, 2020e. UNData Cambodia [WWW Document]. URL http://data.un.org/en/iso/kh.html (accessed 5.25.20).

United Nations, 2019. Country Profile Lao's PDR [WWW Document]. URL http://data.un.org/CountryProfile.aspx?crName=Lao People%27s Democratic Republic (accessed 3.27.20).

United Nations, 2017. Harmonized Commodity Description and Coding Systems (HS) [WWW Document]. URL https://unstats.un.org/unsd/tradekb/Knowledgebase/50018/Harmonized-Commodity-Description-and-Coding-Systems-HS (accessed 11.9.19).

United Nations, 2016. What is UN Comtrade? [WWW Document]. URL https://unstats.un.org/unsd/tradekb/Knowledgebase/50075/What-is-UN-Comtrade (accessed 11.9.19).

Vacha, Y., 2019. Luang Prabang City.

Van Eygen, E., 2018. Management of plastic wastes in Austria : analysis of the status quo and environmental improvement potentials. Vienna University of Technology.

Van Eygen, E., Feketitsch, J., Laner, D., Rechberger, H., Fellner, J., 2017. Comprehensive analysis and quantification of national plastic flows: The case of Austria. Resour. Conserv. Recycl. 117, 183–194. https://doi.org/10.1016/j.resconrec.2016.10.017

Vietcombank Securities, 2016. Vietnam Plastic Industry Report.

Vietnam Business Council for Sustainable Development, 2019. Vietnam Materials Marketplace.

Vietnam Plastics Association, 2014. Vietnam Plastics Industry Overview. Ho Chi Minh City.

VPA, n.d. Overview of Vietnam plastics industry [WWW Document]. URL http://vpas.vn/introduction/industry-overview.html (accessed 3.13.19).

Vu, K., 2018. Vietnam to limit waste imports as shipments build up at ports [WWW Document]. URL https://www.reuters.com/article/us-vietnam-waste/vietnam-to-limit-waste-imports-as-shipments-build-up-at-ports-idUSKBN1KG0KL (accessed 1.6.19).

Wilson, D.C., Rodic, L., Modak, P., Soos, R., Carpintero Rogero, A., Velis, C., Iyer, M., Simonett, O., 2015. Global Waste Management Outlook. https://doi.org/10.1177/0734242X15616055

Wilson, D.C., Velis, C., Cheeseman, C., 2006. Role of informal sector recycling in waste management in developing countries. Habitat Int. 30, 797–808. https://doi.org/10.1016/j.habitatint.2005.09.005

World Bank, 2020a. Country Profile Myanmar [WWW Document]. URL https://databank.worldbank.org/views/reports/reportwidget.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=n&country=MMR (accessed 5.22.20).

World Bank, 2020b. Country Profile Thailand [WWW Document]. URL https://databank.worldbank.org/views/reports/reportwidget.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=n&country=THA (accessed 5.22.20).

World Bank, 2020c. Country Profile Cambodia [WWW Document]. URL https://databank.worldbank.org/views/reports/reportwidget.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=n&country=KHM (accessed 5.22.20).

World Bank, 2020d. Meet our Innovator Protecting Our Oceans in Lao PDR: Dr. Vatthanamixay Chansomphou [WWW Document]. URL

https://www.worldbank.org/en/news/feature/2020/06/02/meet-our-innovator-protecting-our-oceans-in-lao-pdr-dr-vatthanamixay-chansomphou (accessed 6.25.20).

World Bank, 2019. Country Profile Lao PDR [WWW Document]. URL https://databank.worldbank.org/views/reports/reportwidget.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=n&country=LAO (accessed 3.27.20).

World Bank, 2018. Vietnam Overview [WWW Document]. URL https://www.worldbank.org/en/country/vietnam/overview (accessed 10.21.18).

World Bank, 2012. A Global Review of Solid Waste Management. World Bank Urban Dev. Ser. Knowl. Pap. 1–116. https://doi.org/10.1111/febs.13058

World Bank, 2004. Vietnam Environment Monitor.

World Bank, MONRE, CIDA, 2005. Vietnam Environment Monitor 2004.

Žmak, I., Hartmann, C., 2017. Current state of the plastic waste recycling system in the European Union and in Germany. Teh. Glas. 11, 138–142.

Annex

Annex I

CC	Comodity Name
3901	Polymers of ethylene, in primary forms
3902	Polymers of propylene or of other olefins, in primary forms
3903	Polymers of styrene, in primary forms
3904	Polymers of vinyl chloride or of other halogenated olefins, in primary forms
3905	Polymers of vinyl acetate or of other vinyl esters, in primary forms; other vinyl polymers in primary forms
3906	Acrylic polymers in primary forms
3907	Polyacetals, other polyethers and epoxide resins, in primary forms; polycarbonates, alkyd resins, polyallyl esters and other polyesters, in primary forms
3908	Polyamides in primary forms
3909	Amino-resins, phenolic resins and polyurethanes, in primary forms
3910	Silicones in primary forms
3911	Petroleum resins, coumarone-indene resins, polyterpenes, polysulphides, polysulphones and similar products of chemical synthesis n.e.c. in chapter 39, in primary forms
3912	Cellulose and its chemical derivatives, n.e.c. or included, in primary forms
3913	Natural polymers (e.g. alginic acid) and modified natural polymers (e.g. hardened proteins, chemical derivatives of natural rubber), n.e.c. or included, in primary forms
3914	Ion-exchangers; based on polymers of heading no. 3901 to 3913, in primary forms
3915	Waste, parings and scrap, of plastics
3916	Monofilament of which any cross-sectional dimension exceeds 1mm, rods, sticks and profile shapes, whether or not surface-worked but not otherwise worked, of plastics
3917	Tubes, pipes and hoses and fittings thereof (for example, joints, elbows, flanges), of plastics

3918	Floor coverings of plastics, self-adhesive or not, in rolls or tiles; wall or ceiling coverings of plastics, in rolls of a width not less than 45cm
3919	Self-adhesive plates, sheets, film, foil, tape, strip and other flat shapes, of plastics, whether or not in rolls
3920	Plastics; plates, sheets, film, foil and strip (not self-adhesive); non-cellular and not reinforced, laminated, supported or similarly combined with other materials, n.e.c. in chapter 39
3921	Plastic plates, sheets, film, foil and strip n.e.c. in chapter 39
3922	Sanitary ware; baths, shower-baths, sinks, wash-basins, bidets, lavatory pans, seats and covers, flushing cisterns and sanitary ware, of plastics
3923	Plastic articles for the conveyance or packing of goods; stoppers, lids, caps and other closures of plastics
3924	Tableware, kitchenware, other household articles and hygienic or toilet articles, of plastics
3925	Plastics; builders' wares n.e.c. or included
3926	Articles of plastics and articles of other materials of heading no. 3901 to 3914, n.e.c. in chapter 39

Annex II

Questionnaire

Elisabeth Bundschuh

Master Thesis: "*Market situation, collection and treatment of plastic waste in Lao and Vietnam"*

As part of my master thesis in environmental management and engineering I am conducting a questionnaire to gain further information on plastic manufacturing, recycling and waste management. The thesis shall give an overview of the current state of the art in plastic manufacturing and recycling in Laos and in Vietnam and shall depict the status quo of the waste management sector as well as the plastic consumption.

All questions asked can be answered on a local or regional level for a city or for the whole country. I would appreciate if you could answer my following questions. Please also name the sources of information and data.

- **Production:**

  Import and export:

  1. Is there available data on import and export of plastic material (e.g. PP, PE, PS or plastic foil, plastic bags…)?
  2. Is there any export statistic on products which contain a high amount of plastic (e.g. PSU, notebooks, automotive, toys)?

  Domestic production:

  3. What amount and which types of plastic products are produced within the country (types: eg. PP, PE, PS)?
  4. Is there any data on the amount of plastic recycling (formal in industry, informal in craft villages)?
  5. Which types of plastic are mainly recycled?
  6. Which technologies are used for plastic recycling?
  7. Which are the main industry sectors with demand for plastic scrap?
  8. What products are manufactured from recycling material?

- **Waste Management**

  Industrial waste:

  9. What happens to industrial waste?
  10. Is it collected or treated separately? (by industry sectors, with emphasis on plastic processing industry)
  11. Are there any studies on industrial waste composition?
  12. Is there any plan to collect plastic waste at industry separately?

  Household waste:

  13. Do you have data on generated household waste?
  14. Is there any data on household waste composition and quantity?
  15. Where does the household waste end up?
  16. Is there any separation done by the formal sector?
  17. Are there types of plastic waste which are recycled or treated?
  18. Which share of household waste is disposed of at a landfill without prior treatment?
  19. Are there any plans on strengthening recycling?
  20. What happens with the separately collected plastic waste?
  21. Is plastic waste exported?
  22. Is there any waste incineration plant?