SWAP

Sustainable solid WAste management and Policies

DELIVERABLES 1.1
Education on Solid Waste Management. The cases of Vietnam, Cambodia and Thailand

Project Acronym	**SWAP**
Work Package	WP1-Task 1.1
Deliverable	D 1.1 – Task 1.1, Task 1.2, Task 1.4, Task 1.5
Deliverable Lead	HUAF – Task Lead HUAF
Type	Report
Dissemination Level	Public
Contractual delivery date	M4 (15/04/2021 14/05/2021)
Actual submission date	15/05/2021
Author(s)	Le Thi Thuy Hang, Tran Thanh Duc, Le Ngoc Phuong Quy, Le Dinh Huy, Ve Quoc Linh

HAMBURG UNIVERSITY OF TECHNOLOGY

ABSTRACT

As a part of Work package 1, this deliverable 1.1 report has been done to provide an overview and detailed information of the Education on Solid Waste Management (SWM) for the present in the Partner Countries. There are three main findings: (1) For teaching SWM at the Academic level, most of the surveyed universities have teaching programs that have met the social demands. However, SWM-related courses seem to be more popular at Bachelor level than Master level. This is reflected in the number of curricula as well as the number of students participating. However, a common problem at both levels is the lack of equipment status, as a result, the needs of students are not fully met. (2) For SWM training at the Non-academic level, the general conclusion is that the partner universities have not received the investment. In addition, these TVET courses have not received the attention of the learners. Therefore, this is still an educational level with many shortcomings and need a lot of investment to develop in the future. (3) For the gaps in training and teaching capacities and possible improvement options of curriculum updating in the Master and Bachelor programmes, together with TVET program where all ASEAN Higher Education Institutions (HEIs) would need to improve the capacity their students through providing internship programme at private sector or NGOs related fields. As known that both new and updated courses will be shown in detail so that they are officially approved from the management board at the university levels. Finally, the highlighted courses to fill in the gaps in training and teaching will support and improve more for curriculum both master and bachelor levels.

KEYWORDS

Cambodia, Education, Solid Waste Management, SWAP, Thailand, Vietnam.

DISCLAIMER

The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

from risk, and does not accept any liability for loss or damage suffered by any person using this information.

ACKNOWLEDGEMENT

This document is a deliverable of the SWAP project. This project is co-funded by the Erasmus+ Programme of the European Union under the call for proposals EAC/A02/2019 and carries the project n° 618723-EPP-1-2020-1-DE-EPPKA2-CBHE-JP.

ABBREVIATIONS

BSc: Bachelor degree

CAP: Cleansing Authority of Phnom Penh

CCET: IGES Centre Collaborating with UNEP on Environmental Technologies

C&D: Construction and Demolition

CMU: Chiangmai University

DPWT: Department of Public Work and Transport

EEE: Electrical and Electronic Equipment

E-Waste: Electronic and Electrical Waste

GAEA: Global Action for Environment Awareness

GGGI: Global Growth Institute

HEIs: Higher Education Institutions

HUAF: Hue University of Agriculture and Forestry

MBT: Mechanical-Biological-Treatment

MEF: Ministry of Economy and Finance

MJU: Maejo University

MoH: Ministry of Health

MoE: Ministry of Environment

MPP Municipality of Phnom Penh

MPWT: Ministry of Public Works and Transport

MSc: Master degree

MSW: Municipal Solid Waste

MWMU: Medical Waste Management Unit

NCSD: National Council for Sustainable Development

PAD: Pacific Asia Development

PCD: Pollution Control Department

PCD: The Public Cleansing Department

PPC: Phnom Penh Cleansing

PPWM: Phnom Penh Waste Management Authority

RGC: Royal Government of Cambodia

RUA: Royal University of Agriculture

SDGs: Sustainable Development Goals

SWM: Solid Waste Management

TVET: Technical and Vocational Education and Training

TUAF: Thai Nguyen University of Agriculture and Forestry

UHST: University of Heng Samrin Thbongkhmum

UNEP: United Nations for Environment Programme

WEEE: Waste Electrical and Electronic Equipment

WP1: Work package 1

WtE: Waste-to-Energy

Table of Contents

1 INTRODUCTION AND AIM OF THE STUDY

This deliverable 1.1 report was made to provide an overview and detailed information on Solid Waste Management (SWM) education in the Partner Countries.

The report 1 aims to:

- Show the current state of SWM teaching and training education at Higher Education Institutions (HEIs) of Partner Countries.
- To understand the available information relating to informal sector in Partner Countries.
- To find the gaps and improvement options for tertiary and academic education at HEIs of Partner Countries.

To achieve this task, a methodology was defined to address the gaps related to the degree courses offered by HEIs involving in SWAP (Table. 1).

Table 1. LIST OF UNIVERSITIES FROM PARTNER COUNTRIES

NO.	UNIVERSITY	CODE	COUNTRY
1	Chiangmai University (CMU)	T1	Thailand
2	Maejo University (MJU)	T2	Thailand
3	Royal University of Agriculture (RUA)	C1	Cambodia
4	University of Heng Samrin Thbongkhmum (UHST)	C2	Cambodia
5	Hue University of Agriculture and Forestry (HUAF)	V1	Vietnam
6	Thai Nguyen University of Agriculture and Forestry (TUAF)	V2	Vietnam

2 METHODOLOGICAL APPROACH

The first step involves the identification of course offered by the HEIs as shown in figure 1 They are RUA, UHST, CMU, MJU, TUAF, and HUAF. The second step is to identify the degree courses offered by the university and related to environmental issues. The degree courses can be divided in Bachelor (BSc), Master (MSc), and Technical and Vocational Education and Training (TVET) programs.

They contain a series of information necessary for all HEIs on how the degree course is taught related to the solid waste management. However, the HIEs have similar courses to be updated and new courses also collected. This step needs comparison to find out the potential courses to be improved for tertiary at higher education levels and to define gaps and improvement options of the ASIAN partners HEIs with those identified in WP1. The information is collected through desk research based on the survey questionnaire.

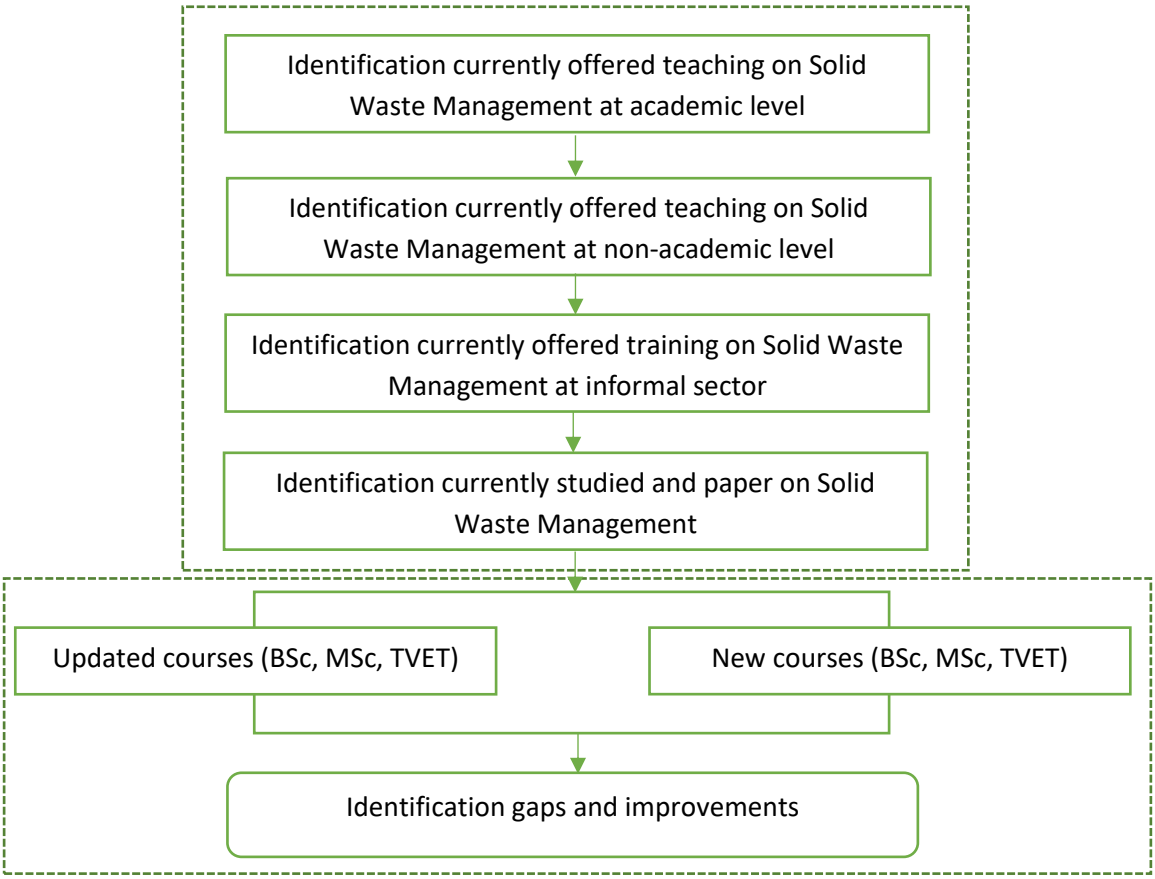


Figure 1. Methodological approach

3 RESULT

PART 1. CURRENTLY OFFERED EDUCATIONAL PRODUCTS AT DIFFERENCE LEVELS IN PARTNER COUNTRIES

3.1 Currently offered teaching on Solid Waste Management at Academic level in Partner countries

3.1.1 Bachelor level

At the Bachelor level, SWM-related education becomes more popular in 3 partner countries in Asia. This is evident in the survey contents of curricula information as well as the number of students and the state of facilities for teaching about SWM.

Table 2. NUMBER OF CURRICULA CURRENTLY OFFERED AT BACHELOR LEVEL RELATED TO SOLID WASTE MANAGEMENT

NO	UNIVERSITY	TOTAL	RELATED TO SWM	
			Number	Percentage

1	T1	47	1	2.1
2	T2	93	1	1.1
3	C1	3	3	100
4	C2	48	2	4.2
5	V1	28	9	32.1
6	V2	20	1	5.0

At the Bachelor level, the number of SWM-related curricula varies by subject and by different universities. Because the number of courses at this level is more, therefore, the content of courses related to SWM also becomes more detailed and goes into more specific content according to the requirements of each discipline. The proportion of learning programs that provide SWM information as a whole also varies significantly at this academic level (Table 2).

Teaching methods, number of credits, and number of lecturers show similarities between Bachelor level and Master level. However, at this level, the types of group exercises (project, oral presentation) become popular and are widely used to familiarize students with theoretical concepts related to SWM. However, field survey activities and laboratory practice are not common in these cases.

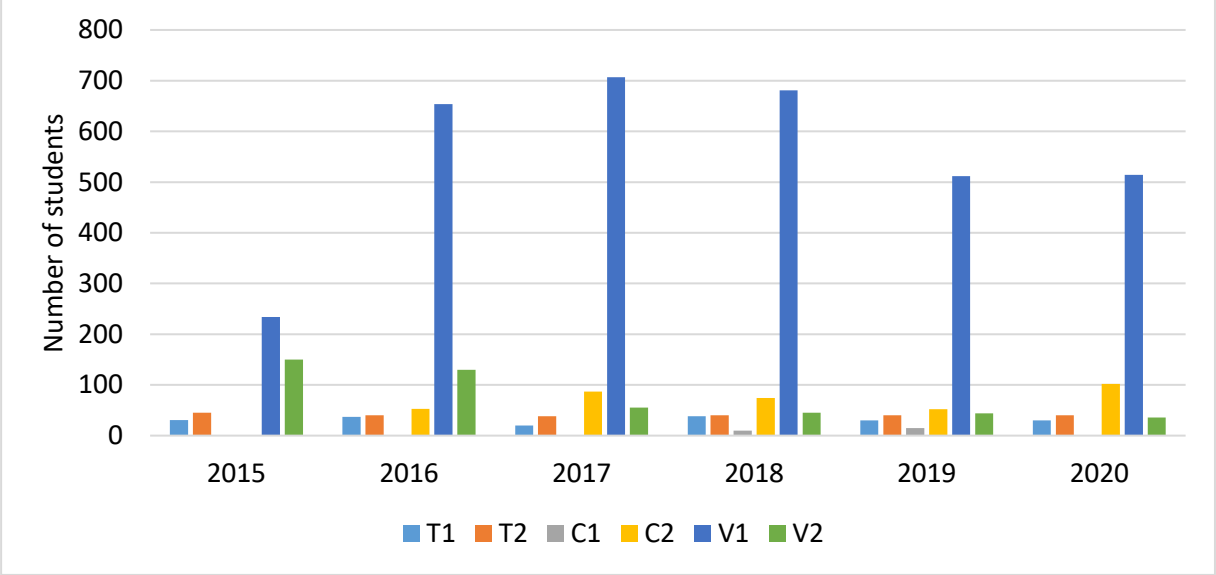


Figure 2. NUMBER OF STUDENTS AT BACHELOR LEVEL ON TOPICS RELATED TO SWM BETWEEN 2015-2020

Figure 2 shows that compared to Master's level, at Bachelor level the number of students participating in SWM-related courses is significantly higher. Particularly, 2 universities in Vietnam (V1 and V2) still stand out with a very high number of participants. The total number of students of 2 universities in Thailand and 2 universities in Cambodia does not show a significant difference.

Even with a large number of students participating, the adequacy of equipped laboratories is substantially low and of all the universities surveyed were not able to meet the equipment demand. Especially in the case of V1, with an average number of 550 students per year, the number of

laboratories and equipment is seriously inadequate. This can be an obstacle to the provision of knowledge related to SWM as well as be reducing the ability to attract learners to participate in SWM-related courses.

Table 3. NUMBER OF LABORATORIES AND EQUIPMENT AT BACHELOR LEVEL ON TOPICS RELATED TO SWM

NO	UNIVERSITY	NUMBER OF LABORATORIES AND EQUIPMENT	STATUS
1	T1	n/a	n/a
2	T2	6	Lack of new equipment
3	C1	n/a	n/a
4	C2	8	No equipment related with SWM
5	V1	1	Lack of new equipment
6	V2	n/a	n/a

3.1.2 Master level

From Table 4, the number of curricula provided at Master level related to SWM is described. Overall, SWM related courses are few with the average rate of less than 5% at universities in Thailand and less than 33.33% at universities in Vietnam. Since two partner universities (C1 and C2) in Cambodia do not have training at Master level, the number of courses related to SWM is zero.

Table 4. NUMBER OF CURRICULA CURRENTLY OFFERED AT MASTER LEVEL ON TOPICS RELATED TO SOLID WASTE MANAGEMENT (SWM)

NO	UNIVERSITY	TOTAL	RELATED TO SWM	
			Number	Percentage
1	T1	25	1	4
2	T2	50	1	2
3	C1	0	0	0
4	C2	0	0	0
5	V1	10	3	30
6	V2	9	1	11.1

The SWM-related content of each curriculum is diverse and changeable according to the requirements of each different course and university. Some of the subjects covered are as follows:

Subjects in T1 include: Waste generation, Characteristics, Properties, Source management, Utilization, Landfill Design, thermal conversion, Composting, Waste Transfer and Collection.

Subjects in T2 include: Sources, components, disposal technologies and management system of solid wastes and hazardous waste; Information of soil and soil pollution in Thailand; Introduction to different types of pollution, technologies and processes for pollution control and prevention.

Subjects in V1 include: Information about relationship between the environment and animals, also providing the knowledge of applying biotechnology in animal husbandry as well as in livestock waste treatment. And other course discusses about the relation between waste management and urban environmental problems.

Subjects in V2 include: The module considers solid wastes from industry, commerce and domestic sources (waste minimization, reuse, recycling and recovery, technology and management strategies)

Regarding teaching methods, traditional methods combined with online lessons are used. For practice-required lessons, laboratories become places for learners to conduct experiments and gain practical knowledge in terms of relevant content. Besides, field trips are also implemented at some universities in Vietnam according to the specific requirements of the course.

The number of credits depends on the content taught at each partner university, approximately from 2 to 4 credits per SWM-related course, and the average number of teaching lecturers is one faculty per credit of SWM.

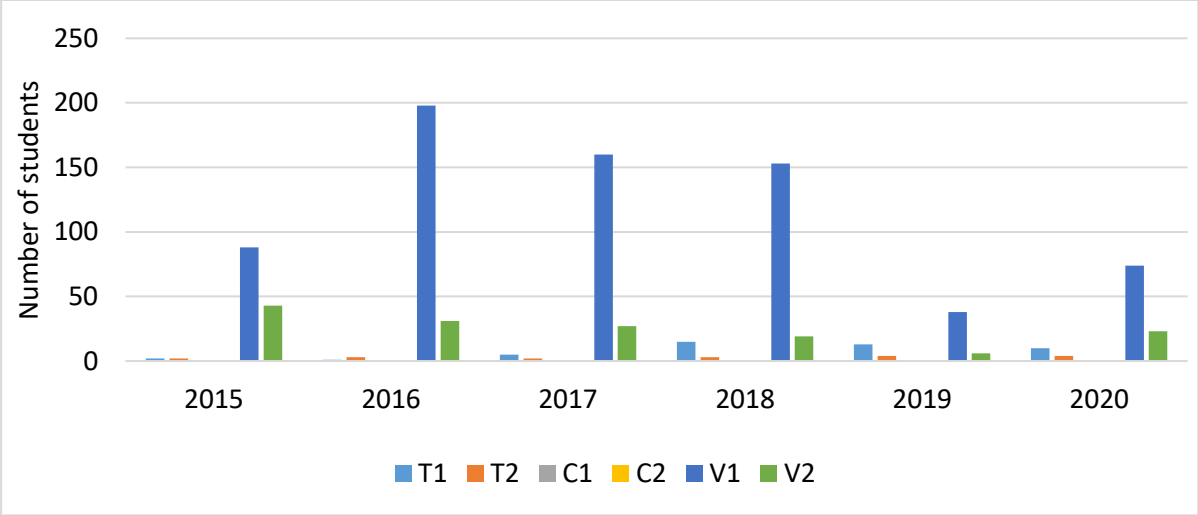


Figure 3. NUMBER OF STUDENTS AT MASTER LEVEL ON TOPICS RELATED TO SWM BETWEEN 2015-2020

Regarding the number of Master's students studying SWM-related courses, 2 universities in Vietnam dominate, the number of students of V1 is 711 people and V2 is 149 people. This number is much smaller in 2 Thailand universities (T1 and T2), respectively 46 and 18 students. In the case of universities in Cambodia, because the Master's program has no content related to SWM, no students have access to SWM at this level.

Despite a large number of students, the provision of facilities and equipment for SWM-related courses has not been paid attention to at 2 partner universities in Vietnam. The same case also happened at T2 in Thailand. According to the survey, only T1 has equipment for SWM-related courses, however, when looking specifically, these tools can only meet basic research tasks (Table 5).

Table 5. NUMBER OF LABORATORIES AND EQUIPMENT AT MASTER LEVEL ON TOPICS RELATED TO SWM

NO	UNIVERSITY	NUMBER OF LABORATORIES AND EQUIPMENT	STATUS
1	T1	1	Enough
2	T2	n/a	n/a
3	C1	n/a	n/a
4	C2	n/a	n/a
5	V1	2	n/a
6	V2	n/a	n/a

3.2 Currently offered teaching on Solid Waste Management at Non-academic level

The TVET course that is classified as non-academic level, is not common in partner universities.

The data in Table 6 indicates that only 3 universities in Thailand and Cambodia (T1, C2) have organized non-academic training activities whereas non-academic courses related to SWM have not been implemented at partner universities in Vietnam. The specific SWM content of universities with TVET training is as follows:

T1: Life cycle assessment as a tool for measuring environmental impact; Principles of biogas technology: industrial application; Transformation of MSW into renewable energy and usable products; Utilization of wasted biomass in the permeable reactive barrier for remediation of acid mine drainage; Biorefinery in biofuel/bioenergy production; Compressed biogas for household and how to make it work; Use of Sanitary landfill for renewable energy production.

C2: Understand the values of the natural environment in rural areas; Explaining the conservation of natural ecosystem; Describe the relationship between agricultural activities and environmental conservation. Describe how to select varieties, systems of cultivation, control of pests, harvesting and storage of crops, income expenditure plans in the crop production process; Practice how to manage waste and produce organic fertilizer used on crops; Cultivate the idea of loving agricultural work, wanting to maintain, protect and develop agriculture for growth.

Table 6. NUMBER OF CURRICULA CURRENTLY OFFERED AT NON-ACADEMUC (TVET) LEVEL ON TOPICS RELATED TO SOLID WASTE MANAGEMENT (SWM)

NO	UNIVERSITY	TOTAL	RELATED TO SWM	
			Number	Percentage
1	T1	6	2	33.3
2	T2	0	0	0
3	C1	0	0	0
4	C2	2	2	100
5	V1	0	0	0
6	V2	0	0	0

The general comment, in this case, is that the training duration is irregular and no rules, which proves that SWM training is not popular and is not an official training activity of universities such as teaching academic courses (in Master level and Bachelor level).

Due to these courses is temporary, the training time is quite short, measured only in hours or days. Therefore, the forms of teaching and examination were also shortened and simplified, mostly focusing on group exercises (presentation) and written examination. The number of participants in SWM training at TVET level programs is small and mostly concentrated at T1 and C2. In Thailand, although both surveyed universities have training TVET courses, only T1 can attract participants, the number is 64 people in 6 years. In contrast, C2 in Cambodia has been able to attract nearly twice as many participants as T1 (Table 7) in 4 years. This may be due to equipment and facilities issues, which are further analyzed below.

Table 7. NUMBER OF STUDENTS AT TVET LEVEL ON TOPICS RELATED TO SWM BETWEEN 2015-2020

NO	UNIVERSITY	2015	2016	2017	2018	2019	2020	TOTAL
1	T1	19	29	0	16	0	0	**64**
2	T2	0	0	0	0	0	0	**0**
3	C1	0	0	0	0	0	0	**0**
4	C2	0	0	56	0	21	36	**113**
5	V1	0	0	0	0	0	0	**0**
6	V2	0	0	0	0	0	0	**0**

In Table 8, there is only one university in Cambodia (C2) that has 2 laboratories for TVET level training, however, there is no dedicated equipment for SWM practice, and currently has to share a laboratory with the other field (with agriculture laboratory).

Table 8. NUMBER OF LABORATORIES AND EQUIPMENT AT TVET LEVEL ON TOPICS RELATED TO SWM

NO	UNIVERSITY	NUMBER OF LABORATORIES AND EQUIPMENT	STATUS
1	T1	n/a	n/a
2	T2	n/a	n/a
3	C1	n/a	n/a
4	C2	2	No equipment related to SWM
5	V1	n/a	n/a
6	V2	n/a	n/a

For all 6 universities belonging to 3 partner countries in Asia, the current problem is not only the lack of content and permanent schedule for the SWM-related training program but also the lack of equipment and facilities for the training process. This significantly affects the attractiveness of the

universities towards students that are interested in topics related to sustainable solid waste management, as a tool for sustainable development and environmental protection.

3.3 Currently offered training on Solid Waste Management at Informal Sector Level

There is no specific data about the education of informal sector in Cambodia. As experienced from informal interviews with some of their representatives, their education is quite low ranging from illiteracy up to primary schools only. Most of them are at the middle age up to elderly from 18 years old up to 55 years old and having family member of around 5 persons. Normally they have good experience in identifying various types of plastic waste, paper, metal and other types of recyclable waste, which has good market price; and they have good knowledge of the waste flow, markets and having good network in the informal sector. Moreover, they are good at waste clean-up and waste segregation either at the waste generating sources or at the landfill or at waste recycling facilities to take away the high value recyclable waste from its disposal effectively.

Figure 4. CLEANING AND SORTING OF RECYCLABLE WASTE AT JUNKSHOPS (LEFT) AND AT RECYCLING FACILITY (RIGHT)

In Thailand, waste scavengers lack of education and vocational skills as they mostly studied at lower than junior high school and they only make their living by collecting recyclable waste daily and facing various challenges in their work performance, limitation on know how skills. They are required to get training as well as the environmental education programs to be integrated in the formal sector in the country. In the case of Phitsanulok Municipality, the community-based solid waste management was introduced by promoting public participation in 3R and actively engaging the informal sector into SWM as the best case in Thailand.

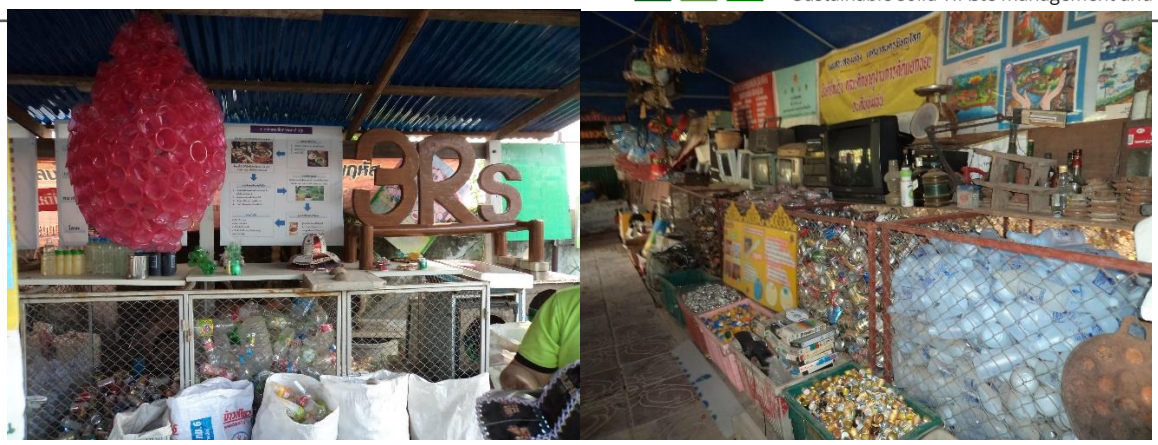


Figure 5. COMMUNITY-BASED SOLID WASTE MANAGEMENT IN PHITSANULOK MUNICIPALITY

In Viet Nam, recycling and reuse is an active industry, driven by an informal network of waste pickers at landfills, informal waste scavengers, and waste buyers [35]. The informal waste scavengers include Street Scavengers and Landfill/Transfer Station Scavengers, in which there are around 45 dumpsite/transfer station scavengers. Mostly they are female; and a hundred of them are scavenging in the cities. In their families, there are around one or two family members as waste scavengers and normally got the education up to Grade 12 and they are considered as unskilled labours and also employed in agricultural activities as well as in small businesses or as workers in local companies or manufacturing factories.

Figure 6. WORKING PERFORMANCE AT IRRC, QUY NHON (LEFT) AND AT INCINERATION STATION HANOI (RIGHT). COMPED IN 2014 (LEFT) AND IN 2019 (RIGHT)

4 Studies and papers on waste management

4.1.1 Cambodia

4.1.1.1 Introduction

Cambodia is facing challenges in its economic development over the last decade. Due to rapid economic and population expansion, rising income and consumption levels, and expanding

urbanization, the country has significant issue in solid waste management [28]. The population growth as a result of industrialization, as well as urbanization in response to the city's expansion, has resulted in a rapid increase in trash output in Phnom Penh. Each stage of waste management has its own set of challenges: collection, disposal, and recycling, and inefficiencies in the industry have already resulted in a slew of health and environmental issues, including increased air and water pollution. Up to now, the increase of municipal solid waste and other waste streams such as hazardous waste, industrial waste, medical waste, construction and demolition waste, and agriculture waste are also on the rise, posing significant challenges for the city in terms of proper waste collection, treatment, and disposal.

Recently, waste collection and management are becoming increasingly recognized as a major issue that the public should be dealt with, notably in Phnom Penh, Battambang, Siem Reap, and Sihanoukville. In 1999, the Royal Government of Cambodia decided to decentralize the operational task of waste management to the local management level, yet some local authorities are unknown their roles and responsibilities in terms of waste management [9]. As mentioned, private companies operated the waste collection and management and transport service in the major cities only. However, some towns at the provincial administration still do not have any waste management service at all, and also the financial resources or land available to invest in suitable landfill sites.

According to the report of EuroCham Cambodia [9], it said that there were five different sectors of managing waste including: 1) construction and demolition waste (C&D)- is an important pillar of Cambodian economic development and still undergo to grow drastically. The waste is collected, treated and disposed of by the informal sector. 2) industrial waste- rapidly increase due to the fact development of the industrial sector. For example, in Phnom Penh and Kandal province, the private company Sarom Trading-which was given a licence to operate by the Ministry of Environment in 2002. 3) hazardous waste- is generated increasingly along with the growth of the industrial sector as well as the consumption of goods that contain hazardous substances. This waste was applied by Sarom Trading only in Phnom Penh and Kandal Province where the service provided. There is no specific private companies or public institution recently operate to collect and transport general waste in the rest of the country. 4) medical waste-expands more and more that cause the amount of medical waste is increasing, especially in Phnom Penh where healthcare services are focused, and they are generated around 40 tonnes each month. And 5) E-wastes-the Cambodian consumer economy developed and had led to a key increase in e-waste, especially TVs, PCs, refrigerators, air conditioners and washing machines and so on as an informal network of waste picker plays an essential role in collecting recyclable material for e-waste.

4.1.1.2 Analysis of current solid waste management

a. Solid waste management

In general, there are three main types of solid waste in Cambodia: (1) domestic/household, (2) commercial and (3) industrial and hazardous including medical waste. In addition, they do not yet have specific data on these types of solids. It is recognized by the Ministry of Environment that hospital waste data, and information on waste for the whole country is based on estimates and is not up-to date. On the other hand, improper management of these wastes poses a risk to health, the environment and the loss of the national budget. According to the report [28], the average daily solid

waste in Cambodia will increase from 0.113 tons to 0.361 tons and in 2030 it will increase to 3,112 tons per day. The methane emissions from Cambodia's four major landfills currently represent about 360,000 tons of CO_2 emissions per year [19]. Waste management is not only associated with environmental and health issues but also with social, political, financial and governance issues. The Figure 7 showed the analysis of the current waste management and waste flow from generation until final disposal in Phnom Penh city. It also mentioned that the waste flow and gap analysis was carried out across the waste management chain with regards to institutions, policies, financing, infrastructure, technology and demarcation of roles and responsibilities among actors [28]. In Phnom Penh, average annual municipal solid waste alone grew from 0.136 million tonnes to 0.361 million tonnes Between 1995 and 2008, and estimates indicate by 2030 Phnom Penh could be producing 3,112 tons per day. The report emphasizes that current methane emissions from landfill sites across Cambodia's four major cities have been estimated to be as high as 360,000 tonnes CO_2 equivalent per year, making landfills one of the largest contributors to Cambodia's overall emissions [19].

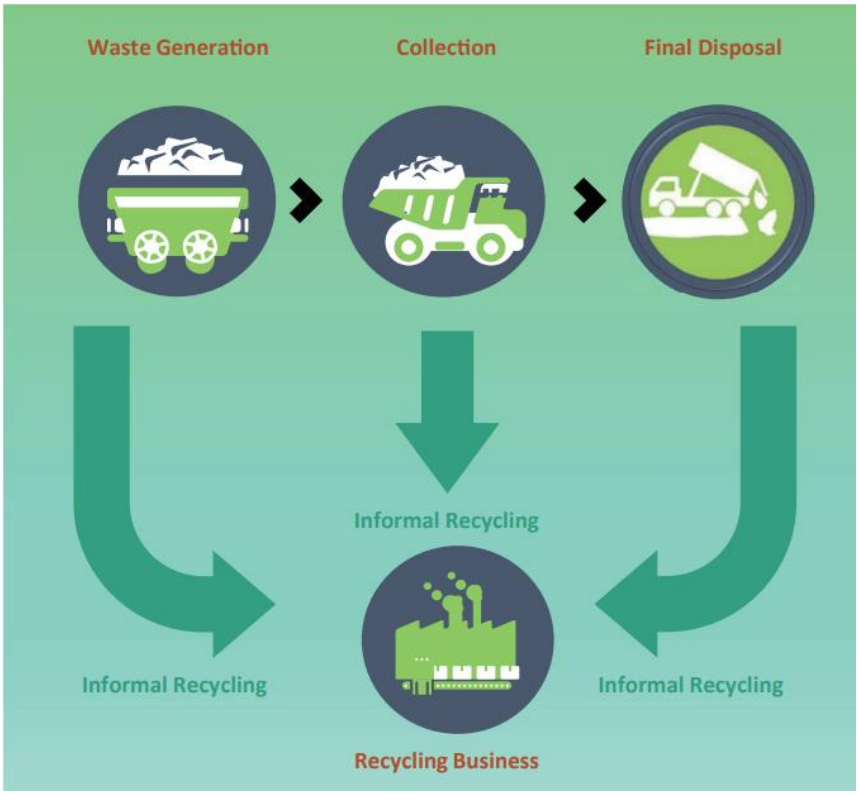


Figure 7. MUNICIPAL SOLID WASTE FLOW IN PHNOM PENH
Source: [28]

In Phnom Penh, Municipal Solid Waste (MSW) generated amounts to 4.09 million t/year, and per capita is 0.73 kg/day [9]. Three ways of treating including: landfill, recycling, and incineration. The majority of Cambodia's landfill sites are open dumps without any specific management system. Loudspeaker systems have been introduced by other municipalities and towns to inform households

about the environmental and health risks of dumping waste along the roadside; such as Kep, which is a coastal town, has installed billboards.

Recycle waste in Cambodia was lack of actual data of recycling and export of solid waste, only in Phnom Penh City is observed with recycling activities of limited. The organic waste from Daeum Kor Market was accepted by the local NGOs such CSARO and COMPED. The figure 8 presents the trend of such recyclable waste exported under the permission scheme of the Ministry of Environment [27].

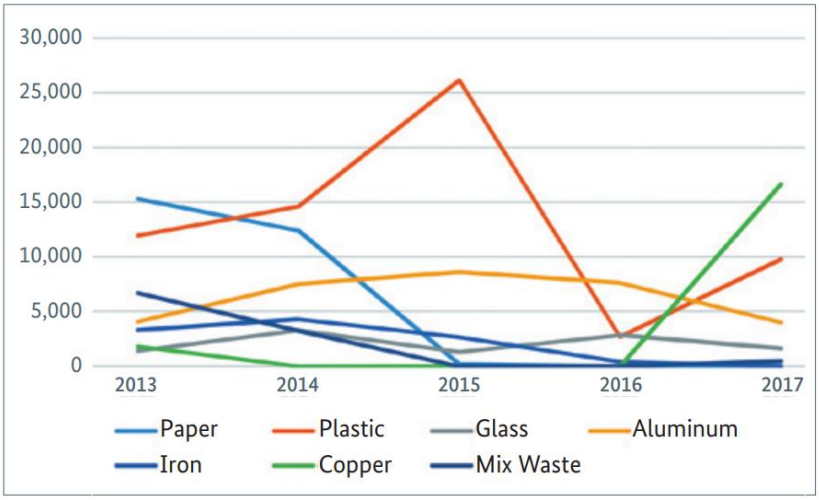


Figure 8. AMOUNT OF RECYCLABLE WASTE EXPORTED UNDER THE DUE PROCESS OF MOE (TONNES/YEAR)
Source: [16]

According to the Department of Planning [7], Phnom Penh, which is the capital and the largest city of Cambodia, generates around 4.09 million t/year of municipal solid waste, with the per-capita-per-day generation of households in Phnom Penh estimated to be 0.73 kg based on a population of 15.39 million in 2015. Due to the rapid population growth, the city has industrialization and urbanization together with expansion of city area has led to increase waste production in Phnom Penh since the beginning of last decade. The study conducted by Institute of Technology of Cambodia (Figure 9) estimated that the prospective trend of waste generation in Phnom Penh continued to grow until 2030, while the collection amount has a rising trend over the years (Figure 10). The Dangkor Landfill Authority of the Phnom Penh Capital Administration [26] indicated that the average daily amount of MSW taken to the Dangkor final landfill was 2,215 tonnes/day in 2017.

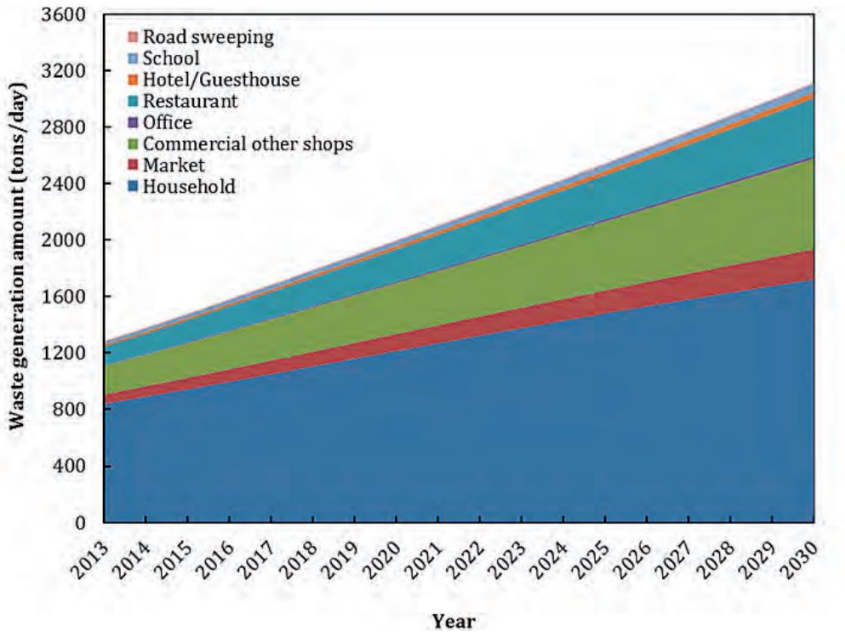


Figure 9. PROSPECT OF WASTE GENERATION GROWTH IN PHNOM PENH UNTIL 2030

Source:[31]

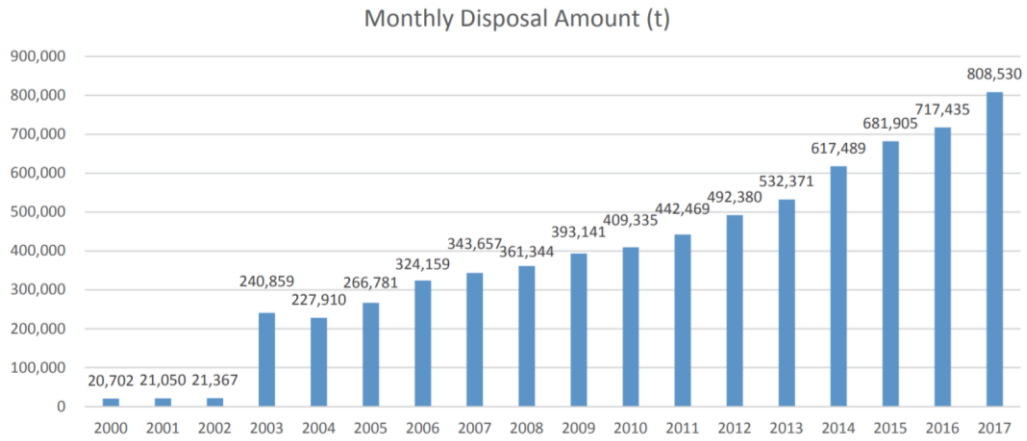


Figure 10. TREND OF MSW DISPOSAL AT LANDFILL, PHNOM PENH

Source: [24]

The Figure 11 presented the MSW collected and brought into the final disposal sites from 12 Khans across the city including household waste (55.3%), followed by hotels/guesthouses (16.7%), restaurants (13.8%) and markets (7.5%).

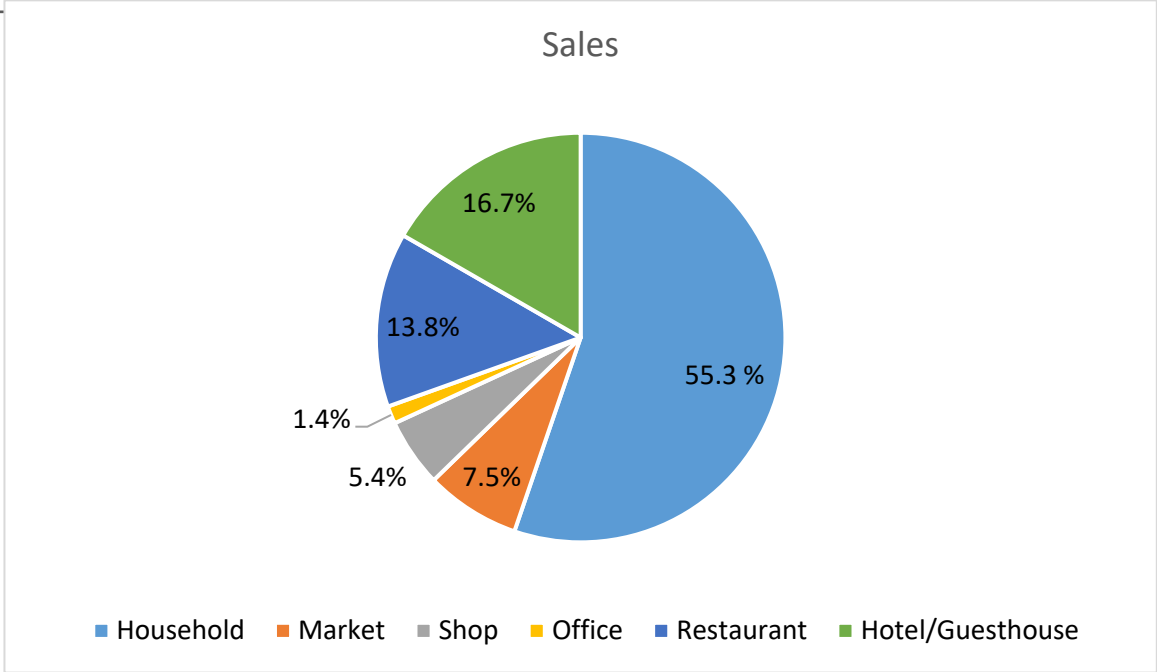


Figure 11. SOURCES OF MSW GENERATED IN PHNOM PENH
Source: [31]

c. Waste Composition

The composition of MSW sampled at the generation points in Phnom Penh (Figure 12) showed the largest over 50% of food/organic waste, followed by plastic and paper about 20.9% and 9.9% respectively.

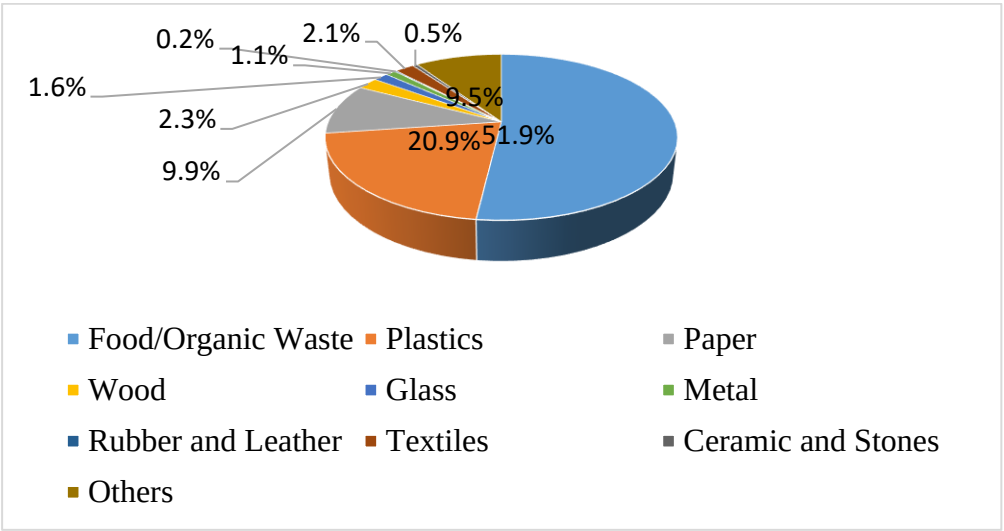


Figure 12. WASTE COMPOSITION AT GENERATION POINT IN PHNOM PENH
Source: [31]

Table 9: MUNICIPAL SOLID WASTE COMPOSITION IN FOUR PROVINCES IN CAMBODIA

COMPOSITION (%)	PHNOM PENH	BATTAMBANG	SIEM REAP	KAMPONG CHAM
FOOD WASTE	70	71	54	60
PAPER/CARDBOARD	5	2	6	5
WOOD/GLASS	6	6	11	3
PLASTIC	6	10	11	12
METAL	2	3	1	1
TEXTILE	3	2	3	1
GLASS	2	4	3	2
OTHER	6	2	11	16

Source: [6]

d. Collection and Transportation

The following private operator companies are responsible for collection and transportation of the waste generated in the city and has gradually expanded its geographical coverage over the years. The private sector plays a critical role in collection and transport of solid waste, and they have two major operational divisions: Cleaning Operation and Collection and Transport Operation [28].

Table 10: TRANSITION OF MSWM SERVICE PROVIDERS IN PHNOM PENH CAPITAL HALL

DPWT 1994	Department of Public Work and Transport (DPWT) of Municipality of Phnom Penh (MPP) operated directly until 1994.
PAD 1994-1995	Pacific Asia Development (PAF), with a 50-year contract from France. The contractual agreement was cancelled by July 1995.
Direct operation by districts 1995-1996	The solid waste collection service was taken over by individual districts on their own until January 1996.
PPC 1996-1996	A Cambodian company is Phnom Penh Cleansing (PPC), took over solid waste collection service on a temporary basis until December 1996.
ENV 1996-1997	ENV, with a 50-year franchise agreement, is a company from the former East Germany. Due to the war erupted in July 1997, ENV decided to leave Cambodia.
PSBK 1997-2002	PSKB Ltd continued the service for waste collection and dumpsite with sub-contractor after ENV. Then, a 50-year franchise agreement was made between MPP and PSBK as a waste collection service provider in January 1998,
CAP 2001-2001	The Cleansing Authority of Phnom Penh (CAP) was established in 2001, to collect the peri-urban area, covering about 1% of the total population of MPP, as well as dump-site management.
PPWM 2001-2009	The Phnom Penh Waste Management Authority (PPWM) was established in 2001 to oversee SWM in the city as well as manage landfill. The PPWM is under the control of DPWT and MPP
Waste management division	Phnom Penh Waste Management Division of Phnom Penh Capital

2009-present	Mall operated from 2009 to the present, PPWM was disappeared while the landfill has been moving to new site in Dangkor district.
CINTRI 2002-Present	PSBK sold contractual right to CINTRI (Cambodia) Ltd in 2002. At the same time, CINTRI and MPP signed a new 50-year contract to provide waste collection service in Phnom Penh.
GAEA Plc. 2007-Present	Global Action for Environment Awareness (GAEA) Plc. performs Municipal Solid Waste (MSW) collection and disposal as well as cleaning services in 4 provinces: Siem Reap, Kampong Thom, Bantay Meanchey and Kampot province.

Source: [28]

CINTRI Cambodia Co., Ltd, a private operator company, is currently responsible for collection and transportation of the waste in the city over the years. Nevertheless, the service is still limited with unsatisfied technical standard. Due to the delayed collection and unsanitary collection practices, the company was complained among others [24]. Recently, on 30 June 2021, Phnom Penh Capital Administration declared on initiative practise cleaning service, collection, and transport of solid waste in municipality by new operators as described in table 11.

Table 11: WASTE OPERATORS UPDATE IN PHNOM PENH MUNICIPALITY

ZONE	COMPANY	DISTRICT/KHAN
I	800 Super/Global Action for Environment Awareness Public Limited	Toul Kork, Russey Keo, Sen Sok, Chroy Changvar and Prek Pnov
II	Mizuda Group Co, Ltd	Doun Penh, 7 Makara, Dangkor, Pursenchey and Kambol
III	CINTRI (Cambodia)/Everbright (China)	Chamkar Morn, Boeng Keng Korng, Meanchey and Chbar Ampov

Source: [25]

4.1.1.3 Industrial and other waste

a. Industrial waste

The current waste management system for industrial solid waste in Phnom Penh has been divided into Hazardous Solid Waste, Medical Solid Waste, Construction, and Demolition Solid Waste. According to the Royal Government of Cambodia [30], the factories or enterprises of industrial solid waste do not contain toxic substances or hazardous waste to the solid waste remaining or generated from production activities. The Ministry of Environment of Cambodia (2002) reported, industrial waste, hazardous waste, and medical waste is also disposed to Sarom Industrial Landfill, such as the waste of semi-dry muddy which removed from treatment pools, waste of coloured fibbers and pieces of fabrics, waste of plastic which containing Polyvinyl Chloride, waste of rubber and vulcanized rubber which containing Polymer-Butilin, waste of batteries, waste of medical which leftover ashes after burning, waste of electronic, waste of lacquer paint and packaged materials, waste of Agriculture insecticide and package material, waste from production and utilization of printing ink, waste of expired of sub-standard goods and medical products, and the waste of containing the asbestos substance.

b. Medical Waste

According to the Declaration of Waste management from the Health Care Service in Cambodia, the public and private hospitals, health centers, clinics, and medical laboratories are the key resource of medical waste [9]. There are two types of medical waste: Firstly, general waste including office residues, kitchen waste, etc., Secondly, health care waste such as infectious waste (flesh, bandage, blood, etc.), sharps waste, pharmaceutical waste, chemical waste, radioactive waste, etc [17] .

Based on data in 2011 of Department of Hospitals Service (Project Coordination Unit, 2014), 8 national hospitals in Phnom Penh City, 24 provincial referral hospitals, 64 district referral hospitals, and 1097 health centers, as well as 87 health post location throughout the country, was generated medical waste 40t/month in Phnom Penh included waste of infectious, pathological, sharps (i.e. knives and syringes) and pharmaceutical [5]. The data from medical services show the quantity of medical waste increasing (Figure 13).

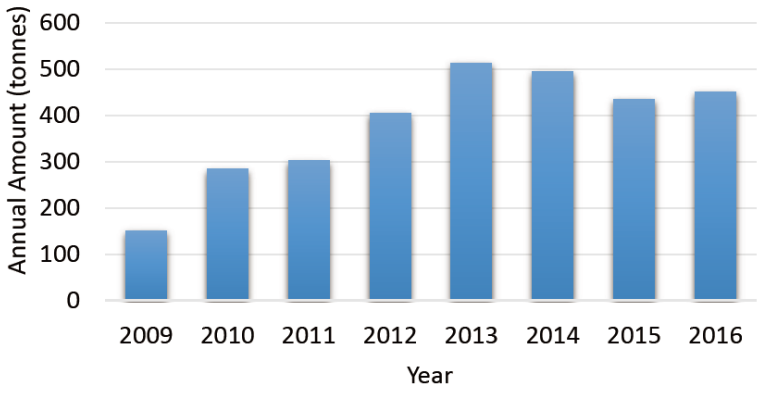


Figure 13. AMOUNT OF COLLECTED ANNUAL MEDICAL WASTE
Source: [5]

The four most common categories of HCW including waste of infectious, pathological, sharps and pharmaceuticals is produced in National hospital in Phnom Penh (Table 12). The highest amount medical waste is infectious waste about 33Kg/day.

Table 12: AVERAGE AMOUNT OF HEALTH CARE WASTE GENERATED FROM NATIONAL HOSPITALS IN PHNOM PENH

Health care facilities	INFECTIOUS WASTE		PATHOLOGICAL WASTE		SHARPS	PHARMACEUTICAL WASTE	
	kg/day	l/day	kg/day	l/day	Box/day	kg/day	l/day
National hospitals	33.22	1.85	14.83	1.46	12.43	20	0.1

Source: Department of Hospital Services, 2006

c. Hazardous Waste

According to the declaration of the Royal Government of Cambodia 2015, hazardous waste includes any substances which are radioactive, inflammable, infected, oxidation, toxic, or another chemical. The hazardous solid waste has been classified by sub-decree No.113, which is generated

from households, public institutions, commercial facilities, industrial and tourism sectors. Cambodia is imported many types of second-hand EEE from various countries such as monitors, printers, keyboards, CPUs, typewrites, projectors, mobile phones, PVC wires, etc. Singapore is one of the destination counties that imported e-waste from Cambodia in approximately amount 3,513 T in 2013 and 5,588 T in 2014 [17]. Observation of E-waste in Phnom Penh is rapidly increased (Table 13).

Table 13: PROJECTED E-WASTE FRACTION (METRIC TONS)

E-waste items	2009			2019		
	Reusable	Recyclable	Residues	Reusable	Recyclable	Residues
TV	980.54	792.05	131.37	5,517.54	4,456.88	739.24
PC	1,706.69	964.62	59.39	2,247.85	1,270.48	78.23
MP	26.17	14.22	2.69	90.38	49.09	9.30
Refrigerator	548.70	387.79	62.97	1,716.15	1,212.87	196.94
Air conditioner	490.83	377.56	19.99	1,908.53	1,468.10	77.72
Washing Machine	525.39	175.13	175.13	842.30	280.77	280.77

Source: [16]

d. Construction and Demolition (C&D) Waste

The most common Construction and Demolition(C&D) waste includes paper/cardboard, garden/vegetation, wood/timber, carpets, other textiles, rubber, glass, plastics, metals, hazardous waste, ceramics, soil/rubble, cobbles/boulders, clean soil, concrete, plasterboards, bricks, asphalt/bitumen, cement sheet, insulation and others [37]. The Official National data of C&D waste generated hasn't been verified yet and generally, the waste generation is estimated based on the types of property (single family residential, multifamily residential, commercial and non-residential) with footage based on the available data. Accordingly, United Nations for Environment Programme (UNEP)'s report in 2009, which conducted on composition assessment of C&D waste with sampling at several sites in Phnom Penh, and roughly estimated amount of waste composition is about 60% of broken brick, rock, left-over cement, and soil; 20% of wood; 10%of metal; 5% plastic; 5% paper and other waste.

Regarding the major challenge of collection and disposal of C&D waste, Sub-decree No.113 [30] stipulates the responsibility of generators of C&D waste and contractors for proper waste management as bellow:

- Properly dispose or store C&D waste to avoid impacts on the public order and environment
- Use the service of the local urban waste collection company or own means to urban municipal landfill to clean, collect and transport C&D waste.
- The C&D waste also allows to be brought into public landfill sites for final disposal.

4.1.1.4 Legal and Policy Framework

a. Municipal Solid Waste

City of Phnom Penh is the Phnom Penh (PPCA) that has visualized the city to become a competitive political, economic, business and cultural center of Cambodia with sustainable and

equitable development. A major societal issue for Phnom Penh is waste management. Over the last decade, the monthly amount of disposed waste increased doubled time at the landfill [27]. PPCA has been working hard to organize waste management system in the city, dealing with a hush increase of challenged tasks. Regarding the municipal solid waste, there are various laws, regulations, declarations, sub-decrees and instructions have been issued by both national agencies as well as PPCA, includes:

National Regulations

- Sub-Decree on Solid Waste Management, No. 36 (1999).
- Inter-Ministerial Declaration of Ministry of Interior-Ministry of Environment on Waste and Solid Waste Management in Province / Municipalities of Cambodia, No. 80 (2003).
- Sub -Decree on Urban Solid Waste Management, No. 113 (2015).
- Waste Management Strategy and Action Plan of Cambodia (planned).

Sub-national Regulations

- Draft Strategy and Methodology for Improving Waste Management and Cleansing,
- Collection and Transport of Solid Waste in Phnom Penh Capital.
- Sechkdey Chun Damnoeng (Notification) On Waste Storage, Cleansing, Waste Discharge and Penalties on Improper Waste Disposal in Phnom Penh Municipality, No. 13 (2013).
- Instruction Plan on the Application of Penalties to Promote Environmental Sanitation Raising in Phnom Penh Municipality, No. 09 (2010).
- Sechkdey Nainoam (Instruction) on Penalties on Waste Disposal in Public Areas, No. 16 (2010).
- Instruction Plan on Waste Separation Promotion in Phnom Penh Municipality, No. 08 (2010).
- Waste Storage, Cleansing, Waste Discharge and Penalties on Improper Waste Disposal in Phnom Penh Municipality (2013).

b. Construction and Demolition (C&D) Waste

Currently, no laws or policies have been issue targeting specifically C&D waste.

c. Medical Waste

The Ministry of Health and its sub-national representatives play main roles in the management of medical waste on the three national regulations below:

- Prakas on Health Care Waste Management (2008).
- Decision on creation of MWMU, No. 96 of Red Cross Cambodia (2009).
- National Guideline on Health Care Waste Management (2012).

d. Industrial Waste

The following hazardous solid waste generated from various sources, such as from households, public institutions, commercial facilities and tourism facilities is classified and regulated by the annex of Sub-Decree No. 113 as follows:

National Regulations

- Guideline on Solid Waste Management at factories, enterprises and companies, No. 11 (2003).
- Guideline on Sludge Waste Management at Factories – Enterprises (2000).
- Guideline on Manufacturing Hazardous Waste Management, No. 87 (2000).

Municipal Regulations adopted by Phnom Penh City

- Declaration on Industrial Solid Waste Collection and Transport in Phnom Penh and Kandal, No. 148 (2002).

- Declaration on the permitting Sarom Trading to collect and transport industrial wastes from Phnom Penh and Kankal province, No. 156 (2001).

e. Hazardous Waste

There are two regulations for the management of hazardous waste in general, while specific regulations were enacted for medical waste and E-Waste.

- Sub-Decree No 446 on the organisation and function of the Department of Hazardous Substance Management (2015).
- Declaration No 387 on the enforcement of standard levels of amounts of toxic or hazardous substance that can be abandoned (2015).

f. E-Waste

The Ministry of Environment (MoE) 2016 issued a new Sub-Degree to regulate companies that purchase, dismantle and dispose of E-Waste.

- Sub-decree on E-Waste and Electronic Equipment (2016).

4.1.1.5 Positioning of Waste Management Strategy and Action Plan

a. Alignment with National and Subnational Policies

The figure 14 presents the strategy is developed based on the needs and priorities of the current waste management of Phnom Penh Capital Administration, and it integrated into part of the city's development policies, which have been made public in the form of plans and strategies on both sector-specific and cross-cutting issues.

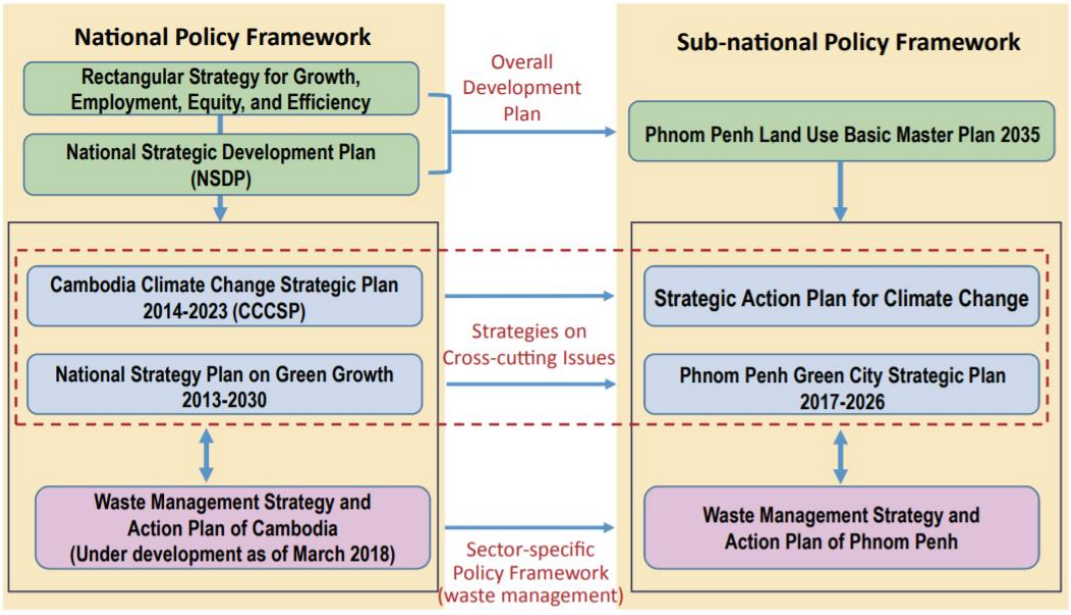


Figure 14: POSITIONING OF THE WASTE MANAGEMENT STRATEGY AND ACTION PLAN OF PHNOM PENH

Source : [27]

Subnational Policy Framework

Phnom Penh Master Plan on Land Use 2035

The Master Plan 2035 aims to address the rapidly growing population of the city, which is expected to exceed three million by 2020, while providing a vision for the city to become "a competitive

political, economic, business and cultural centre of Cambodia with sustainable and equitable development" by 2035.

Phnom Penh Capital City Strategic Action Plan for Climate Change

The Strategic Action Plan was published in July 2017 between Phnom Penh Capital City and its sister city Kitakyushu City (Japan) on various environmental issues, and is expected to contribute in "Cambodia Climate Change Strategic Plan 2014-2023" established in November 2013 by the Royal Government of Cambodia (RGC). The policy direction is in six fields – waste, energy, transportation, waterworks/sewerage/rainwater drainage, environmental conservation, and green production, to address climate-induced environmental challenges of PPCC.

Phnom Penh Green City Strategic Action Plan 2017-2026

The Green City Strategic Action Plan for Phnom Penh is the result of collaborative efforts by PPCA, National Council for Sustainable Development (NCSD) and Global Growth Institute (GGGI), and provides key policy directions for eight components of Green Growth city planning – urban planning, urban vulnerability, energy, transport, built environment, manufacturing, solid waste management, and public spaces and cultural heritage. The strategy complements Phnom Penh's Master Plan on Land Use 2035 which envisions the city to transform itself as a "competitive political, economic, business and cultural center of Cambodia with sustainable and equitable development".

National Policy Framework

Waste Management Strategy and Action Plan of Cambodia

A project of development a national waste management strategy and action plan, launched in 2018, a national policy framework for accelerating waste management implementation in the country was initiated by the Cambodian environment ministry with support from UN Environment and IGES Center with UNEP on Environment Technologies (CCET) in 2016.

Cambodian Climate Change Strategic Plan (CCCSP) 2014-2023

The key challenges were highlighted in the Strategy and promote low carbon planning and technologies to support sustainable development will meet Strategic Objective 1, "Promote climate resilience through improving food, water and energy security" of the CCCSP 2014-2023. The emission reduction analysis and mitigation potential of proposed interventions in the Strategy will meet Strategic Objective 4, "Promote low-carbon planning and technologies to support sustainable development by providing sectoral analysis on low emission options and sources of emissions in waste management.

b. Alignment with Sustainable Development Goals

This strategy and action plan improved and will result in many co-benefits extending to various goals and targets pointed out by the Sustainable Development Goals (SDGs) and Global Waste Management Goals.

4.1.1.6 Financial Solid Waste Management

There were some challenges of SWM system for managing solid waste in over the last several decades. The country is lack of detailed regulation, standards and guideline for the implementation, capacity of personnel is limited, and the constrains of budget of the public and private sector in Cambodia are addressing aps in waste management. In addition to this, the majority of waste

collection companies have negotiated with the national and sub-national authorities on the service based on profit margin calculation with regard to waste fee collection [28]. Funding for waste management is received from user fees, including type of residence numbers of floors, and waste sources from business activities, supermarkets, apartments, clinics, schools, and universities. Also, private companies contracted to provide waste management service to collect residential waste without any subsidies or financial support from government.

a. Public financing

The national budget through projects implemented to build capacity in the waste sector in the country; similarly, some development partners and NGOs have provided technical assistance to RGC, Phnom Penh Capital Administration and relevant local stakeholders aimed at improving Phnom Penh's waste management system.

Cambodia's Ministry of Environment issued a Circular Decree on the Implementation of Environmental and Hygiene Service Programme in 2015, which was at improving solid waste and wastewater management for a total of 26 cities across the country other than Phnom Penh municipalities. The national budget is the Ministry of Economy and Finance (MEF), the overall funding of this programme is 5,000 million Riels (USD1.25 million) for 2015, which is to increase to 9,000 million Riels (USD 2.25 million) in 2016.

b. Other Revenues

Figure 15 below based on Top Management Seminar on Decentralisation and leadership Towards Local Needs and Changing Society Kamiko [13] illustrated that in 2013 the streams and the average scale of the intergovernmental transfer from the national to sub-national governments. In reality, sub-national level are almost entirely dependent upon such revenues from national levels whose limited budgetary scale with limited public service delivery. Consequently, waste management from the public financing is limited in scale to operate in Phnom Penh City.

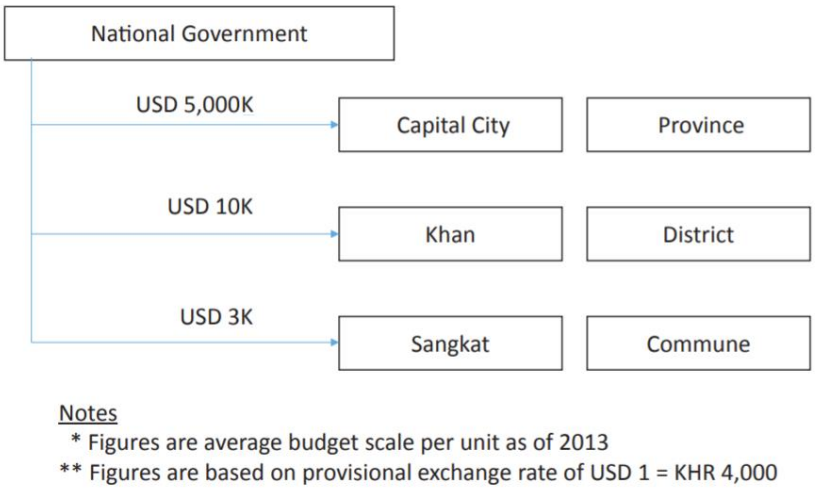


Figure 15. FLOW OF INTERGOVERNMENTAL TRANSFER FROM NATIONAL TO SUB-NATIONAL ADMINISTRATIONS
Source: [13]

Additionally, the PPCA operated and managed the financial viability of the Dangkor landfill site that is another issue of concern. Currently, the site charges a disposal fee of USD 0.75 for every tonne of

waste. A recent report conducted by JICA (2005) provided an analysis of the landfill and managed its sanitary status to a satisfactory level would require increasing the disposal fee to USD 4.4/t with additional grant assistance, or USD 5.92/t without grant assistance [12]. In contrast, CINTRI has suspended the payment of disposal fee since January 2018 due to insufficient fund. This non-payment continues as of July 2018 despite repeated request by PPCA for payment.

- ASIA-PRO-ECO-Program was the EU-Funded project was also designed to build the capacity of waste management sectors in Cambodia including MOE, MoH, Phnom Penh Waste Management Authority (PPWM), CINTRI, as well as to develop technical guidelines on solid waste management in close cooperation with concerned ministries.
- The Asia Foundation supported a pilot project in 2014 was conducted in the district of Khan DaunPenh in collaboration with CINTRI and PPCH.
- The Government of Japan through JICA started in 1997, provided servant grants to the RGC aimed at improving solid waste management in Cambodia, such as: i) JICA study on Solid Waste Management in the Municipality of Phnom Penh (2003-2005); ii) JICA project on solid waste management improvement for the municipality of Phnom Penh including capacity building and infrastructure development (October 2006 – March 2008).

4.1.1.7 Major Waste Management Challenges

Some of the key challenges in waste management sector are stated below:

- Most residents have limited knowledge to understand about correct waste and sanitation methods, and improper waste disposal practices.

- The data on solid waste management in Phnom Penh, such as illegal dumping, total recycled waste volumes, number of recyclers, and recycling operations, are still limited.

- The issue of regulations on waste management that have yet to be prioritized and local competent authorities are often unclear on what should be enforced in place of the central government.

- In Phnom Penh and nearby provinces as well as other areas are mainly industrial factories clustered.

- The estimations data of waste volumes are only available in solid waste collection rates measured in cubic meters, most of which is garment/ textile waste.

- Many industries have a limited awareness to manage and store their waste such as integration of industrial waste and general waste.

- There is a still limitation of clear responsibilities at both national and sub-national levels, and also the improvement of monitoring and inspecting capacities competent officers with understanding technical aspect of concerning industrial waste management are low.

- The management of hazardous waste in Phnom Penh of public participation of relevant stakeholders is still limited, especially in terms of consumer awareness.

- Regulatory measures, technical guidelines, methods, and budget for implementation of hazardous waste management also still have limited.

- Lack of information/data, expertise, and expertise on the proper management of e-waste, including laws relating to the establishment of relevant legal sources on the import of EEE / UEEE products

- Regard importation of e-waste such as electronics equipment/ devices/instruments, Cambodia still lacks requisite technology for testing or examining safety issue.

- Limited awareness/knowledge regarding unintentionally generated POPs

- The Medical Waste Management Unit (MWMU) collected medical waste mixed with urban waste which most health care service disposal.

- High investment capital needs to be cooperated in managing medical waste, Including operation and maintenance cost.

- The data/information of volume of generated C&D waste and its composition is insufficient.

- There are no legal instruments or guidelines focused on the management of C&D waste.

- Lack of technical and financial support for case study/survey to make data sheet/information related to home compliance such as fluorescent lamp, up-date ULAB.

- Hazardous waste from chemicals waste/waste containing toxic substances (Industrial, Consumer's product, Agriculture sector…).

- Lack of the facility for treatment, recycling and disposal of Hazardous waste.

4.1.2 Thailand

4.1.2.1 Introduction (adapted from [4])

Thailand, one of the developing countries in Southeast Asia with a current population of 66.19 million (in the year 2020), has increasingly witnessed solid waste management and disposal problems. The country's municipal solid waste (MSW) generation showed a growing trend parallel to economic condition, urbanization, and rapid growth of population (Visvanathan et al. 2004). As a result, vast amounts of waste are generated daily; and management is a challenging task. This task encompasses various strategies, such as recycling and reusing, efficient waste collection and disposal system, enhancing financial capability, and effective government, public, and private sectors participation.

MSW, as described by the Regulation and Guideline for Solid Waste Management by the Pollution Control Department, refers to any solid waste generated from community activities. The waste-generating locations include household residences, commercial and business establishments, fresh markets, institutional facilities, construction and demolition sites, excluding hazardous and infectious wastes. The waste compositions in Thailand do not differ much from other developing countries in Asia. It is composed of a large proportion of organic materials, followed by plastic and paper. Recycling of potential resource materials from the MSW stream is actively performed by informal sectors, which helps reduce the burden of waste disposal. MSW collection and disposal in most

regions in Thailand, especially in Bangkok metropolises, has exhibited substantial improvements compared to other areas in Thailand. However, more efforts still need to be undertaken. For years, MSW has been commonly disposed of in open dumpsites which lack any precautionary environmental and health measures. Reducing negative environmental impacts, sanitary landfilling, is encouraged and gradually replacing open dumping. This report aims to review the solid waste management situation in Thailand. Information has been gathered from different sources to cover essential aspects of solid waste management and possible up-to-date data.

4.1.2.2 Municipal Solid Waste generation in Thailand

In year 2020, the Pollution Control Department of Thailand [23] reported that, total amounts of municipal solid waste (MSW) generated in Thailand was approximately 27.35 million tons. This figure is about 4% less than those generated in the year 2019. Amounts of solid waste that were segregated at the source for utilisation was 11.93 million tons (14% increased from that in year 2019). Of all solid waste generated, 4.23 million tons were unsanitarily disposed (34% less than that in year 2019). Spreading of COVID-19 partly contributed to reduction of solid waste in year 2020 as travel of tourists was firmly restricted. However, using of the single-use-plastic was found to be increased by the increase of online food delivery. In all 76 provinces outside Bangkok, the average solid waste generation before the spread of COVID-19 (Oct.2019-Mar.2020) was 68,000 tons/d while the figure was decreased to 63,000 tons/d in Apr.2020 during the work-from-home period. Amounts of solid waste were decreased further to 58,000 tons/d during the second wave spreading of COVID-19 during Dec.2020-Jan.2021. In Bangkok, 9,940 tons of MSW were collected per day in year 2014. In this year the average amount of MSW was 3,628,100 tons/year. In regard to the population this could be calculated as 438 kg per capita-year [3].

Up to 15% increase of plastic wastes was detected during the pandemic when 6,300 tons/d of plastic waste were recorded (the normal figure of plastic waste was approximately 5,500 tons/d). Since the 1st of January 2020, the campaign “Everyday Say No to Plastic Bags” has been launched. Plastic bags have been banned by more than 90 of department stores, super markets and convenience stores. Moreover, the MOU has been signed between the Ministry of Natural Resource and Environment and some delivery companies, e.g., Grab Food, Line Man, Wongnai, Gojek, Food Panda, Lalamove, to decrease amounts of the single-use-plastic in the food delivery activities on the 30th Sep 2020.

In the year 2020, 658,651 tons of household hazardous wastes were generated which was 1.6% increased from those in year 2019. Most of these household hazardous wastes were electrical and electronic appliances (428,113 tons or 65% of all hazardous wastes). The rest of the household hazardous wastes were batteries, chemical containers, spray bottles, etc. (230,538 tons or 35% of all hazardous wastes). Thanks to supports from the government for the local administration to set up the system for household hazardous waste management, the collecting points in the community and province have been located. This afford has led to 121,695 tons or 18.5% of household hazardous waste being properly managed. The figure was much higher for the infectious wastes, in which 98.91% (47,440 tons) were reported to be properly managed even during the time of pandemic.

4.1.2.3 **Municipal** Solid Waste characteristic and composition in Thailand (adapted partly from [24])

In most Asian countries, the solid waste is generally biodegradable as it comprises organic fraction with high moisture content. Food waste, plastic/foam, paper, rubber/leather, wood/grass, metal, glass, and textiles are the common Municipal Solid Waste (MSW) components [4]. The average moisture content of MSW in Thailand is approximately 55% on a wet mass basis. However, it reaches up to 70% in some areas such as those in Samutprakarn and Pattaya provinces. The physical composition of MSW varies depending on consumer patterns, lifestyle, and economic status. From selected municipalities in Thailand and Bangkok areas during 2003, it was shown that MSW primarily contained food waste (41–58%), followed by paper (4–25%) and plastics (3.6–28%).

This study characterized solid waste composition at the transfer station. The corresponding generation rates in the municipalities presented in Table 14 are also included. Bangkok's per capita generation rate (1.5 kg/capita/day) was significantly higher than that in other municipalities in Nonthaburi and Angthong (0.6 kg/capita/day). Such a high amount is definitely due to the high influx of commercial activities in Bangkok. Furthermore, tourist areas in Thailand, such as Patong Beach (Phuket), exhibited the highest waste generation rate of around 5 kg/capita/day. MSW physical composition collected from Bangkok and selected provinces in Thailand and their per capita generation rates are shown in below [4].

Table 14. VOLUME OF SW GENERATION AND WASTE COMPOSITION IN SOME CITIES IN THAILAND (MODIFIED FROM [24])

Location	Generation rate (kg/capita/day)	Waste composition (%)			
		Food waste	Paper	Plastic	Others
Bangkok	1.5	43	12.1	10.9	34
Angthong	0.6	42	13.5	12.4	32.1
Chiangmai	-	54	11.0	15.1	19.9
Chiangrai	1.1	45	10.0	12.0	33
Kanchanaburi	0.9	50	17.7	19.7	12.6
Nakornratchasima	1.2	44	20.1	21.0	14.9
Nakornsawan	0.6	53	13.2	13.7	20.1
Nonthaburi	0.6	52	6.8	28.4	12.8
Pattaya	1.0	41	25.0	17.6	16.4
Petehburi	0.9	55	11.3	19.3	14.4
Phitsanulok	0.9	58	5.0	26.2	10.8
Note: (-) Lack of statistics data					

Study of MSW composition in the Highland Rural Tourist Area in Thailand [33] showed similar pattern, in which organic wastes were accounted for the most composition (42.79%), while 26.53% were recycle waste (Figure 16). The general waste was found to be 29.19% and plastic bags were the main components (63.2%).

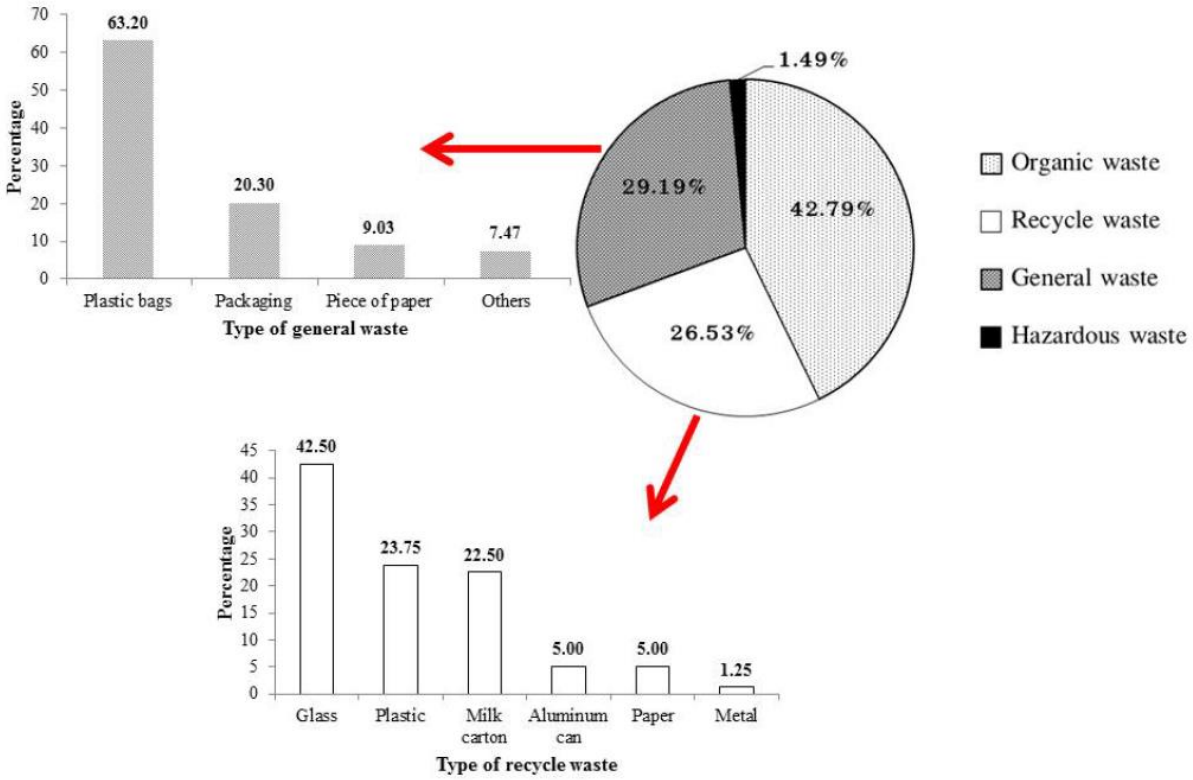


Figure 16. WASTE COMPOSITION OF MAE SALONG NOK SUB-DISTRICT, THAILAND (SUMA ET AL. 2019)

4.1.2.4 MSW disposal and management in Thailand (adapted partly from [24])

Generally, MSW disposal requires adequate environmental control from waste collection to disposal and regular monitoring of landfills. Thailand's current solid waste management strategy centers on bulk collection and mass disposal. Adequate waste transportation and collection through the applications of transfer stations is not widely practiced. Nevertheless, Bangkok holds three operational transfer stations, including the On-Nuch, Nong Khaem, and Tha Raeng stations, with solid waste capacities of 3,500, 2,800, and 2,300 tons/day, respectively. The Public Cleansing Department (PCD) in BMA is responsible for collecting solid waste in Bangkok. BMA operates the most extensive single solid waste management system in Thailand, collecting and transporting municipal refuse from responsible areas. It employs private transporters to haul the wastes from the transfer stations using 20- to 30-ton trailers for final disposal at the designated disposal sites. Collectively, Thailand's goods and services for MSW management costs approximately $41 million a year. Although waste collection services have been improved in Bangkok and Muang municipalities (large municipalities), it is not fully delivered in Tambon areas or smaller towns. Before the 1990s, most of the waste collected from Thailand's urban areas was dumped in open areas. During the past decades, though,

there has been a gradual improvement in waste disposal practice from open dumping to sanitary landfilling.

Nonetheless, until recent years, over 60% of the MSW disposal system has been carried out by open dumping (Figure 17). Unfortunately, it has remained a common practice due to inadequate funding, poor planning, and lack of technical knowledge and expertise. While the landfills in Bangkok take approximately 4,500 tons/day, the majority of disposal sites take approximately 25 tons/day of MSW on average.

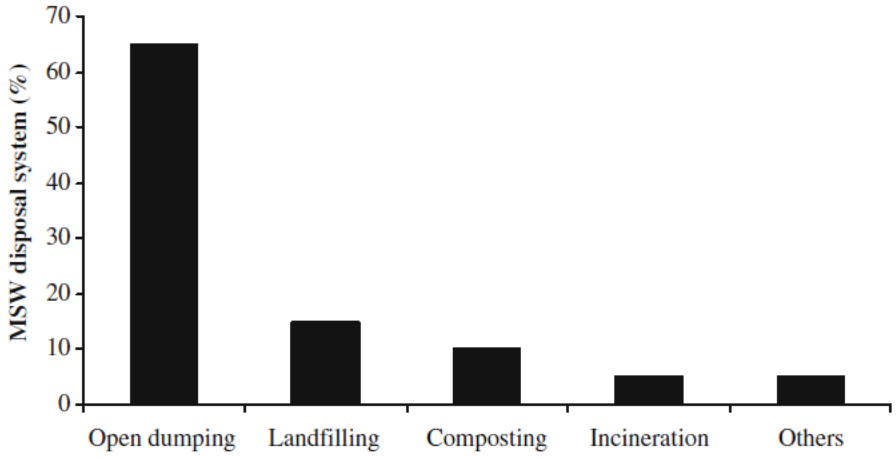


Figure 17. MSW DISPOSAL IN THAILAND (CHIEMCHAISRI, JUANGA, AND VISVANATHAN 2007)

Currently, in some provinces, e.g., Chiang Mai, Nakhon Pathom, there have been uses of the MSW-to-energy landfill in order to sanitarily dispose of MSM and extract energy from landfills in the form of biogas. In Chiang Mai, approximately 600 tons/d of MSW collected from Chiang Mai Municipality (300 tons/d) and local government organization of 4 districts (250-300 tons/d) have been landfilled at Bantan MSW Disposal Centre, Hod District, Chiang Mai which is owned by THANET construction Ltd. The total area of the landfill is around 320 ha, comprising the already closed landfill (24 ha), the under operating landfill (8 ha) and office buildings, power plant and leachate treatment system (20 ha). The rest of the area is available for further landfilling. This landfill has started receiving MSW since year 1997. The construction and operation of Bantan MSW Disposal Centre are conducted according to the sanitary landfill concept with the system to collect the leachate for treatment and biogas generating inside the landfill for generating electricity. Each facility is located so that the environmental effects on the nearby communities can be minimized. The activity of the company starts from transferring MSW at its two transfer stations. The collected MSW is transported by the trucks covering the distance of 115 km. (2-3 hr.) to the landfill site in Hod District. Figure 18 shows the current activities and future plans for utilizing the site of the company.

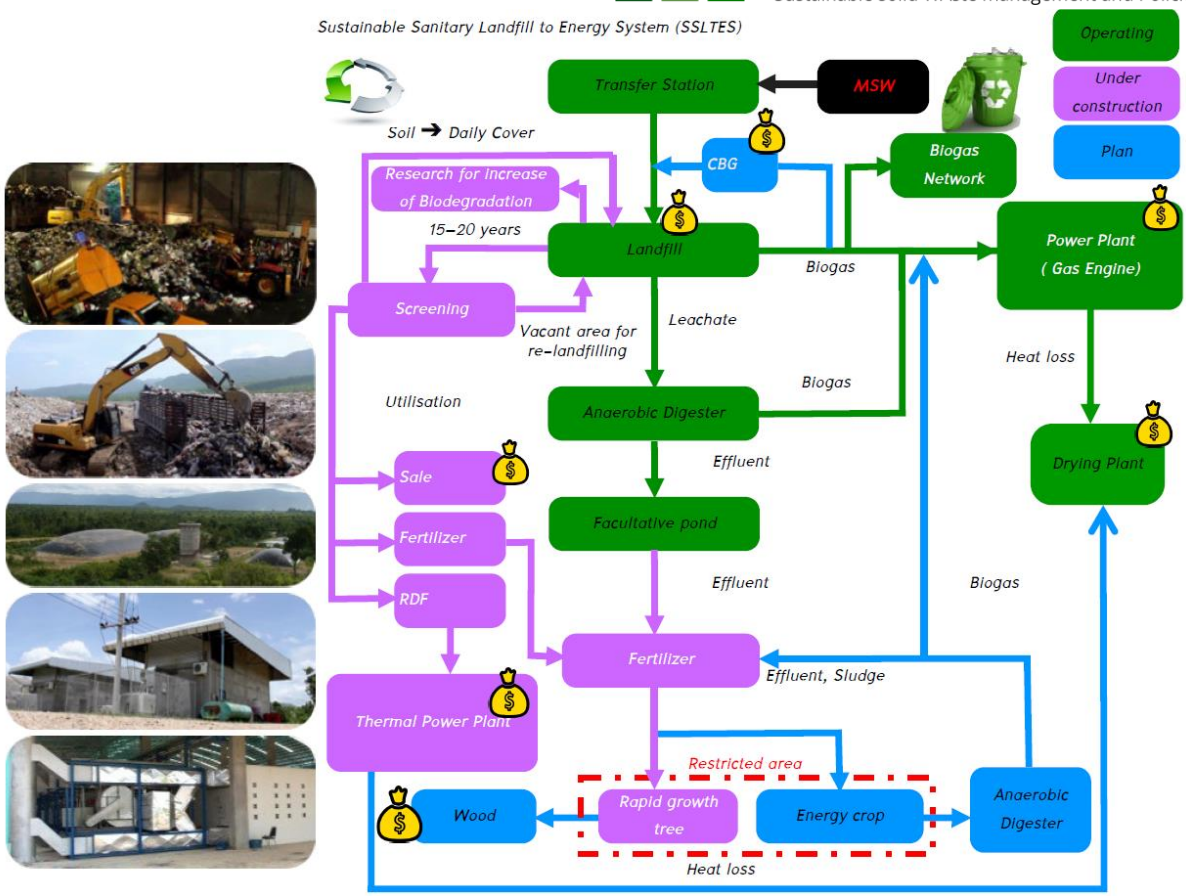


Figure 18. BANTAN MSW DISPOSAL CENTRE OPERATION
(Adapted from the presentation slide of Bantan MSW disposal centre, 2016)

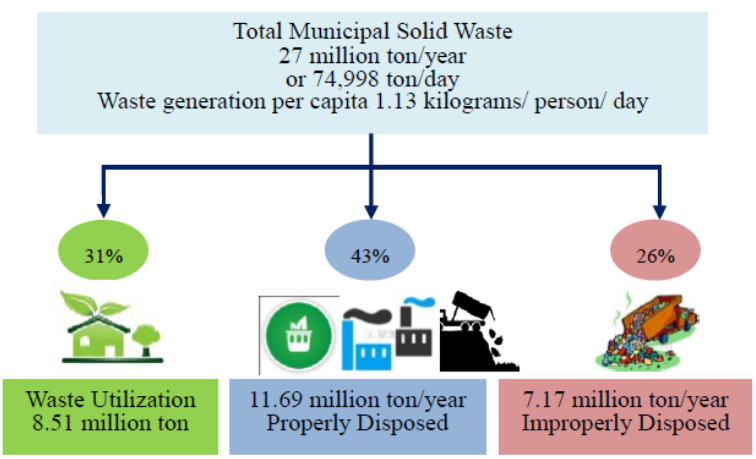
Presently Bantan MSW Disposal Centre conducts the sanitary landfilling with the system to collect biogas for electricity generation. The produced electricity (maximum capacity of 1,063 kw) is sold to the Provincial Electricity Authority. Heat loss generated during electricity production is used in the drying plant for drying longan, which is the main agricultural product of the area. Moreover, some amounts of biogas are disseminated through the biogas network for nearby communities in order to be used as a substitute of the LPG. Leachate collected from the landfill is treated in the anaerobic digester to also produce biogas. The effluent of the anaerobic digester is further treated in the facultative ponds and disposed on-land inside the area of the landfill. The company has also conducted some studies to accelerate the biodegradation process of MSW in the landfill. Contents of the fully degraded MSW in the closed landfill are excavated and degraded organic fractions are used as fertilizer for growing some utilizable plants. Components, such as glass, metal are sold for recycling process. RDF is planned to be used in the thermal power plant. The vacant volume of the landfill can, then, be used for another re-landfilling. The company has also set the future plan to upgrade the biogas to produce CBG for being used as the fuel in the MSW transferring trucks. Moreover, the fertilizer is planned to be used for energy crop production to produce more biogas in the future.

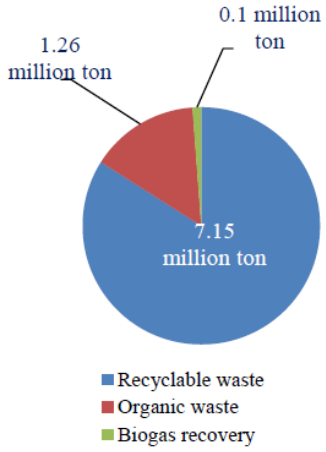
4.1.2.5 Thailand's National Waste Management Master Plan 2016-2021

To tackle MSW problems in Thailand, the cabinet approved the National Waste Management Master Plan 2016-2021 on the 3rd of May 2016. The master plan aims to (1) Encourage population, including children, and the private sector to reduce waste at the source by following the 3Rs concept (Reduce, Reuse, Recycle); (2) Utilize centralized facilities for clusters of municipalities emphasizing waste utilization and waste to energy methods to establish proper disposal methods for municipal solid waste and household hazardous waste; and (3) Bring all relevant sectors to participate in the management of solid and hazardous waste. The target of the National Waste Management Master Plan 2016-2021 is presented in Figure 19. It can be seen that the responsible organisation in Thailand has planned to holistically manage the MSW and also household hazardous wastes to achieve set goals by the year 2021. Figure 20 shows the situation of Thailand MSW management according to the National Waste Management Master Plan 2016-2021 in the year 2017. Of all MSW generated (27 million tons), 43% (11.69 million tons) were disposed of properly. While 31% of MSW (8.51 million tons) were reported to be utilised (in forms of recyclable waste (84%), organic waste (14.8%) and biogas recovery (1.2%)), up to 26% (7.17 million tons) were still improperly disposed of. Aluminium, plastic, and paper were the top three materials recovered from waste stream both from MSW and industrial wastes. From all figures shown in Figure 20, the country still needs to do more to fill the gap in order to achieve the set goals. Effects of economic recession and COVID-19 that have tempered Thailand's economic growth and development at least in the last 5 years are expected to have some adverse consequences on the MSW management plans. These anticipated effects are still to be assessed and revealed as the responsible organisations are still in the process of collecting all relevant data and information.

Figure 19. TARGETS AND TIMELINES OF THE NATIONAL WASTE MANAGEMENT MASTER PLAN 2016-2021 (WWW.PCD.GO.TH)

Flow Diagram of Municipal Solid Waste Management in 2017





Waste recovery by types of material as of 2017

Type	Waste generation (tons)	Amount recovery		Total		End product uses
		Recovery from MSW (tons)	Industrial Waste exchange (tons)	Tons	%	
Glass	2,550,000	950,000	650,000	1,600,000	63	Recycling
	-		250,000	250,000	10	Reuse
Paper	4,500,000	2,534,000	340,000	2,874,000	64	Recycling
Plastic	3,284,400	2,100,000	350,000	2,450,000	75	Recycling
Steel/Metal	4,000,000	861,000	1,180,000	2,041,000	51	Recycling
Aluminum	820,000	540,000	150,000	690,000	84	Recycling
Rubber	521,000	175,000	120,000	295,000	57	Recycling
	-		75,000	75,000	14	Reuse
Total	**15,675,400**	**7,160,000**	**3,115,000**	**10,275,000**	**66**	

Figure 20. THAILAND'S MSW MANAGEMENT SITUATION IN YEAR 2017 (WWW.PCD.GO.TH)

4.1.3 Vietnam

4.1.3.1 Introduction

In Southeast Asia region, Vietnam with an area of 330,000 km^2 has been experiencing a fast increase in waste generation. The urbanization, population growth, industrialization, rising living standards and rapid technological development are the main reasons for fast growth rate of waste generation [10,20,36]. According to [10], in 2018, the urbanization rate increased to 38.4% and the urban population accounted for 36% of the total population. Moreover, in 2021, the population density in Vietnam is of 314 inhabitants/km^2, and this makes Vietnam the 15th most populous country in the world. It is obvious that the rapid growth rate in urbanization and population without a proper strategy of waste management will result in negative impact on economy and health. Therefore, the appropriate management in solid waste should be considered and studied to minimize the effect of solid waste on the environment.

4.1.3.2 Waste generation and composition in Vietnam

Solid waste (SW) can be classified into different types based on two major criteria: solid waste generation and toxicity level. Domestic waste, industrial waste, construction and demolition waste, and medical solid waste belong to the former classification, whereas, ordinary solid waste and hazardous solid waste belong to the latter classification. According to National state of environment report 2019 on solid waste released [8], in comparison to the solid waste generation in 2010, the solid waste generation in 2019 increased significantly by 46%. The volume of daily waste generation was nearly 65,000 tons, therein, the total amount of solid waste generated in urban areas was nearly 36,000 tons/day accounting for 55%. Ha Noi and Ho Chi Minh cities are the two largest source of solid waste generation with 6,500 tons/day and 9,400 tons/day, respectively (Table 15).

Table 15. VOLUME OF SW GENERATION IN SOME CITIES IN VIET NAM (MODIFIED FROM [8])

NO	Location	Volume of SW generation (ton/day)			
		2010	2015	2018	2019
1	Ha Noi	5,000	5,515	6,500	6,500
2	Bac Ninh	-	-	870	900
3	Quang Ninh	-	805	1,397	1,539
4	Hai Phong	1,250	1,000	1,715	1,982
5	Thanh Hoa	-	-	2,246	2,175
6	Nghe An	-	-	1,629	2,464
7	Thua Thien Hue	225	-	559	550
8	Da Nang	805	900	1,168	1,100
9	Quang Nam	198	-	920	920
10	Khanh Hoa	486	-	869	1,068

11	Dak Lak	246	-	1,444	1,370
12	Binh Duong	378	-	1,838	2,661
13	Dong Nai	773	-	1,838	1,885
14	Ba Ria – Vung Tau	456	700	912	914
15	Ho Chi Minh	7,081	8,323	9,128	9,400
16	Long An	179	-	1,086	1,086
17	Dong Thap	209	-	1,060	800
18	Kien Giang	376	-	1,300	481

Note: (-) Lack of statistics data

The volume of municipal household solid waste generation depends on the population size, urbanization growth rate and industrialization. From figure 21 the municipal household SW generated in Southeast regions was the largest with 35% of the total volume of municipal household SW generation, followed by Red River Delta with 24%. According to [3], from October 2014 to June 2015, 57.9% of municipal SW was generated from households (about 2 million households). Table 16 also shows the compositions in percentage of municipal household SW in Ha Noi and Ho Chi Minh city. As can be seen from Table 16, the proportion of organic waste was the largest amount.

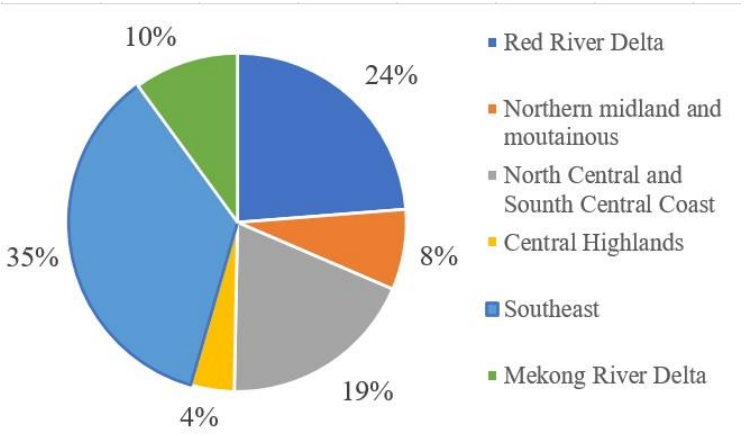


Figure 21. Volume of municipal household SW generation between regions (modified from [8])

Table 16. COMPOSITION OF MUNICIPAL SOLID WASTE GENERATED IN HA NOI AND HO CHI MINH (MODIFIED FROM [8, 20])

Composition	**Ha Noi***	**Ho Chi Minh****
Organic waste	51,9%	59,2%
Wood, straw	-	2.4%
Plastic and Nylon	3,0%	10.9%
Paper	2,7%	6.4%
Textile	-	4%

Metal	0,9%	5.5%
Glass	0,5%	2.6%
Porcelain	-	2.8%
Soil, sand	-	-
Styrofoam	-	3%
Inert substance	38%	-
Rubber and leather	1,3%	2.6%
Hazardous waste	-	-
Others	1,6%	-

Note: (*) Statistics data in 2018 (**) statistics data in 2017, (-) lack of statistics data

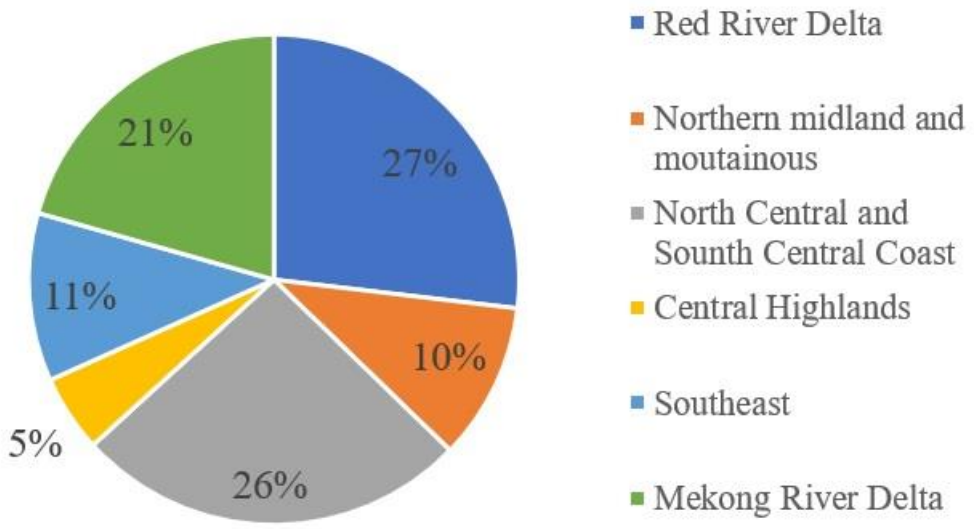


Figure 22. Volume of rural household SW generation between regions (modified from [8])

The rural SW was generated from different sources: households, markets, storages, schools etc. The major composition of rural SW was biodegradable organic (food waste, garden waste) with the moisture being over 60%. However, the non-biodegradable organic, inorganic substances (glass, porcelain, metal, paper, plastic, household electricity waste) and especially nylon bags were more and more. Figure 22 illustrates that the largest volume of rural SW generation was for Red River Delta region with nearly 2,784,494 tons/year, corresponding to 27% of the total rural waste

generated. Moreover, most of rural SW were not separated into different types at source, therefore the recycle rate of SW was low.

4.1.3.3 Status of classification, collection, and transportation of household SW

a. Sorting at sources

The purpose of the SW classification at source is the separation of high valuable recycled SW in the point of waste generation (for instance households), especially the biodegradable organic substance (60-80%) to create the clean organic source for processing high quality compost. In addition, SW separation at source also contributes to creating a source of raw material for recycling activities, and reducing the volume of household SW buried in landfills. The classification program of household SW have been piloted in Hanoi since 2007 and in Ho Chi Minh since 1999. Until now, many localities have also implemented the classification program of household SW at source like Hung Yen (2012-2014), Bac Ninh (2014), Lao Cai (2016), Binh Duong (2017-2018), Dong Nai (2016-2018), Da Nang (2017), and Ha Tinh (2019).

In Ho Chi Minh city household SW is treated by different ways, including 69% for sanitary landfill technology, 20% for compost processing and 11% for incineration technology [8]. To reduce the landfill rate, Ho Chi Minh city has also implemented the classification program of household SW at source through several stages, from piloting a residential area or a ward in a district to replicating it in many districts. From statistics data in [20], there was no separation stage of municipal SW at source in Ho Chi Minh city from 2014 to 2015. However, valuable waste such as paper, plastic, cans, etc., was separated by households and was sold to waste buyers. Generally, some reasons could be included: large amount of generated SW, limited space for placing rubbish bin in households, no standard rubbish bin for storage, high amount of leachate and malodour generation, and lack of public awareness. According to [38], “household waste separation guidelines at source” have already been deployed in efforts to reduce the waste going to landfill in Ho Chi Minh city. Two teams from the Citenco company were deployed to collect organic waste (from 5:00 PM – 8:00 PM on Wednesdays and Sundays) and inorganic waste (from 4:00 PM daily), separately. Two types of bins (blue and grey) were provided to household for sorting of waste, in which blue for organic and grey for the remaining waste.

The classification of household SW in rural areas is mainly conducted at households for some types of solid waste such as paper, cardboard, metal (for sale), food waste (used for livestock). Other solid wastes are mostly unclassified, including biodegradable and non-biodegradable SW such as plastic bags, glass, branches, leaves, fruits and dead animals. Generally, the efficiency of classification of household SW is not high. The government need to implement some appropriate policies to promote the classification program of household SW at many localities across the country.

b. Collection and transportation of household SW

In Viet Nam, some popular types of collection and transportation of household SW are [8]:

- Collecting at public places: this collection type uses the common storage locations with large areas to collect and receive household SW.

- Collecting at residential areas: the collection trucks stop at the specified locations and collect the household SW in these areas. Then, household SW will be transported to transit station or processing facilities.

- Collecting at home: workers collect household SW at each household and bring the rubbish bin to the collection trucks. Then, the empty rubbish bins are returned back. This collection type is commonly conducted in Ho Chi Minh city and in Southwest provinces. In Ho Chi Minh city, the collection system includes two types: private and public one. Therein, 60% of household SW collection at sources belongs to the private types and the public collection type accounts for 40%.

c. The rate of collection and transportation of household SW

Collection and transportation of municipal household SW

As can be seen from figure 23, the collection rate of municipal household SW has been increasing year by year. The table 17 shows that the average collection rate of municipal household SW is nearly 92% in 2019. The cities under the central government have quite high collection rate of municipal household SW, with 99% for Ha Noi, 100% for Ho Chi Minh and Da Nang, 95.5% for Can Tho and 97% for Hai Phong [8]. From Table 17, the highest collection rate of municipal household SW belongs to Southeast with 98.6%, followed by the Red River Delta with 96.8%. The Central Highlands Region has the lowest collection rate of municipal household SW with 62.5%.

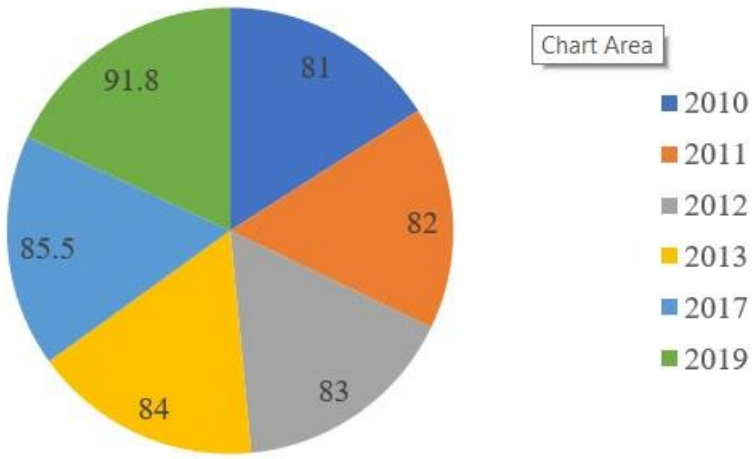


Figure 23. Collection rate of household SW, in % [8]

Table 17. THE COLLECTION RATE OF MUNICIPAL HOUSEHOLD SW IN DIFFERENT REGIONS IN 2019 [8]

Order	Region	Volume of SW generation (ton/day)	Volume of SW collection (ton/day)	Collection rate (%)

1	Red River Delta	8,466	8,191	96.8
2	Northern midland and mountainous	2,740	2,255	82.3
3	North Central and South-Central Coast	6,717	5,705	84.9
4	Central Highlands	1,485	929	62.5
5	Southeast	12,639	12,457	98.6
6	Mekong River Delta	3,577	3,159	88.3
	Total	35,624	32,695	91.8

In Ho Chi Minh city, 60% of municipal SW was collected by private system including informal collectors and cooperatives, whereas the remaining 40% was collected by public system such as HCMC City Urban Environment Company Limited (CITENCO) and 22 District Public Work Service Company Limited (DPWSCLs) [20]. There were some disadvantages in municipal SW collection in Ho Chi Minh city. Firstly, the collection equipment's are not standardized. Secondly, the transport pathways are narrow which causes delays in collection time and pollution. Thirdly, there is lack of collection skill, lack of monitoring and control and non-integrated management. For municipal transportation, there were 33 transfer stations with the total capacity of 5,477 tons/day in Ho Chi Minh city during 2014-2015 [20]. Although 100% of municipal SW was collected, transferred and transported, the municipal SW transfer and transportation is complicated and inadequate due to the following reasons: (a) this activity relates to many companies working independently from each other, therefore it is not easy to organize and integrate; (b) lack of meeting points, inadequate infrastructure, insufficient transfer stations; (c) lack of tools, guidelines, regulations to support the municipal SW transportation system; (d) insufficient management capacity and insufficient funding.

Collection and transportation of rural household SW

According to preliminary statistics, the national average collection rate of rural SW is nearly 66%, as shown in Table 18. The Southeast region has the highest collection rate of rural SW with 87.5%, whereas the lowest collection rate of rural SW is for Central Highlands, with 29.1% [8]. Moreover, amongst different cities, there is a big difference in collection rate of rural SW. The higher collection rates of rural SW are for Ha Noi, Ninh Thuan and Dong Nai, with over 85%, whereas the much lower collection rates of rural SW belong to Hoa Binh, Dak Lak, Dien Bien and Lai Chau, with under 30% [8].

Table 18. THE COLLECTION RATE OF RURAL HOUSEHOLD SW IN DIFFERENT REGIONS IN 2019 [8]

Order	Region	Volume of SW generation (ton/day)	Volume of SW collection (ton/day)	Collection rate (%)
1	Red River Delta	7,629	6,459	84.7
2	Northern midland and mountainous	2,949	1,529	51.8
3	North Central and South-Central Coast	7,371	4,628	62.8
4	Central Highlands	1,443	420	29.1
5	Southeast	3,150	2,758	87.5
6	Mekong River Delta	5,852	2,871	49.1

Total	**28,394**	**18,665**	**65.7**

4.1.3.4 Status of household SW treatment technology

Currently, there are 1,322 treatment facilities of household SW, including 381 incinerators, 37 compost processing lines, and 904 landfills (many of which are unsanitary) [8]. Some facilities implement the burning method to recover energy for generating electricity of combine with other treatment methodologies. Amongst these household SW treatment facilities, there are 78 provincial-level facilities, the rest are district, commune and inter-commune level facilities. As can be seen from *Figure* , in the total collection volume of household SW, the amount of household SW for landfilling, compost processing and incinerating is 71%, 16% and 13%, corresponding to 35,000 tons/day, 7,900 tons/day, and 6,400 tons/day, respectively.

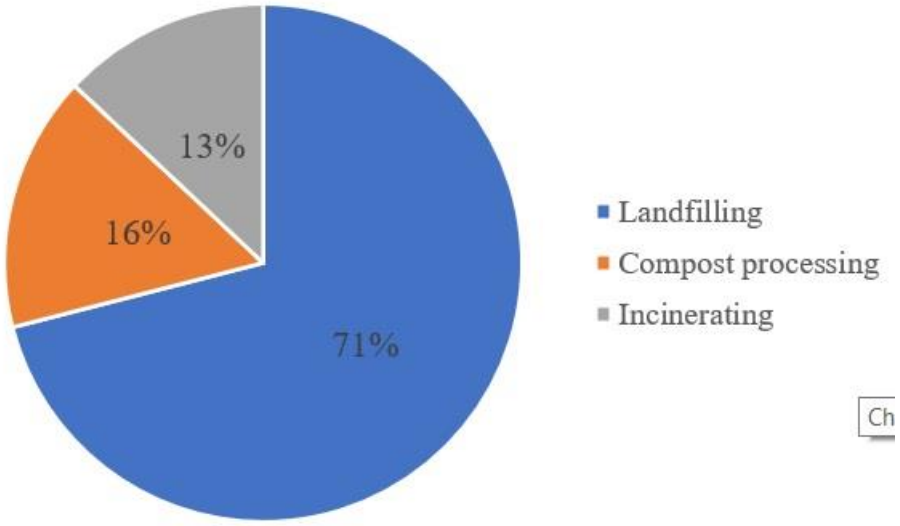


Figure 24. Treatment methodologies of collection household SW [8]

Before 2010, there were 34.4% of compost processing facilities and 31.8% of landfills built and operated. Meanwhile, there was only 4.5% of incinerating facilities built and operated in the same time. After 2014, the number of incinerators increased due to the convert from landfilling method into incineration.

a. Landfilling

In Vietnam, landfilling is the dominant method of municipal solid waste treatment [11], where 76% - 82% of the total collected solid waste in the country is disposed in 98 open dumping sites and landfills. Among the landfills in the country, only 16 are sanitary (nearly 20%), thereby causing pollution problems [21, 22], and the rest are unsanitary landfills or commune level landfills. To deal with this issue, the Vietnamese government enacted the National Strategy for Integrated Management of Solid Waste Until (2025) and Vision towards 2050, which stipulate that waste must

be separated at source [15] as this is a sustainable method of waste reduction [32]. Sanitary landfilling is the main method being applied in large urban areas, such as Ha Noi, Ho Chi Minh, and Da Nang. In some cases, the management and the operation of the landfills should accompany by the responsibility of collecting and treating the generated leachate. In other cases, the treatment of leachate is assigned to an independent unit which is not relevant to the unit managing and operating the landfills. The mentioned landfills in the big cities are currently overloaded, and these landfills can pollute the environment. Currently, the incineration method to generate electricity is proposed to replace the landfilling technology.

Most of landfills receive the household SW that has not been classified at source. These landfills have high organic composition, low stability characteristics, and they occupy a large area of land. Therefore, these landfills cause environmental pollution due to foul smell, gas emissions, leachate.

In Ho Chi Minh city, there were 2 sanitary landfills in operation: Da Phuoc SW treatment complex with the capacity of 5,000 tons/day and Tay Bac Cu Chi SW treatment complex with the capacity of 2,000 tons/day [20, 38]. According to analysing data, 68%-86% of the SW collection was disposed at sanitary landfills [20, 38].

In Ha Noi, the number of designed sanitary landfills is three. According to [34], the amount of SW that these landfills received was 1,701,630 tons/year (84.4% of the total collected municipal SW). Therein, Nam Son, Kieu My and Xuan Son landfill received 4,400 tons/day, 150 tons/day and 100 tons/day of municipal SW [34]. Moreover, the life of landfills will be longer if the amount of organic waste was composted [34].

b. Recycling for compost

Currently, there are 37 facilities implementing this technology across the country. This technology uses organic waste to make compost, whereas, the inorganic waste and other residues must be treated by other methods. If the household SW is not classified thoroughly, the compost product will contain many impurities. Therefore, it is quite hard to consume the compost product. In 2015, there was three compost processing plants in Ho Chi Minh city: Vietstar with the capacity of 1,200 tons/day; Tam Sinh Nghia with the capacity of 1,000 tons/day and Vietnam Waste Solution (VWS) company with capacity of 1,000 tons/day [20]. However, the VWS company is not operated due to lack of municipal SW separation at source. At the Vietstar and Tam Sinh Nghia plants, the technology relating to aerated static pile composting was used. Out of the total 1,200 ton/day at Vietstar plant, 773 tons of municipal SW are for compost processing, 7 tons of municipal SW was recyclable plastic, and 420 tons of non-recyclable municipal SW was buried at Phuoc Hiep No.3 sanitary landfill. In Tam Sinh Nghia plant, the amount of municipal SW for compost processing was 350 tons/day, while 50 tons/day and 600 tons/day were for recycling plastic and for incineration [20].

c. Incinerating

In this technology, the household SW after classification is put into an incinerator with a primary combustion chamber (temperature > 400^0C) and a secondary combustion chamber at high

temperature (> 950^{0}C) to form combustible gas and ash. This technology reduces 80-90% the volume of household SW.

Out of 381 incinerators, only 294 incinerators (about 77%) having capacity of over 300 kg/h meet the requirements of National technical regulations (QCVN 61-MT:2016/BTNMT). Many incinerators, especially small incinerators do not have exhaust gas treatment systems or the exhaust gas treament systems do not meet the requirements of environmental protection. By 2018, Ha Noi has invested and operated SW incineration plants following the SW treatment plan, which is approved by the Prime Minister in Decision No. 605/QD-TTg dated April 25, 2014. These plants are: Son Tay SW treatment plant with capacity of 700 tons/day-night; SW treatment plant with capacity of 150 tons/day-night in Xuan Son, Son Tay; SW treatment plant with capacity of 200 tons/day-night in Phuong Dinh, Dan Phuong; SW treatment plant using plasma technology with capacity of 500 tons/day-night in Viet Hung, Dong Anh [8].

d. Waste to Energy facilities for SW

This is a technology with economic and environmental efficiency due to the reuse of household SW to recover energy. However, this technology requires large investment, high technical requirements, high operating cost. The electricity price of this technology is much higher than that from other technologies. Therefore, there should be some policies and incentives in terms of investment support, loan capital, tax, electricity selling price to have an economically feasible household SW burning plant. Currently, the Ha Noi People's Committee has approved the investment policy to build, renovate and upgrade some household SW treatment plants to modern technological plants (incineration or gasification) to recover energy to generate electricity at treatment zones, mainly in Nam Son, Soc Son and Xuan Son, Son Tay town and Ba Vi district. By the end of 2020, the trial plant of household SW burning for electricity generation with the capacity of 4,000 tons/day could be operated at Nam Son treatment complex zone [8].

4.1.3.5 Existing problems, difficulties, and supplementation in classification, collection, transportation and treatment of household SW

According to the survey results and the investigation of the current situation of household SW management in 2019, although the implementation of household SW management solutions has achieved certain results, the following problems need to be addressed in order to manage household SW synchronously, effectively and safely:

- The integrated management method should be applied and the management of household SW should focus on solutions to reduce in daily life [8, 38].
- The rapid population growth causes the SW to increase year by year. Therefore, the policies and standards approved by the government need to be improved in terms of the implementation and enforcement. The SW separation guideline at source to reduce the amount of SW to landfill need to be improved [8, 38].
- The responsibility of concerned authorities is not clear by law although the legal framework of solid waste management in Viet Nam has been enhanced. This situation results in the

management of SW is overlapped under control by multiple agencies. Therefore, the institutional framework of SW management needs to be improved for operating easily [8, 38].

- Technological and infrastructure in terms of SW classification, SW collection and transportation, and SW transfer station need to be improved. Currently, the SW collection system is lack of advance technology. Therefore, the proportion of organic matter in SW for landfilling and compost processing is still high. Moreover, the opening landfills are resulting in environmental pollution relating to gas emission and leachate. As a result, the environmental sound technology (EST) needs to be considered and installed for sustainable management purpose of SW. In case of collection and transportation stage, the systems are outdated and the hygienic condition is low [8, 34, 38].
- The recycling facilities are small businesses scale. Moreover, the recycling technologies may not be modern enough for producing high quality of recycled products due to insufficient investment [8, 38].

PART 2. THE GAPS IN TRAINING AND TEACHING CAPACITIES AND POSSIBLE IMPROVEMENT OPTIONS

5 The gaps in training and teaching capacities

According to ASEAN HEIs, the courses of Master's and Bachelor's Degree have varied subjects at different HEIs. It highlighted that both curriculums included the subjects offered by its own university. However, in the SWAP project, different gaps and improvement have been identified. These are summarised in Tables 19 and 20

Table 19: IDENTIFIED GAPS IN TRAINING AND TEACHING IN BACHELOR COURSES

NO.	TITLE	GAPS	STATUS
C1	Solid waste management (elective course)	Need for Solid Waste Management Solid Waste Management and Regulation	Updated
	Agriculture residual management (elective course)	Management of Crop Residues for Improving Input Use Efficiencies Crop Residues Improve the Fertility and Productivity of Soil	Updated
C2	Solid Waste Management	Need for Solid Waste Management Solid Waste Management and Regulation	Updated
	Crop Residual Management	Management of Crop Residues for Improving Input Use Efficiencies Crop Residues Improve the Fertility and Productivity of Soil	Updated
T1	Solid Waste	National solid waste management	Updated

	Management	Risk Assessment in Solid Waste Management	
	Fundamental of Material Flow Analysis and Life Cycle Assessment	Materials Recovery and Recycling	Updated
T2	Biotechnology	Aerobic and Anaerobic Treatment. Emerging Biological Technologies	Updated
V1	Environmental Management of Urban and Industrial zone	Management of MSW by Vermicompost	Updated
	Solid Waste Management	Integrated Solid Waste Management Based on the 3R Approach	Updated
V2	Solid waste management and treatment	Emerging Biological Technologies Technology Status of Waste Collection Systems	Updated
	Environmental Microbiology	Design and Planning of Waste Collection System Sustainability and Circular Economy Considerations	Updated

Table 20: IDENTIFIED GAPS IN TRAINING AND TEACHING IN MASTER COURSES

NO.	TITLE	GAPS	STATUS
C1	Economics of Solid Waste Management (elective course)	• Overview of economics of solid waste management • Solid waste management technologies • Legal framework of solid waste management	New
C2	Solid Waste Management	• Overview of solid waste management • Solid waste management technologies • Legal framework of solid waste management	New
T1	Circular Economy and Sustainable Waste Management (3 Credit)	• Financial issues in solid waste management	New
	Advanced Solid Waste Management	• Characteristics and Quantity. • Storage of hazardous waste • Treatment and dispersal	Updated
T2	Environmental Technology	• Aerobic and Anaerobic Treatment.	Updated

		• Removal and Recovery Method • Emerging Biological Technologies	
V1	Environment and Sustainable Development	• Optimizing Urban Material Flows and Waste Streams in Urban Development through Principles of Zero Waste and Sustainable Consumption	Updated
V2	Waste resources management	• Waste Management Through Waste Hierarchy: Reduce, Reuse, Recycle, Recover, and Disposal	Updated

6 Possible improvement options

According to the table 19&20 above, we would suggest to see the detail curriculum both Master and Bachelor courses of each higher education institutions due to having different course for new and updated courses. The table 20&21 indicated that numbers of course need to fill in the gaps by providing the courses related and linked to the curriculums. Also, TVET program should include gaps in training and teaching such as Innovation technologies for waste management, National and International research collaboration among HEIs in the field of solid waste management, R&D National Capacity and Roles of Private Sectors, and financial and resources for research in waste management at HEIs. To cover these gaps, the following courses have been preliminary proposed (a detailed overview is proposed in Annex 2, as a result of Task 1.2). This list is a draft and will be used as a basis for defining the final list of modules and courses to be developed for academia and TVET (subject of, respectively, deliverables 2.1 and 3.1).

Lecture module Bachelor level (3 ECTS = 90 hours study time)

Introduction to Sustainable Solid Waste Management and Circular Economy

Number	Title of lecture and seminar
1	Introduction Waste Management and Circular Economy
2	Waste types, streams, characterisation and waste analysis
3	Waste collection, transportation and transfer
4	Overview on waste treatment technologies
5	Biomass (Types, characterization, concepts and technologies)
6	Residual waste treatment and recovery
7	Landfill (Introduction, elements and operation)
8	Landfill (After care)

9	Waste associated regulations

Lecture module Bachelor level (3 ECTS = 90 hours study time)

Secondary raw materials life cycle – A Circular Economy for resources recovery

Number	Title of lecture
1	Introduction of Life cycle assessment and eco balance in waste management and circular economy
2	Institutional framework, rules and responsibilities
3	Treatment of Organic Waste (composting and anerobic)
4	Mechanical-Biological-Treatment (MBT)
5	Waste-to-Energy (WtE)
6	Basics Packaging waste (plastics, glass, paper, metal)
7	Waste Electrical and Electronic Equipment (WEEE)
8	Construction and Demolition Waste
9	Case study – Biowaste treatment facility in one Asian Country (tbd)
10	Case study – Plastic packaging waste recycling facility in one European Country (tbd)

Lecture module Master level (1st option) (3 ECTS = 90 hours study time)

Technical Aspects of Waste Management (with Problem-based learning approach)

Number	Title of lecture
1	Waste Management and treatment – Recap bachelor
2	Packaging Waste (plastics, glass, paper, metal)
3	Urban mining (construction and demolition waste, WEEE)
4	Industrial and Hazardous Waste
5	Technology of Thermal waste treatment and Emission control
6	Biological Treatment plant design (anaerobic digestion and composting) – Problem based learning → students will be presented with initial data (composition and characteristics of the waste, available infrastructure, etc.) and will need to design a biowaste treatment facility in groups. Supervision of the teachers throughout the semester.

Lecture module Master level (2nd option) (3 ECTS = 90 hours study time)

Advanced Waste Management Aspects in a Circular Economy

Number	Title of lecture
1	International Regulations, Treaties and Goals (SDG) in Circular Economy
2	Logistics (concept, strategies, business models, operating and costs)
3	Policies and tools for the Circular Economy (waste hierarchy, EPR, recycling targets and incentives)
4	International waste management
5	Regulations and Framework conditions in the region
6	Problem-based learning: group work to calculate and design logics for collection and treatment of MSW generated by a city in the region.

Lecture module TVET level

Advanced Waste Management Aspects in a Circular Economy

Number	Title of lecture
1	Introduction Waste Management and Circular Economy
2	Waste management and treatment technologies
3	Green business models and entrepreneurship in SWM sector
4	Practical course: biowaste treatment operation[a]
5	Practical course: recycling E-Waste[b]
6	Practical course: MSW characterization and sorting

[a]Possibly, the trainee should do this in an existing WM facility.

[b]5 and 6 can be done in the Training Hubs to be set up during SWAP Project.

7 CONCLUSION

For teaching SWM at the Academic level, most of the surveyed universities have teaching programs that have met the social demands. However, SWM-related courses seem to be more popular at Bachelor level than Master level. This is reflected in the number of curricula as well as the number of students participating. However, a common problem at both levels is the lack of equipment status, as a result, the needs of students are not fully met.

For SWM training at the Non-academic level, the general conclusion is that the partner universities have not received the investment. In addition, these TVET courses have not received the attention of the learners. Therefore, this is still an educational level with many shortcomings and need a lot of investment to develop in the future.

For the gaps in training and teaching capacities and possible improvement options of curriculum updating in the Master and Bachelor programmes, together with TVET program where all ASEAN HEIs would need to improve the capacity their students through providing internship programme at private sector or NGOs related fields. As known that both new and updated courses will be shown in detail so that they are officially approved from the management board at the university levels.

Finally, the highlighted courses to fill in the gaps in training and teaching will support and improve more for curriculum both master and bachelor levels.

References

1. Administration, P. P. (2021, June 30). Declearation.
2. Cambodia, E. (2019). *Waste Management.* Phnom Penh: Global Bussiness Network Programme.
3. CCAC. 'Solid Waste Management City Profile'. https://www.waste.ccacoalition.org/sites/default/files/files/bangkok_-_city_profile_final_draft_03102015_0.pdf.
4. Chiemchaisri, C., J. P. Juanga, and C. Visvanathan. 2007. 'Municipal solid waste management in Thailand and disposal emission inventory', *Environmental Monitoring and Assessment*, 135: 13-20.
5. Choeu. (2016). *Basic Information of Medical Waste Management Unit 24-April-2016.*
6. COMPED. (2013). *Cambodia Education and Waste Management Organization*. Retrieved from https://www.comped-cam.org/wastesurvey.php
7. Department of Planning. (2015). *Data Documentation on Phnom Penh Municipality Situation in 2015.*
8. Environment, M.o.N.R.a., *National state of environmental report 2019 on Solid waste released*. 2019.
9. EuroCham Cambodia. (2019). *Global Business Network (GBN) Programme.* Bonn and Eschborn, Germany: GIZ.
10. Hai, H.T., N.D. Quang, N.T. Thang, and N.H. Nam, *Circular Economy in Vietnam*, in *Circular Economy: Global Perspective*, S.K. Ghosh, Editor. 2020, Springer Singapore: Singapore. p. 423-452.
11. Idris, A., B. Inanc, and M.N. Hassan, *Overview of waste disposal and landfills/dumps in Asian countries.* Journal of Material Cycles and Waste Management, 2004. **6**(2): p. 104-110.
12. JICA, & MPP. (2005). *Study on Solid Waste Management in the Municipality of Phnom Penh in the Kingdom of Cambodia; Main Report.*
13. Kamiko. (2016). *Top Management Seminar on Decentralisation and leadership Towards Local Needs and Changing Society.*
14. Ministry of Health. (2008). *Declaration No. 19 on Waste Management from Health Care Service in the Kingdom of Cambodia.*
15. Minister, O.o.t.P., *Approval on the National strategy for integrated management of solid waste until 2025 and vision towards 2050*. 2009.
16. MoE. (2009). *WEEE / E-waste Management Report Phnom Penh Municipality Kingdom of Cambodia.* .
17. MoE. (2014). *Medical waste for dioxin.*
18. NCSD. (2016). Retrieved from https://ncsd.moe.gov.kh: https://ncsd.moe.gov.kh/dcc/project/solid-waste-management-strategy

19. NCSD. (2019). *Solid Waste Management Strategy*. Retrieved from The National Council for Sustainable Development: https://ncsd.moe.gov.kh/dcc/project/solid-waste-management-strategy

20. Nguyen, T., Sharp, A., & Babel, S, *Challenges and opportunities to approach zero waste for municipal solid waste management in Ho Chi Minh City.* APN Science Bulletin, 2020. **10**(1).
21. Nguyen, T.T. and T. Watanabe, *Win-win outcomes in waste separation behavior in the rural area: A case study in vietnam.* Journal of Cleaner Production, 2019. **230**: p. 488-498.
22. Nguyen, X.C., T.P.Q. Tran, T.T.H. Nguyen, D.D. La, V.K. Nguyen, T.P. Nguyen, X.H. Nguyen, S.W. Chang, R. Balasubramani, W.J. Chung, and D.D. Nguyen, *Call for planning policy and biotechnology solutions for food waste management and valorization in Vietnam.* Biotechnology Reports, 2020. **28**: p. e00529.
23. PCD. 2021. 'Thailand's Pollution Situation in year 2020'. www.pcd.go.th.
24. PPCA. (2017). *Phnom Penh Capital City Strategic Action Plan.* Phnom Penh City Administration.

25. PPCA. (2021, June 30). Declearation.

26. PPCA, I. N. (2018). *Phnom Penh Waste Management Strategy and Action Plan 2018-2035.* Phnom Penh, Cambodia: Phnom Penh Capital Administration.

27. PPCA, IGES, Nexus, UN Environment, & CCCA. (2018). *Phnom Penh Waste Management Strategy and Action Plan 2018-2035.* Phnom Penh, Cambodia: Phnom Penh Capital Administration.

28. Rajeev Kumar Singh, D. G. (2020). *State of Waste Management in Phnom Penh, Cambodia.* Phnom Penh: COMPED.

29. Rathana, K. (2009). *Solid Waste Management in Cambodia.* Phnom Penh: Cambodian Institute for Cooperation and Peace.

30. Royal Government of Cambodia. (2015). *Sub-Decree No.113 on Garbage and Urban Solid Waste Management.*

31. Seng, K. (2015). *Analysis of solid waste composition and waste forecasting in Phnom Penh with the production of methane from Dangkor landfill, Cambodia.* Institute of Technology of Cambodia.

32. Song, Q., J. Li, and X. Zeng, *Minimizing the increasing solid waste through zero waste strategy.* Journal of Cleaner Production, 2015. **104**: p. 199-210.
33. Suma, Y., N. Pasukphun, A. Hongtong, V. Keawdunglek, P. Laor, and T. Apidechkul. 2019. 'Waste composition evaluation for solid waste management guideline in highland rural tourist area in Thailand', *Applied Environmental Research*, 41: 13-26.

34. Thanh, H.T., H. Yabar, and Y. Higano, *Analysis of the Environmental Benefits of Introducing Municipal Organic Waste Recovery in Hanoi City, Vietnam.* Procedia Environmental Sciences, 2015. **28**: p. 185-194.

35. The World Bank, Cida, & MONRE. (2004). Viet Nam Environment Monitor: Solid Waste. 1–6

36. Truong, N. *Solid Waste Management in Vietnam : Current situation, challenges and strategies for development*. 2018.
37. UNEP. (2009). *Developing Integrated Solid Waste Management Plan: Training Manual, 1, 1–77.*
38. Verma, R.L., G. Borongan, and M. Memon, *Municipal Solid Waste Management in Ho Chi Minh City, Viet Nam, Current Practices and Future Recommendation.* Procedia Environmental Sciences, 2016. **35**: p. 127-139.

Annexes

Annexes 1

Questionnaire for task 1.1 &1.4.

QUESTIONNAIRE FOR TASK 1.1

Inventory of currently offered teaching and training in partner countries

1. General information

- Name of your Higher Education Institution (HEI): ……
- Country: …….
- Year of establishment: ……
- Start and end period of the semesters: ……
- Average time of accreditation process in your institution and accreditation body: …….

2. Currently offered teaching and training

Table 1. Number of curricula currently offered at academic level and non-academic level on topics related to Solid Waste Management (SWM)

Academic level				Non-academic level TVET courses	
Master course		Bachelor course		Total	Related to SWM
Total	Related to SWM	Total	Related to SWM		

Table 2. List name of curricula currently offered at academic level and non-academic level including aspects or related to SWM

No	Academic level		Non-academic level TVET courses
	Master course	Bachelor course	

Note: Please add as many rows as necessary

Table 3. Information of curricula currently offered for Master course

at Academic level on topics related to SWM

No	Name of the curricula	Training duration (year)	Number of courses (in total)	Number of courses addressing specifically SWM (*)	Number of credits/workload of courses addressing specifically SWM (**)	Number of lecturers in courses addressing specifically SWM

Note: Please add as many rows as necessary

(*) For each of the courses addressing specifically SWM listed above, please describe in as many details as possible into the below table

No	Name of courses addressing specifically SWM	The main topics covered during the course	Teaching method	Final examination
1			For example, normal classes during the semester and exam at the end, project-based learning, etc.)	For example, written examination, presentation, oral exam, essay, etc.):

(**)Workload refers to how many hours of study per week (including lecture time, self-study time, etc.)

Table 4. Information of curricula currently offered for Bachelor course

at Academic level on topics related to SWM

No	Name of the curricula	Training duration (year)	Number of courses (in total)	Number of courses addressing specifically SWM (*)	Number of credits/workload of courses addressing specifically SWM (**)	Number of lecturers in courses addressing specifically SWM

Note: Please add as many rows as necessary

(*) For each of the courses addressing specifically SWM listed above, please describe in as many details as possible into the below table

No	Name of courses addressing specifically SWM	The main topics covered during the course	Teaching method	Final examination
1			For example, normal classes during the semester and exam at the end, project-based learning, etc.)	For example, written examination, presentation, oral exam, essay, etc.):

(**)Workload refers to how many hours of study per week (including lecture time, self-study time, etc.)

Table 5. Information of curricula currently offered

at TVET level on topics related to SWM

No	Name of the curricula	Training duration (year)	Number of courses (in total)	Number of courses addressing specifically SWM (*)	Number of credits/workload of courses addressing	Number of lecturers in courses addressing

					specifically SWM (**)	**specifically SWM**

Note: *Please add as many rows as necessary*

(*) For each of the courses addressing specifically SWM listed above, please describe in as many details as possible into the below table

No	Name of courses addressing specifically SWM	The main topics covered during the course	Teaching method	Final examination
1			For example, normal classes during the semester and exam at the end, project-based learning, etc.)	For example, written examination, presentation, oral exam, essay, etc.):

(**)Workload refers to how many hours of study per week (including lecture time, self-study time, etc.)

Table 6. Number of students at Academic level on topics related to SWM between 2015-2020

Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Master course						
Bachelor course						

Table 7. Number of students at TVET level study on topics related to SWM between 2015-2020

Year	2015	2016	2017	2018	2019	2020

Table 8. Number of laboratories and equipment for curricula currently offered at for master course at Academic level on topics related to SWM

No	Name of courses addressing specifically SWM	Number of laboratories	Laboratories and main equipment	Describe the status of laboratories and intent to purchase equipment

Note: Please add as many rows as necessary

Table 9. Number of laboratories and equipment for curricula currently offered at for Bachelor course at Academic level on topics related to SWM

No	Name of courses addressing specifically SWM	Number of laboratories	Laboratories and main equipment	Describe the status of laboratories and intent to purchase equipment

Note: Please add as many rows as necessary

Table 10. Number of laboratories and equipment for curricula currently offered at TVET level on topics related to SWM

No	Name of courses addressing specifically SWM	Number of laboratories	Laboratories and main equipment	Describe the status of laboratories and intent to purchase equipment

Note: Please add as many rows as necessary

QUESTIONNAIRE FOR TASK 1.4

Defining gaps and improvement options for tertiary and academic education

For new courses	
What new courses will the project implement in your HEI?	
For each course please state:	
Title	
Level of study	
List of subjects and credits for each of them	
Estimated date of accreditation and accreditation body	
Number of students to be accepted in the first year/ second year	
Number of teaching staff to be trained	
Internship /placements (if applicable)	
List of equipment to be purchased for this course and for what purpose? (if applicable)	
Date of submission to intra-university organs	
Date of accreditation	
Date of implementation (up and running)	

For updated courses	
Which existing courses will be updated in your HEI?	
For each course please state:	
Title(s)	
Which degrees does this course count towards?	
Level of study	
List of subjects to be updated and credits for each of them	

If accreditation is needed provide the estimated date of accreditation and accreditation body	
Why it was decided to update this course rather than create a new one?	
What % of the course will be changed?	
Number of students enrolled in these courses	
Which of the equipment purchased will be used for this course and for what purpose?	
Date of submission to intra-university organs	
Date of accreditation	
Date of implementation (up and running)	

QUESTIONNAIRE FOR TASK 1.5

Assessing the influence of the informal sector in Waste Management

I. National level

1. **What are the current laws and policies relevant to solid waste management?**

.....

.....

2. **What are the existing enforcement measures to implement those laws and policies?**

.....

.....

3. **What is the current state of the solid waste management and the role of informal sector in the country?**

.....

.....

4. **What do you think of necessary regulatory framework to develop or to improve to support and foster the informal sector to engage more active in waste management financially and sustainably?**

.....

.....

5. **Does government have specific plans to enhance the policies to promote waste separation at source? And waste recycling promotion to enhance circular economy in the country?**

.....

.....

6. **What are the major challenges when implementing and enforcing them?**

.....

.....

II. Assessment of Waste Informal Sector

1. **How many waste pickers at the landfills (Age < 18 years old? Women?) (large, medium and small cities?)**

.....

.....

2. **How many waste pickers at inner the city (Age < 18 years old? Women?) (large, medium and small cities?)**

.....

.....

3. **How is about waste pickers' education/vocational skills?**

.....

.....

4. **Are there any waste pickers organization/association in the city/country?**

.....

.....

5. **What types of waste are waste pickers collecting? The amount respectively? And Price?**

About ……..kgs/week including:

Glass…….. kg …….. USD/kg

Paper ……..kg…….. USD/kg

PET bottle ……kg …….. USD/kg

Plastic (specify type of plastics)……kg …… USD/kg

Steel ……. kg ……. USD/kg

Aluminium…….kg ……. USD/kg

Copper……..kg ……. USDUSD/kg

Others……..kg ……. USDUSD/kg

6. **How often and to where/who the recyclable waste sold by waste pickers?**

Junk shops/middlemen/….?

……Times/month sell to junkshop

where it is located at ……

which is ……..kms far from here; or……Times/month sell to middlemen, who is Mr/Ms……living in…… and come to buy directly at……..which is ……..kms far from here; or Others:…… ……Times/month sell to …… where it is located at ……which is ……..kms far from here.

7. **From when to when waste pickers are working?**

8. Health and safety measure for waste pickers during their working?

.....

9. What are their careers besides collecting waste for their daily living

.....

10. What are the roles of waste pickers in waste management?

.....

11. How much is the average waste quantity that junkshops buy from each waste picker?

Plastics recycled per year ……. t/year

Paper recycled per year ……. t/year

Cardboard recycled per year ……. t/year

Metal recycled per year ……. t/year

Glass collected/separated per year ……. t/year

12. How are recyclable quantities estimated?

☐ **Scale)** ☐ **Truck count**

☐ **Best guess** ☐ **Others**

13. Are there the advantage and disadvantage of having informal sector in solid waste management?

.....

Annexes 2.

Report of task 1.2. Identification of similar educational offers in Programme Countries and definition of the Best Practices

7.1 1. INTRODUCTION AND AIM OF THE STUDY

Task 1.2 is aims to identify the curricula offered by the European university partners, to define best practices and to compare them with similar curricula identified in Task 1.1 concerning the Asian countries involved in SWAP. The educational offer intended in the task 1.1 and 1.2 concerns the topic of solid waste management with particular reference to Municipal Solid Waste.

In order to achieve the fixed objectives, an ad hoc methodology was defined to show the reader how the construction of each teaching unit was achieved. The methodology was then applied considering the degree courses offered by the High Education Institutes (HEIs) involved in SWAP such as the Politecnico di Bari (Italy) and the Hamburg University of Technology (Germany).

3. Methodological approach

Its objective is to identify the contents of a university course concerning the subject of solid waste, starting from the experience of the HEIs involved in SWAP.
The methodology consists of six steps as visible in Figure 1 and here described.

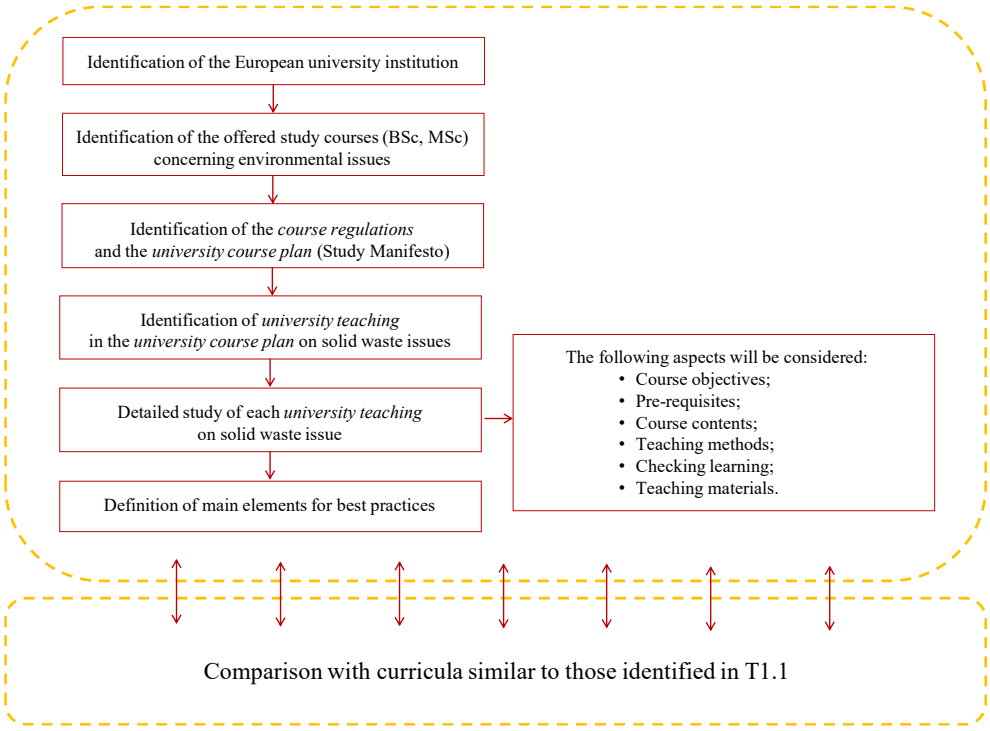


Figure 1. Methodological approach.

The first step involves the identification of the HEIs. They are the Politecnico di Bari and the Hamburg University of Technology.
Having established the partner institution, the second step is to identify the degree courses offered by the university and related to environmental issues. The degree courses can be divided in bachelor (BSc) and master's degrees (MSc).
Subsequently, in the third step, the "Study Course Regulations" are identified. They contain a series of information necessary for the student on how the degree course is structured, the requirements that led to its construction, the professional outlets and the Study Manifesto. The latter contains all teaching units that will lead the student to the degree. Its duration depends on the degree course, 3 years for a BSc course and 2 years for an MSc one.
Starting with the Study Manifesto, the fourth step involves identifying individual teaching units (or university courses) in solid waste topics. The in-depth study of these courses is part of the fifth step. The following aspects will be considered: (i) Course objectives, (ii) Pre-requisites; (iii) Course contents; (iv) Teaching methods; (v) Checking learning and; (vi) Teaching materials.
The last step is to compare the curricula and teaching units of the European institutions with those identified in Task 1.1, which will also be explored in the remaining tasks of WP1.

4. Identification of Institutions Programs of Partners. The case of the Politecnico di Bari (Italy)

Politecnico di Bari is a public university offering various Bachelor's and Master's degree courses in the fields of civil, environmental and industrial engineering. With reference to the degree courses of greatest interest to SWAP, the Politecnico di Bari offers the Bachelor's degree course in *Civil and Environmental Engineering* and the Master's degree course in *Environmental and Land Engineering*. Information that is relevant to the objectives of this Task 1.2 will be herein deepened.

4.1. Data input

5. Regulations related to the Degree Courses identified

The three-year degree course in Civil and Environmental Engineering has the primary goal of ensuring that students have an adequate knowledge of general scientific methods and content, as well as the acquisition of specific professional knowledge in the area of Civil, Environmental and Territorial Engineering and of Safety and Civil Protection.
The specific goal of the BSc Degree in Civil and Environmental Engineering proposed by the Politecnico di Bari is to train a professional with a good basic preparation in the disciplines characterizing civil and environmental engineering, qualified to deal with technical and design problems in the field of construction and infrastructure and able to understand and use innovation in practice by updating the knowledge with the evolution of technology and means of calculation and allowing access to the State Exam qualifying for the profession of Junior Engineer with the skills that characterize the members of the Register of Junior Engineers section (B Civil-Environmental, according to the Italian legislation).
The educational activities are grouped into (a) basic, (b) characterizing and (c) complementary activities.
The basic activities are divided into two disciplinary areas (Mathematics, Computer Science and Statistics; Physics and Chemistry) while those characterizing into three disciplinary areas (including Environmental and Land Engineering).
Some of the courses are divided into modules, but there is only one final examination to assess the educational activity. The Education Credits (ECs) corresponding to each course are acquired by the student on passing the exam.

The normal duration of the degree course is three years for a full-time student.
Table 1S in Annex I shows the study manifesto for the three-year BSc degree in Civil and Environmental Engineering. It is possible to note that in the third year of the Study Manifesto there is the course *Elements of sanitary engineering and Environmental protection technologies*, which covers wastewater treatment in the module of *Elements of sanitary engineering* and solid waste management in the module of *Environmental protection technologies*.
The Master's Degree Course (MSc) in *Environmental and Territorial Engineering*, held at the Bari and Taranto campuses (Apulia Region, Italy), trains professionals with in-depth technical and scientific knowledge, capable of tackling and proposing innovative solutions to complex problems, also through an interdisciplinary approach. The curriculum offered at the Bari campus is geared towards training professionals with knowledge mainly related to soil protection, risk prevention and environmental quality management. The curriculum in Taranto aims to meet the demand for professionals able to deal with the complex environmental problems that characterize both natural resources and the built heritage. In both cases, the course of study is structured in such a way as to offer a specific, but at the same time transversal engineering preparation. The course of study aims to train highly qualified figures through an educational pathway oriented to develop skills in the analysis of the interrelationships between the various physical processes involved in complex environmental systems, and especially in the design and evaluation of engineering interventions in the natural and man-made environment and in the planning, organization and management of complex and/or innovative processes and services for environmental sustainability. Master's graduates will be able to carry out, in addition to their free profession, functions of high responsibility in public administrations, public and private bodies. The educational activities required to achieve the objectives of the MSc Course in Environmental Engineering all belong to the subject area of Environmental Engineering; in addition to the characterizing educational activities, complementary activities are foreseen.
In the MSc Course in Environmental and Land Engineering, students may also choose their own educational activities, provided they are consistent with the educational project, and activities related to the preparation of the final examination for the degree. The teaching of some courses may be divided into modules, but with a single final examination. The Educational Credits (ECs) corresponding to each course are acquired by the student on passing the examination. In order to obtain the degree, the student must have obtained a number of ECs equal to 120.
Table 2S of Appendix I shows the study manifesto for the two-year MSc degree in Environmental and Land Engineering. It is possible to note that in the first year of the Study Manifesto there is the course *Solid waste management and Remediation of contaminated sites*, which covers solid waste management in the module of *Solid waste management* and remediation of contaminated sites in the module of *Remediation of contaminated sites*.
In the next section the two teaching units on the topic of solid waste are discussed in more detail.

6. Teaching courses

The didactic activity offered by the Politecnico di Bari is designed to provide skills from the "perspective of the supply chain".
The teaching unit *Environmental protection technologies* in the BSc course provides the first definitions of solid waste and, more generally, the basic elements for understanding more complex concepts (e.g., unitary treatment processes).
With reference to the topic of solid waste, the *Environmental protection technologies* course deepens the European strategy for solid waste management and those treatment processes aimed at the reuse/recycling/recovery of the dry components of Municipal Solid Waste, such as plastic, paper and glass.

The course content is shown in Table 1.

Table 1. Contents of the course "Environmental protection technologies", Bachelor's degree in Civil and Environmental Engineering, Politecnico di Bari.

Course name	**Elements of sanitary engineering and Environmental protection technologies** [(*)] [(*)]**:** The course is structured in following 2 modules: 1. Elements of sanitary engineering, concerning wastewater treatment; 2. **Environmental protection technologies, concerning MSW management.** **Here, only the solid waste module (Environmental protection technologies) is discussed in more detail.**
Course objectives	**Expected learning outcomes:** • Knowledge and understanding; • Knowledge of the European and Italian regulations and relating to the MSW Management; • Ability to characterise and classify MSW; • Capacity to dimension a differentiated waste collection system; • Knowledge of the treatment chains of the MSW dry fraction coming from the separate collection and to be sent to the recycling/recovery facilities; • Ability to apply knowledge and understanding; • Ability to interpret the analyses carried out on MSW and to evaluate the necessary treatments for their recycling/recovery; • Ability to dimension the individual separation processes of the dry fraction of MSW. **Possible further expected learning outcomes related to:** • Autonomy of judgement: development of the capacity of engineering judgement concerning the choice of the correct treatment chain of the dry fraction of municipal solid waste; • Communication skills: ability to illustrate and argue the processes commonly used in recovery and recycling plants for the dry fraction of MSW from separate collection; • Ability to learn: the preparation acquired makes it easier to understand the technologies and processes not covered in the course (valorisation of the organic fraction of waste, energy recovery from waste, disposal in a controlled landfill), and which will be the subject of specialised study.
Pre-requisites	**Knowledge of Physics and Chemistry, developed in the first year**.
Course contents	• **Characterisation and classification of MSW (1 EC):** Origin and production data. Product analysis. Physical, chemical and biological properties of MSW. European Waste Catalogue. Waste classification; • **MSW management systems (0.5 EC):** Solid waste management strategies (Directive 2008/98/EC). Management of MSW in Italy and Europe. Cold management systems; • **Separate collection (1.25 EC):** Separate collection trends in Italy and Apulia.

	Collection modalities: (i) Bring-points, (ii) separate collection. Dimensioning of a separate collection system. Municipal collection centres; • **Technologies and processes for waste separation and size reduction (1.25 EC):** Size reduction: Crushing, grinding, pulverisation. Efficiency of separation units. Separation: dimensional (vibrating, rotating and disc screens), gravimetric (aeraulic classifiers, ballistic separators), magnetic and electrical, optical (NIR, colorimetric analysis, MIR). Thickening. Conveyor belts. Case studies; • **The industry of recycling and recovery of materials from MSW (1.25 EC):** Packaging and packaging waste. CONAI. ANCI-CONAI framework agreement. Supply chain consortia. Treatment platforms for the recovery of materials. Case study of a plant for the selection of multi-material from separate collection. Environmental aspects of the recycling industry. • **Case study analysis and management plan of MSW in Apulia (0.75 EC):** Valorisation plant and pushed recovery from Secondary Raw Materials (SRM).
Teaching methods	• Lectures are conducted with the aid of slides; • During the lectures some numerical examples are given to consolidate the concepts discussed; • The classroom lessons are complemented by at least one lesson in a MSW facility.
Checking learning	• The oral examination is designed to test the student's theoretical and applicative knowledge, also on the basis of a short exercise; • As a minimum, the student will have to demonstrate that they are able to apply a mass balance to the solid waste dry fraction treatment chains shown in the course.
Teaching materials	• Course booklets; • Tchobanoglous, R.C.N. La Diega (2009). Ingegneria dei rifiuti solidi, McGraw-Hill Education, ISBN 978-88-386-6527-1.

(*): EC = education credits, where 1 EC = 8-hours study time in the classroom.

It is possible to observe that students attending the course must have basic skills in chemistry and physics.
The *Solid waste management* teaching unit of the MSc degree course explores all those aspects that are complementary to those already shown in the three-year course.
The course aims to deepen the processes for the treatment of the wet fraction from separate collection, intended for composting, anaerobic digestion or their combination. It also aims to deepen the processes for the treatment of the undifferentiated or residual fraction from separate collection, destined, as is common practice in the European Union, to mechanical-biological treatment plants. The course covers the thermal treatment of Refuse-Derived-Fuel (RDF) for energy recovery as well as the criteria for the design of safe landfills for the disposal of both hazardous and non-hazardous waste, according to the European and Italian legislations.
The course content is shown in Table 2.

Table 2. Contents of the course "Solid waste management", Master's degree in Environmental Engineering, Politecnico di Bari.

Course name	**Solid waste management and remediation of contaminated sites** [(*)] [(*)]**:** The course is structured in following 2 modules: 1. Solid waste management, concerning solid waste; 2. Remediation of contaminated sites, concerning the remediation of contaminated sites **Here, only the solid waste module (Solid waste management) is discussed in more detail.**
Course objectives	**Expected learning outcomes:** • The course aims to introduce students to the techniques and processes useful for the correct management of waste from municipal and industrial activities (reduction/reuse/recovery of secondary raw materials and energy/disposal)
Pre-requisites	**Knowledge of Chemistry and Environmental Protection Technologies, developed in the BSc degree in Civil and Environmental Engineering**
Course contents (6 EC)	• **Regulatory framework concerning MSW and Special Waste (0.5 EC)** at European and Italian level; • **Recycling and material recovery (1.5 EC):** Recycling of waste and recovery of secondary raw materials. Mechanical pre-treatments: particle size reduction, separation. Chemical-physical inertisation treatments. Biological treatments; • **Energy recovery (2 EC):** Waste and Refuse Derived Fuel (RDF) incineration; Flue gas cleaning.; • **Landfilling (2 EC):** Classification of landfills according to the European and Italian legislation. Elements of landfill design, construction and management.
Teaching methods	• Lectures are conducted with the aid of slides; • During the lectures some numerical examples will be given to consolidate the concepts discussed; • The classroom lessons will be complemented by at least one lesson in a MSW facility.
Checking learning	• The oral examination is designed to test the student's theoretical and applicative knowledge, also on the basis of a short exercise; • As a minimum, the student will have to demonstrate that he/she is able to apply a mass balance to the solid waste dry fraction treatment chains shown in the course.
Teaching materials	• Course booklets; • Tchobanoglous, R.C.N. La Diega (2009). Ingegneria dei rifiuti solidi, McGraw-Hill Education, ISBN 978-88-386-6527-1.

[(*)]: EC = education credits, where 1 EC = 8-hours study time in the classroom

It is possible to observe that students attending the course must have basic skills in chemistry and environmental protection technologies.
The demand for these didactic units, as well as for the whole study manifesto, comes from the stakeholders of the territory, such as professional orders, private companies and public administrations.

7.2 Identification of Institutions Programs of Partners. The case of the Hamburg University of Technology (Germany)

7. Data input

8. Regulations related to the Degree Courses identified

The didactical offer on topics related to solid waste management at the TUHH is predominant at M.Sc. level, with a total of 5 modules (6 ECTS each), whereas one 6 ECTS module is taught at bachelor level. In addition to technical modules, students of the TUHH are required to take so-called non-technical lecture, i.e. those aiming to increase the student's soft skills as well as those dealing with societal and/or economic issues. In this sense, two non-technical courses dealing with the topics of Circular Economy and Sustainability are offered for Master level students, whereas one non-technical course is offered at Bachelor's level.

Table 3 provides an overview of the offered modules and courses as well as the teaching method used.

Table 3. List of modules and courses offered at the TUHH at Bachelor and Master level dealing with solid waste management and treatment.

Level	Title	Teaching method [(a)]	Workload
Bachelor Technical Module	Waste and Soil 1. Waste resource Management 2. Waste, Biology and Soil	Lecture	6 ECTS. Independent Study Time: 110, Study Time in Lecture: 70 1. 3 h/week lecture 2. 2 h/week lecture
Master Technical Module	Special Aspects of Waste Resource Management 1. Advanced Topics in Waste Resource Management 2. International Waste Management	Problem-based Learning	6 ECTS. Independent Study Time: 110, Study Time in Lecture: 70 3. 3 h/week lecture 4. 2 h/week lecture
Master Technical Module	Waste and Energy 1. Waste Recycling Technologies 2. Waste to Energy	1. Lecture 2. Problem-based Learning	6 ECTS. Independent Study Time: 110, Study Time in Lecture: 70 1. 3 h/week lecture 2. 2 h/week lecture
Master Technical Module	Waste Treatment Technologies 1. Biological Waste Treatment 2. Waste and Environmental	1. Problem-based	6 ECTS. Independent Study Time: 110, Study Time

	Chemistry	Learning 2. Practical Course	in Lecture: 70 1. 3 h/week lecture 2. 2 h/week lecture
Master Technical Module	Sustainability and Risk Management 1. Environment and Sustainability 2. Safety, Reliability and Risk Assessment	Lecture	6 ECTS. Independent Study Time: 124, Study Time in Lecture: 56 1. 2 h/week lecture 2. 2 h/week lecture
Master Technical Module	Waste Treatment and Solid Matter Process Technology 1. Solid Matter Process Technology for Biomass 2. Thermal Waste Treatment	Lecture	6 ECTS. Independent Study Time: 110, Study Time in Lecture: 70 1. 2 h/week lecture 2. 3 h/week lecture
Master Non-technical course	Social challenge plastic recycling	Challenge-based learning	2 ECTS. Independent Study Time: 32, Study Time in Lecture: 28
Master and Bachelor Non-technical course	TUHH goes circular - Sustainability in Research, Education and campus management	Problem-based learning	2 ECTS. Independent Study Time: 32, Study Time in Lecture: 28

[(a)]: The different teaching methods are explained below.

In this regard, there are typically three categories of teaching in the TUHH: (i) lectures and/or practical courses; (ii) problem-based learning; (iii) challenge-based learning.

Lectures and seminars are typically structured in two main parts: classroom lectures and small exercises sessions, whereas practical courses usually take place in laboratories. With problem-based learning, the students are given an open-ended problem or a scenario and are requested to come up with a solution.
Challenge-based learning (CBL) is a novel pedagogical approach which definition is provided by Kohn Rådberg as follows (Kohn Rådberg et al. 2020, page 2): *Challenge-based learning takes places through the identification, analysis and design of a solution to a sociotechnical problem. The learning experience is typically multidisciplinary, involves different stakeholder perspectives, and aims to find a collaboratively developed solution, which is environmentally, socially and economically sustainable*. CBL differs from PBL in that, given a big idea to be tackled, the students identify the challenge they want to confront with. The advantage of this approach is that it has the potential to bring in the same

group students from different backgrounds, levels and study programs while working with researchers, entrepreneurs and other stakeholders to find solutions to current challenges. In this context, the role and potential of this novel pedagogical approach is perceived as key to be transferred to the Asian HEI involved in the SWAP project. In fact, since the students have the possibility to face a real challenge with the contribution of different stakeholders, they increase their problem-solving, communication and teamwork skills as well as technical knowledge, thereby increasing their employability.

9. Teaching courses

The contents of the modules and courses taught at the TUHH and listed in Table 8 vary both in terms of topics and in terms of teaching objectives. The one module offered at Bachelor level aims at providing the students the means to know how to describe relevant waste resources as well as the principles for the collection, the treatment of waste resources and primary resource mining.

On the other hand, the modules at master level have a more practical imprint and aim to train students so that they are eventually capable of choosing and designing suitable processes for specific waste treatment with respect to different national and cultural contexts, while evaluating the ecological and economic impacts as well as the technical effort of different technologies and management systems. Table 9 provides an overview of the contents and learning objectives of each course listed in Table 4.

Table 4. Contents of the modules and courses offered at TUHH and dealing with solid waste treatment and management.

Module name and courses	**Waste and Soil** 1. **Waste resource Management** 2. **Waste, Biology and Soil**
Module's objectives	**Expected learning outcomes:** The students know relevant waste resources as well as the principles for the collection, the treatment of waste resources and primary resource mining. They have knowledge about resource strategies, like decoupling and urban mining as well as the consequences of worldwide demand on renewable and non-renewable resources. Additional, obstacles and efforts of waste resource management and urban mining and new technological approaches are identified. The students are capable to make their own decisions with respect to the selection of suitable resources and ecologically/economically feasible treatment processes.
Pre-requisites	Knowledge of Chemistry
Course contents (6 EC)	**1. Waste resource Management:** Decoupling; Waste as a resource; Resource Biomass - Food Waste; Resource Biomass - Waste Wood; Resource Biomass- Paper; Ores and industrial minerals - Aluminum; Ores and industrial minerals- Gold; Ores and industrial minerals - Copper; Fossil Energy carrier- RDF; Fossil Energy carrier – Biogas; Fossil Energy carrier – Plastic; Construction Material. **2. Waste, Biology and Soil** Ecological and economic consequences as well as appropriate alternatives to conventional treatment of organic wastes, focusing integrated solution and concepts. Therefore, biological processes in

	soil, composting and anaerobic digestion are the main topic of the course. Based on general roles, biological basics, entropic discussions and efficiency definition, specific technologies and combined or integrated processes will be taught. Seldom-used technologies, foreign developments and innovative own research concepts are presented. Students learn recycling of organic wastes in the context of sustainable material management and learn to develop systematic solutions. Topics are, e.g., Basics of biology; degradation principles of organic substances in soil and waste; contaminate soils and sites; identification, evaluation and remediation of contaminate soils; microbiological remediation processes.
Checking learning	Written exam
Teaching materials	• Course booklets; • Decoupling natural Resource Use and Environmental impacts from economic growth UNEP 2011 • Waste Management. Bernd Bilitewski; Georg Härdtle; Klaus Marek (Eds.), ISBN: 9783540592105, Springer
Module name and courses	Special Aspects of Waste Resource Management 1. Advanced Topics in Waste Resource Management 2. International Waste Management
Module's objectives	**Expected learning outcomes:** The students are able to describe waste as a resource as well as advanced technologies for recycling and recovery of resources from waste in detail. This covers collection, transport, treatment and disposal in national and international contexts. Students are able to select suitable processes for the treatment with respect to the national or cultural and developmental context. They can evaluate the ecological impact and the technical effort of different technologies and management systems. Students can work together as a team of 2-5 persons, participate in subject-specific and interdisciplinary discussions, develop cooperated solutions and defend their own work results in front of others and promote the scientific development of colleagues. Furthermore, they can give and accept professional constructive criticisms.
Pre-requisites	Basics in waste treatment technologies
Course contents (6 EC)	1. Advanced Topics in Waste Resource Management Development of waste management, legislation, collection, transportation and organisation of waste management, costs, fees and revenues. 2. International Waste Management Waste avoidance and recycling are the focus of this lecture. Additionally, waste logistics (Collection, transport, export, fees and taxes) as well as international waste shipment solutions are presented. Other specific wastes, e.g. industrial waste, treatment concepts will be presented and developed by students themselves. Waste composition and production on international level, waste logistic, collection and treatment in emerging and developing countries.

Checking learning	Team presentation
Teaching materials	• Course booklets; • Basel convention
Module name and courses	Waste and Energy 1. Waste Recycling Technologies 2. Waste to Energy
Module's objectives	**Expected learning outcomes:** Students are able to describe and explain in detail techniques, processes and concepts for treatment and energy recovery from wastes. The students are able to select suitable processes for the treatment and energy recovery of wastes. They can evaluate the efforts and costs for processes and select economically feasible treatment Concepts. Students are able to evaluate alternatives even with incomplete information. Students are able to prepare systematic documentation of work results in form of reports, presentations and are able to defend their findings in a group.
Pre-requisites	Basics of process engineering
Course contents (6 EC)	1. Waste Recycling Technologies • Fundamentals on primary and secondary production of raw materials (steel, aluminum, phosphorous, copper, precious metals, rare metals) • Use and demand of metals and minerals in industry and society • collection systems and concepts • quota and efficiency • Advanced sorting technologies • mechanical pre-treatment • advanced treatment • Chemical analysis of Critical Materials in post-consumer products • Analytical tools in Resource Management (Material Flow Analysis, Recycling Performance Indicators, Criticality Assessment, statistical analysis of uncertainties) 2. Waste to Energy • Thermal Process (incinerator, RDF combustion) • Biological processes (Wet-/Dry fermentation) • technology, energy, emissions, approval, etc. • Group work: design of systems/plants for energy recovery from waste ○ Input: waste (fraction collection and transportation, current quantity, material flows, possible amount of development)

	○ Plant (design, process diagram, technology, energy production) ○ Output (energy quantity/type, by-products) ○ Costs and revenues ○ Climate and resource protection (CO_2 balance, substitution of primary raw materials/fossil fuels) ○ Location and approval (infrastructure, expiration authorization procedure) ○ Focus at the whole concept (advantages, disadvantages, risks and opportunities, discussion)
Checking learning	Team presentation
Teaching materials	Course booklets
Module name and courses	Waste Treatment Technologies 1. Biological Waste Treatment 2. Waste and Environmental Chemistry
Module's objectives	**Expected learning outcomes:** The module aims possess knowledge concerning the planning of biological waste treatment plants. Students are able to explain the design and layout of anaerobic and aerobic waste treatment plants in detail, describe different techniques for waste gas treatment plants for biological waste treatment plants and explain different methods for waste analytics.
Pre-requisites	Basics of chemistry and biology
Course contents (6 EC)	1. Biological Waste Treatment • Introduction • biological basics • determination process specific material characterization • aerobic degradation (Composting, stabilization) • anaerobic degradation (Biogas production, fermentation) • Technical layout and process design • Flue gas treatment • Plant design practical phase 2. Waste and Environmental Chemistry The participants are divided into groups. Each group prepares a transcript on the experiment performed, which is then used as basis for discussing the results and to evaluate the performance of the group and the individual student. In some experiments the test procedure and the results are presented in seminar form, accompanied by discussion and results evaluation. Experiments are e.g. screening and particle size determination; Fos/Tac; AAS; calorific value.
Checking learning	Team presentation
Teaching materials	Course booklets
Module name and courses	Sustainability and Risk Management

	1. Environment and Sustainability 2. Safety, Reliability and Risk Assessment
Module's objectives	**Expected learning outcomes:** Students are able to describe single techniques and to give an overview for the field of safety and risk assessment as well as environmental and sustainable engineering, in detail: basics in safety and reliability of technical facilities; safety and reliability analysis methods; risk assessment; Production and usage of bio-char; energy production and supply; sustainable product design.
Pre-requisites	none
Course contents (6 EC)	1. Environment and Sustainability This course presents actual methodologies and examples of environmental relevant, sustainable technologies, concepts and strategies in the field of energy supply, product design, water supply, wastewater treatment or mobility. The following list show examples. Production and Usage of Bio-char Energy production with algae Environmental product design Clean Development mechanism (CDM) Democracy and Energy; new Concepts for a sustainable Energy Supply; recycling of Wind Turbines Alternative Mobility Disposal of Nuclear Wastes Waste2Energy Offshore Wind energy 2. Safety, Reliability and Risk Assessment An introduction in safety and risk assessment is given and some typical problems of structural and environmental engineering are treated: • basics in safety and reliability of technical facilities • safety and reliability analysis methods • risk assessment • practical examples and excursions • discussions and presentations
Checking learning	Written elaboration
Teaching materials	Course booklets
Module name and courses	Waste Treatment and Solid Matter Process Technology 1. Solid Matter Process Technology for Biomass [(a)] 2. Thermal Waste Treatment
Module's objectives	**Expected learning outcomes:** The students can name, describe current issue and problems in the field of thermal waste treatment and particle process engineering and contemplate them in the context of their field. The industrial application of unit operations as part of process engineering is explained by actual examples of waste incineration technologies and solid biomass processes. Composition, particle sizes, transportation and dosing, drying and agglomeration of renewable resources and wastes are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, electricity, heat and mineral recyclables.
Pre-requisites	Basics of thermo dynamics, fluid dynamics, chemistry
Course contents	2. Thermal Waste Treatment

(4 EC)	• Introduction, actual state-of-the-art of waste incineration, aims. legal background, reaction principals • basics of incineration processes: waste composition, calorific value, calculation of air demand and flue gas composition • Incineration techniques: grate firing, ash transfer, boiler • Flue gas cleaning: Volume, composition, legal frame work and emission limits, dry treatment, scrubber, de-nox techniques, dioxin elimination, Mercury elimination • Ash treatment: Mass, quality, treatment concepts, recycling, disposal
Checking learning	Written exam
Teaching materials	• Course booklets • Thomé-Kozmiensky, K. J. (Hrsg.): Thermische Abfallbehandlung Bande 1-7. EF-Verlag für Energie- und Umwelttechnik, Berlin, 196 - 2013.
Module name and courses	Non-technical courses 3. Solid Matter Process Technology for Biomass [(a)] 4. Thermal Waste Treatment
Module's objectives	**Expected learning outcomes:** mparts skills that, in view of the TUHH's training profile, professional engineering studies require but are not able to cover fully. Self-reliance, self-management, collaboration and professional and personnel management competences. The department implements these training objectives in its teaching architecture, in its teaching and learning arrangements, in teaching areas and by means of teaching offerings in which students can qualify by opting for specific competences and a competence level at the Bachelor's or Master's level. The teaching offerings are pooled in two different catalogues for nontechnical complementary courses. Students can • explain specialized areas in context of the relevant non-technical disciplines, • outline basic theories, categories, terminology, models, concepts or artistic techniques in the disciplines represented in the learning area, • different specialist disciplines relate to their own discipline and differentiate it as well as make connections, • sketch the basic outlines of how scientific disciplines, paradigms, models, instruments, methods and forms of representation in the specialized sciences are subject to individual and socio-cultural interpretation and historicity, • communicate in a foreign language in a manner appropriate to the subject.

Pre-requisites	none
Course contents (4 **EC)**	1. TUHH goes circular - Sustainability in Research, Education and campus management It addresses environmental challenges and seeks solutions in the field of responsible consumption. The students are being introduced to the concept of environmental footprint and are going to reflect their personal consumer behaviour in a practical task. The findings are going to be put into relation to resource consumption, waste production, consumer research and marketing. Therefore, the students will in a first part form groups of maximum five researchers and develop a method to measure one category of consumption and survey questions. In the second part, the students will launch and participate in the survey. Finally, the results and interpretation will be presented in the initial groups. 2. Social challenge plastic recycling The aim of the seminar is to conduct comprehensive research that is well-founded in terms of content and concept in order to create a basis for actionable and sustainable solutions addressing current challenges. The seminar will focus on potential contributions of social actors, such as consumers. The concept of Challenge Based Learning includes the involvement of external experts if needed and in response to specific questions.
Checking learning	Presentation
Teaching materials	• Course booklets • Ellen MacArthur Foundation, 2017. The New Plastics Economy: Rethinking the future of plastics & catalysing action. • Garcia, Jeannette M., and Megan L. Robertson. "The future of plastics recycling" Science (2017).

[(a)]: This course does not deal directly with solid waste and is left out of the scope of this report.

7.3 Towards Best Practices definition

On the basis of the contents of the previous chapters, the key elements for the construction of a single university teaching within the SWAP project are identified and elaborated in Table 5.

Table 5. Summary of the main elements necessary for the construction of a solid waste course.

Summary elements	Description
On the need for solid waste courses in engineering curricula (interaction between the university and territorial stakeholders)	• Consultation with stakeholders in the Apulia region, where the Politecnico di Bari operates, highlighted the need to provide solid waste expertise for both Bachelor and Master degree engineers; • Stakeholders also highlighted the importance of providing students with legislative knowledge on the solid waste topic, taking into account European and Italian legislation, as well as design knowledge to enable students to design waste treatment and disposal plants; • Furthermore, stakeholders highlighted the opportunity to divide the

	waste contents in such a way as to focus first on the dry fraction of MSW, generally destined for recovery/recycling/reuse, and then on the MSW wet fraction, generally involved in composting/anaerobic digestion processes; • Stakeholders also highlighted the need to look more closely at thermal treatment of waste (combustion, gasification, pyrolysis) and the design criteria for landfills, so that they are environmentally friendly.
On prerequisites	Pre-requisites should be carefully defined. As examples only, the Politecnico di Bari courses are listed below. • The first course, "Environmental Protection Technologies", requires a basic knowledge of physics and chemistry by the students. • The second course, "Solid waste management", requires basic knowledge of chemistry and the contents of the previous course of "Environmental Protection Technologies".
On the duration of the courses	It is appropriate to establish the correct duration of courses. As example only, the duration of Politecnico di Bari courses are listed below: • In total, the courses must have a duration of 12 EC, divided into two modules of 6 EC.
On course content	It is appropriate to define the contents of the course by first starting with the current state of waste management in Asian countries and then proposing upgrades. These upgrades must take into account the fundamental elements of the European waste management strategy, which include: prevention; recycling; material recovery; energy recovery; and landfill. In addition, the upgrades must be commensurate with their real feasibility. As an example, the contents of courses at Politecnico di Bari are given below: The first course, "**Environmental Protection Technologies**", introduces the student to the subject of solid waste. Firstly, legislative notions are to be provided, covering European and Italian legislation. This legislation is based on different waste management strategies that provide for the minimisation of waste production, separate collection and subsequent treatment aimed at material and energy recovery. The last strategic option is landfilling. After the regulatory review, the following topics will be developed: • Characteristic data on per capita production of municipal waste: • MSW collection methods; • Technologies and processes for waste separation and size reduction; • The industry of recycling and recovery of materials from MSW. The second course, entitled "**Solid Waste Management**", is complementary to the previous one. The course contents are as follows: • Management of the wet fraction of solid urban waste, through the in-depth study of aerobic (composting) and anaerobic treatment processes and their combination;

	• Management of the residual fraction from separate collection or the undifferentiated fraction, through in-depth study of Mechanical-Biological Treatments (MBT); • Treatment of the dry fraction from mechanical-biological treatment plants in order to produce end-of-waste RDF (Refuse Derived Fuel); • Thermal treatment of waste-derived fuel by combustion in grate furnaces and fluidized bed furnaces; • Disposal of residual waste, not otherwise recoverable, in landfills for hazardous and non-hazardous waste; • Design of environmental facilities for the treatment of emissions from composting, TMB and thermal treatment plants. It is possible to observe an important aspect: *the chain training*. The contents are never repeated, and what is given in the first basic course is taken for granted in order to be able to follow the topics of the next course.
On teaching methods	Teaching methods include theoretical and practical lectures. If present, study visits to installations in the area must be planned.
On teaching materials	The teaching material should be specially prepared for Asian course students, based on teaching material used in Italy and worldwide.

7.4 Proposed Courses for Asian Partners HEIs

From what has been shown so far, and taking into account the outputs from Task 1.1, a list of subjects is here proposed as an additional outcome of this task. The list is indicative and does not represent a definitive course structure in any way. However, it should be regarded as a supporting document for Asian Partners HEIs to better identify and choose the courses that need to be updated and, if that is the case, if a new course needs to be set up (objective of Task 1.4). The following tables present the suggested contents of the courses.

Lecture module Bachelor level (3 ECTS = 90 hours study time)

Introduction to Sustainable Solid Waste Management and Circular Economy

Number	Title of lecture and seminar
1	Introduction Waste Management and Circular Economy
2	Waste types, streams, characterisation and waste analysis
3	Waste collection, transportation and transfer
4	Overview on waste treatment technologies
5	Biomass (Types, characterization, concepts and technologies)
6	Residual waste treatment and recovery
7	Landfill (Introduction, elements and operation)
8	Landfill (After care)

9	Waste associated regulations

Lecture module Bachelor level (3 ECTS = 90 hours study time)

Secondary raw materials life cycle – A Circular Economy for resources recovery

Number	Title of lecture
1	Introduction of Life cycle assessment and eco balance in waste management and circular economy
2	Institutional framework, rules and responsibilities
3	Treatment of Organic Waste (composting and anerobic)
4	Mechanical-Biological-Treatment (MBT)
5	Waste-to-Energy (WtE)
6	Basics Packaging waste (plastics, glass, paper, metal)
7	Waste Electrical and Electronic Equipment (WEEE)
8	Construction and Demolition Waste
9	Case study – Biowaste treatment facility in one Asian Country (tbd)
10	Case study – Plastic packaging waste recycling facility in one European Country (tbd)

Lecture module Master level (1st option) (3 ECTS = 90 hours study time)

Technical Aspects of Waste Management (with Problem-based learning approach)

Number	Title of lecture
1	Waste Management and treatment – Recap bachelor
2	Packaging Waste (plastics, glass, paper, metal)
3	Urban mining (construction and demolition waste, WEEE)
4	Industrial and Hazardous Waste
5	Technology of Thermal waste treatment and Emission control
6	Biological Treatment plant design (anaerobic digestion and composting) – Problem based learning → students will be presented with initial data (composition and characteristics of the waste, available infrastructure, etc.) and will need to design a biowaste treatment facility in groups. Supervision of the teachers throughout the semester.

Lecture module Master level (2nd option) (3 ECTS = 90 hours study time)

Advanced Waste Management Aspects in a Circular Economy

Number	Title of lecture
1	International Regulations, Treaties and Goals (SDG) in Circular Economy
2	Logistics (concept, strategies, business models, operating and costs)
3	Policies and tools for the Circular Economy (waste hierarchy, EPR, recycling targets and incentives)
4	International waste management
5	Regulations and Framework conditions in the region
6	Problem-based learning: group work to calculate and design logics for collection and treatment of MSW generated by a city in the region.

Lecture module TVET level

Advanced Waste Management Aspects in a Circular Economy

Number	Title of lecture
1	Introduction Waste Management and Circular Economy
2	Waste management and treatment technologies
3	Green business models and entrepreneurship in SWM sector
4	Practical course: biowaste treatment operation[a]
5	Practical course: recycling E-Waste[b]
6	Practical course: MSW characterization and sorting[b]

[a]Possibly, the trainee should do this in an existing WM facility.

[b]5 and 6 can be done in the Training Hubs to be set up during SWAP Project.