# Nationally Appropriate Mitigation Action (NAMA) programme for the solid waste sector of Viet Nam

## – Design Study –

## “Waste-to-Resources for Cities in Viet Nam”

April 2016

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## Executive Summary


**Nationally Appropriate Mitigation Actions** (NAMAs) refer to strategies, programmes and projects that developing countries may voluntary adopt in order to support greenhouse gas emission reduction initiatives and sustainable development goals in their respective countries. Viet Nam has been one of the most active countries in the Asia-Pacific region in the development of NAMAs, with several initiatives conducted over the past few years. Among these, the government of Viet Nam has identified the management of solid waste as one the sectors of interest for NAMA development.

As the population grows and the country quickly urbanizes, dealing with solid waste has become an increasing burden for both national and local governments alike. Although an estimated 85% of solid waste is collected in Viet Nam, most of it is disposed in dump sites, resulting in severe environmental degradation, the spread of disease vectors and the emissions of methane, a greenhouse gas.

The government of Viet Nam recognizes the need to shift from current waste management practices to approaches that are focused in the recovery of resources from waste. Several policy documents have been approved by the national government in support of such approaches, amongst them the **National Strategy for Integrated Management of Solid Waste up to 2025 and Vision towards 2050** (2009), which sets ambitious targets for years 2020 and 2025 for the collection and treatment of waste. Other policy documents exist that are supportive of "waste-to-resource" approaches and a wider adoption of the principles of Reducing, Reusing, Recycling (3R), including the **National Climate Change Strategy** (2011) and the **Intended Nationally Determined Contribution** (INDC) of Viet Nam to the new climate change treaty that was agreed in Paris in December 2015.

In spite of the ambition of existing policies and strategies, to which the national government should be commended for, several difficulties hinder the implementation of "waste-to-resource" initiatives in Viet Nam. These have been identified with this study and are summarized as follows:

- **Lack of guidelines and regulations**, especially at local level, to stimulate and/or enforce the implementation of the targets laid out on the national policy documents;
- **Insufficient policy, regulatory and market incentives** for stimulating investment on solid waste management infrastructure which is compliant with the principles of Reducing, Reusing, Recycle (3R) and "waste-to-resource" approaches;
- **Institutional arrangements** for the climate change and waste sectors in Viet Nam are complex, often unclear and with an overlap of roles and responsibilities;
- **Limited funds** to finance "waste-to-resource" projects and initiatives at the local level;
- A general **lack of capacities, know-how and expertise** on "waste-to-resource" methods and technologies.

These barriers are expected to be overcome, partially or in full, with the support of the NAMA programme whose design elements are laid out in this study. This programme, which has been titled

as “**Waste-to-Resources for Cities in Viet Nam**”, has as an **overarching goal** the reduction of greenhouse gas emissions from the waste sector through the application of integrated solid waste management practices that support the conversion of waste into resources, while at the same time contributing to sustainable development goals in Viet Nam.

The NAMA will address the barriers identified through the **establishment of a policy and institutional framework** that will:

- **Stimulate and encourage cities to voluntarily propose their own targets for reusing, reducing and recycling** solid waste, based on those laid out on the National Strategy for Integrated Management of Solid Waste up to 2025 and Vision towards 2050;
- Establish a **NAMA Management Board** to operate as a “one-stop shop” and steering committee for the activities under the NAMA, and as a coordinating entity among ministries with a stake in the solid waste sector;
- Set-up of a **dedicated financing vehicle** to channel funds from international and national sources to cities, provinces, and other entities, including the private sector, that implement measures aligned with those endorsed by the NAMA;
- Create **incentive schemes at national, provincial and city level** that enable the financial-economical viability of “waste-to-resource” initiatives. Incentives include, but are not restricted to, the payment of tipping fees to waste treatment plant operators, the set-up of local programmes for the purchase of compost, tax rebates on equipment, etc.
- Provide **technical and operational support** to officials and practitioners in the form of training programmes, “on-site” assistance by technical experts, the sharing of good-practices, both nationally and internationally, etc.

All cities in Viet Nam are eligible to be part of the NAMA as long as they voluntarily implement some of the measures endorsed by the programme. Below is a summary of **eligible measures of the Waste-to-Resource NAMA**, which will be subject to some type of monitoring, verification and reporting (MRV) procedures when implemented in cities:

i) Reduction of solid waste generated and implementation of waste segregation practices, preferably at source;

ii) Diversion of waste streams from final disposal sites, with diverted waste being treated applying the following measures:

   a. Biological treatment of the organic component of waste, particularly through composting and anaerobic digestion;

   b. Recovery, reuse and recycling of inorganic waste;

   c. Physical methods for treating waste, including the production of refuse-derived fuel and related briquetting techniques;

d. Implementation of integrated and sustainable waste management approaches in line with the principles of 3R, including good practices identified in Viet Nam such as the **Integrated Resource Recovery Centre (IRRC)** model;

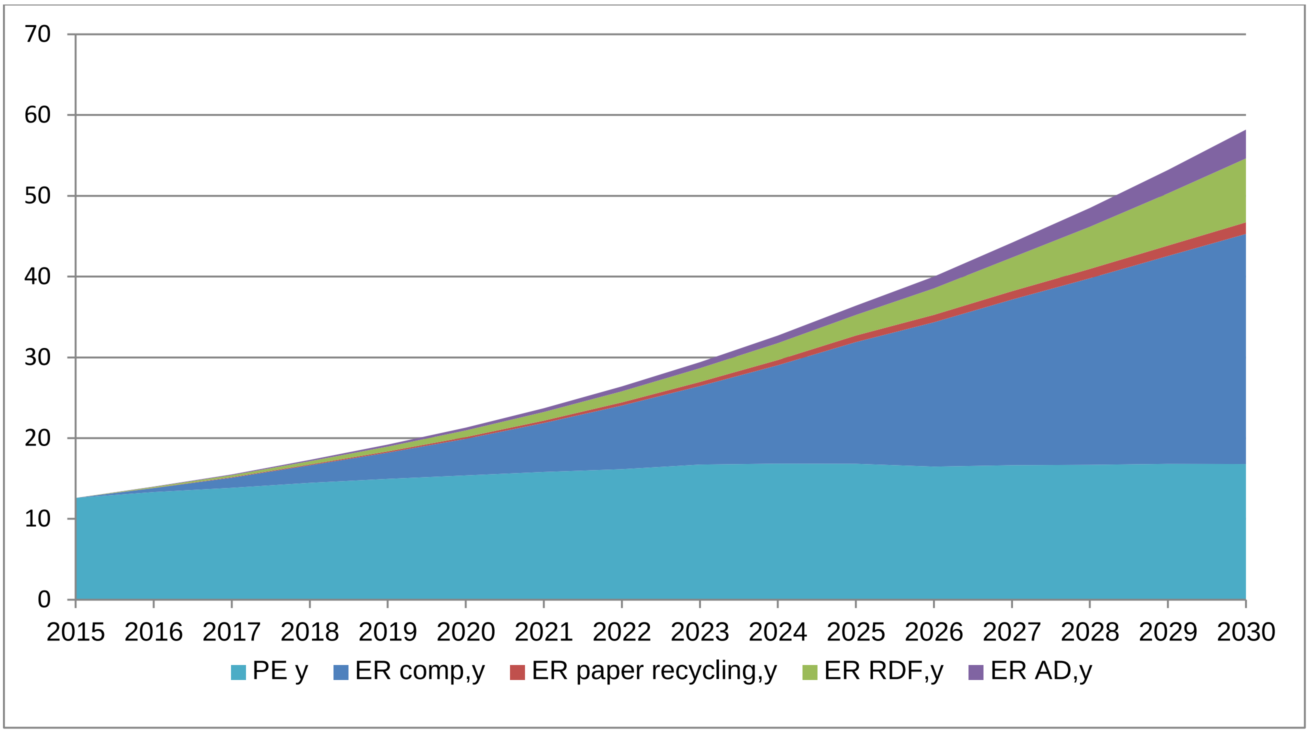
e. Strategies and policies designed at city or provincial level for a "**zero waste**" or "**carbon neutral waste sector**".

The eligibility of measures that are in line with 3R principles and waste-to-resource approaches but are not included in any of those laid out in this study will be considered on a case-to-case-basis by the **NAMA Management Board** referred above. This Board is proposed to be managed by the **Department of Science, Technology and Environment (DSTE)**, under the Ministry of Construction.

The implementation of the NAMA will result in **several benefits to Viet Nam**. Among these, the NAMA will lead to a cleaner and healthier environment through the adoption of improved waste collection and treatment methods, create business opportunities along the waste management value chain, and contribute to improved living conditions of populations throughout the country. The NAMA is fully aligned with existing national policies on climate change and solid waste management, and it also supports Viet Nam in achieving several **Sustainable Development Goals (SDGs)**, especially SDGs 11, 12 and 13, on more sustainable cities, increased sustainable consumption and production patterns, and enhanced climate action, respectively.

A **baseline** and **emission reduction (NAMA) scenarios** were modelled to assess the GHG emission reduction impacts of implementing the measures endorsed by the NAMA. The baseline – or business-as-usual – scenario assumes that ongoing practices of disposing and not treating waste continue unchanged, with waste generation rates increasing annually by 10% and waste compositions remaining the same over the 2010-2030 period. Under this scenario, it is expected that the solid waste sector of Viet Nam will be generating 2030 58.2 million ton of carbon dioxide equivalent (t $CO_2$eq) in year 2030, up from 14 million t $CO_2$eq in 2016.

The NAMA scenario reflects a complete transformation of Viet Nam's solid waste sector from practices currently observed, whereby all waste generated in 2030 is collected and treated through the methods and technologies supported by the NAMA, i.e. through composting (60%), recycling (20%), anaerobic digestion (10%) and the production of refuse-derived fuel (10%). This is expected to reduce the emissions of greenhouse gases from the solid waste sector of Viet Nam by 71% by 2030, i.e. by 41.4 t $CO_2$eq in relation to the business-as-usual scenario. Results of the modeling are shown in the following graph:

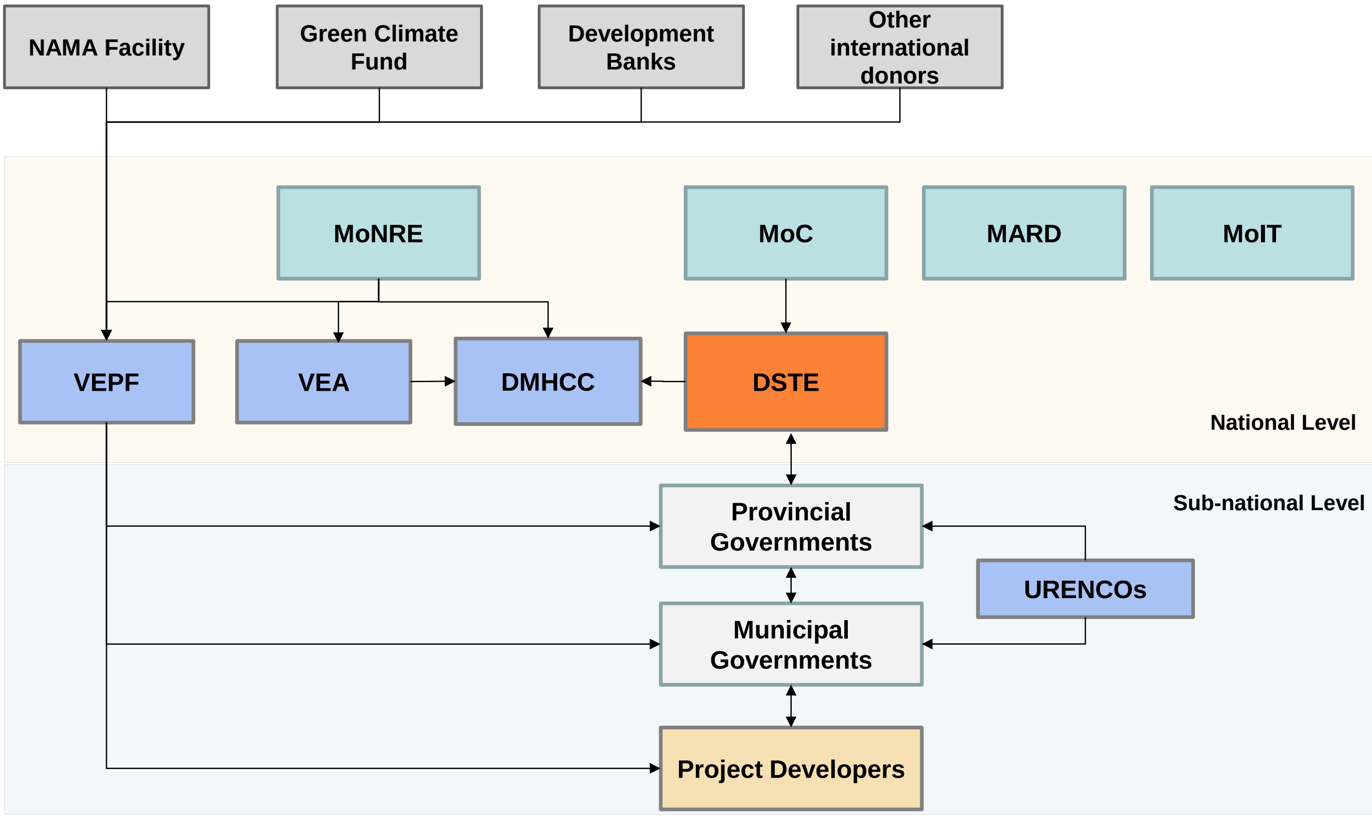



**Graph above** – Total emission reductions (expressed in million ton of $CO_2$eq) from the waste-to-resource NAMA. Legend: PE: project emissions, ER: Emission Reductions; comp: composting; RDF: refuse-derived fuel; AD: anaerobic digestion.

The implementation of these ambitious targets is estimated to require **an average minimum investment of 110 million USD per year** in waste treatment facilities up until 2030. It is expected that 80% of these investment requirements could be met by domestic sources of financing, both public and private, with the remainder (approx. 22 million USD per year) proposed to be made available through international climate support programmes. The required support could be channeled in the form of loans and grants through international climate financing mechanisms (particularly the Green Climate Fund), bilateral ODA, market-based schemes, and/or “pay-for-performance” programmes. Depending on the outcomes and impacts resulting from the piloting phase of the NAMA, international climate funding could account for a higher proportion of the total costs of implementing the programme.

As part of this NAMA, it is proposed that the **Viet Nam Environmental Protection Fund (VEPF)** is established as the **national-level financing entity** that is responsible for gathering funds from both national and international sources and disbursing them to cities, provinces and other eligible entities that implement activities that can be considered as part of the NAMA. An illustration of the institutional architecture proposed for the NAMA is provided in the following page.

Prior to the full deployment of the NAMA programme, a **piloting phase** is proposed to be conducted for at least 1.5 years. During this phase, specific elements of the programme will be tested and operationalized, including the basic requirements for the MRV system and a methodology to measure sustainable development benefits (“co-benefits”). This phase would also serve to set-up the institutional framework of the NAMA and build-up the capacities of key individuals working on a day-to-day basis in the coordination and implementation of the programme.




**<u>Figure above</u>** – Proposed organizational structure for the Waste-to-Resource NAMA.

## List of Acronyms Used

| | |
|---|---|
| **3R** | Reduce, Reuse, Recycle |
| **AD** | Anaerobic Digestion |
| **ADB** | Asian Development Bank |
| **BAU** | Business-as-usual |
| **BUR** | Biennially updated reports |
| **CAPEX** | Capital Expenditures |
| **CBO** | Community-based organization |
| **CDM** | Clean Development Mechanism |
| **CER** | Certified Emission Reduction |
| **$CH_4$** | Methane |
| **$CO_2$** | Carbon dioxide |
| **DMHCC** | Department of Hydrology, Meteorology and Climate CHange |
| **DOC** | Department of Construction (at Province or City level) |
| **DONRE** | Department of Natural Resources and Environment (at Province or City level) |
| **DSTE** | Department of Science, Technology and Environment (Ministry of Construction) |
| **ESCAP** | United Nations Economic and Social Commission for Asia and the Pacific |
| **FAO** | Food and Agriculture Organization |
| **FOD** | First Order Decay method |
| **GHG** | Greenhouse gas |
| **GIZ** | Deutsche Gesellschaft für Internationale Zusammenarbeit |
| **HCMC** | Ho Chi Minh City |
| **HDPE** | High-density polyethylene |
| **IMHEN** | Institute of Meteorology, Hydrology and Climate Change of Vietnam |
| **INDC** | Intended Nationally Determined Contributions |
| **IRRC** | Integrated Resource Recovery Centre |
| **ISPONRE** | Institute of Strategy and Policy of Natural Resources and Environment |
| **JICA** | Japan International Cooperation Agency |
| **LULUCF** | Land Use, Land-Use Change and Forestry |
| **MARD** | Ministry of Agriculture and Rural Development |
| **MOC** | Ministry of Construction |
| **MOFA** | Ministry of Foreign Affairs |
| **MOH** | Ministry of Health |
| **MOIT** | Ministry of Industry and Trade |
| **MONRE** | Ministry of Natural Resources and Environment |
| **MOST** | Ministry of Science and Technology |

| | |
|---|---|
| **MOT** | Ministry of Transport |
| **MPI** | Ministry of Planning and Investment |
| **MRV** | Monitoring, Reporting and Verification |
| **MSW** | Municipal Solid Waste |
| **NAMA** | Nationally Appropriate Mitigation Action |
| **NC** | National Communications |
| **ODA** | Official Development Assistance |
| **OPEX** | Operational Expenditures |
| **PPC** | People’s Committee |
| **RDF** | Refuse Derived Fuel |
| **REDD** | Reduced Emissions from Deforestation and Forest Degradation |
| **SDGs** | Sustainable Development Goals |
| **UNDP** | United Nations Development Programme |
| **UNEP** | United Nations Environment Programme |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **UNIDO** | United Nations Industrial Development Organization |
| **URENCO** | Urban Environment One Member Limited Company |
| **VEA** | Vietnam Environmental Agency |
| **VEPF** | Vietnam Environment Protection Fund |

# 1. Introduction

Nationally Appropriate Mitigation Actions (NAMAs) refer to a set of strategies, programmes and projects that developing countries can undertake on a voluntary basis in order to reduce their emissions of greenhouse gases (GHG). The concept of NAMA was first proposed in 2007, at the 13th Conference of the Parties Meeting of the United Nations Framework Convention on Climate Change (UNFCCC) held in Bali, Indonesia. Central to the concept of NAMAs is that mitigation actions should be framed in the context of sustainable development, and that they should be supported and enabled by international financing, technology, and capacity building[1].

At present, NAMAs are considered an important tool that developing countries can use to structure, promote and support their GHG emission reductions. In the Asia-Pacific region, Viet Nam has been one of the most active countries developing NAMA programmes[2], and over the past 4-5 years a number of initiatives has been carried out by national institutions, mostly related to the conceptualization of NAMA programmes and the set-up of capacities of relevant institutions, activities usually known as "NAMA-readiness" or "NAMA-preparedness". At the beginning of 2016, NAMA concepts had been finalized for major national sectors, including energy, agriculture and the cement industry.

The **management of solid waste**[3] is one of the priorities of Viet Nam's national government. Sustained economic growth and increasing consumption patterns have been driving solid waste generation rates, which have increased in 10-16% on an annual basis since the beginning of the century. As of 2011, approximately 26,000 ton of solid waste were generated per day in Viet Nam, with most of it being disposed in dump sites and unsanitary landfills without any prior treatment. This has led to severe environmental stress, including soil, water and air pollution, with negative impacts on populations. At the same time, local government authorities are incurring in increasingly higher costs just to collect and transport waste, with little or no value derived from these activities. Ongoing waste management practices are also major contributors to global climate change, as the decay of organic matter in disposal sites leads to emission of methane, a greenhouse gas.

The Government of Viet Nam recognizes the need for a paradigm shift in the way waste is managed towards approaches that privilege the **recovery of resources from waste** ("waste-to-resource"). This is reflected, for example, in the ambitous targets for the collection and treatment of waste that are laid out in the **National Strategy for Integrated Management of Solid Waste up to 2025 and Vision towards 2050**. However, several barriers – institutional, financial, technical, etc. – are hindering this transformational change. On the other hand, **NAMAs** are regarded as a vehicle that could support policymakers and practitioners in Viet Nam, both at national and local level, overcoming some of these gaps.

[1] UNFCCC), 2007, http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf

[2] For a reference on NAMA programmes developed in Asia and globally: http://www.nama-database.org/index.php/Main_Page.

[3] In the scope of this work, solid waste pertains to domestic waste streams originating from households, markets, commercial centers, offices, research facilities, schools, etc., generated both in urban and rural areas. This excludes industrial, medical, construction and electronic wastes.

It is in this context that the Government of Viet Nam, through the Ministry of Natural Resources and the Environment (MONRE), has mandated the **Institute of Meteorology, Hydrology and Climate Change of Vietnam (IMHEN)** to design a **NAMA programme** that could support a wider adoption of waste-to-resource approaches in Viet Nam, while at the same time contributing to sustainable development goals and a reduction in solid waste sector GHG emissions. This **NAMA programme** – which from this point onwards is referred interchangeably as "NAMA", "programme", "NAMA programme" or "Waste-to-Resource NAMA" – has been named "**Waste-to-Resources for Cities in Viet Nam**".

The development of this NAMA has been structured along three main phases, as illustrated in figure 1.1:

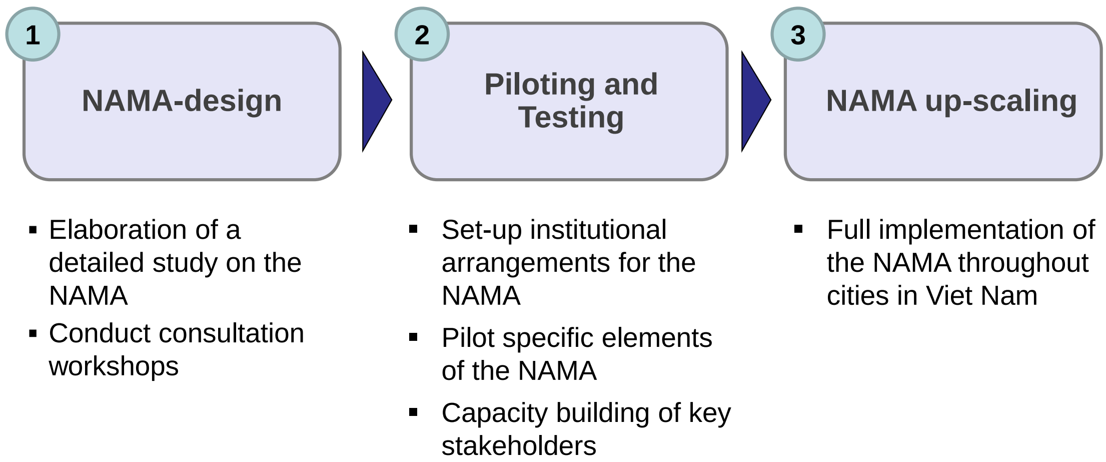



**Figure 1.1** – Development process of the NAMA "Waste-to-Resources for Cities in Viet Nam".

The purpose of **Phase I** is to come up with the design elements of the NAMA programme and obtain the support of relevant national stakeholders through formal and informal consultations. This is based on the premise that a NAMA can only be successfully implemented if it has strong domestic support. The central output of Phase I is the elaboration of a "**NAMA-design study**", which is the document hereby presented. The goal of this study is to formulate the building blocks of the NAMA programme and detail its key design features. The study was conceived and prepared by IMHEN with the technical and financial assistance of ESCAP.

**Phase II** aims to enable and demonstrate certain elements of the NAMA programme through the implementation of specific activities. These include the implementation of pilot projects, the set-up of the institutional arrangements necessary to make the NAMA operational, and capacity building[4]. Efforts are expected to be carried out during this phase to mobilize domestic resources for the full implementation of the NAMA, which could be structured in a way so as to leverage international sources of finance. These would include, *inter alia*, the UK/Germany NAMA Facility, the Green Climate

[4] Activities proposed for this phase are detailed in chapter 8 of the study.

Fund, the Global Environmental Facility, bilateral sources of financing, market-based mechanisms, and/or "pay-for-performance" programmes.

**Phase III** consists in the nation-wide up-scaling of the programme to cities of Viet Nam. The realization of this phase should build on the experiences of the pilot stage. Based on the outcomes of Phase 2, some of the design elements of the NAMA as proposed in this study may be reformulated or re-designed so as to better reflect the lessons learned during the piloting phase.

The NAMA programme proposed is fully in line with national policies on solid waste management and climate change of Viet Nam, particularly the National Strategy for Integrated Management of Solid Waste up to 2025 and Vision towards 2050 and the **Intended Nationally Determined Contribution (INDC)** of Viet Nam to the new climate change treaty that was agreed in Paris in December 2015. The scope and ambition of the NAMA are as follows:

- The development of a programme to reduce GHG emissions from the solid waste sector through the application of integrated solid waste management practices that look into waste as a resource, while at the same time contributing to sustainable development goals and seizing opportunities for international climate support in terms of finance, capacity building and technology transfer;
- The promotion of waste management strategies that are in line with the principles of Reducing, Reusing and Recycling (3R), including the improvement of waste collection services in cities of Viet Nam;
- The diversion of waste streams from "end-of-pipe" methods, particularly unsanitary landfills and open-dumps, which are the prevailing practice in Viet Nam;
- To create an enabling framework to support a higher deployment of biological methods for treating the organic fraction of solid waste, and recycling methods for addressing the inorganic components;
- Support the dissemination and replication of good waste-to-resource practices identified in Viet Nam, such as the Integrated Resource Recovery Center (IRRC) model[5].
- The generation of strong benefits to local communities with the implementation of the measures endorsed by the NAMA in the form of a cleaner environment, improved well-being, etc., which would also support Viet Nam in meeting its Sustainable Development Goals (SDGs)[6].

The NAMA design study hereby presented is organized into **two parts**.

**The first part** consists of a detailed analysis of the policy and institutional framework of Viet Nam's climate change and solid waste management sectors. The analysis identifes existing barriers and the main gaps hindering the implementation of the measures that the NAMA programme endorses, i.e. the establishment of sustainable waste management practices in Viet Nam based on the principles of 3R

[5] Further details on the Integrated Resource Recovery Center model are provided in chapter 4.
[6] The NAMA is expected to support the achievement of at least 9 SDGs, as elaborated in section 5.5 of the study

and the conversion of waste into resources. This assessment also examines how the NAMA can support existing policies and strategies in Viet Nam, and analyzes which measures and technologies could be included under the framework of the programme.

Based on the findings of Part I, **Part II** sheds light on the design elements of the proposed NAMA. The objectives of the programme are stated, its scope is defined, and its main elements are described. An important component of this part is the quantification of GHG emissions from the baseline and NAMA scenarios. Other components of the programme which are formulated are its estimated costs, financing mechanisms to leverage domestic and international sources of funding, and the institutional arrangements that need to be in place to ensure the implementation of the programme. **In short, while Part I of the study presents the basis for coming up with the NAMA, Part II consists of the NAMA programme itself** [7].

It was noted above that an important element of the NAMA-design phase was to consult different national stakeholders, and as of January 2016 two consultation workshops were held. The first one was conducted prior to the preparation of this study, on 26 November 2013, to present the NAMA concept and obtain initial feedback on its proposed elements. A second consultation was conducted on 19 May 2015 in order to present the preliminary findings of the design study and seek detailed feedback concerning its main components. On both workshops, participating stakeholders have fully endorsed the NAMA programme, and their views on specific elements have been reflected to the extent possible on this NAMA design study.

A brief overview of each of the chapters of this NAMA-design study is presented below. Chapters 2 to 5 are under Part I of the study, while chapters 5 to 8 belong to the second Part. The study also contains four annexes.

**Chapters 2 and 3** present a review of existing policies, strategies and regulations related to the climate change and solid waste sectors of Viet Nam. The focus of chapter 2 is on climate change, while chapter 3 is on solid waste management. The aim of these chapters is to understand the *status quo* of both sectors and identify policy, regulatory and institutional barriers that could be overcome throught the proposed NAMA. The NAMA design-elements proposed in chapter 5 build upon the gaps and shortcomings identified on these chapters. Linkages among the solid waste and climate change sectors are also established in both chapters.

**Chapter 4** assesses different measures and technologies that can be applied for processing solid waste into resources. It also examines how a good “waste-to-resource” practice in Viet Nam, in the form of the “Integrated Resource Recovery Center” model, could be supported through the NAMA framework. This analysis supports the rationale for the NAMA endorsing a set of technical measures, as elaborated in Part II of the study.

[7] This NAMA is referred throughout the text as a “NAMA proposal”. This is based on the assumption that until some sort of formal approval by the national government is granted, the NAMA programme as formulated in this document will remain as a “proposal”.

Based on the assessment and findings of Part I of the study, **Chapter 5** details the main design elements of the proposed NAMA. This includes the stated objectives of the programme, its boundaries, the measures endorsed, how the programme can support overcoming the barriers and gaps identified, and the benefits and co-benefits expected to be achieved with its implementation.

**Chapter 6** presents the modeling exercise that was prepared to come up with the baseline scenario and the GHG emission reduction trajectory that could be expected with the implementation of the measures endorsed by the NAMA. This chapter also lays out a blueprint of the Monitoring, Reporting and Verification (MRV) arrangements that need to be in place as part of the programme.

**Chapter 7** focuses on two of the main elements of the programme. Firstly, it elaborates on the institutional architecture of the NAMA, proposing and defining the roles and responsibilities of key stakeholders, as well as an organizational model to coordinate and oversee the implementation of the programme. Secondly, it is made an estimate of the costs of fully deploying the programme, and it delineates some options for financing its implementation.

**Chapter 8** lays out an implementation roadmap for the NAMA by proposing specific activities for phase 2 of the programme, including cost estimates and an implementation timeframe. Details on the set up of the institutional arrangements, capacity building needs and piloting requirements are also provided in this chapter.

**Annex I** describes in detail the Integrated Resource Recovery Center model, which was identified as a good “waste-to-resource” practice in Viet Nam. **Annex II** elaborates on specific measures that could be adopted as part of the NAMA by different stakeholders (e.g. local government authorities, communities, business enterprises, etc.). **Annexes III and IV** provide a detailed description of how the baseline and NAMA scenarios presented in chapter 6 were modelled.

# PART I – Context of Viet Nam and Background for Proposing a NAMA Programme for the Solid Waste Sector

## 2. Analysis of the Policy and Institutional Framework on Climate Change in Viet Nam

### 2.1 Climate Change Mitigation Policies in Viet Nam

Acknowledging the serious impacts of climate change to the sustainable development of the country, the Government of Viet Nam has realized that an appropriate response is necessary. This is considered to be and endeavor involving not only the political system, but the society as whole. In this connection, several different initiatives, policies and programmes have been implemented in Viet Nam over the past two decades to cope with climate change.

Viet Nam signed the UNFCCC in June 1992 and ratified it in November 1994. The country signed the Kyoto Protocol in November 1998 and ratified it in November 2002. Viet Nam has also developed several legal documents on climate change, which led to the creation of a framework for the prevention and mitigation of natural disasters. Since 2008, Viet Nam has shown a high level of commitment towards climate change, with a primary focus on adaptation and increasingly higher attention paid to mitigation. Mitigation actions are regarded in official documents as opportunities for achieving sustainable development in the country and the efficient use of national resources. Key official documents that shape the vision, target and baseline for mitigation activities in Viet Nam are presented in figure 2.1.

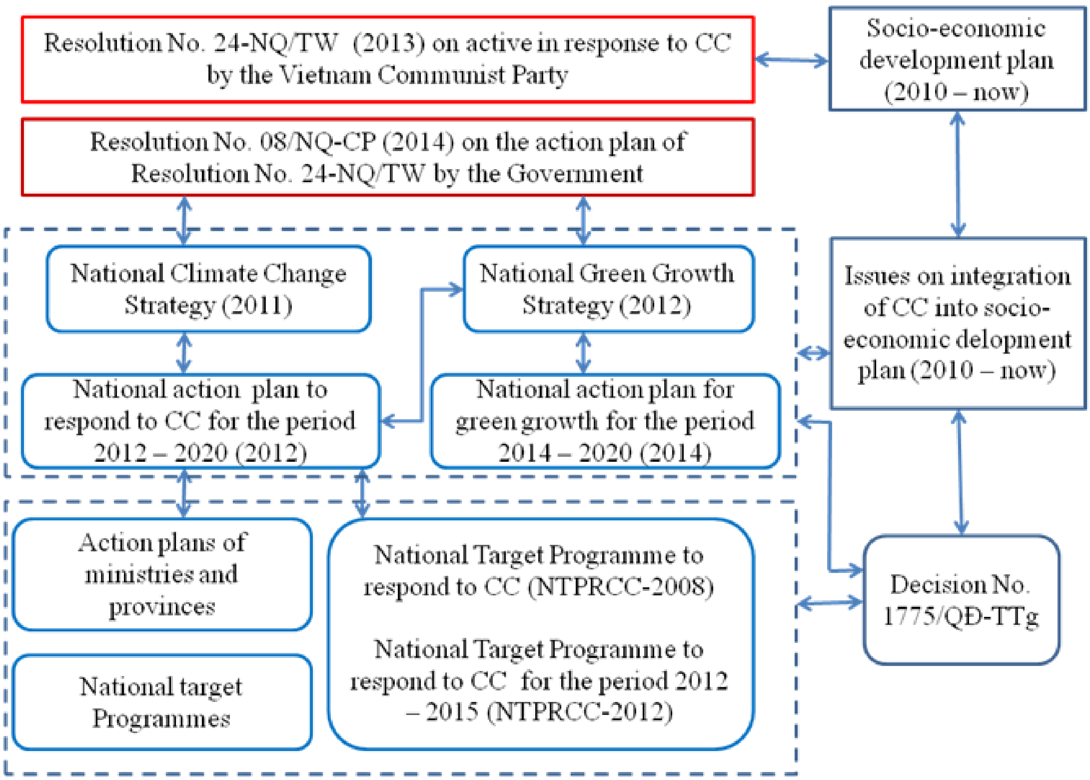



**Figure 2.1** – Key mitigation documents, plans and programmes for climate change in Viet Nam.

An overview of the main policies and documents on climate change in Viet Nam is provided in this section, and are presented in the following order: i) national; ii) ministerial/sectorial; and iii) sub-national level initiatives.

## Policies and Relevant Documents at National level

The Ministry of Natural Resources and Environment (MONRE) is Viet Nam's focal point to the UNFCCC and the implementation of the Kyoto Protocol. After the Protocol officially entered into force in February 2005, the Government issued **Decision No. 47/2007/QĐ-TTg**, which approved a plan for implementing the Protocol for the 2007-2010 period. The Decision set a clear mandate for completing the legal framework in Viet Nam so as to properly reflect the commitments made as part of the Protocol, including the implementation of Clean Development Mechanism (CDM) projects.

In 2008, the **National Target Program to Respond to Climate Change** (NTP-RCC) was approved by the Prime-Minister. The strategic objectives of the program are to "periodically assess climate change impacts on sectors and regions, and to develop feasible action plans to effectively respond to climate change in the short and long-term to ensure sustainable development of Viet Nam, to take opportunities to develop a low-carbon economy and to join the international community's efforts in mitigating climate change and protecting the climatic system".

The **National Strategy on Climate Change** (2011) was issued alongside **Decision No. 2139/QĐ-TTg** dated 5 December 2011 by the Prime Minister. It states that "Viet Nam considers the response to climate change a vital issue" and that "Viet Nam's response to climate change must be closely attached to sustainable development towards a low-carbon economy" and also "to simultaneously adapt to climate change and reduce GHG emissions, focusing on adaptation in early stages". The strategy proposes to "increase the absorption of GHGs" and the "reduction of GHG emissions" by 2020 for the forestry, energy, industry and construction, transportation, agriculture and waste management sectors.

The **National Green Growth Strategy for the period 2011-2020 with a vision to 2050** was approved by the Prime Minister of Viet Nam in September 2012. In line with the National Strategy on Climate Change, it includes targets for achieving a low-carbon economy and the reduction of GHG emissions. The Strategy also sets GHG emission reduction targets for specific periods, considering 2010 as the baseline year.

| Phase/Period | Emissions reduction targets |
|---|---|
| Period 2011 - 2020 | - Reduce the intensity of GHG emissions by 8 to 10% based on 2010 levels.<br>- Reduce GHG emissions from energy activities by 10% to 20% compared to the business as usual case with 2010 as reference (10% voluntary reduction and 10% reduction with additional international support). |
| Orientation towards 2030 | - Reduce annual GHG emissions by at least 1.5 to 2%.<br>- Reduce GHG emissions in energy activities by 20 to 30% compared to business as usual (20% voluntary reduction and an additional 10% reduction with further international support). |

| | |
|---|---|
| Orientation towards 2050 | - Reduce GHG emissions by 1.5 to 2% on an annual basis. |

**Table 2.1** – GHG emission reduction targets in the National Green Growth Strategy of Viet Nam.

In October 2012, the **National Action Plan on Climate Change** (2012-2020 period) was issued along with **Decision No. 1474/QD-TTg**, which laid out 65 programs, projects and tasks towards a low-carbon economy by 2020. Priority tasks focus principally on developing monitoring systems to climate change and sea level rise; modernizing hydro-meteorological monitoring systems; hydro-meteorological forecasting and climate change information systems; GHG emission reductions; flood mitigation and community based climate change adaptation.

In November 2012, the Prime Minister approved **Decision No. 1775/QD-TTg**, whose guiding objective is the "management of GHG emissions in order to implement the UNFCCC and other international agreements to which Viet Nam is a party, while at the same time harnessing opportunities to develop a low-carbon economy, promote green growth and, together with the international community, strengthen the efforts to reduce GHG emissions, and contribute to sustainable development goals in Viet Nam". The Decision sets a target for reducing GHG emissions by 2020, with 2005 as a baseline year, as indicated in the table below:

| Sectors | GHG emission reduction targets |
|---|---|
| Energy and transportation | 8% |
| Agriculture | 20% |
| LULUCF | 20% |
| Waste | 5% |

**Table 2.2** – GHG emission reduction by sectors from Decision No. 1775/QD-TTg.

Decision No. 1775/QD-TTg also mentions the development of an action plan for GHG emissions reductions in accordance with the national context of Viet Nam, as well as the registration and implementation of national GHG emissions actions, with a focus on the following priority sectors: energy, agriculture, LULUCF and forestry.

In June 2013, the Seventh Congress of the Eleventh Central Executive Committee adopted **Resolution No. 24-NQ/TW** on the active response to climate change, improvement of natural resource management and environmental protection, which demonstrate the concern of the Party and Government in responding to climate change issues in Viet Nam. So far, Resolution No. 24-NQ/TW is the highest legal oriented-document in Viet Nam, with specific targets to reduce the levels of GHG emissions per unit of GDP in 2020 of 8-10% compared with the levels observed in year 2010.

In order to implement Resolution No. 24-NQ/TW, the Government of Viet Nam issued **Resolution No. 08/NQ-CP**, which lays out an action program to implement Resolution No.24-NQ/TW. This action plan includes 3 objectives, 9 tasks and a list of 44 plans, programs, and projects. Concerning climate change, Resolution No. 08/NQ-CP mentions 3 tasks focusing on disaster prevention, climate change adaptation, reduction of the effects of tides and sea level rise, and the reduction of GHG emissions.

In March 2014, the Prime Minister approved the **National Action Plan on Green Growth** for the period 2014 to 2020, in which “reducing GHG emissions and promoting clean energy, renewable energy" are the main tasks laid out. The plan comprises 20 main activities divided into 4 main groups: i) industry, ii) transportation, iii) agriculture, forestry, and fisheries, and iv) alternative sources of energy production, including renewable energy.

In September 2015, the government of Viet Nam officially submitted its **Intended Nationally Determined Contribution** (INDC), in preparation for the 21st Session of the Conference of the Parties (COP-21), which resulted in the agreement of the new international climate change treaty. In the INDC, the government of Viet Nam pledges an unconditional contribution to reduce GHG emissions by 8% in 2030 compared to a business-as-usual (BAU) scenario by relying solely on domestic resources. This contribution could be increased to 25% if international support is provided through bilateral and multilateral cooperation. To achieve the proposed targets, a number of measures are proposed to major economic sectors, including energy, industry, agriculture and waste.

## Policies and Documents at the Ministerial/Sectorial level

One of the key tasks of the National Target Program to Respond to Climate Change (2008) is “to develop and implement action plans in every ministry, sector and locality to respond to climate change”. As a consequence, all ministries have developed their action plans, in particular:

- In 2010, MONRE issued its action plan for the 2011-2015 period. The action plan has 4 objectives and 9 key tasks, including the aim to “study and propose policy mechanisms, technologies for GHG emission reduction, and to adopt opportunities to progress towards a low-carbon economy”.
- In 2010, the Ministry of Industry and Trade (MOIT) issued its action plan for the 2010-2015 period, whereby “MOIT will give priority to the tasks of adaptation and readiness to implement GHG emissions reductions on the basis of technical, financial and technological support from the international community”.
- In 2010, the Ministry of Health (MOH) issued Decision No. 3557/QD-BYT on its action plan to respond to climate change for the 2010-2015 period, with the overarching objective of reducing the effects of climate change to public health;
- In 2011, the Ministry of Transportation (MOT) issued its action plan for the 2011-2015 period, with the overarching goal of “creating capacities to cope with climate change and to contribute to sustainable development in the transportation sector”. The plan includes three specific targets, including the “mobilization of international resources to support adaptation measures and the mitigation of GHG emissions".
- In 2013, the Ministry of Agricultural and Rural Development (MARD) issued Decision No. 66/QD-BNN-KHCN on its action plan for the 2012-2020 period. With this plan, MARD became the first ministry to detail GHG emission reduction targets for each domain within the sector up to 2020.

- In 2014, the Ministry of Construction (MOC), issued its action plan for the 2014-2020 period, as part of Decision No. 209/QD-BXD. The overall objective is to "enhance the construction industry's capacity to respond to natural disasters and climate change; the efficient use of energy; and the development of the construction industry towards green and sustainable growth". To achieve those objectives, MOC laid out specific goals including the reduction of energy consumption and related GHG emissions, especially in the production of construction materials, and promoting the development of green buildings and green urban areas.

**Policies and Documents at sub-national level**

As of June 2014, 62 out of 63 provinces and cities had approved their action plans to respond to climate change, which identify specific tasks and projects for the 2016-2020 period. However, most of the action plans are on adaptation and have few actions on mitigation. At present, provinces and cities are mainly focusing in implementing communication activities to raise awareness on climate change, the preparation of climate change impact assessment studies, and the elaboration of action plans to respond to climate change. Some of these sub-national level initiatives have received international support, such as those in of Quang Nam and Ben Tre provinces.

## 2.2 Institutional arrangements for climate change response in Viet Nam

At the national level, the highest body tasked with addressing climate change matters is the **National Committee on Climate Change**, which was established on 9 January 2012 by **Decision No. 43/QD-TTg**. The Committee is mandated with advisory functions, assisting the Government and the Prime Minister in researching, proposing, directing, regulating, and coordinating multi-sectoral tasks and national strategies on climate change. The organizational structure of the Committee is presented below:

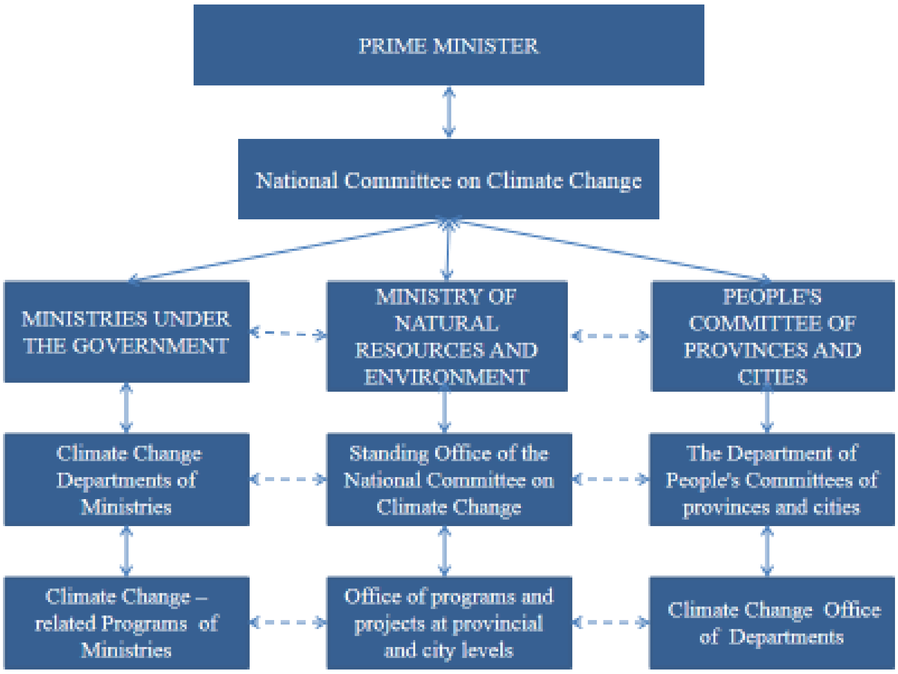



**Figure 2.2** – Organizational structure of the State management on climate change in Viet Nam.

The National Committee on Climate Change is chaired by the Prime-Minister, followed by the Vice-Chairmen, who include the Deputy Prime Minister and the Minister of Natural Resources and Environment. MONRE is the permanent agency of the Committee and, *inter alia*, is tasked with helping the Chairman in developing the work program and plan of the Committee. MONRE is also in charge of coordinating, collaborating, and speeding up the implementation of the tasks of the different ministries, sectors and city-level programmes. Besides, the Minister of Natural Resources and Environment, as one of the Vice-Chairmen of the Committee, oversees the functions, tasks, and organizational structure of the Standing Office of the National Committee on Climate Change. The Standing Office of the National Committee on Climate Change is placed under MONRE and is headed by the Director of the **Department of Meteorology, Hydrology and Climate Change (DMHCC)**.

According to **Decree No. 21/2013/ND-CP** from March 2013, with respect to climate change mitigation, MONRE is responsible for, *inter alia*: (i) development and implementation of MRV systems for domestic and international mitigation activities; (ii) organization of the national inventory of GHG; (iii) management of carbon credits and trading; (iv) organization of international negotiations on climate change, implementation of international conventions and treaties, and participation in international conferences on climate change; (v) mobilization of international resources; and vi) assisting the National Committee on Climate Change in supervising and speeding up the Strategy and the National Action Plan on Climate Change. Key agencies under MONRE with responsibilities on climate change issues include the Department of Meteorology Hydrology and Climate Change (DMHCC), the Institute of Meteorology, Hydrology and Environment (IMHEN), and the Institute of Strategy and Policy of Natural Resources and Environment (ISPONRE).

**DMHCC** was established in 2008, and its main functions are in the fields of meteorology, hydrology, climate change, and ozone layer protection. DMHCC is also the standing office of the National Committee on Climate Change, as well as the National Steering Committee to implement the UNFCCC and the Kyoto Protocol. It also acts as the Designated National Authority of Viet Nam for CDM activities. The responsibilities of DMHCC with respect to climate change mitigation are:

- To propose the amendment of policies, legal documents and technical standards related to the climate change response based on the national and international context;
- To develop and implement MRV systems for mitigation actions;
- To prepare, compile data, and periodically update national GHG inventories;
- To oversee, guide and manage carbon-trading activities in Viet Nam.

**IMHEN** is a research and implementation institute under MONRE. IMHEN was established in 1977 and over the past 30 years it has grown to become one of the leading research institutes in Viet Nam, with a long experience in conducting applied research in the fields of meteorology, hydrology, oceanography, environment and climate change. IMHEN conducts research, provides training and postgraduate education programs, including on climate change.

**ISPONRE** is tasked with the responsibilities of researching and developing strategies in the fields of natural resources and the environment. ISPONRE also conducts scientific research and provides training on natural resource management and environmental protection.

## 2.3 NAMA development and implementation in Viet Nam

### 2.3.1 Legal framework and institutional setup for NAMAs in Viet Nam

NAMAs are a new concept in the climate policy agenda, and few policy documents in Viet Nam make reference to NAMAs. Nothwithstanding, the development of a NAMA framework and NAMA programmes referred to in the "Management of greenhouse gas emissions; management of the activities of trading carbon credits to the international market", approved by Decision 1775/QD-TTg, which was noted in the previous section. A list of tasks and initiatives to implement the plan were approved along with Decision No. 1775/QD-TTg, including the following:

- Development of a NAMA framework for Viet Nam, including the conduct of research initiatives to develop methodologies, register, pilot and implement NAMA programmes (2012-2015);
- Development of a MRV system for NAMAs (2012-2015);
- Review, assessment and completion of the legal framework on mechanisms and policies for CDM projects (2012-2014);
- Development of national and sectorial MRV systems for relevant NAMA sectors (2016-2020).

**Decision No. 187/QD-BTNMT** from January 2013 established a working group to prepare for the integration of NAMAs into the socio-economic development policies of different ministries, including MONRE, MPI, MOT, MOFA, MOF, MOST, MOIT, MARD and MOC. The task of the working group is to advise and recommend to the Minister of Natural Resources and Environment, as well as other related ministries and agencies, on measures to develop an institutional, policy and legal framework to enable the integration of NAMAs into sustainable development strategies and programmes. This working group acts as the focal point for the collaboration amongst line ministries, agencies and sub-national authorities.

With respect to the institutional arrangements, NAMAs are under the management of the National Committee on Climate Change, with the focal point agency DMHCC, under MONRE. To date, Viet Nam has developed several NAMA-readiness projects in cooperation with international donors (elaborated in section 2.3.1). There is no institutional framework yet in place for the registration, formulation or implementation of NAMAs. However, this is currently being addressed in the context of a joint programme being implemented by IMHEN and GIZ.

According to line ministries, the MRV system for NAMAs should be based on the experiences of the CDM. Experts from line ministries recomend that a "Monitoring" system should be implemented by line Ministries, while the "Reporting" should be implemented under the guidance of MONRE, and the "Verification" implemented by third parties or NAMA implementation agencies.

### 2.3.2 NAMA and MRV-related activities in Viet Nam

NAMA-related initiatives in Viet Nam have so far consisted mostly of “readiness” activities, such as institutional capacity building, technical assistance for the development of baseline and NAMA scenarios, setting up of MRV systems, etc. In addition, there are several internationally supported initiatives for the preparation of NAMA proposals. As of early 2016, no NAMA project or proposal was at the implementation stage, to an extent due to the lack of a legal basis and institutional framework. In addition, the capacity of agencies involved in the implementation of mitigation activities in general, and NAMAs in particular, is still limited, especially with respect to MRV processes. At the time of writing, no NAMA proposals had successfully qualified for international assistance. Table 2.3 below provides a taxonomy of NAMA-related projects and activities in Viet Nam.

| Project/Activity | Organizations Involved | Timeframe |
|---|---|---|
| Vietnam-Japan Capacity-building and Joint Study Project for NAMA in the waste sector in a MRV manner | IMHEN; OECC | 2012-2013 (Phase 1)<br>2013-2014 (Phase 2) |
| Technical guidelines on NAMA and MRV in Viet Nam | IMHEN; UNDP | 2013 |
| Pilot Programme for supporting up-scaled mitigation action in Viet Nam’s cement sector | Ministry of Construction; Nordic Partnership Initiative | Started in May 2013 |
| Development of a methodology to design NAMAs and assess, review and improve the institutional system to support the design and implementation of NAMAs | DMHCC | 2012-2013 |
| Green Growth Strategy | MPI | 2012 |
| Climate-smart agriculture | MARD; FAO | - |
| Green industry for a low-carbon economy | MOIT; MPI; MONRE; UNIDO | - |
| Facilitating implementation and Readiness for Mitigation – FIRM | DMHCC; UNEP Risoe | 2012-2014 |
| National target program on energy efficiency and the efficient use of energy | MOIT; Danish government | - |
| Support for national target program on climate change with a focus on energy and transport | ADB; MOT; MONRE | Apr. 2012 - Dec. 2013 |
| Strengthening planning capacity for low-carbon growth in developing Asia | ADB; Indonesia; Malaysia; Philippines; Thailand and Viet Nam. | Nov. 2010 - Jun. 2013 |
| Renewable Energy Support Programme | MOIT; GIZ | - |
| UN-REDD+ Program | MARD | - |
| Creation of an overarching framework for NAMAs and MRV in Viet Nam | IMHEN; GIZ | 2014-2018 |
| Develop, implement and manage NAMAs in Viet Nam | DMHCC; JICA | Started in 2014 |

**Table 2.3** – NAMA-readiness projects and activities in Viet Nam.

As can be observed from the table above, there have been several activities in Viet Nam associated with the development of NAMAs. These include economy-level policies such as the Viet Nam Green Growth Strategy, as well as more specific initiatives such as, for instance, NAMA programmes on energy efficiency and the agriculture sector. It should be noted the development of the GIZ/IMHEN project for the "Creation of an overarching framework for NAMAs and MRV in Viet Nam", which aims at addressing one of the main limitations of Viet Nam's national framework on NAMAs, by setting-up the institutional structure and arrangements for NAMAs in an "MRV manner".

**NAMA Proposals and Programmes**

A number of organizations in Viet Nam have been involved in the development of specific NAMA proposals, most of these with the financial and technical assistance of international organizations. An overview of NAMA proposals under development in Viet Nam is presented in table 2.4 below. It may be observed that these are mostly in the energy and transport sectors, which are those with the highest levels of GHG emissions.

| Proposal | Organizations Involved | Timeframe |
|---|---|---|
| Waste-to-resource for cities in Viet Nam | IMHEN; ESCAP | 2013-2015 |
| Support wind power development in Viet Nam | IMHEN; DMHCC; UNEP Risoe | 2013-2014 |
| Wind power development fund for Viet Nam | MOIT; GIZ | 2013 |
| Support bioenergy development in Viet Nam | Climate change and Sustainable Development Center; DMHCC; UNEP Risoe | 2013-2014 |
| Research and application of electric cars and hybrid electric vehicles in Viet Nam | IMHEN; Mai Linh Corporation | 2013-2014 |
| Energy efficiency in commercial buildings | DMHCC; UNEP | 2014 |

**Table 2.4** – Progress in developing NAMA proposals in Viet Nam.

### 2.3.3 Challenges of developing NAMAs in Viet Nam

There are a number of challenges hindering the development of NAMAs in Viet Nam, especially at policy and institutional levels:

**Policy and legal framework**

Climate change is still a relatively new topic in Viet Nam, and despite the existence of several policies, guidelines and regulations, there is not a national law on climate change. This poses difficulties to the implementation of climate change initiatives, especially among line ministries. There is also a lack of harmonization of existing policies and legal documents.

One of the areas where a lack of harmonization exists are the targets set for GHG emission reductions. Illustrative of this is Decision No. 1775/QD-TTg from November 2012, where a set of mitigation targets are identified for different sectors. On the other hand, the National Green Growth Strategy proposes a different set of mitigation targets for the 2011-2020 period based on GHG emission intensity and a business-as-usual scenario with reference to 2010. This lack of harmonization on GHG emission reduction targets may pose some challenges in achieving a common GHG emission reduction goal.

Another challenge is that data necessary for GHG inventory and baseline setting has been gathered from unofficial sources, and in formats that are not in line with those of GHG emission inventories. This is the result of a lack of coordination among different departments and ministries, as well as a lack of guidelines for data collection at both national and sectorial levels. This also leads to uncertainties in the definition of emission reduction scenarios and targets. These challenges spill-over to NAMAs, as a particular type of mitigation activities.

On challenges more specific to NAMAs, at present there is not a policy framework or legal documents in place concerning the development of NAMAs. The only one existing are the “Technical guidelines for the construction and implementation of NAMAs”, issued by MONRE in 2012. However, the lack of such policy documents is one of the most important barriers to the approval and implementation of NAMAs in Viet Nam.

**Institutional arrangements for NAMAs**

Viet Nam has a solid institutional foundation for managing of climate change activities, which is embodied in the National Committee on Climate Change. The Committee involves 28 ministries, departments and agencies. However, its members are usually involved in multiple tasks, with some of them lacking specific knowledge on climate issues. Therefore, the operation of this committee has faced some challenges. Another challenge is that the operation of the committee has proved effective in ensuring inter-ministerial coordination, as an overlapping of functions is still observed in a number of climate-related areas.

More specifically to NAMAs, it was noted above that the Prime Minister of Viet Nam assigned MONRE as the focal point for guiding the implementation of NAMAs. However, the lack of more specific documents, including guidelines and regulations, on the functions of each ministry has resulted in a lack of harmonization in the implementation of NAMA readiness activities.

**Other Challenges**

Although climate change has been a priority for Viet Nam, awareness on NAMAs is still limited due to the novelty of the concept. While information and know-how on NAMAs exists on a number of organizations in Viet Nam, this knowledge has not spilled over to general practitioners and other stakeholders. The development of NAMAs has also been hampered by a general lack of capacities at the technical and managerial levels.

Another challenge concerns financing opportunities and mechanisms. Even though the Government of Viet Nam has shown strong commitment on climate issues, financial resources have mostly been allocated to adaptation, while the bulk of mitigation funding has been derived from overseas ODA. These funds are of importance but still short of the levels required to develop and implement meaningful sector and economy-wide mitigation programmes. International private-sector investments have also been limited so far.

One more challenge pertains to the preparation of GHG emission inventories and National Communications (NC). To date, Viet Nam has completed and submitted two NCs. The first was completed and submitted in 2003 (including a national GHG inventory for the base year 1994), while the second one in 2010 (with data from the national GHG inventory for the base year 2000). The national inventory of GHG in previous NCs has been prepared with the support of international organizations. However, there is still a need to establish the institutional arrangements for national inventory systems. One of the implications is that compiling and maintaining data quality for GHG inventories is often challenging, especially when it comes to ensuring the consistency and continuity of inventory data over time. On the other hand, in December 2015 a decision was approved by the national government for the harmonization and coordination of GHG inventories.

## 2.4 Concluding remarks

The Government of Viet Nam has showcased strong commitment to climate change, with a number of legal documents being issued on both mitigation and adaptation issues. While the priority of the national government has been on adaptation, the relevance of mitigation has increased over the years. Mitigation-related initiatives are now see on all relevant climate-change documents, including the INDC submitted to the UNFCCC in September 2015.

The National Strategy on Climate Change and the National Strategy on Green Growth are the most important national-level documents on climate change. These documents steer Viet Nam into a low-carbon development path, and propose specific GHG emission reduction targets. An institutional framework for dealing with climate change issues exists at the highest level, with the establishment of the National Committee on Climate Change, which is headed by Viet Nam’s Prime-Minister.

NAMAs are recognized by the national government as a mechanism to reduce GHG emission and, accordingly, national ministries and sub-national authorities are encouraged to design and implement such programmes. A number of NAMA-related initiatives have been developed in Viet Nam, mostly focused on NAMA-readiness, including on capacity building and the preparation of NAMA proposals.

However, a number of challenges hinder the development of NAMAs in Viet Nam. Firstly, the NAMA framework is still in an early stage, with its institutional and legal structure in the process of being established. Its completion is foreseen for 2018, when the IMHEN-GIZ project on the establishment of a NAMA framework for Viet Nam is finalized. A general lack of coordination and harmonization between different ministries and agencies has been identified as an important barrier for the NAMA development in Viet Nam. Other challenges are the lack of technical know-how among managers and practitioners, and the need to come up with an inventory system with accurate and reliable data on GHG emissions. An MRV system also needs to be established for NAMAs, although guidelines issued by MONRE indicate that it should build on the experiences of the CDM.

# 3. Analysis of the Solid Waste Management Sector in Viet Nam

## 3.1 Current state of the Solid Waste Sector

### 3.1.1 Solid waste generation and composition

In recent years, along with the economic development of Viet Nam, the amount of waste generated has been increasing dramatically, especially in larger cities. As of 2011, around 26,000 ton of solid waste were generated per day (MONRE, 2011). Sources of waste, volumes and compositions are described in the following section.

**Definition of Municipal Solid Waste**

According to MONRE (2011), **municipal solid waste** (MSW) includes domestic solid wastes, construction waste, industrial waste, and medical waste. MSW is mostly composed of organic matter (e.g. food waste) which constitutes 60-75% of the total MSW volume. Specifically:

- Domestic waste streams originating from households, dormitories, markets, commercial centers, offices, research facilities, schools;
- Construction waste generated from construction related activities, including demolition waste;
- Industrial waste generated from industrial facilities located in urban or industrial zones;
- Medical waste generated from hospitals and health care facilities;
- Electronic waste or "e-waste", which includes discarded electronic equipment.

The **focus of this study** as well as the scope of the Waste-to-Resource NAMA is on the "domestic sources" of municipal solid waste, generated in both urban and rural areas, which are referred to throughout the study as "**solid waste**".

**Solid Waste Volumes in Viet Nam**

According to MONRE (2011), volumes of solid wastegenerated in Viet Nam have increased at an average of 10-16% per year, as shown in figure 3.1. It can be observed from this graph that solid waste amounts have been rising dramatically in recent years, even though it is noted a deceleration of this trend between years 2009 and 2010.

Table 3.1 presents the volume of solid waste generated in cities of Viet Nam in 2007. It may be observed that the per capita generation of solid waste is positively related to the dimension of the city: the larger the city, the higher the quantities of waste generated.

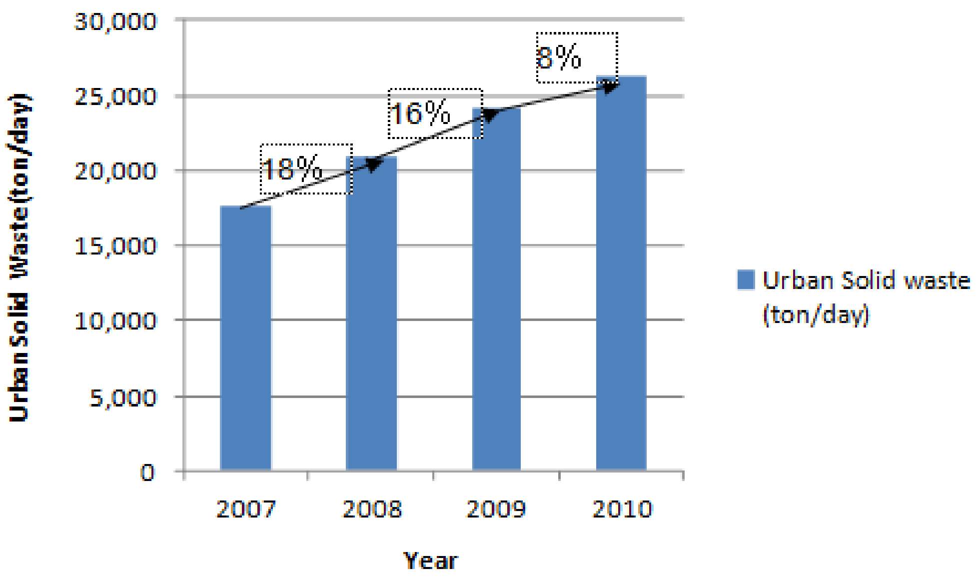



**Figure 3. 1** – Historical trend of urban solid generated per day in the 2007-2010 period (Source: calculations based on data from MONRE (2011), National Environmental Report: Solid Waste, p.16)

| No. | Type of city | The average solid waste per capita (kg/person/day) | Volume of solid waste | |
|---|---|---|---|---|
| | | | ton/day | ton/year |
| 1 | Special[8] | 0.96 | 8,000 | 2,920,000 |
| 2 | Type 1[9] | 0.84 | 1,885 | 688,025 |
| 3 | Type 2[10] | 0.72 | 3,433 | 1,253,045 |
| 4 | Type 3[11] | 0.73 | 3,738 | 1,364,370 |
| 5 | Type 4[12] | 0.65 | 626 | 228,490 |
| **Total** | | | **17,682** | **6,453,930** |

**Table 3.1** – The volume of solid waste generated in cities of Viet Nam in 2007 (Source: MONRE, 2011)

## Composition of Solid Waste in Viet Nam

The composition of solid waste depends on different factors, such as the level of economic development, household income and living standards in urban areas. The organic component of solid waste is usually above 50% and, in some cities, it can be as high as 85%, as can be observed in table 3.2. The share of plastic waste usually ranges between 8 and 16%, while hazardous waste in solid waste streams is usually less than 1%. The share of recyclable waste, such as paper, plastic and metal typically accounts for about 8 to15% of the total (MONRE, 2011).

[8] Cities with a population over 5 million people
[9] Cities with a population over 1 million people for cities under the Central Government and cities over 500.000 people for cities under Provincial authorities
[10] Cities with a population over 800.000 people for cities under the Central Government and cities over 300.000 people for cities under Provincial authorities
[11] Cities with a population of over 150.000 people
[12] Cities of which population of over 4.000 people

| Province | Biodegra-dable | Paper | Metal | Glass | Cloth | Plastic, Rubber | Brick and pottery | Hazardous materials | Other materials |
|---|---|---|---|---|---|---|---|---|---|
| Can Tho | 79.65 | 2.79 | 0.70 | 1.52 | 1.86 | 9.57 | 3.10 | 0.03 | 0.76 |
| Ca Mau | 57.30 | 4.50 | 0.10 | 0.50 | 1.40 | 6.10 | 2.10 | - | 28.00 |
| Soc Trang | 70.35 | 4.12 | 0.78 | 0.66 | 3.11 | 7.24 | 9.63 | - | 4.11 |
| Tien Giang | 77.53 | 3.89 | 0.23 | 0.21 | - | 6.37 | 2.14 | 0.06 | 9.57 |
| Long An | 76.3 | 5.1 | 0.37 | 0.7 | - | 13.63 | 2.68 | 0.15 | 4.08 |
| Ben Tre | 73.85 | 6.5 | 1.75 | 0.85 | - | 5.2 | 1.6 | 0.3 | 9.95 |
| Tra Vinh | 87.25 | 2.05 | 0.45 | - | - | 3.16 | 2.04 | - | 5.05 |
| Vinh Long | 66.25 | 11.5 | 0.55 | 4.00 | 6.5 | 9.45 | 0.75 | - | 1.00 |
| Bac Lieu | 53.34 | 4.51 | 4.59 | 4.91 | - | 4.44 | 10.81 | 2.78 | 14.62 |
| Hau Giang | 82.60 | 1.8 | 0.4 | 0.9 | 1.5 | 5.7 | 1.6 | 4.0 | 1.5 |
| Kien Giang | 72.52 | 6.38 | 1.27 | 1.64 | 1.29 | 7.69 | 7.49 | - | 1.72 |
| Dong Thap | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| An Giang | NA | NA | NA | NA | NA | NA | NA | NA | NA |

**Table 3.2** – Solid waste composition of several cities in Viet Nam (Source: MONRE, 2011)

### 3.1.2 Segregation of waste at source in Viet Nam

In most urban areas, solid waste is not segregated at the source. According to MONRE (2011), some cities in Viet Nam have implemented pilot programmes for the separation of waste at source, including large cities such as Ho Chi Minh City, Hanoi and Da Nang. Results achieved have been limited and these experiences not up-scaled or replicated due to the following reasons:

- Lack of public participation: communities are not aware of the benefits and are reluctant to comply with the separation of waste at source;
- Lack of treatment facilities to process the segregated waste;
- Lack of financial resources for the up-scaling of pilot projects.

Despite the above noted challenges, successful experiences for the separation of waste do exist in Viet Nam. The city of Quy Nhon, for instance, is able to separate 30-40 ton of organic waste on a daily basis, and this was achieved on a timeframe of less than 2 years. The city is currently implementing a five-year strategy to upscale the separation of waste at source to the whole city, which has a population of approx. 250,000 people[13].

### 3.1.3 Collection and transportation of solid waste in Viet Nam

Waste in Viet Nam is not usually separated, and thus the collection of unsegregated mixed waste is the common practice. According to MONRE (2011), the average rate of waste collection in urban areas increased from 72% in 2004 to 80-82% in 2008, and reached 83-85% in year 2010. Though the collection rate has increased in recent years, 15-17% of urban waste is still dumped in the environment or simply burned. Table 3.3 below indicates solid waste collection rates in cities of Viet Nam.

[13] United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), 2015, "Valuing Waste, Transforming Cities", http://www.unescap.org/resources/valuing-waste-transforming-cities

| | **City** | **Collection rate** (%) | | **City** | **Collection rate** (%) |
|---|---|---|---|---|---|
| **Special municipality** | Hanoi | 90-95 (in 4 core districts)<br>83.2 (in 10 districts) | **Type 3 city** | Bac Giang | >80 |
| | Ho Chi Minh | 90-97 | | Thai Binh | 90 |
| **Type 1 city** | Hai Phong | 80 - 90 | | Phu Tho | 80 |
| | Da Nang | 90 | | Bao Loc | 70 |
| | Hue | 90 | | Vinh Long | 75 |
| | Nha Trang | 90 | | Bac Lieu | 52 |
| | Quy Nhon | 60.8 | **Type 4 city** | Song Cong – Thai Nguyen | >80 |
| | Buon Ma Thuot | 70 | | Tu Son – Bac Ninh | 51 |
| **Type 2 city** | Thai Nguyen | >80 | | Lam Thao – Phu Tho | 80 |
| | Viet Tri | 95 | | Sam Son – Thanh Hoa | 90 |
| | Nam Dinh | 78 | | Cam Ranh – Khanh Hoa | 90 |
| | Thanh Hoa | 84.4 | | Thu Dau Mot – Binh Duong | 84 |
| | Ca Mau | 80 | | Dong Xoai – Binh Phuoc | 70 |
| | My Tho | 91 | | Go Cong – Tien Giang | 60 |
| | Long Xuyen | 69 | | Nga Bay – Hau Giang | 60 |
| **Type 3 city** | Dien Bien Phu | 80 | **Type 5 city** | Tuu Chua – Dien Bien | 75 |
| | Bac Ninh | 70 | | Tien Hai – Thai Binh | 74 |

**Table 3.3** – Solid waste collection rates in cities of Viet Nam, 2009 (Source: JICA, 2011)

Solid wastes generated from households are typically collected by means of waste collection trucks or handcarts, based on a pre-arranged schedule. In larger cities, the state-owned waste collection company URENCO is responsible for the collection, transportation and disposal. In Hanoi, in addition to URENCO, there are approximately 30 other private companies involved in waste collection and transportation (MONRE, 2011). In small towns, cooperatives, community-based organizations (CBOs), and private companies also provide these services.

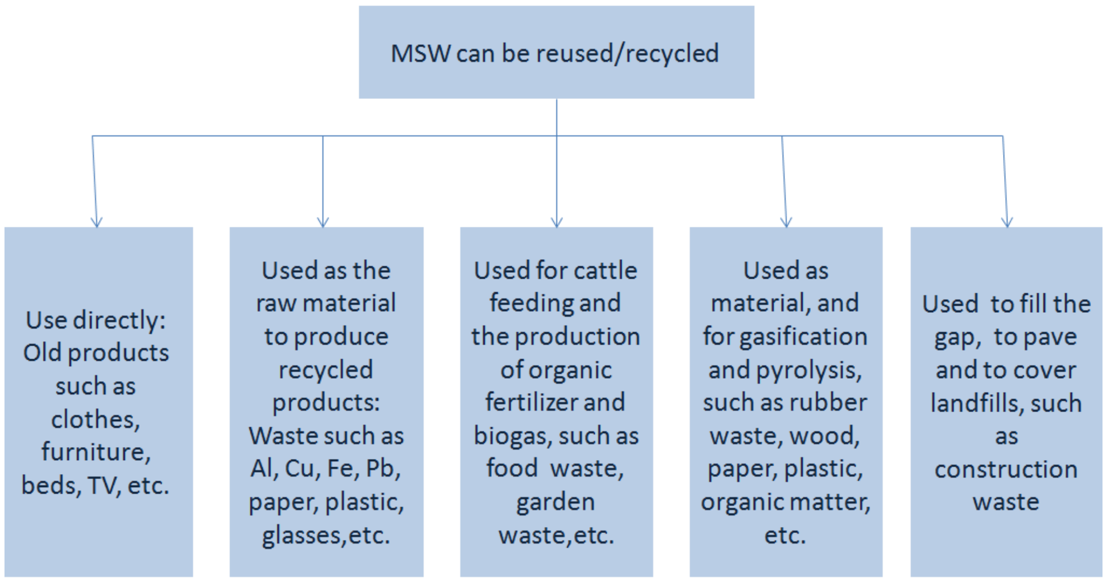
Transfer stations are seldom observed in cities of Viet Nam. This is the case, for example, of Hanoi, where waste collection trucks need to cover a distance of 50 km from waste collection points up until the disposal site. These transportation costs could be significantly reduced with the installation of transfer stations.

### 3.1.4 Diversion, treatment and disposal of solid waste in Viet Nam

In Viet Nam, municipal solid waste is generally disposed in landfills. According to MONRE (2011), at present 76-82% of collected waste is landfilled. According to provincial statistics, there are about 450 landfills in operation in Viet Nam, 80-85% of which are unsanitary. There are 98 centralized landfills serving major cities in Viet Nam; of these only 16 are engineered or sanitary landfills. The combustion of domestic urban waste is a practice observed in Viet Nam and it mainly occurs in unsanitary landfills, where 40-50% of waste is burned. However, during the monsoon season, waste cannot be burned or the combustion process is not complete.

Waste that is not collected or landfilled is processed either through incineration, composting or recycling. Modern technologies for incineration have only been applied in one facility, Son Tay, in Hanoi. The cities of Hanoi and Ho Chi Minh are planning to import technology which can recover the combustion heat for power generation. It should be noted, however, that given the high humidity and low calorific value of waste streams in Viet Nam (900-1,100 kcal/kg), the incineration of waste has not been a common practice, most especially in small and medium-sized cities.

On the way forward, waste treatment technologies in Viet Nam are expected to be developed in order to minimize landfill waste and increasing the rates of re-use and recycling. Indeed, municipal solid waste streams can be reused and recycled into many different valuable products such as organic fertilizer, recycled paper, metal, plastic, glass, as presented in figure 3.2 below. At present, recycling rates in Viet Nam account for approximately 8-12% of collected municipal solid waste.




**<u>Figure 3. 2</u>** – Options for reducing, reusing and recycling solid waste (Source: MONRE, 2011)

Recycling of waste streams such as paper, plastic and metal in Viet Nam is mostly conducted by the private sector and at “craft” villages or workshops. These are relatively well developed and established activities, carried out mostly by informal waste sector members, and bringing economic benefits to the individuals involved.

As the fraction of organic waste is relatively high, techniques and approaches to recycle organic waste hold significant potential in Viet Nam. One such option is composting. As of March 2013, there were 41 composting plants in Viet Nam, out of which 28 were in operation, 10 under construction, and 3 with their operations suspended. Indeed, the operation of these projects has been marred by a set of difficulties, including:

- Poor or no source segregation of the waste that is sourced to the plants results in the production of low-quality compost;
- Challenges in finding markets for the compost produced, and low prices fetched as compost competes with subsidized chemical fertilizers. This is compounded by the low-awareness of farmers about the benefits of compost, who eventually prefer to use chemical fertilizers;
- Low or inexistent incentive schemes for supporting the operation of these plants, such as tipping fees or waste collection charges, which pose challenges to their financial sustainability.

The anaerobic digestion of the organic component of urban waste is an alternative, or can be used in complement, to the composting of waste. A study by Nguyen et al.[14] revealed that food waste from municipal solid waste streams has the potential of meeting 2.4-4.1% of Viet Nam's electricity needs through the anaerobic digestion of waste and the conversion of the biogas generated into power. However, the technology is still not well known in Viet Nam, with limited data and experiences existing. Besides, its applicability in the context of Viet Nam may be hindered by the same difficulties that hamper composting, particularly the need to separate waste at source and lack of support schemes (e.g. feed-in tariffs).

### 3.1.5 Greenhouse gas emissions from the waste sector in Viet Nam

According to the Second National Communication of Viet Nam to the UNFCCC, in 2000 the GHG emissions from the waste sector totalled 7,925.18 thousand ton of carbon dioxide equivalent (ton $CO_2e$), which corresponded to a share of 5.3% of the total. GHG emissions from the waste sector consisted of 331.48 thousand ton of $CH_4$ and 3.11 thousand ton of $N_2O$. With 5.6 million ton of $CO_2e$, solid waste was the largest source of GHG emission from waste, accounting for 70.6% of the total. Industrial wastewater was the second largest contributing source at 16.8% with 1,336 thousand ton of $CO_2e$ emitted. Finally, human waste and wastewater contributed 964 thousand ton of $CO_2e$ and 28.4 thousand ton of $CO_2e$, respectively.

Unit: thousand ton

| **Sub-sector** | **$CH_4$** | **$N_2O$** | **$CO_2e$** | **Percentage (%)** |
|---|---|---|---|---|
| Solid waste | 266.52 | | 5,596.92 | 70.6 |
| Wastewater | 1.35 | | 28.35 | 0.4 |
| Industrial waste | 63.61 | | 1,335.81 | 16.8 |
| Human waste | | 3.31 | 964.10 | 12.2 |
| Total | 331.48 | 3.11 | 7,925.18 | 100 |

**Table 3.4** – GHG emissions from the waste sector in 2000 (Source: Second National Communication of Vietnam to UNFCCC (2010), 2005 GHG inventory)

[14] Nguyen, H. H., Heaven, S., Banks, C., 2014, "Energy potential from the anaerobic digestion of food in municipal solid waste stream of urban areas in Vietnam", International Journal of Energy Environmental Engineering, 5:133

The waste sector covers emissions of $CO_2$, $CH_4$ and $NO_2$ from different sources, including waste disposal sites, wastewater treatment, human sewage and industrial waste. Based on the result of the project for “Capacity Building for National Greenhouse Gas Inventory in Viet Nam” supported by JICA, in 2005 the volume of GHG emissions from the waste sector in Viet Nam totalled 8,118 thousand ton $CO_2$ equivalent. A summary of the results of the GHG emission inventory in 2005 is displayed in the table below:

| **Category** | **Emissions (Gg)** | | | |
|---|---|---|---|---|
| | **$CO_2$** | **$CH_4$** | **$N_2O$** | **$CO_2$ equivalent** |
| 6A – $CH_4$ emission from solid waste disposal sites | NE | 109.708 | | 2,303.86 |
| 6B1 – $CH_4$ emission from industrial wastewater | | 31.803 | | 667.857 |
| 6B2 – $CH_4$ emission from domestic wastewater | | 163.965 | | 3,443.258 |
| 6B – $N_2O$ emission from human sewage | | | 5.467 | 1,694.701 |
| 6C – $CO_2$ emission from waste incineration | 8.424 | | NE | 8.424 |
| **Total** | **8.424** | **305.475** | **5.467** | **8,118.100** |

**Table 3.5** – Overview of GHG emissions from the waste sector in Viet Nam (Source: National Inventory Report, 2005)

It can be seen that over the 2000-2005 period, the GHG emissions from the waste sector have increased from 7,925 thousand ton of $CO_2e$ to 8,118 thousand ton $CO_2e$. Therefore, although the percentage of GHG emissions is relatively small compared to those of other sectors, they are still significant and are likely to increase in the future if no appropriate waste management measures are adopted.

## 3.2. Policies on solid waste management in Viet Nam

### 3.2.1 General policies on solid waste management at national level

In order to improve its waste management capacity and the services provided, the country has responded with an improved policy framework and an aggressive investment plan, especially in major cities. Decrees enacted in 2006 and 2007 provide detailed regulations and guidelines for the implementation of the Law on Environmental Protection, define the rights and obligations of entities engaged in solid waste management activities, and stipulate environmental protection charges for solid waste handling. In general, waste management policies in Viet Nam are very supportive of measures aligned with 3R principles, and the recovery of resources from waste. On the other hand, there is no legal enforcement to implement the directions and targets laid out on existing policies and strategies. Besides, few policies regulate, guide or enforce waste separation at source.

The most important policy on waste is the **National Strategy for Integrated Management of Solid Waste up to 2025 and Vision towards 2050**, approved by Decision No. 2149/QD-TTg dated 17 December 2009. The strategy sets the vision that by 2050 all sorts of solid wastes are to be collected reused, recycled and treated completely by technologies that are environmentally friendly, suitable to each location, and enable the minimization of waste that is landfilled. The Strategy sets ambitious targets for the collection, reduction, reuse and recycling of waste for the whole of Viet Nam to 2015, 2020 and 2025, as follows:

- 85%, 90% and 100% set as targets for waste collection rates in urban areas for 2015, 2020, and 2025, respectively. The waste collected is to be treated in an environmentally-friendly manner, with 60%, 70% and 90% (respectively for each target year) of the waste collected to be recycled, reused or recovered for utilization as an energy resource or to produce organic fertilizer;
- 50%, 80% and 100% of cities in Viet Nam have their own recycling facilities and solid waste is segregated at the source, for years 2015, 2020 and 2025, respectively.

GHG emission reduction targets for the waste sector are proposed in the Plan **"Management of greenhouse gas emissions: management of the activities of trading carbon credits to the international market**", approved by Decision No. 1775/QD-TTg dated 21 November 2012 of the Prime-Minister. As noted in the previous chapter, the plan sets the target of a 5% reduction in GHG emissions from the waste sector by 2020 compared to the base year of 2005 through the recovery and utilization of methane from landfills and industrial waste water treatment.

The **National Strategy for Climate Change**, approved by Decision No 2139/QD-TTg of the Prime Minister on 5 December 2011 contains several strategic directions related to the management of waste, as follows:

- To come up with waste management plans so as to maximize recycling practices and the reuse of wastes, so as to attain greenhouse gases GHG emission reductions;
- To foster research & development, as well as the introduction of advanced waste treatment technologies, both in urban and rural areas;
- By 2020, 90% of the total volume of urban domestic solid wastes to be collected and treated, from which 85% to be recycled and reused.

The **Intended Nationally Determined Contribution** (INDC) of Viet Nam to the UNFCCC, which was submitted in September 2015, does not indicate specific targets for GHG emission reductions in the waste sector. However, it reckons the need to develop enhanced waste management capacities, the promotion of 3Rs, and the adoption of advanced waste treatment technologies in urban and rural areas as a means to meet GHG emission reduction goals of Viet Nam.

Albeit not as recent as the previous documents, **Decision No.59/2007/ ND-CP on Solid Waste Management**, issued by the Prime-Minister on 9 April 2007, regulates the principles for solid waste management, through the following guidelines:

- Organizations and individuals responsible for the generation of solid waste shall pay charges for the collection, transportation and disposal of those waste streams;
- Waste shall be segregated at the source, recycled, reused and processed into resources, including energy;
- To prioritize the application of technologies for processing "hard-to-decompose" solid waste, which may help reducing the volume of waste that is disposed, and thus save land used for this purpose;
- The State encourages the "socialization" of the collection, separation, transportation and disposal of solid waste.

It can be elicited from the above that even though the separation of waste at source is not a common practice in Viet Nam, it is supported and endorsed by all major policies and regulations on solid waste management. In addition to those mentioned, the following specific policies regulate and/or provide guidelines for the separation of waste at source:

- **Strategic Orientation for Sustainable Development in Viet Nam** (Vietnam Agenda 21) (approved in 2004), determined that waste management is one of the key issues for environmental protection, including 3R solutions such as the separation of waste at source and waste recycling;
- **Directive 23/2005/CT-TTG** dated 21 June 2005 on enhancing the management of solid wastes in urban centres and industrial parks, which set forth the target of achieving a 100% waste segregation rate at household level in urban areas, so as to support the establishment of a recycling infrastructure.

## 3.2.2 Policies on waste collection and treatment at the regional level

Viet Nam has developed numerous official documents providing guidelines, targets and instructions for cities, provinces, industrial zones, and regions on solid waste management. Among these, Decision No 1873/QD-TTg on "**Planning on developing the solid waste treatment zone in the key economic region of the Red River Delta until 2020**", approved on 11 October 2011 by the Prime-Minister, it is set the target that 90% and 100% of the solid waste from the cities and industrial zones of the Red River Delta region are to be collected and treated by 2015 and 2020, respectively.

On 10 July 1999, the Prime-Minister issued Decision No 152/1999/QĐ-TTg "**Strategy on solid waste management in the cities and industrial zones of Vietnam until 2020**". Two of the long-term objectives (until year 2020) include the collection, transport and treatment of 80-95% of the total volume of solid waste generated in cities and industrial parks, and to collect and thoroughly treat hazardous medical solid waste in cities with advanced technology(ies). This strategy also prescribes directions for the recycling and reuse of waste.

On 21 June 2005, the Prime-Minister issued Directive 23/2005/CT-TTG on "**Enhancing the management of solid wastes in urban centres and industrial parks**", which instructs an increase in the efficiency and quality of solid waste management services, thereby creating a solid foundation for implementing the strategy for managing solid wastes in Viet Nam's urban centres and industrial parks mentioned in the paragraph above.

It can be concluded that the policy framework in place encourages and promotes the implementation of practices in line with the principles of Reducing, Reusing and Recycling (3R), particularly the "National Strategy for Integrated Management of Solid Waste up to 2025 and Vision towards 2050" and the Climate Change Strategy.

## 3.3 Institutional arrangements for the solid waste sector in Viet Nam

The management of solid waste involves a vast array of stakeholders, with different roles and responsibilities.

According to the 2011 National Environment Report on Solid Waste published by MONRE, there are five ministries involved in solid waste management in Viet Nam: Ministry of Construction (MOC), Ministry of Industry and Trade (MOIT), Ministry of Health (MOH), Ministry of Agriculture and Rural Development (MARD) and MONRE. Roles and responsibilities are as follows:

- **MONRE** is the major state authority on environmental management and protection, and the key ministry for hazardous waste management. MONRE is also in charge of coordinating other line ministries and agencies in issuing guidance, regulations and standards on waste management, the development of long-term and short-term plans and strategies, and the delivery of national budgets for R&D for waste treatment projects. The Vietnam Environmental Agency (VEA) operates under MONRE, and it is responsible for developing, guiding and implementing programmes on waste segregation at source, as well as waste reduction, reuse and recycling.
- **MOC** is responsible for planning aspects related to solid waste management at regional, inter-provincial and inter-city levels, including key economic regions of Viet Nam. MOC is also the focal point for coordinating with other line ministries and agencies on solid waste treatment.
- **MOIT** has responsibilities in providing guidance and verifying the implementation of environmental protection laws and regulations related to industrial waste.
- **MOH** is in charge of steering, guiding and verifying the implementation of medical waste management. Responsibilities of MOH in consist in assessing the impact of solid waste on human health, inspection of medical waste, etc..
- **MARD** is in charge of steering, guiding and verifying the implementation of agriculture waste management policies and guidelines, developing programmes to improve the effectiveness of solid waste management in rural areas, etc.

The institutional arrangements for waste management in Viet Nam are presented in figure 3.3 below:

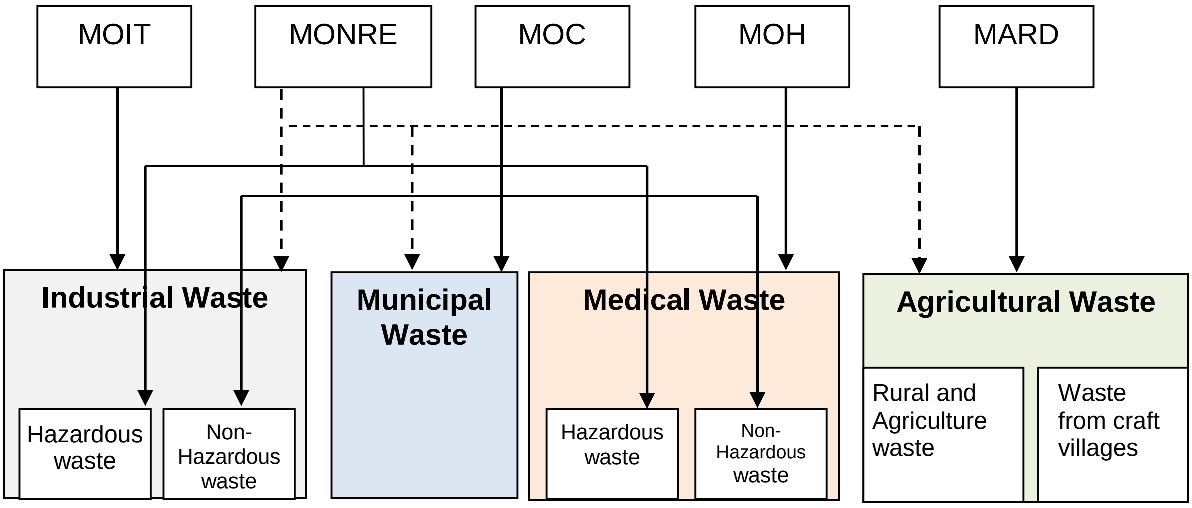



**Figure 3.3** – Solid waste management arrangements in Viet Nam (MONRE, 2011). Dashed lines indicate an indirect relationship among entities or sectors.

As in many countries across the globe, the responsibilities of implementing solid waste projects rest upon provincial and municipal governments, and Viet Nam is not an exception. In this regard, it should be mentioned the role of the following entities:

- **Department of Construction (DOC)**: usually in charge of managing solid waste, dumps sites and landfills, monitoring the implementation of urban planning for provinces or cities, collaborating with DONREs for planning disposal sites and waste treatment plants, etc.
- **Department of Natural Resources and Environment (DONRE)**: usually have under their purview the monitoring of environment quality, the management and implementation of policies and regulations, approval of environmental assessment studies for waste treatment projects, etc.. The roles of DOC and DONRE on waste management issues may vary from province to province.
- **Urban Environment One Member Limited Companies (URENCOs)**: they are public companies whose major responsibilities are the collection, transport and treatment of waste at province or city levels. URENCOs can either belong to DONRE or DOC, depending on the specific circumstances of each province.

To illustrate the roles and responsibilities of the above stakeholders, the waste management model observed in Ho Chi Minh City (HCMC) is showcased as a good practice in Viet Nam, and is illustrated in figure 3.4.

In HCMC the city People's Committee provides overall direction and ensures coordination between URENCO and DONRE, which in this case is the department which acts as the solid waste management lead office. URENCO, for example, operates under the People's Committee of HCMC. On this model, the coordination and management of solid waste issues is unified and efficient, which has led to waste collection rates of 95% in the past few years, one of the highest in the country.

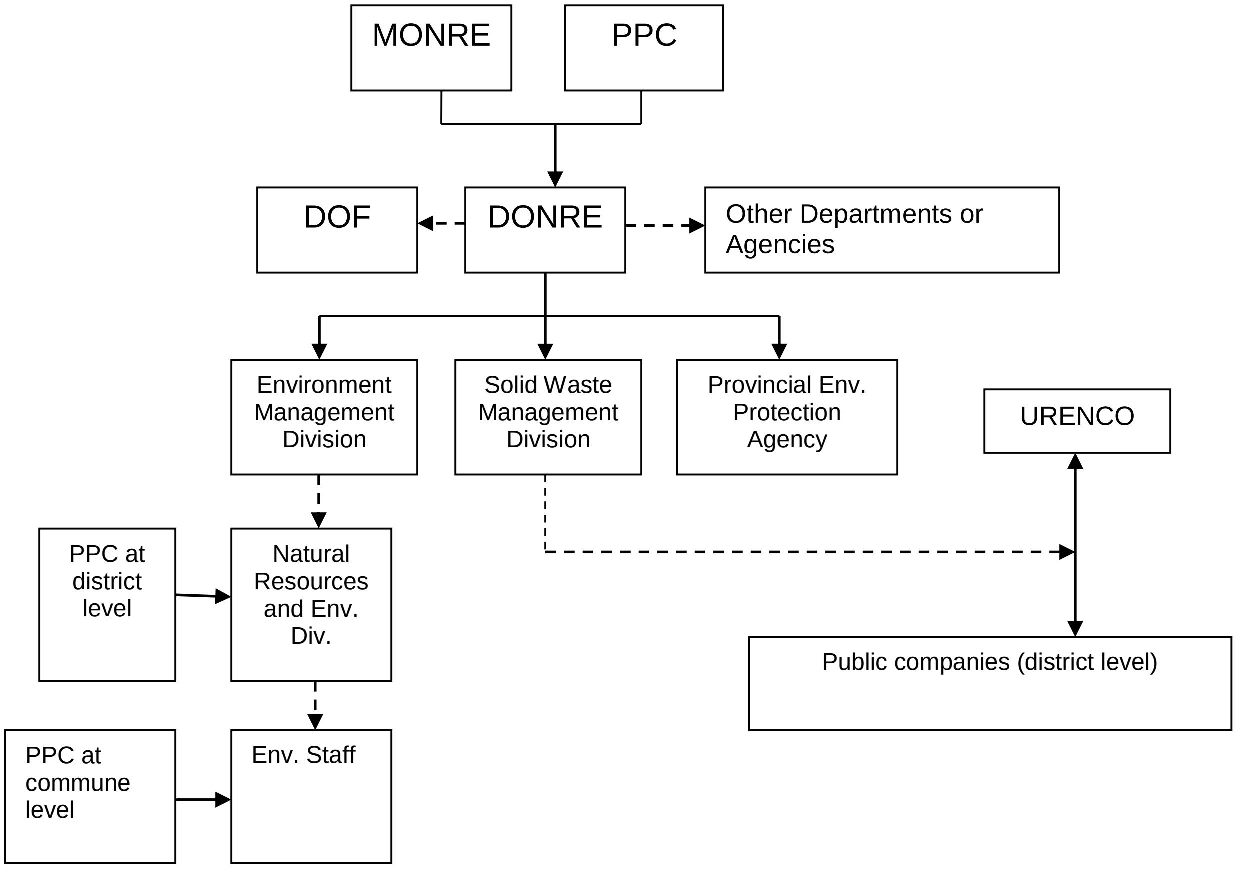



**Figure 3.4** – Solid waste management arrangements in Ho Chi Minh City (HCMC Department of Natural Resources and Environment, 2011). Dashed lines indicate an indirect relationship among entities or sectors.

## 3.4 Conclusions: barriers to solid waste management in Viet Nam

Viet Nam has developed a comprehensive policy framework on solid waste management, which is fully supportive of measures in line with the 3Rs and a paradigm shift towards waste-to-resource approaches. Yet, a **number of barriers** need to be addressed for this shift to occur. These can be identified at several levels, including on policy, financing and institutional set-up.

At **policy level**, it was noted the existence of a significant number of policies and regulations on solid waste. Among these, the most far reaching is the "National Strategy for Integrated Management of Solid Waste up to 2025 and Vision towards 2050", which sets ambitious targets for the collection, recovery and treatment of waste. However, Viet Nam does not have a legal system to enforce the implementation of those targets in cities and provinces. This is also motivated by the fact that the management of solid waste is typically a function under the purview of local governments, and thus the implementation and enforcement of measures needs to be led either by municipal or provincial governments.

**Institutional barriers** are identified in Viet Nam's solid waste sector, and the main challenge derives from overlapping responsibilities at national and sub-national levels. MONRE is the responsible entity on behalf of the government for implementing environmental protection measures, including on waste management. On the other hand, under the provisions of the Environmental Protection Law and other related documents, the disposal of domestic solid waste falls within the responsibility of MOC. This has resulted in coordination challenges concerning the design, approval and implementation of policies, regulations and programmes in Viet Nam. These institutional challenges also trickle down to provinces and cities, resulting in unclear responsibilities of concerned agency(ies), including on aspects such as the investment in infrastructure to collect/transport/treat solid waste, the design and implementation of waste management programmes, the issuance and enforcement of regulations, etc. As will be seen in part II of the study, the Waste-to-Resource NAMA proposes the establishment of a one-stop-shop agency, at the national level, to address these coordination issues.

Challenges are identified, too, on the **economic and financing** dimensions of solid waste management. The costs incurred with handling waste, from generation to disposal, often take a substantial portion of city budgets. Income generated from collection fees may, in some cases, suffice to cover the operational costs of collection/transport. However, they are typically not enough to cover investment requirements. Consequently, local governments often depend on the national government for subsidies or on official development assistance (ODA) for the investment in new infrastructure. In addition, URENCOs often depend directly on local or provincial governments for their budgetary requirements, which are in most cases insufficient to cover investment costs, especially for new technologies that fall beyond current business-as-usual practices. There is therefore a need to mobilize additional financial resources to implement waste-to-resource initatives in Viet Nam.

Barriers at the **economic level** are those associated with the failure to reflect an “adequate” economic value to the products generated from waste. In the case of compost, for example, its marketability is severely hindered by the need to compete with heavily subsidized chemical fertilizers, which is further compounded by the low-awareness of consumers and the lack of standards for this product. The same rationale applies to other resources derived from waste, such as biogas and refuse-derived fuel: without additional incentives, either in the form of a feed-in-tariff, tipping dee, etc., they are unable to compete with cheaper and more carbon intensive fossil-fuel based alternatives (e.g. coal), which may also benefit from subsidies. In addition, there is a generalized lack of specific instruments to promote the valuation of resources derived from waste, for example in the form of tax exemptions to equipment or companies investing in the sector, concessional loans, etc.

In order to instill the paradigm shift laid out on national policies, there is also a need to address **social and behavioural barriers** related to the waste sector as a whole, as communities are typically unaware of the need for their engagement in sustainable waste management practices, by reducing the generation of waste, and participating in waste segregation practices. Finally, the **low-level of capacities** (technical, operational, managerial, etc.) among a wide range of stakeholders in the development and implementation of waste-to-resource initiatives is another barrier that needs to be addressed.

In conclusion, all these barriers are hindering the deployment of more sustainable waste management practices. Without being addressed, current practices of collecting and disposing waste will continue, leading to severe environmental stress, increasing waste handling costs, and the emission of greenhouse gases.

# 4. Analysis of appropriate technologies for the solid waste sector of Viet Nam

## 4.1 Introduction and context

This chapter assesses technologies and methods for the treatment of solid waste, so as to identify which are the most suitable to the context of Viet Nam. This assessment supports the rationale for endorsing specific mitigation actions as eligible measures under the Waste-to-Resource NAMA in Chapter 5.

When considering the most appropriate methods, approaches and strategies for managing solid waste, it is important to take account of the waste management hierarchy, as shown in figure 4.1. The hierarchy ranks waste management options based on the environmental, social and economic benefits they can generate. The most preferred options are found when moving up to the top of the pyramid. The disposal of waste into dumpsites and unsanitary landfills is the least preferred option due to the negative impacts created on the environment and public health. Methods based on the principles of reducing, reusing and recycling (3R) are the most preferred and, accordingly, these are placed in the top of the pyramid.

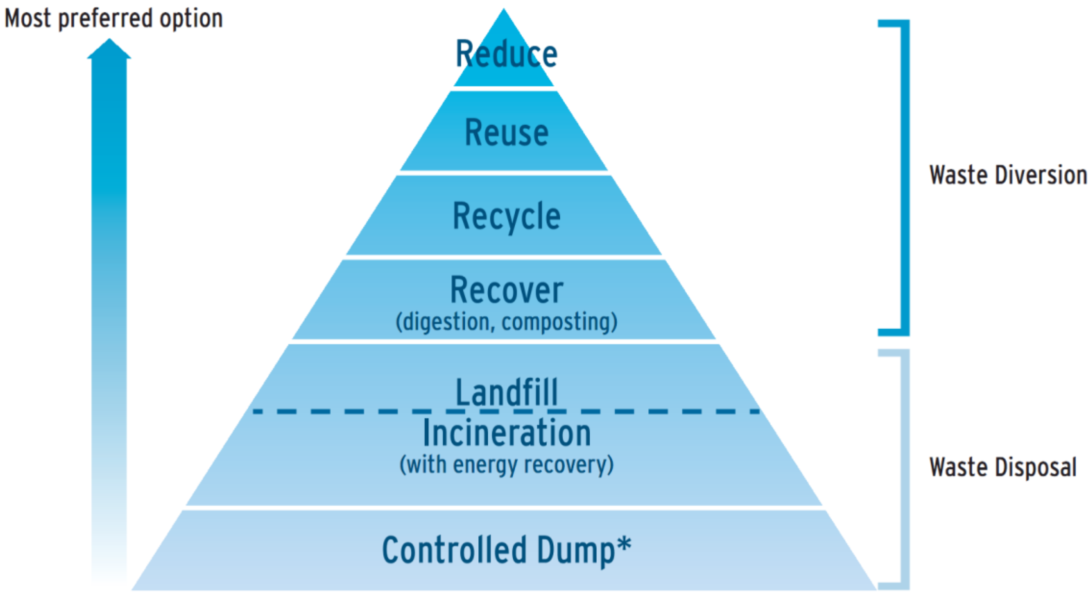



**Figure 4.1** – Waste management hierarchy.

The disposal of waste, especially in unsanitary landfills and open dumps (so-called “end-of-pipe”), is associated with several negative externalities, including a higher risk of disease vectors, odor nuisance, groundwater pollution and the emission of greenhouse gases. There is thus a need to move away from a focus on disposal to approaches that focus on the principles of 3Rs and the generation of resources from waste alongside its value chain, as illustrated in figure 4.2 below.

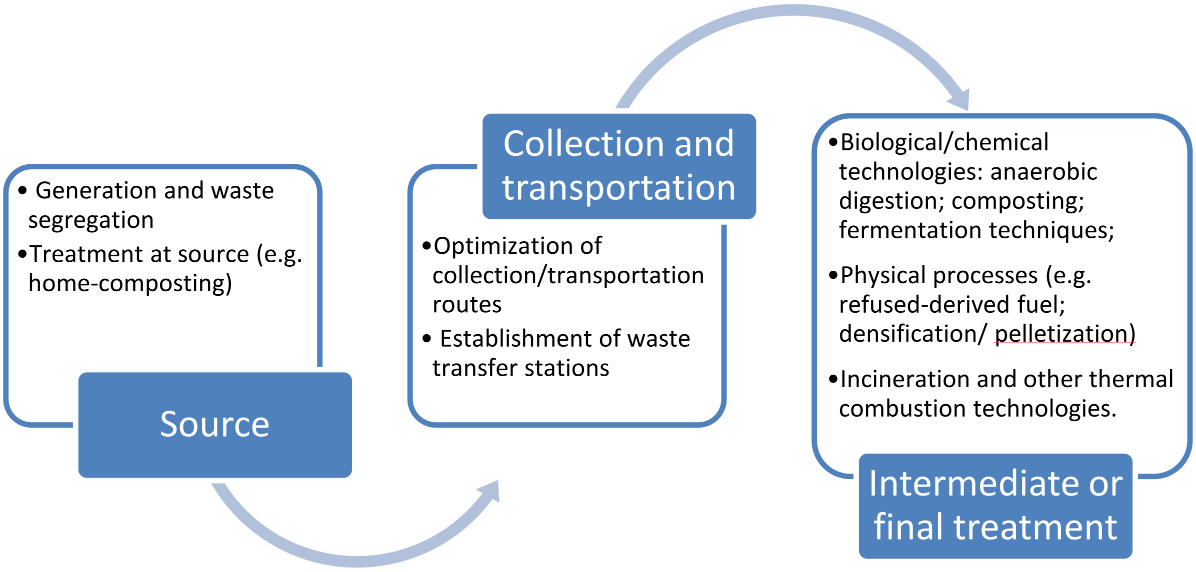



**Figure 4.2** – Options for waste diversion.

There is no "one-size fits all" waste treatment method or technology that addresses every single waste management problem. To understand the local context and waste characteristics is essential for selecting the most appropriate choice of method or technology. Having as a reference the waste pyramid hierarchy, **this chapter assesses waste treatment technologies that imply a shift from the current practices observed in Viet Nam**. These methods are in line with the principles of 3R, and thus their focus is on waste diversion from disposal sites and resource recovery. In this context, four categories of treatment technologies/measures are assessed and discussed: i) aerobic digestion of waste (composting); ii) anaerobic digestion (AD); iii) material recovery and recycling; and iv) production of refuse derived fuel (RDF).

In addition to the characterization of these groups of technologies, this chapter provides an introduction to a good waste-to-resource practice in Viet Nam, whose replication and dissemination could be supported through a NAMA programme. This is the so-called **Integrated Resource Recovery Center (IRRC) model**, which has been piloted in the cities of Quy Nhon and Kon Tum.

## 4.2 Overview and assessment of solid waste treatment technologies for Viet Nam

### 4.2.1 Composting of Waste

Composting is the process of biodegradation of organic matter into a humus type of material through the activity of microorganisms. It occurs as a natural decomposition process under controlled conditions, and as a result the volume of organic wastes can be reduced in 50-85%.

There are two main composting methods: aerobic and anaerobic composting. The aerobic conversion method is by far the most commonly applied: the decomposition occurs in the presence of oxygen, volumes of organic waste can be reduced in 50-85%, and the process typically take between 60-90 days to be completed. Several techniques exist for carrying out this process, including the windrow method, in-vessel composting, box method and vermi-composting, as illustrated below.

| | | |
|---|---|---|
|  |  |  |
| **Manual windrow composting** | **Mechanized windrow composting** | **In-vessel composting** |
|  |  |  |
| **Box composting** | **Vermi-composting** | **Home-composting** |

**Figure 4.3** – Illustration of composting methods.

Composting is a waste treatment method that, if properly applied, can reduce a significant portion of the organic fraction of waste sent to disposal sites. In addition to addressing a waste handling aspect, the application of compost in agriculture can bring several benefits, including the following (EPA, 2013):

- Enrichment of soils with nutrients: compost can re-establish the fertility of soils by returning organic matter, while increasing the nutrient content and helping soils retaining moisture.
- Improvement of soils' structure: compost improves the structure of soils by creating a better environment for plant roots, and the capacity of the soil to retain water.
- Pollution control: compost helps preventing pollutants reaching water resources, and prevents the erosion of soils.
- Economic and environmental benefits: compost reduces the need for water, fertilizers and pesticides.

**Application of composting in Viet Nam**

It was noted in chapter 3 that a number of composting plants have been developed in Viet Nam for processing solid waste. Most of these are centralized and industrial-scale facilities, relying on foreign technology. An overview of composting plants in Viet Nam is provided in the table below:

| Scale | Technology and approach | Representative Plants |
|---|---|---|
| Large/ Industrial scale | Foreign technology, treating segregated waste | Organic waste treatment plant Cau Dien- Ha Noi |
| | | Waste treatment plant Loc Hoa - Nam Dinh |
| | | Composting plant Trang Cat - Hai Phong |
| | | Waste treatment Viet Tri |
| | | Compost plant from MSW - Ha Nam |
| | | Compost plant Long My - Quy Nhon |
| | | Waste treatment plant Cu Chi |
| | | Waste treatment plant Hooc Mon, Ho Chi Minh City |
| | Domestic technology, treat integrated waste | Domestic waste treatment Son Tay |
| | | Waste treatment plant Thuy Phuong- Hue |
| | | Waste treatment plant Dong Vinh, Nghe An |
| | | Waste treatment plant Dong Thanh- Ninh Thuan |
| Small-scale | Others | Xuan Tho Farm, Organik Dalat, Thuy Luc Co., Ltd. |
| | | In Dong Van Industrial Zone, Ha Nam |

**Table 4.1** – Composting technologies of MSW applied in urban areas in Viet Nam (Nghiem Van Khanh, 2012).

Of the plants above, 7 of them apply forced-aeration composting, 3 the windrow composting method combined with forced aeration, and 4 plants apply the non-aerated windrow composting method (Nghiem Van Khanh, 2012).

In Viet Nam there are domestically available technologies for composting, namely SERAPHIN and ANSINH-ASC, which have been certified by governmental agencies. Plants applying these technologies are in operation in Ha Noi, Hue and the provinces of Nghe An and Ha Nam. However, the composting efficiency of these plants has been relatively low since waste streams are not segregated at source. In most of these plants, the rejects that need to be disposed still account for 35-40% of the total waste inputs, even though a large proportion of the incoming waste is organic.

The composting plant of Long My, in Quy Nhon, can be pinpointed as an example of how important is the separation of waste at source for the operation of a large-scale and centralized composting plant that relies on mechanization. As with many other similar plants in developing countries, the first years of operation of the Long My plant have been marked with difficulties associated with having mixed waste as feedstock, resulting in low efficiencies and the production of a low-quality product. To tackle this challenge, the municipal People's Committee of Quy Nhon initiated a 5-year strategic programme to expand the separation of waste at source to the whole city, which has a population of more than 250,000 people. Two years following the start of the programme, the city has been able to separate 30-40 ton of organic waste on a daily basis, which has significantly improved the operation of the Long My plant. As of 2015, the management of the plant had to decrease the production of compost due to challenges in finding a market for compost, whose prices have been too low to sustain the plant's operational costs.

Despite being a potentially useful and cost-effective means for treating solid waste in Viet Nam, the share of waste that is composted in Viet Nam is not particularly high at present. It is estimated that with the operation of all existing composting plants at full capacity, the quantity of solid waste composted would be short of 2,500 tons/day, which is less than 10% of the amounts currently generated (MONRE, 2011).

### 4.2.2 Anaerobic Digestion of Waste

The decomposition of organic matter can be made through the activity of both anaerobic and aerobic bacteria. With anaerobic bacteria, which operate in the absence of oxygen, the organic matter is decomposed into biogas, a mixture of methane ($CH_4$) and carbon dioxide ($CO_2$). The process of anaerobic digestion (AD) has been practiced for decades in developing countries for the treatment of different waste inputs. Several types of organic waste can be treated through AD, including animal waste, faecal matter, food and kitchen waste.

The AD of organic waste can bring significant sustainable development benefits in addition to those associated with the implementation of 3Rs and the diversion of waste from disposal sites. One of the key benefits is the harnessing of a renewable energy source in the form of biogas, which can result in a reduced dependency on fossil fuels. Besides, the liquid effluent and the sludge resulting from the AD process may be subsequently processed and utilized as fertilizer, thereby contributing to the closing of the nutrient cycle[15]. There are also potential climate change benefits to be derived from AD. Compared to landfilling, biogas digesters are fully enclosed systems and, as such, all methane generated from the decomposition of waste is captured (if leakages do not exist), thereby reducing GHG emissions.

While the application of AD to substrates such as swine or cattle waste can now be considered as a mature and well established approach, the application of this treatment method to the organic fraction of urban solid waste is more recent. Countries from Europe and North America have showcased significant interest on the technology, particularly since the 1990s, and a number of medium and large scale facilities have started operation in recent years. Such facilities are mostly centralized and rely on expensive and cutting edge technology, and their economic viability is due to the existence of generous support schemes, like feed-in tariffs for the sale of electricity from biogas and the payment of tipping-fees. Due to a generalized lack of such supporting mechanisms, large scale AD plants for treating urban solid waste have been few and far between in developing countries. Besides, of the few projects commissioned in developing countries, most have been marred by operational difficulties resulting from the improper separation of waste at source.

In Viet Nam, the production of biogas through AD has been introduced quite recently. However, these programmes have essentially dealt with agricultural wastes and manure, mostly at the household level. The Biogas Program for Vietnamese Livestock Production, with the support of the Dutch government, has supported farmers in Viet Nam in building 18,000 biogas plants in the 2003-2005 period (in the

[15] Vögeli Y., Lohri C. R., Gallardo A., Diener S., Zurbrügg C., 2014, “Anaerobic Digestion of Biowaste in Developing Countries: Practical Information and Case Studies”, EAWAG.

first phase). At present, it is estimated that 150,000 biogas plants have been built and are in operation in Viet Nam.

With regards to the AD of urban solid waste, no experiences are known in Viet Nam, as this has been an approach somewhat overlooked by national level decision-makers, which can be ascribed to the dearth of successful experiences in countries of the region. On the other hand, the National Environment Report of Viet Nam (MONRE, 2011) indicates that strategies from now up until 2025 will focus on methods to recover energy and materials from domestic solid waste. The National Climate Change Strategy also sets a target for 2020, whereby 90% of the urban household solid waste is to be collected and treated, of which 85% to be recycled, reused and recovered for energy generation. In this context, it is reasonable to expect that AD could play a relevant role in the achievement of these targets. As mentioned in section 3.1.4, a study estimated that food waste can potentially meet up to 4% of Viet Nam's electricity needs through AD processing, and up to 4.7% of the fuel consumption demand in the transportation sector.

### 4.2.3 Production of Refuse-derived fuel (RDF)

Refuse-derived fuel (RDF) is produced through the shredding and dehydration of municipal solid waste. An RDF production system encompasses two processes: the separation of waste into combustible and non-combustible components, and turning the combustible components into fuel briquettes. The final product consists largely of the combustible components of municipal waste such as plastics and biodegradable waste. RDF can be used as a fuel in industrial boilers, such as cement factories or brick kilns, thereby reducing the need for fossil fuels, especially coal. One of the main advantages of RDF is the potential to increase the calorific value of solid waste from around 1,000 kcal/kg to 4,000 kcal/kg. On average, 100 tons of raw waste can generate 15-20 tons of RDF pellets.

In Viet Nam, there are no known experiences with the application of this technology. However, projects do exist in South-East and South-East Asia, which attest to the viability of the technology as long as certain conditions are met (e.g. segregation of waste at source, proximity to sources of demand sources for the fuel, etc.). As a waste-to-energy approach, RDF production is supported by national policies and strategies on solid waste management.

### 4.2.4 Material Recovery and Recycling

Material recovery and recycling consist in the process of converting waste streams into new products by preventing the discarding of potentially useful materials. Recycling is a key component of any modern waste reduction approach, and it typically involves three main stages: i) collection of recyclables; ii) processing of recyclables and conversion into recycled-content products; and iii) marketing of recycled products.

In Viet Nam there is a relatively well developed recycling industry. Informal waste sector members are very active on this industry, particularly in the collection and transportation of recyclables. On average, it is estimated that each city in Viet Nam has up to 700 scavengers. In Hanoi for example, statistics indicate that there are 6,000 recyclers and scavengers. Other actors include small household/commercial recyclers, larger recyclers and manufacturers that produce recycled products. Recyclers are at the middle of the recycling value chain, and they usually collect recyclable materials from scavengers. The potential in Viet Nam for recycling is considered high, although there is a scarcity of data about the industry. On the other hand, high recycling rates are achieved in some cities in Viet Nam; in Hanoi it is estimated that 20% of all domestic solid waste generated is recycled[16].

### 4.2.5 Technology Assessment

A comparative analysis of the four categories of technologies is presented in table 4.2 in relation to the following parameters:

- Desirable context for the application of the technology / measure;
- Desired waste composition;
- Quality of waste requirements;
- Moisture content requirements;
- Calorific value of waste requirements;
- Investment and operational costs;
- Operational requirements;
- Barriers to the marketing of outputs;
- Capacity of the project/facility;
- Technology supported or not supported by existing policies in Viet Nam.

A discussion of the merits, drawbacks and challenges associated with these technologies is provided in the following table.

[16] Thai, N. T. K., 2014, "Municipal solid waste management in Vietnam challenges and solutions", in "Municipal Solid Waste Management in Asia and the Pacific Islands: challenges and strategic solutions", Springer-Verlag Singapore, 2014

| Indicator \ Technology | Composting | Anaerobic Digestion | Refuse-Derived Fuel | Material Recovering and Recycling |
|---|---|---|---|---|
| **Desirable context for the application of the technology/ measure** | • High fraction of the biodegradable component of waste<br>• Relative proximity to demand centers for (organic) fertilizers<br>• Favorable climate conditions | • High fraction of the biodegradable component of waste<br>• Proximity to demand sources for the biogas generated<br>• Favorable climate conditions | • Proximity to demand sources for the RDF generated, such as cement factories, brick kilns, etc. | • Significant portion of waste is composed of recyclables |
| **Desired Waste Composition** | • Waste rich in biodegradable organic matter. It is recommended the use of vegetable market waste and wet organic waste from hotels and restaurants. | • Waste rich in biodegradable organic matter. It is recommended the use of vegetable market waste and wet organic waste from hotels and restaurants. | • Waste should be classified. Source segregation program can improve the quality of the product | • Waste streams rich in recyclable materials, such as plastic, aluminum, glass, etc. |
| **Quality of waste requirements** | • Medium (low heavy metal) quality required<br>• Source separated waste would be highly desired | • Medium (low heavy metal) quality required<br>• Source separated waste is a key success factor | • Low quality (no dioxin emitting waste)<br>• PVC with chlorine should be controlled to avoid emission of highly toxic gases (dioxin and furan). | • Some level of separation of waste is necessary, otherwise the quality of recyclables may be too low to ensure resource recovery. |
| **Moisture content requirements** | • Medium (low amounts may require water to be added to the compost pile, while high moisture content may imply the removal of water with the support of blowers) | • Medium (depending on whether the AD process is wet or dry, water may have to be added to the incoming waste) | • Preferably low, otherwise heating requirements for the drying process may incur on an energy penalty and higher costs incurred with the process. | • N/A |
| **Calorific value of the waste requirements** | • N/A (Composting is not a waste-to-energy process) | • N/A | • Preference for waste streams with components high in calorific value, such as plastic residues, rags, etc. | • N/A (Recycling and material recovery is not a waste-to-energy process) |
| **Investment and operational costs** | • Low CAPEX and OPEX for home composting<br>• Medium to high CAPEX and OPEX for medium to large scale composting facilities<br>• $100–$30,000/ton | • Medium to high CAPEX requirements<br>• Low-medium OPEX requirements<br>• $350–$500 per m3 of digester size (with electricity generation option) or US $ 23, 333/ton to 33,300/ton of waste | • Medium to high CAPEX requirements<br>• High OPEX requirements<br>• $75,000–$100,000/ton of design capacity | • Dependent on the material to be recycled |

**Table 4.2** – Comparative analysis of technologies and methods for treating waste.

| | | | | |
|---|---|---|---|---|
| | | input (dry matter) | | |
| **Operational requirements** | • No need for specific training in small-scale settings, such as home composting<br>• Trained manpower required in medium to large-scale plants | • Trained and qualified manpower required in medium to large-scale plants<br>• On a wet digestion process, may be necessary to re-circulate water | • Trained manpower required | • Trained manp be required fo recycling facil depending on complexity of process and t recycled. |
| **Barriers to the marketing of outputs** | • Low-price of compost in Vietnam (~30 USD/ton), which is a challenge to the financial sustainability of composting<br>• Subsidies to chemical fertilizers, do not allow for the creating of a<br>• Perception that compost is harmful to agriculture, due to the risk of soil contamination | • Difficulties in selling the biogas or the electricity produced from it in the absence of support schemes, such as feed-in tariffs | • May be challenging to sell the final product without a demand for it in the proximity, such as cement factories or brick kilns<br>• Government support may be required to ensure adequate levels of return of the facilities | • Depending or product, mark the recyclable significantly fl throughout a |
| **Capacity of the Project/Facility** | • Household to large scale | • Household to large scale | • Medium to large scale | • Small to large |
| **Is the technology supported by existing policies?** | **Partly:**<br>• Recovery of resources from solid waste is in general supported by policies, including the National Strategy for Integrated Management of Solid Waste with a vision up to 2025 and towards 2050 (Decision No. 2149/QĐ-TTg);<br>• No specific incentive schemes to the practice of composting<br>• Decision No. 04/2007/QĐ-BNN by MARD restricts the use of compost in agriculture | **Not specifically:**<br>• National Climate Change Policy endorses the conversion of collected solid waste into energy, but AD is not specifically indicated as a technology option.<br>• No specific incentive schemes exist to this technology | **Not specifically:**<br>• National Climate Change Policy endorses the conversion of collected solid waste into energy, but RDF is not specifically indicated as a technology option | **Partly:**<br>• Decision No. TTg is (Nation on Solid Was Management) supportive of<br>• Lack of specit incentives and instruments to the further de recycling in V<br>• Recycling act Viet Nam are large extent c by the informa |

### 4.2.6 Discussion

Composting and anaerobic digestion are biological treatment methods particularly suited to the context of Viet Nam in light of the high share of biodegradable matter on solid waste streams. Waste streams in Viet Nam are usually high in moisture content and low in calorific value (in the range of 900-1,100 kcal/kg), with the implication that they are not particularly suited to thermal treatment approaches, such as incineration or gasification. Despite their appropriateness to the national context, both composting and AD face several challenges concerning their uptake and further deployment in Viet Nam.

Amongst the challenges associated with composting are the need to ensure some degree of segregation of waste at the source, otherwise the effectiveness of the process and quality of the final product are negatively impacted. Another challenge is that the business case for a composting project can be difficult to attain without the existence of regulatory or fiscal incentives, such as tax holidays, investment subsidies or the charge of a tipping fee by the plant operator. Furthermore, market distortions in the form of subsidies to chemical fertilizers significantly impact the financial viability of composting plants. While the policy framework in Viet Nam is, in general, supportive of measures based on 3Rs and the recovery of resources, there are no specific incentive mechanisms to the use of compost in agriculture. This is further compounded by regulations that restrain the use of compost in agriculture, particularly Decision No.04/2007/QĐ-BNN on 19/01/2007 issued by the Ministry of Agriculture and Rural Development.

With respect to the AD of municipal solid waste, its dissemination in Viet Nam also faces several challenges. First of all, experiences with AD are still quite recent in the country, and the use of domestic waste streams as a feedstock is virtually unheard of. Secondly, the possible high upfront costs of AD solutions and the fact that, technically, it can be a more difficult waste-to-resource conversion route than composting. Lastly, and similarly to composting, there is a lack of economic, financial and fiscal incentives in Viet Nam to support the uptake of AD. In particular, the inexistence of a feed-in tariff or the charge of tipping fees make the economically viability of such initiatives very difficult to achieve. On the other hand, some policy documents in Viet Nam, such as the National Climate Change Policy, set clear goals for the conversion of waste into energy, which may open up opportunities for more specific instruments to stimulate the uptake of AD in Viet Nam.

The production of **refuse-derived fuel (RDF)** is another renewable energy resource that can be harnessed from solid waste. However, unlike AD, for RDF production it is essentially the combustible components of solid waste streams that are used as feedstock. On the other hand, RDF shares similar challenges to the deployment of AD in Viet Nam. Firstly, experience with this technology in Viet Nam is still limited. Secondly, there is a need to ensure a demand for the RDF in the form of a relative proximity to industrial facilities with energy requirements, like brick kilns or cement factories. Thirdly, incentive schemes of some sort are also necessary for ensuring the viability of RDF plants, such as in the form of tipping fees or fiscal benefits. Lastly, some level of waste segregation needs to be conducted, so as to ensure that only streams rich in energy content are obtained and that they are dioxin free.

Among the four technology groups analysed, **material recovery and recycling** is the better established in Viet Nam, despite the lack of specific policy, regulatory or fiscal instruments to support its dissemination. This has been due in part to an active informal sector that has been harnessing opportunities for recovering resources out of waste. Amongst the challenges and barriers associated with a higher deployment of the technology are the poor compliance and enforcement of waste segregation at source, and the high upfront costs associated with medium and large scale facilities. There is also a need to ensure better living and working conditions for informal waste sector workers.

All in all, this chapter showcased that, except for the recycling of inorganic materials, the uptake of composting, AD and RDF production, are far from their potential. Even though the overall policy framework in Viet Nam is supportive of these technologies and the principles of 3R, in order to further stimulate their uptake additional policy, regulatory, financial, economic and fiscal measures are necessary, specifically:

- The creation of a level-playing field for products that can be generated out of waste in order to overcome distortion created with subsidies to energy and chemical fertilizers;
- The need for specific guidelines from the national government that could be adopted by provincial and municipal governments and which could contribute to a higher dissemination of waste separation at source;
- Fiscal incentives to reduce the risks of high upfront costs of technologies, such as tax rebates on equipment, tax holidays, production tax credits, etc.
- Creation of a favourable framework to stimulate and accelerate the transfer of technologies and approaches based on 3Rs from overseas, including the know-how and experiences;
- Issuance of standards and regulations for the commercialization of products derived from waste in order to provide guarantees to potential purchasers of their quality and characteristics, especially in the case of compost and RDF;
- Breakdown of targets for 3Rs at provincial and city level, which could include tentative quotas for specific technologies for the treatment of waste based on the principles of 3R.

Some of the suggested measures could be brought into fruition with the support of the proposed NAMA programme. Different options are discussed in Part II of this study.

## 4.3 The Integrated Resource Recovery Center model –a good practice for the adoption of waste-to-resource approaches in Viet Nam

It was noted already that the solid waste sector in Viet Nam faces several challenges, with ongoing practices focusing on the “end-of-the-pipe”, with most waste being disposed in landfills or open dumps. Yet, these challenges also pose immense opportunities for sustainable urban development. It has been against this backdrop that, ESCAP, in partnership with Waste Concern, an NGO in Bangladesh specialized on waste management, has been supporting cities and countries in the Asia-Pacific region in managing their solid waste in a pro-poor, sustainable and economically viable manner. This support has hinged in the application of the **Integrated Resource Recovery Centre** (IRRC) model, which was developed by Waste Concern, and in supporting local and national governments in up-scaling such initiatives. As of the end of 2015, two cities in Viet Nam – Quy Nhon (Binh Dinh Province) and Kontum (Kontum Province) – had piloted the IRRC model, with several others, such as Ha Tinh and Hoi An, showing strong interest in adopting the model as well.

An integrated Resource Recovery Center (IRRC) is a facility where a large portion of domestic waste (e.g. from households, markets, commercial establishments), can be processed in a cost effective way with low-cost appropriate technologies. An IRRC mainly focuses on **organic waste** (fresh organic waste coming mainly from kitchens, restaurants, vegetable wholesale markets, parks and lawns) including meat and fish waste, and **inorganic waste** (mainly paper, packaging materials and appliances made of plastic, glass, tin, aluminum, iron, etc.). In some cases, too, used cooking oil and human excreta can be efficiently processed in a decentralized manner. The waste treatment approaches that are part of the IRRC model are presented in the figure below:

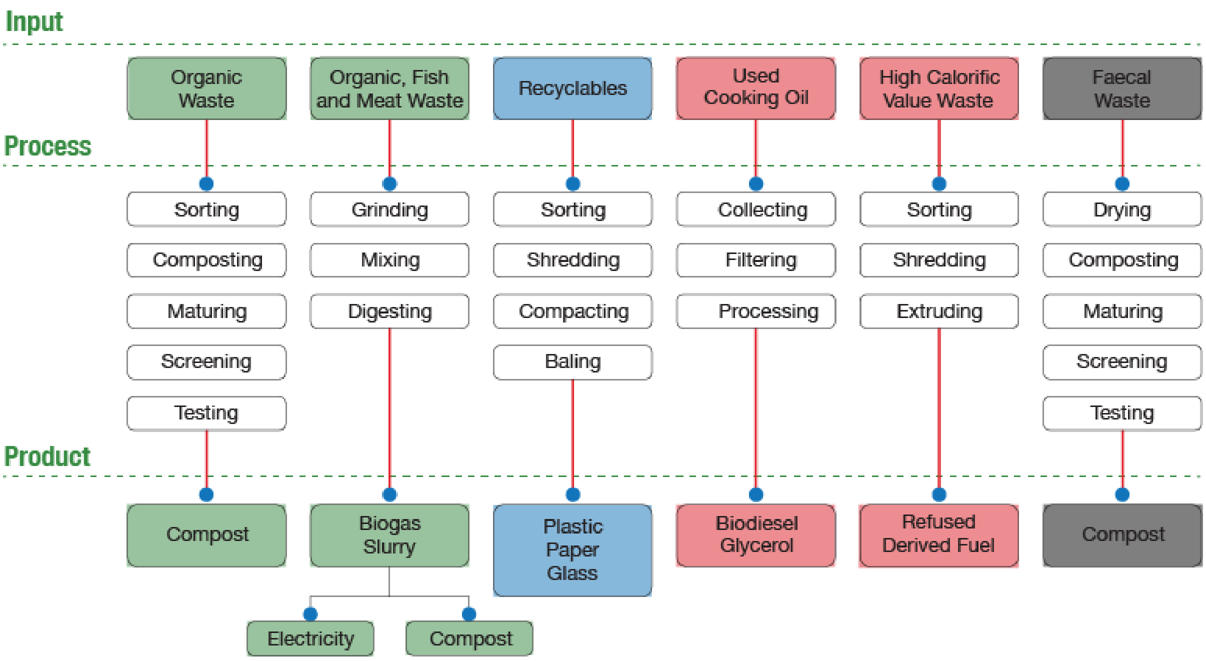


**Figure 4.3** – Options for processing waste through the IRRC model[17].

IRRCs typically have the capacity to process 2 to 20 tons per day, depending on the population whose needs have to be met and investment size. Considering an average waste generation rate of 0.4 kg/day, an IRRC can serve a population of 5,000-50,000 people. IRRCs can be established near communities, and/or serve more than one community at the same time. An IRRC project can be initiated by municipal governments, the private sector (both formal and informal), or can be established in partnership arrangements, for instance through Public Private and Community Partnership models. It can be municipally owned/municipally operated, municipally owned/community operated, privately owned/ privately operated, or municipally owned/ privately operated.

A significant portion (approx.. 90%) of collected waste can be processed into products with economic value, with the unusable inert materials landfilled. As indicated in figure 4.3 above, the activities of an IRRC can be organized into three major stages: collection of waste, treatment of waste, and marketing of the resources generated from waste. A detailed description of these different processes is provided in Annex I.

As a waste-to-resource approach, the adoption of the IRRC model can result in many sustainable development benefits, as follows:

- By utilizing a major portion of the waste it reduces environmental pollution and other negative impacts resulting from unmanaged waste;
- By applying treatment methods, it reduces the quantity of waste that needs to be collected, transported and disposed by local authorities;
- Creates economic opportunities for profit generation from waste;
- Creates jobs for the poor, often informal waste pickers, as workers of an IRRC, providing them with better working conditions;
- Saves foreign currency from the government by avoiding the import of raw virgin materials;
- In addition to the income generated from the sale of recycled goods, an IRRC can harness carbon emission trading (1 ton of organic waste processed through composting can reduce the emissions of 0.5-1 ton of $CO_2$) and bring in investment from both private and public sectors.

The sustainable development benefits – "co-benefits" – that can result from the adoption of the IRRC model, alongside with the potential to reduce the emissions of GHG emissions, make this model especially suited for being part of a waste-sector NAMA. While the IRRC model is one of the measures endorsed through the Waste-to-Resource NAMA whose design elements are laid out in

[17] United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), 2015, "Valuing Waste, Transforming Cities", http://www.unescap.org/resources/valuing-waste-transforming-cities

Part II of the study, in Annex I it is provided a brief assessment on how the model on its own could be taken as the central piece of a NAMA programme.

**The Integrated Resource Recovery Center Model in Viet Nam**

The city of Quy Nhon has been a pioneer in the implementation of the IRRC model. An IRRC with a capacity to process 2 ton of organic waste per day was established in the Nhon Phu Ward in 2007. The facility employs 6 workers who collect waste from approximately 700 households and two nearby small markets. The IRRC is operated by the community, and the income generated from the sale of compost and the charge of collection fees enabling its operation to be financially sustainable. The experiences with this IRRC pilot showcased the benefits of a waste-to-resource approach to municipal leaders in Quy Nhon, who have been implementing a 5-year strategy to promote the separation of waste at source to the whole city. As noted in chapters 3 and 4, after two years the programme was already bearing fruit, with 30-40 ton of organic waste separated on a daily basis, which had significantly improved the operation of a large and centralized composting plant at Long My, co-located at the city's landfill site.

In December 2012 the city of Kon Tum commissioned an IRRC with the capacity to process 5 ton of organic waste per day. The facility currently treats the domestic waste generated in the Quang Trung ward, the city's largest, as well as two markets. A programme for the separation of waste at source was implemented, which has also resulted in households conducting home composting. Unlike the IRRC in Quy Nhon, in Kontum the facility is operated by the local branch of URENCO.

In light of prevailing waste practices and the characteristics of solid waste streams in Viet Nam, there is a significant potential for the adoption of the in other cities of Viet Nam. However, the dissemination of a waste-to-resource model such as this is hindered by the challenges already outlined in this chapter concerning composting, AD, RDF production and recycling. However, among these two main challenges are emphasized: the need to promote the separation of waste at source, and the financial sustainability and profitability of the operations. It should also be mentioned as an additional challenge that the possibility of tapping from carbon financing through the CDM for small-scale community based IRRCs has proved to be particularly hard. While additional revenues from carbon credits could substantially improve the overall economic performance of IRRCs, the high transaction costs associated with the development of CDM projects and the sharp decline in the market value of CERs have all but ruled out this possibility. On the other hand, NAMAs could offer an alternative means to tap from the climate change mitigation benefits that IRRCs can deliver.

# PART II – Design Elements of the Waste-to-Resource NAMA for Cities in Viet Nam

# 5. Elements of the Waste-to-Resource NAMA and Boundaries of the Programme

## 5.1 Introduction

This chapter sheds light on the design elements of the Waste-to-Resource NAMA. It lays out the specific goals and scope of the NAMA, the activities eligible/endorsed by the programme, and discusses the benefits that are expected to result with its implementation. The design elements proposed are based on the assessment conducted in Part I of the study, as well as the feedback obtained from different stkaholders consultated during national consultation workshops held in November 2013 and May 2015.

## 5.2 Goals and scope of the NAMA

The **overall goal of this NAMA programme** is to support the Government of Viet Nam in reducing emissions of greenhouse gases from the solid waste sector with the implementation of sustainable waste management approaches that are in line with the principles of 3R (Reducing, Reusing, Recycling). In the scope of this programme, **solid waste pertains** to domestic waste streams originating from households, markets, commercial centers, offices, research facilities, schools, and similar institutions, generated both in urban and rural areas. This excludes e-waste, as well as industrial, medical and construction wastes.

The analysis conducted in Part I of the design study indicated that national policies and strategies in Viet Nam on 3Rs already exist and are very ambitious in scope. While this level of ambition is reflected in specific targets for the recovery and recycling of waste, it was concluded that these targets have limited or no implementation, especially at the sub-national level. In this context, this NAMA programme aims to establish a framework for assisting cities and provinces of Viet Nam in the implementation of the measures andtargets laid out on national policies and strategies on 3R.

**Any city in Viet Nam is eligible to be part of the NAMA programme**. The programme covers solid waste that is generated in residences, institutions, commercial shops, markets, etc, both in urban and rural areas, which has been referred to throughout the study as "solid waste". It excludes the following waste streams: demolition and construction waste, medical waste, hazardous and electronic waste, wastes from the industrial and agricultural sectors[18].

The proposed programme has elements of **both domestic (unilateral) and internationally supported NAMAs**, which are further elaborated in subsequent sections. The programme also allows the possibility of including a **crediting mechanism** (i.e. a credited NAMA component) under its

[18] Please refer to section 3.1.1 for a more detailed discussion on the definitions of solid waste adopted in Viet Nam.

umbrella, especially for initiatives that require higher levels of support from international funders (e.g. international donors or the private sector). However, this will be contingent on the progress at national and international level in the establishment of crediting mechanisms and credited NAMAs, and especially in the wake of the Paris Agreement and the newly introduced concept of “Internationally Transferred Mitigation Outcomes”. One initiative to consider in Viet Nam, in particular, are the activities under the Partnership for Market Readiness (PMR)[19].

**Eligible measures** of the Waste-to-Resource NAMA, which will be subject to some type of **monitoring, verification and reporting (MRV)** procedures when implemented in cities, are as follows:

i) Reduction of solid waste generated and implementation of waste segregation practices, preferably at source;

ii) Diversion of waste streams from final disposal sites, with diverted waste being treated applying the following approaches:

   a. Biological treatment of the organic component of waste, particularly through composting and anaerobic digestion;

   b. Recovery, reuse and recycling of inorganic waste;

   c. Physical methods for treating waste, including the production of refuse-derived fuel and related briquetting techniques;

   d. Implementation of integrated and sustainable waste management approaches in line with the principles of 3R, including “good practices” identified in Viet Nam such as the **Integrated Resource Recovery Centre (IRRC)** model;

   e. Strategies and policies designed at city or provincial level for “**zero waste**” or a “**carbon neutral waste sector**”.

The eligibility of other measures in line with 3Rs but not included in any of the above will be considered on a case-to-case-basis by a **NAMA Management Board** that is proposed to be established for supervising and coordinating the NAMA.

This NAMA programme is structured as a combination of a **top-down** and **bottom-up** approach:

**Top-down** initiatives include, but are not restricted to, the following:

- Establishment of a NAMA Management Board which will act as a steering committee and one-stop-shop for coordinating the NAMA;

[19] Further information about this initiative in Viet Nam can be found in http://carbon-pulse.com/11090/

- Leverage the role and expertise of the Viet Nam Environmental Protection Fund (VEPF) by establishing a financial mechanism at national level that can gather funds from national and international sources and make them available to cities, provinces and other eligible entities – such as private sector entities – either in the form of grants, concessional loans or both;
- Expertise on GHG emission inventories, baseline setting, data collection, etc., to be provided by specific agencies associated with the Ministry of Natural Resources and Environment (MONRE), such as DMHCC and/or IMHEN.

**Bottom-up** initiatives that are part of the NAMA include the following:

- Cities and provinces voluntarily take part on the NAMA and propose to come up with their own targets on 3R measures based on national plans and strategies;
- Cities and provinces propose specific plans and make tangible contributions to the implementation of the measures and initiatives they propose, which are subsequently reported and assessed by the NAMA Management Board.

The implementation of the NAMA is expected to support a **transformational change** in the waste sector of Viet Nam by shifting current waste management practices based on waste collection and disposal only, to approaches that value the recovery of resources from waste, with strong co-benefits resulting to local populations along the economic, social and environmental dimensions.

## 5.3 Measures supported by the NAMA programme and barrier analysis

The Waste-to-Resource NAMA is structured around **five key building blocks**:

I. Waste segregation;
II. Development of solid waste management infrastructure;
III. Market creation / market support;
IV. Capacity building; and
V. Measurement, Reporting and Verification (MRV) system.

An important factor of success for obtaining resources from waste is to achieve some degree of **segregation of the different solid waste streams**, if possible at source. National policies and strategies at national level on 3R exist and are supportive of these measures. As see in chapter 3, some municipalities in Viet Nam already have in place specific regulations for promoting waste segregation and it is thus expected that under the NAMA the bulk of these activities can be borne by local and provincial governments, both technically and financially. Such measures, initiatives and activities would thus fall under the category of a domestically supported NAMA.

**Solid waste infrastructure** encompasses all activities related to the collection, transport and treatment of solid waste. In Viet Nam these activities traditionally fall under the responsibility of city and provincial governments, and under this NAMA it is expected that they will continue to be driven by these stakeholders. On the other hand, the national government, either through a specific ministry or vehicle (e.g. Ministry of Construction (MOC), MONRE or VEPF), may provide additional support for infrastructure initiatives that are in line with the measures endorsed by the NAMA. International support on this stage could be provided, for example, in the form of foreign direct investment in waste processing facilities in Viet Nam. On the other hand, such investment flows would only be expectable when the necessary enabling conditions are in place which, as shown in Part I, is not to the case in most cities in Viet Nam.

In connection to the above, the **market creation and market support** component consists in establishing the conditions that enable approaches and technologies for converting waste into resources to be economically feasible. Examples of such measures are the payment of a tipping/gate fee to a waste processing facility, the establishment of programmes to encourage the purchase of compost, and/or the approval of a feed-in tariff for electricity generated from biogas plants. The creation of these enabling conditions is expected to be driven by national, provincial and local governments. However, international support could also be provided on this component, for example, by topping-up the feed-in tariff level paid to a project developer.

**Capacity building activities** to enable the operationalization of the NAMA are expected to be carried out continuously throughout the whole duration of the programme. These pertain to the establishment of the institutional capacities necessary to manage, implement and oversee the NAMA, at both national and sub-national level. This would consist in the preparation of detailed “terms of reference” for specific functions and duties, the conduct of training programmes for practitioners and technicians, awareness raising initiatives, etc. The elaboration of feasibility studies or surveys, for example to support the selection of the most appropriate approaches for a certain city or area, is also part of this component. These activities are expected to be mostly borne by international climate finance support.

The **Measurement, Reporting and Verification (MRV) system** will be a central piece of the NAMA programme, and both national and sub-national stakeholders are proposed to have roles and responsibilities in the operationalization and implementation of the system. The MRV system of this NAMA shall be linked with the national MRV system to be established for NAMAs through the GIZ supported project named “Creation of an overarching NAMAs and MRV in Viet Nam”, which is expected to be finalized in 2018. The establishment of the framework for MRVing the NAMA is also expected to be supported through international climate finance vehicles.

The table below identifies the level of involvement expected from the three stakeholder groups playing a major role on this NAMA: the national government, sub-national governments (local and provincial) and international donors/ organizations:

| | Waste segregation | Solid Waste Infra-structure * | Market creation / market support | Capacity Building** | M | R | V |
|---|---|---|---|---|---|---|---|
| **Local and provincial governments** | X | X | X | X | X | X | X |
| **National government** | X | X | X | X | X | X | X |
| **International donors and organizations** | X | X | X | X | X | X | X |

**Table 5.1** – Involvement of stakeholders on the key building blocks of the NAMA.

* **Collection, transport and processing of waste**

** **These activities also include the preparation of feasibility studies that will support the implementation of the NAMA**

X: high involvement

X: moderate involvement

X: limited involvement

The Waste-to-Resource NAMA is proposed to operate along the following steps:

1. The Waste-to-Resource NAMA is formally endorsed/enacted at national level by relevant ministries;
2. The NAMA Management Board is established;
3. Provincial and city authorities are informed about the NAMA and its operational methods, as well as other actors with a stake in the solid waste sector;
4. Cities that agree to be part of the NAMA prepare a detailed implementation plan that should include, but is not necessarily restricted to, the following elements:

    a. Voluntary target(s) for the adoption of 3R measures, including targets for waste reduction, waste diversion and recycling of organic and inorganic waste;

    b. Detailed description of the initiatives that the city proposes to implement, including how they support and are aligned with the Waste-to-Resource NAMA;

    c. Estimation of the total cost of the plan, including an indication of the share of the budget that would be supported by the local government, and the share that would require additional support from the national government and/or through international climate financing opportunities.

5. City-specific plans are submitted to the NAMA Management Board and are assessed by its staff, who would deliberate whether the initiatives proposed by cities fall under the NAMA and, if so, which require the support of the national government and/or international donors. This step may include back and forth communication with local government authorities.

6. Activities considered eligible under the NAMA are communicated to the local government by the NAMA Management Board. For the activities that need additional support from the national government and/or international donors, the Board will request line ministries (e.g. MoC, MoNRE) or the Vietnam Environment Protection Fund (VEPF) to mobilize the necessary funds. Both local and national level contributions will be considered part of the "domestic NAMA". The NAMA Management Board will also appraise the capacity building requirements of the local government, and deliberate on the type of support to assign.

7. Based on the funds mobilized, both from national and international sources, the local government initiates the activities proposed under the NAMA, which would be subject to MRV procedures.

The analysis conducted in Part I of the study[20] identified **key barriers** that hinder the adoption of 3R principles and waste-to-resource approaches in Viet Nam. The table below explains how these barriers will be addressed with the support of the NAMA, and indicates the expected outcomes:

| Barriers | Measures and actions to address barriers | Expected outcomes |
|---|---|---|
| **1. Policy and legal** | • Through the implementation of the institutional framework established through the NAMA, cities and provinces will be encouraged to **voluntarily** propose their own targets for reusing, reducing and recycling waste based on those laid out on the "National Strategy for Integrated Management of Solid Waste up to 2025 and Vision towards 2050"[21].<br>• Cities/provinces are expected to come up with their own enforcement instruments (e.g. fines for non-compliance with waste segregation) to achieve the targets they propose. | • The NAMA establishes a framework that will act as a "trigger" for the implementation at city and provincial levels of measures that are in line with those of the "National Strategy for Integrated Management of Solid Waste up to 2025 and Vision towards 2050" for the collection and treatment of waste |

[20] Sections 3.4 and 4.2.6 provide a summary of most of these barriers.

[21] It should be noted that this NAMA does not propose a duplication of already existing policy/legal documents. Instead, it establishes a platform to support their implementation on a voluntary basis in cities and provinces of Viet Nam. This is based on the assumption that the benefits that the programme can deliver (e.g. by mobilizing additional financial resources, capacity building) are a strong motivation to trigger the implementation of projects on the ground.

| | | |
|---|---|---|
| **2. Institutional** | • Establishment of a **NAMA Management Board** which will function as a “one-stop-shop” and steering committee for the NAMA and as a coordinating entity among ministries with a stake in the solid waste sector. The NAMA Management Board will be responsible for articulating with different stakeholders, and it is proposed to be established as an extension of DSTE, a unit within MOC, which is the key Ministry in Viet Nam with a stake on solid waste management issues.<br>• The NAMA Management Board will be vested with supervisory and operational responsibilities with regards to the NAMA, including on the assessment of proposals of cities that voluntarily accept to be part of the programme, definition of eligibility measures, and record taking of activities that are considered eligible (e.g. policies, specific projects, investment requirements, GHG emission reductions at the city level).<br>• Roles of other stakeholders involved on climate change and waste management issues are clarified, including those of MONRE, IMHEN and the URENCOs (detailed in chapter 8). | • The NAMA Management Board will ensure coordination among national-line ministries and agencies, and support the streamlining of roles and responsibilities among different stakeholders |
| **3. Financing** | • Establishment of a **dedicated vehicle** to channel funds from international and national sources to cities, provinces, URENCOs and/or other private-sector organizations to implement measures endorsed by the NAMA. It is proposed that **VEPF** takes this role.<br>• Cities and provinces will be encouraged to voluntarily propose their own targes and measures, and to allocate part of their own budgets to implement those initiatives. | • Higher availability of funds and financing instruments (e.g. in the form of concessional loans, grants, etc.) to develop and implement waste waste-to-resource initiatives. |
| **4. Economic** | In most locations in Viet Nam, the marketing of resources that can be generated from waste (e.g. compost, recyclables, biogas, RDF, etc.) face a set of barriers, which can be broadly categorized as “economic”, as they pertain to the failure of adequately internalizing externatlities resulting from the disposal of waste. Examples of measures that would address those barriers and would be eligible under the NAMA are:<br>• **At city and province level**: payment of tipping fees to waste treatment plant operators; allocation of land free of cost or below market prices to these plants; set-up of local programmes for the purchase of compost; etc.;<br>• **At national level**: tax rebates on equipment, tax holidays to private sector organizations investing or involved in waste-to-resource intiatives eligble under the NAMA, measures to stimulate the use of compost through standards and regulation, set-up of a feed-in tariff scheme for biogas generated from the anaerobic digestion (AD) of solid waste, etc.<br>• **International level**: financial support to measures considered “too costly” in the context of Viet Nam (e.g. large-scale AD facilities). This support could be provided through international donors or mechanisms (e.g. as an “adder” to an existing feed-in tariff, as a subsidy to the investments required for a certain waste treatment plant). | • Economic and fiscal incentives will be set in place as drivers and enablers of waste-to-resource initiatives. |
| **5. Social and behavioural** | • **Education and awareness programmes**, for instance to educate communities on the need to reduce and segregate waste, on the benefits of a cleaner environment, are expected to be part of the plans implemented by cities and provinces that agree to be part of the NAMA. While the bulk of the funds for such programmes is expected to be made available from sub-national (i.e. city and provincial budgets), the NAMA is expected to provide opportunities for knowledge transfer (e.g. city-to-city cooperation) and the exchange of good practices.<br>• In view of the important **role played by the informal waste sector** in the collection of waste and recovery of recyclable materials, the NAMA programme will support the adoption of city-level programmes that enable members of this sector to be co-opted, especially women, into | • Increased community awareness and participation on waste-to-resource initiatives<br>• Higher compliance on waste segregation at the source<br>• Improved conditions of informal waste sector members, especially |

| | | |
|---|---|---|
| | formal waste management processes. While such programmes are expected to be funded from local government budgets, on specific cases the NAMA Management Board shall consider the option of partially allocating grants. It is also expected that the social benefits resulting from integrating the informal sector can be quantified and formally accounted as “co-benefits” from the programme. | women |
| **6. Technical and operational (including MRV)** | • Cities that agree to take part in the NAMA will be eligible to receive support to address any technical/operational barriers they may face in the adoption of waste-to-resource measures. Support can be in the form of training programmes, consultation workshops, preparation of training manuals, organization of on-site visits to technical personnel, etc. It is proposed that these capacity building initiatives can be funded, mostly, through international donors or an international mechanism (e.g. bilateral ODA, the NAMA Facility, GEF or GCF).<br>• The MRV system of the NAMA, including MRV procedures, is expected to be set up, in full or to a large extent, with the support of international climate finance. Once MRV arrangements are in place, monitoring and reporting will need to be conducted domestically. | • Improved know-how and capacities to design, implement and operate waste-to-resource initiatives among concerned stakeholders. |

**Table 5.2** – Measures introduced by the Waste-to-Resource NAMA to address key barriers in Viet Nam’s waste sector and expected outcomes.

The NAMA also proposes to **support the dissemination of the IRRC model in Viet Nam** through the following measures:

- Preparation of a standard IRRC design that could be adapted by cities that are interested in adopting the model;
- Capacity building and training on the IRRC model, based on the good practices of the cities of Quy Nhon and Kon Tum, where IRRC projects are already in operation. It will also be considered the establishment of a training center in one of these cities to showcase the approach and experiences in adopting the IRRC model.

The dissemination of other good practices in Viet Nam, such as the IRRC model, can be supported through the adoption of measures similar to those above.

## 5.4 Specific measures supported by the Waste-to-Resource NAMA

The implementation of any action or initiative aligned with the principles of 3R and waste-to-resource approaches needs to take into account the local context and conditions. In view of this, the Waste-to-Resource NAMA is not meant to prescribe specific measures to municipal and provincial authorities, but rather to provide a general framework of eligible measures that local stakeholders can implement taking into consideration their respective local circumstances.

Notwithstanding the above, it was considered useful to provide more detailed guidance on the type of measures that could be implemented by practitioners and decision makers, especially in cities and provinces, which could be eligible as voluntary contributions under this NAMA. These guidelines and “portfolio” of measures are detailed in **Annex II** of the study, and organized in line with the four main stages of the waste management value chain or “cycle”. A summary of these measures is provided in the table below, while additional elaboration is found in the annex:

| Stage | Measures/Activities |
|---|---|
| 1. Waste separation at source | 1.1. Enhance awareness on waste separation at source<br>1.2. Set up of waste separation facilities and equipment, which should be accompanied by the establishment of a collection and transportation infrastructure that ensures that segregated components can be processed into resources without being mixed up with other waste streams.<br>1.3. Complement/complete policy framework for waste separation at source at city and province level<br>1.4. Set-up incentives for the separation of waste at source |
| 2. Waste separation and transfer centers | 2.1. Support provided by local government authorities (e.g. in the form of tax rebates to operators, land free of charge, etc.)<br>2.2. Integration and/or formal recognition of the activities of the informal waste sector, who play a role in many cities in providing collection services and the recovery of recyclable materials |
| 3. Waste treatment | 3.1. Enhancement of waste treatment through composting<br>3.2. Enhancement of waste treatment through the anaerobic digestion of waste<br>3.3. Enhancement of waste recycling<br>3.4. Enhancement of other alternative methods for waste treatment, such as RDF production |
| 4. Market creation | 4.1. Development of regulations, standards, etc. for the products produced from waste<br>4.2. Design and implementation of support schemes (e.g. tipping fees, tax rebates, feed-in tariffs) for the resources generated from waste |

**Table 5.3** – Measures supported/endorsed by the NAMA for each stage of the waste management value chain.

## 5.5 Benefits of the NAMA programme

Several benefits are expected to result from the operationalization of the NAMA with concrete activities on the ground. These benefits will consist of both GHG emission reductions, and sustainable development benefits (usually known as “co-benefits”).

The climate change mitigation benefits are assessed in detail in chapter 6 of the study, whereas the co-benefits from the NAMA are described below.

**Sustainable development benefits (Co-benefits)**

The sustainable development benefits associated with the implementation of the Waste-to-Resource NAMA are discussed along the three pillars of sustabiable development: economic, social and environmental. It is also indicated their linkages with the 17 Sustainable Development Goals (SDGs) under the 2030 Agenda for Sustainable Development, which entered into force on 1 January 2016.

The following SDGs haver been identified as having direct or indirect relation with the Waste-to-Resource NAMA:

**SDG 1** - No Poverty
**SDG 3** - Good Health and Well-Being
**SDG 5** - Gender Equality
**SDG 6** - Affordable and Clean Energy
**SDG 8** - Decent Work and Economic Growth
**SDG 10** - Reduced Inequalities
**SDG 11** - Sustainable Cities and Communities
**SDG 12** - Responsible Consumption and Production
**SDG 13** - Climate Action

**Economic benefits**

On the economic pillar, the NAMA will contribute to the conservation of resources through the reuse and recycling of solid waste. The benefits accruing from the implementation of some of the key measures endorsed by the NAMA are as follows:

- Composting: increase in agricultural yields through the use of compost to replace chemical fertilizers; savings in subsidies to chemical fertilizers; increase in the market value of agricultural products produced through the utilization of an organic fertilizer; improved resilience and capacity of soils to retain water and nutrients with the application of compost (SDGs 8,11,12,13);
- Recovery of recyclables: conservation of resources in the form of raw materials, energy, water, etc. (SDGs 6,12);
- Biogas production through AD: production of a gas which can be sold and hence generate income to project developers; savings in subsidies to energy through the replacement of a fossil fuel (e.g. coal, LPG) with biogas; enhanced energy security with the harnessing of an indigenous resource in the form of biogas (SDG 6);
- RDF production: production of a fuel that can be sold in the marketplace and thus generate income to investors; savings in energy subsidies by replacing the utilization of fossil fuels with RDF pellets; enhanced energy security with the harnessing of an indigenous resource in the form of a pelletized fuel (SDG 6);
- Others: reduction in waste transportation costs with the avoided disposal of waste; mobilization of financing in different forms, including private, for the investment and operation of waste treatment plants and the supporting infrastructure (SDGs 7,11,12).

**Social benefits**

The implementation of the NAMA programme will result in multifold social benefits, particularly the following:

- Enhanced public awareness on the need for recycling and the protection of the environment, including a stronger involvement of communities in the processes of segregating waste (SDG 12);
- Increased opportunities for job creation with the construction and operation of waste treatment plants (SDG 8);
- Increased opportunities for integrating and creating better working conditions for the informal sector[22], including the most vulnerable groups and especially women (SDGs 2,5,8,10);
- Reduction of the incidence of disease vectors, such as rodents and flies, with improved waste management practices which are less reliant on disposal (SDGs 3,11).

**Environmental benefits**

Environmental benefits associated with the NAMA include the following:

- Conservation of natural resources with improved waste collection and recycling (SDGs 3,11,12);
- Reduction of air, soil and water pollution with improved and more environmentally sound waste management practices (SDGs 3,11,12).
- Elimination of the odor nuisance and environmental degradation of land with avoided disposal and landfilling (SDGs 3,11,12).

A methodology to measure and quantify, whenever feasible, the co-benefits delivered by the NAMA is proposed to be implemented once the programme enters into operation. Its development is proposed as one of the activities in the piloting phase of the NAMA, as indicated in section 8.3. A tool developed by Waste Concern and ESCAP[23] could serve as an initial guiding framework to set-up a system for the quantification of such co-benefits.

[22] Role of the informal sector in Viet Nam's waste sector was elaborated in sections 3.1.4 and 4.2.4.

[23] Santucci, L., Puhl, I., Sinha, M., Enayetullah, I., Agyemang-Bonsu, W., 2015, "Valuing the sustainable development co-benefits of climate change mitigation actions", http://www.unescap.org/sites/default/files/Valuing%20the%20Sustainable%20Dev%20Co-Benefits%20%28 Final%29.pdf.

# 6. Baseline and Greenhouse Gas Emission Reduction Scenarios of the NAMA Programme

## 6.1 Introduction

This chapter lays out the business-as-usual (BAU) scenario for emissions from solid waste in Viet Nam, as well as the GHG emissions reduction trajectory that is expected with the implementation of the measures endorsed by the Waste-to-Resource NAMA. For the purpose of this modeling exercise, it was taken into account solid waste data from urban and rural areas, as defined in the beginning of chapter 3. The BAU (or “baseline”) scenario represents the reference level that is used to determine the potential of the Waste-to-Resource NAMA to generate GHG emission reductions. The BAU scenario assumes that “alternative” solid waste treatment measures are not be implemented, i.e. that almost all solid waste generated in Viet Nam will be disposed in landfill sites. An important assumption is that the solid waste composition is assumed to remain unchanged during the period under analysis.

The targets proposed for the collection of waste laid out in the **National Strategy for the Integrated Management of Solid Waste by 2025 and Vision towards 2050** were used in the BAU scenario. For the NAMA scenario were taken the waste treatment targets proposed set forth in the Strategy, which are also in line with the measures proposed by the government of Viet Nam on its Intended Nationally Determined Contribution (INDC).

This chapter presents the results of the modeling worked that was conducted to estimate the emissions from the baseline and NAMA scenarios, which are presented in sections 6.2. and 6.3 respectively. A step-by-step detailed description of the calculation process is presented in **Annexes 3 and 4**. The chapter also sheds light on the MRV arrangements that will need to be put in place for implementing the NAMA.

## 6.2 Baseline Scenario

The baseline – or business-as-usual (BAU) – scenario consists of methane emissions resulting from the disposal of solid waste in landfills and dump sites. Major assumptions for this scenario are as follows:

- The scenario only includes urban and rural solid waste, thereby excluding industrial, construction and electronic waste.
- The current status of solid waste treatment methods is assumed to remain unchanged during the projection period.
- The composition of solid waste is assumed to remain unchanged due to the lack of projection data.

- Targets for the collection of waste as laid out in the “National Strategy for the Integrated Management of Solid Waste by 2025 and Vision towards 2050” are taken for the baseline scenario, as follows: 85% collection rate in 2015, 90% in 2020 and 100% in 2025.
- Default factors from the IPCC Guidelines were taken for the methane correction factor (MCF), and DOC (degradable organic carbon), which are input parameters to the model.
- Specific GHG emission reduction targets, such as those in Decision 1775 on “Managing GHG emissions and managing carbon credit trading to the world market”, which proposes a 5% GHG emission reduction for the waste management sector, was considered beyond business as usual, and therefore not part of the baseline.

The calculation of the methane emissions from solid waste disposal sites was made through the application of the First Order Decay (FOD) method, using data from the 2010 national GHG inventory. Solid waste generation rates in both urban and rural areas were estimated, with figures for the 2010-2030 period presented in the table below:

| Year | Amount of urban solid waste collected (ton) | Amount of rural solid waste collected (ton) | Total amount of solid waste collected (ton) |
|---|---|---|---|
| 2010 | 10,091,780 | 2,646,221 | 12,738,001 |
| 2011 | 11,396,984 | 2,984,392 | 14,381,376 |
| 2012 | 12,862,310 | 2,999,075 | 15,861,385 |
| 2013 | 14,506,732 | 3,014,091 | 17,520,823 |
| 2014 | 16,351,415 | 3,019,105 | 19,370,520 |
| 2015 | 18,419,968 | 3,019,105 | 21,439,073 |
| 2016 | 20,500,340 | 3,471,343 | 23,971,683 |
| 2017 | 22,812,588 | 3,922,190 | 26,734,778 |
| 2018 | 25,382,282 | 4,371,440 | 29,753,722 |
| 2019 | 28,237,789 | 4,819,687 | 33,057,476 |
| 2020 | 31,410,574 | 5,257,807 | 36,668,381 |
| 2021 | 35,319,445 | 5,542,549 | 40,861,994 |
| 2022 | 39,695,985 | 5,823,271 | 45,519,256 |
| 2023 | 44,594,639 | 6,100,021 | 50,694,660 |
| 2024 | 50,076,063 | 6,373,570 | 56,449,633 |
| 2025 | 56,207,826 | 6,632,822 | 62,840,648 |
| 2026 | 61,828,609 | 6,739,345 | 68,567,954 |
| 2027 | 68,011,470 | 6,842,224 | 74,853,694 |
| 2028 | 74,812,616 | 6,939,434 | 81,752,050 |
| 2029 | 82,293,878 | 7,034,264 | 89,328,142 |
| 2030 | 90,523,266 | 7,112,543 | 97,635,809 |

**Table 6.1** – Projection of urban and rural solid waste generation up to 2030 (Source: modelling by IMHEN).

To apply the FOD method, solid waste compositions had to be determined. These figures were taken from the Environmental Status Reports of provinces, with the average composition assumed to remain unchanged up until 2030.

| Composition of waste | Share (%) |
|---|---|
| Food, organic | 59.24 |

| | |
|---|---|
| Garden | 2.76 |
| Paper | 2.7 |
| Wood | 1.05 |
| Textile | 3.30 |
| Nappies | 0.01 |
| Plastic, other inert | 30.94 |

**Table 6.2** – Composition of solid waste (Averaged). (Sources: Synthesis of Vietnam Environment Administration)

The baseline emissions of $CH_4$ from the disposal of solid waste in the baseline scenario, for the 1995-2030 period, are summarized as follows:

| Year | Total $CO_2$e emissions (million tons) | Year | Total $CO_2$e emissions (million tons) | Year | Total $CO_2$e emissions (million tons) | Year | Total $CO_2$e emissions (million tons) |
|---|---|---|---|---|---|---|---|
| **1995** | 0.8 | **2004** | 4.3 | **2013** | 10.3 | **2022** | 26.4 |
| **1996** | 1.5 | **2005** | 4.6 | **2014** | 11.4 | **2023** | 29.4 |
| **1997** | 2.0 | **2006** | 5.3 | **2015** | 12.6 | **2024** | 32.7 |
| **1998** | 2.5 | **2007** | 5.9 | **2016** | 14.0 | **2025** | 36.4 |
| **1999** | 2.8 | **2008** | 6.5 | **2017** | 15.5 | **2026** | 40.0 |
| **2000** | 3.2 | **2009** | 7.1 | **2018** | 17.3 | **2027** | 44.2 |
| **2001** | 3.5 | **2010** | 7.7 | **2019** | 19.2 | **2028** | 48.5 |
| **2002** | 3.7 | **2011** | 8.5 | **2020** | 21.3 | **2029** | 53.2 |
| **2003** | 4.0 | **2012** | 9.4 | **2021** | 23.7 | **2030** | 58.2 |

**Table 6.3** – Projection of emissions from solid waste disposal up to 2030.

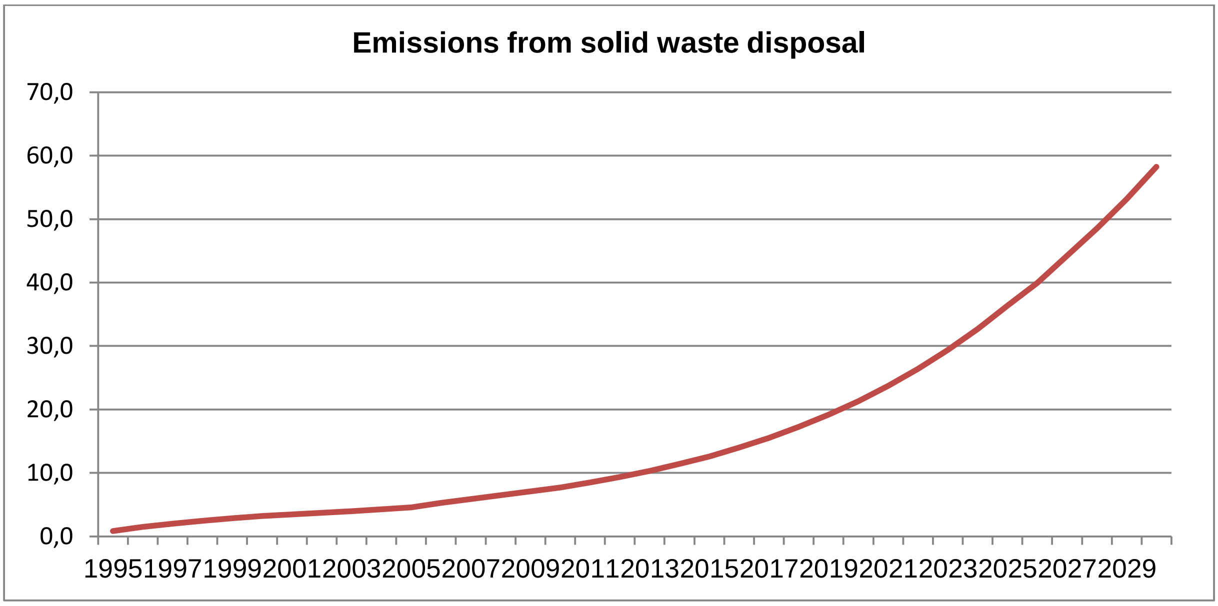



**Figure 6.1** – Baseline $CO_2$e emissions from solid waste disposal up to 2030.

## 6.3 NAMA scenario

The GHG emissions reduction scenario – or “NAMA scenario” – was modelled based on a set of options for treating solid waste generated in Viet Nam. The methods considered as part of the NAMA scenario are composting, refuse-derived fuel (RDF) production, recycling and anaerobic digestion.

In the NAMA scenario, integrated solid waste treatment facilities are assumed to be built all over Viet Nam so as to meet the ambitious targets laid out in the “National Strategy on Integrated Solid Waste Management to 2025, vision to 2050” (Decision 2149/QĐ-TTg, 2009) (henceforth designated as “National Strategy”). Solid waste treatment options considered are composting, recycling, RDF production and anaerobic digestion. The targets assumed for each technology option are based on the waste collection and treatment targets set out in the National Strategy as well as the average waste composition in Viet Nam, which is high in biodegradable organics and recyclable materials. With reference to the National Strategy, the following parameters were taken for the mitigation scenario:

- **Specific targets by 2015**: 85% of total solid waste generated to be collected. Of the waste collected, 60% to be recycled, reused or utilized to produce compost and biogas.
- **Specific targets by 2020**: 90% of total solid waste generated to be collected. Of the waste collected, 85% to be recycled, reused or utilized to produce compost and biogas.
- **Specific targets by 2025**: 100% of total solid waste generation to be collected. Of the waste to be collected, 90% to be recycled, reused or utilized to produce compost and biogas.

To develop the mitigation scenario and the pathway for technology penetration until 2030, targets from the National Strategy for year 2025 were taken as reference. For modeling purposes, year 2016 is the starting point for the implementation of solid waste treatment measures under the NAMA scenario. Composting measures begin with a 15% share in 2016, gradually increasing to 60% in 2025 and continuing as such up to 2030. Recycling measures begin with a share of 2% in 2016, increasing up to 20% in the 2025-2030 period. The share of anaerobic digestion will increase from 1% in 2016 to 5% in 2025 and 10% in 2030. RDF production follows the same pathway as anaerobic digestion. Details of the mitigation scenario and the treatment methods are summarized in the tables below:

| Year | Solid waste collection (%) | Solid waste treated (%) | Composting (%) | Recycling (%) | Anaerobic digestion (%) | RDF (%) |
|---|---|---|---|---|---|---|
| 2015 | 85 | | | | | |
| 2016 | 86 | - | 15 | 2 | 1 | 1 |
| 2017 | 87 | - | 20 | 4 | 1.5 | 1.5 |
| 2018 | 88 | - | 25 | 6 | 2 | 2 |
| 2019 | 89 | - | 30 | 8 | 2.5 | 2.5 |
| 2020 | 90 | - | 35 | 10 | 3 | 3 |
| 2021 | 92 | - | 40 | 12 | 3.4 | 3.4 |
| 2022 | 94 | - | 45 | 14 | 3.8 | 3.8 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2023 | 96 | - | 50 | 16 | 4.2 | 4.2 |
| 2024 | 98 | - | 55 | 18 | 4.6 | 4.6 |
| **2025** | **100** | **90** | **60** | **20** | **5** | **5** |
| 2026 | 100 | 92 | 60 | 20 | 6 | 6 |
| 2027 | 100 | 94 | 60 | 20 | 7 | 7 |
| 2028 | 100 | 96 | 60 | 20 | 8 | 8 |
| 2029 | 100 | 98 | 60 | 20 | 9 | 9 |
| 2030 | 100 | 100 | 60 | 20 | 10 | 10 |

**Table 6.4** – Share of solid waste treated by 2030. (Source: modelling by IMHEN)

| Year | Solid waste collection (ton) | Solid waste treated (ton) | Composting (ton) | Recycling (ton) | Anaerobic digestion (ton) | RDF (ton) |
|---|---|---|---|---|---|---|
| 2015 | 21,439,073 | | | | | |
| 2016 | 23,971,683 | 4,554,620 | 3,595,752 | 479,434 | 239,717 | 239,717 |
| 2017 | 26,734,778 | 72,18,391 | 5,346,956 | 10,69,391 | 401,022 | 401,022 |
| 2018 | 29,753,722 | 10,413,802 | 74,38,431 | 17,85,223 | 595,074 | 595,074 |
| 2019 | 33,057,476 | 14,214,715 | 99,17,243 | 26,44,598 | 826,437 | 826,437 |
| 2020 | 36,668,381 | 18,700,873 | 12,833,933 | 36,66,838 | 1,100,051 | 1,100,051 |
| 2021 | 40,861,994 | 24,026,853 | 16,344,798 | 49,03,439 | 1,389,308 | 1,389,308 |
| 2022 | 45,519,256 | 30,315,825 | 20,483,665 | 63,72,696 | 1,729,732 | 1,729,732 |
| 2023 | 50,694,660 | 37,716,828 | 25,347,330 | 81,11,146 | 2,129,176 | 2,129,176 |
| 2024 | 56,449,633 | 46,401,598 | 31,047,298 | 10,160,934 | 2,596,683 | 2,596,683 |
| 2025 | 62,840,648 | 56,556,583 | 37,704,389 | 12,568,130 | 3,142,032 | 3,142,032 |
| 2026 | 68,567,954 | 63,082,518 | 41,140,772 | 13,713,591 | 4,114,077 | 4,114,077 |
| 2027 | 74,853,694 | 70,362,472 | 44,912,216 | 14,970,739 | 5,239,759 | 5,239,759 |
| 2028 | 81,752,050 | 78,481,968 | 49,051,230 | 16,350,410 | 6,540,164 | 6,540,164 |
| 2029 | 89,328,142 | 87,541,579 | 53,596,885 | 17,865,628 | 8,039,533 | 8,039,533 |
| 2030 | 97,635,809 | 97,635,809 | 58,581,485 | 19,527,162 | 9,763,581 | 9,763,581 |

**Table 6.5** – Amount of solid waste treated by 2030. (Source: modelling by IMHEN)

### 6.3.1 Solid waste treatment through composting in the NAMA scenario

In the NAMA scenario, composting is the waste treatment solution with the highest share over the 2016-2030 period, as it is considered the most appropriate method to treat the organic component present in waste streams, as explained in chapter 4 of the study.

In order to estimate the GHG emission reductions from composting, CDM methodology AMS.III.F (Avoidance of methane emissions through composting) developed by UNFCCC was applied. This methodology comprises measures to avoid the emissions of methane to the atmosphere from biomass or other organic matter that would have otherwise been left to decay anaerobically in a solid waste disposal site (SWDS), or in an animal waste management system (AWMS), or in a wastewater treatment system (WWTS). With AMS.III.F, measures are limited to those that result in emission reductions less than or equal to 60 kt $CO_2$ equivalent annually. This does not imply, however, that the

NAMA is only supporting composting facilities that can lead to the reduction of 60 kt of $CO_2$ equivalent per year, as the main purpose of modelling this scenario is to come up with a notional figure of the reductions that can be achieved with the measures supported by the NAMA.

The summary of emissions for the composting component under the NAMA scenario are presented in the table and figure below:

| Year | $BE_y$ (t $CO_2$e) | $PE_{CH4,y}$ (t $CO_2$e) | $PE_{N2O,y}$ (t $CO_2$e) | $ER_{comp,y}$ (t $CO_2$e) |
|---|---|---|---|---|
| 2016 | 766,469 | 124,143 | 147,979 | 494,347 |
| 2017 | 1,666,329 | 184,604 | 220,048 | 1,261,677 |
| 2018 | 2,733,216 | 256,812 | 306,120 | 2,170,284 |
| 2019 | 4,000,488 | 342,393 | 408,132 | 3,249,963 |
| 2020 | 5,502,159 | 443,092 | 528,165 | 4,530,902 |
| 2021 | 7,295,335 | 564,304 | 672,650 | 6,058,381 |
| 2022 | 9,426,970 | 707,199 | 842,981 | 7,876,790 |
| 2023 | 11,643,247 | 875,117 | 1,043,139 | 9,724,991 |
| 2024 | 14,530,309 | 1,071,908 | 1,277,714 | 12,180,687 |
| 2025 | 17,921,612 | 1,301,744 | 1,551,679 | 15,068,189 |
| 2026 | 20,987,814 | 1,420,385 | 1,693,099 | 17,874,330 |
| 2027 | 23,908,617 | 1,550,594 | 1,848,308 | 20,509,715 |
| 2028 | 26,812,051 | 1,693,494 | 2,018,645 | 23,099,912 |
| 2029 | 29,792,884 | 1,850,432 | 2,205,715 | 25,736,737 |
| 2030 | 32,922,197 | 2,022,526 | 2,410,851 | 28,488,820 |

**Table 6.6** – Emission reductions from composting (t $CO_2$e). (Source: modelling by IMHEN)

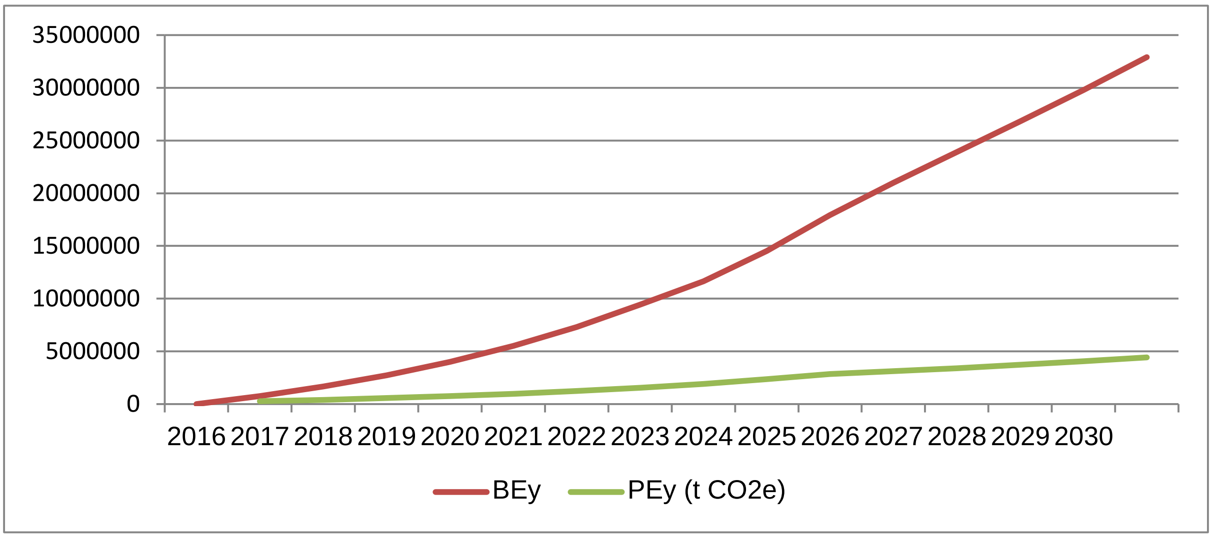



**Figure 6.2** – Baseline and project emissions from composting under the NAMA scenario. (Source: modelling by IMHEN)

In summary, the conversion of solid waste into compost can reduce GHG emissions from the waste sector in approximately 28.5 million $tCO_2e$ in 2030, which corresponds to a reduction of approximately 86.5% from a business-as-usual scenario.

### 6.3.2 Solid waste treatment through the production of refuse-derived fuel (RDF)

In order to estimate GHG emission reductions from the production of refuse-derived fuel (RDF), CDM-approved methodology “AM0025/Version 05: Avoided emissions from organic waste through alternative waste treatment processes” was applied. The methodology is applicable for mechanical processes to produce refuse-derived fuel (RDF) and its use.

RDF are pellets that, typically, consist of approximately 90% biomass and 10% fossil-based materials. For the modelling exercise, it was assumed that in the combustion of RDF only the fossil-fuel component would lead to GHG emissions. The remainder 90% would not count as project emissions due to the biogenic origin of the biomass.

In addition to the reduction of baseline emissions from the disposal of solid waste, RDF produced in the NAMA scenario was assumed to replace the utilization of coal, the main fossil fuel utilized in Viet Nam. In order to calculate the emissions from coal combustion, it had to be identified the amount of coal replaced by RDF. This calculation was based on the heat value of both coal and RDF. Also important to note, the compostion of waste used for RDF production includes garden, paper, wood, textile, nappies and plastic wastes.

A summary of the emissions under the baseline and NAMA scenarios for the production of RDF is presented in the table below:

| Year | $BE_{SWD,y}$ (t $CO_2e$) | $BE_{fuel,y}$ ($tCO_2e$) | $PE_{RDF,y}$ (t CO2e) | $ER_{RDF,y}$ (t CO2e) |
|---|---|---|---|---|
| 2016 | 51,098 | 84,877 | 5,118 | 130,857 |
| 2017 | 120,586 | 141,990 | 8,562 | 254,014 |
| 2018 | 209,880 | 210,699 | 12,705 | 407,874 |
| 2019 | 320,974 | 292,618 | 17,645 | 595,947 |
| 2020 | 456,341 | 389,497 | 23,486 | 822,351 |
| 2021 | 612,062 | 491,914 | 29,662 | 1,074,314 |
| 2022 | 793,075 | 612,448 | 36,930 | 1,368,593 |
| 2023 | 987,016 | 753,880 | 45,459 | 1,695,437 |
| 2024 | 1,227,542 | 919,411 | 55,440 | 2,091,513 |
| 2025 | 1,508,359 | 1,112,504 | 67,083 | 2,553,779 |
| 2026 | 1,906,536 | 1,456,677 | 87,837 | 3,275,376 |
| 2027 | 2,417,549 | 1,855,248 | 111,871 | 4,160,927 |
| 2028 | 3,042,997 | 2,315,684 | 139,635 | 5,219,047 |
| 2029 | 3,789,287 | 2,846,568 | 171,647 | 6,464,208 |

| | | | | |
|---|---|---|---|---|
| 2030 | 4,666,400 | 3,457,004 | 208,456 | 7,914,948 |

**Table 6.7** – Emission reductions from RDF production. (Source: modelling by IMHEN)

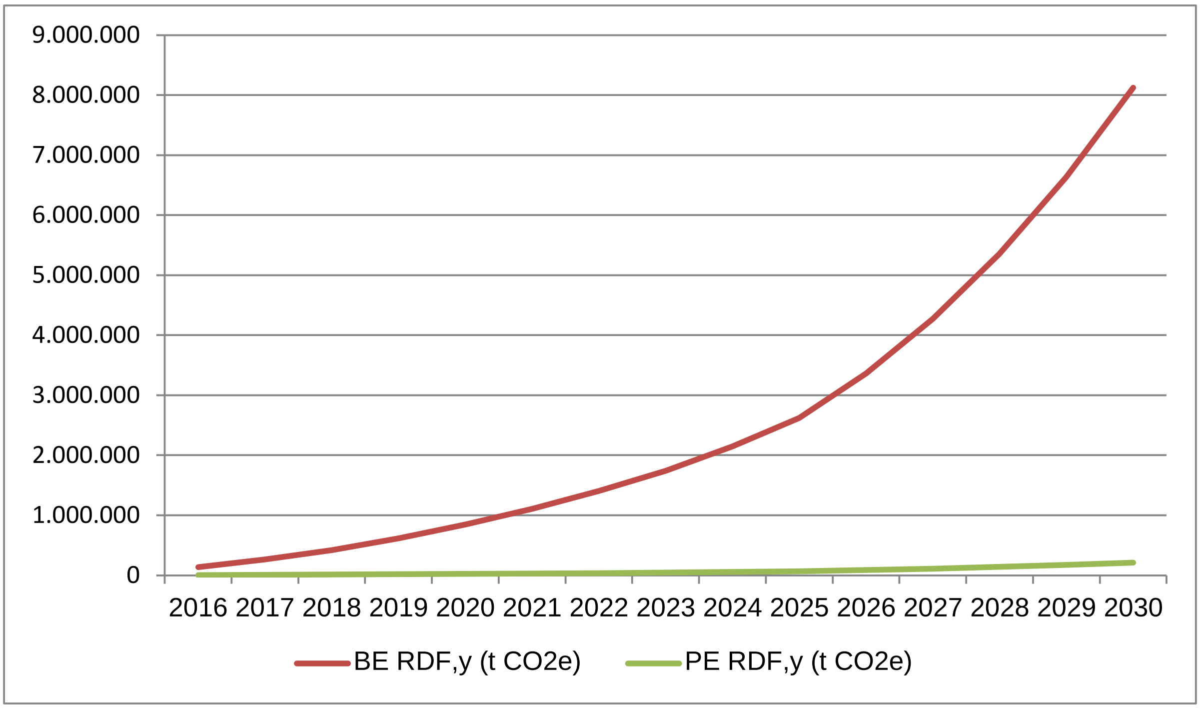



**Figure 6.3** – Baseline and project emissions from RDF production under the NAMA scenario. (Source: modelling by IMHEN)

In summary, the production of RDF from solid waste and its utilization as a fuel to replace coal can reduce 7.9 million t $CO_2$eq by 2030, or approximately 97.4% of emissions on a business-as-usual scenario.

### 6.3.3 Solid waste treatment through recycling methods

GHG emission reductions from recycling have only been calculated for two materials: paper and plastics. For this purposes, CDM methodology AMS-III.AJ “Recovery and recycling of materials from solid wastes” (Version 4.0) was applied. This methodology comprises activities for the recovery and recycling of materials present in solid waste streams by converting them into intermediate or finished products, thereby resulting in energy savings. In addition, for paper and cardboard, emissions associated with the anaerobic decay of these materials in a disposal site may be claimed. Therefore, baseline emissions for the recovery and recycling of waste will be equal to the sum of emissions from the use of energy used in the production of virgin materials (paper and plastic) and from the disposal of waste (for paper only). The results are presented in the table below:

| Year | $BE_{paper\ production,y}$ (t $CO_2$e) | $BE_{paper\ disposal,y}$ ($tCO_2$e) | $PE_{recycling,y}$ (t $CO_2$e) | $ER_{paper\ recycling,y}$ (t $CO_2$e) | $ER_{plastic\ recycling,y}$ (t $CO_2$e) |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| 2016 | 67,108 | 2,363 | 44,738 | 24,733 | 597,378 |
| 2017 | 149,684 | 7,474 | 99,789 | 57,369 | 1,332,470 |
| 2018 | 249,876 | 15,767 | 166,584 | 99,059 | 2,224,402 |
| 2019 | 370,162 | 27,735 | 246,775 | 151,122 | 3,295,190 |
| 2020 | 513,247 | 43,932 | 342,164 | 215,015 | 4,568,909 |
| 2021 | 686,332 | 65,128 | 457,554 | 293,906 | 6,109,724 |
| 2022 | 891,983 | 92,133 | 594,655 | 389,461 | 7,940,429 |
| 2023 | 1,135,312 | 134,781 | 756,875 | 513,218 | 10,106,551 |
| 2024 | 1,422,218 | 177,186 | 948,145 | 651,259 | 12,660,603 |
| 2025 | 1,759,150 | 228,588 | 1,172,767 | 814,971 | 15,659,988 |
| 2026 | 1,919,482 | 282,160 | 1,279,655 | 921,987 | 17,087,242 |
| 2027 | 2,095,444 | 338,307 | 1,396,963 | 1,036,788 | 18,653,658 |
| 2028 | 2,288,555 | 397,457 | 1,525,703 | 1,160,309 | 20,372,739 |
| 2029 | 2,500,640 | 460,076 | 1,667,093 | 1,293,623 | 22,260,713 |
| 2030 | 2,733,201 | 526,651 | 1,822,134 | 1,437,718 | 24,330,997 |

**Table 6.8** – Emission reduction results for paper and plastics recycling.

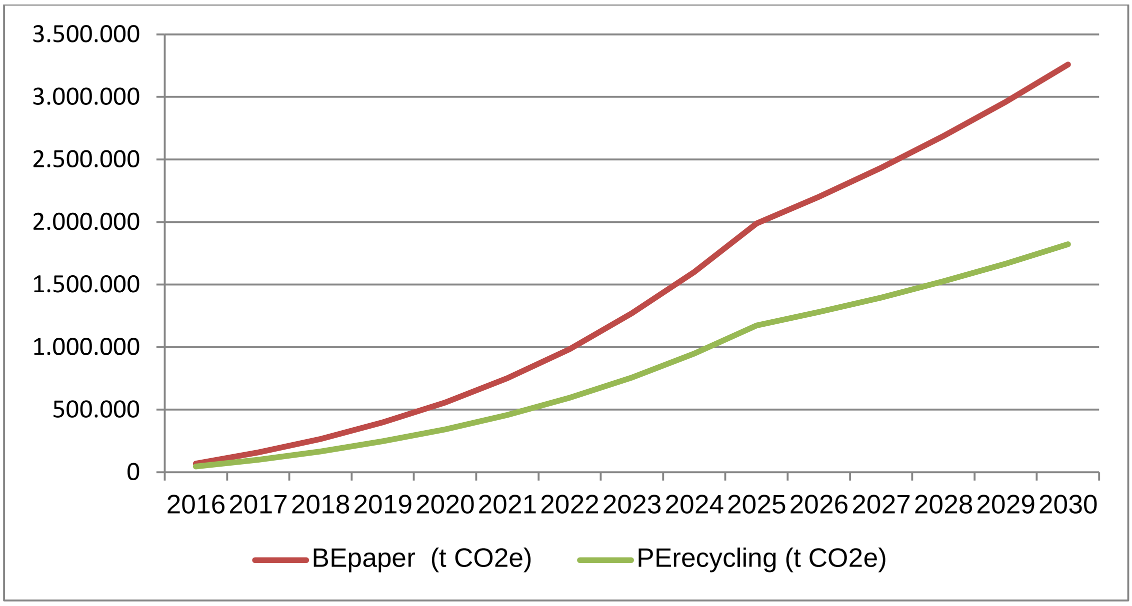



**Figure 6.4** – Baseline emissions and project emissions from recycling paper under the NAMA scenario.

In summary, the recycling of paper and plastics can lead to a reduction of up to 25.8 million t $CO_2$eq by 2030, i.e. a reduction in emissions of 89% in relation to a business-as-usual scenario. The bulk of these emissions is due to the recycling of plastic materials, which account for 24.3 million t $CO_2$eq, which compaers with 1.4 million t $CO_2$eq of emission reductions from paper.

### 6.3.4 Solid waste treatment through anaerobic digestion

In order to estimate GHG emission reductions from the adoption of anaerobic digestion (AD) methods for solid waste, CDM methodologies AM0075 (methodology for the collection, processing and supply of biogas to end-users for heat production, version 1.0) and AMS-I.C (thermal energy production with or without electricity, version 19) were applied.

Baseline emissions comprise methane emissions from the disposal of solid waste in the absence of the activities under the NAMA. Emissions from the NAMA scenario include indirect emissions due to the use of electricity for an anaerobic digestion system, emissions from combusting $CH_4$ for electricity generation and leakage emissions (due to the inefficiency of a biogas capture system). It was also taken into account the balance between the electricity generated by the plant and the electricity consumed on-site for its operation.

The results of baseline and project emissions for anaerobic digestion conversion are presented in the following table and figure:

| Year | $BE_{CH4,SWD,y}$ (t $CO_2e$) | $BE_{combustion,y}$ (t CH4) | $PE_{combustion,y}$ (t $CO_2e$) | $GWP_{CH4}$ | $PE_{AD,y}$ (t $CO_2e$) | $PE_{power,y}$ (t $CO_2e$) | $ER_{AD,y}$ (t $CO_2e$) |
|---|---|---|---|---|---|---|---|
| 2016 | 51,098 | 1,942 | 9,749 | 25 | 12,297 | -151 | 38,952 |
| 2017 | 120,586 | 4,582 | 23,002 | 25 | 29,038 | -487 | 92,035 |
| 2018 | 209,880 | 7,975 | 40,035 | 25 | 50,540 | -930 | 160,270 |
| 2019 | 320,974 | 12,197 | 61,229 | 25 | 77,278 | -1,490 | 245,186 |
| 2020 | 456,341 | 17,341 | 87,052 | 25 | 109,868 | -2,178 | 348,651 |
| 2021 | 612,062 | 23,258 | 116,755 | 25 | 147,367 | -2,990 | 467,685 |
| 2022 | 793,075 | 30,137 | 151,288 | 25 | 190,938 | -3,930 | 606,067 |
| 2023 | 987,016 | 37,507 | 188,285 | 25 | 237,626 | -4,910 | 754,300 |
| 2024 | 1,227,542 | 46,647 | 234,168 | 25 | 295,535 | -6,147 | 938,154 |
| 2025 | 1,508,359 | 57,317 | 287,731 | 25 | 363,165 | -7,592 | 1,152,786 |
| 2026 | 1,906,536 | 72,448 | 363,689 | 25 | 459,025 | -9,483 | 1,456,994 |
| 2027 | 2,417,549 | 91,867 | 461,172 | 25 | 582,046 | -12,006 | 1,847,509 |
| 2028 | 3,042,997 | 115,634 | 580,483 | 25 | 732,630 | -15,157 | 2,325,524 |
| 2029 | 3,789,287 | 143,992 | 722,840 | 25 | 912,327 | -18,957 | 2,895,917 |
| 2030 | 4,666,400 | 177,323 | 890,161 | 25 | 1,123,486 | -23,454 | 3,566,368 |

**Table 6.9 – Emission reductions from anaerobic digestion conversion**

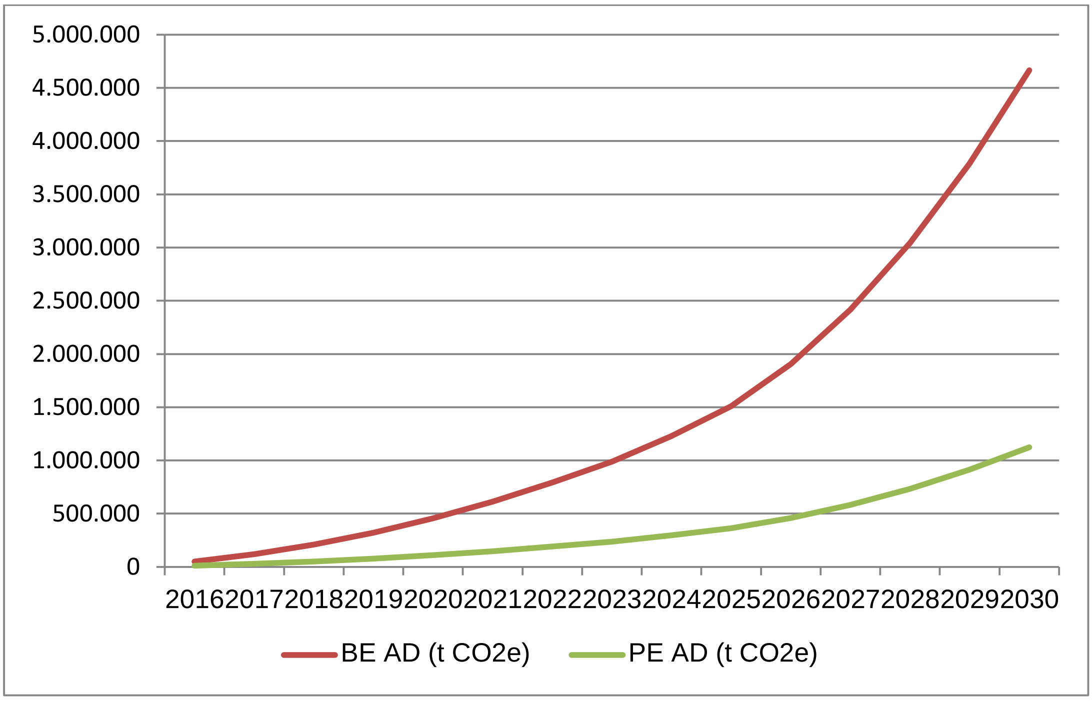



**Figure 6.5** – Baseline emissions and project emissions from solid waste treatment through anaerobic digestion.

In sum, the processing of solid waste through anaerobic digestion can result in a reduction of up to 3.6 million t $CO_2$eq by 2030, i.e. a reduction of 76% from business-as-usual practices.

### 6.3.5 Total potential emission reduction of the Waste-to-Resource NAMA

The results of combining the emission reductions from the different waste treatment measures endorsed by the NAMA are summarized and illustrated below:

| Year | $BE_y$ ($10^6$ $tCO_2e$) | $ER_{comp,y}$ ($10^6$ $tCO_2e$ ) | $ER_{paper\ recycling,y}$ ($10^6$ $tCO_2e$ ) | $ER_{RDF,y}$ ($10^6$ $tCO_2e$) | $ER_{AD,y}$ ($10^6$ $tCO_2e$) | $ER_y$ ($10^6$ $tCO_2e$) |
|---|---|---|---|---|---|---|
| 2016 | 14.0 | 0.49 | 0.02 | 0.13 | 0.04 | 0.68 |
| 2017 | 15.5 | 1.26 | 0.06 | 0.25 | 0.09 | 1.66 |
| 2018 | 17.3 | 2.17 | 0.10 | 0.41 | 0.16 | 2.84 |
| 2019 | 19.2 | 3.25 | 0.15 | 0.60 | 0.25 | 4.25 |
| 2020 | 21.3 | 4.53 | 0.22 | 0.82 | 0.35 | 5.92 |
| 2021 | 23.7 | 6.06 | 0.29 | 1.07 | 0.47 | 7.89 |
| 2022 | 26.4 | 7.88 | 0.39 | 1.37 | 0.61 | 10.25 |
| 2023 | 29.4 | 9.72 | 0.51 | 1.70 | 0.75 | 12.68 |
| 2024 | 32.7 | 12.18 | 0.65 | 2.09 | 0.94 | 15.86 |
| 2025 | 36.4 | 15.07 | 0.81 | 2.55 | 1.15 | 19.58 |
| 2026 | 40.0 | 17.87 | 0.92 | 3.28 | 1.46 | 23.53 |
| 2027 | 44.2 | 20.51 | 1.04 | 4.16 | 1.85 | 27.56 |
| 2028 | 48.5 | 23.10 | 1.16 | 5.22 | 2.33 | 31.81 |
| 2029 | 53.2 | 25.74 | 1.29 | 6.46 | 2.90 | 36.39 |
| 2030 | 58.2 | 28.49 | 1.44 | 7.91 | 3.57 | 41.41 |

**Table 6.10** – Total emission reductions from the Waste-to-Resource NAMA (t $CO_2$e).

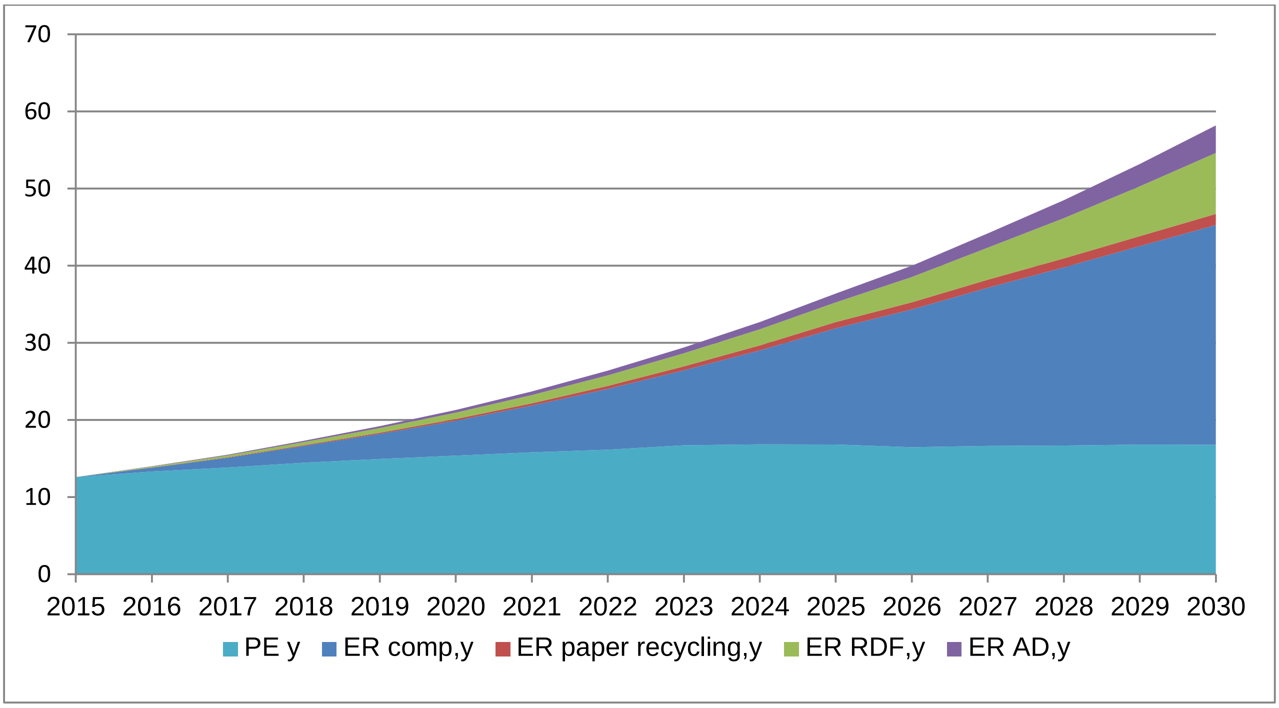



**Figure 6.6** – Total emission reductions from the Waste-to-Resource NAMA . Legend: PE: project emissions, ER: Emission Reductions; comp: composting; RDF: refuse-derived fuel; AD: anaerobic digestion.

The upper line in the graph expresses the total GHG emissions from the solid waste sector in a business as usual scenario. The areas coloured in dark blue, red, green and purple represent the GHG emission reductions, expressed in ton $CO_2e$ that can result from processing waste into compost, recyclable materials, RDF, and biogas, respectively. It can be concluded that the implementation of the measures under the NAMA can reduce annual solid waste emissions from 58.2 t $CO_2e$ to 16.8 t $CO_2e$ by year 2030. This corresponds to a 71% reduction in relation to a business-as-usual scenario on that year.

## 6.4 Measurement, Reporting and Verification (MRV) system of the NAMA

The set-up of a Measurement, Reporting and Verification (MRV) system is an important component of the NAMA, in order to ensure the transparency of the activities implemented and to assess the impacts of the NAMA on both GHG mitigation and sustainable development benefits. The MRV system for this NAMA is proposed to be built based on the national inventory system of Viet Nam and existing methodologies under the CDM framework. The MRV of this NAMA will also be fully in line with the institutional set-up being prepared in the context of the project jointly implemented by GIZ and IMHEN for a nation-wide MRV system.

### Measurement

#### a. Boundary and scale

Activities and outcomes achieved in the scope of the NAMA which will be measured, reported and verified include the following:

- Capacity building activities;
- Policies, laws and regulations implemented at national and sub-national level supporting waste-to-resource activities;
- Financial support received for NAMA activities from international donors;
- Waste-to-resource projects are implemented and put into operation as part of the NAMA;
- Outputs, outcomes and impacts of the projects implemented under the NAMA, taking note of elements that include inputs and outputs of the waste treatment plants, greenhouse gas emission reductions and investments on treatment plants.

MRV will be implemented at three levels:

1. Project and activity level, from where data is recorded on a regular basis;
2. Sector level, whereby all data at activity and project are aggregated into sector level for reporting and verification;
3. National and international level, whereby reports on GHG mitigation activities are compiled and fed into National Communications and Biennial Update Reports.

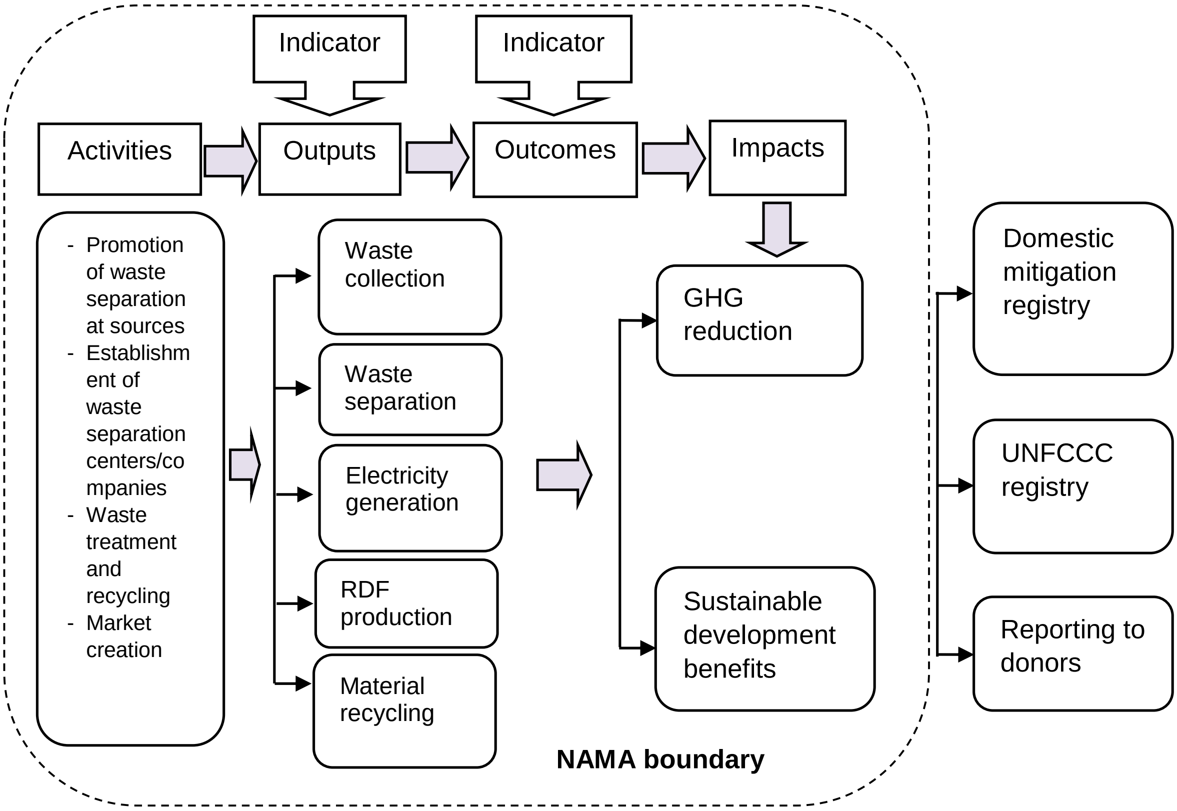



**Figure 6.7** – Boundary and scale of the Waste-to-Resource NAMA

**b. Indicators**

Indicators are quantitative or qualitative variables associated with a target that refers to a qualitative value or quantitative value. Measurement means assessing the value of the indicator for a certain timeframe, which thus serves as a standard for measuring, reporting and verifying the achievement of the outcomes. Indicators should be formulated in a SMART manner (Specific, Measurable, Achievable, Relevant and Timely) to ensure their appropriateness in showing whether an outcome has been achieved.

The implementation of the NAMA activities will result in measurable outcomes and impacts both in terms of the reduction of GHG emissions and sustainable development benefits (also called "co-benefits"). In this context, the table below presents the impact indicators, baseline setting, and data collection requirements proposed for the NAMA. The impact indicators could be quantitative or qualitative to measure the impacts resulting from implementing the NAMA, with reference to the baseline scenario.

| Impact dimension | Outcome | Indicator |
|---|---|---|
| Waste management | Waste is collected | Percentage of waste collection |
| | Waste is segregated | Share of waste separated |
| | Waste is treated by alternative | Quantity of compost produced |

| | | |
|---|---|---|
| | measures | Electricity and heat generated through AD |
| | | Quantity of RDF produced |
| | | Quantity of materials recycled |
| GHG emission reductions | Reduce GHG emissions from disposal methods | $CO_2$e reduced |
| Sustainable development benefits | Job creation and informal sector integration | Number of new companies and their employees. |
| | Increased agricultural output with composting | Increased crop yield with the application of compost in agriculture |
| | Enhanced energy security | Increasing rate of indigenous supply or the share (%) of total energy supply from anaerobic digestion facilities, measured in kWh. |

**Table 6.11** – Impact indicators of the NAMA-

### Data Collection and Reporting

Data collection and reporting is an important part of MRV and will be governed by the requirements of domestic policy makers, financiers, donor organizations, and international reporting requirements. There are three key elements for data collection and reporting: i) frequency of the collection and reporting; ii) data collection instruments; and iii) responsibility for data collection.

At the project/plant level, data will be collected on a regular basis and, as a minimum requirement, records should be made of waste processed (e.g. expressed in ton of waste per day) and outputs generated (e.g. quantities of compost, electricity, etc., produced). Data gathered from projects will then be aggregated at the city level by a focal point at the municipal people's committee (e.g. DOC or DONRE). Next, consolidated data at the city level is to be sent to the NAMA Management Board, which will aggregate all activity-data from NAMA projects. Specific templates will be developed to support these reporting requirements, so as to ensure the consistency of the data collected and reported.

### Verification

Verification refers to the process of independently checking the accuracy and reliability of the information reported, including the procedures for the collection and processing of data. *Inter alia*, the verification process will include the in-desk review of reports submitted, site-visits for specific waste-to-resource projects and interviews with stakeholders involved in the implementation of the NAMA. The NAMA coordinating unit will be in charge of providing the necessary conditions to make available relevant information to third party verification.

The verification process may consist of internal verification and external audits, and its detailed procedures will depend on the requirements of funding organizations, including donors, as well as the modalities internationally agreed by the government of Viet Nam on MRV. The project jointly developed by GIZ and IMHEN in the establishment of a nation-wide MRV framework is expected to shed further light on this.

# 7. Institutional Arrangements and Financing of the NAMA

## 7.1 Introduction

This chapter covers two key components of the Waste-to-Resource NAMA. Firstly, it proposes an institutional architecture for the programme; secondly it comes up with an estimate of its costs, while suggesting financing modalities to support the implementation of concrete projects “on the ground”.

Section 7.2 focuses on the institutional arrangements of the NAMA programme. It draws upon the work developed on the ongoing project that is being developed by IMHEN in partnership with GIZ, which aims at setting-up the institutional structures and arrangements for NAMAs in Viet Nam in an “MRV manner”. Based on the preliminary recommendations of this project, a structure for this specific NAMA is proposed, which takes into account the specific context of the solid waste sector in Viet Nam. Section 7.3 sheds light on the estimated costs of the NAMA, while section 7.4 briefly outlines a set of options for financing the programme.

## 7.2 Proposed Institutional Arrangements for the Waste-to-Resources NAMA

In chapters 2 and 3 (in sections 2.2 and 3.3, respectively) of the study, the institutional arrangements of Viet Nam’s climate change and solid waste sectors were characterized and assessed in detail.

With respect to the climate change framework of Viet Nam, it was observed that a set of different national-level institutions have a stake on climate change matters. Indeed, virtually every national ministry has a role to play on these issues, with several decisions and decrees issued since 2012. The main challenge identified on this organizational set-up was a lack of clear roles and responsibilities among the different cabinets, including the need for a stronger mandate for MONRE, as well as difficulties in establishing a mechanism for inter-ministerial coordination.

With regards to the management of solid waste, it was noted that five ministries are involved on these issues: MOC, MOIT, MARD, MOH and MONRE. On the other hand, most roles and responsibilities are under the umbrella of two ministries: MOC and MONRE. While MONRE is tasked with the overall responsibility of environmental management and protection, MOC is in charge of planning aspects related to the sector. MOC is also tasked with ensuring inter-ministerial coordination.

In this context, it is proposed that at national level all activities related to the coordination and implementation of this NAMA are under the responsibility of MOC. Indeed, as MOC is the main ministry responsible for dealing with waste management issues in Viet Nam, it is proposed that this ministry functions as the focal point and coordinating entity for implementing the Waste-to-Resource NAMA.

The project that is being implemented by GIZ/IMHEN "Creation of an overarching framework for NAMAs and MRV in Viet Nam", proposed the following organizational set-up for establishing and coordinating NAMAs in Viet Nam:

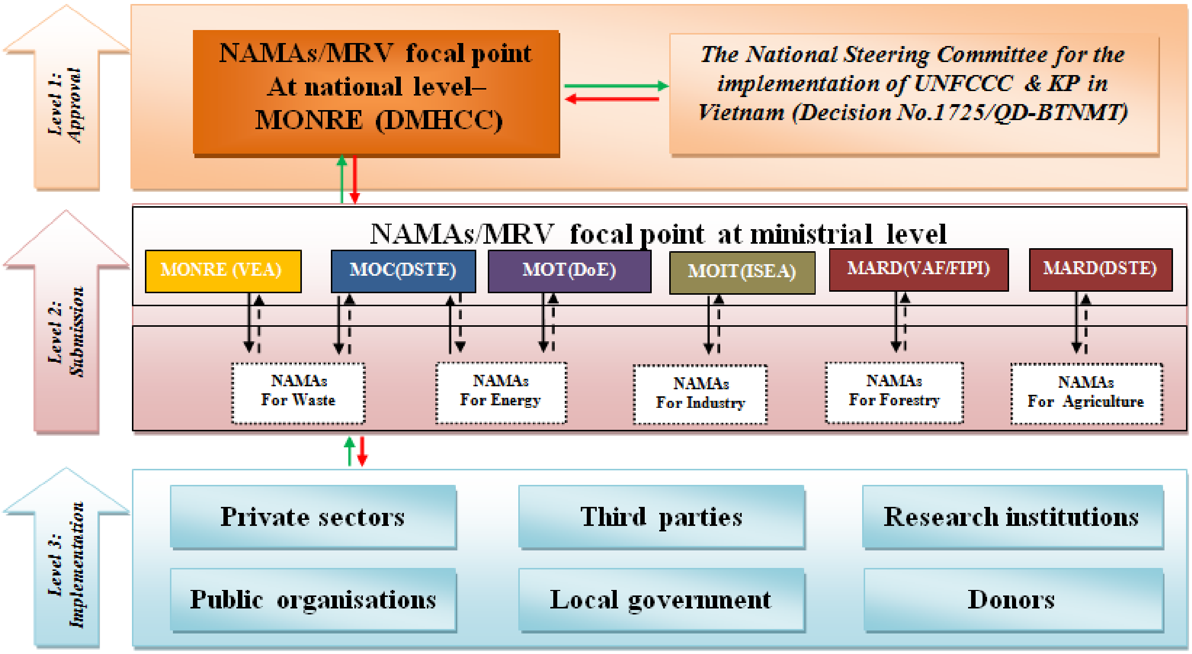



**Figure 7.1** – Proposed organizational set-up for establishing and coordinating NAMAs (Source: IMHEN and GIZ, 2015)

In order to avoid increasing the complexity of the existing institutional structure, it is suggested that organizations/units already in operation can have their mandates extended to deal with matters related to the Waste-to-Resource NAMA. This is in line with the recommendations of the study on the institutional arrangements of the NAMA framework in Viet Nam prepared by IMHEN and GIZ.

Among the units/agencies that are part of the diagram of figure 7.1, it is suggested that three of them can be more strongly involved in the Waste-to-Resource NAMA:

1. **Department of Science, Technology and Environment (DSTE)**, under MoC;
2. **Department of Meteorology, Hydrology and Climate Change (DMHCC)**, under MONRE;
3. **Vietnam Environment Administration (VEA)**, under MONRE.

It was noted above, and elaborated in some detail in chapter 3, that MoC is a key ministry with responsibilities in the solid waste sector of Viet Nam. In light of its role in providing technical and financial support to local governments, it is proposed that the ministry can act as the focal point for the implementation of the Waste-to-Resource NAMA. Moreover, it is proposed that a specific unit, **DSTE**, can serve as the **NAMA Management Board**, as this is a department within the Ministry that already possesses relevant know-how on climate change matters. To fulfil its duties as the NAMA

Management Board, it is suggested that a unit or small cabinet is established under DSTE with the exclusive focus of dealing with the work associated with this NAMA.

**DMHCC** is the functional unit within MONRE that acts as the focal point of Viet Nam to the UNFCCC, thus having under its responsibilities the coordination of all climate change-related activities of the country. DMHCC has also been designated as the focal point of the national government to the coordination and implementation of NAMAs. In this context, and with respect to the Waste-to-Resource NAMA, it is proposed that DMHCC is responsible for compiling relevant data related to the implementation of the programme, based on which reports required for international reporting purposes are prepared, including National Communications and BURs. **VEA** shall support DMHCC on quality assurance/quality control matters.

In addition to these three entities, it is suggested that other organizations/ institutions with a relevant stake in the solid waste sector of Viet Nam can be assigned clear roles and responsibilities in the institutional structure proposed for the NAMA. They are as follows:

- **Vietnam Environmental Protection Fund (VEPF)**: VEPF is a state financial institution established with the mandate to mobilize funds to environment-related initiatives, including CDM projects, from the state budget as well as other funding sources, including international organizations. It has a non-profit status, and it operates under MONRE. It is proposed that VEPF can act as the “preferred” national focal point for financing specific project activities under the NAMA. That does not imply that other national-level entities that have traditionally extended their support to waste management activities in Viet Nam (e.g. MoC, national banks, etc.) would not be eligible as financing entities under the umbrella of the NAMA. However, it is expected that any funds made available from MONRE and international organizations (e.g. NAMA Facility, Green Climate Fund) could be channeled through VEPF. Funds mobilized by VEPF would be directly transferred to the entities who will be implementing the activities under the NAMA (e.g. municipal governments, project developers, URENCOs, etc.).
- **Province level authorities**: Hierarchically on a tier immediately below national ministries, it is proposed that provincial level authorities are tasked with the responsibility of gathering all data within that province related to the implementation of activities under the NAMA. At province level, authorities should help spreading out the word about the NAMA to any relevant stakeholders (e.g. officials working in different cabinets, URENCO, communities, etc.). If desired, provinces may delegate to city level authorities the responsibility of dealing with the **NAMA Management Board** (i.e. DSTE).
- **City level authorities**: under this NAMA, it is proposed that city level authorities can: i) ensure coordination with provinces in reporting initiatives eligible as part of the NAMA that are implemented in the municipality; ii) make a record of the requests from project developers for the

inclusion of activities as part of the NAMA; iii) mobilize their own funds to support NAMA eligible activities; iv) foster the engagement and participation of communities on these activities.

- **URENCOs**: they are public companies whose major responsibilities are the collection, transport and treatment of waste in cities and provinces. URENCOs are important players in handling solid waste in cities of Viet Nam, and they can play a role on the NAMA either as project developers (see below) or in support of the city or province authorities to which they report (i.e. typically they are under the supervision of DONREs or DOCs). It is important that conflicts of interest arising from these two possible roles (as waste management project developer and government body) can be avoided.

- **Project developers**: will be responsible for implementing activities on the ground that are in line with the measures endorsed by the NAMA (e.g. a waste processing facility). They should submit a project note to a focal point in the municipal government with a brief description of the project and the type of support requested as part of the NAMA (if any). After such project is commissioned, the developer is required to report on a set of key performance indicators, such as costs of the project (including a breakdown between equity/loan/grant), and any parameters that are part of the MRV requirements, as indicated in chapter 6 (e.g. quantities of waste processed, etc.).

- **IMHEN**: it is proposed that IMHEN can provide technical support in the implementation of the NAMA, for example by supporting the NAMA Management Board in evaluating the eligibility of proposed activities as part of the NAMA, setting up the MRV system, coordinating with external auditors, etc.

- **Other organizations and stakeholders**: this encompasses other institutions not mentioned above that can play a role in implementing the NAMA. This is the case for example of ministries such as MARD (which can be instrumental in supporting the use of compost in agriculture) or MOIT (which can support the creation of markets for AD and RDF plants); international organizations such as multilateral development banks (which could be additional sources of funding for activities implemented in the scope of the NAMA); community-based organizations; the the informal private sector (i.e. waste pickers, informal door-to-door collection, etc.).

In figure 7.2 below it is presented the proposed organizational structure for the Waste-to-Resource NAMA:

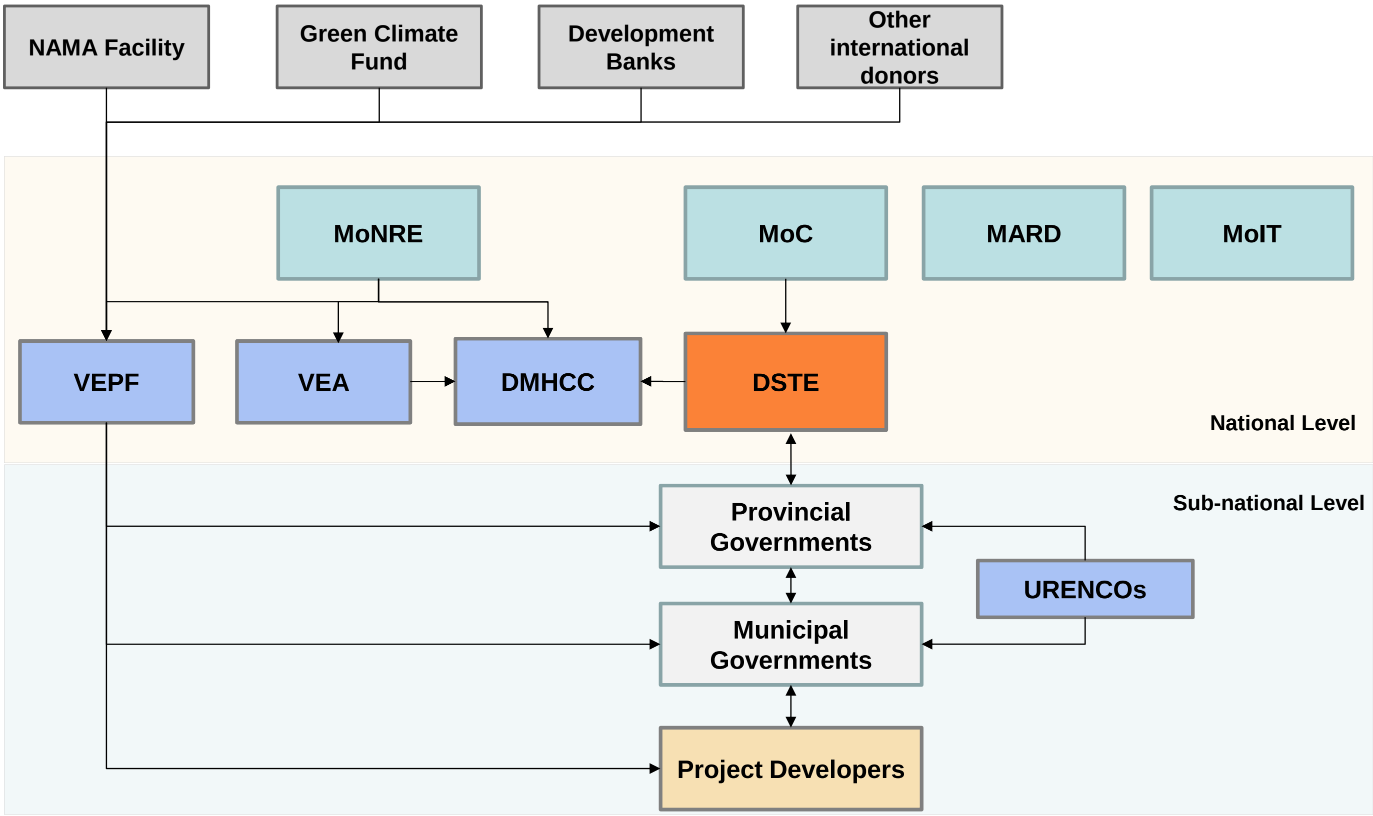



**Figure 7.2** – Proposed organizational structure of the Waste-to-Resource NAMA (Source: own elaboration)

A summary of the roles and responsibilities of each of the agencies proposed is presented in the table below:

| Organization / Functional Unit | Proposed roles and responsibilities |
|---|---|
| **DSTE (MOC)** | • Focal point and overall coordination of the Waste-to-Resource NAMA as the **NAMA Management Board**;<br>• To appraise and decide which projects/initiatives are eligible as part of the NAMA;<br>• To monitor the overall implementation of the NAMA, while ensuring it meets its stated objectives;<br>• Take record of all activities being proposed and/or implemented as part of the NAMA, in coordination with the different stakeholders involved. For each activity, DSTE shall keep a record of key performance indicators such as estimated GHG emission reductions; total costs of the project/initiative; share of national, international and private sector funding contributions to the specific initiative, etc;<br>• Ensure coordination with other Ministries that may only play a relatively small role under the NAMA (e.g. MARD, on the utilization of compost in agriculture; and MOIT, in supporting the creation of incentives for waste-to-energy projects implemented in the scope of the NAMA, such as biogas and RDF). |
| **DMHCC (MONRE)** | • Viet Nam focal point to the UNFCCC, and overall coordination of NAMAs in Viet Nam;<br>• Receive relevant data from DSTE regarding the Waste-to-Resource NAMA, based on which reports required for international reporting purposes shall be prepared; |

| | |
|---|---|
| | • Track the implementation of the Waste-to-Resource NAMA vis-à-vis GHG emission mitigation goals of Viet Nam, especially those concerning the waste sector;<br>• Provide technical assistance to DSTE, on climate change mitigation issues, as necessary (e.g. on reporting requirements, methods for calculating GHG emissions, MRV requirements). |
| **VEA** | • Assist MONRE on QA/QC issues related to the NAMA, especially on technical parameters concerning the management of municipal solid waste in Viet Nam. |
| **VEPF** | • Act as the financing focal point of the NAMA, both in terms of mobilizing funds from the state budget, as well as resources made available through international organizations (e.g. NAMA Facility, Green Climate Fund, etc.);<br>• Establish the financial mechanism for channeling funds provided by national and international organizations, as part of the NAMA, to specific project activities (e.g. grants, soft loans, etc.). |
| **Province-level authorities*** | • To implement national targets for 3R at the province level, which may include the proposal of specific targets for the province;<br>• Assign focal point, within the provincial authority, to be in charge of activities related to the NAMA and the communication with the NAMA Management Board. For instance, these responsibilities could be assigned either to DOC, DONRE or both;<br>• Support activities to raise awareness about the NAMA among cities within the province, as well as other relevant stakeholders;<br>• Coordinate activities under the NAMA with municipal level authorities;<br>• Record all activities being implemented in the province that are in line with the NAMA and formally communicates these to DSTE;<br>• Record all financial contributions made by the provincial government or related organizations (e.g. URENCO) to specific project activities that are in line with the NAMA (which would subsequently be accounted as part of the "domestic" NAMA). |
| **City-level authorities**** | • Based on the guidelines of the province, set the municipality's own strategy and, if applicable, targets for the deployment of initiatives that are in line with those endorsed by the NAMA;<br>• Act as the focal point for any project developers who wish to submit a proposal that could be eligible under the NAMA;<br>• Monitor, record and submit periodic reports on activities being conducted within the city and which are part of the NAMA, either to the provincial level authority or directly to the NAMA Management Board. This should also include all financial contributions made by the province to specific project activities that are in line with the NAMA (which would subsequently be accounted as part of the "domestic" NAMA). |
| **URENCO** | • Work in articulation with city and provincial level authorities in the design and implementation of waste-to-resource plans and strategies;<br>• Take ownsership stakes and operate waste treatment plants which are in line with those supported by the NAMA. |
| **IMHEN** | • Provide technical support to the NAMA Management Board and DHMCC, especially on the set-up of the MRV framework for this NAMA. |
| **Project developers (private or state-owned organizations)** | • Implement projects that are considered eligible under the NAMA<br>• Record operational parameters as per the MRV protocol agreed under the NAMA and submit those records to the respective municipal/provincial government authority, who will subsequently send the data to the NAMA Management Board. |

**Table 7.1** – Proposed roles and responsibilities of different units for establishing and coordinating the Waste-to-Resource NAMA.

* Municipal People's Committee at province level
** Municipal People's Committee at city level

It should be noted that as the MRV set-up for Viet Nam is still under preparation, this NAMA programme does not elaborate on the role of certain organizations that could play an important role in the MRV process. Among these are auditor companies, which would need to be involved to conduct some type of third party verification. Auditor companies could also play a role in the calculation of GHG emission reductions from each project activity implemented under the NAMA. An alternative would be to assign such responsibilities to a national government organization, such as DSTE or IMHEN. It is therefore recommended that these arrangements can be determined once a broader MRV framework for NAMAs is established in Viet Nam.

## 7.3 Estimated Cost of the NAMA programme

In order to estimate the financing requirements and modalities of the proposed NAMA, including the possible contribution of overseas sponsors such as the NAMA Facility and the Green Climate Fund, it is important to have an understanding of the overall costs of the programme. The timeframe for this projection is year 2030, with two main sets of activities considered:

i) **Readiness activities**: these include all activities that are necessary to operationalize the programme. These consist, *inter alia*, on capacity building initiatives (such as the training of stakeholders that will be directly involved in the NAMA), the setting-up of the MRV framework, the conduct of technical studies, etc.

ii) **Project activities**: these pertain to the capital costs associated with the implementation of concrete project activities, such as waste treatment plants, transfer stations, recycling facilities, awareness raising programmes, etc., which would result and/or support greenhouse gas emission reductions once they become fully operational.

Readiness activities are elaborated in chapter 8, whereas the focus on this section is on the costs of project activities implemented as part of the NAMA. These costs were estimated in the following way:

1. **Estimate the amount of solid waste generated in Viet Nam by 2030**. Based on the modelling exercise presented in chapter 6, this figure is estimated at **97,635,809 ton** on that year, which corresponds to **267,495 ton of waste per day** (tpd).
2. **Estimate the amount of solid waste to be collected in Viet Nam by 2030**. In line with the NAMA scenario proposed in chapter 6, it is assumed that all waste generated in 2030 in Viet Nam is collected for treatment, i.e. **267,495 tpd**.
3. **Consider the NAMA scenario for the technology mix in year 2030**. As per the NAMA scenario, all solid waste collected in 2030 is to be treated applying the methods laid out on

this NAMA, whereby 60% is through composting, 20% through recycling, 10% through anaerobic digestion, and 10% being converted into RDF. This means that on that year Viet Nam should be equipped with the following waste processing capacity:

- Composting plants: 160,497 tpd of total capacity;
- Recycling facilities: 53,499 tpd of total capacity;
- Anaerobic digestion facilities: 26,750 tpd of total capacity;
- RDF plants: 26,750 tpd of total capacity.

4. **Estimate technology costs**. The costs of implementing a waste treatment plant are very context specific. Variables to consider include the complexity of the solution, the potential for economies of scale, the cost and availability of equipment and materials locally, etc. Due to this, instead of assuming a single "average" figure for each treatment method, it was taken a CAPEX range,consisting of a low-end and high-end figure. Sources of secondary data were consulted for the determination of this CAPEX range (particularly ADB, 2011a & b[24]), which led to the following CAPEX ranges (which exclude costs incurred with land acquisition):

    - Composting plants: 100-30,000 USD/ton[25];
    - Recycling facilities: 555-32,000 USD/ton[26];
    - Anaerobic digestion facilities: 10,000-75,000 USD/ton[27];
    - RDF plants: 50,000-100,000 USD/ton[28].

5. **Estimate total costs of the proposed technology mix**. Taking into account the technology cost ranges and the processing capacity necessary to meet the 2030 targets for waste treatment, it can be concluded that the solutions implemented as part of the NAMA programme in the 2016-2030 period would require a cumulative investment of between **1,651 million USD** and **11,208 million USD**. This equates to an average annual investment requirement of between 110 million USD and 747 million USD over this period.

It should be underscored that the estimated costs only pertain to capital expenditures on waste treatment facilities, with other cost drivers, such as operational expenditures, being excluded from the

[24] Asian Development Bank (ADB), 2011a, "Towards Sustainable Municipal Organic Waste Management in South Asia – a Guidebook for Policy Makers and Practitioners", Manila, Philippines.

Asian Development Bank (ADB), 2011b, "Materials Recovery Facility Tool Kit", Manila, Philippines.

[25] Low-end figure: cost of home-composting.

[26] Investment costs of recycling facilities can vary sharply depending on several different factors, including the type of material recycled, recycling technology, land available, etc. To come up with the margins of the range, for the lower margin it was taken the average market price of HDPE for a given period based on data of Letsrecycle (Letsrecycle, 2015, "Prices: plastics", http://www.letsrecycle.com/prices/plastics/, [Accessed: 07.07.2015]). (2015) (in order to have a notion of short term recycling costs). For the upper margin it was taken the median CAPEX of a materials recovery facility in the Philippines based on a study commissioned by the Asian Development Bank (ADB, 2011b).

[27] Low-end figure: based on a demonstration project in Yogyakarta, Indonesia. High-end figure based on research of ADB (2011a).

[28] High-end figure taken from ADB (2011a).

calculation. This is based on the assumption that waste treatment plants implemented as part of the NAMA can be operationally sustainable, i.e. that at a minimum revenues generated from the sale of resources from waste can cover operational costs.

## 7.4 Financing modalities for the NAMA

In chapter 5, it was proposed that the programme consists of a mix of "domestic"/unilateral contributions as well as some form of international support (i.e. the "supported" component of the NAMA).

As mentioned in the same chapter, international support would be requested especially for the purposes of capacity building, the set-up of the MRV system of the NAMA, and market creation/ market support.

With regards to the costs of implementing the project activities, which were estimated at a minimum of 110 million USD per year to meet the ambitious targets of the NAMA programme by 2030, it is proposed that at least 20% of this sum can be made available through international donors and/or support mechanisms (e.g. the Green Climate Fund). This corresponds to 22 million USD per year. These funds would be used to "co-leverage" the remainder 80% of the estimated yearly costs of the NAMA, which are expected to be mobilized from domestic sources of funding. Depending on the outcomes and impacts resulting from the piloting phase of the NAMA, international climate funding could account for a higher proportion of the total costs of implementing the programme.

It is proposed that the internationally funds leveraged can be used for the following purposes:

- To be channeled in the form of grants to project developers investing in waste treatment facilities. Such grants would correspond to a maximum of 50% of the total CAPEX of the project;
- To be channeled in the form of subsidies or capital guarantees to financing institutions in Viet Nam, so that the interest rate of loans provided to potential project developers could be reduced.
- To be provided in the form of additional support to national and local government authorities in addressing market distortions, such as in topping-up a feed-in tariff for biogas produced from solid waste.

The bulk of the funds for implementing project activities as part of the NAMA would need to be mobilized domestically, including through URENCO, the private sector, state-owned organizations with a stake in the solid waste sector and local banks.

# 8. Roadmap of Implementation

## 8.1 Introduction

This chapter lays out a roadmap for the steps that will follow the completion of the NAMA-design stage. The roadmap proposed is contextualized within the overall NAMA development process, as shown in figure 8.1 below:

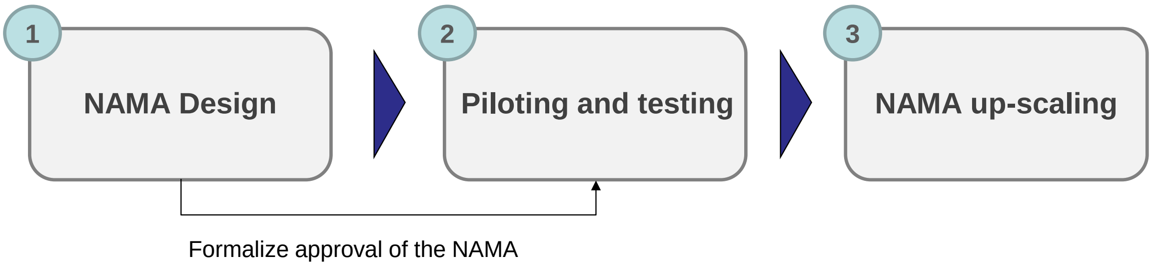



**Figure 8.1** – Development process of the Waste-to-Resource NAMA.

As pointed out already in chapter 1, the NAMA development process consists of three phases. Phase 1 will be complete upon finalization of the NAMA-design phase, whose core output consists of this NAMA-design study. Phase 2, "preparation and piloting", can be considered as stage two of "NAMA-Readiness", and shall focus on three main elements: i) setting-up of the institutional framework of the NAMA; ii) capacity building of stakeholders; and iii) piloting of the key elements of the programme. On this phase it is expected that international sources of funding can be tapped to support the implementation of these activities. The full-implementation of the programme, nation-wide, is expected to occur in phase 3, which could be initiated at the earliest after 1.5 years of preparation and demonstration experience.

It should be noted that a gap of 3-4 months may occur between phases 1 and 2, so as to formalize the approval of the present study and the proposed design elements, among national stakeholders in Viet Nam. Amongst them, full endorsement is necessary from MOC and MONRE, as these are the national level ministries with a higher stake on solid waste management and climate change in Viet Nam. Other organizations that would need to back-up the proposed NAMA are VEPF, the Ministry of Finance, and the Ministry of Planning and Investment (which is the focal point of Viet Nam for the Green Climate Fund, a potential source of funding to support the implementation of NAMAs). In the transition between phases 1 and 2, it may be considered the organization of a national workshop to identify at least two cities where the main elements of this NAMA could be piloted. Such workshop should have the participation of representatives of cities in Viet Nam that are amongst the most progressive in the management of solid waste and the implementation of measures in line with the principles of 3R. The identification of those cities could be made with the support of an organization such as the Association of Cities in Vietnam (ACVN) – the largest and most representative network of cities in Viet Nam – and in consultation with MOC and MONRE.

Given the above context, this chapter sheds light on the activities that are expected and recommended for the implementation of phase 2 of the NAMA. It is divided into three sections. Section 8.2 details the activities required for establishing the institutional framework of the NAMA, including the necessary capacity building initiatives. Section 8.3 proposes the activities that should be carried out to pilot the design elements of the programme, while section 8.4 summarizes and concludes.

## 8.2 Institutional arrangements and capacity building

Prior to the piloting of specific elements of the NAMA and its full-scale implementation, there is a need to set-up the institutional framework and build the capacities of key stakeholders with regards to this NAMA. Tables 8.1 and 8.2 below detail the proposed activities that are needed to fulfil these objectives. A brief explanation is provided to each activity, as well as a tentative timeframe and budget.

| Activity | Rationale | Proposed timeframe | Budgetary requirements* |
|---|---|---|---|
| 1. Preparation of Terms of Reference | • Terms of Reference (ToRs) detailing the roles and responsibilities of stakeholders involved on the NAMA need to be prepared. These should include an estimate of the funds necessary to enable these organizations to fulfil their expected duties once the NAMA is operationalized.<br>• Specific and detailed ToRs are necessary for the NAMA Management Board. ToRs for specific positions should also be prepared.<br>• Alignment with other NAMA programmes in Viet Nam needs to be conducted, in particular to ensure that synergies are leveraged and to avoid any duplication of roles. | 3 months | N/A |
| 2. Mobilization of funds for fulfilling ToRs | • These funds, to be made available through national resources, are required for establishing the NAMA Management Board | 2 months | N/A |
| 3. Staffing | • Based on the ToRs and the funds available, staff should be recruited for fulfilling the duties that are required as part of the NAMA Management Board | 3 months | N/A |
| 4. Enactment and operation | • Team and individuals working exclusively for the NAMA Management Board initiate their work | Rolling basis | 5,000 USD per month ** |

**Table 8.1** – Activities for establishing the institutional arrangements of the NAMA in Phase II.

* This is a notional estimate of budget requirements. “N/A” means “not applicable” or undetermined.

** This is the minimum budgetary requirements estimated for setting-up a small team or group of individuals to work exclusively on this NAMA. This would comprise 5 individuals with a gross salary of 300 USD/month, with the remainder a budget for other operational costs (e.g. office space, travel and accommodation).

| Activity | Rationale | Proposed timeframe | Budgetary requirements* |
|---|---|---|---|
| 1. Capacity building of VEPF staff | • VEPF will have a central role in the operationalization of this NAMA, and thus it is necessary to build the capacities of its staff with regards to the NAMA framework in general, and the Waste-to-Resource NAMA in particular.<br>• International climate support could be leveraged for this activity, and possibly also from existing initiatives in Viet Nam on NAMA MRV and institutional capacity building.<br>• Capacities to be built through the organization of technical workshops and training sessions.<br>• Funding for this activity would be required for organizing and hosting the training sessions. | 9 months** | Up to 50,000 USD |
| 2. Capacity building of “other” stakeholders | • Several different stakeholders would need to be trained on aspects related to the NAMA. These include staff of the NAMA management board, MONRE, MOC, MPI, etc.<br>• Such capacity building initiatives would need to be conducted on a recurring basis during Phase II of the NAMA and even beyond. | 1 year** | Up to 100,000 USD |
| 3. Curricula for capacity building sessions | • Training modules for the capacity building sessions would need to be developed by experts on climate change issues and solid waste management.<br>• The preparation of these training modules could be prepared by experts from IMHEN, ESCAP, Waste Concern, etc.<br>• This activity could include the preparation of a standard design of the IRRC model to assist its replication in Viet Nam, as necessary. | 1.5 years | Up to 100,000 USD |
| 4. Setting-up of training/ competence center | • A training center or competence center could be established to train and disseminate good practices related to the promotion and implementation of measures that are in line with the NAMA.<br>• Such training center could be established, for example, on the IRRC of Quy Nhon, which is considered a good practice of a decentralized solid waste management facility. | 1 year | Up to 100,000 USD |
| 5. Training of sub-national stakeholders | • As cities are shortlisted and they accept being part of the NAMA, provincial and local government officials need to be trained on the operation mode of the NAMA.<br>• Such individuals, which should not be restricted to government officials and may also include local experts, should be trained on aspects such as the MRV of the NAMA, the reporting requirements of the programme, etc. | 6 months | Up to 100,000 USD |

**Table 8.2** – Activities for capacity building initiatives as part of Phase II of the NAMA.

* This is a notional estimate of budget requirements. “N/A” means “not applicable” or undetermined.

** Timeframe for this activity is flexible, and they could start as early as institutional arrangements are formalized and training materials prepared.

In addition to the activities described in the tables above, it is proposed that as part of this phase of the Waste-to-Resource NAMA **a detailed roadmap for Phase III of the NAMA** is prepared. This roadmap would reflect on the experiences of piloting the NAMA on Phase II, and provide details on how the NAMA could support the ambitious goals laid out in the National Strategy for Integrated Management of Solid Waste up to 2025, with a Vision to 2050. It is also suggested that this roadmap could partly consist of a feasibility study, where it could be examined in detail which supporting schemes/mechanisms should be prioritized and enabled on Phase III of the NAMA. Such roadmap is estimated to cost up to 50,000 USD, depending on the level of expertise of the consultants recruited for its preparation.

Last but not the least, it is expected during this phase the preparation of applications to specialized vehicles that can provide technical and financial support to the implementation of the NAMA, such as the UK/German NAMA Facility, the Green Climate Fund (GCF) and the Global Environmental Facility (GEF).

## 8.3 Piloting design elements of the NAMA

In addition to the activities elaborated in the section above, Phase II of the NAMA will empirically test the main design elements of the programme, and specifically its MRV system.

To this end, it is suggested that **two cities** are selected as one of the steps immediately following the completion of Phase I of the NAMA with the organization of a national workshop. The least costly option for this piloting would consist in selecting a city or location where a waste-to-processing facility is already in place, which could serve as the springboard for testing certain elements.

As mentioned in chapter 6, one of the key success factors of an MRV system for NAMAs is the setup of a framework that reduces complexity and bureaucracy to the extent possible. To this effect, the “least complex” monitoring procedures for a plant operator will consist in taking record of inputs (i.e. quantity of waste that is processed in a given period) and outputs (e.g. resources that are recovered from waste, in the form of compost, biogas, etc.). Variables that would require higher capacities for their monitoring (e.g. oxygen concentration of a waste pile, emission factors for a power generation system) could be fixed as default values. It is therefore proposed that, as part of the NAMA, such monitoring framework can be tested in at least one city or waste treatment facility in Viet Nam.

A summary of the activities that are proposed to be carried out is presented in table 8.3 below:

| Activity | Rationale | Proposed timeframe | Budgetary requirements* |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 1. MRV testing** | • Two waste treatment plants (applying the approaches endorsed by the NAMA) serve as a testing board for the MRV component of the programme.<br>• Financing requirements take into account the salaries and travel of the individuals taking part on this activity. | 1 year | Up to 25,000 USD |
| 2. Tool for assessing and measuring “co-benefits” | • Development of a tool to measure co-benefits of the NAMA. Such tool can be based on the methodology developed by ESCAP and Waste Concern for the waste sector.<br>• The methodology is applied in at least two locations.<br>• Funding requirements consist on the fees paid to experts to develop the methodology, as well as the salaries and travel of those who will monitor this component of the NAMA. | 1 year | Up to 70,000 USD |
| 3. Study on incentive schemes to support waste-to-resource initiatives | • The aim of such study would be to understand in detail the level of support required to ensure the financial and economic viability of the waste treatment plants piloted during this phase of the NAMA. Primary data on the operational performance of these plants would need to be gathered and anayzed as part of this study. | 1 year | Up to 50,000 USD |

**Table 8.3** – Activities for empirical testing of Phase II of the NAMA.

* This is a notional estimate of budget requirements. “N/A” means “not applicable” or undetermined.

** It is assumed that funding from other NAMA-Readiness projects in Viet Nam can be leveraged for capacity building and training related to the MRV system.

While the establishment of the institutional set-up and the NAMA piloting are the core activities of Phase II of the Waste-to-Resource NAMA, during this phase it is also suggested the elaboration of technical background studies on specific topics that are in sync with the scope of the NAMA. One such topic emerged from the analysis presented in chapter 5, on the strategic importance of establishing Viet Nam as a recycling hub in the Asian continent. In this context, **a technical study** on the prospects and potential for recycling could be prepared as part of Phase II, at an estimated cost of 150,000 USD, with further elaboration provided in the box below.

**Box 8.1: Technical study on the prospects for fostering the development of the recycling industry in Viet Nam**

In Viet Nam, there is a significant need for recycling facilities. However the current supply of inputs originating in Viet Nam has not met the demand due to the lack of waste materials segregated at the source. In order to facilitate the supply to meet the demand, as part of this NAMA programme it is suggested as an initial step the development of a website that could function as a bridge between private sector organizations involved the segregation of inorganic waste separation and recycling companies. As a first output, the technical study whose elaboration is proposed could lay out the modules and working scheme of such web portal. This could be accompanied by the preparation of a business development analysis on a recycling scheme for paper, plastic and metal wastes in Viet Nam.

Another activity proposed through the NAMA is to conduct research and development (R&D) activities for the production of raw materials from recycled paper, plastic and metal. One of the outcomes of such R&D activities would be the establishment of Viet Nam as a **regional center of**

**excellence for solid waste recycling**. The technical study could elaborate on the strategy and key aspects associated with the establishment of such center, for example the design of a mechanism to support the transfer of recycling technologies into Viet Nam, the human resource development requirements, and the technical, economic and social aspects of recycling technologies and policies necessary for an effective R&D framework to be in place.

Finally, the technical study could shed light on a **roadmap for the transformation of Viet Nam's recycling sector**, which could be structured along two phases.

Activities under a **first phase (2017-2021)** would result in the selection of a pilot city to demonstrate a set of recycling technologies, including the characterization of supply and demand patterns for the raw materials produced from paper, plastic and metal wastes. A business case would be prepared in order to set-up a support scheme for the production of such recyclable materials in Viet Nam. These activities would help stakeholders become acquainted with the recycling business and provide the necessary experience to create policy instruments to government officials.

**A second phase (2021-2025)** would aim at rolling out policy instruments nationwide, which could subsequently be enshrined into the Law on Environmental Protection and/or related decisions. An important part of this component is the set-up of the right incentives, including financial and non-financial, which would be elaborated upon in the scope of the technical study. With respect to non-financial incentives, several options are available to both sub-national and national government authorities, such as:

- Labeling recycled products as green and environmentally friendly products;
- Labeling the carbon foot-print of recycled products;
- Setting up a set of quality standards for recycled wastes;
- Setting up a set of quality standards for recycled products.

Examples of financial incentives to be assessed include:

- Tax exemption for recycling facilities;
- Free use of land and environment fees for recycling facilities;
- Providing concession loans for recycling facilities.

## 8.4 Concluding remarks

This chapter outlined the main components of Phase II of the Waste-to-Resource NAMA. It is estimated that this phase would cost at least 750,000 USD, resulting from the sum of all activities whose costs were quantified in sections 8.2 and 8.3. These funding requirements should be preferably tapped from international donor organizations. At the point of preparing this study, the UK/German NAMA Facility was the most prominent source of funding for the implementation of NAMAs. Even though Phase II of this NAMA mostly consists of "NAMA readiness" elements, it also comprises empirical elements for testing its features, which would make it eligible for support from a vehicle such as the NAMA Facility. Other sources of international climate support for this NAMA are the Green Climate Fund (GCF) and the Global Environmental Facility (GEF).

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## Annex I – The IRRC model as a good practice in Viet Nam for the conversion of waste into resources

This Annex provides additional details on the Integrated Resource Recovery Center (IRRC) model introduced in chapter 4. It is organized into three sections: i) description of the model; ii) summary of sustainable development benefits; and iii) opportunities for replication through the NAMA framework.

The IRRC model was pioneered and developed by Waste Concern, a non-governmental organization and social business enterprise based in Dhaka, Bangladesh. IRRCs are facilities that process waste in a cost effective way, in proximity to the source of generation, and in a decentralized manner. They typically rely on manual labor, are neighborhood based, and have the capacity to process 2-20 tons of organic waste per day. The model consists of three main stages, which are illustrated in the figure below:

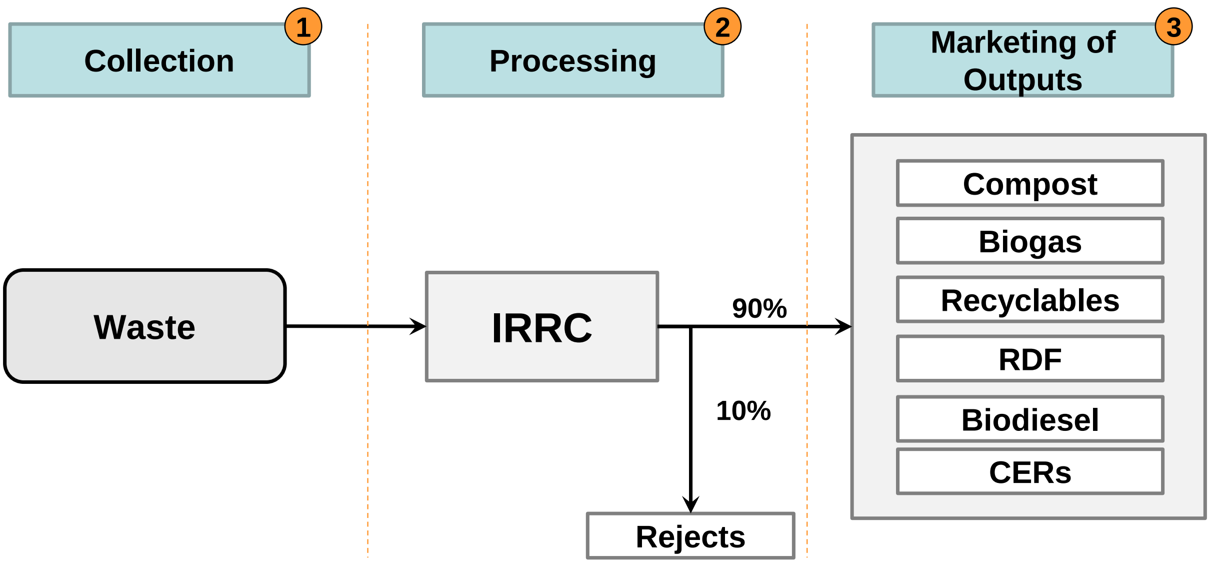


**Table A.1.1** – The Integrated Resource Recovery Center Model.

A step-by-step description of the model is provided below:

### 1. Collection of waste (raw materials)

The IRRC model is based on the assumption that some degree of segregation of waste at the source is conducted by those who generate waste. Regular waste collection typically involves a number of vehicles (non-motorized or motorized) so as to ensure that the supply of waste to the facility is reliable and efficient. Daily door-to-door waste collection services are provided by charging a monthly waste collection fee. Households and other generators of waste are sensitized and trained to segregate their waste into mainly organic and inorganic fractions. Certain organic fractions, such as fish waste, animal fat, meat waste cannot be used as feedstock for composting, and ideally they should be processed in a biogas digester. On an IRRC, regular collection of used cooking oil may be carried out from households, restaurants, hotels and other potential sources so that it can be processed in a biodiesel plant.

An important component of the IRRC model is that, as with any other initiative based on the principles of 3R, it heavily relies on the separation of waste at the source. Effective source separation has three main benefits:

- Contributes to providing a clean organic feedstock which is essential for producing good quality compost or the proper operation of a biogas plant;
- Increases the potential for the valorization of recyclables as they do not get mixed up with wet organic waste;
- Reduces the cost and time required in sorting the waste once it is collected and brought to the resource recovery center.

Two key factors that support effective source separation consist in raising the awareness of the community, and the set-up of appropriate systems for facilitating segregation at the source. Besides, appropriate systems and equipment need to be deployed to facilitate separate collection and transfer of waste. For example, to collect and transfer waste to treatment plants, vehicles such as tractors, trailers and push carts are appropriate, and cities do not need to go for compactor trucks as used in most developed countries, which are significantly more expensive.

## 2. Processing

Upon arrival to the IRRC, the segregated waste streams are directed to the relevant processing units, which are installed within its premises. Here, incoming segregated organic waste is converted into compost through the process of aerobic composting, inorganic waste is stored for some time in a separate room for subsequent sale, and other portions of organic waste such as fish and meat waste are placed in a biogas digester. In case the IRRC is equipped with this equipment, used cooking oil is utilized in the biodiesel plant for further processing into biodiesel. The different technologies applied through the IRRC model are explained below:

### Compost plant

The major portion of the incoming waste should be organic, which is sorted on arrival for a second time. After sorting, the carbon/nitrogen (C/N) ratio is balanced and finally piled in specially designed perforated boxes for the composting process. Compost boxes are designed to allow more oxygen to circulate in the pile and easily allow the drainage of excess water. This consists of the box composting method, and it takes approximately 60 days to produce compost from a ton of raw organic waste. The production of compost involves two types of costs: fixed cost involved with the construction of the composting plant, and operational cost incurred with running the plant. There are three major income streams from a composting plant as conceptualized as part of the IRRC model, and these include proceedings from the sale of compost, recyclables, and the charge of a house-to-house collection fee. Some features of a composting plant are as follows:

**Biogas plant**

A biogas plant is usually introduced as part of an IRRC especially to ensure the proper management of fish and meat wastes that usually come along with other types of organic waste. Inputs to the biogas plant are grinded and mixed together before being fed into the digester. The biogas produced can be used for cooking purposes and/or to generate electricity. Slurry as a bi-product from a biogas plant can be used as fertilizer.

**Recyclables management unit**

Different types of **inorganic waste** (mainly paper, packaging materials and appliances made of plastic, glass, tin, aluminum, iron etc.) are sorted out, cleaned, compacted and stored for a certain time, for the subsequent sale of such items to buyers.

**Eco-sanitation and Co-composting**

Unmanaged human excreta can create health hazards for city populations. To maximize the use of nutrient enriched human excreta, the IRRC model promotes eco-sanitation/ compost toilet and faecal sludge co-treatment alongside municipal organic waste. Toilets installed as part of an IRRC are designed as “compost toilets”.

**Leachate Management System**

A significant amount of wastewater is generated as a result of composting and the cleaning of the facility. Instead of discharging the wastewater into drains, it can be reused on new compost piles to maintain the moisture balance and enhance the decomposition process. Wastewater from the drainage system can be collected in a small covered storage tank below ground level. By mixing this wastewater with fresh water from pipes or rainwater tanks, scarce water resources can be extended and conservation promoted.

**Rainwater Harvesting System**

The IRRC model tries to demonstrate proper use of rainwater, and to this end all roof tops are connected to a rain water collection tank. The use of rainwater reduces the need for extracting ground water and the consumption of electricity for pumping purposes. About 30% of the water demand for washing and composting can be met by rainwater.

**Energy efficiency**

If the compost plant is connected to the electricity grid, an energy-efficient lighting system could be fitted to set a good example of energy conservation, as well as to reduce operational costs in the long run. If electric grid access is not available for an IRRC, solar power can be used for night time lighting.

**3. Marketing of Outputs**

With the IRRC model, different components of solid waste are processed into resources, and an important aspect towards its financial sustainability is to ensure that any products or resources generated can be marketed. The selection of the resources coming from the IRRC may vary depending on the local context and conditions available, such as the demand for a certain resource, existence of competing products (e.g. cheap electricity), etc. For example, if waste is to be processed into power, it should be ensured that there is sufficient demand for electricity in proximity to the plant.

## Sustainable Development Benefits of the IRRC model

Based on the empirical experience of implementing IRRCs in countries of the Asia-Pacific, the following **social**, **environmental** and **economic benefits** can be achieved by processing one ton of waste:

- Creation of 2 new jobs for waste pickers;
- Production of up to 0.25 tons of good quality compost;
- Reduction of 0.5 tons of greenhouse gas emissions;
- Production of 40-80 $m^3$ of biogas
- Savings of the equivalent to 1.1 $m^3$ of landfill volume;
- Directly serving between 2,000-3,000 people in urban low-income settlements;
- The production of between 0.2-0.3 $m^3$ of toxic waste water is avoided, which would otherwise pollute ground and surface water;
- Reduction of the risk of 40 diseases directly or indirectly linked with unmanaged municipal solid waste;
- Increase in crop production by 25-30%, while reducing the use of chemical fertilizers by 35-40%. This also helps to increase food security;
- Benefits both on climate change mitigation and adaptation.

## Opportunities for upscaling the IRRC model into a NAMA

In light of its potential for strong co-benefits and the reduction of greenhouse gases, the IRRC model can serve as a basis, or even the main element, of a waste-sector NAMA programme. Some options were considered at early stages of preparation of the Waste-to-Resource NAMA.

Under a baseline scenario in Viet Nam, the bulk of municipal solid waste is disposed in open dumps without landfill gas collection or utilization. Under a NAMA scenario based on 3Rs and the IRRC model, landfill gas generation can be avoided through the recycling of municipal organic waste at the community level using a decentralized approach. Figures A.2 and A.3 showcase how the IRRC approach could support the Government of Viet Nam attaining its 3R and GHG emission reduction targets. Table A.1 below shows potential GHG emission benefits resulting from waste reduction, composting and the anaerobic digestion of organic waste:

| **Potential net GHG emissions compared to landfill (kg $CO_2$eq/ kg of organic waste)** | | | | | | |
|---|---|---|---|---|---|---|
| **Organic Waste** | **Waste reduction** | | **Composting** | | **Anaerobic digestion** | |
| | Compared to shallow landfill | Compared to deep landfill | Compared to shallow landfill | Compared to deep landfill | Compared to shallow landfill | Compared to deep landfill |
| Food Waste/Vegetable Waste | 0.42 | 1.05 | 0.07-0.40 | 0.70-1.03 | 0.25-0.42 | 0.88-1.05 |

**Table A.1.1** – Potential GHG emissions from waste reduction, composting and anaerobic digestion of organic waste[29].

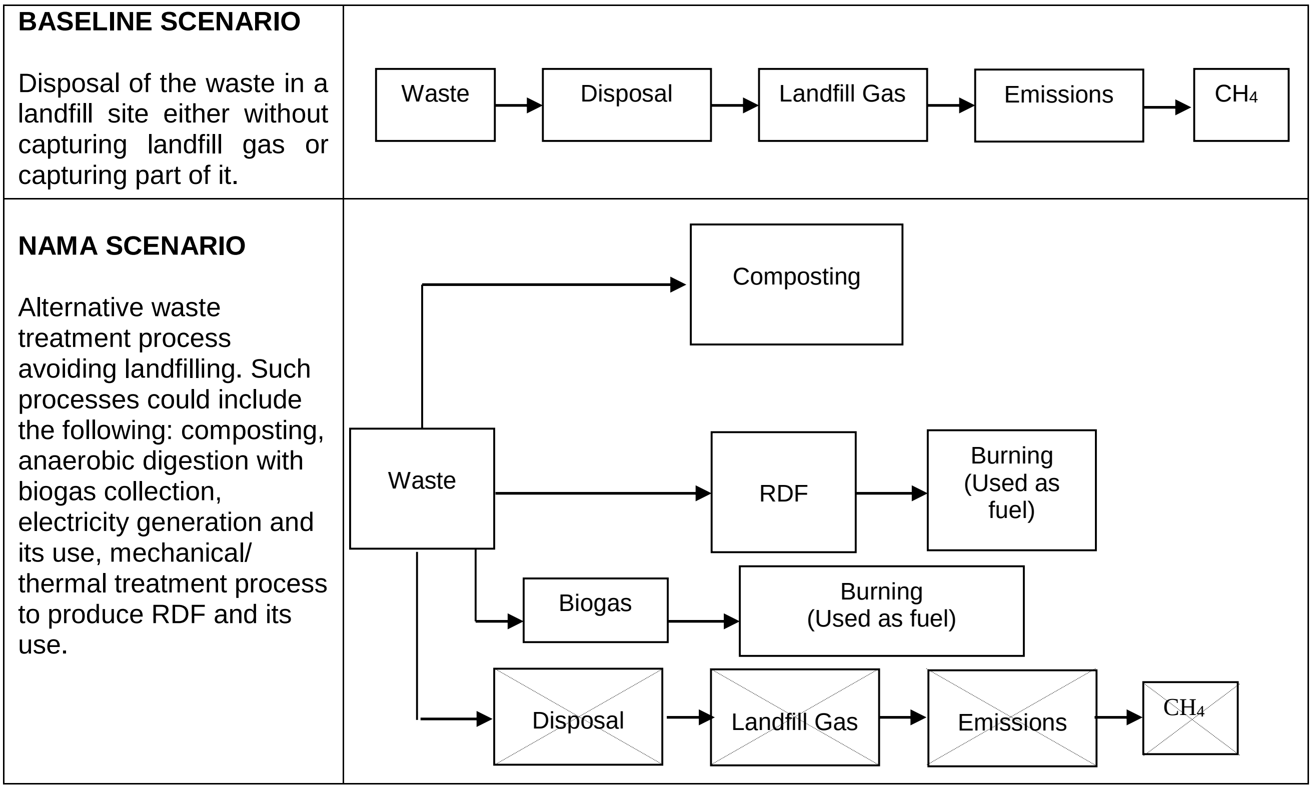


**Figure A.1.2**– Comparison between baseline situation and NAMA situation with IRRC (Source. Waste Concern)

[29] Institute of Global Environmental Strategies, 2011, "Practical guide for Improved Organic Waste Management: Climate Co benefits through 3Rs in developing countries", http://pub.iges.or.jp/modules/envirolib/view.php?docid=3263,

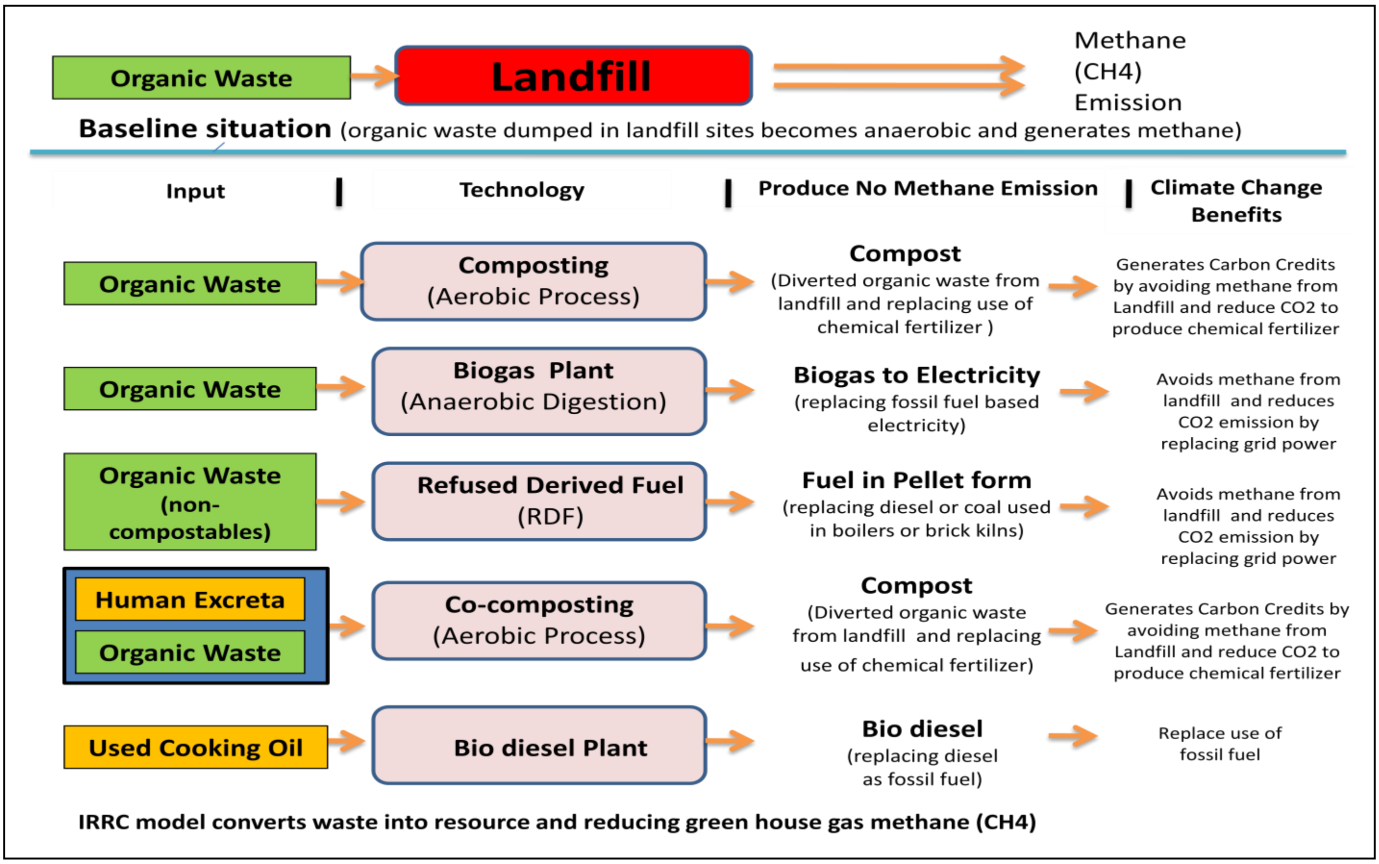


**Figure A.1.3** – Climate change benefits from applying the IRRC model (Source: Waste Concern).

Experience of Waste Concern in Bangladesh shows that by operating a composting plant using the box method applied on a typical IRRC plant, 0.4 -0.5 tons of $CO_2e$ are reduced by composting per each ton of municipal organic waste treated. The technologies promoted by the IRRC model, such as composting, biogas, RDF and the recycling of plastic waste to reduce the amount of virgin plastics, are all supported by UNFCCC methodologies. There are already projects which have obtained certified emission reduction (CERs) issued by the UNFCCC. This could be of relevance in light of the fact that there is a general understanding among line ministries in Viet Nam that the MRV system for NAMAs should be based on the experiences of the CDM.

The UNFCCC methodologies which may be used to claim emission reduction benefits with the application of the IRRC model under the CDM or NAMA include the following:

- **ACM 22**: alternative waste treatment processes, such as composting, anaerobic digestion, gasification to produce, thermal/mechanical treatment to produce RDF, etc.
- **AMS I.H**: biodiesel production and use of energy generation in stationary application.
- **AMS III E**: avoidance of methane generation from the decay of biomass through controlled combustion, gasification or mechanical thermal treatment.

- **AMS III F**: avoidance of methane emissions through composting. Eligible projects involve the biological treatment of biomass or other organic matter through composting and the proper soil application of the compost.
- **AMS III A.J**: recovery and recycling of materials from solid waste. Under this methodology HDPE, LDPE and PET/PP plastic materials are recycled from municipal solid wastes and processed into intermediate or finished products (e.g. plastic bags etc.).

It may be noted that some of these methodologies were applied to calculate the GHG emission reductions under the NAMA scenario, as presented in chapter 6.

## Annex II – Measures endorsed by the NAMA

This Annex provides specific orientation on measures that are endorsed by the Waste-to-Resource NAMA, and which can be adopted by practitioners, decision-makers and any other related stakeholders with the responsibility of implementing the NAMA. These measures are organized in relation to the four main stages of the solid waste management value chain (or "waste cycle"), as presented below:

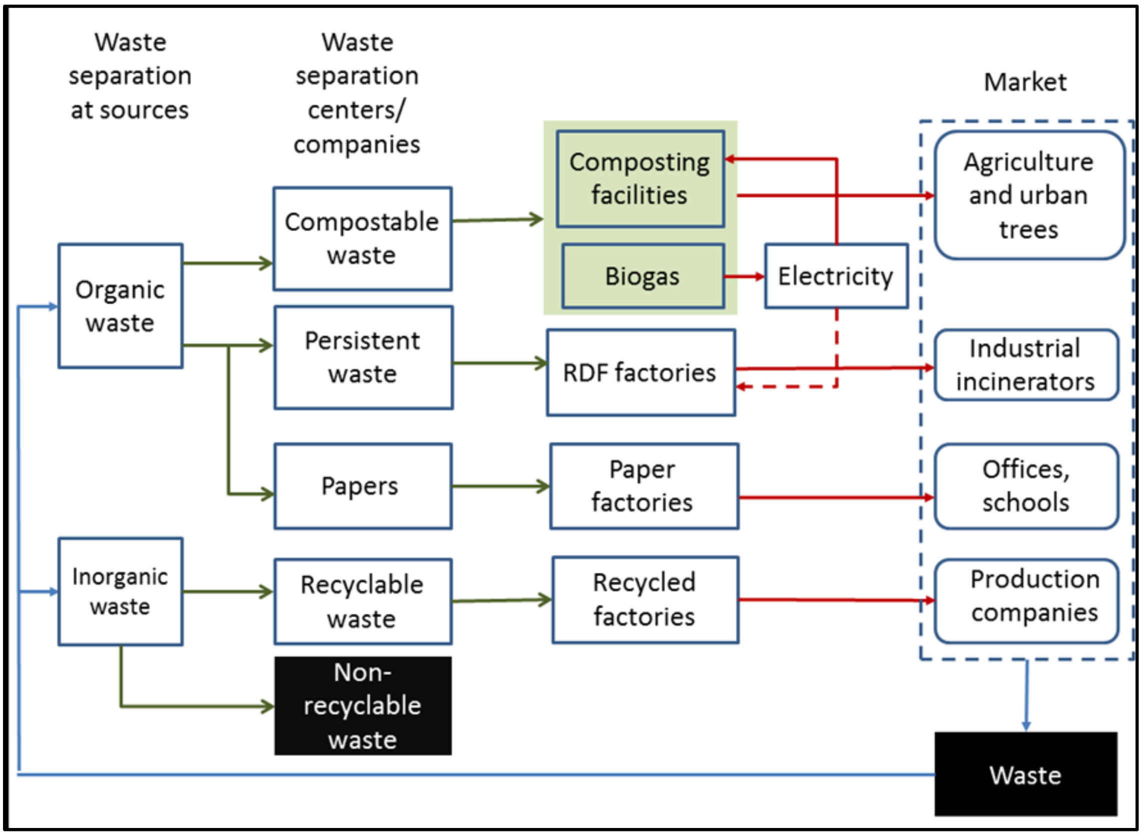


**Figure A.2.1** – Stages of the waste management value chain or "waste-cycle".

At the beginning of the cycle, solid waste is separated at source into organic and inorganic waste. Next, segregated waste is transported and further sorted out at transfer stations and/or at the gate of treatment plants. In this step, waste streams are separated into biodegradable (such as food or market waste) and non-biodegradable components (such as plastic or paper). The inorganic non-biodegradable waste is divided into two types: recyclables and non-recyclables. As the following step, the recovered segregated waste is processed into usable products, such as compost, biogas, RDF and recyclable materials. The final step consists in finding markets for the produced products, ensuring an adequate rate of return for those who invest in the facilities where the conversion into resources takes place. After recyclable products are consumed, they will again become waste and the recycling process will start from the beginning.

For each of the stages indicated above, the NAMA will encourage the following measures and activities:

## I. Waste separation at source

One of the underlying challenges for recycling and reusing waste is that most waste streams are not separated at source, leading to the contamination of the inputs for waste processing facilities, such as recycling centers and composting plants. Therefore, one of the prioritized activities of this NAMA programme is to encourage local authorities and related stakeholders to promote waste separation at source, including the activities suggested in the table below:

| | Barriers | Measures |
|---|---|---|
| **Public participation** | Communities are not aware of the benefits and are reluctant to comply with the separation of waste at source | Enhance awareness of communities on waste separation at source |
| **Infrastructure** | Lack of infrastructure to support the recovery, transportation and treatment of segregated fractions of waste | Design, set-up and mobilize funds for the deployment of the necessary infrastructure |
| **Policy/regulation** | Lack of regulations mandating waste separation at source, especially at the local level | Complement the existing legal documents or develop new policy documents |
| **Finance** | Lack of financial resources for up-scaling waste separation at source nationwide | Support from national and municipal governments, through their own budgetary allocations |

**Table A.2.1** – Measures supported/endorsed by the NAMA to promote the segregation of waste at source.

### a. Enhance awareness on waste separation at source

Communities with a high awareness on the need for the segregation of waste at source will be one of the key success factors for the overall sustainability of the NAMA. Programmes for enhancing awareness on waste separation are encouraged to be implemented at all levels in the cities that voluntarily take part on this NAMA, with different approaches tailored to different stakeholders, as indicated in the table below:

| Targeted stakeholders | Person/Agency in charge | Means for awareness-raising |
|---|---|---|
| Officials working for state agencies | Leaders of state agencies | Official dispatch; guidelines enshrined on a handbook on waste segregation at source |
| Employees of companies | Directors/managers of companies | Incorporation of guidelines on organizations’ regulations |

| | | |
|---|---|---|
| Workers of non-governmental and international organizations | Directors/managers | Incorporation of guidelines on organizations' regulations |
| Households | People's Committee of cities and provinces | Mass media outdoor campaigns; door-to-door campaigns |
| Children | Primary schools and kindergarten managers | Educational programs (e.g. entertainment activities such as musical performance, plays, etc.) |

**Table A.2.2** – Measures supported/endorsed by the NAMA to enhance awareness on the need to segregate waste at source.

For officials working for state agencies, for example MONRE or MOIT, the top leaders of state agencies could issue official dispatches requiring all officials in those agencies to separate waste and collect recyclable waste. In addition, state agencies could organize training courses on waste separation at offices and prepare handbooks on waste separation to participants. In terms of people working for private companies, NGOs and international organizations, waste separation could be integrated in working regulations and promulgated on their websites. At the sub-national level, the People's Committees of cities and provinces could assign officials to conduct door-to-door campaigns for instructing citizens to the need to separate waste.

Raising awareness for children would also be an important activity, as children are the future generation of societies and they may be instrumental as well in changing their parents' behaviors towards waste. For example, waste separation at source could be integrated into educational programmes at kindergartens and primary schools. Furthermore, children could learn about waste separation more effectively through the participation in entertainment activities, such as musical performance and plays.

The measures and activities suggested above are expected to be implemented on a voluntary basis by sub-national authorities (i.e. at city and province level) mostly with their own resources. Support at national level and from international donors is expected to be more limited in the implementation of these initiatives. On the other hand, expenditures undertaken by these sub-nationals will be accounted as part of the domestic component of the NAMA.

**b. Purchase and set up of waste separation equipment**

In order to effectively promote the segregation of waste at the source, city and province authorities may encourage the dissemination of garbage bins for separating waste. The number and type of bins would be decided based on the specific conditions of municipalities.

**c. Complement policy framework for the separation of waste at source**

In order to ensure the sustainability of waste separation at source in the long-term, city and province authorities may wish to develop a legal framework for encouraging and/or enforcing such measures.

Recently, waste separation at source was regulated under Provision 86 on “Waste reducing, reusing and recycling” of the revised Law on environmental protection at Decision 55/2014/QH13 dated 23 June 2014. However, its enforcement has not been empirically verified. Also important, so far there is no circular or directive on guiding relevant stakeholders and community on waste separation at source. Building upon this legal framework at national level, this NAMA programme, sub-national government authorities are encouraged to implement concrete measures for further encouraging the separation of waste at source that are mindful of the local circumstances.

**d. Attract finance for waste separation at source**

The separation of waste at source is expected to be facilitated and funded by sub-national government authorities, which can be complemented by the national government and, in some circumstances, through specific programmes from international sponsors. Private sector organizations can also take part, directly or indirectly, in the process of separating waste at source, especially those organizations that benefit from selling recyclables from waste. Through this NAMA, local government authorities are encouraged to come up with mechanisms or programmes that can stimulate private sector engagement on such activities.

## II. Establishment of waste separation and transfer centers

The establishment of waste separation and transfer centers where waste can be further segregated, before treatment or final disposal, are measures encouraged in the context of the NAMA. Even when the level of compliance among those who generate waste is high, the separation of waste is never a perfect endeavor, and additional sorting of waste is necessary either at intermediary points, such as in transfer stations, or at the gate of treatment plants. Therefore, sub-national government authorities are encouraged to create the necessary framework that enables organizations such as URENCO and/or private enterprises to implement such waste separation/transfer points.

Further to the above, the promotion of waste separation centers/companies is a step in which the informal sector can be involved. Once the waste is separated at source, the organic waste is transferred to waste separation and/or transfer centers for additional segregation of the waste. The biodegradable waste can be processed in composting facilities and for biogas production, while the combustible organic waste can be used for refuse-derived fuel (RDF) production. The recyclable waste should be recycled to the extent possible, while unrecoverable and unrecyclable waste should be sent to disposal sites.

Although the set-up of a waste separation companies is a very context specific issue, their establishment can be supported by local government authorities. Private sector organizations involved in activities related to the processing of waste (e.g. composting plants) may also support the development and operation of waste separation activities.

### III & IV. Waste treatment and market creation

Steps three and four of the waste management value chain are jointly elaborated upon in this section, as they are intrinsically related to each other.

#### a. Enhancing waste treatment by composting

Composting is not widely-practiced in the ASEAN region including Viet Nam. Amongst the challenges associated with the adoption of composting are the high operation and maintenance costs of large-scale facilities, the subsidies that benefit the commercialization of chemical fertilizers, and issues related to the processing of unsegregated (or poorly segregated) waste.

It was also observed that the government of Viet Nam does not provide sufficient support for the treatment of organic waste through composting. Thereby, proposed measures for addressing those barriers which can be implemented as part of this NAMA programme, especially at sub-national level, are as follows:

| | Barriers | Measures |
|---|---|---|
| **Finance** | Lack of financial resources for equipment, infrastructure and human resources | Establishing a financial mechanism that can provide concessional loans to private sector organizations who desire to invest in composting facilities |
| **Policies/Legisla-tion/ Regulation** | Lack of a master plan for the development of composting facilities | Developing a master plan for composting facilities |
| | Lack of regulations that can stimulate investment into composting facilities | Developing regulatory incentives to attract domestic and foreign investors in this sector |
| **Social/Cultural** | Low public awareness on the benefits of composting and its use in agriculture | Enhancing public awareness on composting and its use in agriculture. |
| **Market** | Low-price of compost in Viet Nam, and subsidies to chemical fertilizers | Developing the market for compost through the payment of tipping fees to plant operators or a programme for the purchase of compost among URENCOs |

**Table A.2.3** – Suggested/endorsed measures under the NAMA for the promotion of composting in Viet Nam.

In addition to the measures above, the conduct of research, as well as the selection and transfer of appropriate technologies which are adequate to the national circumstances of Viet Nam’s waste sector, are considered important aspects that should be supported by national and sub-national governments.

As a final remark, the creation of a market for compost requires time as well as a long-term collaboration between farmers, governments and regulators. Successful markets for compost also come with adequate buy-back and distribution policies, whose implementation is encouraged – and will be considered – as part of the NAMA.

**b. Enhancing waste treatment through anaerobic digestion**

According to projections of the Institute of Energy of Viet Nam, over the last 10 years the energy demand of Viet Nam has increased by an average of 10% per year, while the electricity demand has increased at a rate of 14.5%. In order to decrease the use of fossil fuels and hence the negative impacts associated with these, renewable energy resources are being researched and encouraged. These include solutions for the conversion of waste into energy, particularly anaerobic digestion, which are one of the most promising solutions in the context of Viet Nam. However, there remain several barriers to the development of AD technologies in Viet Nam, which were discussed in chapter 4.

In this context, the following table summarizes the main barriers and suggests measures to address them, which are endorsed through this NAMA:

| | Barriers | Measures |
|---|---|---|
| **Finance** | Lack of investment into AD systems | Leveraging financial support from national and international organizations |
| | High investment requirement of AD facilities | Developing a low-interest investment mechanism |
| **Policies/ Legislations/ Regulations** | Lack of policies and mechanisms for the use of biogas for electricity generation | Establishing a feed-in-tariff for electricity generated from biogas |
| | Lack of standards for the application of biogas technology | Establishing of the necessary standards, especially on biogas handling |
| | Poor coordination among governmental and non-governmental actors | Providing legislation for enhanced cooperation and coordination among governmental and non-governmental sectors |
| **Social/Cultural issues** | Farmers, industries and the general public have limited know-how and understanding about biogas technology | Raising awareness on the benefits of biogas technologies through mass media and community campaigns |
| | Lack of experience and skills in the operation and maintenance of anaerobic digestion facilities | Organizing training sessions for capacity building |
| **Market** | The application of AD facilities is small and fragmented | Market establishment through the implementation of the above policies and regulations |
| | Lack of support mechanisms for biogas-generated electricity | Establishing a feed-in-tariff for biogas-generated electricity |

**Table A.2.4** – Suggested/endorsed measures under the NAMA for the promotion of the anaerobic digestion of waste in Viet Nam.

### c. Enhancing waste recycling

**Market creation for recycled paper, plastic and metal**

Several activities are needed to create the right set of incentives for establishing a national market for the raw materials produced from recycled waste, as well as to raise the awareness of populations to the benefits of recycling. An initiative strongly endorsed through this NAMA is to establish Viet Nam as a center of excellence for the research and development (R&D) on recycling technologies. Chapter 8 of the study elaborated on possible ideas for the development of the recycling industry in Viet Nam.

# Annex III – Modeling of the baseline scenario

This Annex describes the methodology and steps followed for calculating the baseline scenario of the Waste-to-Resource NAMA.

## A.3.1 Methodology for calculating GHG emissions in the baseline scenario

The Revised 1996 IPCC Guidelines provide two methods to estimate $CH_4$ emissions from solid waste disposal sites: the default method and the First Order Decay (FOD) method. The default method is used when activity data is not available and $CH_4$ emissions are calculated using IPCC default values. In Viet Nam's Second National Communication, the default method was adopted due to the lack of data for applying the FOD method. However, at present in Viet Nam the data necessary to apply this method can be obtained from several sources (e.g. reports of ministries, research institutes, universities, local governments). In addition, as $CH_4$ emissions are a key GHG emission source category in the 2000 GHG inventory, the FOD method is recommended by the decision tree proposed in the IPCC guidelines. Therefore, $CH_4$ emissions from solid waste disposal sites have been calculated by applying the FOD method to the data of the 2010 GHG inventory. The equations used to calculate $CH_4$ emissions from solid waste disposal sites are as follows:

**EQUATION 1**

**$CH_4$ generated in year t (Gg/yr) =** $\sum_x \left[\left(A \bullet k \bullet MSW_T(x) \bullet MSW_F(x) \bullet L_0(x)\right) \bullet e^{-k(t-x)}\right]$ **for x = initial year to t**

Where:

**t** = year of inventory

**x** = years for which input data should be added

**A** = $(1 - e^{-k})/k$; normalization factor which corrects the summation

**k** = Methane generation rate constant (1/yr)

**$MSW_{T(x)}$** = Total municipal solid waste (MSW) generated in year x (Gg/yr)

**$MSW_{F(x)}$** = Fraction of MSW disposed at SWDs in year x

**$L_{0(x)}$** = Methane generation potential (MCF(x)・DOC(x)・DOCF・F・16/12 (Gg CH4/Gg waste)

**$MCF_{(x)}$** = Methane correction factor in year x (fraction)

**$DOC_{(x)}$** = Degradable organic carbon (DOC) in year x (fraction)(Gg C/Gg waste)

**$DOC_F$** = Fraction of DOC dissimilated

**F** = Fraction by volume of $CH_4$ in landfill gas

**16/12** = Conversion from C to $CH_4$

Summing the obtained results for all years (x):

**EQUATION** 2

**$CH_4$ generated in year t (Gg/yr) = [$CH_4$ generated in year t – R(t)] . (1-OX)**

Where:

**R(t)** = Recovered $CH_4$ in inventory year t (Gg/yr)

**OX** = Oxidation factor (fraction)

## A.3.2 Activity data

*a. Solid waste*

$CH_4$ emissions are estimated by using databases on the volume of solid waste that was disposed in landfill sites, and the composition of waste in years 2020 up to 2030. To apply the FOD method, data on waste from previous years is necessary. A difficulty for conducting the calculation is that there is no reliable population data prior to 1995. Therefore, the data for the 1990-1994 period was estimated by using the population figures of 1995.

For urban areas in the 1995-2003 period, urban domestic solid waste volumes handled at landfill sites was estimated by using: i) average solid waste generation rates per person per day; ii) the rate of urban domestic solid waste that is processed at landfills (these factors are used in the environmental development report of Viet Nam in 2004 - solid waste (MONRE - 2004)); and iii) the urban population in years (according to the Statistical Yearbook - GSO).

The estimated data for urban solid waste in the 1995 - 2003 period is presented in Table A.3.1 below. The waste collection rate in urban areas was estimated through interpolation. The collection rate was assumed to be 55% in year 1995, and through interpolation taking years 2000 and 2003 as reference points. These assumptions are based on the report noted above. Estimating data for urban solid waste is presented in the table below:

| Years | Population in urban area (1,000 persons) | Generation factor (kg/capita/day) | Fraction of urban solid waste in disposal sites (%) | Total (1,000 ton) |
|---|---|---|---|---|
| 1995 | 14,938 | 0.7 | 55.0 | 2,099 |
| 1996 | 15,420 | 0.7 | 57.0 | 2,246 |
| 1997 | 16,835 | 0.7 | 59.0 | 2,538 |
| 1998 | 17,465 | 0.7 | 61.0 | 2,722 |
| 1999 | 18,082 | 0.7 | 63.0 | 2,911 |
| 2000 | 18,725 | 0.7 | 65.0 | 3,110 |
| 2001 | 19,299 | 0.7 | 67.0 | 3,304 |
| 2002 | 19,873 | 0.7 | 69.0 | 3,504 |
| 2003 | 20,725 | 0.7 | 71.0 | 3,760 |

**Table A.3.1** – Solid waste generation in urban area (Source: Synthesis of Vietnam Environment Administration)

For the period of 2004-2010, $CH_4$ emissions have been estimated based on the waste composition, and by using databases on the volume of solid waste disposed on the landfill sites (in this case, the environment status report of the Departments of Natural Resources and Environment), as shown in the table below:

| No. | Province | Amount of solid waste generated | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
| 1 | An Giang | 92,3 | 301,3* | 334,8* | 372,0 | 409,2* | 450,1* |
| 2 | Bac Giang | 58,3 | 57,5 | 60,3 | 68,5 | 71,2 | 76,1* |
| 3 | Bac Kan | 6,6 | 7,4 | 8,1* | 9,0* | 9,8* | 10,8* |
| 4 | Bac Lieu | 73,8 | 127,6* | 141,8* | 157,5* | 175,0 | 192,5* |
| 5 | Bac Ninh | 83,7 | 272,3 | 302,4 | 336,0 | 373,1 | 410,4* |
| 6 | Ben Tre | 31,1* | 34,6 | 38,1* | 41,9* | 46,1* | 50,7* |
| 7 | Binh Duong | 74,3* | 465,8* | 517,6* | 575,1* | 639,0* | 710,0 |
| 8 | BinhPhuoc | 50,0 | 128,8 | 154,0 | 210,0 | 280,0 | 343,5* |
| 9 | BìnhThuận | 149,0 | 154,0 | 169,4* | 186,3* | 205,0* | 225,5* |
| 10 | Ca Mau | 42,0 | 44,9 | 49,4* | 54,3* | 59,8* | 65,7* |
| 11 | Cao Bang | 10,2* | 46,9 | 58,3 | 86,7 | 99,0 | 120,4* |
| 12 | Daknong | 7,1* | 7,8 | 8,6* | 9,4* | 10,4* | 11,4* |
| 13 | Dien Bien | 54,5* | 60,1 | 62,6* | 65,9* | 69,3 | 72,8* |
| 14 | Ha Giang | 23,6* | 29,0 | 37,5 | 37,5 | 69,5 | 85,4* |
| 15 | Ha Nam | 20,9* | 51,6* | 54,5 | 57,6 | 60,9 | 64,1* |
| 16 | Ha Noi | 2.070,0 | 2.539,1* | 2.821,2* | 3.134,7* | 3.483,0* | 3.870,0 |
| 17 | Ha Tinh | 50,0* | 55,0 | 60,5* | 66,6* | 73,2* | 80,5* |
| 18 | Hai Duong | 143,3 | 153,0 | 168,3* | 185,1* | 203,6* | 224,0* |
| 19 | Hai Phong | 483,0* | 531,3 | 584,4* | 642,9* | 707,2* | 777,9* |
| 20 | HauGiang | 39,0* | 52,0 | 58,5 | 59,8 | 62,4 | 66,0* |
| 21 | HoaBinh | 50,2* | 55,2 | 60,7* | 66,8* | 73,5* | 80,8* |
| 22 | Hung Yen | 50,0* | 268,9* | 298,8* | 332,0* | 368,9* | 409,9 |
| 23 | KienGiang | 53,3 | 172,7* | 191,9* | 213,2* | 236,9* | 263,2 |
| 24 | Kon tum | 35,1* | 38,6 | 42,5* | 46,7* | 51,4* | 56,5* |
| 25 | Lai Chau | 18,3* | 20,8* | 23,1* | 25,6* | 28,5 | 31,3* |
| 26 | Lam Dong | 145,5* | 715,4 | 726,6 | 737,8 | 749,0 | 760,4* |
| 27 | Lang Son | 83,2 | 90,0 | 90,5 | 91,0 | 91,5 | 91,9* |
| 28 | Lao Cai | 38,1* | 68,7 | 78,5 | 87,3 | 94,8 | 104,3* |
| 29 | Long An | 45,5* | 99,5* | 110,6* | 122,9* | 136,5 | 150,2* |
| 30 | Nam Dinh | 94,7* | 306,9* | 341,0* | 378,9* | 421,0 | 463,1* |
| 31 | Nghe An | 131,4* | 148,0 | 150,9* | 153,9* | 157,0 | 160,1* |
| 32 | NinhBinh | 123,6* | 80,0 | 88,0* | 96,8* | 106,5* | 117,1* |
| 33 | NinhThuan | 95,5* | 105,0 | 115,5* | 127,1* | 139,8* | 153,7* |
| 34 | PhuTho | 63,3* | 152,2 | 155,0 | 177,9 | 190,9* | 210,0* |
| 35 | Phu Yen | 144,5* | 159,0 | 174,9* | 192,4* | 211,6* | 232,8* |
| 36 | QuangBinh | 90,9* | 100,0 | 110,0* | 121,0* | 133,1* | 146,4* |
| 37 | Quang Nam | 104,4* | 217,1* | 241,3* | 268,1* | 297,9 | 327,7* |
| 38 | Quang Ngai | 100,0* | 110,0* | 115,5* | 121,6* | 128,0 | 134,4* |
| 39 | QuangNinh | 238,1* | 261,9 | 288,1* | 316,9* | 348,6* | 383,4* |
| 40 | Quang Tri | 27,4* | 30,2 | 33,2* | 36,5* | 40,2* | 44,2* |
| 41 | SocTrang | 47,3* | 104,1 | 112,5 | 114,7 | 125,5 | 133,0* |
| 42 | Son La | 35,2* | 36,9 | 40,6* | 44,6* | 49,1* | 54,0* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 43 | TayNinh | 16,9* | 18,6 | 20,5* | 22,5* | 24,8* | 27,2* |
| 44 | Thai Binh | 90,0 | 99,0 | 108,9* | 119,8* | 131,8* | 144,9* |
| 45 | Thai Nguyen | 113,0 | 105,0* | 116,6* | 129,6* | 144,0 | 158,4* |
| 46 | ThanhHoa | 130,5* | 271,1* | 301,2* | 334,6* | 371,8 | 409,0* |
| 47 | Tien Giang | 78,5* | 194,4* | 216,0* | 240,0 | 264,0* | 290,4* |
| 48 | Tra Vinh | 48,4* | 72,5* | 80,5 | 88,6* | 97,4* | 107,1* |
| 49 | Thua Thien Hue | 145,5* | 160,0 | 176,0* | 193,6* | 213,0* | 234,3* |
| 50 | TuyenQuang | 53,5* | 58,8 | 64,7* | 71,1* | 78,3* | 86,1* |
| 51 | Vinh Long | 52,4* | 57,7 | 63,5* | 69,8* | 76,8* | 84,5* |
| 52 | VinhPhuc | 36,6* | 102,1* | 113,4* | 126,0* | 140,0 | 154,0* |
| 53 | Yen Bai | 21,1* | 99,0* | 110,0 | 121,0* | 133,1* | 146,4* |
| 54 | Dong Nai | 362,8 | 1.316,4* | 1.462,7* | 1.625,2* | 1.805,8 | 1.986,3* |
| 55 | Da Nang | 536,4* | 590,0 | 649,0* | 713,9* | 785,3* | 863,8* |
| 56 | KhanhHoa | 197,9 | 304,0* | 337,8* | 375,3* | 417,0 | 458,7* |
| 57 | Vung Tau | 189,0 | 207,9 | 228,7* | 251,6* | 276,7* | 304,4* |
| 58 | Dak Lak | 127,0 | 131,2* | 145,8* | 162,0* | 180,0 | 198,0* |
| 59 | Dong Thap | 108,3 | 151,6* | 168,5* | 187,2* | 208,0 | 228,8* |
| 60 | Gia Lai | 127,0 | 133,4 | 146,7* | 161,4* | 177,6* | 195,3* |
| 61 | Can Tho | 800,0* | 880,0 | 968,0* | 1.064,8* | 1.171,3* | 1.288,4* |
| 62 | Ho Chi Minh | 4.590,0 | 5.200,0 | 5.720,0* | 6.292,0* | 6.921,2* | 7.613,3* |
| 63 | BinhDinh | 108,2 | 119,0 | 186,3* | 207,0* | 230,0 | 252,9* |
| | **Total (ton/day)** | 13.310,7 | 18.732,8 | 20.664,4 | 22.787,4 | 25.134,2 | 27.648,7 |
| | **Total (ton/year)** | 4.858.389 | 6.837.473 | 7.542.509 | 8.317.393 | 9.173.979 | 10.091.780 |

**Table A.3.2** – Amount of urban solid waste generated (Source: 5 years environment status Report of Departments of Natural Resources and Environment)

The provinces marked with an asterisk in the table only have available one, two or three years' data over the 2006-2010 period. Based on the data available, the figures of the years missing were calculated assuming an annual growth rate of 10%.

For the 2015-2030 period, the assumption on urban solid waste collection rate was taken from the National Strategy on Solid Waste Management to 2025. According to the strategy, the rate would be of 85% in 2015; 90% in 2020 and 100% from 2025 onwards.

According to the "2011 Viet Nam Environment Report - Solid Waste" (MONRE 2011), the estimated growth of solid waste is put at 10% per year. It is assumed that this rate will persist until 2030. Taking as reference the solid waste generation observed in 2010 (10,091 million tons), figures from 2011 up to 2030 were estimated based on this growth rate. The projection data is presented in the following table:

| No. | Year | Amount of urban solid waste (ton/year) | Solid waste collection ratio (%) | Amount of urban solid waste collected (ton) |
|---|---|---|---|---|
| 1 | 2010* | 1,3455,707 | 75 | 10,091,780 |
| 2 | 2011 | 1,4801,277 | 77 | 11,396,984 |
| 3 | 2012 | 1,6281,405 | 79 | 12,862,310 |
| 4 | 2013 | 1,7909,546 | 81 | 14,506,732 |

| No. | Year | Amount of urban solid waste (ton/year) | Solid waste collection ratio (%) | Amount of urban solid waste collected (ton) |
|---|---|---|---|---|
| 5 | 2014 | 1,9700,500 | 83 | 16,351,415 |
| 6 | 2015 | 2,1670,550 | 85 | 18,419,968 |
| 7 | 2016 | 2,3837,605 | 86 | 20,500,340 |
| 8 | 2017 | 2,6221,366 | 87 | 22,812,588 |
| 9 | 2018 | 2,8843,502 | 88 | 25,382,282 |
| 10 | 2019 | 3,1727,852 | 89 | 28,237,789 |
| 11 | 2020 | 3,4900,638 | 90 | 31,410,574 |
| 12 | 2021 | 3,8390,701 | 92 | 35,319,445 |
| 13 | 2022 | 4,2229,772 | 94 | 39,695,985 |
| 14 | 2023 | 4,6452,749 | 96 | 44,594,639 |
| 15 | 2024 | 5,1098,024 | 98 | 50,076,063 |
| 16 | 2025 | 5,6207,826 | 100 | 56,207,826 |
| 17 | 2026 | 6,1828,609 | 100 | 61,828,609 |
| 18 | 2027 | 6,8011,470 | 100 | 68,011,470 |
| 19 | 2028 | 7,4812,616 | 100 | 74,812,616 |
| 20 | 2029 | 8,2293,878 | 100 | 82,293,878 |
| 21 | 2030 | 9,0523,266 | 100 | 90,523,266 |

**Table A.3.3** – Projection of urban solid waste up to 2020 and 2030.

With regards to rural solid waste, there is limited data available. Due to this, figures were estimated by taking into account the rural population in each year from 1990 to 2010, solid waste generation rates per capita in rural areas (which amount to 0.3 kg/person/day), were based on the "Viet Nam Environment Status Report - Solid Waste", and waste collection rates in rural areas. This ratio was assumed to be 20% in 1990; having a 2% annual increase from 1991 to 2000; 40% in 2000; 40% in 2006, and a 2% annual increase from that year on. These assumptions are mainly based on the "2011 Viet Nam Environment Status Report - Solid Waste" (MONRE, 2011).

To apply the FOD method, historical quantities of solid waste are required. However, there are no data of population before 1995, which is necessary for estimating activity data before 2003 in urban areas and all year in rural areas. Thus, the data for the 1990-1994 period was estimated by applying the same population of 1995, taking into account that estimation result is relatively insensitive to these numbers.

| Year | Population in rural area (1,000 persons) | Generation factor (kg/capita/day) | Fraction of rural solid waste collected (%) | Total (ton) |
|---|---|---|---|---|
| 1995 | 57.057 | 0.30 | 30 | 1,874,322 |
| 1996 | 57.737 | 0.30 | 32 | 2,023,104 |
| 1997 | 57.472 | 0.30 | 34 | 2,139,683 |
| 1998 | 57.992 | 0.30 | 36 | 2,286,045 |
| 1999 | 58.515 | 0.30 | 38 | 2,434,809 |
| 2000 | 58.906 | 0.30 | 40 | 2,580,083 |
| 2001 | 59.321 | 0.30 | 40 | 2,598,260 |

| | | | | |
|---|---|---|---|---|
| 2002 | 59.665 | 0.30 | 40 | 2,613,327 |
| 2003 | 59.742 | 0.30 | 40 | 2,616,700 |
| 2004 | 59.835 | 0.30 | 40 | 2,620,773 |
| 2005 | 60.060 | 0.30 | 40 | 2,630,628 |
| 2006 | 61.344 | 0.30 | 40 | 2,686,867 |
| 2007 | 61.772 | 0.30 | 40 | 2,705,614 |
| 2008 | 60.445 | 0.30 | 40 | 2,647,491 |
| 2009 | 60.440 | 0.30 | 40 | 2,647,272 |
| 2010 | 60.416 | 0.30 | 40 | 2,646,221 |

**Table A.3.4** – Solid waste generation in rural areas. (Source: Synthesis of Vietnam Environment Administration)

The projected rural solid waste data up until 2030 was calculated by estimating the rural population in Viet Nam, the solid waste generation per capita in rural areas (0.3 kg/person/day from 1995 up to 2010 and 0.34 kg/person/day from 2011 up to 2030, with reference to the "Viet Nam Environment Status Report - Solid Waste"), and waste collection rates in rural areas (20% in 1990; annual increase of 2% from years 1991 up to 2000; 40% in 2000 up to 2015; 70% in 2020; 90% in 2025. The missing figures for the years 2006 and 2030 have been interpolated). Assumptions were made taking as reference the National Solid Waste Strategy.

Population data from 1995 to 2013 was collected from Statistic Year Book issued by the General Statistic Office. Population data from 2014 to 2030 was collected from the report on Vietnamese Population Projection for the period 2009 – 2049 (GSO, 2011).

Results for the solid waste produced in rural areas are presented in the table below:

| Year | Population in rural area (1,000 persons) | Generation factor (kg/capita/day) | Fraction of rural solid waste collected (%) | Total (ton) |
|---|---|---|---|---|
| 2011 | 60,120.70 | 0.34 | 40 | 2,984,392 |
| 2012 | 60,416.50 | 0.34 | 40 | 2,999,075 |
| 2013 | 60,719 | 0.34 | 40 | 3,014,091 |
| 2014 | 60,820 | 0.34 | 40 | 3,019,105 |
| 2015 | 60,820 | 0.34 | 40 | 3,019,105 |
| 2016 | 60,809 | 0.34 | 46 | 3,471,343 |
| 2017 | 60,779 | 0.34 | 52 | 3,922,190 |
| 2018 | 60,733 | 0.34 | 58 | 4,371,440 |
| 2019 | 60,683 | 0.34 | 64 | 4,819,687 |
| 2020 | 60,525 | 0.34 | 70 | 5,257,807 |
| 2021 | 60,354 | 0.34 | 74 | 5,542,549 |
| 2022 | 60,159 | 0.34 | 78 | 5,823,271 |
| 2023 | 59,944 | 0.34 | 82 | 6,100,021 |
| 2024 | 59,719 | 0.34 | 86 | 6,373,570 |
| 2025 | 59,386 | 0.34 | 90 | 6,632,822 |
| 2026 | 59,028 | 0.34 | 92 | 6,739,345 |
| 2027 | 58,654 | 0.34 | 94 | 6,842,224 |
| 2028 | 58,248 | 0.34 | 96 | 6,939,434 |
| 2029 | 57,839 | 0.34 | 98 | 7,034,264 |
| 2030 | 57,313 | 0.34 | 100 | 7,112,543 |

**Table A.3.5** – Projection of rural solid waste generation up to 2030. (Source: based on Synthesis of Vietnam Environment Administration)

Consolidated solid waste generation figures, for urban and rural, are presented in the table below:

| Year | Amount of urban solid waste collected (ton) | Amount of rural solid waste collected (ton) | Total amount of solid waste collected (ton) |
|---|---|---|---|
| 1995 | 2,099,000 | 1,874,322 | 3,973,322 |
| 1996 | 2,246,000 | 2,023,104 | 4,269,104 |
| 1997 | 2,538,000 | 2,139,683 | 4,677,683 |
| 1998 | 2,722,000 | 2,286,045 | 5,008,045 |
| 1999 | 2,911,000 | 2,434,809 | 5,345,809 |
| 2000 | 3,110,000 | 2,580,083 | 5,690,083 |
| 2001 | 3,304,000 | 2,598,260 | 5,902,260 |
| 2002 | 3,504,000 | 2,613,327 | 6,117,327 |
| 2003 | 3,760,000 | 2,616,700 | 6,376,700 |
| 2004 | 2,431,075 | 2,620,773 | 6,929,968 |
| 2005 | 4,858,389 | 2,630,628 | 7,489,017 |
| 2006 | 6,837,473 | 2,686,867 | 9,524,340 |
| 2007 | 7,542,509 | 2,705,614 | 10,248,123 |
| 2008 | 8,317,393 | 2,647,491 | 10,964,884 |
| 2009 | 9,173,979 | 2,647,272 | 11,821,251 |
| 2010 | 10,091,780 | 2,646,221 | 12,738,001 |
| 2011 | 11,396,984 | 2,984,392 | 14,381,376 |
| 2012 | 12,862,310 | 2,999,075 | 15,861,385 |
| 2013 | 14,506,732 | 3,014,091 | 17,520,823 |
| 2014 | 16,351,415 | 3,019,105 | 19,370,520 |
| 2015 | 18,419,968 | 3,019,105 | 21,439,073 |
| 2016 | 20,500,340 | 3,471,343 | 23,971,683 |
| 2017 | 22,812,588 | 3,922,190 | 26,734,778 |
| 2018 | 25,382,282 | 4,371,440 | 29,753,722 |
| 2019 | 28,237,789 | 4,819,687 | 33,057,476 |
| 2020 | 31,410,574 | 5,257,807 | 36,668,381 |
| 2021 | 35,319,445 | 5,542,549 | 40,861,994 |
| 2022 | 39,695,985 | 5,823,271 | 45,519,256 |
| 2023 | 44,594,639 | 6,100,021 | 50,694,660 |
| 2024 | 50,076,063 | 6,373,570 | 56,449,633 |
| 2025 | 56,207,826 | 6,632,822 | 62,840,648 |
| 2026 | 61,828,609 | 6,739,345 | 68,567,954 |
| 2027 | 68,011,470 | 6,842,224 | 74,853,694 |
| 2028 | 74,812,616 | 6,939,434 | 81,752,050 |
| 2029 | 82,293,878 | 7,034,264 | 89,328,142 |
| 2030 | 90,523,266 | 7,112,543 | 97,635,809 |

**Table A.3.6** – Projection of urban and rural solid waste generation up to 2030.

For the purposes of the FOD model, the composition of solid waste had to be determined. These figures were taken from the Environmental Status Reports of provinces, with the average composition assumed to remain unchanged up until 2030.

| Composition of waste | Share (%) |
|---|---|
| Food, organic | 59.24 |
| Garden | 2.76 |
| Paper | 2.7 |
| Wood | 1.05 |
| Textile | 3.30 |
| Nappies | 0.01 |
| Plastic, other inert | 30.94 |

**Table A.3.7** – Composition of waste (Averaged). (Source: Synthesis of Vietnam Environment Administration)

It should be noted as a simplification that the BAU scenario does not take into account existing solid waste treatment plants in Viet Nam. This is because these alternative methods are responsible for a small fraction of the total solid waste generation, with disposal continuing to be the dominant practice.

### A.3.3 Estimation of the Emission Factor

The following parameters were used to calculate $CH_4$ emissions from solid waste disposal sites:

The **Methane correction factor (MCF)** is taken from default values, as per the IPCC guidelines:

- Unmanaged – deep (≥ 5m waste): 0.8
- Unmanaged – shallow (<5m waste): 0.4
- Managed – anaerobic: 1
- Managed – semi – aerobic: 0.5

Based on expert's judgment, in Viet Nam the share of "unmanaged–deep" landfill is 40%, "unmanaged – shallow" is 50 %, "managed – anaerobic" is 5% and "managed– semi-aerobic" is 5%. Therefore, the average MCF is calculated as 0.595, and was applied in the FOD model to the solid generated in all years of the inventory.

The **DOC (degradable organic carbon)** for solid waste are taken from IPCC guidelines, as follows:

DOC of Paper= 0.4

DOC of Garden = 0.17

DOC of Food waste = 0.15

DOC of Wood or straw = 0.3

DOC of Textiles = 0.4

The **DOCf** (fraction of DOC dissimilated) = 0.5

k (methane generation rate constant)

Food waste = 0.2

Garden, Paper, Wood and straw = 0.03

OX (oxidation factor) = 0

F (fraction by volume of $CH_4$ in landfill gas) = 0.5

R (Recovered $CH_4$) is set as zero in 2010.

### A.3.4. Emission reduction results

The baseline emissions of $CH_4$ from the disposal of solid waste in the baseline scenario, for the 1995-2030 period, are summarized as follows:

| Year | Total $CO_2$e emissions (million tons) | Year | Total $CO_2$e emissions (million tons) | Year | Total $CO_2$e emissions (million tons) | Year | Total $CO_2$e emissions (million tons) |
|---|---|---|---|---|---|---|---|
| **1995** | 0.8 | **2004** | 4.3 | **2013** | 10.3 | **2022** | 26.4 |
| **1996** | 1.5 | **2005** | 4.6 | **2014** | 11.4 | **2023** | 29.4 |
| **1997** | 2.0 | **2006** | 5.3 | **2015** | 12.6 | **2024** | 32.7 |
| **1998** | 2.5 | **2007** | 5.9 | **2016** | 14.0 | **2025** | 36.4 |
| **1999** | 2.8 | **2008** | 6.5 | **2017** | 15.5 | **2026** | 40.0 |
| **2000** | 3.2 | **2009** | 7.1 | **2018** | 17.3 | **2027** | 44.2 |
| **2001** | 3.5 | **2010** | 7.7 | **2019** | 19.2 | **2028** | 48.5 |
| **2002** | 3.7 | **2011** | 8.5 | **2020** | 21.3 | **2029** | 53.2 |
| **2003** | 4.0 | **2012** | 9.4 | **2021** | 23.7 | **2030** | 58.2 |

**Table A.3.8** – Projection of emissions from solid waste disposal up to 2030.

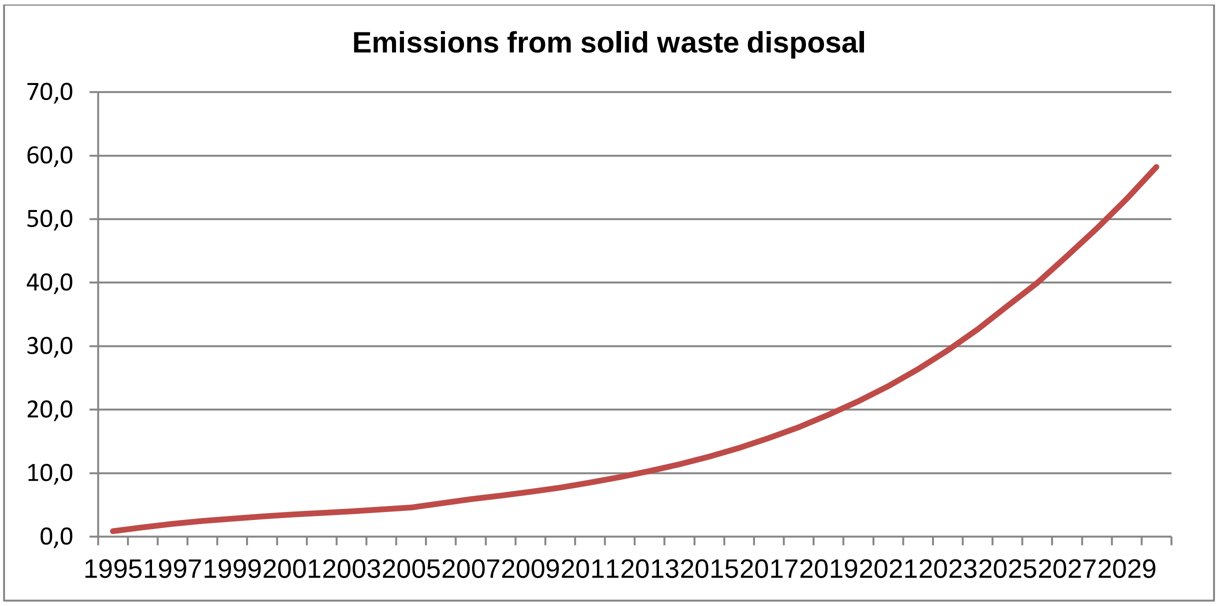


**Figure A.3.1** – Baseline $CO_2$e emissions from solid waste disposal up to 2030.

# Annex IV – Modeling of the NAMA Scenario

This Annex describes the methodology and steps followed for calculating the emission reductions from the NAMA scenario. It involves emission reductions from four different components: composting, production of refuse-derived fuel, recycling and anaerobic digestion. Emissions from this scenario are expressed through the following equation:

**EQUATION 3**

$$PE_y = PE_{comp,y} + PE_{RDF,y} + PE_{recycling,y} + PE_{AD,y}$$

Where:

**$PE_y$**: NAMA scenario emissions in year y (t $CO_2$e)

**$PE_{comp,y}$**: NAMA scenario emissions due to composting activities in year y (t $CO_2$e)

**$PE_{RDF,y}$**: NAMA scenario emissions due to Refuse Derived Fuel production in year y (t $CO_2$e)

**$PE_{recycling,y}$**: NAMA scenario emissions due to recycling activities in year y (t $CO_2$e)

**$PE_{AD,y}$**: NAMA scenario emissions due to anaerobic digestion activities in year y (t $CO_2$e)

The calculation methodology followed for each of the four emissions reduction treatment approaches is detailed in the sections below.

## A.4.1 Solid waste treatment through composting

CDM methodology AMS.III.F (Avoidance of methane emissions through composting) developed by UNFCCC was applied to estimate the emission reductions expected with the adoption of composting. This methodology comprises measures to avoid the emissions of methane to the atmosphere from biomass or other organic matter that would otherwise decay anaerobically in a solid waste disposal site (SWDS), or in an animal waste management system (AWMS), or in a wastewater treatment system (WWTS). With AMS.III.F, measures are limited to those that result in emission reductions less than or equal to 60 kt $CO_2$ equivalent annually.

The baseline scenario is the situation where, in the absence of project activities, biomass and other organic matter (including manure where applicable) are left to decay within the project boundary and methane is emitted into the atmosphere. Baseline emissions shall exclude emissions of methane that would have to be captured, fueled or flared to comply with national or local safety requirement or legal regulations. The following equation was used to calculate the baseline emissions:

EQUATION 4

$$BE_y = BE_{CH4,SWDS,y} - MD_{y,reg} * GWP\_CH_4$$

Where:

**$BE_{CH4,SWD,y}$**: methane generation potential of the solid waste disposal in the absence of NAMA activities;

**$MD_{y,reg}$**: amount of methane that would have to be captured and combusted in year y to comply with prevailing regulations;

**$GWP\_CH_4$**: Global Warming Potential for $CH_4$ (value of 25 is used).

In the case of Viet Nam, $BE_y = BE_{CH4,SWD,y}$ due to the absence of regulations and requirements on methane recovery.

NAMA emissions associated with composting (**$PE_{COMP,y}$**) activities are determined as follows:

EQUATION 5

$$PE_{COMP,y} = PE_{EC,y} + PE_{FC,y} + PE_{CH4,y} + PE_{N2O,y} + PE_{RO,y}$$

Where:

**$PE_{COMP,y}$**: NAMA emissions associated with composting in year y (t $CO_2$e/yr)

**$PE_{EC,y}$**: NAMA emissions from electricity consumption associated with composting in year y (t $CO_2$/yr)

**$PE_{FC,y}$**: NAMA emissions from fossil fuel consumption associated with composting in year y (t $CO_2$/yr)

**$PE_{CH4,y}$**: NAMA emissions of methane from the composting process in year y (t $CO_2$e/yr)

**$PE_{N2O,y}$**: NAMA emissions of nitrous oxide from the composting process in year y (t $CO_2$e/yr)

**$PE_{RO,y}$**: NAMA emissions of methane from run-off wastewater associated with co-composting in year y (t $CO_2$e/yr)

In the case of the NAMA, this equation is simplified as emissions from energy consumption were counted as energy sector related emissions. Therefore, project emissions from composting (**$PE_{COMP,y}$**) were calculated as follows:

EQUATION 6

$$PE_{COMP,y} = PE_{CH4,y} + PE_{N2O,y}$$

The baseline emissions for composting were estimated based on the waste compositions indicated in table 6.2, and the outcomes are presented in Table A.4.1 below:

| Year | The amount of solid waste collected for composting by composition (ton) | | | | | | | BE$_y$ ($tCO_2e$) |
|---|---|---|---|---|---|---|---|---|
| | Food, Organic (ton) | Garden (ton) | Paper (ton) | Wood (ton) | Textile (ton) | Nappies (ton) | Plastic, other inert (ton) | |
| | **59.24%** | **2.76%** | **2.70%** | **1.05%** | **3.30%** | **0.01%** | **30.94%** | |
| 2016 | 2,130,124 | 99,243 | 97,085 | 37,755 | 118,660 | 360 | 1,112,526 | 766,469 |
| 2017 | 3,167,536 | 147,576 | 144,368 | 56,143 | 176,450 | 535 | 1,654,348 | 1,666,329 |
| 2018 | 4,406,526 | 205,301 | 200,838 | 78,104 | 245,468 | 744 | 2,301,450 | 2,733,216 |
| 2019 | 5,874,975 | 273,716 | 267,766 | 104,131 | 327,269 | 992 | 3,068,395 | 4,000,488 |
| 2020 | 7,602,822 | 354,217 | 346,516 | 134,756 | 423,520 | 1283 | 3,970,819 | 5,502,159 |
| 2021 | 9,682,658 | 451,116 | 441,310 | 171,620 | 539,378 | 1634 | 5,057,080 | 7,295,335 |
| 2022 | 12,134,523 | 565,349 | 553,059 | 215,078 | 675,961 | 2048 | 6,337,646 | 9,426,970 |
| 2023 | 15,015,758 | 699,586 | 684,378 | 266,147 | 836,462 | 2535 | 7,842,464 | 11,643,247 |
| 2024 | 18,392,419 | 856,905 | 838,277 | 325,997 | 1,024,561 | 3105 | 9,606,034 | 14,530,309 |
| 2025 | 22,336,080 | 1,040,641 | 1,018,018 | 395,896 | 1,244,245 | 3770 | 11,665,738 | 17,921,612 |
| 2026 | 24,371,794 | 1,135,485 | 1,110,801 | 431,978 | 1,357,645 | 4114 | 12,728,955 | 20,987,814 |
| 2027 | 26,605,997 | 1,239,577 | 1,212,630 | 471,578 | 1,482,103 | 4491 | 13,895,840 | 23,908,617 |
| 2028 | 29,057,949 | 1,353,814 | 1,324,383 | 515,038 | 1,618,691 | 4905 | 15,176,451 | 26,812,051 |
| 2029 | 31,750,795 | 1,479,274 | 1,447,116 | 562,767 | 1,768,697 | 5360 | 16,582,876 | 29,792,884 |
| 2030 | 34,703,672 | 1,616,849 | 1,581,700 | 615,106 | 1,933,189 | 5858 | 18,125,112 | 32,922,197 |

**Table A.4.1** – Baseline emissions for composting.

$CH_4$ emission from composting (**PE$_{CH4,y}$**) activities are determined through the equation below.

EQUATION 7

$$PE_{CH4,y} = Q_y.EF_{CH4,default}.GWP_{CH4}$$

Where:

**PE$_{CH4,y}$**: NAMA emissions of methane from the composting process in year y (t $CO_2e$ / yr);

**Q$_y$**: Quantity of waste composted in year y (t / yr);

**EF$_{CH4,default}$**: Emission factor of methane per tonne of waste composted valid for year y (t $CH_4$/t);

**GWP$_{CH4}$**: Global Warming Potential of $CH_4$ (t $CO_2e$ / t $CH_4$).

Organic wastes used for composting ($Q_y$) include food, garden, paper, wood, textile and nappies. Detailed data and calculations are described in the table below:

| Year | Q$_y$ | EF$_{CH4,default}$* | GWP$_{CH4}$** | PE$_{CH4,y}$ (t $CO_2e$) |
|---|---|---|---|---|
| 2016 | 2,482,866 | 0.002 | 25 | 124,143 |
| 2017 | 3,692,074 | 0.002 | 25 | 184,604 |
| 2018 | 5,136,238 | 0.002 | 25 | 256,812 |
| 2019 | 6,847,857 | 0.002 | 25 | 342,393 |
| 2020 | 8,861,831 | 0.002 | 25 | 443,092 |

| | | | | |
|---|---|---|---|---|
| 2021 | 11,286,082 | 0.002 | 25 | 564,304 |
| 2022 | 14,143,970 | 0.002 | 25 | 707,199 |
| 2023 | 17,502,331 | 0.002 | 25 | 875,117 |
| 2024 | 21,438,159 | 0.002 | 25 | 1,071,908 |
| 2025 | 26,034,881 | 0.002 | 25 | 1,301,744 |
| 2026 | 28,407,702 | 0.002 | 25 | 1,420,385 |
| 2027 | 31,011,885 | 0.002 | 25 | 1,550,594 |
| 2028 | 33,869,875 | 0.002 | 25 | 1,693,494 |
| 2029 | 37,008,649 | 0.002 | 25 | 1,850,432 |
| 2030 | 40,450,516 | 0.002 | 25 | 2,022,526 |

**Table A.4.2** – Data for calculating project emissions of methane (t $CO_2$e).

* ASM. III.F - Avoidance of methane emissions through composting(Version 11.0) and Methodological Tool - Project and leakage emissions from composting (Version 01.0.0), UNFCCC. ** 4th assessment report (AR4) (UNFCCC, 2007).

$N_2O$ emissions from composting (**$PE_{N2O,y}$**) activities were determined as follows:

EQUATION 8

$$PE_{N2O,y} = Q_y.EF_{N2O,default}.GWP_{N2O}$$

Where:

**$PE_{N2O,y}$**: NAMA emissions of nitrous oxide from composting in year y (t $CO_2$e/yr);

**$Q_y$**: Quantity of waste composted in year y (t/yr);

**$EF_{N2O,default}$**: Emission factor of nitrous oxide per tonne of waste composted valid for year y (t $N_2O$/t);

**$GWP_{N2O}$**: Global Warming Potential of $N_2O$ (t $CO_2$e/t $N_2O$).

| Year | $Q_y$ | $EF_{N2O,default}$* | $GWP_{N2O}$** | $PE_{N2O,y}$(t CO2e) |
|---|---|---|---|---|
| 2016 | 2,482,866 | 0.0002 | 298 | 147,979 |
| 2017 | 3,692,074 | 0.0002 | 298 | 220,048 |
| 2018 | 5,136,238 | 0.0002 | 298 | 306,120 |
| 2019 | 6,847,857 | 0.0002 | 298 | 408,132 |
| 2020 | 8,861,831 | 0.0002 | 298 | 528,165 |
| 2021 | 11,286,082 | 0.0002 | 298 | 672,650 |
| 2022 | 14,143,970 | 0.0002 | 298 | 842,981 |
| 2023 | 17,502,331 | 0.0002 | 298 | 1,043,139 |
| 2024 | 21,438,159 | 0.0002 | 298 | 1,277,714 |
| 2025 | 26,034,881 | 0.0002 | 298 | 1,551,679 |
| 2026 | 28,407,702 | 0.0002 | 298 | 1,693,099 |
| 2027 | 31,011,885 | 0.0002 | 298 | 1,848,308 |
| 2028 | 33,869,875 | 0.0002 | 298 | 2,018,645 |
| 2029 | 37,008,649 | 0.0002 | 298 | 2,205,715 |
| 2030 | 40,450,516 | 0.0002 | 298 | 2,410,851 |

**Table A.4.3** – Data for calculating NAMA emissions of nitrous oxide (t $CO_2$e).

Note: * ASM. III.F - Avoidance of methane emissions through composting(Version 11.0) and Methodological Tool - Project and leakage emissions from composting (Version 01.0.0), UNFCCC. ** 4th assessment report (AR4) (UNFCCC, 2007).

Leakage emissions from composting (**$LE_{COMP,y}$**) shall only be accounted for if compost is subjected to anaerobic storage or disposed of in a solid waste disposal site. In the NAMA scenario, compost produced under will not be utilized for this purpose. So project emissions for composting have not been included on this calculation.

The summary of emissions from composting under the NAMA scenario is as follow:

| Year | $BE_y$ (t $CO_2$e) | $PE_{CH4,y}$ (t $CO_2$e) | $PE_{N2O,y}$ (t $CO_2$e) | $ER_{comp,y}$ (t $CO_2$e) |
|---|---|---|---|---|
| 2016 | 766,469 | 124,143 | 147,979 | 494,347 |
| 2017 | 1,666,329 | 184,604 | 220,048 | 1,261,677 |
| 2018 | 2,733,216 | 256,812 | 306,120 | 2,170,284 |
| 2019 | 4,000,488 | 342,393 | 408,132 | 3,249,963 |
| 2020 | 5,502,159 | 443,092 | 528,165 | 4,530,902 |
| 2021 | 7,295,335 | 564,304 | 672,650 | 6,058,381 |
| 2022 | 9,426,970 | 707,199 | 842,981 | 7,876,790 |
| 2023 | 11,643,247 | 875,117 | 1,043,139 | 9,724,991 |
| 2024 | 14,530,309 | 1,071,908 | 1,277,714 | 12,180,687 |
| 2025 | 17,921,612 | 1,301,744 | 1,551,679 | 15,068,189 |
| 2026 | 20,987,814 | 1,420,385 | 1,693,099 | 17,874,330 |
| 2027 | 23,908,617 | 1,550,594 | 1,848,308 | 20,509,715 |
| 2028 | 26,812,051 | 1,693,494 | 2,018,645 | 23,099,912 |
| 2029 | 29,792,884 | 1,850,432 | 2,205,715 | 25,736,737 |
| 2030 | 32,922,197 | 2,022,526 | 2,410,851 | 28,488,820 |

**Table A.4.4** – Emission reductions from composting (t $CO_2$e).

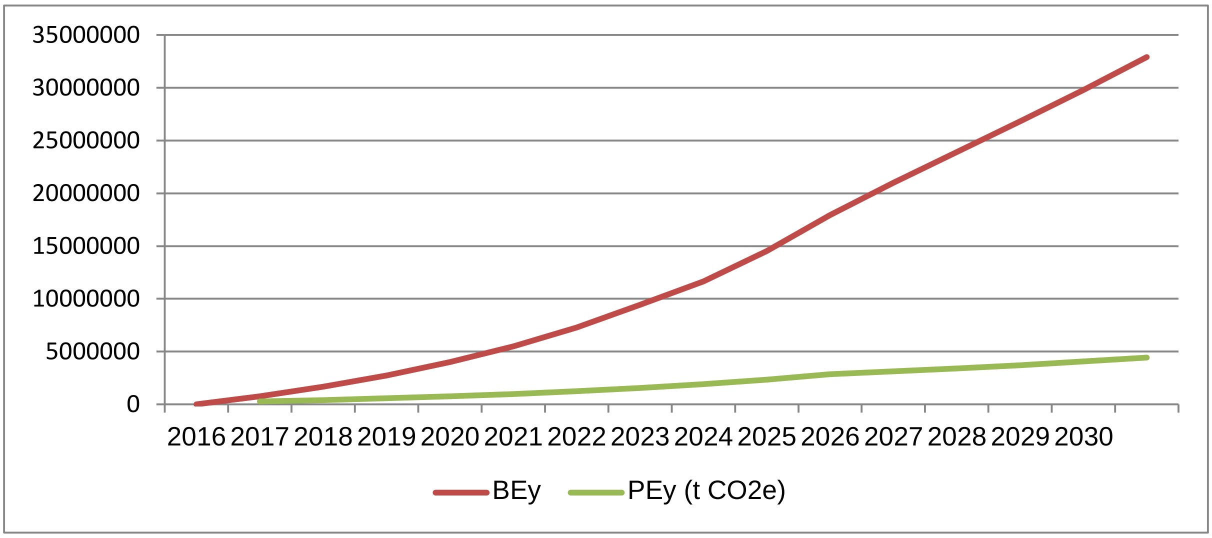


**Figure A.4.1** – Baseline and project emissions from composting in the NAMA scenario.

## A.4.2 Solid waste treatment through conversion into RDF

Refuse-derived fuel (RDF) is a fuel produced via the processes of shredding and dehydrating solid waste through a waste converter technology. RDF consists mostly of the combustible components of waste, such as plastics and biodegradable waste. RDF processing facilities are normally located in proximity both to a source of solid waste and a facility where the fuel could be used as energy input.

The calculation of RDF production under this NAMA was based on technology MBT-CD.08 which converts municipal solid waste into a fuel. This technology was developed by the Hydraulic Mechanical Company (HMC), was approved by the Ministry of Construction in 2008, and it is already applied in Viet Nam. The idea underpinning MBT-CD.08 is to separate and pre-handle combustible wastes and then to compress them into fuel pellets. The fuel pellets are verified by standard QUANTES 1 by combusting in boilers and meet the requirement of TCVN 5939:2005 (Air quality – Industrial emission standards – Inorganic substance and dusts). The heating value of the fuel pellets is around 3,000 – 4,200Kcal/kg (HMC, 2008). The conversion efficiency of this approach is estimated at 98%.

On the other hand, CDM approved methodology "AM0025/Version 05: Avoided emissions from organic waste through alternative waste treatment processes" was applied. The methodology is applicable under the mechanical process to produce refuse-derived fuel (RDF) and its use.

Baseline emissions comprise methane emissions from solid waste disposal in the absence of the NAMA activity as well as emissions from fossil fuel use (coal), which are replaced by the use of RDF pellets in the NAMA scenario.

EQUATION 9

$$BE_{RDF,y} = BE_{CH4,SWD,y} + BE_{fuel,y}$$

Where:

**$BE_{RDF,y}$**: Baseline emissions in year y (t $CO_2$e/yr);

**$BE_{CH4,SWD,y}$**: Methane emission potential of a solid waste disposed (in t$CO_2$e), calculated using the methodological tool "Emissions from solid waste disposal sites";

**$BE_{fuel,y}$**: $CO_2$ emission due to the combustion of coal or other fossil fuels in the production process. This result can be considered as emission reduction potential for the replacement of coal by RDF.

RDF is the combination of approximately 90% biomass and 10% fossil-based materials. If RDF pellets with this composition is combusted, the 90% biomass content that is combusted would not count as project emissions due to its biogenic origin. The combustion of the remainder 10% were counted as project emissions. Under the NAMA scenario, both processes of RDF production and utilization are considered. Therefore, project emissions are calculated as follows:

EQUATION 10

$$PE_{RDF,y} = PE_{elec,y} + PE_{fuel,y} + PE_{r,y}$$

Where :

**$PE_{RDF,y}$**: RDF emissions in the NAMA scenario for year y (t $CO_2$/yr);

**$PE_{elec,y}$**: Emissions from the use of electricity for the operation of the installed facilities in the year *y* (t $CO_2$e);

**$PE_{fuel,y}$**: On-site emissions due to fuel consumption in year y ($tCO_2$e);

**$PE_{r,y}$**: Emissions from the combustion of RDF in year y ($tCO_2$e).

The methane emission potential from solid waste disposal (**$BE_{CH4,SWD,y}$**) is estimated based on the amount of waste which is assumed to be utilized for RDF production, as indicated in Table A.4.5 below.

| Year | The amount of solid waste collected for RDF by composition (ton) | | | | | | | $BE_{CH4,SWD,y}$ ($tCO_2e$) |
|---|---|---|---|---|---|---|---|---|
| | Food, Organic (ton) | Garden (ton) | Paper (ton) | Wood (ton) | Textile (ton) | Nappies (ton) | Plastic, other inert (ton) | |
| | 59.24% | 2.76% | 2.70% | 1.05% | 3.30% | 0.01% | 30.94% | |
| 2016 | 142,008 | 6,616 | 6,472 | 2,517 | 7911 | 24 | 74,168 | 51,098 |
| 2017 | 237,565 | 11,068 | 10,828 | 4,211 | 13,234 | 40 | 124,076 | 120,586 |
| 2018 | 352,522 | 16,424 | 16,067 | 6,248 | 19,637 | 60 | 184,116 | 209,880 |
| 2019 | 489,581 | 22,810 | 22,314 | 8,678 | 27,272 | 83 | 255,700 | 320,974 |
| 2020 | 651,670 | 30,361 | 29,701 | 11,551 | 36,302 | 110 | 340,356 | 456,341 |
| 2021 | 823,026 | 38,345 | 37,511 | 14,588 | 45,847 | 139 | 429,852 | 612,062 |
| 2022 | 1,024,693 | 47,741 | 46,703 | 18,162 | 57,081 | 173 | 535,179 | 793,075 |
| 2023 | 1,261,324 | 58,765 | 57,488 | 22,,356 | 70,263 | 213 | 658,767 | 987,016 |
| 2024 | 1,538,275 | 71,668 | 70,110 | 27,265 | 85,691 | 260 | 803,414 | 1,227,542 |
| 2025 | 1,861,340 | 86,720 | 84,835 | 32,991 | 103,687 | 314 | 972,145 | 1,508,359 |
| 2026 | 2,437,179 | 113,549 | 111,080 | 43,198 | 135,765 | 411 | 1,272,895 | 1,906,536 |
| 2027 | 3,104,033 | 144,617 | 141,473 | 55,017 | 172,912 | 524 | 1,621,181 | 2,417,549 |
| 2028 | 3,874,393 | 180,509 | 176,584 | 68,672 | 215,825 | 654 | 2,023,527 | 3,042,997 |
| 2029 | 4,762,619 | 221,891 | 217,067 | 84,415 | 265,305 | 804 | 2,487,431 | 3,789,287 |
| 2030 | 5,783,945 | 269,475 | 263,617 | 102,518 | 322,198 | 976 | 3,020,852 | 4,666,400 |

**Table A.4.5** – Methane emissions from solid waste disposal ($BE_{CH4,SWD,y}$)

In the NAMA scenario, the amount of RDF produced is assumed to replace the combustion of coal, the main fossil fuel consumed in Viet Nam. In order to calculate the emissions from coal combustion, it is necessary to identify the amount of coal replaced by RDF. This calculation is based on the heating value of coal and RDF. The calculation is described below:

EQUATION 11

$$Q_{coal} = Q_{RDF} * LHV_{RDF} / LHV_{coal}$$

Where:

**$Q_{coal}$**: Amount of coal replaced by RDF;

**$Q_{RDF}$**: Amount of RDF produced;

**$LHV_{RDF}$**: Low heating value of RDF;

**$LHV_{coal}$**: Low heating value of coal.

The amount of solid waste used for RDF production includes garden, paper, wood, textile, nappies and plastic wastes. The composition of plastic waste is of around 9.7 – 13.6% (MONRE, 2011). Therefore, an average of 11% was taken for the plastic waste composition, which was used for this calculation.

| Year | The amount of solid waste used for RDF (ton) | Efficiency of RDF production process (%) | $LHV_{RDF}$ (kcal/kg) | $LHV_{coal}$ (kcal/kg) | $CO_2$ $EF_{coal}$ (tC/TJ) | $CH_4$ $EF_{coal}$ ($kgCH_4$/TJ) | $N_2O$ $EF_{coal}$ ($kgN_2O$/TJ) |
|---|---|---|---|---|---|---|---|
| 2016 | 49,909 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2017 | 83,493 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2018 | 123,894 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2019 | 172,064 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2020 | 229,,031 | 98 | 4200 | 5,,043 | 26.8 | 1 | 1.4 |
| 2021 | 289,254 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2022 | 360,130 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2023 | 443,294 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2024 | 540,629 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2025 | 654,171 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2026 | 856,551 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2027 | 1,090,918 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2028 | 1,361,662 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2029 | 1,673,831 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |
| 2030 | 2,032,778 | 98 | 4200 | 5,043 | 26.8 | 1 | 1.4 |

**<u>Table A.4.6</u>** – Data for calculating $CO_2$ emissions from fuel use ($BE_{fuel,y}$)

| Year | $CO_2$ emission (ton) | $CH_4$ emission (ton) | $N_2O$ emission (ton) | $BE_{fuel,y}$ ($tCO_2e$) |
|---|---|---|---|---|
| 2016 | 84,497 | 0.9 | 1.2 | 84,877 |
| 2017 | 141,354 | 1.4 | 2.0 | 141,990 |
| 2018 | 209,755 | 2.1 | 3.0 | 210,699 |
| 2019 | 291,307 | 3.0 | 4.2 | 292,618 |
| 2020 | 387,752 | 3.9 | 5.5 | 389,497 |
| 2021 | 489,710 | 5.0 | 7.0 | 491,914 |
| 2022 | 609,705 | 6.2 | 8.7 | 612,448 |
| 2023 | 750,503 | 7.6 | 10.7 | 753,880 |
| 2024 | 915,292 | 9.3 | 13.0 | 919,411 |
| 2025 | 1,107,520 | 11.3 | 15.8 | 1,112,504 |
| 2026 | 1,450,151 | 14.8 | 20.7 | 1,456,677 |
| 2027 | 1,846,937 | 18.8 | 26.3 | 1,855,248 |
| 2028 | 2,305,310 | 23.5 | 32.8 | 2,315,684 |
| 2029 | 2,833,816 | 28.8 | 40.4 | 2,846,568 |
| 2030 | 3,441,517 | 35.0 | 49.0 | 3,457,004 |

**<u>Table A.4.7</u>** – $CO_2e$ emissions from fuel use ($BE_{fuel,y}$)

Indirect emissions from RDF production originate mostly from the consumption of electricity. According to research conducted by Khanh V. Nguyen (2015), electricity consumption for RDF production is estimated at 0.17 – 0.26 kWh/kg RDF. An average figure of 0.2 kWh/kg was therefore used for this calculation. Results of the calculation for estimating indirect emissions from RDF production are presented in the table below:

| Year | RDF production (ton) | Electricity consumption (kWh/kg) | $EF_{grid}$ (tCO2/MWh)* | $PE_{RDF,y}$ ($tCO_2e$) |
|---|---|---|---|---|
| 2016 | 48,911 | 0.2 | 0.5232 | 5,118 |
| 2017 | 81,823 | 0.2 | 0.5232 | 8,562 |
| 2018 | 121,417 | 0.2 | 0.5232 | 12,705 |
| 2019 | 168,623 | 0.2 | 0.5232 | 17,645 |
| 2020 | 224,450 | 0.2 | 0.5232 | 23,486 |
| 2021 | 283,469 | 0.2 | 0.5232 | 29,662 |
| 2022 | 352,,928 | 0.2 | 0.5232 | 36,,930 |
| 2023 | 434,428 | 0.2 | 0.5232 | 45,459 |
| 2024 | 529,817 | 0.2 | 0.5232 | 55,440 |
| 2025 | 641,088 | 0.2 | 0.5232 | 67,083 |
| 2026 | 839,420 | 0.2 | 0.5232 | 87,837 |
| 2027 | 1,069,099 | 0.2 | 0.5232 | 111,871 |
| 2028 | 1,334,429 | 0.2 | 0.5232 | 139,635 |
| 2029 | 1,640,354 | 0.2 | 0.5232 | 171,647 |
| 2030 | 1,992,122 | 0.2 | 0.5232 | 208,456 |

**Table A.4.8** – Emissions from electricity use for RDF production.
* Researching and assessing emission factors for the electricity grid in Viet Nam (MONRE, 2014)

A summary of the emissions under the baseline and NAMA scenarios for the production of RDF is presented in the table below:

| Year | $BE_{SWD,y}$ (t $CO_2e$) | $BE_{fuel,y}$ ($tCO_2e$) | $PE_{RDF,y}$ (t CO2e) | $ER_{RDF,y}$ (t CO2e) |
|---|---|---|---|---|
| 2016 | 51,098 | 84,877 | 5,118 | 130,857 |
| 2017 | 120,586 | 141,990 | 8,562 | 254,014 |
| 2018 | 209,880 | 210,699 | 12,705 | 407,874 |
| 2019 | 320,974 | 292,618 | 17,645 | 595,947 |
| 2020 | 456,341 | 389,497 | 23,486 | 822,351 |
| 2021 | 612,062 | 491,914 | 29,662 | 1,074,314 |
| 2022 | 793,075 | 612,448 | 36,930 | 1,368,593 |
| 2023 | 987,016 | 753,880 | 45,459 | 1,695,437 |
| 2024 | 1,227,542 | 919,411 | 55,440 | 2,091,513 |
| 2025 | 1,508,359 | 1,112,504 | 67,083 | 2,553,779 |
| 2026 | 1,906,536 | 1,456,677 | 87,837 | 3,275,376 |
| 2027 | 2,417,549 | 1,855,248 | 111,871 | 4,160,927 |
| 2028 | 3,042,997 | 2,315,684 | 139,635 | 5,219,047 |
| 2029 | 3,789,287 | 2,846,568 | 171,647 | 6,464,208 |
| 2030 | 4,666,400 | 3,457,004 | 208,456 | 7,914,948 |

**Table A.4.9** – Emission reductions from RDF production

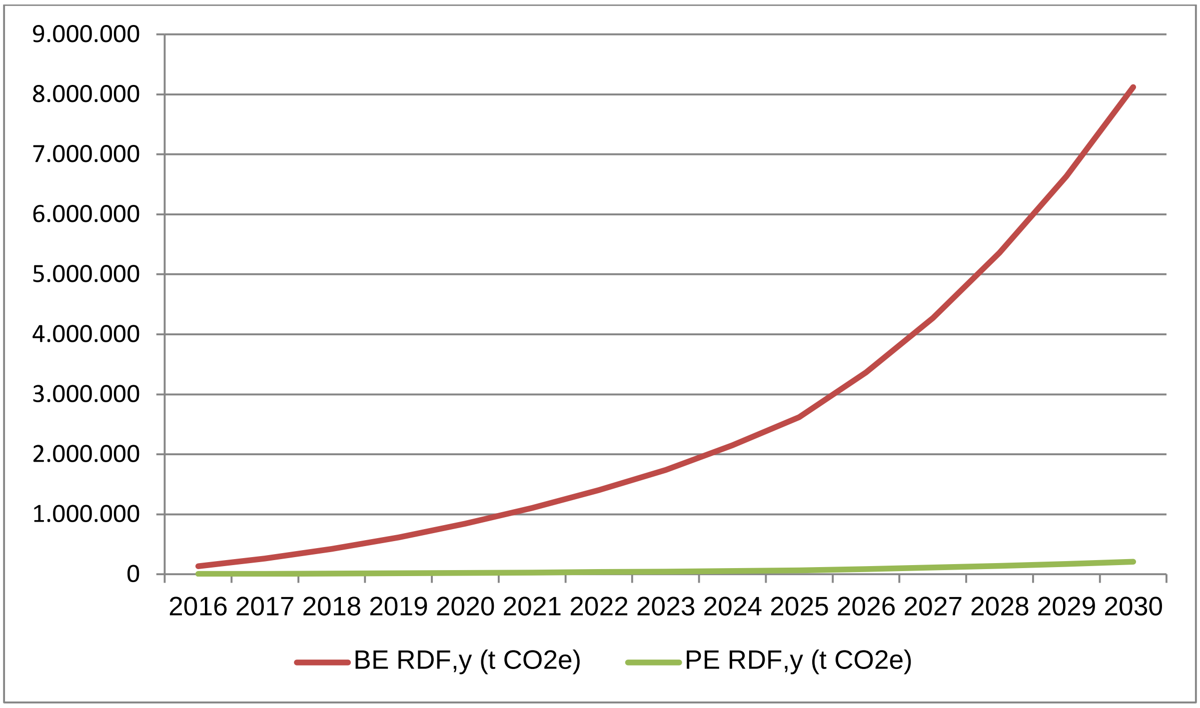


**Figure A.4.3** – Baseline and project emissions from RDF production under the NAMA scenario.

### A.4.3 Solid waste treatment through recycling methods

Emission reductions in the NAMA scenario from recycling waste were calculated for paper and plastic recovered. CDM methodology AMS-III.AJ (Recovery and recycling of materials from solid wastes, version 04.0) was applied. This methodology comprises activities for the recovery and recycling of materials in solid waste by converting them into intermediate or finished products, thereby resulting in energy savings. For paper and cardboard recycling, if the baseline scenario is their decay from a disposal site, avoided methane emissions may be claimed.

Baseline emissions include emissions associated with energy consumption for the production of paper from virgin materials. For paper and cardboard, emissions associated with their anaerobic decomposition in a disposal site may also be claimed.

EQUATION 12

$$BE_y = Q_y.L.(SEC_{Bl}.EF_{el,y} + SFC_{el}.EF_{FF,CO2}) + BE_{SWD,y}$$

Where:

**$BE_y$**: Baseline emissions in year y (t $CO_2$/y);

**$Q_y$**: Quantity of paper recycled in year y (t/y);

**L:** Net to gross adjustment factor to cover degradation in material quality and material loss in the production process of the final product using the recycled material (use 0.75);

**$SEC_{Bl}$:** Specific electricity consumption for the production of virgin material (MWh/t);

**$EF_{el,y}$**: Emission factor for grid electricity generation, as per the most recent version of the "Tool to calculate emission factor for an electricity system" (t $CO_2$/MWh);

**$SFC_{el}$**: Specific fuel consumption for the production of virgin material (GJ/t);

**$EF_{FF,CO2}$:** $CO_2$ emission factor for fossil fuel (t $CO_2$/GJ);

**$BE_{SWD,y}$:** baseline emissions from disposing paper waste(t $CO_2$).

Under the NAMA scenario, energy consumption for producing virgin materials has been accounted so as to compare with the energy needs for recycling materials from waste. Therefore, baseline emissions will be equal to the sum of emissions from waste disposal and the emissions from the use of energy for virgin material production.

The table below indicates the amounts of waste taken for recycling purposes under the NAMA scenario.

| Year | The amount of solid waste collected for recycling by composition (ton) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Food, Organic (ton) | Garden (ton) | Paper (ton) | Wood (ton) | Textile (ton) | Nappies (ton) | Plastic, other inert (ton) |
| | **59.24%** | **2.76%** | **2.70%** | **1.05%** | **3.30%** | **0.01%** | **30.94%** |
| 2016 | 284,017 | 13,232 | 12,945 | 5,034 | 15,821 | 48 | 148,337 |
| 2017 | 633,507 | 29,515 | 28,874 | 11,229 | 35,290 | 107 | 330,870 |
| 2018 | 1,057,566 | 49,272 | 48,201 | 18,745 | 58,912 | 179 | 552,348 |
| 2019 | 1,566,660 | 72,991 | 71,404 | 27,768 | 87,272 | 264 | 818,239 |
| 2020 | 2,172,235 | 101,205 | 99,005 | 38,502 | 121,006 | 367 | 1,134,520 |
| 2021 | 2,904,797 | 135,335 | 132,393 | 51,486 | 161,813 | 490 | 1,517,124 |
| 2022 | 3,775,185 | 175,886 | 172,063 | 66,913 | 210,299 | 637 | 1,971,712 |
| 2023 | 4,805,043 | 223,868 | 219,001 | 85,167 | 267,668 | 811 | 2,509,588 |
| 2024 | 6,019,337 | 280,442 | 274,345 | 106,690 | 335,311 | 1,016 | 3,143,793 |
| 2025 | 7,445,360 | 346,880 | 339,339 | 131,965 | 414,748 | 1,257 | 3,888,579 |
| 2026 | 8,123,931 | 378,495 | 370,267 | 143,993 | 452,548 | 1,371 | 4,242,985 |
| 2027 | 8,868,666 | 413,192 | 404,210 | 157,193 | 494,034 | 1,497 | 4,631,947 |
| 2028 | 9,685,983 | 451,271 | 441,461 | 171,679 | 539,564 | 1,635 | 5,058,817 |
| 2029 | 10,583,598 | 493,091 | 482,372 | 187,589 | 589,566 | 1,787 | 5,527,625 |
| 2030 | 11,567,891 | 538,950 | 527,233 | 205,035 | 644,396 | 1,953 | 6,041,704 |

**Figure A.4.4** – Amount of solid waste collected for recycling purposes.

*Recycling of Paper:*

Baseline emissions for paper recycling include energy-related emissions from virgin paper production as well as its disposal. According to a research paper by Kinsella S. (2012), producing 1 ton of virgin paper would consume 33 million BTUs, which was used to calculate emissions from virgin paper production. The amount of paper used for this calculation was assumed to be equal to the amount of paper that is disposed as waste. Detailed data and calculations are presented in the table below:

| Year | Paper production (ton) | Energy consumption (million BTUs/ton) 1 | BTU/kJ conversion factor 1 | MJ/kWh conversion factor 1 | Emission factor of the national electricity gird ($tCO_2$/MWh) 2 | $BE_{paper\ production,y}$ ($tCO_2e$) |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| 2016 | 12,945 | 33 | 1.054 | 0.28 | 0.5323 | 67,108 |
| 2017 | 28,874 | 33 | 1.054 | 0.28 | 0.5323 | 149,684 |
| 2018 | 48,201 | 33 | 1.054 | 0.28 | 0.5323 | 249,876 |
| 2019 | 71,404 | 33 | 1.054 | 0.28 | 0.5323 | 370,162 |
| 2020 | 99,005 | 33 | 1.054 | 0.28 | 0.5323 | 513,247 |
| 2021 | 132,393 | 33 | 1.054 | 0.28 | 0.5323 | 686,332 |
| 2022 | 172,063 | 33 | 1.054 | 0.28 | 0.5323 | 891,983 |
| 2023 | 219,001 | 33 | 1.054 | 0.28 | 0.5323 | 1,135,312 |
| 2024 | 274,345 | 33 | 1.054 | 0.28 | 0.5323 | 1,422,218 |
| 2025 | 339,339 | 33 | 1.054 | 0.28 | 0.5323 | 1,759,150 |
| 2026 | 370,267 | 33 | 1.054 | 0.28 | 0.5323 | 1,919,482 |
| 2027 | 404,210 | 33 | 1.054 | 0.28 | 0.5323 | 2,095,444 |
| 2028 | 441,461 | 33 | 1.054 | 0.28 | 0.5323 | 2,288,555 |
| 2029 | 482,372 | 33 | 1.054 | 0.28 | 0.5323 | 2,500,640 |
| 2030 | 527,233 | 33 | 1.054 | 0.28 | 0.5323 | 2,733,201 |

**Table A.4.10** – Emissions from virgin paper production.

$CH_4$ emissions from the disposal of paper waste were calculated applying the FOD method for the period 2016 – 2030. Detailed results are as follows:

| Year | Paper (ton) | $BE_{paper\ disposal,y}$ ($tCO_2e$) |
|---|---|---|
| 2016 | 12,945 | 2,363 |
| 2017 | 28,874 | 7,474 |
| 2018 | 48,201 | 15,767 |
| 2019 | 71,404 | 27,735 |
| 2020 | 99,005 | 43,932 |
| 2021 | 132,393 | 65,128 |
| 2022 | 172,063 | 92,133 |
| 2023 | 219,001 | 134,781 |
| 2024 | 274,345 | 177,186 |
| 2025 | 339,339 | 228,588 |
| 2026 | 370,267 | 282,160 |
| 2027 | 404,210 | 338,307 |
| 2028 | 441,461 | 397,457 |
| 2029 | 482,372 | 460,076 |
| 2030 | 527,233 | 526,651 |

**Table A.4.11** – Emissions from the disposal of paper waste.

Indirect emissions from recycling are mostly from energy use (electricity consumption). According to the paper authored by Kinsella S. (2012), recycling 1 ton of paper would consume 22 million BTUs of energy, which was used to calculate emissions from virgin paper production.

| Year | Paper recycling (ton) | Energy consumption (million BTUs/ton)* | BTU/kJ conversion factor* | MJ/kWh conversion factor* | Emission factor of the national electricity gird ($tCO_2$/MWh)** | $PE_{recycling,y}$ ($tCO_2e$) |
|---|---|---|---|---|---|---|
| 2016 | 12,945 | 22 | 1.054 | 0.28 | 0.5323 | 44,738 |
| 2017 | 28,874 | 22 | 1.054 | 0.28 | 0.5323 | 99,789 |
| 2018 | 48,201 | 22 | 1.054 | 0.28 | 0.5323 | 166,584 |
| 2019 | 71,404 | 22 | 1.054 | 0.28 | 0.5323 | 246,775 |
| 2020 | 99,005 | 22 | 1.054 | 0.28 | 0.5323 | 342,164 |
| 2021 | 132,393 | 22 | 1.054 | 0.28 | 0.5323 | 457,554 |
| 2022 | 172,063 | 22 | 1.054 | 0.28 | 0.5323 | 594,655 |
| 2023 | 219,001 | 22 | 1.054 | 0.28 | 0.5323 | 756,875 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2024 | 274,345 | 22 | 1.054 | 0.28 | 0.5323 | 948,145 |
| 2025 | 339,339 | 22 | 1.054 | 0.28 | 0.5323 | 1,172,767 |
| 2026 | 370,267 | 22 | 1.054 | 0.28 | 0.5323 | 1,279,655 |
| 2027 | 404,210 | 22 | 1.054 | 0.28 | 0.5323 | 1,396,963 |
| 2028 | 441,461 | 22 | 1.054 | 0.28 | 0.5323 | 1,525,703 |
| 2029 | 482,372 | 22 | 1.054 | 0.28 | 0.5323 | 1,667,093 |
| 2030 | 527,233 | 22 | 1.054 | 0.28 | 0.5323 | 1,822,134 |

**Table A.4.12** – Emissions from recycling paper

* Recycling versus incineration: an energy conservation analysis (Morris, J 1995)

** Researching and assessing emission factor of Vietnam electricity grid (MONRE, 2014)

*Recycling of Plastic*:

Plastic waste does not emit $CH_4$ when disposed in landfill sites. Therefore, baseline emissions for plastic only include those resulting from the plastic production process. Similarly, project emissions include those from energy for recycling plastic. Research conducted by Morris J. (1996) indicates that recycling plastic may save 42,000 – 111,000 kJ/kg. The average figure of 76,000 kJ/kg was used for calculating emission reductions from plastic recycling, as presented in the table below.

| Year | Plastic recycling (ton) | Energy saves (kJ/kg) | MJ/kWh conversion factor 1 | Emission factor of the national electricity gird ($tCO_2$/MWh) 2 | $ER_{plastic\ recycling,y}$ ($tCO_2e$) |
|---|---|---|---|---|---|
| 2016 | 52,738 | 76,000 | 0.28 | 0.5323 | 597,378 |
| 2017 | 117,633 | 76,000 | 0.28 | 0.5323 | 1,332,470 |
| 2018 | 196,375 | 76,000 | 0.28 | 0.5323 | 2,224,402 |
| 2019 | 290,906 | 76,000 | 0.28 | 0.5323 | 3,295,190 |
| 2020 | 403,352 | 76,000 | 0.28 | 0.5323 | 4,568,909 |
| 2021 | 539,378 | 76,000 | 0.28 | 0.5323 | 6,109,724 |
| 2022 | 700,997 | 76,000 | 0.28 | 0.5323 | 7,940,429 |
| 2023 | 892,226 | 76,000 | 0.28 | 0.5323 | 10,106,551 |
| 2024 | 1,117,703 | 76,000 | 0.28 | 0.5323 | 12,660,603 |
| 2025 | 1,382,494 | 76,000 | 0.28 | 0.5323 | 15,659,988 |
| 2026 | 1,508,495 | 76,000 | 0.28 | 0.5323 | 17,087,242 |
| 2027 | 1,646,781 | 76,000 | 0.28 | 0.5323 | 18,653,658 |
| 2028 | 1,798,545 | 76,000 | 0.28 | 0.5323 | 20,372,739 |
| 2029 | 1,965,219 | 76,000 | 0.28 | 0.5323 | 22,260,713 |
| 2030 | 2,147,988 | 76,000 | 0.28 | 0.5323 | 24,330,997 |

**Table A.4.13** – Emission reductions from plastic recycling.

The results from modeling the emission reduction from recycling paper and plastics are presented in the table and figure below:

| Year | $BE_{paper\ production,y}$ ($t\ CO_2e$) | $BE_{paper\ disposal,y}$ ($tCO_2e$) | $PE_{recycling,y}$ ($t\ CO_2e$) | $ER_{paper\ recycling,y}$ ($t\ CO_2e$) | $ER_{plastic\ recycling,y}$ ($t\ CO_2e$) |
|---|---|---|---|---|---|
| 2016 | 67,108 | 2,363 | 44,738 | 24,733 | 597,378 |
| 2017 | 149,684 | 7,474 | 99,789 | 57,369 | 1,332,470 |
| 2018 | 249,876 | 15,767 | 166,584 | 99,059 | 2,224,402 |
| 2019 | 370,162 | 27,735 | 246,775 | 151,122 | 3,295,190 |
| 2020 | 513,247 | 43,932 | 342,164 | 215,015 | 4,568,909 |
| 2021 | 686,332 | 65,128 | 457,554 | 293,906 | 6,109,724 |
| 2022 | 891,983 | 92,133 | 594,655 | 389,461 | 7,940,429 |

| | | | | | |
|---|---|---|---|---|---|
| 2023 | 1,135,312 | 134,781 | 756,875 | 513,218 | 10,106,551 |
| 2024 | 1,422,218 | 177,186 | 948,145 | 651,259 | 12,660,603 |
| 2025 | 1,759,150 | 228,588 | 1,172,767 | 814,971 | 15,659,988 |
| 2026 | 1,919,482 | 282,160 | 1,279,655 | 921,987 | 17,087,242 |
| 2027 | 2,095,444 | 338,307 | 1,396,963 | 1,036,788 | 18,653,658 |
| 2028 | 2,288,555 | 397,457 | 1,525,703 | 1,160,309 | 20,372,739 |
| 2029 | 2,500,640 | 460,076 | 1,667,093 | 1,293,623 | 22,260,713 |
| 2030 | 2,733,201 | 526,651 | 1,822,134 | 1,437,718 | 24,330,997 |

**Table A.4.14** – Emission reduction results for paper recycling.

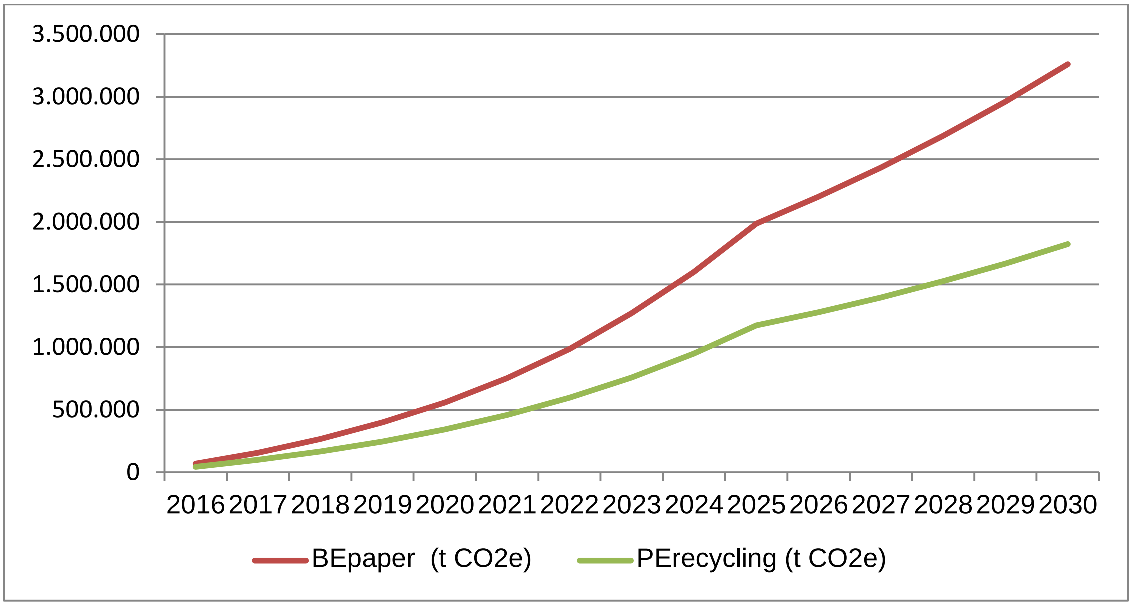


**Figure A.4.4** – Baseline emissions and project emissions from recycling under the NAMA scenario.

## A.4.4 Solid waste treatment through anaerobic digestion

In order to estimate GHG emission reductions from the adoption of anaerobic digestion (AD), CDM methodologies AM0075 (methodology for the collection, processing and supply of biogas to end-users for heat production, version 1.0) and AMS-I.C (thermal energy production with or without electricity, version 19) were applied.

Baseline emissions comprise methane emissions from solid waste disposal in the absence of the activities implemented under the NAMA activities, expressed as follows:

$\mathbf{BE_{AD,y}} = BE_{CH4,SWD,y}$

The amount of $CH_4$ captured for generating electricity were calculated using the following equation:

EQUATION 13

$BE_{combustion,y} = \eta_{PJ}.BE_{CH4,SWD,y} - (1 - OX).F_{CH4,BL,y}.GWP_{CH4}$

Where:

**$BE_{AD,y}$**: Baseline emissions from Anaerobic digestion activity in year y (t $CO_2e$/yr);

**$BE_{CH4,SWD,y}$**: Methane emission potential of a solid waste disposal site (in t $CO_2e$), calculated using the methodological tool "Emissions from solid waste disposal sites";

**OX**: Oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste) (dimensionless). A default value of 0.1 may be used;

**$\eta_{PJ}$**: Efficiency of the Biogas capture system that will be installed in the project activity. It is used for *ex-ante* estimation only. A default value of 50 per cent may be used;

**$F_{CH4,BL,y}$**: Methane emissions that would be captured and destroyed to comply with national or local safety requirement or legal regulations in the year y (t CH4);

**$GWP_{CH4}$**: Global Warming Potential for methane (value of 25).

Emissions from the NAMA scenario include indirect emissions due to the use of electricity for an anaerobic digestion system, emissions from combusting $CH_4$ for electricity generation and leakage emissions (due to the inefficiency of a biogas capture system). It was also taken into account the balance between the electricity generated by the plant and the electricity consumed on-site for its operation, as per the equation below:

EQUATION 14

$$PE_{AD,y} = PE_{Power,y} + PE_{combustion,y} + LE_{AD,y}$$

Where:

**$PE_{AD,y}$**: NAMA emissions from Anaerobic digestion activity in year y (t $CO_2$/yr);

**$PE_{Power,y}$**: Emissions/Reductions from the use/generation of electricity for the operation of anaerobic digestion facilities in year y (t $CO_2e$);

**$PE_{combustion,y}$**: Emissions from flaring or combustion of the biogas in the year y (t $CO_2e$);

**$LE_{AD,y}$**: Leakage emissions due to the inefficiency of biogas capture system ($LE_{AD,y} = BE_{CH4,SWD,y} - BE_{combustion,y}$).

The methane emission potential for solid waste disposal (**$BE_{CH4,SWD,y}$**) was estimated based on the amount of bio-degradable solid waste indicated in the table below:

| Year | The amount of solid waste collected for anaerobic digestion by composition (ton) | | | | | | | $BE_{CH4,SWD,y}$ ($tCO_2e$) |
|---|---|---|---|---|---|---|---|---|
| | Food, Organic (ton) | Garden (ton) | Paper (ton) | Wood (ton) | Textile (ton) | Nap-pies (ton) | Plastic, other inert (ton) | |
| | 59.24% | 2.76% | 2.70% | 1.05% | 3.30% | 0.01% | 30.94% | |
| 2016 | 142,008 | 6,616 | 6,472 | 2,517 | 7,911 | 24 | 74,168 | 51,098 |
| 2017 | 237,565 | 11,068 | 10,828 | 4,211 | 13,234 | 40 | 124,076 | 120,586 |
| 2018 | 352,522 | 16,424 | 16,067 | 6,248 | 19,637 | 60 | 184,116 | 209,880 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2019 | 489,581 | 22,810 | 22,314 | 8,678 | 27,272 | 83 | 255,700 | 320,974 |
| 2020 | 651,670 | 30,361 | 29701 | 11,551 | 36,302 | 110 | 340,356 | 456,341 |
| 2021 | 823,026 | 38,345 | 37,511 | 14588 | 45,847 | 139 | 429,852 | 612,062 |
| 2022 | 1,024,693 | 47,741 | 46,703 | 18,162 | 57,081 | 173 | 535,179 | 793,075 |
| 2023 | 1,261,324 | 58,765 | 57,488 | 22,356 | 70,263 | 213 | 658,767 | 987,016 |
| 2024 | 1,538,275 | 71,668 | 70,110 | 27,265 | 85,691 | 260 | 803,414 | 1,227,542 |
| 2025 | 1,861,34, | 86,720 | 84,,835 | 32,991 | 103687 | 314 | 972,145 | 1,508,359 |
| 2026 | 2,437,179 | 113,549 | 111080 | 43,198 | 135,765 | 411 | 1,272,895 | 1,906,536 |
| 2027 | 3,104,033 | 144,617 | 141,473 | 55,017 | 172,912 | 524 | 1,621,181 | 2,417,549 |
| 2028 | 3,874,393 | 180,509 | 176,584 | 68,672 | 215,825 | 654 | 2,023,527 | 3,042,997 |
| 2029 | 4,762,619 | 221,891 | 217,067 | 84,415 | 265,305 | 804 | 2,487,431 | 3,789,287 |
| 2030 | 5,783,945 | 269,475 | 263,617 | 102,518 | 322,198 | 976 | 3,020,852 | 4,666,400 |

**Table A.4.15** – Methane emission potential of a solid waste disposal site ($BE_{CH4,SWD,y}$).

In Viet Nam, there are no national or local safety requirements or legal regulations on landfill gas capture and destruction. Therefore, $F_{CH4,BL,y}$ was assumed to be zero. Based on this, data for the baseline emissions from anaerobic digestion activities under the NAMA scenario are presented below:

| Year | $BE_{CH4,SWD,y}$ (t $CH_4$) | OX | $\eta_{PJ}$ | $F_{CH4,BL,y}$ | $GWP_{CH4}$ | $BE_{combustion,y}$ (t $CH_4$) |
|---|---|---|---|---|---|---|
| 2016 | 2,044 | 0.1 | 0.95 | 0 | 25 | 1,942 |
| 2017 | 4,823 | 0.1 | 0.95 | 0 | 25 | 4,582 |
| 2018 | 8,395 | 0.1 | 0.95 | 0 | 25 | 7,975 |
| 2019 | 12,839 | 0.1 | 0.95 | 0 | 25 | 12,197 |
| 2020 | 18,254 | 0.1 | 0.95 | 0 | 25 | 17,341 |
| 2021 | 24,482 | 0.1 | 0.95 | 0 | 25 | 23,258 |
| 2022 | 31,723 | 0.1 | 0.95 | 0 | 25 | 30,137 |
| 2023 | 39,481 | 0.1 | 0.95 | 0 | 25 | 37,507 |
| 2024 | 49,102 | 0.1 | 0.95 | 0 | 25 | 46,647 |
| 2025 | 60,334 | 0.1 | 0.95 | 0 | 25 | 57,317 |
| 2026 | 76,261 | 0.1 | 0.95 | 0 | 25 | 72,448 |
| 2027 | 96,702 | 0.1 | 0.95 | 0 | 25 | 91,867 |
| 2028 | 121,720 | 0.1 | 0.95 | 0 | 25 | 115,634 |
| 2029 | 151,571 | 0.1 | 0.95 | 0 | 25 | 143,992 |
| 2030 | 186,656 | 0.1 | 0.95 | 0 | 25 | 177,323 |

**Table A.4.16** – Data for the calculation of baseline emissions for AD activities.

To generate electricity, recovered $CH_4$ needs to be combusted, and in the process a certain amount of $CO_2$ is released, as per the following equation:

EQUATION 15

$$PE_{combustion,y} = BE_{combustion,y}.(1-\eta_{combustion}).GWP_{CH4} + \eta_{flare}.\ BE_{combustion,y}.EF_{combustion,CH4}$$

Where:

**$PE_{combustion,y}$**: Project emissions from flaring of the residual gas in year y (tCO2e);

**$BE_{combustion,y}$**: The amount of $CH_4$ flared (ton);

**$\eta_{combustion}$**: Flare efficiency;

**$EF_{combustion,CH4}$**: Emission factor for combusting $CH_4$ (t $CO_2$/t $CH_4$).

| Year | $BE_{combustion,y}$ (tCH4) | $\eta_{flare}$* | $GWP_{CH4}$** | $EF_{combustion,CH4}$ ($t\ CO_2/t\ CH_4$)*** | $PE_{combustion,y}$ ($t\ CO_2$) |
|---|---|---|---|---|---|
| 2016 | 1,942 | 0.9 | 25 | 2.8 | 9,749 |
| 2017 | 4,582 | 0.9 | 25 | 2.8 | 23,002 |
| 2018 | 7,975 | 0.9 | 25 | 2.8 | 40,035 |
| 2019 | 12,197 | 0.9 | 25 | 2.8 | 61,229 |
| 2020 | 17,341 | 0.9 | 25 | 2.8 | 87,052 |
| 2021 | 23,258 | 0.9 | 25 | 2.8 | 116,755 |
| 2022 | 30,137 | 0.9 | 25 | 2.8 | 151,288 |
| 2023 | 37,507 | 0.9 | 25 | 2.8 | 188,285 |
| 2024 | 46,647 | 0.9 | 25 | 2.8 | 234,168 |
| 2025 | 57,317 | 0.9 | 25 | 2.8 | 287,731 |
| 2026 | 72,448 | 0.9 | 25 | 2.8 | 363,689 |
| 2027 | 91,867 | 0.9 | 25 | 2.8 | 461,172 |
| 2028 | 115,634 | 0.9 | 25 | 2.8 | 580,483 |
| 2029 | 143,992 | 0.9 | 25 | 2.8 | 722,840 |
| 2030 | 177,323 | 0.9 | 25 | 2.8 | 890,161 |

**Table A.4.17** – Data for calculating project emissions from electricity consumption and generation

*Notes:*

**AMS.III.G (version 9.0) and Methodological tool "Project emissions from flaring" (Version 02.0.0), UNFCCC.*
*** Fourth Assessment Report on Climate Change (UNFCCC, 2007)*
****Kelleher, 2007. BioCycle V. 48, No. 8, p.51; also EBMUD March 2008; also Ostrem, 2004 Greening Waste: Anaerobic Digestion for Treating the Organic Fraction of Municipal Solid Wastes.*

The equation below was used to determine the emissions from electricity use (PEpower,y) and emission reductions due to the generation of electricity (EREG,y):

EQUATION 16

$$PE_{power,y} = EC_{PJ,y}.EF_{EL,y} – EG_{PJ,y}.\ EF_{EL,y} = Q_y.SEC_{AD,default}.EF_{EL,y} - EG_{PJ,y}.\ EF_{EL,y}$$

Where:

**$EC_{PJ,y}$**: Quantity of electricity consumed by the project electricity consumption source j in year y (MWh/yr);

**$Q_y$**: Quantity of waste composted in year y (t/yr);

**$SEC_{AD,y}$**: Electricity consumed per tonne of waste handled (kWh/t);

**$EG_{PJ,y}$**: Electricity generation in the year y (MWh/year);

**$EF_{EL,y}$**: Emission factor of the national grid.

Results are presented in the table below:

| Year | $CH_4$ for Electricity generation ($t\ CH_4$) | Conversion factor (kg $CH_4/m^3\ CH_4$)* | Electricity Generator E fficiency (%)** | Electricity Conversion factor ($kWh/m^3\ CH_4$)** | $EG_{PJ,y}$ (MWh/year) |
|---|---|---|---|---|---|
| 2016 | 1,942 | 0.662 | 60 | 1.2 | 643 |
| 2017 | 4,582 | 0.662 | 60 | 1.2 | 1,517 |
| 2018 | 7,975 | 0.662 | 60 | 1.2 | 2,640 |
| 2019 | 12,197 | 0.662 | 60 | 1.2 | 4,037 |
| 2020 | 17,341 | 0.662 | 60 | 1.2 | 5,740 |
| 2021 | 23,258 | 0.662 | 60 | 1.2 | 7,698 |
| 2022 | 30,137 | 0.662 | 60 | 1.2 | 9,975 |

| | | | | | |
|---|---|---|---|---|---|
| 2023 | 37,507 | 0.662 | 60 | 1.2 | 12,415 |
| 2024 | 46,647 | 0.662 | 60 | 1.2 | 15,440 |
| 2025 | 57,317 | 0.662 | 60 | 1.2 | 18,972 |
| 2026 | 72,448 | 0.662 | 60 | 1.2 | 23,980 |
| 2027 | 91,867 | 0.662 | 60 | 1.2 | 30,408 |
| 2028 | 115,634 | 0.662 | 60 | 1.2 | 38,275 |
| 2029 | 143,992 | 0.662 | 60 | 1.2 | 47,661 |
| 2030 | 177,323 | 0.662 | 60 | 1.2 | 58,694 |

**Table A.4.18** – Data for calculating electricity generation ($EG_{PJ,y}$)

*Notes:*
** Palo Alto Utilities Advisory Commission.*
***Kelleher, 2007. BioCycle V. 48, No. 8, p.51; also EBMUD March 2008; also Ostrem, 2004 Greening Waste: A Anaerobic Digestion for Treating the Organic Fraction of Municipal Solid Wastes.*

Electricity consumption for handling waste through anaerobic digestion is calculated based on a case study on energy balances conducted by Zhang, Y (2013). A 500m$^3$ anaerobic digestion system will consume:

| Equipment | Electricity capacity (kW) | Operating time (hour/day) | Electricity consumption (kWh/year) |
|---|---|---|---|
| Reception tank mixer | 3.0 | 0.64 | 701 |
| Feedstock macerator | 2.2 | 1.75 | 1,405 |
| Digester feed pump | 3.0 | 1.75 | 1,916 |
| Digester discharge pump | 3.0 | 1.75 | 1,916 |
| Digester mixing pump | 2.2 | 7.25 | 5,822 |
| Heating pump | 0.5 | 8.0 | 1,460 |
| Total | 13.9 | 21.14 | 13,220 |

**Table A.4.19** – Data for calculating electricity consumption of a 500m$^3$ anaerobic digestion system

According to Decision 88/2008/QDD-UBND of Ho Chi Minh city regulating hygiene and environmental protection fees for solid waste, conversion factor from 1m$^3$ of solid waste is around 420 tons. Therefore, electricity for handling 1 ton of solid waste through AD will be as follows:

| Handling capacity (m$^3$) | Time for digesting (day) | Amount of waste digested in 1 year (ton) | $SEC_{AD,y}$ (kWh/ton) |
|---|---|---|---|
| 500 | 30 | 6,083 | 2.17 |

**Table A.4.20** – Data for calculating electricity consumption per ton of waste handled through AD treatment

The amount of solid waste used for AD processing may include food, garden, paper, wood, textile and nappy wastes. The figures are synthesized in the table below:

| Year | $Q_y$ (ton) | $SEC_{AD,y}$ (kWh/ton) | $EF_{EL,y}$ (t CO2/MWh)* | $EG_{PJ,y}$ (MWh/year) | $PE_{power,y}$ (t $CO_2$) |
|---|---|---|---|---|---|
| 2016 | 165,548 | 2.17 | 0.5323 | 643 | -151 |
| 2017 | 276,946 | 2.17 | 0.5323 | 1,517 | -487 |
| 2018 | 410,958 | 2.17 | 0.5323 | 2,640 | -930 |
| 2019 | 570,737 | 2.17 | 0.5323 | 4,037 | -1,490 |

| | | | | | |
|---|---|---|---|---|---|
| 2020 | 759,696 | 2.17 | 0.5323 | 5,740 | -2,178 |
| 2021 | 959,456 | 2.17 | 0.5323 | 7,698 | -2,990 |
| 2022 | 1,194,553 | 2.17 | 0.5323 | 9,975 | -3,930 |
| 2023 | 1,470,409 | 2.17 | 0.5323 | 12,415 | -4,910 |
| 2024 | 1,793,269 | 2.17 | 0.5323 | 15,440 | -6,147 |
| 2025 | 2,169,888 | 2.17 | 0.5323 | 18,972 | -7,592 |
| 2026 | 2,841,182 | 2.17 | 0.5323 | 23,980 | -9,483 |
| 2027 | 3,618,577 | 2.17 | 0.5323 | 30,408 | -12,006 |
| 2028 | 4,516,637 | 2.17 | 0.5323 | 38,275 | -15,157 |
| 2029 | 5,552,101 | 2.17 | 0.5323 | 47,661 | -18,957 |
| 2030 | 6,742,729 | 2.17 | 0.5323 | 58,694 | -23,454 |

**Table A.4.21** – Data for calculating project emissions from electricity consumption and generation

* Researching and assessing emission factor of Viet Nam electricity grid (MONRE, 2014).

The results of baseline and project emissions for anaerobic digestion are presented in the following table:

| Year | $BE_{CH4,SWD,y}$ (t $CO_2$e) | $BE_{combustion,y}$ (t CH4) | $PE_{combustion,y}$ (t $CO_2$e) | $GWP_{CH4}$ | $PE_{AD,y}$ (t $CO_2$e) | $PE_{power,y}$ (t $CO_2$e) | $ER_{AD,y}$ (t $CO_2$e) |
|---|---|---|---|---|---|---|---|
| 2016 | 51,098 | 1,942 | 9,749 | 25 | 12297 | -151 | 38,952 |
| 2017 | 120,586 | 4,582 | 23,002 | 25 | 29038 | -487 | 92,035 |
| 2018 | 209,880 | 7,975 | 40,035 | 25 | 50540 | -930 | 160,270 |
| 2019 | 320,974 | 12,197 | 61,229 | 25 | 77278 | -1,490 | 245,186 |
| 2020 | 456,341 | 17,341 | 87,052 | 25 | 109868 | -2,178 | 348,651 |
| 2021 | 612,062 | 23,258 | 116,755 | 25 | 147367 | -2,990 | 467,685 |
| 2022 | 793,075 | 30,137 | 151,288 | 25 | 190938 | -3,930 | 606,067 |
| 2023 | 987,016 | 37,507 | 188,285 | 25 | 237626 | -4,910 | 754,300 |
| 2024 | 1,227,542 | 46,647 | 234,168 | 25 | 295535 | -6,147 | 938,154 |
| 2025 | 1,508,359 | 57,317 | 287,731 | 25 | 363165 | -7,592 | 1,152,786 |
| 2026 | 1,906,536 | 72,448 | 363,689 | 25 | 459025 | -9,483 | 1,456,994 |
| 2027 | 2,417,549 | 91,867 | 461,172 | 25 | 582046 | -12,006 | 1,847,509 |
| 2028 | 3,042,997 | 115,634 | 580,483 | 25 | 732630 | -15,157 | 2,325,524 |
| 2029 | 3,789,287 | 143,992 | 722,840 | 25 | 912327 | -18,957 | 2,895,917 |
| 2030 | 4,666,400 | 177,323 | 890,161 | 25 | 1123486 | -23,454 | 3,566,368 |

**Table A.4.22** – Emission reductions from anaerobic digestion conversion.

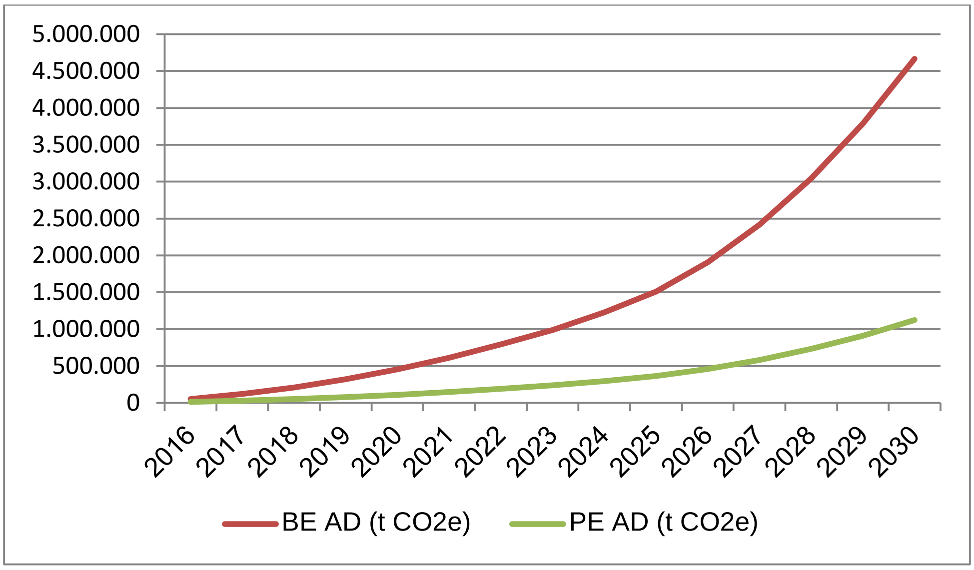


**Figure A.4.5** – Baseline emissions and project emissions from anaerobic digestion under the NAMA scenario.