Kingdom of Bhutan

TECHNOLOGY NEEDS ASSESSMENT AND TECHNOLOGY ACTION PLANS FOR CLIMATE CHANGE MITIGATION

"March 2013"

National Environment Commission
Royal Government of Bhutan

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Disclaimer

This document is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP Risoe Centre (URC) in collaboration with the Regional Centre (from the corresponding region), for the benefit of the participating countries. The present report is the output of a fully country-led process and the views and information contained herein is a product of the National TNA team, led by the National Environment Commission, Royal Government of Bhutan.

Bhutan Technology Needs Assessment Project Team

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AIT Asian Institute of Technology

FOREWORD

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Royal Government of Bhutan

PRIME MINISTER

28 March, 2013.

Foreword

Bhutan, with its commitment to preserve the natural environment, has been actively participating in the fight against one of the most pressing challenges of the current times, the climate change. The country has undertaken the Technology Needs Assessment process to identify, evaluate, and prioritize technologies that fit in the overall development context of the nation while allowing the country to adapt to and mitigate climate change. At the Conference of Parties (COP) 14 in 2008, the Poznań Strategic Programme on Technology Transfer was adopted as a step towards *scaling up the level of investment in technology transfer in order to help developing countries address their needs for environmentally sound technologies*. As part of this programme, in 2010, on behalf of Global Environment Facility (GEF), the United Nations Environment Programme (UNEP) started the implementation of Technology Needs Assessment (TNA) for 36 countries.

Taking forward its commitment at the international forums, I am pleased that the National Environment Commission (NEC) Secretariat has completed the Technology Needs Assessment for Climate Change (TNA) and that it led to the formulation of a Technology Action Plan (TAP) for implementation of the prioritized technologies for adaptation and mitigation. These initiatives fit in the larger scheme of things that we are pursuing for low-carbon and climate-resilient development and will contribute to the development of the 11th Five Year Plan of the country, to be finalized soon.

As a party to the UNFCCC, Bhutan is fully committed to developing and implementing policies, programmes and projects to address the many challenges posed by climate change. We have also adopted a new Economic Development Policy in 2010, which embraces the concept and principles of green economic development. We are now formulating a national strategy for low-carbon and climate-resilient development.

Application of collective knowledge and skills is crucial in developing solutions for combating the challenges of climate change. In this regard, I am encouraged to note that various stakeholders not only from government agencies, but also from the civil society and private sector have been involved in the TNA process and have contributed extensively in selecting the prioritized technologies, identifying the key barriers to technology development and deployment, preparing the Technology Action Plans for overcoming the identified barriers and identifying the implementable project ideas for each technology. I would like to commend all the individuals and organizations that have contributed to the TNA process particularly, the TNA Taskforce members, the respective government departments and agencies and the National Environment Commission for effectively leading this exercise.

I look forward to seeing the findings and recommendations of the TNA project feed into the national strategy for combating climate change in Bhutan.

Tashi Delek !

(Jigmi Y. Thinley)
Prime Minister, and
Chairman of NEC

PREFACE

Given Bhutan's vulnerability to the impacts of climate change, the nation has accorded climate change a high priority. The nation's commitment to remain carbon neutral while ensuring overall social-economic development reflects, its vision to address the challenges of climate change and move towards a sustainable future.

The challenges of addressing climate change, particularly by developing and least developed countries have been recognized at various international forums. Technology transfer as a vital instrument to overcome these challenges has been identified by the UNFCCC in Article 4.5. Subsequently, the need and importance of technology transfer has been reiterated at various Conference of Parties (COP) of the UNFCCC. At COP 14 in 2008, the Poznań Strategic Programme on Technology Transfer was adopted as a step towards *scaling up the level of investment in technology transfer in order to help developing countries address their needs for environmentally sound technologies*. As part of this programme, in 2010, on behalf of Global Environment Facility (GEF), the United National Environment Programme (UNEP) started the implementation of Technology Needs Assessment (TNA) for 36 countries.

Bhutan has undertaken the TNA process to identify, evaluate, and prioritize technologies that fit in the overall development context of the nation while allowing the country to mitigate climate change. The National Environment Commission Secretariat is the nodal agency for the TNA project and has constituted a TNA Task Force involving representatives from various sectors to provide inputs to the TNA and most importantly in preparing the Technology Action Plan for identified technologies.

The TNA report is the first in the series of four reports to be submitted to UNEP. The report begins with the introduction about the TNA project and how it fits in the overall context of Bhutan's development and climate change priorities. The second chapter describes the institutional framework of the TNA process. The third chapter focuses on prioritization of sectors and describes the process adopted and the results. Subsequent chapters explain the process and results of prioritization of technologies for each of the prioritized sectors. The entire process to arrive at prioritized sectors and technologies has been country-driven and highly consultative involving a number of stakeholders from various agencies in the government, civil society and private sector.

Ugyen Tshewang, PhD
Secretary
National Environment Commission

ACKNOWLEDGMENT

The National Environment Commission Secretariat (NECS) sincerely acknowledges the Global Environment Facility (GEF) for the financial support provided for the Technology Needs Assessment (TNA) project in Bhutan. We would also like to thank UNEP Risø Centre (URC) and Asian Institute of Technology (AIT) for their technical guidance during the course of the TNA. The NECS is particularly grateful to Mr. Gordon Mackenzie, TNA country coordinator for Bhutan, for coordinating all the activities between the NECS, AIT and URC.

We would like to thank all the TNA taskforce members for their valuable contribution in prioritization of sectors and technologies, and for their comments on the draft report.

Further, we express our sincere appreciation to Emergent Ventures India and Norbu Samyul Consulting for facilitating the TNA process and putting together the TNA report.

ABBREVIATIONS

3 Rs	Reduce, reuse and recycle
4Rs	Reduce, reuse, recycle and re-export
AIT	Asian Institute of Technology
BRT	Bus Rapid Transit
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
COP	Conference of Parties
DOL	Direct On-line
EAF	Electric Arc Furnace
ECBC	Energy Conservation Building Code
EVI	Emergent Ventures India
FYP	Five-year plan
GDP	Gross Domestic Product
Gg	Giga grams
GHG	Greenhouse gases
GNH	Gross National Happiness
HVAC	Heating Ventilation and Air-conditioning
IEA	International Energy Agency
IEC	International Electrotechnical Commission
INC	Initial National Communication
LEED	Leadership in Energy and Environmental Design
LRT	Light Rail Transit
LUCF	Land Use Change and Forestry
MCDA	Multi Criteria Decision Analysis
NAPA	National Adaptation Programme of Actions
NEC	National Environment Commission
NECS	National Environment Commission Secretariat
SNC	Second National Communication
TAP	Technology Action Plan
TNA	Technology Needs Assessment
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Carbon
VRM	Vertical Roller Mill

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Part I

Technology Needs Assessments Report

Executive Summary

Bhutan has undertaken Technology Needs Assessment (TNA) to identify, assess and prioritize environmentally sound technologies that will, within national development objectives, reduce the impact of climate change and the rate of greenhouse gas (GHG) emissions in Bhutan. The TNA has subsequently led to the formulation of Technology Action Plan (TAP) to implement the prioritized technologies within the overall framework of sustainable development in the country. The TNA and TAP constitute important processes of the global and national efforts to address development and environmental challenges posed by climate change.

The TNA process in the country was steered by the National Environment Commission (NEC) which served as the National Steering Committee for the TNA. The NEC is chaired by the Honourable Prime Minister of Bhutan and made up of high-level representations from various key ministries, civil society and private sector. The TNA coordinating agency was the NEC Secretariat (NECS), which is headed by the Environment Secretary. Mr. Karma Tshering, Programme Officer of the Policy and Programming Services in NECS, was the National TNA Coordinator.

A National Task Force for TNA had also been formed primarily for stakeholder involvement and inputs in the TNA process. The Task Force has a total of 35 members representing various agencies in the government, civil society and private sector. Their areas of work include agriculture, forestry, industry, public works and roads, hydropower and renewable energy, nature conservation, water resources management, waste management, transport management, tourism and hospitality, training and education, and construction. From among the Task Force members, two Task Force leaders have been appointed – one for adaptation and the other for mitigation.

In addition, Emergent Ventures India (EVI) was engaged as the international consultant to carry out and complete the TNA and subsequently formulate TAP. The international consultant was supported by the national consultant, Norbu Samyul Consulting, with rich experience and expertise in the field of environmental management and planning.

The TNA of Bhutan at all stages has followed a transparent consultative process, involving a wide range of key stakeholders in the government, civil society and private sector. The first step in the formulation of Bhutan's TNA was sector prioritization which was done using an iterative online scoring process in which twenty members of the TNA taskforce participated. Using multiple criteria, three top priority sub-sectors were identified for mitigation of climate change. These were solid waste disposal on land, transport and manufacturing industries and construction.

Within each of these sub-sectors, technologies were prioritized against a set of criteria, vis-à-vis, benefits (contribution to economic, environmental and social development priorities; excluding climate change related benefits); relevance to climate change mitigation (GHG reduction potential); appropriateness (technology maturity and potential scale of utilization) and costs, each of which was given a specific scoring weightage. The entire process of criteria weighting and technology prioritization was done using Multi-Criteria Decision Analysis (MCDA) framework at the stakeholder consultation workshop held in Paro, Bhutan from 6 to 8 February 2012. Twenty-two members of the TNA taskforce participated in this workshop.

The workshop led to a list of priority technologies in each of the three sub-sectors. However, the final prioritized technologies for each sub-sector were arrived at after further assessment of technologies on the basis of costs in addition to comprehensive discussions with sectoral experts and other stakeholders.

The results of sub-sector and technology prioritization are given in Table 1.

Table 1: Final prioritized sub-sectors and technologies

Prioritized sub-sectors	Prioritized technologies
Solid waste disposal on land	▪ Composting ▪ Reduce, reuse, recycle (3 Rs) ▪ Anaerobic digestion/ biogas plants

Transport (Fuel combustion activities),	▪ Transport Management Systems ▪ Non-motorized Transport ▪ Mass Transit
Manufacturing industries and construction (Fuel combustion activities)	▪ Construction of energy efficient infrastructure (Energy efficiency in construction) ▪ Improvement in process-related energy efficiency (Cement, iron and steel and ferro alloy industries) ▪ High efficiency electric motors (Cement, iron and steel and ferro alloy industries)

Further, it was suggested by the TNA Task Force members and technical assistance team at the UNEP that it may be practical to conduct in-depth and focused barrier analysis, enabling frameworks and technology action plans for only one technology per sub-sector, rather than for all technologies. Therefore, it was decided that one technology from among the three prioritized technologies in each sub-sector be selected for preparation of barrier analysis, enabling framework and technology action plan reports.

In this regard, discussions with TNA Taskforce members and representatives of the concerned ministries were carried out and one technology from each sub-sector was finalized for the preparation of TAPs. The technologies finalized for each sector are given in Table 2.

Table 2: Finalized technologies for preparation of TAPs

Prioritized sub-sector	**Finalized technology for barrier analysis, enabling framework and TAP**
Solid waste disposal on land	Composting
Transport (Fuel combustion activities)	Intelligent Transport System
Manufacturing industries and construction (Fuel combustion activities)	Waste Heat Recovery

Chapter 1. Introduction

1.1. About the TNA Project

Bhutan signed the United Nations Framework Convention on Climate Change (UNFCCC) at the United Nations Conference on Environment and Development in Rio de Janeiro in June 1992. Subsequently, it ratified the Convention in August 1995 through the National Assembly. As a Party to the UNFCCC, the country is fully committed to addressing climate change and attend environmental and development challenges through international mechanisms as well as national initiatives.

Article 4.5 of the UNFCCC identifies technology transfer as a key mechanism for addressing climate change, and requires developed countries to support technology development and utilization in developing countries. In order to operationalize Article 4.5, Parties agreed to introduce a mechanism known as Technology Needs Assessment (TNA) for climate change. Over the years, the importance of TNA was emphasized at various Conferences of Parties (COPs) of the UNFCCC.

At COP 7 in Marrakech, November 2001, the international community took the decision to encourage developing country Parties "*to undertake assessments of country-specific technology needs, subject to the provision of resources, as appropriate to country-specific circumstances".*

The COP 13 (Bali, December 2007) further reinforced the importance of TNA. The Bali Plan of Action, an outcome of COP 13, emphasized enhanced actions and provision of financial resources to enable technology development and transfer. At COP 14 (Poznan, December 2008), the Poznan Strategic Programme on Technology Transfer was adopted as a step towards scaling up the level of investment in technology transfer in order to help developing countries address their needs for environmentally sound technologies.

Finally, at COP 15 (Copenhagen, December 2009) the future establishment of a Technology Mechanism was suggested *"…to accelerate technology development and transfer in support of action on adaptation and mitigation that will be guided by a country-driven approach and be based on national circumstances and priorities."*

Concurrent with the growing international impetus on developing and using technologies for mitigation of, and adaptation to, climate change, Bhutan has been progressively undertaking initiatives to pursue a low-emission and climate-resilient economic development approach which is congruent with its overarching development philosophy of Gross National Happiness (GNH).

As a Party to the UNFCCC, Bhutan submitted its Initial National Communication (INC) in 2000 The INC enabled the country for the very first time to establish an inventory of greenhouse gas (GHG) emissions by sources and sequestration by sinks, and identify climate change vulnerabilities and adaptation measures. The Second National Communication (SNC), submitted in 2011, presents an updated GHG inventory, and describes mitigation measures, climate change vulnerabilities and a wide range of adaptation options across the various development sectors.

A National Adaptation Programme of Action for Climate Change (NAPA) was produced in 2006, outlining among other things priority projects for adaptation to climate change. On the world stage, Bhutan made the landmark declaration to remain a carbon-neutral economy at COP 15. To this end, it is developing a national strategy and action plan for low-carbon development. A new Economic Development Policy, embedded with green economy concept and principles, has also been adopted in 2010.

It is in the above context of global initiatives and national efforts to address climate change challenges that Bhutan has undertaken this TNA to identify, assess and prioritize environmentally sound technologies that will, within national development objectives, reduce the impact of climate change and the rate of GHG emissions in Bhutan. The TNA has subsequently led to the formulation of a Technology Action Plan (TAP) to implement the prioritized technologies within the overall framework for sustainable development in the country.

1.2. Existing national policies related to climate change and development priorities

With respect to climate change, the country's policies are geared towards low-carbon and climate-resilient development. It fully recognizes that climate change poses serious environmental and development challenges to the world at large but more increasingly to countries like Bhutan, where key economic sectors such as hydropower and agriculture are extremely climate-dependent and the rugged fragile mountain ecosystem is highly vulnerable to climate change. This national outlook on climate change is in line with the country's overall principle for sustainable development defined by the overarching development philosophy of GNH.

The GNH philosophy rests on four pillars, namely: (a) equitable socio-economic development; (b) environmental sustainability; (c) promotion and preservation of culture; and (d) good governance. The GNH philosophy advocates that development should be planned and implemented in a holistic and balanced manner, integrating social, spiritual, economic, and environmental wellbeing in ways that are mutually-reinforcing. It emphasizes that development pursuits should take place within the limits of environmental sustainability and be carried out without impairing the biological productivity and diversity of the natural environment. The Constitution of the Kingdom of Bhutan, formally adopted in July 2008, enshrines GNH as a state policy and spells out the duties and rights of the parliament, the government and the people to safeguard and enhance the environment.

The new Economic Development Policy of Bhutan, launched in 2010, has been formulated with the vision "to promote a green and self-reliant economy sustained by an IT-enabled knowledge society guided by the GNH philosophy." Its key strategies include diversifying the economic base with minimal ecological footprint; harnessing and adding value to natural resources in a sustainable manner; promoting Bhutan as an organic brand; and reducing dependency on fossil fuel especially with respect to transportation.

The Five-Year Plan (FYP), since its advent in 1961, has been the main programmatic vehicle for the implementation of the country's development policies and plans. Recent FYPs feature poverty reduction as the overarching development objective and environmental conservation as a cross-cutting development theme across various sectors and programmes. Guidelines for mainstreaming environment, climate change and poverty issues in the formulation and implementation of FYPs at central, sectoral, and local levels have been developed and are being disseminated through training workshops for their application in the upcoming Eleventh FYP.

While the aforesaid policy and programmatic instruments provide the overall sustainable development framework within which climate change adaptation and mitigation actions can be developed and implemented, there are also a number of sector-based policies and strategies that aid/ influence the decisions pertaining to identification and selection of technologies for climate change adaptation and mitigation. The key sector-based policies and strategies relevant to the TNA are given in Table 3.

Table 3: Key sector based policies and strategies

Policy Document	Relevance to Climate Change
Bhutan Sustainable Hydropower Development Policy 2008	One of the key objectives of the policy is to develop hydropower as a clean energy to mitigate problems related to global warming and climate change. This includes the reduction of dependency on imported fossil fuels, particularly in the transport sector.
Bhutan Water Policy 2003	Outlines social, technical and institutional measures for management of water resources including hydrometeorology, flood monitoring and warning systems.
Biodiversity Action Plan for Bhutan 2009	BAP 2009 recognizes that biodiversity loss can result in increased GHG emissions while careful management of biodiversity can lead to higher levels of carbon sequestration. It sets out various strategies and actions for the conservation and sustainable use of biodiversity, including protection of natural ecosystems and enhancement of their resilience against climate change.

National Action Programme to combat Land Degradation 2009	Many of the strategies and actions outlined in the NAP have relevance to climate change adaptation and mitigation. These include maintenance of the biological productivity and stability of natural lands and farmlands, soil fertility management with attention to organic methods, irrigation management, and solid waste management.
National Adaptation Programme of Action for Climate Change	NAPA identifies priority activities that respond to the country's urgent needs of adaptation to climate change.
National Forest Policy 2011	Bhutan is a net GHG sequester largely due to its vast forest cover. The National Forest Policy is geared towards sustainable management of forests including the maintenance of the health and vitality of forests and a minimum of 60 percent forest cover (as enshrined in the Constitution).
National Irrigation Policy 2011	Irrigation is seen as an increasingly important measure to adapt to growing uncertainties in rainfall patterns that impact crop production season and crop yields. The policy includes objectives for pursuance of sustainable irrigation infrastructure development and integrated water resources management, and ensuring of reliable and efficient water use for irrigated crop production.
National Framework for Organic Farming 2007	Organic farming systems have much lower GHG emission potential per unit area than conventional farming systems and organically farmed soils have higher carbon sequestration capacity. The National Framework for Organic Farming 2007 defines the vision and principles of Bhutan to develop organic farming as a way of life and to become fully organic by 2020.
Second National Communication to the UNFCCC 2011	The SNC presents an updated GHG inventory and describes mitigation measures, climate change vulnerabilities, and a wide range of adaptation options across the various development sectors.
Transport Policy of Bhutan	The policy among other things is directed towards promoting the use of energy-efficient and less polluting modes of transport as well as improving public transport systems that reduces dependency on private vehicles.

Chapter 2. Institutional arrangement for the TNA and the stakeholders' involvement

2.1. The National TNA Team

TNA Steering Committee and Coordinating Agency

The National Environment Commission (NEC) served as the National Steering Committee for the TNA. The NEC is the government's apex policy body for environmental matters and also functions as the National Climate Change Committee. It is chaired by the Honorable Prime Minister of Bhutan and made up of high-level representations from various key ministries, civil society and private sector. With the support of a secretariat, the NEC provides policy decisions and guidance on matters related to environmentally sustainable development and the institution of policy measures to integrate environmental management in the overall development.

The TNA coordinating agency was the NEC Secretariat (NECS), which is headed by the Environment Secretary. The NECS is also the national focal agency for the UNFCCC. Mr. Karma Tshering, Programme Officer of the Policy and Programming Services in NECS, was the National TNA Coordinator.

TNA Task Force

A National Task Force for TNA had been formed primarily for stakeholder involvement and inputs in the TNA process. The Task Force had a total of 35 members representing various agencies in the government, civil society and private sector. Their areas of work include agriculture, forestry, industry, public works and roads, hydropower and renewable energy, nature conservation, waste management, water resources management, transport management, tourism and hospitality, training and education, and construction. From among the Task Force members, two Task Force leaders had been appointed – one for adaptation and the other for mitigation. Ms. Kunzang Choden, Senior Research Officer in the Ministry of Agriculture and Forests was the adaptation Task Force leader, and Mr. Chhimi Dorji, Deputy Executive Engineer in the Department of Hydro-met Services, was the mitigation Task Force leader.

TNA Consulting Team

Emergent Ventures India (EVI), a leading advisory firm in the area of climate change and sustainable development, had been engaged as the international consultant to carry out and complete the TNA and subsequently formulate TAP. The EVI consultants involved in the TNA are:

- Mr. Aloke Barnwal, Principal Consultant and Team Leader (Energy and Climate) with EVI, holds a Masters of Public Affairs degree from Indiana University Bloomington US with specialization in Public Policy, Environment Policy and Natural Resources Management. He has 12 years of experience in the field of climate change policy, clean energy, natural resources management and rural development.
- Ms. Prima Madan, Senior Consultant with EVI holds a Masters degree in Economics from University of Nottingham, UK. She has over 7 years of research experience in the field of climate change, energy and sustainable development.
- Ms. Ishita Singh, Consultant with EVI, holds a Masters degree in Natural Resources Management from TERI University and over a year of work experience in the field of energy and climate change.

The international consultant is supported by Mr. Ugen P. Norbu, a national consultant with a Masters degree in Integrated Conservation and Development and over 20 years of experience in the field of environmental management and planning.

The institutional arrangement for TNA in Bhutan is explained in Figure 1.

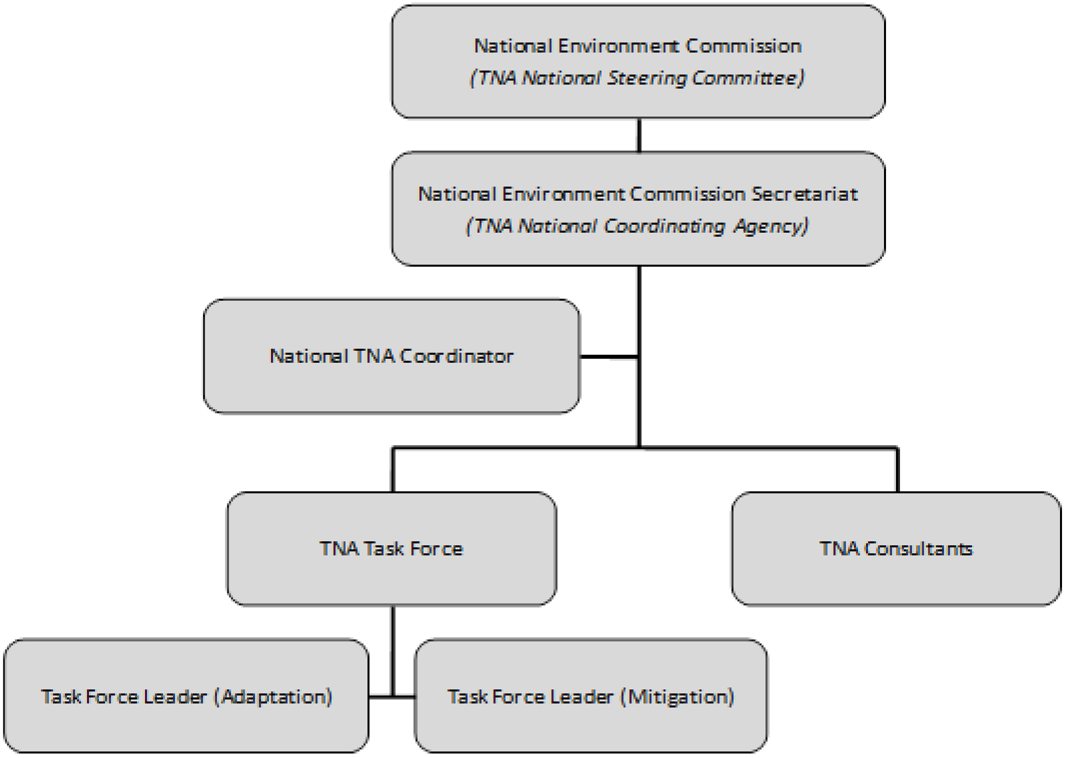

Figure 1: Institutional arrangement for TNA in Bhutan

2.2. Stakeholder engagement process followed in TNA – Overall assessment

The TNA of Bhutan at all stages has followed a transparent consultative process involving a wide range of stakeholders in the government, civil society and private sector. The prioritization of sub-sectors was done using an iterative online scoring process in which twenty members of the TNA taskforce participated. The list of participants is given in Annex II. The scores provided by task force members were collated, analyzed and sent back to them for review. At this stage, participants were free to reconsider and change their scores if they deemed necessary. The scores received at the end of this stage were taken as final scores on the basis of which the sub-sectors were prioritized for mitigation.

After the three top priority sub-sectors were identified, a three day TNA Technology Prioritization Workshop was held in Paro, Bhutan from 6-8 February, 2012. The workshop was attended by 27 people, including the TNA task force members, resource persons from Asian Institute of Technology (AIT) Bangkok and consultants. The list of workshop participants is given in Annex II. The workshop built consensus on the criteria to be used for technology prioritization and their weightage. The criteria included environmental, social and economic benefits, potential to reduce GHG emissions, potential scale of utilization of the technology, and technological maturity.

As a next step, low carbon technology options for each of the priority sub-sectors were identified and their key features were presented to the participants of the workshop. Based on the presentations and ensuing discussions on the technologies, the TNA task force members scored the technologies against the set of criteria decided in the previous step. The criteria related to benefits (excluding climate change related benefits), relevance to climate change mitigation and appropriateness. After the TNA workshop in Paro, further consultations with sectoral experts were carried out and cost was also included as one of the criterion for prioritization. In absence of quantitative data for the cost of identified technologies, qualitative assessment of costs was done with help of TNA task force members and sectoral experts. This led to the final list of prioritized technologies in each of the three sub-sectors for mitigation.

Chapter 3. Sector prioritization

3.1. An overview of sectors, projected climate change, and trends of the different sectors

The GHG inventory 2000, as specified in Bhutan's Second National Communication (SNC) to UNFCCC includes the following five categories of emission sources:

- Energy
- Industrial processes
- Agriculture
- Land use change and forestry (LUCF)
- Waste

According to Bhutan's SNC, the total GHG emissions (excluding LUCF) in 2000 were 1559.56 Gg CO_2e, which includes 270.23 Gg CO_2e from energy; 237.76 Gg CO_2e from industrial processes; 1005.30 Gg CO_2e from agriculture, and 46.27 Gg CO_2e from waste. CO_2 sequestration by the land use and forestry sector in 2000 amounted to 6,309.6 Gg. Total GHG emissions, including LUCF, are estimated to be negative 4,750.04 Gg CO_2e, indicating that Bhutan is a net sink for GHG emissions. The contribution of each of the sectors and their respective subsectors to national GHG inventory is given in Figure 2 and Table 4.

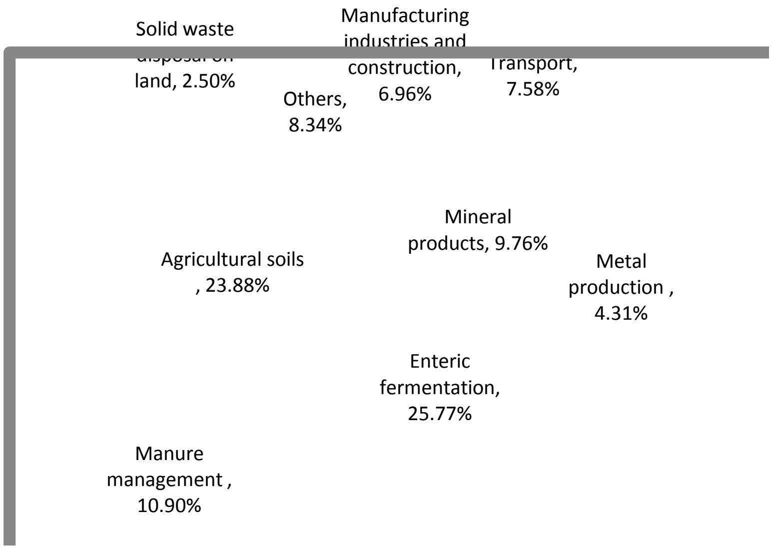

Figure 2: Percentage contribution of various sub-sectors to national GHG

Source: National Environment Commission, 2011

Table 4: Total GHG emissions in Bhutan, 2000 (excluding LUCF)

Sector		**Sub sector**	**GHG emissions (Gg CO_2e)**	**Percentage contribution to the overall GHG emissions (excluding LUCF)**
Energy emissions= 270.23 Gg CO_2e	Fuel combustion activities	Energy industries	0.7	0.04%
		Manufacturing industries and construction	108.5	6.96%
		Transport	118.11	7.58%

		Other sectors	41.64	2.67%
	Fugitive emissions from fuels	Solid fuels	0.21	0.01%
Industry emissions = 237.76 Gg CO_2e	Industrial processes	Mineral products	152.07	9.76%
		Chemical industry	18.47	1.19%
		Metal production	67.22	4.31%
Agriculture emissions = 1005.30 Gg CO_2e		Enteric fermentation	401.65	25.77%
		Manure management	169.80	10.90%
		Rice cultivation	61.15	3.92%
		Agricultural soils	372.10	23.88%
		Field burning of agricultural residues	0.60	0.04%
Waste emissions = 46.27 Gg CO_2e		Solid waste disposal on land	38.90	2.50%
		Wastewater handling	7.38	0.47%

Source: National Environment Commission, 2011

Figure 3 depicts the changes in total GHG emissions for 1994, base year for the Initial National Communication (INC), and 2000. Emissions excluding LUCF for the revised 1994 are higher at 1,413 Gg CO_2e compared to 1,292 Gg CO_2e in the INC; the differences are traced to omission of emissions from rice cultivation, omission of some coal types in industry and construction for energy, and different choices of emission factors for metal industries in the INC (National Environment Commission, 2011).

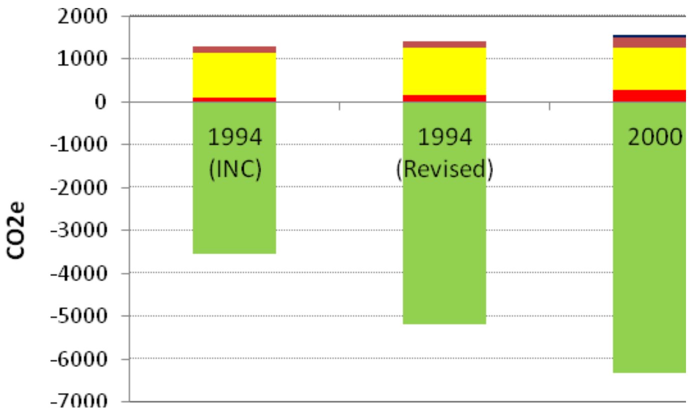

Figure 3: Total GHG emission trend, 1994 & 2000

Source: National Environment Commission, 2011

The total GHG emissions (excluding LUCF) increased by about 10%, from 1,413 Gg CO_2e in 1994 (revised estimates) to 1,560 Gg CO_2e in 2000. This increase has mainly occurred due to increase in industrialization and rapid urbanization. Emissions from manufacturing industries increased from 154.27 Gg CO_2e to 237.76 Gg CO_2e, and emissions from energy combustion increased from 159.95 Gg CO_2e to 270.23 Gg CO_2e. The emissions from agricultural sector are about 8.47% lower in 2000 from 1994 level. Waste related emissions were not estimated in the INC and the revised estimates for 1994 and the contribution of the sector in 2000 is small as compared to other sectors (National Environment Commission, 2011).

3.2. Process, criteria, and results of sector selection

The subsectors with maximum contribution to the nation's GHG emissions are given in Table 5.

Table 5: Sectors/subsectors with maximum contribution to Bhutan's GHG inventory

Sector	Sub sector
Agriculture	Enteric Fermentation Manure Management Agricultural Soils
Energy sector (Fuel combustion activities)	Manufacturing Industries & Construction Transport Mineral Products Metal Production
Waste	Solid Waste Disposal on Land

Source: National Environment Commission, 2011

These preliminary identified sub-sectors were subject to scoring by the members of the TNA taskforce. The scoring was based on the contribution of the sub-sector to the nation's economic, environmental and social priorities as well as its

GHG reduction potential through technological measures. A total weightage of 1 was divided equally among each of these criteria, indicating that each of the criteria was equally important for sector prioritization. The scoring was done on a scale of 0-5 as depicted in Table 6.**Error! Reference source not found.**

Table 6: Sector prioritization framework

Sector	**Contribution to economic development priorities**	**Contribution to environmental development priorities**	**Contribution to social development priorities**	**GHG reduction potential**
Sector 1	Score	Score	Score	Score
Sector 2	Score	Score	Score	Score

Scale of score: 0-5

0: No benefit; 1: Faintly desirable; 2: Fairly desirable;

3: Moderately desirable; 4: Very desirable; 5: Extremely desirable

The entire process of sub-sector prioritization was conducted through an iterative process of scoring using the electronic mail. Twenty members of the TNA taskforce participated in the scoring process. The details of the participants are given in Annex II.

The scores from these participants were collated, analyzed and communicated back to all participants of the first round. The participants were then given an option to reconsider their scores based on other scores and the calculated mean values. Only a few changes in the scoring were received in this round. The mean values of the scores received in the second round from twenty members of the TNA taskforce were taken as the final scores for sub-sector prioritization. The detailed results of the sub-sector prioritization process for mitigation are given in Table 7. As per the final scores, **Solid waste disposal on land, Transport (Fuel combustion activities) and Manufacturing industries and construction (Fuel combustion activities)** are the prioritized sub-sectors for identifying technology needs.

Table 7: Results of sector prioritization

Sector	**Sub-sector**	**Criteria**	**Contribution to economic development priorities**	**Contribution to environmental development priorities**	**Contribution to social development priorities**	**GHG reduction potential**	**Total score**
		Weightage	**0.25**	**0.25**	**0.25**	**0.25**	
Waste	**Solid Waste Disposal on Land**	Score	2.9	4.5	4.1	4	
		Standardized score	8%	100%	100%	75%	
		Weighted score	0.02	0.25	0.25	0.19	**0.71**
Energy sector (Fuel combustion activities)	**Transport**	Score	4.1	3.9	3.4	4.3	
		Standardized score	100%	50%	30%	100%	
		Weighted score	0.25	0.13	0.08	0.25	**0.70**

Energy sector (Fuel combustion activities)	**Manufacturing Industries & Construction**	Score	4	3.7	3.4	4.1	
		Standardized score	92%	33%	30%	83%	
		Weighted score	0.23	0.08	0.08	0.21	**0.60**
Agriculture	**Agricultural Soils**	Score	4.1	3.8	3.7	3.1	
		Standardized score	100%	42%	60%	0%	
		Weighted score	0.25	0.10	0.15	0.00	**0.50**
Industrial processes	**Mineral Products**	Score	3.6	3.7	3.2	3.5	
		Standardized score	62%	33%	10%	33%	
		Weighted score	0.15	0.08	0.03	0.08	**0.35**
Industrial processes	**Metal Production**	Score	3.6	3.6	3.2	3.6	
		Standardized score	62%	25%	10%	42%	
		Weighted score	0.15	0.06	0.03	0.10	**0.35**
Agriculture	**Manure Management**	Score	3.4	3.5	3.6	3.4	
		Standardized score	46%	17%	50%	25%	
		Weighted score	0.12	0.04	0.13	0.06	**0.34**
Agriculture	**Enteric Fermentation**	Score	2.8	3.3	3.1	3.6	
		Standardized score	0%	0%	0%	42%	
		Weighted score	0.00	0.00	0.00	0.10	**0.10**

Chapter 4. Technology prioritization for solid waste disposal on land sub-sector

4.1. GHG emissions and existing technologies of the sector

Greenhouse gas emissions from wastes in Bhutan have been estimated from two sources; solid waste disposal on land (84% of total waste-related emissions in 2000) and domestic and commercial wastewater handling (16% of total waste-related emissions in 2000) (National Environment Commission, 2011). In 2000, GHG, emissions from solid waste were estimated from ten urban areas in Bhutan (National Environment Commission, 2011). However most of the emissions were attributed to the two cities of Thimphu and Phuentsholing. According to Bhutan's SNC, in 2000, GHG emissions from the waste sector in Bhutan accounted for 2.9% of the total national emissions. Emissions in waste sector have steadily risen since the past decade, especially from solid waste disposal on land (Figure 4**Error! Reference source not found.**). This increase in waste generation has been primarily because of rapid rates of urbanization, rural-urban migration, changing consumption pattern and high population growth rate (National Environment commission, 2011).

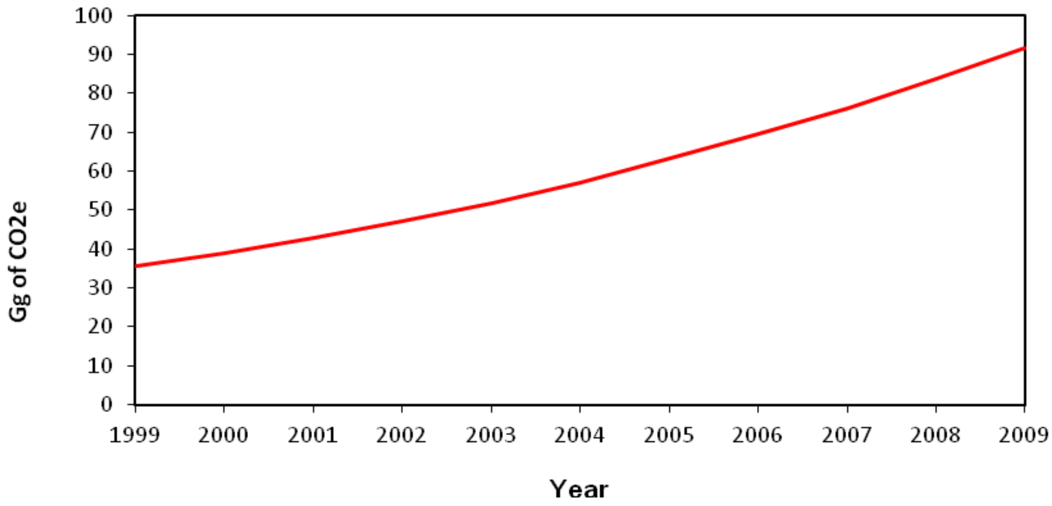

Figure 4: Emissions from solid waste disposal on land

Source: National Environment Commission, 2011

At present, the waste management system in Bhutan is guided by the Waste Prevention and Management Act, 2009 and is based on three guiding principles of Precautionary principle; Polluter pays principle and Principle of 3 Rs (reduce, reuse, recycle) and Waste Minimization Hierarchy. Bhutan has started exploring public-private partnership projects to improve solid waste management systems. In addition, the country has a few landfills where most of the waste is disposed. Also, a compost plant has been installed in Thimphu.

Other technology options that can reduce GHG emissions from the sub-sector are listed in Table 8**.**

Table 8: Technology options for reducing GHG emissions from solid waste disposal on land sub-sector

1.	Advanced paper recycling
2.	Aerobic biological treatment (Composting)
3.	Anaerobic biological treatment (Anaerobic digestion)
4.	Bioplastics
5.	Biorefinery

6.	Combustion of Municipal Solid Waste for District Heat or Electricity
7.	Gasification of Municipal Solid Waste for Large-Scale Electricity/Heat
8.	Methane capture at landfills for electricity and heat
9.	Waste management: increased recycling of products, components and materials

4.2. An overview of possible mitigation technology options in the sector and their mitigation benefits

A Technology Prioritization Workshop was held in Paro, Bhutan where a number of technology options for the sub-sector were discussed and debated. Extensive discussions lead to a preliminary list of technologies as given in Table 9 **Error! Reference source not found.**.

Table 9: Potential technology options for solid waste disposal on land sub-sector in Bhutan

I.	Reduce, reuse, recycle and re-export
II.	Composting
III.	Waste-water treatment
IV.	Landfill gas capture
V.	Combustion of municipal solid waste (for electricity/heat)
VI.	Gasification of municipal solid waste (for electricity/heat)
VII.	Medical waste incineration
VIII.	Anaerobic digestion/ Biogas

There is a significant potential to reduce GHG-emissions through the technologies listed in Table 9**Error! Reference source not found.**. For instance, through the implementation of the four Rs (reduce, reuse, recycle and re-export) and other technologies such as composting, a lot of waste that would be generated and disposed on land is avoided, thereby avoiding the associated methane emissions. Further, the GHG impact of the production of other waste categories, such as old washing machines, computers, mobile phones, etc. can be significantly reduced by reusing them or formulating them with a view to promote durable, re-usable and recyclable products.

Waste-to-energy projects such as incineration, combustion, gasification or landfill gas capture prevent the emissions of methane (which is 25 times more potent a GHG than CO_2) and other pollutants from landfills into the atmosphere. Rather, they convert the methane to energy that can be used to generate heat or electricity. The energy generated from these projects replaces the fossil fuel-based capacity contributing to even further reduced emissions.

4.3. Criteria and process of technology prioritization

MCDA was used to prioritize technologies through a process that was country-driven, participatory and involved a number of stakeholders. A three day workshop for criteria weighting and technology prioritization was held at Paro, Bhutan from 6 to 8 February 2012 where 22 members of the TNA taskforce participated. The list of participants is given in Annex II.

Two rounds were followed for criteria weighting and technology prioritization. In the first stage, cost was not considered as a criterion for prioritization of technologies. In the next round, cost was considered as a criterion in addition to the criteria used in the first round[1]. In other words, a two stage MCDA was done for technology prioritization: one without costs as a criteria and the other with cost as a criteria. The results of both MCDA were analyzed by the TNA taskforce to understand the impact of cost criterion on the list of prioritized technologies. Based on the two results, further stakeholder discussions took place. For all the sectors, the results of MCDA with cost as a criterion were taken as final results. These results were agreed upon by the TNA Task Force.

Criteria weighting

Extensive discussions among the workshop participants led to the finalization of criteria and their scope for technology prioritization. The criteria were initially categorized under three broad heads namely benefits (excluding climate change related benefits) (contribution to economic, environmental and social development priorities); relevance to climate change mitigation (GHG reduction potential) and appropriateness (technology maturity and potential scale of utilization). The list of criteria and their scope is given in Table 10.

Table 10: Criteria, sub-criteria and their scope used for technology prioritization

Criteria	**BENEFITS (EXCLUDING CLIMATE CHANGE RELATED BENEFITS)**			**RELEVANCE TO CLIMATE CHANGE MITIGATION**	**APPROPRIATENESS**		**COSTS**
Sub-Criteria	Contribution to economic development priorities	Contribution to environment development priorities	Contribution to social development priorities	GHG reduction potential	Potential scale of utilization	Technology maturity	Cost
Scope of the criteria	▪ Job creation ▪ Improved livelihoods ▪ Enhanced energy security ▪ Overall contribution to GDP	▪ Improved air, water and soil quality ▪ Conservation of bio-diversity	▪ Cultural acceptance ▪ Equitable development ▪ Improved health conditions ▪ Enhanced food security ▪ Minimal impact on vulnerable groups	Reduction in GHG emissions through application of the identified technologies/ measures	Market and implementation potential in Bhutan	Status of the technology	Approximate capital and operation and maintenance cost for implementation of the technology

Based on extensive discussions among TNA Task Force members, it was decided that each sub-criteria should be given different weights. Therefore, members were requested to score each sub-criterion on a scale of 0 to 5 as given in Table 11**Error! Reference source not found.**. The Task Force members decided to take mean values of the scores of each member and build a consensus on it. The mean values of each of the sub-criteria were divided by the sum total of mean values of all the sub-criteria to arrive at weightages for each sub-criteria. Further discussions on each sub-criterion were held during the workshop to allow consensus to be built. Final sub-criteria and their weights for technology prioritization are given in Table 12.

[1] Many members of the TNA Task Force were of the opinion that cost is a barrier to the implementation of technologies and can be addressed through various means. However, some felt that it was important to understand the implication of costs for technology implementation. Also, the TNA guidebook prescribes costs as a criterion for technology prioritization. Therefore, two rounds of MCDA for prioritization of technologies were done, one without cost as a criterion and the other with cost as a criterion.

Table 11: Scale used for criteria weighting and technology prioritization

0: No benefit	1: Faintly desirable	2: Fairly desirable
3: Moderately desirable	4: Very desirable	5: Extremely desirable

Table 12: Final criteria weighting used for technology prioritization for solid waste disposal on land sub-sector

Criteria	**BENEFITS (EXCLUDING CLIMATE CHANGE RELATED BENEFITS)**			**RELEVANCE TO CLIMATE CHANGE MITIGATION**	**APPROPRIATENESS**		**COST**
Sub-Criteria	Contribution to economic development priorities	Contribution to environment development priorities	Contribution to social development priorities	GHG reduction potential	Potential scale of utilization	Technology maturity	Cost
Weight-age	0.14	0.17	0.14	0.17	0.13	0.11	0.14

Technology prioritization

In the first round, the participants of the workshop scored each of the technologies in the solid waste disposal on land sub-sector against all the sub-criteria given in Table 12, except costs on a scale of 0-5 (Table 11).

The results of the technology prioritization were presented to all the participants and they were then given an option to change their scores based on the results. Extensive discussions took place between the participants to allow consensus to be built. Mean values of the final scores received were taken as the final scores for technology prioritization against these sub-criteria.

In the next round, scoring of technologies against costs as an additional criterion was done by sectoral experts only based on their qualitative assessment of the capital and operation and maintenance costs of the technologies[2].

Finally, based on the results of MCDA without cost as a criterion and MCDA with cost as a criterion, further stakeholder discussions took place. Discussions on the two results finally led to consensus for the prioritized technologies that resulted from MCDA with cost as a criterion.

4.4. Results of technology prioritization

According to MCDA (with cost as a criterion), composting, 4Rs (reduce, reuse, recycle and re-export), wastewater treatment were the three prioritized technologies. The detailed results are given in Table 13.

[2] Since estimates for cost of technologies in Bhutan were not available, the scoring of technologies against costs as a criterion was done by sectoral experts only based on their expert judgment and qualitative assessment of the capital and operation and maintenance costs of the technologies.

Table 13: Results of technology prioritization for solid waste disposal on land sub- sector

Sub-criteria		Contribution to economic development priorities	Contribution to environmental development priorities	Contribution to social development priorities	GHG reduction potential	Potential scale of utilization	Technology maturity	Costs	Final Score
Technology	**Weightage**	**0.14**	**0.17**	**0.14**	**0.17**	**0.13**	**0.11**	**0.14**	
Composting	Score	3.90	3.90	3.76	3.48	3.71	3.76	4.00	
	Standardized score	100%	80%	100%	83%	96%	100%	100%	
	Weighted score	0.14	0.14	0.14	0.14	0.12	0.11	0.14	**0.93**
Reduce, reuse, recycle, re-export (4 Rs)	Score	3.90	4.10	3.62	3.43	3.76	3.59	4.00	
	Standardized score	100%	100%	80%	78%	100%	78%	100%	
	Weighted score	0.14	0.17	0.11	0.13	0.13	0.09	0.14	**0.91**
Waste-water treatment	Score	3.38	4.00	3.62	3.35	3.10	3.19	2.50	
	Standardized score	58%	90%	80%	69%	39%	29%	50%	
	Weighted score	0.08	0.15	0.11	0.12	0.05	0.03	0.07	**0.62**
Anaerobic digestion/ Biogas plants	Score	3.33	3.24	3.14	3.33	3.14	3.24	3.00	
	Standardized score	54%	10%	13%	67%	43%	35%	67%	
	Weighted score	0.08	0.02	0.02	0.11	0.06	0.04	0.09	**0.41**
Combustion of municipal solid waste (for electricity/heat)	Score	3.38	3.48	3.10	3.48	2.71	3.19	2.50	
	Standardized score	58%	35%	7%	83%	4%	29%	50%	
	Weighted score	0.08	0.06	0.01	0.14	0.01	0.03	0.07	**0.40**
Landfill gas	Score	3.05	3.38	3.10	3.62	2.76	3.05	1.00	

capture	Standardized score	31%	25%	7%	100%	9%	12%	0%	
	Weighted score	0.04	0.04	0.01	0.17	0.01	0.01	0.00	**0.29**
Gasification of municipal solid waste (for electricity/heat)	Score	3.10	3.24	3.05	3.24	2.67	2.95	1.00	
	Standardized score	35%	10%	0%	56%	0%	0%	0%	
	Weighted score	0.05	0.02	0.00	0.09	0.00	0.00	0.00	**0.16**
Medical waste incineration	Score	2.67	3.14	3.38	2.76	2.71	3.14	2.00	
	Standardized score	0%	0%	47%	0%	4%	24%	33%	
	Weighted score	0.00	0.00	0.07	0.00	0.01	0.03	0.05	**0.14**

However, further discussions among stakeholders on the top three technologies led to the substitution of 4 Rs with 3 Rs (reduce, reuse, recycle). This is because it was discussed that when a waste product is exported back to the country where it was initially produced, it only shifts the burden of emissions from one country to the other. Also, it does not have any effect on the global emissions pattern. Further, waste-water treatment as technology option was excluded from the solid waste disposal on land subsector. This is because it was felt that it is a technology option for 'wastewater handling' sub-sector whose contribution to the national GHG inventory is negligible. Thus, anaerobic digestion (biogas plants) came to the third position, replacing waste-water treatment.

Thus, as per the final results **composting, 3Rs and anaerobic digestion (biogas plants)** are the three prioritized technologies for the sub-sector. The final list of prioritized technologies is given in Table 14**Error! Reference source not found.Error! Reference source not found.**, followed by a brief description of each of the three technologies

Table 14: Final prioritized technologies for solid waste disposal on land sub-sector

Final Prioritized technologies
Composting
3 Rs (Reduce, reuse, recycle)
Anaerobic digestion (Biogas plants)

Composting

The term composting is defined as biological degradation under controlled aerobic conditions. The waste is decomposed into CO_2, water and the soil amendment or mulch. In addition, some carbon storage also occurs in the residual compost. Further, the process results in reduced waste stream volume which results in a reduced waste volume going into landfills.

Reduce, reuse, recycle (3Rs)

Reducing, re-using and recycling waste requires a high degree of coordination and organization of the waste management chain. It results in lower volumes of wastes to be disposed on land. Further, recycling can result in a reduction of energy use, and therefore its associated GHG emissions, in the material/product production process. For example, the copper recycling process results in energy savings of up to 85% compared to primary production (European Copper Institute, 2008).

Anaerobic digestion (Biogas plants)

The process of anaerobic digestion is decomposition of biodegradable material by micro-organisms in the absence of oxygen. Three principal products, biogas (used for energy production), nutrient-rich digestate and liquid liquor (used as a fertilizer), are produced through the process of anaerobic digestion. The process prevents methane emissions associated with manure management into the atmosphere. In addition, the energy produced by the biogas facility offsets energy derived from fossil fuels and can therefore help reduce overall quantities of CO_2.

A detailed description of each of these technologies is provided in Annex 1.

4.5. Final prioritized technology for preparation of Technology Action Plan

It was suggested by the TNA Task Force members that it may be practical to conduct in-depth and focused barrier analysis, enabling frameworks and technology action plans for only one technology per sub-sector, rather than for all technologies. Therefore, it was decided that one technology from among the three prioritized technologies in each sub-sector be finalized for preparation of barrier analysis, enabling framework and technology action plan reports.

In this regard, the TNA Taskforce finalized **composting** as the technology for preparation of barrier analysis, enabling framework and technology action plan in the solid waste disposal on land sub-sector. This is also the top technology as per the results of technology prioritization and offers immense scope for widespread implementation, given the government policy vision of going fully organic in agricultural production by 2020.

Chapter 5. Technology prioritization for transport sub-sector

5.1. GHG emissions and existing technologies of the sector

The transport sector in Bhutan is characterized by the dominance of road and air transport. Diesel, gasoline, and aviation turbine fuel are the main fuels consumed in the sector. The number of vehicles is also growing at 9-10% per annum and the consumption of petroleum products for surface transport is likely to grow 3 times the current level of petroleum product consumption by 2020 (Road Safety and Transport Authority, 2007 in National Environment Commission, 2011). International aviation from Bhutan is limited to the Druk Air, the national carrier, which operates two Airbus A319s, and supplemented by one turboprop aircraft on lease. Limited domestic air services with turboprop planes have started since December 2011.

The transport sector is one of the major emission intensive sectors in Bhutan. Emissions from transport have grown consistently from 66.81Gg CO_2in 1995 to 230.36 Gg CO_2 in 2009 (Figure 5) (National Environment Commission, 2011)

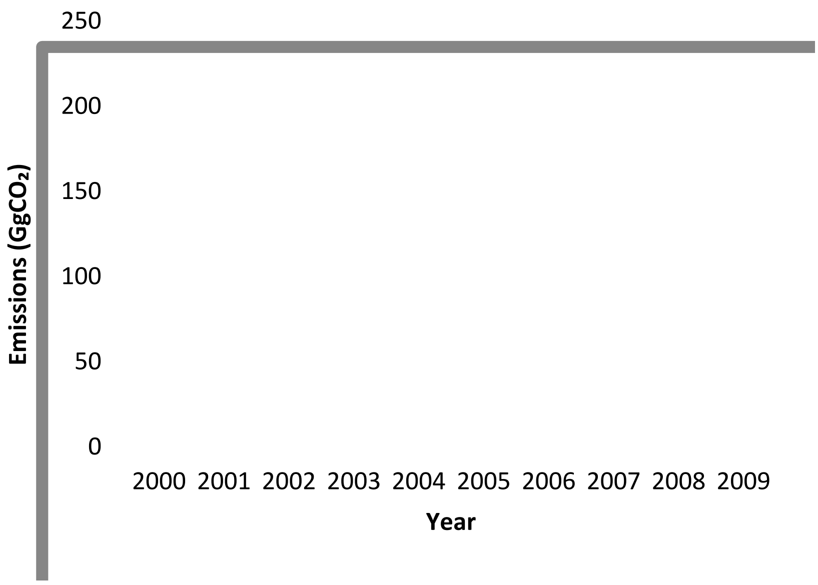

Figure 5: GHG emissions from the transport sub-sector

Source: National Environment Commission, 2011

Bhutan's SNC has listed the following mitigation options for the transport sector:

a. Improving efficiency of petrol and diesel vehicles through standards

b. Introduction of vehicles running on alternative fuel such as compressed natural gas, liquefied petroleum gas and biofuels

c. Electric vehicles

d. Mass transit options (Electric Trolley Bus, Light Rail Transit (LRT), Bus Rapid Transits (BRT))

e. Transport demand management through promotion of non motorized transport, integration of land use and transport planning, car pooling and car sharing practices, parking management and road pricing and congestion charging.

5.2. An overview of possible mitigation technology options and their mitigation benefits

The Technology Prioritization Workshop was held in Paro, Bhutan where a number of technology options for the transport sub-sector were discussed and debated. Extensive discussions led to a preliminary list of technologies as given in Table 15.

The low carbon technologies identified in the workshop discussions can be broadly classified into four categories; avoid (demand elimination), modal shift, road network improvement and technological improvement. Demand elimination and modal shift, both have high potential for improvement in mobility as well as emission reduction. Road network improvement generally brings in temporary improvement in mobility and emission reduction. The effect of improved mobility and reduced emissions is generally reduced due to induced and rebound effect. Technological improvements generally have low improvements in mobility but high potential to bring in emission reductions.

Table 15: Technology options for transport sub-sector

I.	**Avoid (Demand Elimination)**
A.	Private Vehicle Demand Management
B.	Integration of Land Use and Transport Planning
II.	**Modal Shift**
A.	Mass Transit
B.	Non-motorized Transport
III.	**Road Network Improvement**
A.	Intelligent Transport Systems
B.	Infrastructural improvements (shorter networks, gradient etc)
IV.	**Technological Improvement**
A.	Alternative Fuels (Bio-fuels, CNG, LPG)
B.	Electric Vehicles
C.	Up gradation of existing fuel standards
D.	Fuel-efficient cars
E.	Efficient driving techniques

5.3. Criteria and process of technology prioritization

Multi-criteria decision analysis (MCDA) was used to prioritize technologies through a process that was country-driven, participatory and involved a number of stakeholders. A three day workshop for criteria weighting and technology prioritization was held at Paro, Bhutan from 6 to 8 February 2012 where 22 members of the TNA taskforce participated. The list of participants is given in Annex II.

Two rounds were followed for criteria weighting and technology prioritization. In the first round, cost was not considered as a criterion for prioritization of technologies. In the next round, cost was considered as a criterion in addition to the criteria used in the first round[3]. In other words, a two stage MCDA was done for technology prioritization: one without costs as a criteria and the other with cost as a criteria. The results of both MCDA were

[3] Many members of the TNA Task Force were of the opinion that cost is a barrier to the implementation of technologies and can be addressed through various means. However, some felt that it was important to understand the implication of costs for technology implementation. Also, the TNA guidebook prescribes costs as a criterion for technology prioritization. Therefore, two rounds of MCDA for prioritization of technologies were done, one without cost as a criterion and the other with cost as a criterion.

analyzed by the TNA taskforce to understand the impact of cost criterion on the list of prioritized technologies. Based on the two results, further stakeholder discussions took place. Based on the two results, further stakeholder discussions took place. For all the sectors, the results of MCDA with cost as a criterion were taken as final results. These results were agreed upon by the TNA Task Force.

Criteria weighting

Extensive discussions among the workshop participants led to the finalization of criteria and their scope for technology prioritization. The criteria were categorized under four broad heads namely benefits (excluding climate change related benefits; contribution to economic, environmental and social development priorities); relevance to climate change mitigation (GHG reduction potential), appropriateness (technology maturity and potential scale of utilization) and cost. The list of criteria and their scope is given in Table 16.

Table 16: Criteria, sub-criteria and their scope used for technology prioritization

Criteria	BENEFITS (EXCLUDING CLIMATE CHANGE RELATED BENEFITS)			RELEVANCE TO CLIMATE CHANGE MITIGATION	APPROPRIATENESS		COST
Sub-Criteria	Contribution to economic development priorities	Contribution to environment development priorities	Contribution to social development priorities	GHG reduction potential	Potential scale of utilization	Technology maturity	Cost
Scope of the criteria	▪ Job creation ▪ Improved livelihoods ▪ Enhanced energy security ▪ Overall contribution to GDP	▪ Improved air, water and soil quality ▪ Conservation of bio-diversity	▪ Cultural acceptance ▪ Equitable development ▪ Improved health conditions ▪ Enhanced food security ▪ Minimal impact on vulnerable groups	Reduction in GHG emissions through application of the identified technologies/ measures	Market and implementation potential in Bhutan	Status of the technology	Approximate capital and operation and maintenance cost for implementation of the technology

Based on extensive discussions among TNA Task Force members, it was decided that each sub-criteria should be given different weights. Therefore, members were requested to score each sub-criterion on a scale of 0 to 5 as given in Table 17. The Task Force members decided to take mean values of the scores of each member and build a consensus on it. The mean value of each of the sub-criteria was divided by the sum total of mean values of all the sub-criteria to arrive at weightages for each sub-criteria. Further discussions on each sub-criterion were held during the workshop to allow consensus to be built. Final sub-criteria and their weights for technology prioritization are given in Table 18.

Table 17: Scale used for criteria weighting and technology prioritization

0: No benefit	1: Faintly desirable	2: Fairly desirable
3: Moderately desirable	4: Very desirable	5: Extremely desirable

Table 18: Final criteria weighting used for technology prioritization for transport sub-sector

Criteria	**BENEFITS (EXCLUDING CLIMATE CHANGE RELATED BENEFITS)**			**RELEVANCE TO CLIMATE CHANGE MITIGATION**	**APPROPRIATENESS**		**COST**
Sub-Criteria	Contribution to economic development priorities	Contribution to environment development priorities	Contribution to social development priorities	GHG reduction potential	Potential scale of utilization	Technology maturity	Cost
Weight-age	0.14	0.17	0.14	0.17	0.13	0.11	0.14

Technology prioritization

In the first round, the participants of the workshop scored each of the technologies in the transport sub-sector against all the sub-criteria given in Table 18, except costs on a scale of 0-5 (Table 17).

The results of the technology prioritization were presented to all the participants and they were then given an option to change their scores based on the results. Extensive discussions took place between the participants to allow consensus to be built. Mean values of the final scores received were taken as the final scores for technology prioritization against these sub-criteria.

In the next round, scoring of technologies against costs as an additional criterion was done by sectoral experts only based on their qualitative assessment of the capital and operation and maintenance costs of the technologies[4].

Finally, based on the results of MCDA without cost as a criterion and MCDA with cost as a criterion, further stakeholder discussions took place. Discussions on the two results finally led to consensus for the prioritized technologies that resulted from MCDA with cost as a criterion.

5.4. Results of technology prioritization

Intelligent Transport Systems, Non-Motorized Transport and Mass Transit were identified as the prioritized technologies for transport sub-sector. Detailed results of technology prioritization for the sector are given in Table 19, followed by a brief description of the prioritized technologies.

Also, as per discussions on the final results, integration of land use and transport planning, up gradation of existing fuel standards and transport demand management (private vehicles) were removed from the list of technologies as it was discussed and decided that these are more of planning and policy decisions rather than technology options. These could rather work as an enabling framework for the introduction of various technologies in the transport sub-sector.

[4] Since estimates for cost of technologies in Bhutan were not available, the scoring of technologies against costs as a criterion was done by sectoral experts only based on their expert judgment and comparative assessment of the capital and operation and maintenance costs of the technologies.

Table 19: Results of technology prioritization for transport sub-sector

Sub-criteria		Contribution to economic development priorities	Contribution to environmental development priorities	Contribution to social development priorities	GHG reduction potential	Potential scale of utilization	Technology maturity	Costs	Final Score
Technology	**Weightage**	**0.14**	**0.17**	**0.14**	**0.17**	**0.13**	**0.11**	**0.14**	
Intelligent Transport System	Score	3.76	3.81	3.76	3.95	3.57	3.33	2.83	
	Standardized score	100%	50%	100%	48%	100%	29%	62%	
	Weighted score	0.14	0.08	0.14	0.08	0.13	0.03	0.09	**0.70**
Non-Motorized Transport	Score	2.95	3.95	3.62	4.57	3.33	3.62	3.50	
	Standardized score	6%	71%	81%	100%	62%	65%	92%	
	Weighted score	0.01	0.12	0.11	0.17	0.08	0.07	0.13	**0.69**
Mass Transit	Score	3.67	4.05	3.57	3.95	3.33	3.57	2.00	
	Standardized score	89%	86%	75%	48%	62%	59%	23%	
	Weighted score	0.12	0.15	0.11	0.08	0.08	0.06	0.03	**0.63**
Fuel-efficient cars	Score	3.38	3.86	3.43	3.90	3.52	3.62	3.00	
	Standardized score	56%	57%	56%	44%	92%	65%	69%	
	Weighted score	0.08	0.10	0.08	0.07	0.12	0.07	0.10	**0.62**
Integration of Land Use and Transport Planning	Score	3.71	3.86	3.57	3.90	3.33	3.38	2.50	
	Standardized score	94%	57%	75%	44%	62%	35%	46%	
	Weighted score	0.13	0.10	0.11	0.07	0.08	0.04	0.06	**0.59**
Electric/hybrid vehicles	Score	3.38	4.14	3.24	4.29	3.19	3.10	1.83	
	Standardized	56%	100%	31%	76%	38%	0%	15%	

	score								
	Weighted score	0.08	0.17	0.04	0.13	0.05	0.00	0.02	**0.49**
Infrastructural improvements (shorter networks, gradient etc)	Score	3.71	3.76	3.62	3.71	3.38	3.14	1.67	
	Standardized score	94%	43%	81%	28%	69%	6%	8%	
	Weighted score	0.13	0.07	0.11	0.05	0.09	0.01	0.01	**0.47**
Up gradation of existing fuel standards	Score	3.24	3.71	3.24	3.57	3.24	3.38	3.50	
	Standardized score	39%	36%	31%	16%	46%	35%	92%	
	Weighted score	0.05	0.06	0.04	0.03	0.06	0.04	0.13	**0.41**
Transport Demand Management (Private vehicles)	Score	3.24	3.67	3.19	3.95	3.24	3.10	2.67	
	Standardized score	39%	29%	25%	48%	46%	0%	54%	
	Weighted score	0.05	0.05	0.04	0.08	0.06	0.00	0.08	**0.36**
Alternative Fuels (Biofuels, CNG, LPG)	Score	3.14	3.71	3.00	3.76	2.95	3.90	1.50	
	Standardized score	28%	36%	0%	32%	0%	100%	0%	
	Weighted score	0.04	0.06	0.00	0.05	0.00	0.11	0.00	**0.26**
Efficient driving techniques	Score	2.90	3.48	3.00	3.38	3.19	3.10	3.67	
	Standardized score	0%	0%	0%	0%	38%	0%	100%	
	Weighted score	0.00	0.00	0.00	0.00	0.05	0.00	0.14	**0.19**

Intelligent Transport System

Intelligent Transport System (ITS) basically refers to the application of information and communication technologies (ICT) to vehicles and to transport infrastructure. It is primarily an ICT based system designed to improve operational and managerial efficiency of transport system in general and public transport in particular. Some examples of transport management systems include GPS based vehicle tracking systems, online travel information, computerized traffic signaling, etc.

Non-motorized Transport

Non-motorized transportation can be encouraged by improving sidewalks, crosswalks, paths, bicycle lanes and networks, pedestrian oriented land use and building design, traffic calming, streetscape improvements, traffic speed reductions, vehicle restrictions etc. Since non-motorized transport does not make use of motorized vehicles, it prevents the combustion of fossil fuels and results in no GHG emissions.

Mass Transit

Mass transit is one of the main components in a sustainable, low-carbon transport future and covers modes of public transport such as light rail (or trams), BRT and electric trolley buses. Since mass transit moves more people at less cost, it leads to reduced private vehicle use, thereby causing reductions in GHG emissions and traffic congestion.

A detailed description of each of the prioritized technologies is provided in Annex 1.

5.5. Final prioritized technology for preparation of Technology Action Plan

Intelligent Transport System was the technology finalized by the TNA Task Force for the preparation of barrier analysis, enabling framework and technology action plan. This is also the top technology as per the results of technology prioritization. Moreover, this technology is included in the Surface Transport Master Plan of Bhutan, 2007 and is in line with Bhutan's Transport Policy that envisages safe, reliable, affordable, convenient, environment-friendly, responsible and high quality surface transport system in the country by minimizing constraints to the mobility of people, goods and services.

The other two prioritized technologies were not finalized since these are being considered under separate plans and programmes in Bhutan. Promotion of non-motorized transport is being considered (particularly for Thimphu) by the Thimphu Thromde. Further, mass transit, specifically bus rapid transit is being considered under the Bhutan Urban Transport Systems project.

Chapter 6. Technology prioritization for manufacturing industries and construction sub-sector

6.1. GHG emissions and existing technologies of the sector

Bhutan has many small and medium scale industries; however energy consumption in the sector is dominated by few large energy-intensive industries. These energy intensive industries are primarily the iron and steel, ferro-alloy and cement manufacturing units. The SNC has used data from six major energy intensive operating units, namely, Bhutan Ferro Alloys Ltd, Bhutan Calcium Carbide Ltd, Penden Cement Authority Ltd, Druk Cement Company Ltd, Druk Iron and Steel Ltd and Bhutan Steels Ltd for the calculation of GHG emissions from the sector. In 2005, these six energy intensive industries consumed close to 90% of the total sectoral energy consumption and 62% of the country's electricity consumption (National Environment Commission, 2011). Most of the energy requirements of the sector are met through electricity and coal. Other fuels that are used in the sector include furnace oil, kerosene, light diesel oil, and fuel wood (National Environment Commission, 2011).

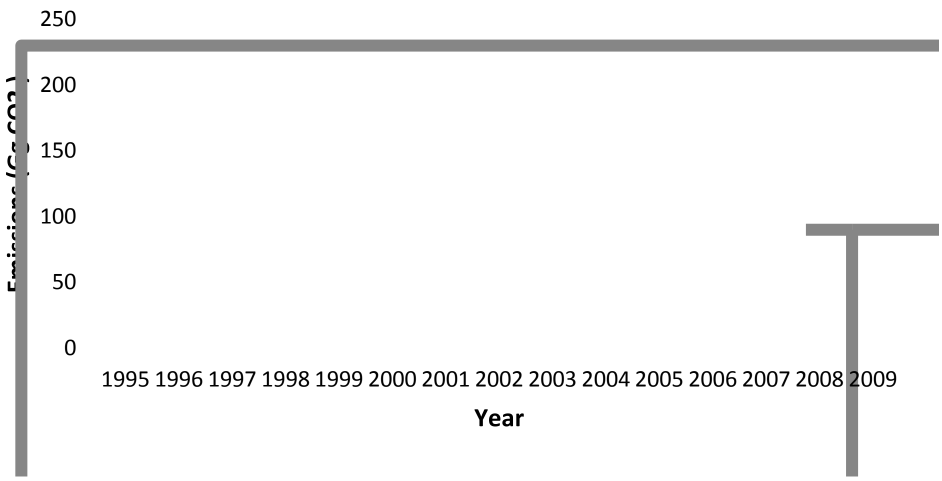

Figure 6: GHG emissions from energy consumption in manufacturing industries

Source: National Environment Commission, 2011

According to Bhutan's SNC, emissions from energy use in manufacturing industries have grown from 81.42 Gg CO_2 in 1995 to 228.10 GgCO_2e in 2009, an increase of approximately three times (Figure 6**Error! Reference source not found.**). The growing trend of emissions from the sector is consistent with the rapid economic development in Bhutan (National Environment Commission, 2011).

The GHG emissions from industries and some of the recommended options for reducing energy consumption in the sector are listed below.

- In 2000, 17237.02 tons of ferro alloys production emitted 67.22 Gg CO_2, accounting for more than one-third of the domestic electricity consumption (National Environment Commission, 2011). As per SNC, application of energy efficient technologies holds great potential for energy savings and thereby emission reductions in the sector. This can be achieved by modification of existing submerged electric arc smelting furnace(s) into open slag bath smelting furnace(s), or by modification of existing co-current rotary kilns into counter-current rotary kilns. Waste heat recovery is another widely applied technology in the ferro alloy industries for improving process efficiency and energy efficiency.
- Cement industry is heavy user of electricity and one of the biggest consumers of coal in Bhutan. In 2000, 293994.67 tons of clinkers production emitted 152.07 Gg CO_2 (National Environment Commission, 2011). Bhutan's SNC lists process optimization, load management, and operational improvement as options that can lead to significant energy saving in the industry. Although these involve marginal financial investment, it is found to have encouraging results in energy saving. Some of the options as listed in the SNC include the following:
    - Plugging of leakages in kiln and pre-heater circuit, raw mill, and coal mill circuits

- Reducing idle running
- Installing improved insulating bricks/blocks in kilns and pre-heaters
- Utilizing hot exit gases in an efficient manner
- Optimizing cooler operation
- Optimum loading of grinding media/grinding mill optimization
- Rationalizing compressed air utilization
- Redesigning of raw mix
- Installing capacitor banks for power factor improvement
- Replacing over-rated motors with optimally rated motors
- Optimizing kiln operation
- Changing from flat belt to V-belt.

Further, use of combustible wastes and biomass briquettes for heat generation in cement plants can lower GHG emissions by replacing the use of fossil fuels and maximizing energy recovery since all the available energy is used directly in the kiln for clinker production. Combustible wastes and biomass briquettes have been successfully used in cement plants in Belgium, France, Germany, the Netherlands and Switzerland where substitution rates of about 35% to 70% have been achieved.

In addition, CO_2 emissions from clinker production can be avoided by increasing the use of blending material like fly ash, gypsum, slag.

Technology options for improvement in process energy efficiency also have the potential of reducing emissions. Comparison between low technologies options and global technology used in the cement industry is presented in Table 20.

Table 20: Technology options for process efficiency improvement in cement industry

Process	Low technology options	Modern plants	Global technology
Grinding	Ball mills with/without conventional classifiers	VRM, Roller presses with dynamic classifier	VRM, Roller presses with dynamic classifier

Pyro-processing	• Wet
	• Semi-dry
	• Dry
	  • 4-stage pre-heater
	  • Conventional cooler
	  • Single channel burner
		Dry
		• 5-6 stage pre-heater
		• High efficiency cooler
		• Multi-channel burner
			Dry
			• 5-6 stage pre-heater
			• High efficiency cooler
			• Multi-channel burner

Blending and storage	Batch-blending silos	Continuous blending silos	Continuous blending , multi chamber, dome silos

Energy consumption levels	90-100 kWh/t cem. 900-1000 kcal/kg cl.	75-85 kWh/t cem. 700-800 kcal/kg cl.	70-80 kWh/t cem. 675-740 kcal/kg cl.
Plant type (TPD)	300-1800	3000-6000	6000-12000

Source: Saxena, N D

- Emissions from iron and steel industry along with ferro alloys have increased significantly since 2006 and surpassed emissions from cement industry (National Environment Commission, 2011). As per the SNC, demand side management in industries can effectively reduce emissions by adopting energy efficiency measures and promoting energy-efficient technologies. Also, process efficiency measures such as use of efficient motors and implementation of waste heat recovery technologies are widely adopted by iron and steel industries for improving energy consumption and increasing production efficiency.

6.2. An overview of possible mitigation technology options in the sector and their mitigation benefits

At the technology prioritization workshop held in Paro, Bhutan a number of technology options for the manufacturing industries and construction sub-sector were discussed and debated. Extensive discussions led to a preliminary list of technologies as given in Table 22. These have been broadly categorized as technologies for all three industries (cement, iron and steel and ferro-alloys), technologies specific to the cement industry and for energy efficiency in the construction sector.

Table 21: Technology options for manufacturing industries and construction sub-sector

I. General (Cement, iron and steel and ferro-alloys)

- **A.** Improvement in process-related efficiency (Waste Heat Recovery)
- **B.** Improved management systems
- **C.** High efficiency electric motors

II. Cement industry

- **A.** Switching over to cleaner fuels (rice husk, waste)
- **B.** Increasing blend in cement production

III. **Energy efficiency in construction**

A. Construction of energy efficient infrastructure

B. Energy conservation codes and standards (a possible cap and trade mechanism)

C. Energy efficient construction equipment and methods

All the technologies given in Table 21 have great potential to reduce the sub-sector's contribution to GHG emissions. For instance, waste heat recovery systems collect steam and waste energy and use it in a steam turbine to convert the energy to electricity. In this case no added fuel is required, thereby saving fossil fuels and reducing the release of related emissions into the atmosphere. Waste heat recovery for power generation in cement plants can save up to 45000 tonnes of CO_2 annually (Saxena, N.D.). Improvement in energy efficiency also result in significant energy savings through reduced requirement of energy and therefore decline in related GHG emissions, Also, switching over to cleaner fuels such as rice husk and waste and increasing blend in cement production lowers the emissions of GHGs by replacing the use of fossil fuels and maximizing energy recovery since all the available energy is used directly in the kiln for clinker production.

6.3. Criteria and process of technology prioritization

MCDA was used to prioritize technologies through a process that was country-driven, participatory and involved a number of stakeholders. A three day workshop for criteria weighting and technology prioritization was held at Paro, Bhutan from 6 to 8 February 2012 where 22 members of the TNA taskforce participated. The list of participants is given in Annex II.

Two rounds were followed for criteria weighting and technology prioritization. In the first stage, cost was not considered as a criterion for prioritization of technologies. In the next round, cost was considered as a criterion in addition to the criteria used in the first round[5]. In other words, a two stage MCDA was done for technology prioritization: one without costs as a criteria and the other with cost as a criteria. The results of both MCDA were analyzed by the TNA taskforce to understand the impact of cost criterion on the list of prioritized technologies. Based on the two results, further stakeholder discussions took place. For all the sectors, the results of MCDA with cost as a criterion were taken as the final results. These results were agreed upon by the TNA Task Force.

Criteria weighting

Extensive discussions among the workshop participants led to the finalization of criteria and their scope for technology prioritization. The criteria were categorized under four broad heads namely benefits (excluding climate change related benefits) (contribution to economic, environmental and social development priorities); relevance to climate change mitigation (GHG reduction potential); appropriateness (technology maturity and potential scale of utilization) and cost. The list of criteria and their scope is given in Table 22.

Table 22: Criteria, sub-criteria and their scope used for technology prioritization

Criteria	BENEFITS (EXCLUDING CLIMATE CHANGE RELATED BENEFITS)	RELEVANCE TO CLIMATE CHANGE MITIGATION	APPROPRIATENESS	COST

[5] Many members of the TNA Task Force were of the opinion that cost is a barrier to the implementation of technologies and can be addressed through various means. However, some felt that it was important to understand the implication of costs for technology implementation. Also, the TNA guidebook prescribes costs as a criterion for technology prioritization. Therefore, two rounds of MCDA for prioritization of technologies were done, one without cost as a criterion and the other with cost as a criterion.

Sub-Criteria	Contribution to economic development priorities	Contribution to environment development priorities	Contribution to social development priorities	GHG reduction potential	Potential scale of utilization	Technology maturity	Cost
Scope of the criteria	▪ Job creation ▪ Improved livelihoods ▪ Enhanced energy security ▪ Overall contribution to GDP	▪ Improved air, water and soil quality ▪ Conservation of bio-diversity	▪ Cultural acceptance ▪ Equitable development ▪ Improved health conditions ▪ Enhanced food security ▪ Minimal impact on vulnerable groups	Reduction in GHG emissions through application of the identified technologies/ measures	Market and implementation potential in Bhutan	Status of the technology	Approximate capital and operation and maintenance cost for implementation of the technology

Based on extensive discussions among TNA Task Force members, it was decided that each sub-criteria should be given different weights. Therefore, members were requested to score each sub-criterion on a scale of 0 to 5 as given in Table 23. The Task Force members decided to take mean values of the scores of each member and build a consensus on it. The mean value of each of the sub-criteria was divided by the sum total of mean values of all the sub-criteria to arrive at weightages for each sub-criteria. Further discussions on each sub-criterion were held during the workshop to allow consensus to be built. Final sub-criteria and their weights for technology prioritization are given in Table 24.

Table 23: Scale used for criteria weighting and technology prioritization

0: No benefit	1: Faintly desirable	2: Fairly desirable
3: Moderately desirable	4: Very desirable	5: Extremely desirable

Table 24: Final criteria weighting used for technology prioritization for manufacturing industries and construction sub-sector

Criteria	**BENEFITS (EXCLUDING CLIMATE CHANGE RELATED BENEFITS)**			**RELEVANCE TO CLIMATE CHANGE MITIGATION**	**APPROPRIATENESS**		**COST**
Sub-Criteria	Contribution to economic development priorities	Contribution to environment development priorities	Contribution to social development priorities	GHG reduction potential	Potential scale of utilization	Technology maturity	Cost

Weightage	0.14	0.17	0.14	0.17	0.13	0.11	0.14

Technology prioritization

In the first round, the participants of the workshop scored each of the technologies in the transport sub-sector against all the sub-criteria given in Table 24, except costs on a scale of 0-5 (Table 23).

The results of the technology prioritization were presented to all the participants and they were then given an option to change their scores based on the results. Extensive discussions took place between the participants to allow consensus to be built. Mean values of the final scores received were taken as the final scores for technology prioritization against these sub-criteria.

In the next round, scoring of technologies against costs as an additional criterion was done by sectoral experts only based on their qualitative assessment of the capital and operation and maintenance costs of the technologies[6].

Finally, based on the results of MCDA without cost as a criterion and MCDA with cost as a criterion, further stakeholder discussions took place. Discussions on the two results finally led to consensus for the prioritized technologies that resulted from MCDA with cost as a criterion.

6.4. Results of technology prioritization

Construction of energy efficient infrastructure (Energy efficiency in construction), improvement in process-related energy efficiency (iron and steel, ferroalloys and cement industry) and High efficiency electric motors (iron and steel, ferroalloys and cement industry) are the prioritized technologies for manufacturing industries and construction sub-sector. Detailed results of technology prioritization for the sector are given in Table 25, followed by a brief description of the prioritized technologies.

Table 25: Results of technology prioritization for manufacturing industries and construction sub-sector

Sub-criteria		**Contribution to economic development priorities**	**Contribution to environmental development priorities**	**Contribution to social development priorities**	**GHG reduction potential**	**Potential scale of utilization**	**Technology maturity**	**Costs**	**Final Score**
Technology	**Weightage**	0.14	0.17	0.14	0.17	0.13	0.11	0.14	
Construction of energy efficient infrastructure	Score	3.55	3.75	3.25	3.65	3.45	3.35	2.20	
	Standardized score	100%	82%	100%	73%	90%	75%	50%	
	Weighted score	0.14	0.14	0.14	0.12	0.12	0.08	0.07	**0.81**
Improvement	Score	3.45	3.60	3.00	3.85	3.30	3.20	3.80	

[6] Since estimates for cost of technologies in Bhutan were not available, the scoring of technologies against costs as a criterion was done by sectoral experts only based on their expert judgment and qualitative assessment of the capital and operation and maintenance costs of the technologies.

in process-related energy efficiency	Standardized score	78%	65%	55%	100%	60%	38%	100 %	
	Weighted score	0.11	0.11	0.08	0.17	0.08	0.04	0.14	**0.72**
High efficiency electric motors	Score	3.20	3.65	2.85	3.60	3.10	3.40	3.20	
	Standardized score	22%	71%	27%	67%	20%	87%	81%	
	Weighted score	0.03	0.12	0.04	0.11	0.03	0.10	0.11	**0.54**
Increasing blend in cement production	Score	3.20	3.45	2.95	3.55	3.30	3.40	2.00	
	Standardized score	22%	47%	45%	60%	60%	87%	44%	
	Weighted score	0.03	0.08	0.06	0.10	0.08	0.10	0.06	**0.51**
Improved management systems	Score	3.10	3.05	3.05	3.20	3.50	3.40	3.60	
	Standardized score	0%	0%	64%	13%	100%	87%	94%	
	Weighted score	0.00	0.00	0.09	0.02	0.13	0.10	0.13	**0.47**
Switching over to cleaner fuels (rice husk, waste)	Score	3.20	3.90	2.90	3.65	3.00	3.05	2.00	
	Standardized score	22%	100%	36%	73%	0%	0%	44%	
	Weighted score	0.03	0.17	0.05	0.12	0.00	0.00	0.06	**0.44**
Energy conservation codes and standards (a possible cap and trade mechanism)	Score	3.10	3.35	3.00	3.10	3.00	3.10	3.20	
	Standardized score	0%	35%	55%	0%	0%	13%	81%	
	Weighted score	0.00	0.06	0.08	0.00	0.00	0.01	0.11	**0.26**

Construction of energy efficient infrastructure means constructing buildings that are energy efficient and lead to energy savings in the construction sector.Energy conservation in buildings can be achieved through a variety of technologies, such as energy efficient building materials (e.g. double glazed windows), energy efficient lighting systems and HVAC systems.

Improvement in process-related energy efficiency refers to use of technologies such as waste heat recovery, soft starters for motors, replacing conventional ball mills with new technology vertical roller mills, oxy-fuel burners etc. in iron and steel, ferro-alloy and cement industries.

High efficiency electric motors normally are 2-8% more efficient than normal or standard motors. These are more efficient due to better construction quality and therefore have less windage loss, stator copper loss, rotor loss, iron and stray loss.

A detailed description of these technologies is given in Annex I.

6.5. Final prioritized technology for preparation of Technology Action Plan

Improvement in process related energy efficiency was the technology finalized by the TNA Task Force for the preparation of barrier analysis, enabling framework and technology action plan. This is because there haven't been any studies or programmes on this technology in Bhutan even though it has the maximum emission reduction potential and a highly matured technology implemented worldwide. It was also finalized by the TNA task force that under this broad technology, waste heat recovery technologies for ferro alloy and iron and steel sector should be selected for preparation of technology action plan as the technology will be highly effective in these industries to improve production efficiency and achieve energy efficiency.

Chapter 7. Summary / Conclusions

Although Bhutan is a net sink of GHGs owing to its large forest cover, the nation is planning to undertake actions for mitigation of climate change to ensure that the overall development process of the country is sustainable and follows the development philosophy of Gross National Happiness (GNH). The TNA document prepared with support from GEF, UNEP and AIT presents the key technologies for accelerating climate change mitigation in Bhutan while meeting the national development goals.

The technologies were selected through a rigorous process of analytical research and stakeholder consultation. One to one meetings with sectoral experts and policy makers were conducted followed by a three-day workshop with TNA Task Force members in Paro to arrive at the final list of prioritized technologies for each of the prioritized sub-sectors.

The prioritized sub-sectors identified were Solid waste disposal on land, Transport (Fuel combustion activities) and Manufacturing industries and construction (Fuel combustion activities). Within each of these sub-sectors, technologies were prioritized against a set of criteria each of which was given varying weightage. The criteria were the following:

1. Benefits (excluding climate change related benefits): Contribution to economic, environmental and social development priorities

2. Relevance to climate change mitigation: GHG reduction potential

3. Appropriateness: Technology maturity and potential scale of utilization

4. Costs

The prioritized technologies in each of the sub-sectors are given in Table 26.

Table 26: Final prioritized technologies in the prioritized sub-sectors

Prioritized sub-sectors	Prioritized technologies
Solid waste disposal on land	▪ Composting ▪ Reduce, reuse, recycle (3 Rs) ▪ Anaerobic digestion/ biogas plants
Transport (Fuel combustion activities),	▪ Intelligent Transport System ▪ Non-motorized Transport ▪ Mass Transit
Manufacturing industries and construction (Fuel combustion activities)	▪ Construction of energy efficient infrastructure (Energy efficiency in construction) ▪ Improvement in process-related energy efficiency (e.g. Waste Heat Recovery in Cement, iron and steel and ferro alloy industries) ▪ High efficiency electric motors (Cement, iron and steel and ferro alloy industries)

Further discussions among TNA Task Force members suggested that it may be practical to conduct in-depth and focused barrier analysis, enabling frameworks and technology action plans for only one technology per sub-sector, rather than for all technologies. Therefore, one technology from each sub-sector was finalized for the preparation of TAPs. The technologies finalized for each sector are given in Table 27**Error! Reference source not found.**.

Table 27: Finalized technologies for preparation of TAPs

Prioritized sub-sector	Finalized technology for barrier analysis, enabling framework and TAP
Solid waste disposal on land	Composting
Transport (Fuel combustion activities)	Intelligent Transport System
Manufacturing industries and construction (Fuel combustion activities)	Waste Heat Recovery in Iron and Steel and Ferro Alloy industries

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Annexes

Annex I. Technology Factsheets

I. Composting

Introduction

The term composting is defined as biological degradation of waste under controlled aerobic conditions. The waste is decomposed into CO_2, water and the soil amendment or mulch. In addition, some carbon storage also occurs in the residual compost. Today many developed and developing countries practice composting of mixed waste or biodegradable waste fractions (kitchen or restaurant wastes, garden waste, sewage sludge). It is best suited for source segregated biodegradable waste. Figure 7 illustrates the process of composting.

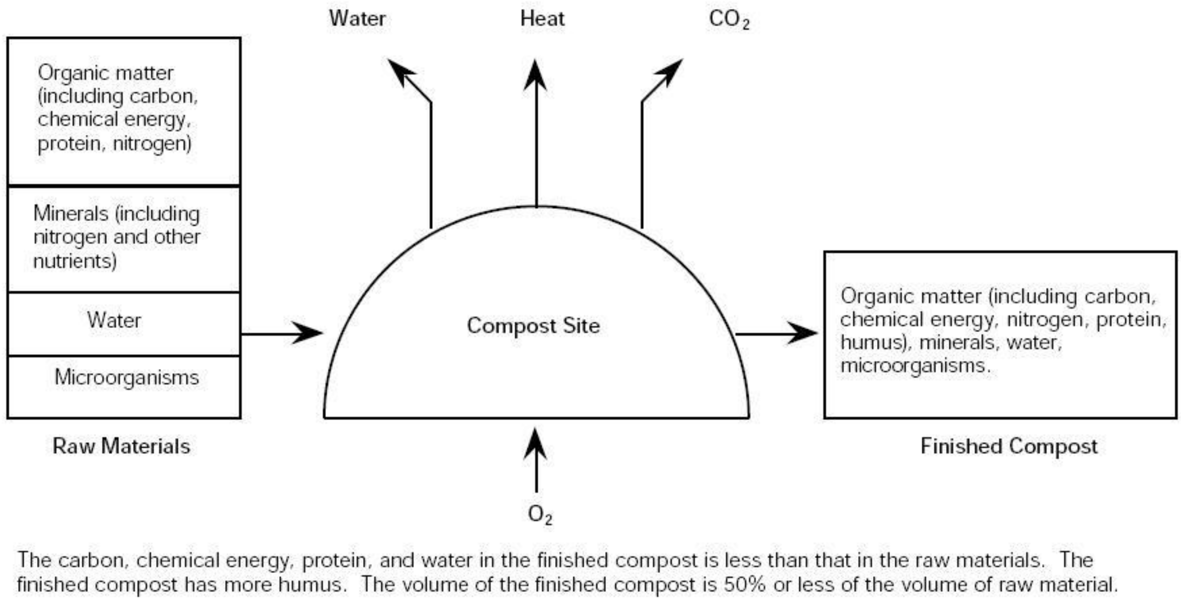

Figure 7: The composting process

Source: Rynk, et al., 1992[7]

Technology Characteristics

Three composting techniques available are windrow, aerated static pile, and in-vessel composting. Supporting techniques include sorting, screening and curing also. Each technique varies in procedures and equipment needs. Other variations between the technologies are issues such as air supply, temperature control, mixing, and the time required for composting. Moreover, their capital and operating costs also differ widely.

In-vessel composting: It occurs within a contained vessel, thus nullifying the effects of weather, resulting in a product of more consistent. In addition, due to the lesser man power and smaller space requirement, in-vessel technology is more suitable in suburban and urban technologies compared to the other composting technologies. Also, the in-vessel system allows for detailed containment and treatment of air to remove odours before release.

However, this technique is comparatively more costly than the other methods. The higher level of mechanization with this technique also results in more maintenance requirements which increase operational costs.

Windrow composting: Windrow composting often requires large tracts of land, sturdy equipment, a continual supply of labour. In this technique, segregated organic waste is placed into rows of long piles (pile height-4 to 8 feet, width- 12-16 feet) called windrows and exposed to air by turning the pile periodically by either manual or mechanical methods. This height allows for a pile large enough to generate sufficient heat yet small enough to allow oxygen to flow to the window's core.

[7] In ClimateTechWiki, available at http://climatetechwiki.org/technology/jiqweb-abt-0, accessed on 6 August 2012

The technique is suitable for large quantities such as that generated by entire communities and collected by local governments and high volume food-processing businesses. Windrow composting can work in both warm, arid climates and in cold climates. Rainy seasons sometimes require adjustment of the shape of the pile to ensure that the water runs off the top of the pile rather than being absorbed into the pile. In cold climates, the pile might freeze at the outside, but will remain warm in the core.

It is important to collect and treat the leachate that is released during the composting process, else it might contaminate local ground-water and surface-water supplies.

Aerated static pile (EPA, 2000): Aerated static pile composting involves mixing organic waste together in one large pile instead of rows. To ensure adequate flow of oxygen throughout the pile, layers of loosely piled bulking agents such as wood chips are added so that air can pass from the bottom to the top of the pile. Oxygen may also be delivered mechanically into the pile with the use of air blowers and a network of pipes which are placed into the piles.

This technology is applicable for a relatively homogenous mix of organic waste and works well for larger quantity generators of yard trimmings and compostable municipal solid waste, hence suitable for local governments, farms or landscapers.

Sometimes, aerated static piles are placed indoor with proper ventilation to exclude climate or seasonal influences. Since the technique doesn't use physical turning of the pile it is essential to carefully monitor the pile to ensure that the outside of the pile heats up as much as the core. The technique requires equipment such as blowers, pipes, sensors and fans. The use of this equipment might cause significant costs and require technical assistance. The advantage of the technique is that it requires less land than the windrow method. Additionally, the method has a high production rate – it only takes about 3 to 6 months to produce compost.

Country specific applicability and potential

In view of the high organic content (>50%) of the municipal solid waste, there is opportunity to convert this into good compost. Composting will help to reduce the waste volume. The Waste Prevention and Management Act 2009 and the subsequent Waste Prevention and Management Regulation 2012 also emphasizes on the importance of composting in the country. The Waste Prevention and Management Regulation 2012 calls it a preferred method for organic waste management

Status of technology in country

The country has a single composting plant in Serbithang, set up by the Thimphu City Corporation. The plant is however facing barriers in terms of low waste availability, high transportation cost and operational and technical inefficiencies leading to high cost of composting.

Benefits to economic / social and environmental development

Economic benefits

- Composting programs launched by small communities can provide benefits to the local community in the form of increased local employment and reduced costs for waste removal.
- Producing compost is found to be a profitable business in many parts of the world if implemented in public private partnerships models and right choice of centralized and decentralized composting units.
- Compost application in farm fields also results in economic benefits by enhancing the availability of nutrients in the soil to crops and improving the effectiveness of other fertilizers.

Social benefits

- Composting done by utilizing municipal solid waste generated from the cities/municipalities can result in effective management of waste thereby assisting local authorities in providing critical waste management services for city dwellers' overall social well being.

- The economy of many developing countries is based on the agrarian sector. When the farms utilizes compost, the need to purchase chemical fertilizers is reduced which thereby results in reduction in human and soil health problems.
- Composting also provides benefits for waste handling agencies. Composting part of the waste the agency receives increases the landfill lifetime and provides the waste handling agency with a marketable product in the form of compost.
- The technology is applicable for both small scale and large scale applications. Either of these will support local employment generation.

Environmental

- Composting directly leads to avoidance of methane emissions thereby improving the air quality.
- Composting results in a reduced waste volume going into landfills.
- The leachate from conventional waste management practices in developing countries can be addressed through the implementation of composting technology.
- Composts directly replace the application of chemical fertilizers in farm lands thereby resulting in reduction of chemical effects on soil and water.

Climate change mitigation benefits

Composting of waste reduces the amount of waste to be disposed of in landfills. This directly prevents the emissions of methane (which is 25 times a more potent GHG than CO_2) that would have occurred from waste disposal on land.

Costs

Composting requires equipment, labour, and management, cost of which may be very high if the waste generation scale is very low. Also, the cost of composting increases with high cost of transportation of waste materials to the composting sites which are generally far from the cities. A 70 TPD (tons per day) compost plant in Uganda has an investment cost of $ 421,344 with operating cost of $47,525 per annum[8]. While large scale centralized commercial composting may not be economical if revenue from compost is not significant, it could be more economical to set up decentralized small scale composting systems if amount of waste generated is low in cities of country like Bhutan.

[8] UNFCCC, PoA 2956 : Uganda Municipal Waste Compost Programme
http://cdm.unfccc.int/ProgrammeOfActivities/poa_db/JL4B8R2DKF90NE6YXCVOQ3MWSGT5UA/view

II. Reduce, reuse and recycle (3Rs)

Introduction

Reducing the generation of waste, re-using and recycling products can substantially reduce the amount of wastes to be disposed on land. These activities **r**equire a high degree of coordination and organization of the waste management chain.

Technology characteristics

To reduce waste problems in future, reduction in waste generation and re-use of old products such as electronics can be one of the most important factors. Examples of possible reduction at the consumption level include better buying habits and cutting down on the use of disposable products and packaging.

Further, recycling is a viable option for a range of waste products. In some economies, there already are well-organized recycling businesses and processes in place for a range of products (e.g. furniture, clothing textile, etc.) and materials (e.g. paper, iron, glass and steel). For some specific wastes many dedicated so-called 'end-of-pipe' recycling lines have also been developed. Examples of such dedicated lines are plastic bottles (i.e. PET), glass, aluminium, steel, copper, etc.

Country specific applicability and potential

The policy and institutional arrangement options of the 3Rs concept may be more cost-effective and for this the public awareness and education has to be a priority. Although, the concept of 3Rs has been known to Bhutan for a long time, the actual implementation of the 3Rs concept has been difficult due to lack of proper guidance, budget, human resource and public awareness. However, Bhutan has now managed to take a step forward in managing organic waste, PET bottles and paper wastes through the application of 3R technologies[9].

Status of technology in country

One of the guiding principles of the Waste Prevention and Management Act 2009 is the principles of Reduce, Reuse and Recycle. Public Private Partnership models for waste management have also been initiated.

Benefits to economic / social and environmental development

- Lower volumes of waste to be disposed, thereby reducing pressure on land and also the associated GHG emissions.
- Lower air and water pollution impact due to avoidance of primary production processes.
- Reduction of energy use in the material/product production process such as mining, quarrying, processing, etc. For instance, the copper recycling process results in energy savings of up to 85% compared to primary production.
- Increased employment associated with handling and processing of waste streams, additional employment could be in waste collection, waste handling and processing, secondary material/product trade (e.g. second-hand store).

Climate change mitigation benefits

A lot of waste that would be generated and disposed on land is avoided by the implementation of 3Rs, thereby avoiding the associated methane emissions. In addition, the GHG impact of the production of other waste categories, such as old

[9] Country Analysis Paper (Draft), Third Meeting of the Regional 3R Forum in Asia**,** Technology Transfer for promoting the 3Rs–Adapting, implementing, and scaling up appropriate technologies
Singapore, 5-7 October 2011, available at
http://www.uncrd.or.jp/env/spc/docs/3rd_3r/Country_Analysis_Paper_Bhutan.pdf, accessed on 4 May 2012.

washing machines, computers, mobile phones, etc. can be significantly reduced by reusing them or formulating them with a view to promote durable, re-usable and recyclable products.

Further, there is a significant potential for reducing GHG-emissions through recycling processes, due to reduced process energy consumption. Primary production processes for intermediate products such as aluminium production require large amounts of energy input to melt the raw material (i.e. bauxite). Recovering and melting secondary aluminium requires much less energy as the scrap aluminium is already of high purity (as compared to bauxite). Lower energy consumption in turn implies lower CO_2 emissions.

Costs

The economics of waste management practices and specifically recycling activities are often a crucial factor in successful adoption of a new process or technology. In general, there are many factors that shape the financial and economic environment for recycling initiatives. In some cases basic legislative changes, such as closure of a nearby landfill site or a regional ban on landfilling can make recycling more attractive as the costs of waste disposal go up.

Given the wide variety of waste types a multitude of recycling processes is possible. Therefore it is difficult to provide clear-cut cost figures for recycling practices.

III. Anaerobic digestion (Biogas plants)

Introduction

The anaerobic digestion is decomposition of biodegradable material by micro-organisms in the absence of oxygen. Anaerobic digestion is often used for industrial or domestic purposes to manage waste streams. Three principal products are produced through the process of anaerobic digestion. First, the process produces a biogas, consisting mainly of CH_4 and CO_2, which can be used for energy production. Second, the process results in a nutrient-rich digestate. Finally, the process results in liquid liquor that can be used as a fertilizer.

Technology Characteristics

As illustrated in Figure 8, a biogas facility with an anaerobic digester has four main components:

1. A manure (or waste-water) collection system.
2. The anaerobic digester: The production of the biogas consisting of methane and CO_2 occurs here.
3. A biogas handling system: A device that puts the biogas to use such as a combined heat and power plant.

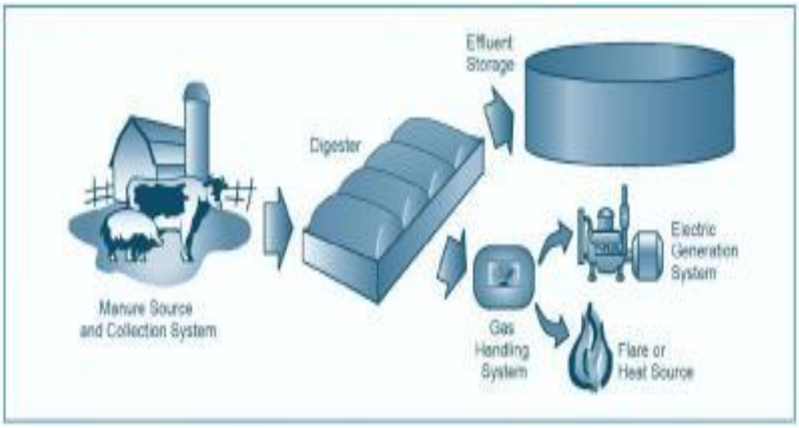

Figure 8: Main components of anaerobic digester facility

SOURCE: EPA, 2002

There are two basic types of digesters: batch and continuous.

Batch-type digesters are the simplest to build. Their operation consists of loading the digester with organic materials and allowing it to digest. The retention time depends on temperature and other factors. Once the digestion is complete, the effluent is removed and the process is repeated. In a continuous digester, organic material is constantly or regularly fed into the digester. The material moves through the digester either mechanically or by the force of the new feed pushing out digested material.

Continuous digesters produce biogas without the interruption of loading material and unloading effluent. They may be better suited for large-scale operations. Proper design, operation, and maintenance of continuous digesters produce a steady and predictable supply of usable biogas.

Many different variations of anaerobic digesters exist. The three most common variations are: the covered lagoon, the completely mixed reactor, the plug flow anaerobic digester and the induced blanket reactor.

Country specific applicability and potential

The recovery of biogas through anaerobic digestion systems is a proven technology. Both in the United States and the European Union the anaerobic digestion of animal waste streams has been used extensively. The technology has great potential in Bhutan too.

Annex I

Kingdom of Bhutan

Status of technology in country[10]

The Bhutan Biogas Project was launched in 2011 with the aim of building capacity in the public and private sectors to construct and operate 1,600 biogas plants in four project areas Dzongkhags namely, Tsirang, Sarpang, Samtse and Chukha from March 2011 to February 2014 on a pilot basis.

Benefits to economic, social and environmental development

- The sector in which the technology is mainly applied is the agriculture sector, which is the mainstay of Bhutanese economy. Projects using anaerobic digestion technology improve the viability of these rural enterprises. The technology is therefore capable of strengthening the backbone of the economy and subsequently improves social development.
- The current waste stabilization technique most often used at farms and industrial locations is the open anaerobic lagoon. Next to emitting methane directly into the atmosphere, this technique has several disadvantages that would be solved by the introduction of anaerobic digester facility. The workplace at an open lagoon system is unhealthy and unpleasant to work at. Local air quality at such facilities is poor and strong odour is produced by the open lagoon. The implementation of an anaerobic digester facility makes the workplace safer and healthier. Local air quality is significantly improved.
- Several economic development benefits arise from the energy production of the technology.
- National energy self sufficiency is increased due to the local energy production. This also would reduce Bhutan's dependency on other countries for fossil fuel imports, which in turn would lead to an improved economic balance sheet of the country and a higher level of energy security.
- Large amounts of animal waste can create serious environmental concerns. When animal manure enters rivers, streams or groundwater supplies it can have environmentally detrimental effects. In addition, decomposing manure causes air quality concerns associated with ammonia emissions, and the contribution of methane emissions to global climate change. The implementation of an anaerobic digestion offers a number of air and water quality benefits.
- Digester **s**ystems isolate and destroy disease causing organisms that might otherwise enter surface waters and pose a risk to animal and human health. Moreover, anaerobic digesters help protect ground water. Synthetic liners provide a high level of groundwater protection for manure management systems (EPA, 2002). The concrete or steel in plug flow and complete mix digesters also effectively prevent untreated manure from reaching the ground water.
- Biological treatment of waste, such as composting and anaerobic digestion reduces volume of waste and therefore the lowers landfill requirements. Recycling of the residual solids as fertilizer further reduces waste volume.

Climate change mitigation benefits

The main climate related benefit of this technology is the prevention of methane emissions associated with conventional manure management practices. In addition, the energy produced by the biogas facility offsets energy derived from fossil fuels. Therefore, anaerobic digesters with a biogas recovery system can help reduce overall quantities of CO_2. For example, the Colorado based pork farm with an anaerobic digester was able to reduce fossil fuel derived CO_2 emissions by 409 tons per year and methane emissions on a CO_2eq basis by at least 3022 tons per year[11].

Costs

[10] http://bio-gas-plant.blogspot.in/2011/07/bhutan-biogas-project.html, accessed on 18 June 2012

[11] ERG, 2003. An assessment of the Colorado Pork, LCC. Anaerobic digestion and biogas utilization system. Eastern Research Group submission to AgSTAR programme of the United States Environmental Protection Agency. Retrieved 25th October from: http://www.epa.gov/agstar/anaerobic/evaluation.html, cited in http://climatetechwiki.org/technology/jiqweb-anbt, accessed on 4 May 2012.

Kingdom of Bhutan

Installation and operation of an anaerobic digestion facility differs between the type and variation of installation. Moreover, the characteristics of the waste stream also influence the economics of the system. A typical anaerobic system constructed in the U.S. can have average costs of US$ 470 per cow. More generally, anaerobic systems for digestion, solids processing, and generation are expected to cost US$ 500 to US$ 800 per cow in the U.S.[12]

Table 28 illustrates the capital and operating costs of European digestion systems.

Table 28: Operating and capital costs of European Digester Systems

	Large 1 MW 5000 Cow Facility	Small 25 kW 125 Cow farm
Capital Cost	US $ 9.113.000,-	US $ 500.000,-
Annual Operating Cost	US $ 643.000,-	US $ 8.800,-
Power Sale Rate $/kW	US $ 0.06	US $ 0.06
Heat Sale $/kW	US $ 0.01	US $ 0.01
Solids Sales	US $ 700.000,-	US $ 20.000

[12] Burke, 2001. Dairy waste anaerobic digestion handbook: options for recovering beneficial products from dairy manure. Environmental Energy Company report. Retrieved 25th October from: www.mrec.org/pubs/dairy%20waste%20handbook.pdf, cited in http://climatetechwiki.org/technology/jiqweb-anbt, accessed on 4 May 2012.

IV. Intelligent Transport System

Introduction

Intelligent Transport System (ITS) basically refers to the application of information and communication technologies to vehicles and to transport infrastructure. Some examples of transport management systems include GPS based optimization of public transport, computerized traffic signaling, information systems such as e-ticketing, e-information etc. Such systems increase the reliability, safety, efficiency and quality of transport systems. An increase in the efficiency of the transport system also leads to a reduction in associated GHG emissions.

The UK Department for Transport strategy includes the following objectives for ITS (DfT, 2005)[13]:

- Improving road network management, including road pricing.
- Improving road safety, by reducing collisions, casualties and deaths.
- Better travel and traveller information, helping to match supply and demand by providing better information so that travellers can make informed choices on when and how to travel.
- Better public transport on the roads, supporting more reliable, more accessible, safer and more efficient services.
- Supporting the efficiency of the road freight industry.
- Reducing negative environmental impacts.
- Supporting security, crime reduction and emergency planning measures

The components of ITS systems generally include[14]:

- Data Acquisition Systems
- Data Communication Systems
- Data Management Systems
- Display Systems

Data Acquisition Systems: This includes sensors, automatic vehicle identifiers (AVI) and GPS. Sensors are used to obtain traffic parameters such as vehicles count, occupancy and speed. AVI systems are used to specifically identify a vehicle and its speed on road. GPS systems are used to identify the vehicle location and velocity in real time. Travel time, speed, distance and delay are estimated with help of GPS systems.

Data Communication Systems: Data captured using data acquisition systems needs to be effectively communicated to its intended users such as control centres and public display systems. Wireless technology is normally used for data communication systems.

Data Management Systems: for generating short and long term trends, data gathered through acquisition systems must be clean and removed from garbage values. Once the data is clean, data can be aggregated or disaggregated and subsequent analysis is done to generate effective traffic management policies and forecast traffic status. Based on forecast status real time decisions could be taken to prevent congestion etc.

Display Systems: These display systems are used to convey information to travellers using Message Signs, Radio, SMS, etc. ITS can provide information on travel times, travel speed, delay or accidents etc.

Intelligent Transport System could be applied to various areas as highlighted below[15]:

[13] DfT (UK Department for Transport, 2005). Intelligent Transport Systems (ITS). The policy framework for the roads sector. http://www.solihull.gov.uk/planappdocs/msadocuments/CD253.pdf taken from http://climatetechwiki.org/technology/transport-management

[14] Vanajakshi L, 2010, Synthesis Report on ITS including issues and challenges in India , Centre of Excellence in Urban Transport , IIT Madras, http://coeut.iitm.ac.in/ITS_synthesis.pdf

[15] *ibid*

1) **Advanced traffic management systems:** These systems integrate various sub components such as CCTV, sensors for vehicle detection, communication and messaging into a single system for real time traffic monitoring so that traffic management is efficient, real time information to users about traffic conditions, incident detection, signal control, predict traffic trends in real time to avoid congestion.
2) **Advanced traveller information systems:** It provides travel related information to users such as estimated travel times of buses on bus stops, route selection, parking availability, so that users can take intelligent decisions as per their convenience.
3) **Advanced public transport systems** – It includes passing of real time information of public transport to passengers such as real time passenger information systems, prioritization of public transport, estimated time for bus arrival at bus stops, transit priority of public transport etc.
4) **Advanced Rural Transport Systems** – These systems provide information about remote road and weather conditions. This type of systems can be valuable for implementation in rural areas of the country to provide information for users travelling in those areas.
5) **Advanced Vehicle Control systems** – These systems enhances the driver control on the vehicles by alerting the driver of possible collision due to vehicle speed or location.
6) **Commercial Vehicles Operations** – These systems are implemented to track commercial vehicles such as trucks and taxis for enhanced safety and

Technology Characteristics

Some characteristics of a successful transport management system are:

- Creation of a sound hierarchy of roads and streets that ensure particular street use, and so vehicles tend to be restricted to the most suitable thoroughfares to minimize traffic impacts
- Designing roadways to maximize connectivity, with least possible number of dead-ends, especially for walkways and cycling routes
- Encouraging private and public vehicles to use GPS systems that provide information about traffic and destination
- Using design features and road laws to ‘calm’ or slow down traffic to avoid accidents that result in long duration congestions and bottle necks
- Installing automated traffic controls at intersections, in the interests of safety, fair access for all traffic modes, and smooth flow of traffic
- Installing electronic tolling systems at tolls that experience heavy traffic
- On the demand side management including pricing mechanisms and restrictions on road space and parking, to ensure that more smoothly flowing traffic does not have the adverse effect of encouraging large numbers of extra motorized vehicles onto the roads
- Educating drivers and the proper enforcement of road laws, doing away with corrupt unlawful practices.

Country specific applicability and potential

Establishing a proper traffic management system will go a long way in solving Bhutan’s transport woes and help it achieve its target of reducing carbon emissions from its transport sector and move towards a low carbon economy. It is certainly possible to set up such a system in Bhutan and would be especially useful in managing the nation’s public transport. The city of Thimphu has planned implementation of Bus Rapid Transit System in which application of ITS can enhance the effectiveness of the proposed mass transit system. The inter-city bus transport systems can also be benefited by implementing ITS technologies such as smart displays and vehicle information systems for commuters.

Status of technology in the country

Although there is still plenty of room for improvement in Bhutan’s transport management system, there is no doubt in Bhutan’s willingness to upgrade its existing transport system which is more intelligent, efficient and environmentally friendly. This has been made clear in Bhutan’s National Transport Policy to “provide and develop safe, reliable, efficient, cost- effective and environment friendly transport services in support of strategies for socio-economic development of the country. Further, ITS has been included in Bhutan's Surface Transport Master Plan, 2007. However, till date the technology has not yet been implemented in the country.

Benefits to economic / social and environmental development

Economic benefits

- A better transport management system directly results in fuel savings thereby reducing dependence on import of fuel
- There are fewer costs to health from pollution and accidents
- The cost of additional transport infrastructure (e.g. new roads, flyovers) could be avoided

Social benefits

- An efficiently managed transport system makes urban areas safer, healthier, increasing the quality of living.
- It provides for a more balanced and sociable use of public spaces.

Environmental benefits

- A good transport management system reduces air pollution and GHG emissions by reducing traffic congestions.
- Calming motorized traffic helps control noise pollution.

Climate change mitigation benefits

Intelligent Transport Systems (ITS) apply information and communication technologies to vehicles and to transport infrastructure. This increases the efficiency of the transport systems leading to a reduction in associated GHG emissions. ITS also has a supporting role for the successful implementation of transport emission reduction strategies such as low-carbon fuels, energy efficient vehicles, public and non-motorised transport, mostly by supporting a more efficient organization of the transport system.

In Santiago de Chile, a project consisting electronic communications-based train control in one metro line, which allows for determining the exact position and speed of the metro trains was implemented. This increased the efficiency of train operations, resulting in 16 ktCO_2-eq/yr emission reductions[16].

Financial Requirements and Costs

Cost of setting up an effective traffic management system varies greatly. It depends on what is infrastructural developments need to be made, over what area or length of road or pathway as well as the degree and type of changes necessary. Some of the major costs incurred are for alterations to roads for traffic calming, creation of dedicated, lanes for buses and bikes, better controls and safety at intersections, driver education, and stronger enforcement. A part of the cost could be partly funded out of taxes, elevated parking charges, higher interests on inefficient private vehicles.

The Surface Transport Master Plan of Bhutan (2007) identifies installation of communication systems integrated with tracking components for public transport as an important measure for managing the transport systems in the country. Such a system would be play an important role in improved traveler advisory services, schedule adherence and could be archived to support future planning efforts that minimize GHG emissions. For such a system, the communication network available in Bhutan would have to be considerably upgraded to ensure coverage of all areas on the road corridor. It is estimated that the cost of setting up the infrastructure would be to the tune of USD 400,000[17]. The GPS unit mounted on each vehicle would cost approximately USD 500[18].

[16] UNFCCC, 2011 in http://climatetechwiki.org/technology/transport-management, accessed on 1 August 2012

[17] Assuming 1 USD = Nu. 50

[18] Assuming 1 USD = Nu. 50

V. Non-motorized Transport

Introduction

Non-motorized transport includes as walking, cycling and its variants such cycle rickshaws, skates, push scooters to and from transit stations. Since non-motorized transport does not make use of motorized vehicles, it prevents the combustion of fossil fuels and results in no GHG emissions. Well designed non-motorised transport systems can also help foil nuisance related to traffic congestions, noise pollution, extra cost on maintenance of roads etc.

Technology Characteristics

Some of the common ways to incorporate non-motorised transport include the following:

- Improved sidewalks, crosswalks, paths, bicycle lanes and networks.
- Public bicycle systems
- Pedestrian oriented land use and building design
- Increased road and path connectivity, with special non-motorized shortcuts
- Traffic calming, streetscape improvements, traffic speed reductions, vehicle restrictions
- Safety education
- Bicycle parking and integration in transit systems

Country specific applicability and potential

Bhutan being dominated by mountain peaks in the north, characterised by perpetual snow, accompanied by blizzards during the winter, make walking or cycling a not so pleasant or safe option. However, the central and southern regions; and the valleys of Bhutan present a good case for developing walkways. They have more or less pleasant climatic conditions all year round, along with suitable topographic conditions. To counteract the problem of sometimes severe precipitation, covered walkways, cycle routes can be constructed.

Status of technology in country

Walking has been traditionally a common practice in Bhutan. However over the past decade there has been a steady rise in motorized transport. This has resulted in increased traffic congestion, as well as a rise in consumption of fossil flues and GHG emissions in Bhutan. Realizing this fact, walking and cycling are seriously being considered as sustainable and viable modes of transport. Bhutan's Tenth Five-Year Plan (2008–2013) has stated the government's intention to "encourage non-motorized transport such as cycling and walking".

Benefits to economic, social and environmental development

Economic benefits

- Walking and cycling provide an inexpensive mode of transport for the common people, helping them save money (and time due to lesser congestions) that they can direct towards other necessities.
- Cost of building walkways and cycling routes require merely require a small portion of the total cost of building infrastructure for motorised transport, helping the nation save its gross expenditure.
- Shifting to non-motorized mode of transit helps countries shed their dependence on foreign oil, thus giving them a political and economic edge.

Social benefits

- Walking and cycling are healthy practices and can help combat multiple disorders like obesity, diabetes, cardio-vascular disorders, asthma and other respiratory problems.
- It provides a safe mode of transport, leading to fewer road accidents and resulting deaths.

Environmental benefits

- Since non-motorized transport does not make use of motorized vehicles, it prevents the combustion of fossil fuels and results in no GHG emissions.
- These create less pollution, fewer traffic accidents, lesser congestion and noise.
- These also help in improving general air quality by reduced emissions of air pollutants.
- Non-motorised transport helps reduce noise pollution.

Climate change mitigation benefits

A two kilometer walk or bicycle trip saves 419 grams of CO_2e if it replaces a car trip. However, these estimates don't take into account the emissions generated in the production and distribution of bicycles, or for building the infrastructure.

Financial requirements and costs

Non-motorized transport policies and investments have a positive benefits-cost ratio. The cost of bicycle paths, including construction, maintenance and awareness campaigns, has been estimated at being USD 200,000 per km.

VI. Mass transit

Introduction

Mass transit is one of the main components in a sustainable, low-carbon transport future and covers modes of public transport such as light rail (or trams), bus rapid transit, electric trolley buses and trains including long haul trains, metro and conventional suburban trains. Since mass transit moves more people at less cost, it leads to reduced private vehicle use, thereby causing reductions in greenhouse gas emissions and traffic congestion.

The mass transit system is usually accompanied by non-motorized transport such as walking, cycling and its variants such cycle rickshaws, skates, push scooters to and from transit stations.

Technology Characteristics

Some characteristics that a successful mass transit system should include are the following –

- Dedicated lanes should in order to have an efficient mass transit system.
- Priority traffic signals are required to achieve speed advantage.
- Making private vehicle travel more expensive would encourage people to switch from private to public transport.
- Educating and making people aware of the benefits of the transit is also one of the key requirements for its success

Country specific applicability and potential

Mass transit can prove to be a genuine solution for Bhutan to reduce the number of cars running on its roads and provide for a better, more consistent transportation system that can boast of reliability, safety as well as comfort.

Electric trolley buses with motors powered by electricity from overhead wires and rubber-tyres have potential in certain areas of Bhutan. Also, the cheap hydropower in Bhutan is an advantage for this type of transport. In addition, LRT as urban rail transit can either run along the streets or share space with road traffic or along their own right-of-way separated from road traffic. However, it may not be feasible in Bhutan due to high infrastructure costs and limited space for dedicated lines. Among other mass transit options, BRT is the most viable and flexible option. These buses running on dedicated lanes or by providing priority on roads could be powered by electricity and the need to create an electric bus trolley line will not be necessary.

Status of technology in country

As per the SNC, options for mass transit such as electric trolley buses and light rail transit are being explored through the Bhutan Urban Transport Systems Project as alternative transport systems.

Benefits to economic, social and environmental development

Economic benefits

- Mass transit can move large numbers of people at less cost to the individual and society.
- It has been observed that cities and countries that have high rates of mass transit use spend much less on transport overall than others.
- Mass transit also makes it easier for people who can’t afford private vehicles, or can’t drive them.
- Mass transit moves large numbers of people in a smaller space, thus saving space and allowing greater urban density and a denser city’s infrastructure costs less per resident.

Social benefits

- A good mass transit system provides services that are frequent, fast, punctual, safe, comfortable, clean and affordable.
- Mass transit and non-motorized transport lead to greater equality and social inclusion as more people can use it to meet their needs, that is, to get to health and other services, social connections, work etc.

Environmental benefits

- Mass transit and non-motorized transport use lesser energy and emit less GHG leading to energy savings. Thus, these are low carbon and sustainable modes of transport.
- These create less pollution, fewer traffic accidents, lesser congestion and noise.
- These also help in improving general air quality by reduced emissions of air pollutants.

Climate change mitigation benefits

Mass transit leads to reduced traffic congestion, which leads to GHG reductions for individual vehicles, as they can travel more efficiently. Also, if efficient, it can reduce private vehicle use at the same time leading to substantial GHG reductions.

Financial requirements and costs

When assessing the benefits and costs of mass transit, many factors need to be taken into account. These factors include an assessment of travel time savings, reductions in fuel, pollution and accidents, and space saved.

Transit systems can be financed and managed through public-private-partnerships, with private partners building the system, operating it, or both.

Public funds may also be available through the World Bank, regional development banks or bilateral development cooperation arrangements. In addition, climate change funding mechanisms may fund transit projects. Transit operating costs can of course be at least partially covered by passenger fares.

Almost all modern public transit systems are subsidized by government, and each city or locality must decide the amount of subsidy it can afford to provide. Higher capacity systems cost more to put in, but offer much more potential reduction in total transport costs and GHG emissions.

VII. Construction of energy efficient infrastructure

Introduction

Construction of energy efficient infrastructure means constructing buildings that are energy efficient and lead to energy savings in the construction sector. Many green or energy efficient building rating tools are currently followed to rate and certify the environmental performance of buildings across the globe. For example, The British Research Establishment launched the first commercial green building rating tool in 1990, known as BREEAM (British Research Establishment Environmental Assessment Method). This was followed by LEED (Leadership in Energy and Environmental Design) in the United States, CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) in Japan and Green Star in Australia.

In India, The Energy Conservation Building Code (ECBC) has been developed. This code defines norms and standards for the energy performance of the building and its components, depending on the climate zones in which they are located. The code is applicable to buildings or building complexes having a minimum connected load of 100kW.

Technology characteristics

Energy conservation in buildings can be achieved through a variety of technologies, some of which have been explained below.

- **Building Envelope**: The Building Envelope is defined as a separator between the interior and the exterior environments of the building such as roof, windows and doors. Proper insulation of the building envelop can lead to energy savings.
- **Double Glazed windows:** A double glazed window consists of two layers of glasses, which are separated by a spacer bar. The cavity between the two panes is filled with inert gas or air and sealed around the perimeter. As inert gas or air is poor conductor of heat, it reduces heat conduction between the two panes. This reduces the peak heating and cooling load of the building, resulting in reduced size of air- conditioner/heating unit.
- **Energy Efficient HVAC Systems**: HVAC (heating, ventilation, and air conditioning) provides conditioning of space with respect to temperature, humidity also using fresh air from outdoors. Since heating or cooling a space contributes to maximum energy consumption of the building, using energy efficient systems help to conserve energy, without compromising with the quality and comfort of living.

  Further**,** intelligent HVAC systems provide variable fan speeds, results in energy saving when the room is empty or has less occupancy as designed for. Temperature control mechanism allows setting the desired temperature of the room, avoiding excess cooling or heating in the room. Additionally, room heating is performed by recovery of the waste heat from present HVAC systems or any other systems available at site.
- **Energy Efficient Lighting System**: Energy Efficient Lighting System such as Light Emitting Diode and Compact Fluorescent Lamps give better light outputs, bringing in substantial energy savings. In case of LEDS, 80% of the electricity gets converted to light energy as compared to incandescent bulbs that convert only 20 % of electrical energy into light energy. CFLs also use at least two thirds less electricity than the standard incandescent lamps they replace and last up to 4 times longer

Country specific applicability and potential

Buildings in Bhutan use twice the energy for half the size compared to Nordic countries mainly due to poor insulation levels. The residential sector is the highest energy consumer, accounting for 48.7% of the total energy consumption[19].

TERI has also designed and set up an energy laboratory, which has been constructed according to energy efficient green building design principles.[20]

[19] http://www.undp.org.bt/404.htm, accessed on 4 May 2012
[20] http://www.teriin.org/index.php?option=com_ongoing&task=about_project&sid=54, accessed on 4 May 2012

Status of technology in Bhutan

The government has recognized the need for energy efficiency in Bhutan's energy sector, and improvements in efficiency and energy conservation standards for the building sector are being promoted by the government, particularly in terms of lighting and ventilation.[21]

Benefits to economic / social and environmental development

Energy efficient construction can generate business opportunities for individuals and business dealing in this technology, thus generating employment for the people. In addition, energy efficient motors consume less energy, thereby reducing the monthly energy bill for the built up space.

Climate change mitigation benefits

Electricity savings will directly lead to CO_2 mitigation benefits.

Financial Requirements and Costs

In India, ECBC complaint buildings bring in energy savings of the order of 50% as compared to conventional buildings. Initial costs generally increase by 10-15%, and the payback period is 5-7 years[22].

[21] http://www.reegle.info/countries/bhutan-energy-profile/BT#energy_efficiency , accessed on 4 May 2012
[22] http://www.indiaworldenergy.org/brochure/ECBC.pdf, accessed on 4 May 2012

VIII. Waste Heat Recovery

Introduction

Waste heat is the heat generated in a process or operation due to fuel combustion or any chemical reaction, which is then wasted into the environment and is not used for any economic purposes. This waste heat if recovered and used for economic purpose prevents consumption of fossil fuel and improves production efficiency. Methods of waste heat recovery includes transfer of heat for cooling requirements, preheating purposes, transferring heat to load which is about to enter furnace, generating mechanical or electrical power and using heat pump for heating or cooling purpose.

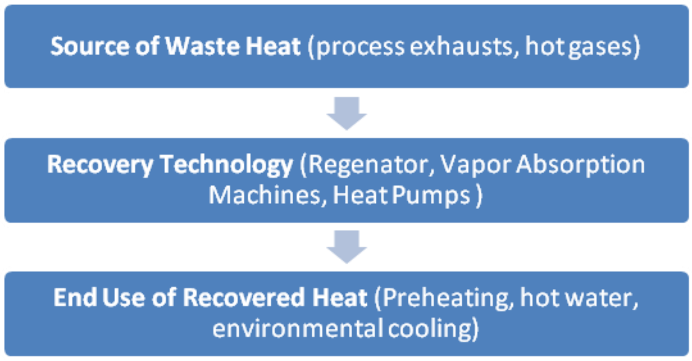

Figure 9: Key components of WHR

Technology characteristics

Various equipment such as Heat Exchangers, Vapour Absorption Machines (VAM), Recuperators, Regenerators, Waste Heat Boilers and Heat Pumps are utilized for purpose of WHR. For implementation of WHR projects in industries three components are studied essentially which include i) source of waste heat ii) feasible technology for recovery iii) use for recovered energy[23].

In Bhutan, the waste heat source is primarily available with Iron & Steel and Ferro Alloy industries. Since the size of industries is quite small, the temperatures of heat sources in the industries are comparatively low. According to the Bhutan Industry Association, the temperature of waste heat (in form of steam) in Ferro Alloy industry is nearly 300 degree Celsius. For this temperature range, the recovered heat may not be used for power generation and other conventional applications as compared to waste heat recovered from large iron and steel industries where temperature of heat sources is as high as 1000 degree centigrade.

However, through use of Vapour Absorption Machines (VAM) using waste steam at 300 degree Celsius environmental cooling and chilled water production is feasible. VAM could be used with steam pressure as low as 0.5 KG/cm^2. In addition, heat pump can also be used to extract heat from cooling water (used in chillers) and reduce energy consumption required for water heating in industries. Absorption Heat Pump generates the hot water based on 75% heat from heat source (e.g. diesel, steam, gas). Hence 25% heat from existing sources (diesel, gas, steam) can be saved. The concept is shown in the below figure 5.

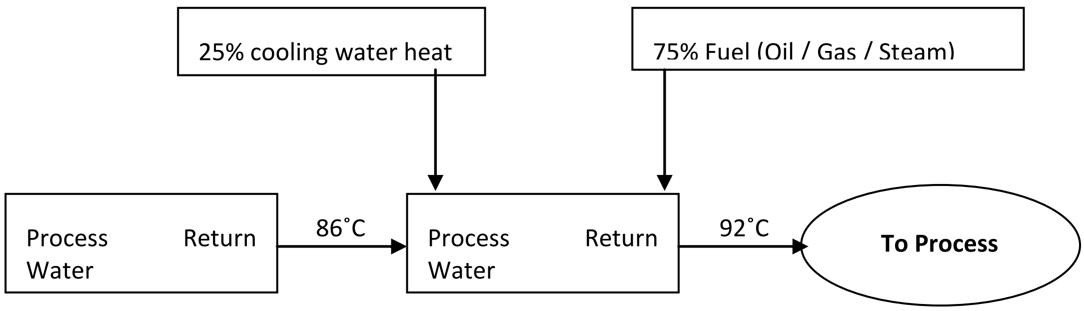

Figure 10: Illustration of energy efficiency through use of Heat Pump

Therefore, the recovered waste heat in Bhutan's industries can be best utilized for water heating, room heating/cooling and other process heat requirements. In addition, since the industries in Bhutan are located in close vicinity, waste heat recovery can be done in cluster basis and the heat utilized from one industry can be used in other industry as process input.

23 Waste Heat Recovery: Technology and Opportunity in US Industry, US Department of Energy, https://www1.eere.energy.gov/manufacturing/intensiveprocesses/pdfs/waste_heat_recovery.pdf page 10

Annex I

Kingdom of Bhutan

Country specific applicability and potential

All the technologies discussed above can be used in Bhutan as discussed above. For more details refer to Technology Action Plan Report for Waste Heat Recovery technology.

Benefits to economic / social and environmental development

- Enhanced energy savings and resource efficiency thereby increasing production efficiency
- Reduced Volatile Organic Carbons (VOCs) such as NO_X, SO_X, particulate matter.
- Health benefits to the employees of the plants due to reduced pollution inside the plant[24].

Climate change mitigation benefits

Waste Heat Recovery technologies can reduce GHG emissions by reducing consumption of grid electricity, coal and other fossil fuel such as diesel in industries.

Financial Requirements and Costs

The cost of Waste Heat Recovery depends on the choice of the technology and application of waste heat in the industry. A case study shows that replacing split AC units with waste heat driven absorption chillers will cost around $50,510[25]. Based on estimates taken from few technology suppliers, systems which can tap heat upto 300 degree Celsius for various purposes may cost in the range of $50,000 to $100,000 excluding transportation cost which could be significant in case of Bhutan.

[24] www.bhutanobserver.bt/cement-plants-and-its-pollution/, accessed on 4 May 2012

[25] Sethi Girish, 2009, Cleaner Production Study of Island Resorts in Maldives, http://www.direc2010.gov.in/pdf/Cleaner%20Production%20Study.pdf

IX. High efficiency electric motors

Introduction

High efficiency electric motors are normally 2-8% more efficient than normal or standard motors. The International Electrotechnical Commission (IEC) has introduced new standards related to energy efficient motors.

IEC/EN 60034-2-1 specifies new rules concerning efficiency testing methods and IEC 60034-30 defines new efficiency classes IE1, IE2 and IE3 for DOL (Direct-On-Line) motors. In addition, standard IECTS60034-31 defines super premium efficiency class IE4 for both DOL and driven motors. These standards provide major energy and cost savings to industrial and commercial motor users, while helping to moderate the growth in the world's electricity demand. As of now IE3 is the highest efficiency class prevalent among the countries adopting IEC standards.

Technology characteristics

These motors are more efficient due to better construction quality and therefore have less windage loss, stator copper loss, rotor loss, iron and stray loss. IE efficiency class motors, as compared to the non IE motors available in the market, offer substantial savings in energy. For example, when IE3 motors are used the customers can save anywhere up to 10% depending on the frame sizes. The advantages of high efficient motors are:

- Optimum use of energy as operating losses is lower
- Efficiency figures remain constant up to 75% of the rated output and drop maximum by 1% at 50% rated output
- Reduced magnetic loss resulting in cooler applications
- Low life cycle cost
- Robust design to take care of wider supply variations (± 10%) and ambient temperature up to 80^{o}C.

Country specific applicability and potential

In industrial sector, 70-75% of energy is handled by motors with conservation potential of up to 25%. Bhutan has many iron and steel, ferro alloy and cement industries which have highest potential of energy efficient motors. Most of the electricity consumption goes into running motors. Old motors (10 year old or more) which are standard could be replaced with energy efficient motors. Motors which are rewound twice or more could be replaced with energy efficient motors. New motors that are purchased by industry should be minimum IE2.

Pilot audit can be done on specific industry to find overall energy reduction potential of energy efficient motors in these industry.

Status of technology in Bhutan

All major motor technology vendors provide energy efficient motors namely Siemens, ABB, Kirloskar etc. The Royal Government of Bhutan can adopt the energy efficient motors standards as adopted in India and globally to promote energy efficient motors.

Benefits to economic / social and environmental development

Energy efficient motors provide huge financial savings due to lower life cycle cost of energy efficient motors. Energy efficient motors, if promoted in industries, can generate business opportunities for individuals and business dealing in this technology, thus generating employment for people. In addition, energy efficient motors consume less energy, thereby bringing in substantial energy and associated cost savings.

Climate change mitigation benefits

Electricity savings will directly leads to CO_2 mitigation benefits.

Financial requirements and costs

The typical payback on above mentioned replacement should be less than 1-2 years but since cost of power is low in Bhutan it may go up to 3-4 years. If one analyzes the life cycle cost of these motors, 2-5% cost is generally purchase cost, 5 % maintenance costs and 90-92 % is running cost of motor. Purchase of Energy Efficient Motors requires more upfront costs but it usually recovered in less than 3-4 years.

Annex II. List of stakeholders involved and their contacts

List of stakeholders involved in sector prioritization

S.No.	Name	Designation	Organization
1.	Cheki Dorji	Head Civil Dept. of college	College of Science and Technology
2.	Chhimi Dorji	Deputy Executive Engineer	Department of Hydro-met services
3.	Jigme Nidup	Sr. Environment Officer	National Environment Commission
4.	K. Junwar	GM, Adm, P.O. Box 173	Druk Wang Alloys Ltd
5.	Karma Pemba	Deputy Chief Transport Officer	Road Safety and Transport Authority, Ministry of Information and Communications
6.	Karma Toep	Head, Geology Division	Department of Geology and Mines, Ministry of Economic Affairs
7.	Kesang Wangdi	Secretary, PSDC Secretariat	Bhutan Chamber of Commerce & Industry
8.	Krishna Bahadur Rai	Environmental Officer	Bhutan Power Corporation Ltd.
9.	Kritika Neopaney	Environment Officer	Druk Holding & Investments
10.	Kunzang Choden	Sr. Forest Research Officer	Council for RNR Research of Bhutan, Ministry of Agriculture and Forests
11.	Naiten Wangchuk	Dy. Chief Livestock Production Officer (DCLO)	Department of Livestock, Ministry of Agriculture and Forests
12.	Pema Dorji	Assistant Manager (Environment)	Druk Green Power Corporation
13.	Pema Thinley	Sr. Planning Officer	Ministry of Agriculture and Forests
14.	Sonam Lhaden	Sr. Environment Officer	National Environment Commission
15.	Sonam Lhamo	Geologist	Department of Geology and Mines, Ministry of Economic Affairs
16.	Sonam Tashi	Sr. Planning Officer, PPD	Ministry of Economic Affairs
17.	Tashi Wangdii	Manager Quality Control / Environmental Officer	Bhutan Ferro Alloys Ltd
18.	Tsheten Dorji	Dy. Chief SS & LE Officer	National Soil Survey Centre, Department of Agriculture, Ministry of Agriculture and Forests

19.	Tshewang Lhamo	Environment Officer	National Environment Commission
20.	Yeshey Penjor	Climate Change Specialist	United Nations Development Programme

List of stakeholders involved in technology prioritization

PARTICIPANTS OF THE WORKSHOP, PARO, BHUTAN, 6-8 FEBRUARY 2012

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1.	*Aloke Barnwal	Principal Consultant	Emergent Ventures India (TNA International Consultant)
2.	*Amandeep Singh Sangha	Project Manager	Asian Institute of Technology
3.	Bharat Kumar Humagai	Lecturer	College of Science & Technology, Royal University of Bhutan
4.	Birkha B. Chhetri	General Secretary	Association of Bhutanese Industries
5.	*Charles OP Marpaung	Visiting Faculty and Co-Principal Investigator, TNA Project	Asian Institute of Technology
6.	Chencho Dorji	Sr. Soil Survey & Land Evaluation Supervisor	National Soil Services Center
7.	Chhimi Dorji	Deputy Executive Engineer	Department of Hydro-met Services
8.	G. Karma Chhopel	CEO	National Environment Commission (Water Resources Coordination)
9.	*Ishita Singh	Consultant	Emergent Ventures India (TNA International Consultant)
10.	Karchaen Dorji	Environment Officer	Environment Unit, Department Of Industry, Ministry Of Economic Affairs
11.	Karma	Chief Geologist	Department of Geology & Mines
12.	Karma Pemba	Deputy Chief Transport Officer	Road Safety and Transport Authority, Ministry of Information and Communications
13.	Karma Tshering	Programme officer	Policy and Programming services at National Environment Commission

14.	Krishna B Rai	Environmental Officer	Bhutan Power Corporation. Ltd.
15.	Kunzang Choden	Sr. Forest Research Officer	Council for RNR Research of Bhutan, Ministry of Agriculture and Forests
16.	Pema Dorji	Assistant Manager (Environment)	Druk Green Power Corporation Ltd.
17.	Pema Thinley	Sr. Planning Officer	Ministry of Agriculture & Forestry (MOAF)
18.	*Sanjay Dube	Vice President	Emergent Ventures India (TNA International Consultant)
19.	Sanjay Gurung	Focal person Environment	Druk Ferro Alloys Ltd.
20.	Sonam Dagay	Assistant Environment Officer	National Environment Commission
21.	Sonam Lhaden khandu	Sr. Environment Officer	National Environment Commission
22.	Tashi Wangdi	Manager Quality Control/ Environmental Officer	Bhutan Ferro Alloys Ltd.
23.	Thinley Namgyel	Chief Environment Officer	Climate Change Division at National Environment Commission
24.	*Ugen P. Norbu	Consultant	Norbu Samyul Consulting
25.	Ugyen Dorji	President/ MD	Automobile Services Association Bhutan/ Yangki Automobiles
26.	Yenten Thinley	Marketing Officer	Pelden Group Of Companies (Ferro & Steel)
27.	Yeshey Penjor	Climate Change Policy specialist	United Nations Development Programme

**AIT representatives and Consultants*

OTHER STAKEHOLDERS INVOLVED IN TECHNOLOGY PRIORITIZATION

S.No.	Name	Designation	Organization

Annex II

Kingdom of Bhutan

1.	Chhimi Dorji	Deputy Executive Engineer	Department of Hydro-met Services
2.	Karma Pemba	Deputy Chief Transport Officer	Road Safety and Transport Authority, Ministry of Information and Communications
3.	Loknath Sharma	Senior Regional Transport Officer	Road Safety and Transport Authority, Ministry of Information and Communications
4.	Ngawang Choeda	Dy. Executive Engineer	Department of Hydropower and Power Systems Ministry of Economic Affairs
5.	Prem Adhikari	Senior Transport Officer	Road Safety and Transport Authority, Ministry of Information and Communications
6.	Satchi Dukpa	Officiating Chief	Department of Renewable Energy Ministry of Economic Affairs
7.	Tashi Wangdi	Sr. Manager (QC)	Bhutan Ferro Alloys Limited
8.	Thuken Wangmo	Chief	Monitoring and Evaluation Division, Bhutan Electricity Authority
9.	Yeshey Penjor	Climate Change Policy specialist	United Nations Development Programme