Technology Needs Assessment Report

Climate Change Mitigation

Government of Pakistan

Ministry of Climate Change

Islamabad, Pakistan

February 2016

Supported by

Technology Needs Assessments For

Climate Change Mitigation

National TNA Coordinator:
Muhammad Irfan Tariq, Director General, (Environment & Climate Change)
Ministry of Climate Change, Government of Pakistan

Contributors and Supporting Team:
Working Group on Mitigation, Ministry of Climate Change

Lead Expert:
Jawed Ali Khan

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 DTU Partnership (UDP) in collaboration with the Regional Centre Asian Institute of Technology, Bangkok. 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 Federal Ministry of Climate Change, Government of Pakistan.

Table of Contents

List of Tables

List of Figures

List of Annexures

Abbreviations and Acronyms

ADB	Asian Development Bank
AEDB	Alternate Energy Development Board
AIT	Asian Institute of Technology
ALGAS	Asian Least Cost GHG Abatement Strategy
AJ & K	Azad Jammu and Kashmir
Btu	British Thermal unit
CC	Climate Change
CDM	Clean Development Mechanism
CH_4	Methane
CO_2	Carbon dioxide
COP	Conference of Parties
CTCN	Climate Technology Centre and Network
DG	Director General
DTU	Technical University of Denmark
E&CC	Environment and Climate Change
EE	Energy Efficiency
EGTT	Expert Group on Technology Transfer
ENDA	Energy Environment Development
ENERCON	National Energy Conservation Centre
EPA	Environmental Protection Agency
ESTs	Environmentally Sound Technologies
GCF	Green Climate Fund
GCISC	Global Change Impact Studies Centre
GEF	Global Environment Facility
GHG	Greenhouse Gas
GHGR	Greenhouse Gas Reduction
GoP	Government of Pakistan
IGCC	Integrated gasification combined cycle
JICA	Japan International Co-operation Agency
kW	Kilo watt
kWh	Kilo watt hour
LED	Light emitting diode
LPG	Liquefied Petroleum gas
LULUCF	Land Use, Land Use Change and Forestry
MCDA	Multi criteria decision analysis
MNF	Multi-nutrient feed blocks
MtCDE	Metric Tons of Carbon Dioxide Equivalent
MoCC	Ministry of Climate Change
M TOE	Million tons of Oil Equivalent
MW	Mega watt
NAMA	Nationally Appropriate Mitigation Actions
NCS	National Conservation Strategy
NDMA	National Disaster Management Authority
NEAP	National Environmental Action Plan
NEQS	National Environmental Quality Standards
N_2O	Nitrous oxide
NZET	Near Zero-Emission Technology
O_2	Oxygen
Pak EPA	Pakistan Environmental Protection Agency
PC	Planning Commission
PC-1	Planning Commission Performa-1
PEP	Pakistan Environment Program
PFBC	Pressurized fluidized bed combustion
PV	Photo voltaic
SC	Super critical
TAP	Technology Action Plan

TEC	Technology Expert Committee
TNA	Technology Need Assessment
TOE	Tons of Oil Equivalent
UNCBD	United Nations Convention on Biodiversity
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
URC	UNEP Ris∅ Centre
USC	Ultra-super critical

Foreword

Innovation is the key to knowledge, technology and creative outputs. Achieving global reduction of GHG emission requires innovation to transform current technologies into cleaner and climate resilient technologies. Hence, innovation serves as the foundation for sustainable socio-economic and climate resilient development.

Pakistan is in dire need of innovative technologies to effectively manage recurring natural disasters triggering climate change as well as rapidly increasing level of GHG emissions and inflicting colossal damage to life, property, natural eco-system and economy of the country.

In this backdrop, I am confident that the Technology Need Assessment project initiated by the Ministry of Climate Change in collaboration with the United Nations Environment Program (UNEP), Climate Technology Centre & Network (CTCN) and Technical University of Denmark (DTU) partnership will play an effective role in reducing GHG emissions as well as increasing resilience against climate change vulnerabilities through transfer and diffusion of prioritized technologies and removing barriers in their adoption.

I am looking forward to collaboration of implementing partners as with their assistance Pakistan will soon be able to implement these environmentally-sound climate resilient technologies on the ground, so that Pakistan's capacity for climate resilient measures and sustainable socio-economic development is enhanced.

The Ministry of Climate Change will take all necessary steps to streamline the policies, legislation etc. to help transfer and diffusion of technologies prioritized by experts in the energy, agriculture and transport sectors. I am confident that the international community will contribute to the joint efforts in addressing the climate change threat and the TNA process will facilitate access to funds and create an enabling environment for the transfer of priority technologies which will improve climate resilience of the most vulnerable sectors of Pakistan.

(Zahid Hamid)
Federal Minister
Ministry of Climate Change

Acknowledgement

The fact that the Ministry of Climate Change has initiated an important project on "Technology Needs Assessment" in collaboration with the United Nations Environment Program (UNEP), Climate Technology Centre & Network (CTCN) and Technical University of Denmark (DTU) partnership as a part of the strategic program on technology transfer by UNEP is an encouraging step forward in the country's progress towards climate change adaptation and mitigation. The Ministry earnestly hopes that the Technology Needs Assessment (TNA) project will serve as a key step towards addressing our climate change concerns by providing an assessment of the priority technology requirements. I am sure that this exercise will trigger a process for making Pakistan climate resilient and usher an era of low carbon development.

My special thanks are due to the members of the Expert Working Group on Mitigation, especially Dr. Arshad M. Khan and Dr. M. Mohsin Iqbal (GCISC), Dr. Qamar-uz-Zaman Chaudhry, Dr. Muhammad Parvaz (HDIP), Dr. Saleem Janjua and Mr. Asad Mehmood (ENERCON), Dr. Zafar Mahmood Khalid (IIU), Mr. Muhammad Irshad Ramay (NCPC), Mr. Aqeel Jafri (AEDB), Ms. Munnaza Naqvi (UNDP-Pakistan), Mr. Bilal Anwar (COMSATS) and all other experts who contributed to the TNA process. I am grateful to the officers of Ministry of Climate Change especially Mr. Muhammad Irfan Tariq, Director General (Env&CC) and Mr. Imran Khan, Assistant Director.

I would also like to thank the numerous other ministries, divisions of the government, non-government and private sector experts who took time out of their busy schedule to meet with our consultants and provide data and information; their names are too many to register here.

Special gratitude is extended to National Transport Research Center, Ministry of Communication, Hydrocarbon Development Institute of Pakistan, Alternate Energy Development Board, ENERCON, UNDP, National Cleaner Production Center, Pakistan Atomic Energy Commission, Islamic International University and Center for Climate Research and Development (CCRD) of COMSATS University. Further I also acknowledge the hard-work put in by the lead-expert Mr. Jawed Ali Khan and members of his team Ms. Yasmin Jawed Khan and Mr. Tayyab Shahzad in carrying out the TNA exercise.

I also wish to take this opportunity to extend my gratitude to the Global Environment Facility for its funding of this TNA and UNEP and UNEP-DTU Partnership for implementing this project in collaboration with Asian Institute of Technology (AIT).

(Syed Abu Ahmad Akif)
Secretary
Ministry of Climate Change

Chapter 1: Background and Introduction

1.1. Background

Pakistan played an active role in negotiation and paving the way for adoption of United Nations Framework Convention on Climate Change (UNFCCC) as leader of G-77 and China. Recognizing the increasing vulnerability of climate change, the UNFCC Convention was signed at first Rio Summit in 1992 and was ratified in 1994.The instrument of accession to the Kyoto Protocol was also deposited on 11th January 2005.The Pakistan Clean Development Mechanism (CDM) strategy, National Climate Change Policy audits framework was also formulated to effectively address impacts of climate change in the country in 2006, 2012 and 2013, respectively. To benefit from the emerging carbon market thirty-eight CDM projects in the potential Greenhouse Gas (GHG) emission sectors were developed and registered with CDM Executive Board. In addition, Pakistan also accessed funding from Global Environment Facility (GEF) for mitigation of climate change impacts in the country.

On the basis of GHG Inventory carried out in 1994 Pakistan submitted its First report on National Communication during 10thSession of Conference of the Parties (COP) held in 2004 in Buenos Aires, Argentina. The second inventory was carried out in 2008 to provide back-up data to the National Climate Change Task Force as well as for preparation of National Climate Change Policy, in 2010 and 2012 respectively. Recently, the GHG inventory of 2008 was updated in 2012. However, the work on Second National Communication is in progress. For this purpose, as per Inter-governmental Panel on Climate Change (IPCC) guidelines, a fresh exercise will be carried out for preparation of up to date GHG inventory.

Pakistan is a low GHG emitting country, but is severely impacted by climate change impacts for the last four decades. Out of 15 recurring natural disasters, 13 were triggered by the changing climate. The Global Climate Risk Index 2014 of German Watch ranked Pakistan among one of the three countries as most affected by climate change for the last three years. The impacts of flash floods, glacier lake outburst floods, landslides, avalanches, drought, sea water intrusion and cyclones, inflicted colossal damage to life, property, natural eco-system as well as to the economy of the country. The estimated damage cost of 2010 Floods alone was about US$9.7 billion.

Pakistan's economy is targeted to grow by over 8% by 2025 with single digit inflation. This will result in GDP per capita increasing from $1,300 to $4,200[1]. The population of Pakistan is projected to be around 251 million by 2025 and 344 million by 2050. Pakistan's GHG emissions are also expected to grow between now and 2030 as the Pakistan Vision 2025 aims to double the GDP growth as well as boost transportation and industrial activities along the Pakistan China Economic Corridor. The Vision 2025 envisages to double power generation to over 45,000 MW to provide uninterrupted and affordable electricity to its citizens and increase electricity access rate from 67% to over 90% of the population. The vision also aims to reduce average cost per unit of electricity by over 25% by improving generation mix (15%) and reducing distribution losses (10%). In addition, the Vision 2025 proposes to increase percentage of indigenous sources of power generation to over 50% and to address demand management issues by increasing usage of energy efficient appliances/products to 80%.

[1] Government of Pakistan; 2013; Pakistan Vision 2025; One Nation – one vision; Planning Commission; Ministry of Planning, Development and Reforms, Islamabad.

1.2. Technology Needs Assessment Project

The work on technology need assessment was initiated after an agreement among the Parties, at the seventh session of the Conference of the Parties (COP-7) in 2001.The implementation of technology transfer framework included: technology needs assessment; the enabling environments; technology information; capacity building and mechanisms for technology transfer. An Expert Group on Technology Transfer (EGTT) was established with the aim to enhance the implementation of this framework and to advance the technology transfer activities. Further, progress was made at the Copenhagen Climate Change Conference in 2009 in this domain, and the resulting Copenhagen Accord focusing technology transfer high on the climate change agenda.

The Technology Expert Committee (TEC), along with the Climate Technology Centre and Network (CTCN), are the two components of the UNFCCC Technology Mechanism agreed upon at the 2010 Conference of the Parties (COP-16) in Cancun, Mexico. The Mechanism's main objective is to accelerate development and transfer of climate change technologies in support of climate mitigation and adaptation. The TEC and CTCN have helped in carrying out technology need assessment, identification of barriers to technology and development of technology action plans to remove such barriers as well as creating enabling environment; dissemination of technology information; capacity building and mechanisms for technology transfer within the framework of UNFCCC.

In 2015, the Ministry of Climate Change, Government of Pakistan being the national focal point for UNFCCC has been selected to implement TNA project in collaboration with the United Nations Environment Program (UNEP), Climate Technology Centre & Network (CTCN) and Technical University of Denmark (DTU) partnership on behalf of UNFCCC and Global Environment Facility is undertaking Technology Needs Assessment. The Asian Institute of Technology (AIT) is tasked to provide technical supervision of the process in Pakistan.

The purpose of TNA project is to assist Pakistan in identification and analysis of its priority technology needs. This will form the basis for development of environmentally sound technology projects and program to facilitate transfer and access technologies in accordance with Article 4.5 of UNFCCC. The main objectives of the project are to:

1. Identify and prioritize through country driven participatory processes the technologies that can contribute to mitigation and adaptation goals of the participating countries while, meeting their national sustainable development goals and priorities.
2. Identify barriers hindering the acquisition, deployment and diffusion of prioritized technologies; and
3. Develop Technology Action Plans (TAP) specifying activities and enabling framework to overcome the barriers and facilitate the transfer, adoption and diffusion of selected technologies in the priority areas of national relevance.

The project also aims to build capacity of Pakistan to effectively meet the obligations under the UNFCCC for mitigating GHG emissions, to reduce vulnerability of sectors, and to protect livelihoods of the communities exposed to the adverse impacts of climate change. For implementation of TNA project in Pakistan and accomplishment of the above stated objectives, the UNEP has engaged the services of National Mitigation and Adaptation Consultants. Director General (Environment and

Climate Change), Ministry of Climate Change was designated as TNA Coordinator and his office will serve as the Secretariat for the project.

The Technology Need Assessment report on Mitigation has been prepared by the National Consultant on Mitigation. This report fulfills the first objective of the project and presents the assessment of prioritized technologies for mitigation in the energy, including waste, agriculture and livestock including Land use, land use change and forestry (LULUCF) and transport Sectors. The other two reports on Barrier analysis and Technology Action Plan will be prepared in due course as per agreed work program.

1.3. Existing National Policies and Sustainable Development Strategies on Climate Change Mitigation & Development Priorities

The national policies on Climate Change mitigation and development priorities are reflected in the following government policies, strategies and plans:

i. Pakistan Vision 2025;
ii. National Climate Change Policy, 2012;
iii. National Development Strategy, 2012;
iv. National Energy Conservation Policy, 2007;
v. National Operational Strategy for Clean Development Mechanism, 2006;
vi. Renewable Energy Policy for Development of Power Generation, 2006;
vii. National Environmental Policy, 2005;
viii. Pakistan National Conservation Strategy (NCS), 1992

1.3.1. Pakistan Vision 2025

The perspective plan, "Pakistan Vision 2025" recognizes climate changes as one of its priority areas. It states that climate change had already begun to impose steep social and economic costs, especially in developing countries. These costs have manifested themselves conspicuously in Pakistan, and include high intensity floods (Flash floods & Glacial lake outburst floods), avalanches and land-slides; persistent drought, sea water intrusion, and cyclone. These disasters have direct and major impact on vital considerations like water, energy, and food security. The Vision 2025 recognizing the impact of vulnerability to climate change and increased frequency and severity of recurring natural disasters, sets out the following key goals for responding climate change induced challenges;

- Design water, food and energy security policies and plans of the country with specific reference to the profound challenges posed by climate change.
- Explicit recognition of the relevant risks (and associated economic and social costs and implementation of well-defined mitigation and adaptation strategies / measures.
- To promote long term sustainability, conservation and protection of natural resources.

Relevance with TNA: The Vision also underlines the low technical and financial capacity to mitigate the effects of climate change and recommends mobilizing financial and technical support from Global financing sources such as Green Climate Fund; Nationally Appropriate Mitigation Actions (NAMA) and technical capacity building and institutional strengthening support through UNFCCC financing

mechanisms. The TNA exercise will identify and prioritize technologies for climate change mitigation and mobilize financial resources for these sectors.

1.3.2. National Climate Change Policy 2012

The goal of National Climate Change Policy 2012 is to ensure that climate change is mainstreamed in the economically and socially vulnerable sectors of the economy and to steer Pakistan towards climate resilient development. Major policy objectives include the following:

- To pursue sustained economic growth by appropriately addressing the challenges of climate change;
- To focus on pro-poor gender sensitive adaptation while also promoting mitigation to the extent possible in a cost-effective manner;
- To ensure water, food and energy security of the country in the face of the challenges posed by climate change;
- To enhance the awareness, skill and institutional capacity of relevant stakeholders.

The policy recognizes that developing countries face the dual challenge of addressing the negative impacts of climate change and pursuing socioeconomic development. Hence, it is essential that they work together to face these challenges. Pakistan is committed to engage vigorously with the international community to find solutions and help the world towards a new era of global cooperation on climate change. Moreover, the policy focuses on adoption of innovative technological solutions to solve the climate change challenges of mitigation for reduction of GHG emissions in the energy including industries and buildings; agriculture and livestock; forestry; and transport sectors. The Policy recommends following measures in this regard:

a. Ensure that the technology needs to support actions on mitigation and adaptation are nationally determined and are based on national priorities;
b. Promote the development and use of local technologies, based on innovation and technological advancement in the field of climate change, as an effective way to implement adaptation and mitigation measures;
c. Prepare detailed area analysis for possible wind and solar energy sites in Pakistan, and establish regional partnerships for technology transfer and development;
d. Seek technological breakthroughs to harness the potential of geothermal energy in the northern mountain areas of Pakistan;
e. Explore new technological breakthroughs in the field of bio-fuels;
f. Obtain and introduce clean coal technologies;
g. Ensure technology transfer for the design and manufacture of emission monitoring equipment, to be installed near urban and industrial areas in Pakistan;
h. Establish a base for technology transfer and absorption at technical institutes, engineering colleges and universities;
i. Ensure transfer of technology for designing electric/ hybrid vehicles in Pakistan;
j. Develop new breeds of crops and livestock, which are less vulnerable to climate change impacts.
k. Ensure the access and effective use of opportunities available internationally for adaptation and mitigation efforts, e.g. through the Green Climate Fund (GCF), Clean Development Mechanism (CDM), Adaptation Fund (AF), Global Environmental Facility (GEF), World Bank's Forest Carbon Partnership Facility (FCPF) and Carbon credit trading.

l. Incorporate an appropriate role for women into the decision-making process on climate change mitigation initiatives;
m. Undertake a comprehensive study of the gender-differentiated impacts of climate change with particular focus on gender difference in capabilities to cope with climate change mitigation strategies in Pakistan.
n. Plan the necessary expansion of nuclear power for Pakistan's energy security while ensuring the highest safety standards

Relevance with TNA: The TNA will directly meets the policy's recommended measures, particularly stated at a, f, h and k above.

1.3.3. National Sustainable Development Strategy 2012

The National Sustainable Development Strategy (NSDS) defines sustainable development and the pathway to a "green economy" in Pakistan's context. The overall focus of NSDS in the environmental context is on safeguarding the environment by:

- Conserving and enhancing the natural resource base while protecting biodiversity and managing fragile ecosystems through an integrated natural resource management approach.
- Enhancing the life support system by addressing air and water pollution and reducing the ecological footprint of growth through strengthening the regulatory framework and community-based interventions.
- Preparing for climate change and its accompanying uncertainties through comprehensive adaptation and mitigation planning and concrete implementation measures.

Relevance with TNA: The TNA exercise will help in achieving the objectives of NSDS by facilitating preparation of plans for climate change mitigation, reduction of carbon footprints and promotion of green economy in the country through implementation of prioritized technologies.

1.3.4. National Energy Conservation Policy (2007)

The National Energy Conservation Policy (2007) focuses on energy efficiency and conservation measures to reduce CO_2 emissions and help Pakistan meet its international climate change responsibilities. The policy underlines that a unit of energy conserved is a unit of energy produced. Efficient use of energy in various sectors of economy to reduce adverse local environmental effects which are otherwise attributed to energy inefficiency and wasteful energy use practices is an important goal of the policy. Provision of energy to rural areas serves the goals of gender equality and mainstreaming energy conservation as a part of development policy process. The policy also provides sectoral guidelines for industrial; transport; building and household; Agriculture including livestock and forestry sectors.

Relevance with TNA: Out of sixteen (16) prioritized technologies; eleven (11) relate to energy conservation which is in line with the measures identified in the National Energy Conservation Policy.

1.3.5. National Operational Strategy for Clean Development Mechanism 2006

This operational strategy has been developed to fulfill the requirements of establishing a Designated National Authority (DNA) and ensuring transparent, participatory and effective management of CDM process in the country. The strategy describes the functions and powers of the DNA and the national approval process. It builds on preliminary studies for initial projects including Asia Least Cost

Greenhouse Gases Abatement Strategy (ALGAS) and Pakistan's Initial Communication on Climate Change, which provides a general framework for operating CDM in Pakistan.

Relevance with TNA: All the identified and prioritized technologies will generate Certified Emission Reductions (CERs) and reduce carbon foot print. These would also help in developing new CDM projects for the country.

1.3.6. National Renewable Energy Policy for Development of Power Generation 2006

The renewable energy policy emphasizes on the following policy guidelines:

i. Energy Security
ii. Economic Benefits
iii. Social Equity
iv. Environmental Protection

The Policy emphasizes on mainstreaming of renewable energy and greater use of indigenous resources to help diversify Pakistan's energy mix and reduce the country's dependence on any single source, particularly imported fossil fuels, thereby mitigating against supply disruptions and price fluctuation risks. When properly assessed for their externalities, renewable energy options to become economically competitive with conventional energy sources on a least-cost basis.

To elevate Pakistan's present low per-capita consumption of energy through greater renewable energy use, issues relating to social equity such as equal rights and access for all citizens to modern energy supplies, improved human development indicators, poverty alleviation amongst deprived sections of society, and reduced burden on rural women for biomass fuel collection and use to be addressed significantly through widespread renewable energy deployment. Local environmental and health impacts of unsustainable and inefficient traditional biomass fuels and fossil fuel-powered electricity generation and GHG emissions need to be largely circumvented through clean, renewable energy alternatives.

Relevance with TNA: Four prioritized renewable technologies including, solar; micro-hydel; wind and bio-methane production relate to measures recommended in the National Renewable Energy Policy for Development of Power Generation.

1.3.7. National Environment Policy 2005

The policy provides guidelines for protection, conservation and restoration of Pakistan's environment in order to improve the quality of life of citizens through sustainable development. The policy provides sectoral and cross-sectoral guidelines for environment protection and sustainable development. The Policy also focuses on climate change and ozone depletion; energy efficiency and renewable; water supply and management; air quality and noise; waste management; agriculture, livestock; forestry, biodiversity and protected areas and multi-lateral environmental agreements.

Relevance with TNA: The prioritized technologies will help in achieving the objectives of National Environment Policy as the mitigation technologies will improve environment, reduce carbon foot print, and promote sustainable development.

1.3.8. Formulation of National Conservation Strategy 1992

The Pakistan National Conservation Strategy (NCS) 1992; provides a broad framework for addressing environmental concerns of the country in the following 14 core areas: (i) Maintaining soils in cropland; (ii) Increasing irrigation efficiency; (iii) Protecting watersheds; (iv) Supporting forestry and plantations; (v) Restoring rangelands and improving livestock; (vi) Protecting water-bodies and sustaining fisheries; (vii) Conservation of biodiversity; (viii) Increasing energy efficiency; (ix) Developing and deploying renewable; (x) Preventing and abating pollution; (xi) Managing urban wastes; (xii) Supporting institutions for common resources; (xiii) Integration population and environment programs; and (xiv) Preserving the cultural heritage. A Ministerial Committee was formed to oversee the implementation of the strategy.

To support implementation of the NCS, Pakistan Environment Program (PEP) and National Environmental Action Plan (NEAP)-Support Program were signed by the Government of Pakistan with the World Bank and UNDP, respectively.

- Pakistan Environment Program (PEP) was initiated in July 1994 and concluded in 2002 for the twin purposes of (a) capacity building of the partner organizations themselves as the key institutions for sustaining the environment agenda in Pakistan, and (b) capacity building for the environment in the country at large, through activities of the PEP partners. These initiatives were designed to implement the recommendations of the NCS. Some of these included the following: Sustainable Development Policy Institute, an independent, non-profit policy research institute was established. Capacity of Ministry of Environment and Pakistan Environmental Protection Agency (Pak EPA) were strengthened. New institutions like Environment wing in the Planning Commission of Pakistan and Provincial EPAs were established and their capacities were built to monitor implementation of environmental and climate change initiatives at the federal and provincial levels. Provincial Conservation Strategies for Sarhad (Khyber Pakhtunkhwa), Balochistan and Punjab were formulated.
- National Environmental Action Plan (NEAP) was approved in 2001 which focuses on four core areas viz. clean air; clean water; solid waste management; and eco-system management. An integrated approach with involvement of provincial and local government has been adopted to implement the plan. Towards this aim, the UNDP supported NEAP-Support Program (2002-2007) that proposed a wide range of technical, institutional, regulatory, social and economic interventions in terms of different projects grouped under the following six major sub-programs; (a) policy coordination and environmental governance; (b) pollution control; (c) ecosystems management and natural resources conservation; energy conservation and renewable; (e) dry land management; and (f) grassroots initiatives.
- In addition, Global Change Impact Studies Centre (GCISC), the research arm of the then Ministry of Environment, Government of Pakistan was formed in 2002 for conducting climate change research and studying its effects and impacts.

Relevance with TNA: The NCS provided comprehensive strategic measures to arrest GHG emissions from industries, power, wastes, agriculture, building, transport. It also guided in increasing carbon sink by conservation of biodiversity and mass scale afforestation in the country. The TNA exercise will help in achieving these objectives.

1.3.1. Legislative Actions

Pakistan Environmental Protection Act, 1997

Pakistan Environmental Protection Act was enacted in 1997. Under the Act, apex body on environment called as "Pakistan Environmental Protection Council" has been established and headed by the Prime Minister. The Council co-ordinate and supervise enforcement of the provisions of this Act. Furthermore, it provides guidelines for the protection and conservation of species, habitats, and biodiversity in general, and for the conservation of renewable and non-renewable resources and co-ordinate integration of the principles and concerns of sustainable development into national development plans and policies. Institutions such as Environmental Protection Agencies at the federal and provincial/territories level and for appellate jurisdiction Environmental Tribunals have been established. The Environmental Protection Agencies administer and implement this Act and the rules and regulations made thereunder.

National Environmental Quality Standards (NEQS) for air, water and land pollutions and abatement of GHG emissions were also prepared and notified in 2000 and emended in 2012, and these have been enforced. The Environmental Protection Agencies review the initial environmental examination and accord its approval, or may call for submission of an environmental impact assessment by the proponent. The Agencies may levy a pollution charge on any person who contravenes or fails to comply with the provisions of the Act. The Act also provides for the establishment of Sustainable Development Fund Board as a mechanism to sanction financial assistance for eligible projects for achieving the objectives of this Act. The Board may constitute committees of its members to undertake regular monitoring of such projects.

However, after the 18th Constitutional Amendment in October 2010, the subject of Environment has been devolved to the provinces except federal functions, particularly those related to multi-lateral environmental agreements, conventions, and protocols. The provinces are in a process of developing legal instruments for protection and conservation of environment in their respective jurisdiction.

Energy Efficiency & Conservation Bill (2015)

Energy Efficiency & Conservation Bill (2015) has been approved by the National Assembly Standing Committee of Water and Power and waiting approval of the National Assembly and Senate of Pakistan. On approval of this legislation Pakistan Energy Efficiency and Conservation Board will be established and it would be empowered to implement a fine up to Rs. 500,000 for not using efficient power devices.

Chapter2. Institutional Arrangement for the TNA and Stakeholders involvement

The Federal Ministry of Climate Change (MoCC) being focal ministry for UNFCCC was designated as the national focal point for the implementation of TNA project. For facilitating implementation of the TNA project, the National Climate Change Policy Implementation Committee has been designated as the National TNA Steering Committee. This Committee is headed by the Federal Minister for Climate Change and represented by the Federal Secretaries of the Ministry of Climate Change, Planning and Development, Foreign Affairs, Science and Technology, Industries and Production, Finance, Water and Power, Food and Agriculture, Health and Defence. Provincial chief secretaries, Chairman National Disaster Management Authority (NDMA), Federal Flood Commission, Heads of the Research Organizations, academia, cooperate sector and civil society.

The TNA project implementation comprises of five tiers process. The TNA project management included National Climate Change Policy Implementation Committee, Project Management Office, Mitigation Expert, Expert Working Group on Mitigation, Partner Organization (UNEP-DTU Centre, Climate Technology Centre & Network, and the Asian Institute of Technology) and other national stakeholders including public/private sector, academia, and civil society. National Climate Change Policy Implementation Committee also serves as National TNA Steering Committee. The overall goal of involvement of all stakeholders is to ensure project's effectiveness, efficiency, relevance, alignment and timely implementation. The institutional structure of the TNA process is as shown in Figure1. The roles and responsibilities of each tier are described in section 2.1 while section 2.2 provides information on the engagement processes.

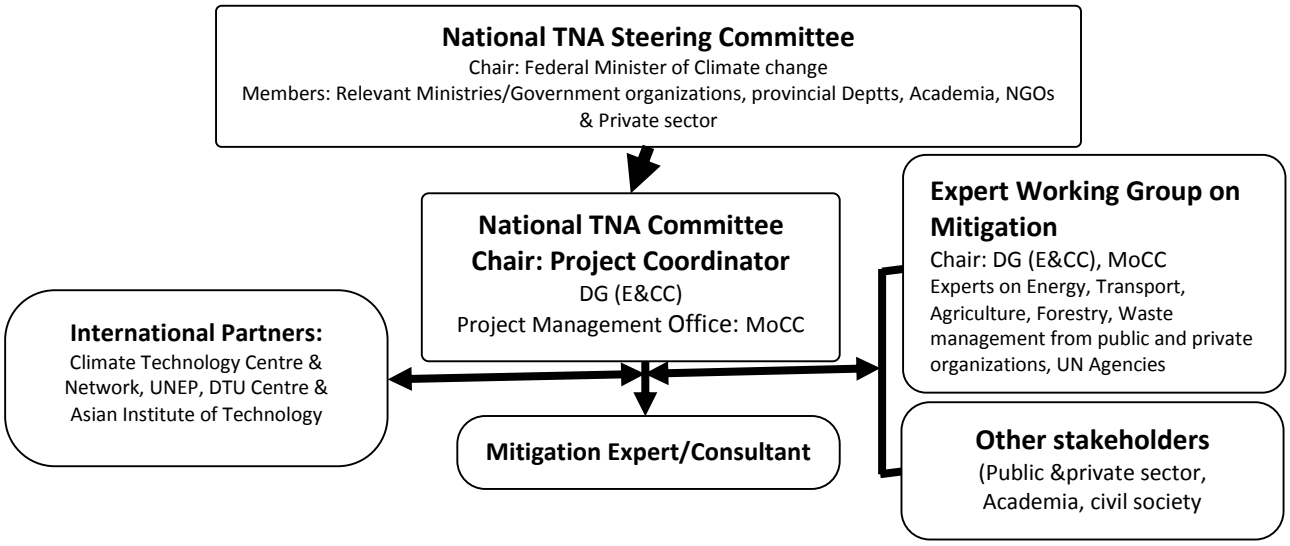


Figure: 2.1 TNA Project Implementation Tiers

2.1. Ministry responsible for the overall process

The Ministry of Climate Change, Government of Pakistan is the focal ministry responsible for the overall process of technology needs assessment. This Ministry is mandated by the Government for the

preparation of national policies, plans and programs for climate change mitigation and adaptation. The Ministry is also the national focal point for Kyoto Protocol/ CDM, UNFCCC, Montreal Protocol, UNCBD, UNCCD and other environmental conventions and protocols. The National Climate Change Policy states "To ensure that the technology needs to support actions on mitigation and adaptation are nationally determined and are based on national priorities". As such, the Ministry has the mandate to carry the TNA process forward.

2.2. National TNA Committee &Team for Technology Needs Assessment

The **Project Management Office** is headed by the Director General (Environment and Climate Change), Ministry of Climate Change, Government of Pakistan. The Director General is the Chair of National TNA Committee (Composition is at Annex XVIII) and Project Coordinator for TNA project. He is also the UNFCCC focal point. The overall role and responsibility of this office is to coordinate with ministries and experts from other institutions etc. for the implementation of the TNA project and report to the National Climate Change Policy Implementation Committee/ TNA Steering Committee, UNEP-DTU Centre and other international stakeholders.

The TNA Project Coordinator's office serves as Secretariat for the TNA project, facilitates in coordinating both technical and administrative tasks as well as with the Consultants, UNEP- DTU Center, the Asian Institute of Technology (AIT), Technical Working Group and other Stakeholders to facilitate the implementation of the project.

The **Expert/National Consultant:** Two national experts have been selected for the exercise, one for mitigation and another for adaptation. Each Expert is responsible for identification and prioritization of technologies as well as carrying out technology needs assessment, barrier analysis, and preparation of draft project proposals for priority technologies and Technology Action Plan (TAP) in consultation with stakeholders. In addition the consultant is providing process-related technical support, facilitation, including research, analysis and synthesis to the TNA Project Coordinator.

The mitigation consultant prepared **fifteen** fact sheets (annexed at I to XV) for prioritization of technologies in energy, agriculture & forestry and transport sectors. These sectors were selected based on the Inception Workshop held on 30th June-1st July 2015. The list of participants of the Inception workshop is at Annex XVI.

2.3. National Stakeholder Groups

The National Climate Change Policy Implementation Committee acts as **Steering Committee for TNA project**. The committee is a group of senior and decision making members, who were officially nominated for ensuring effective implementation of National Climate Change Policy and Action plans. This Committee will also guide and provide policy advice for the TNA process in Pakistan. Furthermore, it will approve Action plan and guide implementation of TNA in Pakistan.

The **Expert Working Group on Mitigation** is comprised of thirty two eminent experts from energy, agriculture, industries, waste management, and transport sectors as well as ministries of Climate Change, Water and Power, Communication, Pakistan Atomic Energy Commission, Alternative Energy Development Board, National Centre for Energy Conservation, National Cleaner Production Centre,

National Transport Research Center, Global Change Impact Study Centre, Academia and UNDP. (List of Expert Working Group on Mitigation members are at Annex XVII)

2.4. International Partner Organizations

The Pakistan TNA processes commenced with the training workshop for the Asian Region partner countries for the Project Coordinators and the Consultants by the **International Partner Organizations** namely UNEP-DTU Partnership, Climate Technology Centre & Network and Asian Institute of Technology (AIT) in July2015 in Bangkok.

This was preceded by convening of the inception workshop in Islamabad from 30th June to 1st July 2015 which among other national stakeholders was also attended by representatives of AIT. This workshop after detailed discussion and considering the national circumstances and development needs; identified following sectors in Pakistan where the strongest development and climate benefits are expected to be achieved.

- Adaptation: a) water sector b) agriculture sector
- Mitigation: a) energy and waste sector, b) agriculture &LULUCF sector, c) transport sector

For Latin American and African partner countries a training workshop for Project Coordinators and the Consultants was arranged by UNEP-DTU and ENDA Energie in October 2015 at Dakar, Senegal. The Pakistan Consultant on Mitigation attended the training workshop in Senegal.

2.5. Consultations with stakeholders

In two days inception workshop held on 30th June – 1st July 2015 in Islamabad, three priority sectors for mitigation were selected i.e. energy and waste sector; agriculture, land use change and forestry sector; and transport sector. The work plan for TNA with tasks and milestones was finalized.

The members of the Expert Working Group on Mitigation (List attached at Annex XVII) in their meeting held on 27thOctober 2015 prioritized the technologies on mitigation through Multi-Criteria Decision Analysis (MCDA). The MCDA process followed and technologies prioritized in each of the three sectors are described in the relevant chapters (Chapter 4, 5 & 6) Other Stakeholders

The Other Stakeholders including public, private, academia and civil society are fully on board (List provided at Annex XIX. The representatives of the other stakeholders were invited in inception workshop as well as in the meeting of Expert working group on mitigation which prioritized the technologies on mitigation. The Mitigation Consultant also held bilateral meetings with the stakeholders for obtaining relevant data and discussion on future mitigation projects.

Chapter 3: Sector Selection

Like other developing countries, Pakistan's emissions are bound to increase considerably as the country climbs over the development ladder and strives to provide adequate amount of energy to support its growing socio-economic development needs. The level of GHG emission is 369 million tons of CO_2equivalent in 2012 which is projected to sharply rise by one and a half times by 2020. It will further rise by about three times by 2030 from the level of 2012. It will spike between 2030 and 2050 by four and a half times higher. This trend is a result of increasing energy needs due to increase in population growth, urbanization, industrialization and massive economic growth projected as a result of Pakistan China Economic Corridor initiative. This is illustrated in the Figure 3.1[2]

[2]Khan, M.A.A; 2011; National Economic and Environmental Development Study (NEEDS); Ministry of Climate Change, Government of Pakistan & United Nations Convention on Climate Change (UNFCCC). Page:37, table 9

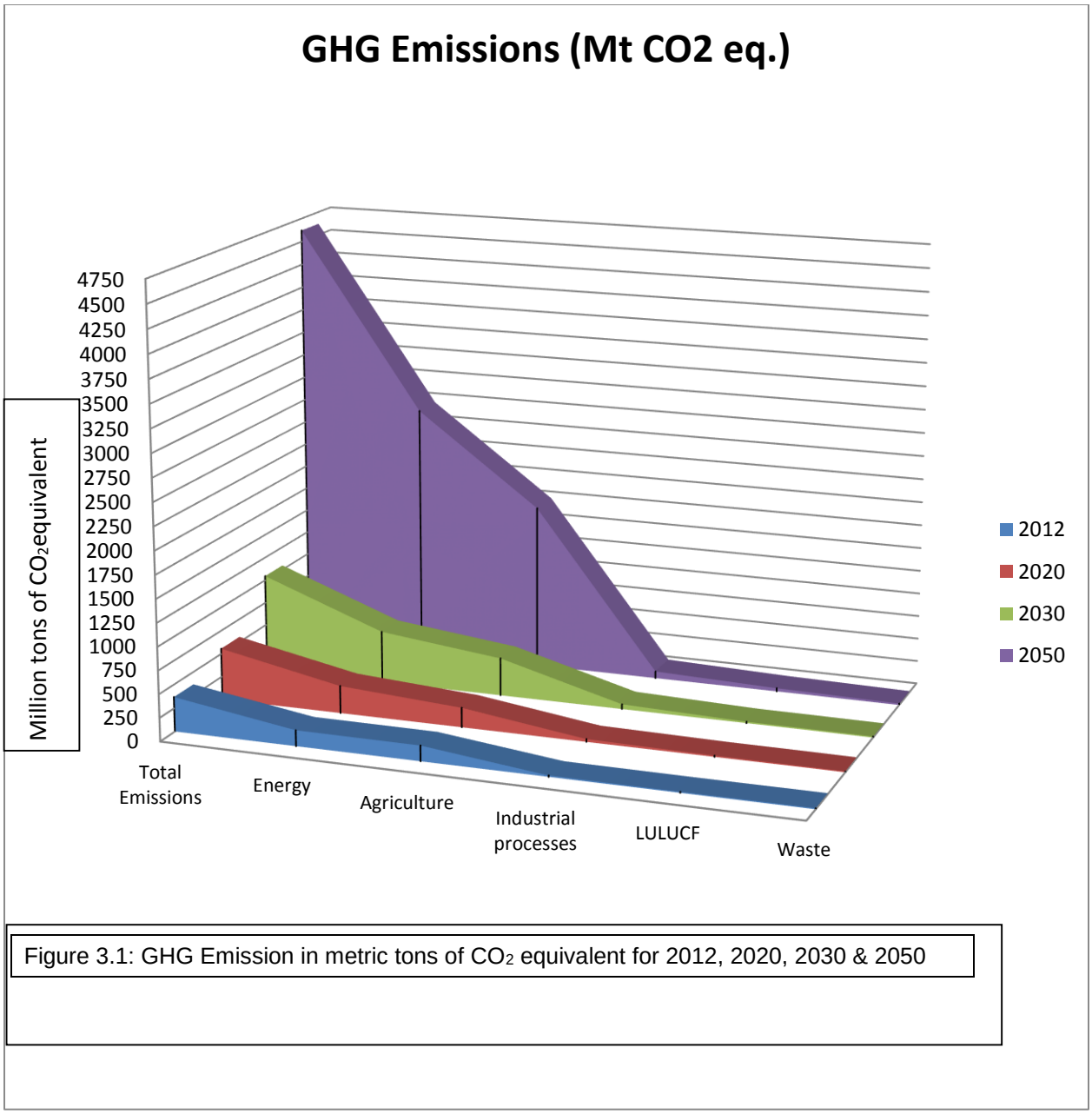


Figure 3.1: GHG Emission in metric tons of CO_2 equivalent for 2012, 2020, 2030 & 2050

3

3.1. Selection of Sectors and GHG emission

The National Inception Workshop on Technology Needs Assessment (TNA) was held from 30th June 2015 to 1st July, 2015 in Islamabad for climate change mitigation sector selection through a multi-stakeholder participatory process. It was highlighted that the total estimated GHG emissions of 2012 are 369 million tons of CO_2 equivalent with 45.9 percent share of energy including transport sector, 3.9

[3]Khan, M.A.A; 2011; National Economic and Environmental Development Study (NEEDS); Ministry of Climate Change, Government of Pakistan & United Nations Convention on Climate Change (UNFCCC). Page:37, table 9 & Government of Pakistan, Planning Commission; 2010; Task Force on Climate Change, Final report; page 8; table 3.3

percent share of industrial processes, 44.8 percent share of Agriculture, 2.6 percent share of land use change and forestry and 2.8 percent share of waste sector[4].

3.1.1 Process of Sector Prioritization:

After a detailed discussion and considering the national circumstances, development needs and GHG emission reduction potential of various sectors of economy, the expert group during its meeting came to conclusion that high emitting sectors should be chosen as priority sectors for climate change mitigation efforts in the country. Furthermore, it was agreed to combine Agriculture with land use change and forestry as the forestry sectors is also a part of the definition of the Agriculture sector. As the transport sector is growing at a much faster rate so national GHG emissions from transport sector were taken as a separate sector. Emissions from transport sector increased from 19.848 million tons in 1994 to 42.572 million tons in 2012. The following sectors were identified for TNA under mitigation:

a) Energy Sector[5]

i. Industry,
ii. Buildings,
iii. Renewables

b) Agriculture and forestry

i. Agriculture
ii. Land use change & forestry

c) Transport Sector

i. Road
ii. Rails
iii. Maritimes
iv. Air

The overall GHG emissions and removals in different sectors in Pakistan over three inventory years i.e. 1994, 2008 and 2012 are presented below in the Table 3.2:

Table 3.1: Overall GHG emissions and removals in different sectors in Pakistan over three inventory years i.e. 1994, 2008 and 2012[1]

GHG national emissions & removals	Total emissions million tons of CO_2 equivalent Inventory year		
	1994	2008	2012
Energy sector (Excluding transport)	65.968	123.347	126.694
Transport	19.848	33.474	42.572
Energy sector	85.816	156.821	169.266
Industrial processes	13.297	17.866	14.301
Agriculture	71.632	120.284	165.295
Land use change & forestry	6.527	8.920	9.671
Waste	4.454	5.505	10.470

[4]Mir, K.A; Ijaz, M (May 2015); Greenhouse gas emission inventory of Pakistan for the Year 2011-2012; Global Change Impact Study Centre, Islamabad, Pakistan GCISC Interim Research Report RR-19 (Interim)

[5] Energy sector includes industrial process, building, and power

Total	**181.726**	**309.396**	**369.003**

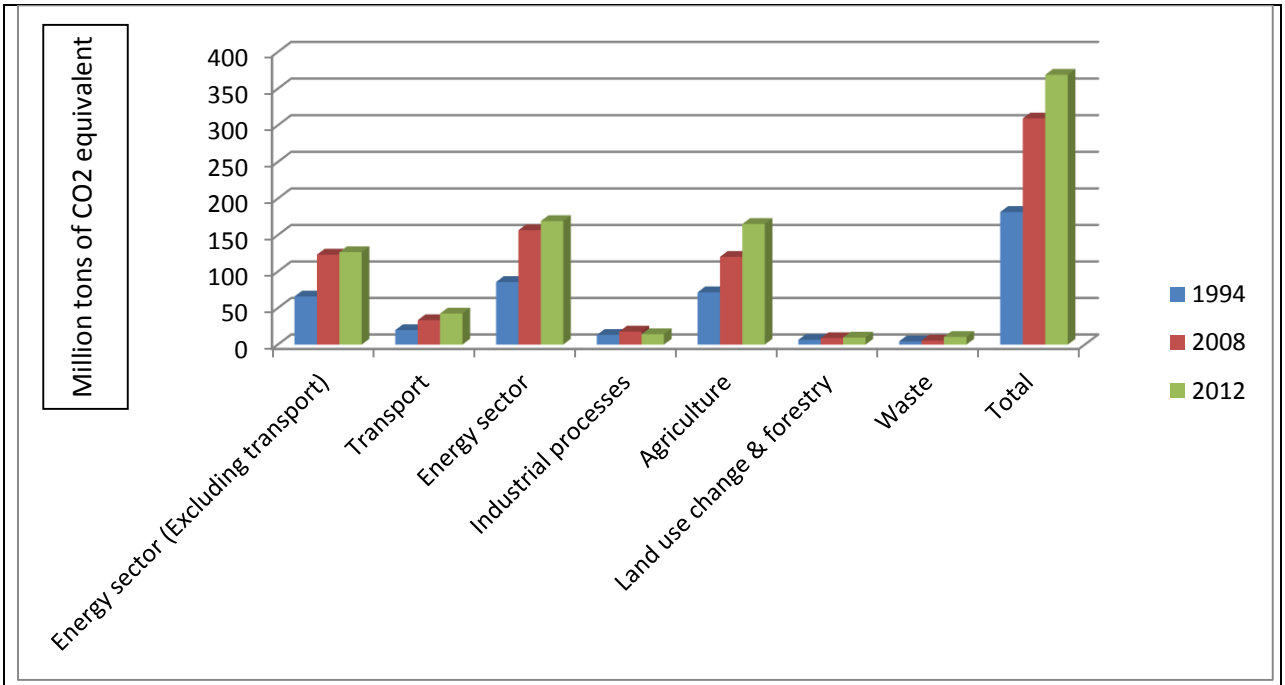


Figure 3.2: Total National GHG emissions & removals million tons of CO2 equivalent by Inventory year

The Table 3.1 and figure 3.2 indicates that the GHG emissions from energy sector remained high during both the inventory years of 1994 and 2008, while the agriculture sector, which was the second largest emitter after the energy sector in the past two inventory years became the largest GHG emission source as per Inventory year 2012. While transport sector remained third largest source of GHG emission in all the three Inventory years. The other two sectors land use change, forestry and waste remained less than 4 percent of the total national GHG emissions.

3.2. Energy Consumption by sectors and by sources

Energy consumption by sectors for the years 2008-9 to 2013-14 are explained in Figure 3.3. The energy consumption of industrial sector was highest during the year 2009-10, but with the energy crisis, the energy consumption of the sector followed a decreasing trend. Building sector showed an increasing trend up to 2012-13 while transport sector is witnessed an increasing trend.

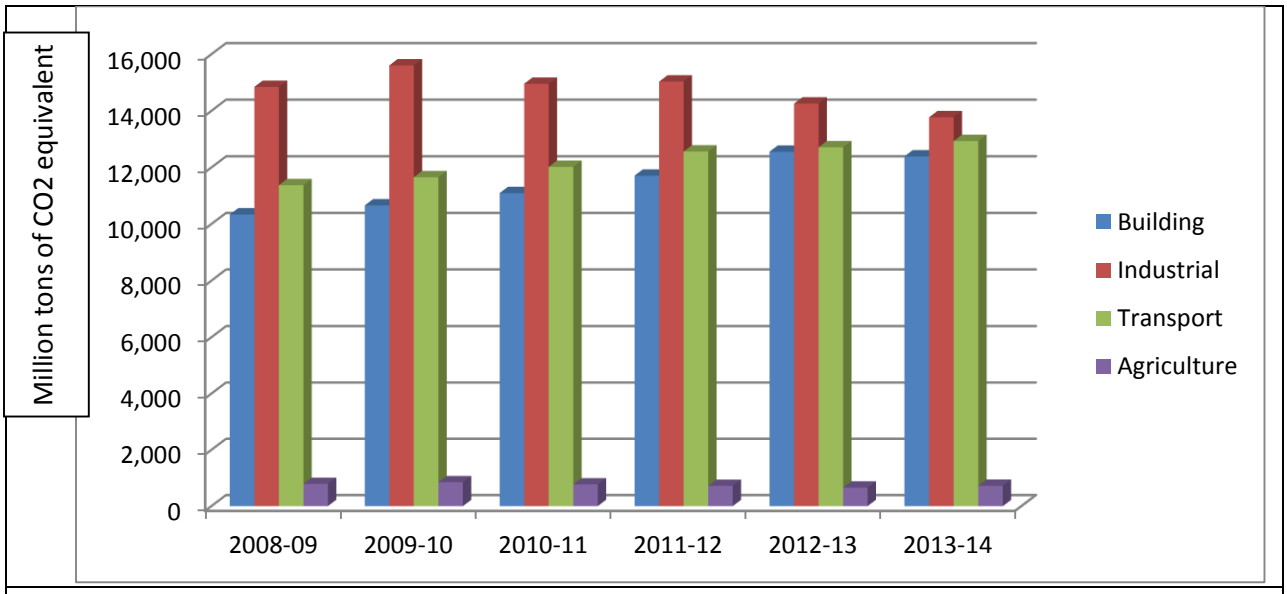


Figure 3.3: Energy Consumption by Sector (Thousand TOE) from 2008-2014[6]

The overall energy consumption trend by major sources including oil, gas, coal, electricity and liquefied petroleum gas (LPG) from 2008 to 2014 are shown below at Figure 3.4.

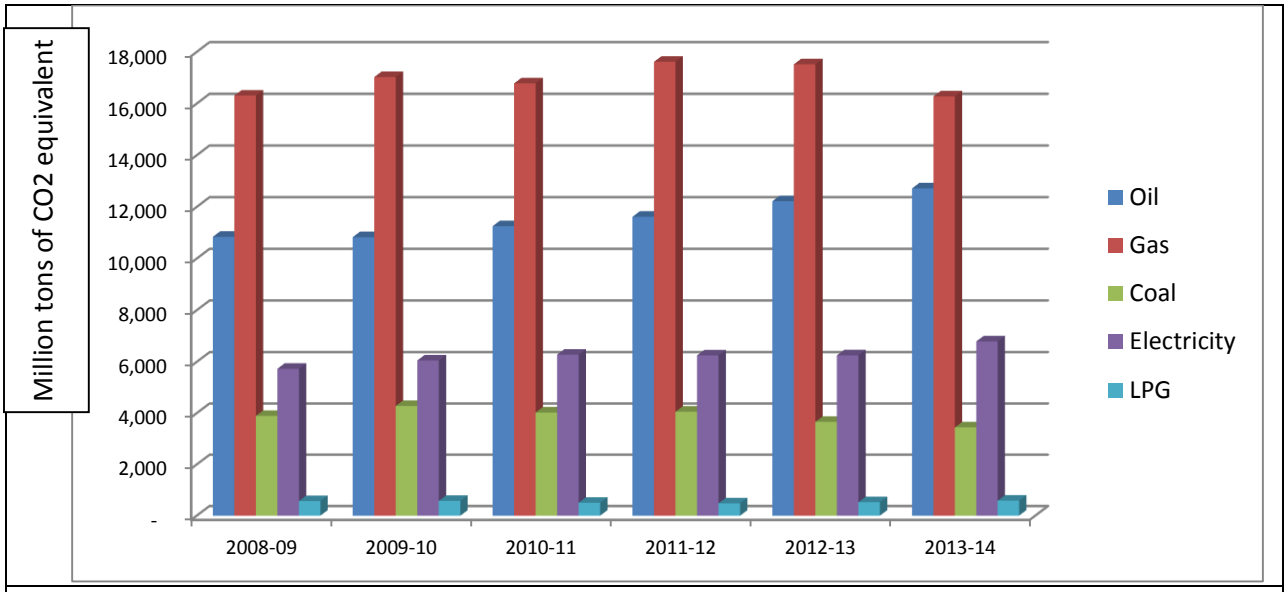


Figure 3.4: Energy Consumption by Source (Thousand TOE) 2008-2014[7]

The trend shows that energy consumption from gas source is highest compared to other sources of energy consumption. But the energy consumption from gas source is following a decreasing trend from year 2011-12. While oil source of energy is showing an increasing trend because of its decreasing cost in the country as well as expansion of increasing trend in total number of vehicles. From year 2000 to 2009, the annual increasing in total number of vehicles was less than 6 percent but in 2010 and 2011, it was 19.7

[6] Hydrocarbon Development Institute of Pakistan, Energy Yearbook 2014
[7] Hydrocarbon Development Institute of Pakistan, Energy Yearbook 2014

percent and 15.6 percent, respectively[8].It is also noted that GDP growth rate was 0.4%; 2.6%; 3.7% and 4.4% in 2008-9; 2009-10; 2010-11 and 2011-12, respectively[9].

Chapter 4: Technology prioritization for the Energy and Waste sectors

Technology prioritization for energy and waste sectors was carried out by assessing technologies through multi-criteria analysis; which were based on determining assessment framework and conducting assessment on technologies based on their contribution to development goals, potential for GHG emission reduction on vulnerability reduction costs and benefits as well as use of TNA tools which were based on establishing a decision context and criteria, following which the performance of the technologies was assessed against the established criteria. Final decisions were made on the basis of reviewing assessment results as well as conducting sensitivity analysis on assessment results and deciding prioritization of technologies for sub-sectors.

The technology prioritization was conducted in the technology prioritization workshop held on 27th October 2015, which was attended by participants from relevant departments; ministries and organizations (Participants' list at Annex XVII).The technology prioritization process and Multi-criteria analysis[10],as per material and excel software provided during consultant's training in Senegal from September 30 to October 2, 2015, was introduced and applied in the work shop and the results are described in Section4.4.3.

4.1. GHG emissions; Existing and Potential Technologies in the Energy and Waste sectors

4.1.1. Energy sector GHG Emissions

The total estimated GHG emissions from the energy including transport sector is 169.266 million tons of CO_2 equivalent or 45.9percent of total GHG emissions in 2012. The above estimated emission when compared with 1994 and 2008 inventory years, indicates that in 1994, the level of energy sector emissions was85.816 metric tons of CO_2 equivalent or 47.2 percent of total GHG emission and in 2008 156.821 metric tons of CO_2 equivalent or 50.7 percent of total GHG emission.

The reason for decline in the level of GHG emissions in terms of percentage of total GHG emissions could be attributed to a number of measures such as Pakistan's ratification of Kyoto Protocol and opening of the new window of carbon trading under CDM. These included switching from fossil fuel to natural gas in power production in industries and power sector. Another factor contributing to reduction in GHG emissions in the industrial sector is closing down of production of some high energy consuming industries due to energy shortage. The other industries which are operating within the energy shortage have reduced their working hours.

[8] Government of Pakistan, Pakistan Economic Survey 2011-12; Chapter 13: Transport and Communication; Finance Division, Economic Advisors Wing, Islamabad; table 13.3

[9] Government of Pakistan, Pakistan Economic Survey 2012-13; Chapter 1: Growth and Investment; Finance Division, Economic Advisors Wing, Islamabad; Figure 1.1

[10] Reference: MCA Guidance for Mitigation available at http://www.tech-action.org/Publication/TNA-Guidebooks

Further, with the reduction of natural gas reserves, the Government is now importing Liquefied Natural Gas (LNG) to meet the demand of natural gas supply. The oil resources are dismally low; about85% of the country's oil requirements (equivalent to 29% of the total energy supply) are being met through imports, with the oil imports bill siphoning off one-third to half of the precious exports earnings (36% in 2006-07 and 57% in 2007-08) until late 2014 when the global oil price started falling sharply and touched below US$50 per barrel in January 2015.

In terms of energy demand, the country is presently faces situation of unmet demand. Pakistan's current installed electricity capacity is 20,000MW, which is not enough to meet the country's current electricity demand[11] leading to frequent load-shedding especially during peak consumption times. In 2015 Pakistan faced the highest energy shortfall of 7,712MW[12]. This situation has also led domestic and industrial users to rely, more upon inefficient electricity generators running on furnace oil, which, in turn, has increased average energy usage costs as well as GHG emissions.

4.1.2. GHG Emissions in Industrial processes

The GHG emissions from industrial processes have shown significant downward trend in the past three inventory years of 1994, 2008 and 2012. It was 13297 (7.3%); 17866 (5.8%) and 14301 million tons of CO_2 equivalent (3.9%) of the total GHG emissions, in inventory years 1994, 2008, and 2012, respectively. There are several reasons for such a declining trend that can be attributed to a large number of fuel switching CDM projects from fossil fuel to CNG. Other factors being, frequent electricity load-shedding causing diminishing level of productivity. In Pakistan, most high emission industries are cement, brick kiln, metal, textiles, petroleum refining, fertilizer, leather, mining, sugar and chemical industries. In various industries, boilers account for 35% of energy consumed and about 50% of these boilers are either more than fifty years old or imported second-hand and tend to be highly energy inefficient[13]. Thus, conversely, there exists a considerable potential for carbon mitigation through efficiency enhancement in these boilers.

4.1.3. GHG Emissions in Waste sector

The GHG emissions from waste sector contribute very little in the range of 1.5 to less than three percent of the total GHG emissions from all sectors. The level of emission was 4454 (2.45%), 5505 (1.77%) and 10470 million tons of CO_2 equivalent (2.83%) of the total GHG emissions in 1994, 2008 and 2012, respectively. Since recent past, due to severe energy crunch in the country, the industries particularly, cement industries have started using refused derived fuel (RDF) and tire derived fuel (TDF) as alternate source of energy to overcome the fuel shortage. Under CDM, two projects for compost making from waste have been registered under CDM and one project "Lahore Compost" is already under implementation. The project will save 548,407 tonnes of CO_2 in seven years. Another project namely "Waste to Energy" has been submitted for funding under NAMA Facility.

[11] Alauddin, A. (2009). 'Energy efficiency & Renewable Energy: The key to Sustainable Development'. AEDB.

[12] Pakistan Defence; CPEC group forecasts energy shortfall to increase to 10,844MW;
Source: http://defence.pk/threads/cpec-group-forecasts-energy-shortfall-to-increase-to-10-844mw.403719/

[13] Khan S.R., Khwaja M.A., Khan A. M., Kazmi S. and Ghani H. Environmental Impacts and Mitigation Costs of Cloth and Leather Exports from Pakistan, SDPI Monograph Series M. 12, Islamabad, Pakistan.1999

The 1994; 2008 and 2012 GHG inventory indicates that 2548; 4733 and 8610 thousand tons of CO_2 equivalents as Methane are discharged from waste management disposal facilities in Pakistan of these 2300; 2832 and 7707 tones are generated from solid wastes and the remainder from the management of waste water. In addition N_2O emission of 1906; 772 and 1860 thousand tons of CO_2equivalent is also discharged from these sources[14] (Figure 4.1).

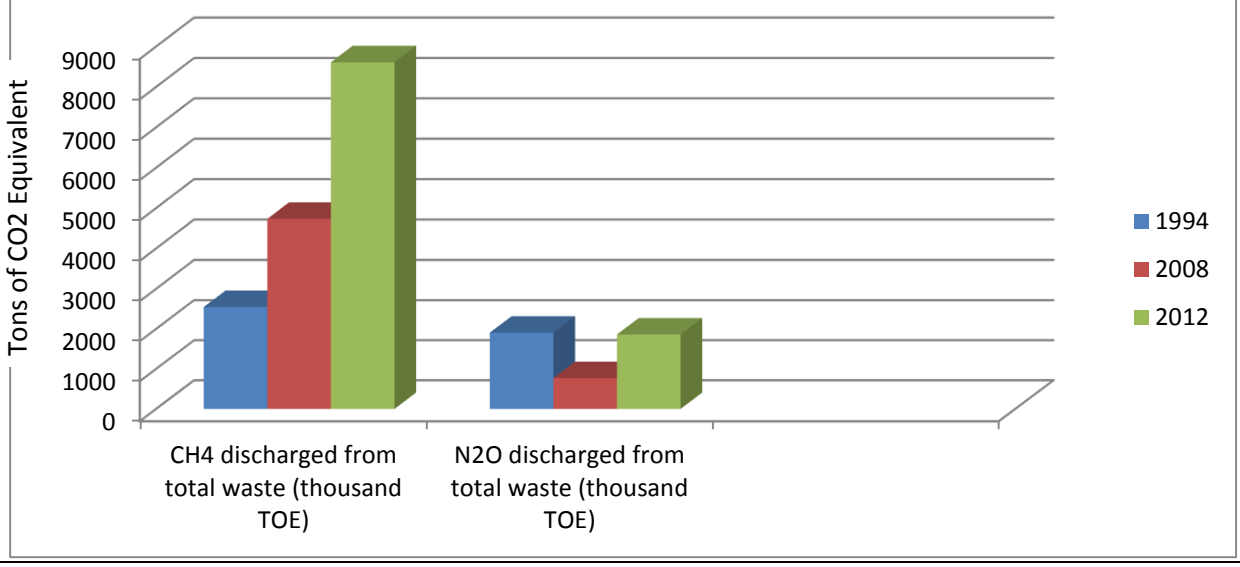


Figure 4.1: CH_4 discharge from total and solid waste, & N_2O discharge from total waste (Thousand TOE)

About 60,000 ton of solid waste is generated daily in urban areas of Pakistan and 60 percent of it is collected by the municipal authorities[15]. Some portion of waste is collected by private contractors or NGOs. There are three main ways of disposing waste, i.e. landfill, size reduction and screening. Waste to energy is an emerging technology in Pakistan and it is gaining importance.With the passage of time, it will replace the practice of informal disposal of solid waste in cities of Pakistan. In waste to energy sector, the Punjab Government has taken an initiative to set up a Waste to Energy power plant using "fluidized incineration technology" considering the characteristics of low caloric value and high moisture contents in the solid waste collected from Lahore city. Under this program, Lahore Waste Management Company has awarded the contract of preparing feasibility study to Eco Air's US Company that will also provide technical assistance to the project. There are some landfill sites in Pakistan but these are designed poorly leading to incomplete decomposition, methane production, and contamination of ground and surface water. Fermentation of organic matter in informal waste dumps and industrial organic effluents also has the potential to generate significant quantities of methane which makes up 45-60% of the landfill gas mixture.

[14]Mir, K.A; Ijaz, M (May 2015); Greenhouse gas emission inventory of Pakistan for the Year 2011-2012; Global Change Impact Study Centre, Islamabad, Pakistan GCISC Interim Research Report RR-19 (Interim)

[15]Planning Commission of Pakistan, 2015; Working paper for 11th Five Year Plan, http://www.pc.gov.pk/wp-content/uploads/2015/10/Ch22-Environment.pdf

4.1.4. Situational Analysis of coal

Pakistan has a vast coal reserves estimated to be 185 billion tonnes (82,700 m tons of oil equivalent), or about 2% of the world coal resources[16]. This coal reserves is of similar size as the combined oil reserves of Saudi Arabia and Iran (GoP-PC 2007) Coal in Pakistan has high moisture and sulfur contents. Therefore, in order to keep its energy import dependence to within manageable level (at present it stands at 35% level), Pakistan has no alternative but to utilize coal as an energy source in an environmental friendly manner. It is expected that the international community will help Pakistan to make use of its coal resources in a way consistent with the mitigation objectives. Historically, the country has low reliance on coal despite vast proven coal reserves and the total energy consumption from coal is 3.446 million TOE[17], which results in about 10 million Tons of CO_2 equivalent[18].

In 2008-09 and 2013-14 Pakistan's total energy consumption increased from 37.3 to 39.8 million tonnes[19] of oil equivalent (m TOE) which was met from a supply mix of gas decreased from 43.4% to 40.9%, oil increased from 29% to31.9%, electricity increased from 15.3% to 17.1%, coal decreased from 10.4% to 8.7%, and LPG remained constant at 1.5%[20]. The fossil fuel cumulatively accounted for almost 51% of the national GHG emissions in 2008-09 which has reduced to 46% in 2012.

This trend suggests that energy supply mix is shifting towards oil, coal, and other energy resources due to dropping of oil prices in the global market and Government's policy to promote coal by using clean coal technology. Pakistan's natural gas resources are depleting rapidly and the option for sustaining or increasing reliance upon natural gas by importing from Iran or Central Asian countries is being explored but remains uncertain owing to political and economic constraints.

4.1.5. Existing and potential mitigation technologies in the energy and waste sectors

There are a number of mitigation measures and technologies practiced in Pakistan for reducing GHG emissions in the energy sector. Prior to prioritizing the technologies in the energy sector the existing and potential mitigation technologies are mentioned below.

- ***Industrial***

  A.1. Steam boiler & furnace energy efficiency (EE) Improvement

  A.1.1. Boiler & furnace tune up

  A.1.2. Boiler air leakage

  A.1.3. Boiler insulation

  A.1.4. Clean coal technologies

  A.1.5. Boiler high turndown burner

[16]Task Force on Climate Change (2010).'Final Report of the Task Force on Climate Change'.Planning Commission, Pakistan. Available at: http://202.83.164.26/wps/wcm/connect/3782a300427619029d8bff44f6212cf9/TFCC_Final_Report_19_Feb_2010.pdf?MOD=AJPERES&CACHEID=3782a300427619029d8bff44f6212cf9&CACHEID=3782a300427619029d8bff44f6212cf9

[17] Energy Year book 2013-14

[18]Multiply TOE with 2.8 for converting it to tons of CO_2 equivalent

[19]Hydrocarbon Development Institute of Pakistan, Energy Yearbook 2013 & 2014

[20]Pakistan Economic Survey 2008-9 and 2013-14

A.1.6. Controlling boiler blow-down

A.1.7. Boiler air pre-heater

A.1.8. Variable frequency drive coupled with O2 trimming system

A.1.9. Feed water treatment

A.1.10. Flash steam recovery

A.1.11. Condensate recovery

A.1.12. Fouling of heat transfer surfaces

A.1.13. Boiler instrumentation and control

A.1.14. Combustion controls

A.1.15. Boiler water treatment

A.1.16. Solar water heating systems

A.1.17. Co-generation

A.2. Improving energy efficiency in electrical system in industries

A.2.1. Reducing losses in electrical distribution system

A.2.2. Power factor improvement

A.2.3. Maximum demand control

A.2.4. Efficient lighting systems

A.2.5. Efficient motors and pumps

A.2.6. Efficient fans and blowers

A.2.7. Improving efficiency in compressed air systems

A.2.8. Refrigeration improvement

A.2.9. Cooling towers

A.2.10. Heating, ventilation and air-conditioning system improvement

A.2.11. Building envelop improvement & introduction of renewable technologies

- ***Building***

B.1. Building design

B.2. Air conditioner inverter

B.3. Power factor improvement

B.4. Efficient lighting

B.5. Efficient motors and pumps

B.6. Efficient fans, over, heaters and other household equipment

- ***Energy production and its distribution***

  C.1. Micro and small hydro

  C.2. Solar concentrators and cookers

  C.3. Solar PV & LED lighting

  C.4. Solar domestic water heater

  C.5. Biogas – Compressed bio-methane

  C.6. Wind mill and generator

  C.7. Bagasse

  C.8. Integrated resource recovery or Extracting different products from waste

  C.9. Solar dryer

  C.10. Geothermal

  C.11. Bio-fuels

  C.12. Pressurized fluidized bed combustion (PFBC) for coal

  C.13. Near Zero-Emission Technology (NZET) for coal (Involving super-critical and Carbon capture and storage technologies)

  C.14. Pulverized coal integrated gasification combined cycle (IGCC)

  C.15. Waste to energy through fluidized incineration technology

  C.16. Waste to energy through anaerobic fermentation

  C.17. Waste to energy through its gasification

  C.18. Solar thermal electricity

  C.19. Reducing transmission and distribution losses of electricity

- ***Coal***

  D.1. Coal water slurry fuel
  D.2. Underground gasification
  D.3. Integrated Coal Gasification Combined Cycle (IGCC)
  D.4. Fluidized bed combustion
  D.5. Supercritical
  D.6. Ultra-supercritical

- ***CO_2 capture***

  D.1. Coal bed methane capture
  D.2. Biochar

4.1.6. Technology Fact Sheets of Shortlisted technologies

Out of the existing and potential energy technologies in Pakistan, the consultant initially identified 20 most relevant technologies for climate change mitigation based on literature review and prepared fact

sheets. These fact sheets were presented in the meeting of Expert Working Group on Mitigation for prioritization through MCDA. During the meeting the experts suggested to club all the six technologies for energy conservation in boiler and furnaces into one technology "Boiler and furnace energy efficiency improvement". Similarly, they suggested to club three technologies in the building sector into one technology "Reducing energy consumption in homes and offices through building design, air conditioning and power factor improvement in warmer areas"; four technologies of the solar (Technology No. 4, 5, 10& 12) into one "solar energy technologies" and Biogas was combined with bagasse and integrated resource recovery. Thus, the 20 technologies initially identified by the consultant were reduced to eight (8) technologies. Furthermore, eight (8) other technologies were added in the list of technologies for climate change mitigation in Pakistan. These included: (i) Appropriate Application of Fertilizers & Soil Carbon Management; (ii) Reducing Methane Emission from Rice cultivation; (iii) Diet options for reducing Enteric Fermentation in ruminant animals; (iv) Social forestry and Agro-forestry; (v) Reducing emissions from deforestation, forest degradation & NTFPs; (vi) Bus rapid transport system; (vii) Rail transport system and (viii)Using nuclear technologies for electricity generation. Fact sheets of seven new technologies were prepared by the consultant. However, fact sheet on "Using nuclear technologies for electricity generation" could not be prepared because of lack of information in this sector.

A. Industrial

1. Boiler and furnace energy efficiency improvement through Boiler & furnace tune up; Boiler air leakage; Boiler insulation; Boiler high turndown burner; Controlling boiler blow-down and Boiler air pre-heater etc.

B. Building

2. Building energy efficiency improvement through improving building design; Air conditioner inverter& Power factor improvement

C. Renewable

3. Micro and small hydro
4. Solar PV & LED lighting
5. Solar domestic water heater
6. Biogas – Compressed bio-methane
7. Wind mill and generator
8. Bagasse
9. Integrated resource recovery
10. Solar dryer
11. Waste gasification
12. Solar thermal electricity

D. Coal

13. Clean coal technology: Pulverized coal fired power generation under Supercritical (SC) and ultra-supercritical (USC) steam conditions

4.2. Decision Context

The mitigation technology needs were prioritized by the Expert Group in the context of climate change mitigation potential in the selected sectors (Energy including waste; Agriculture including LULUCF; & Transport) and development priorities identified in the National Climate Change Policy and Pakistan Vision 2025. The process also took into consideration the Multi-Criteria Decision Analysis (MCDA)[21].

4.2.1 National Priorities

The National Climate Change Policy recommends the following policy measures with respect to energy sector:

1. Promote the development of renewable energy resources and technologies such as solar, wind, geothermal and bio-energy;
2. Promote futuristic building designs with solar panels for energy self-sufficiency, especially in public sector buildings;
3. Explore the possibility of obtaining technological know-how and its transfer for installation of clean coal technologies;
4. Ensure that new coal-fired power stations perform at high-efficiency level;
5. Install plants to generate power from municipal waste;
6. Strive to conserve energy and improve energy efficiency in all energy using devices and processes;
7. Improve energy efficiency in building by standardizing building and construction codes and legislating/creating incentives for retrofitting, maximum use of natural light, better insulation and use of energy efficient lights, boilers, appliances and groundwater pumping units;
8. Promote and gradually make it mandatory to specify the energy efficiency/fuel consumption rates of energy using equipment and devices of common use;
9. Incentivize CDM projects in the field of energy efficiency and energy conservation;

Moreover, in the energy sector, Pakistan Vision 2025has identified the following top 10 goals: (i) Eliminate current electricity supply-demand gap by 2018, and cater to growing future demand by addition of 25,000 MW by 2025; (ii) Optimize energy generation mix between oil, gas, hydro, coal, nuclear, solar, wind and biomass– with reference to its indigenousness, economic feasibility, scalability, risk assessment and environmental impact; (iii) Complete two major hydel projects: Diamer-Bhasha and Dasu dams; (iv) Operationalize the immense potential of Thar coal and complete Gaddani Energy Park with 6600 MW capacity; (v) Tap Pakistan's huge potential for alternative energy; (vi) Complete new Nuclear power generation plants; (vii) Maximize distribution efficiency and cut wasteful losses through investment in transmission and distribution infrastructure and effective enforcement of controls; (viii) Address institutional fragmentation and decay of the sector due to poor capacity; (ix) Focus on demand management and conservation to ensure prioritization in allocation, elimination of wasteful use, incentives to use more energy efficient equipment and appliances and achieve better balance between

[21] Reference: MCA Guidance for Mitigation available at http://www.tech-action.org/Publication/TNA-Guidebooks

peak and off-peak hours; and (x) Introduce institutional reform and strengthen regulatory frameworks to improve transparency and efficiency.

4.3. Overview of potential mitigation technology options in the energy sector and their mitigation potential and other Co-benefits

The 20 potential technologies of climate change mitigation were clubbed into eight (8) technologies and additional eight (8) technologies were added in the list of technologies for climate change mitigation. All the sixteen (16) technologies were analysed through MCDA process. Out of these eight (8) were in energy sector. An overview of these eight (8) climate change mitigation technology options in energy sector and their performance matrix showing scores of these technologies are presented in the Table 4.1:

Table 4.1: Performance matrix showing scores of selected technologies in energy sector

#	Technology Name	Potential to save usage of fuel	Time saving	Reduction of GHGs	Health benefits	Sustain ability	Initial/ Capital cost	Operation and Maintenance cost	Capacity building is required	safety and reliability	Employment generation & market potential	Social impacts
1	Steam boiler & furnace energy efficiency (EE) Improvement	80	90	80	60	50	85	80	70	80	85	75
2	Energy Efficiency improvement in buildings	70	60	80	80	85	70	80	70	85	80	75
3	Solar energy technology	80	90	90	80	80	80	95	90	55	60	80
4	Electricity generation from large hydropower plants	90	20	80	55	70	55	90	60	75	90	50
5	Electricity generation from micro, mini, & small Hydro power plants	90	60	80	75	70	70	75	65	65	40	80
6	Wind generators for electricity generation	70	75	90	75	75	75	75	70	70	75	65
7	Using nuclear technologies for electricity generation	90	30	90	60	70	50	80	40	80	80	60
8	Clean coal technology	50	45	50	40	80	50	50	55	65	80	55

4.4. Criteria and process of technology prioritization

For selection of criteria and its weightage, MCDA approach was adopted. An Expert Working Group on Mitigation has been established comprising of various stakeholders.

4.4.1. Multi Criteria Decision Analysis (MCDA), Determination of Criteria and Weightings

The evaluation criteria and weight-age were finalized by Expert Working Group on Mitigation (Section 2.3), details in table 4.2.

The highest weightage was given to the environmental criteria because the exercise is being conducted to select the technologies having highest mitigation potential, followed by technology, cost, and social criteria.

Table 4.2: Weight-age of evaluation criteria

Criteria	Unit	Weight-age
Cost related criteria		21
❖ Initial/ Capital cost	Pak Rs.	15
❖ Operation and Maintenance cost	Pak Rs./month	6
Environmental & Climate related Criteria	35	
❖ Greenhouse Gas Reduction (GHGR)	Tons of oil equivalent	35
Economic Criteria	5	
❖ Employment generation & market potential	Man months & Unit sales	5
Institutional/ political		3
❖ Capacity building is required	Number of relevant specialist	3
Social Criteria	14	
❖ Social impacts	Level of acceptance	10
❖ Health benefits	Number of beneficiaries	4
Technology related Criteria	22	
❖ Time efficiency (Quick implementation & result)	Number of months	5
❖ Sustainability		10
❖ Safety and reliability	Level of acceptance	7

4.4.2. Process of technology prioritization

The Expert Working Group on Mitigation observed that boilers in industries and building sectors play critical role in energy conservation and GHG emission reduction. As such the technologies proposed in these sub-sectors need to be clubbed together.

The consequences of each option were assessed on the basis of criteria described in Section 4.4.1.Each option was assigned weight-age from 0 to 100[22] based on its importance as per local conditions, national priorities and mitigation potential. Weight-age of different members of the group was adjusted by the consultant after interactive discussion and sensitivity analysis during the meeting.

Sensitivity Analysis:

Final decisions were made on the basis of reviewing assessment results as well as conducting sensitivity analysis on assessment results and deciding prioritization of

[22] 0 means that the option is least preferred, not that it has a zero performance

technologies for sub-sectors. The relative weight-age points were put in the excel sheet programmed for ranking of options.

The scores assigned to each technology were based on the Expert opinion given in the meeting of Expert Working Group on Mitigation keeping in view the following: (i) relevance of technology with national priorities as stated in Vision 2025 and nation policies; (ii) GHG emission reduction potential of the technology; (iii) cost and market potential; and (iv) availability of the technology. There was unanimous agreement of all the members of the Expert Working Group on Mitigation on the scores to each technology after thorough discussion on the four factors mentioned above.

4.4.3. Results of technology prioritization

The options ranked higher and found best in meeting the national priorities were selected in order of ranking scoring above 55 percent. Result ranking is mentioned in Table 4.3.

Table 4.3: Aggregated ranking of mitigation technologies by Expert Working Group on Mitigation

#	Sub-sector	Technology	Aggregated score	Rank
1	Industries	Boiler and furnace energy efficiency improvement	76.0	2
2		Existing technology of operating boiler and furnaces (Routine manual tune up for air fuel ratio adjustment, conventional methods of steam leakage detection & reduction and waste heat recovery)	24.0	10
3	Building	Reducing energy consumption in homes and offices through building design, air conditioning and power factor improvement in warmer areas	61.0	6
4		Existing technology of design, air conditioning and power management in buildings	34.0	10
5	Energy Production	Solar energy technology	80.7	1
6		Electricity generation from micro and small hydropower plants	69.0	3
7		Wind generators for electricity generation	67.1	4
8		Biogas – Compressed bio-methane including Waste & Bagasse	61.4	5
9		Using nuclear technologies for electricity generation	57.0	7
10		Clean Coal Technology (Super & Ultra-supercritical)	56.3	8
11		Electricity generation from large hydropower plants	51.5	9

Ranking of each sector was done by the Expert Working Group on Mitigation based on the criteria mentioned in Section 4.4.1. Solar energy technology was ranked highest because it has high mitigation potential as well as has vast scope in the country being in the temperate zone.Solar energy technologies include both solar PV and solar thermal technologies. Solar Photo-voltaic (PV) technology is an emerging technology which people are purchasing on their-own. It is mostly used to fulfil basic electricity needs of

households, particularly in the off-grid locations and during electricity load shedding hours for running fans, lights, television and computers.

Second in the ranking was boiler and furnace energy efficiency improvement because of its mitigation potential and the immediate recovery cost. Energy reduction in boilers and furnaces can be achieved through nine interventions: boiler & furnace tune up, control of air leakage, insulation, blow-down; introducing high turn-down burner, air pre-heater, variable frequency drive coupled with O_2 trimming system, feed water treatment, flash steam recovery.

The third rank was given to electricity generation from micro, mini and small hydropower plants being the national priority, high mitigation potential and also serves agriculture sector.Electricity generation from micro, mini, & small Hydropower plants is in practice in the mountainous region since last thirty years and there is a huge un-tapped potential of up-scaling such technologies. Micro-hydro plants are up to 150 KW, mini-hydro are up to 1 MW, and small hydropower plants are up to 25 MW capacity.

The other selected technologies that scored more than 55 were: Wind generators for electricity generation; Biogas – Compressed bio-methane including Waste & Bagasse; Energy efficiency improvement in buildings; Using nuclear technologies for electricity generation; and Clean Coal Technology.

Wind generators with capacity more than 50 KW have been considered for electricity generation which is viable because Pakistan has wind corridors in Sindh and Balochistan. For bio-methane production, cluster of fermentation plants of aggregated capacity of approximately over 1,000 m3 are mostly required. Waste can be used for methane production. Power generation from bagasse is an important source of energy in the country having many sugar mills. Energy Efficiency improvement in buildings are achieved through building design, air conditioner inverter, power factor improvement, efficient lighting & fuel-efficient stoves. In addition, considering the prevailing huge energy shortfall as well as national development priorities nuclear technology option was added after recommendations of the Expert Working Group on Mitigation. Further, in case of coal, the technologies like Supercritical (SC) and ultra-supercritical (USC) power plants were added as these technologies are proven for energy efficiency and Pakistan has significant coal reserves and the government has a clear policy to promote electricity production from coal to overcome the electricity challenges by the year 2025. Pakistan can depend upon coal power for long term sustainability as its energy cost is low and with the use of appropriate technology its GHG emissions can be reduced considerably as compared to other fossil fuels.

Finally based on above process of pre-selection, selection and standardized ranking, eight recommended mitigation technologies for short to medium term diffusion and deployment at more large scale were prioritized for adoption in Pakistan. These have been endorsed by the TNA committee. These technologies are in full support with the National Climate Change Policy and Pakistan Vision 2025.

Chapter 5: Technology prioritization for the Agriculture including Land use, Land use change and Forestry sector

The prioritization of mitigation technologies for Agriculture including Land use, Land use change and Forestry sectors were carried out in similar process followed for selection of Energy technologies.

5.1. GHG emissions and existing technologies of Agriculture including land use and forestry sector

5.1.1. Agriculture/ Livestock sector GHG emissions

The Agriculture[23]including Livestock sector is one of the most important sector of economy in Pakistan. It is responsible for 20.9% of the GDP, employs 43.5% of labour force, and earns valuable foreign exchange for the country. In 2013-14, the livestock sector contributed 56.45% of total agricultural earnings, and 11.8% of GDP[24]. Over recent years, share of livestock has increased in agricultural value-addition while share of crops in gross value added for agriculture sector has gradually declined. Livestock population has increased gradually but the poultry population has increased rapidly since 2004-05. The graph shown below, Figure 5.1represents the behaviour of growth in livestock sector since 1993-4 to 2013-14.

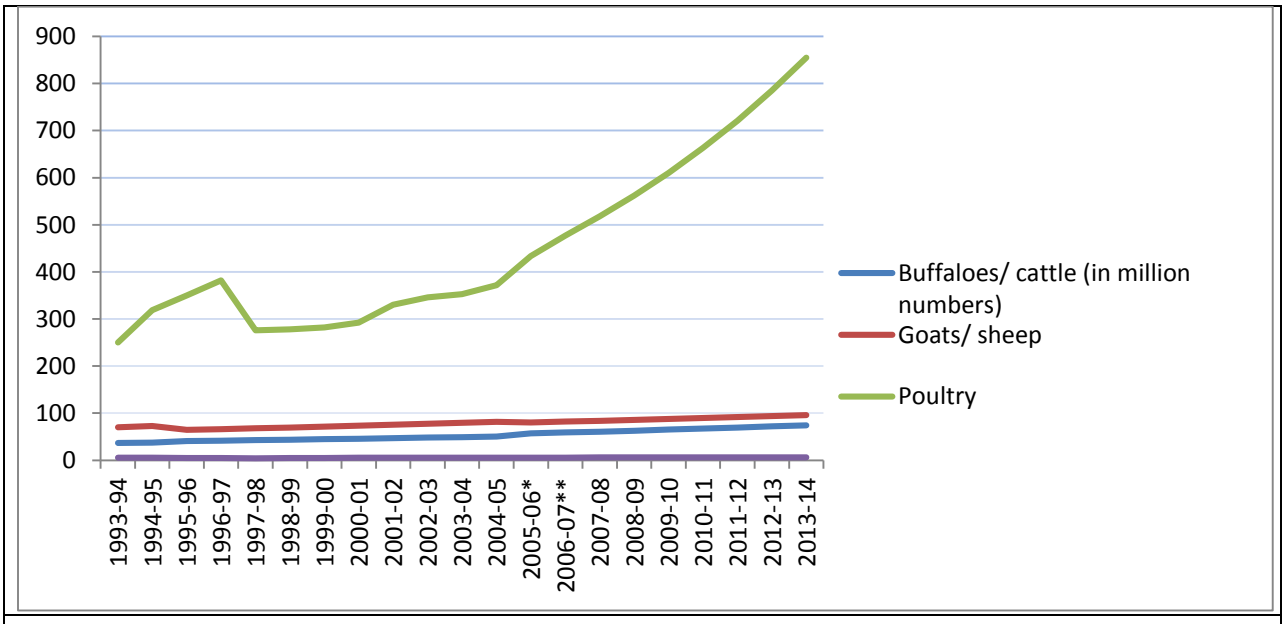


Figure-5.1 : Pakistan Livestock Population (1993-2014)

The Agriculture and livestock sectors accounted for 71.632, 120.284 and 165.295 Gega gram (Gg)/ kilotons (kt) of CO_2 equivalent GHG emissions in the inventory years of 1994, 2008 and 2012[25], respectively. Out of this the contribution from livestock sector accounted for 57.120, 87.198 and 84.318 Gg/ kt of CO_2 equivalent GHG emissions in the inventory years of 1994, 2008 and 2012, respectively.

[23] In Pakistan national documents mostly livestock and fisheries are included in Agriculture sector

[24] Pakistan Economic Survey 2013-14

[25]Mir, K.A; Ijaz, M (May 2015); Greenhouse gas emission inventory of Pakistan for the Year 2011-2012; Global Change Impact Study Centre, Islamabad, Pakistan GCISC Interim Research Report RR-19 (Interim)

While the aggregate numbers of cattle, sheep, goat, camel, asses, horses and mules have increased from 116; 155 and 177 million and the number of poultry has increased from 319; 562 and 855 million in the inventory years of 1994, 2008 and 2012, respectively (Figure 5.2).The Agriculture and Livestock sectors are responsible for the second largest GHG emissions in Pakistan after energy sector as per 1994, 2008 and 2012 inventory years.

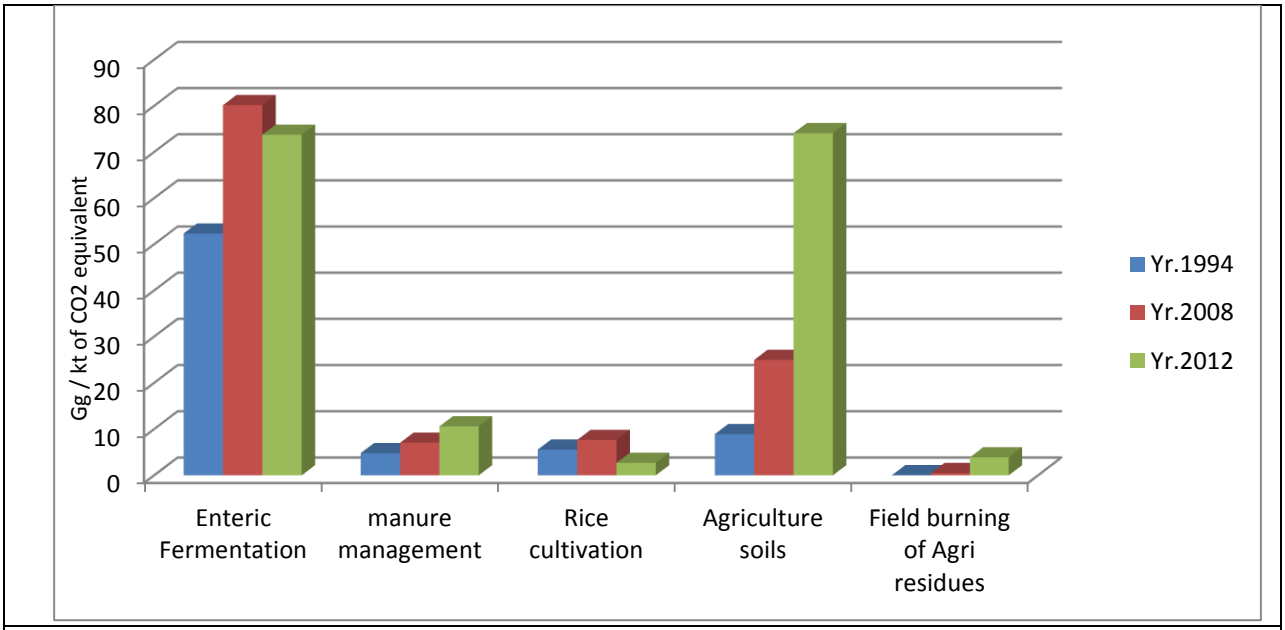


Figure 5.2: GHG emissions from Agriculture including livestock sector for inventory years

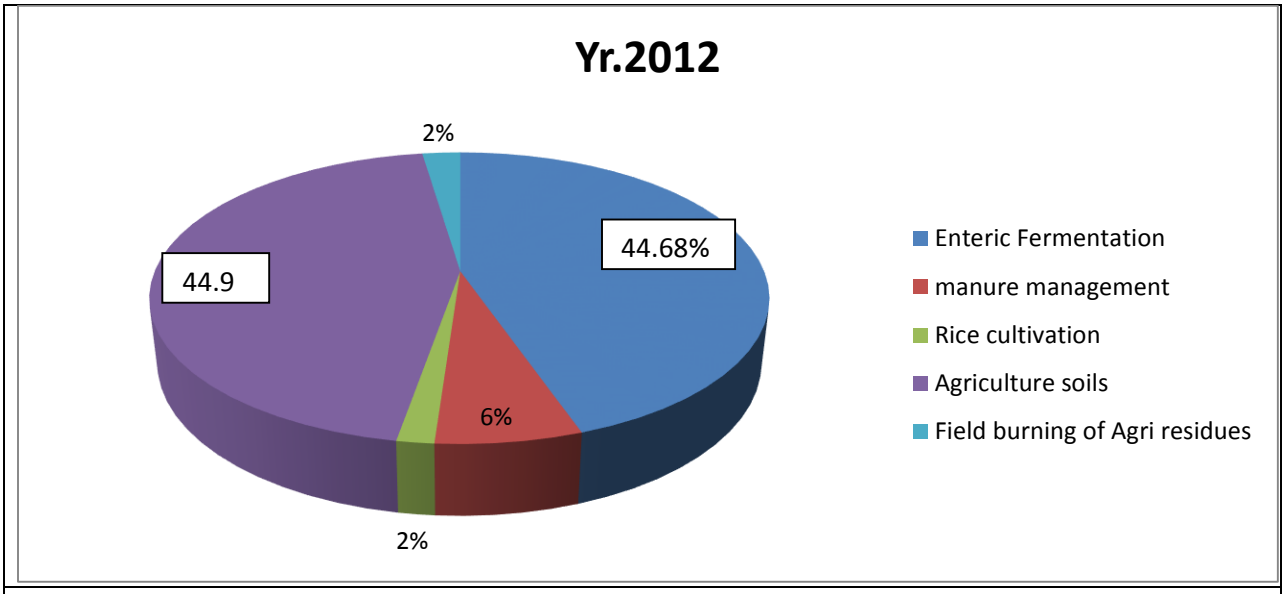


Figure 5.3: GHG emissions from Agriculture including livestock sector for year 2012

According to Figure 5.3, the emissions are mainly from Agricultural soils and enteric fermentation in domestic livestock. Enteric fermentation results from the normal digestive process of ruminative animals. The amount of methane produced by an animal varies according to its type, which determines the nature of its digestive system and its feed intake. The amount of emissions increases proportionally with the feed

intake. Also, methane is produced from agricultural soils mostly during decomposition of organic material in agricultural fields due to excessive tillage and imbalanced and inefficient use of nitrogen fertilizers, mismanagement of water, and various other agricultural practices exacerbate nitrous oxide emissions from the soil.

In the agricultural sector, the major crops produced in Pakistan are wheat, rice, cotton, and sugarcane. Other important crops produced are maize, bajra, jowar, tobacco, barley, mustard, and a variety of pulses. Wheat, rice, cotton, and sugarcane, contribute 39.22, 15.37, 24.61 and 11.68 percent to the value added in overall agriculture. Wheat is the leading food grain of Pakistan. Cotton contributes significantly to exports and is responsible for a large share of foreign exchange earnings. Pakistan grows some of the highest quality rice in the world, which meets domestic demand and is an important export item for the country. Rice paddies contribute 6% of GHG emissions of total GHG emissions produced by the agricultural and livestock sector. These emissions are largely in form of methane which escapes to the atmosphere by diffusive transport through the rice plants during the growing season.

5.1.2. Land-use, Land-use change, and Forestry sector GHG emissions

The contribution of land use change and forestry sector to the total GHG emissions in Pakistan has decreased from 3.59% to 2.88% to 2.62% during the inventory years of 1994, 2008 and 2012, respectively. It is attributed to high rate of deforestation and land use change triggered by increasing population, influx of Afghan refugees as well as demand for food, shelter and wood. Hence, the importance of Land-use, Land-use change, and Forestry (LULUCF) is significant in Pakistan, owing to its potential for reforestation, reducing forest degradation and biodiversity conservation as a sink for carbon to mitigate climate change. The government has taken a number of initiatives including launch of REDD+ Readiness Preparation Project; introducing amendments in the relevant laws to discourage conversion of forest land into other uses and launch of projects to promote afforestation, reforestation as well as avoiding deforestation.

The combinations of great variations in relief, landscape and climate have given rise to tropical, subtropical, moist and dry temperate, sub alpine and alpine zones.

Table5.1: Temperature Regimes in Various Climatic Zones of Pakistan

Zone	Mean Annual Temperature	Mean January Temperature	Type of winter
Tropical	Over 75°F	Over 60°F	Mild, no frost.
Sub-tropical	65 – 75°F	50 - 60°F	Definite but not severe, and occasional frost.
Temperate	50 - 65°F	30 - 50°F	Pronounced with frost in lower and snow on higher reaches.
Alpine	Under 50°F	Under 30°F	Severe cold and much snow in winter but pleasant in summer.

Forests and trees planted on farmlands cover about 4.392 million hectares or 5.01%[26] of the land area of Pakistan. The main types of forests in Pakistan include conifer, including juniper (moist and dry temperate; 1.913 million hectare), tropical thorn broad-leaved or scrub (1.191 million hectare), riverine

[26]REDD+ Readiness Preparation Proposal (2013); Forest Carbon Partnership Facility; submitted by MoCC, Government of Pakistan. https://forestcarbonpartnership.org/sites/fcp/files/2013/Nov2013/Pakistan's%20REDD%20proposal%208.11.2013%20final%20clean_0.pdf

(0.173 million hectare) and mangrove (0.207 million hectare) forests. Additionally, there are irrigated plantations in the floodplains. Figure 5.4summarizes the statistics of forest cover in Pakistan. Furthermore, there are 21 different types of wetlands. The Western Himalayan moist temperate forests ecosystem of Pakistan is included in the list of global 200 priority ecosystems of the Millennium Ecosystem Assessment.

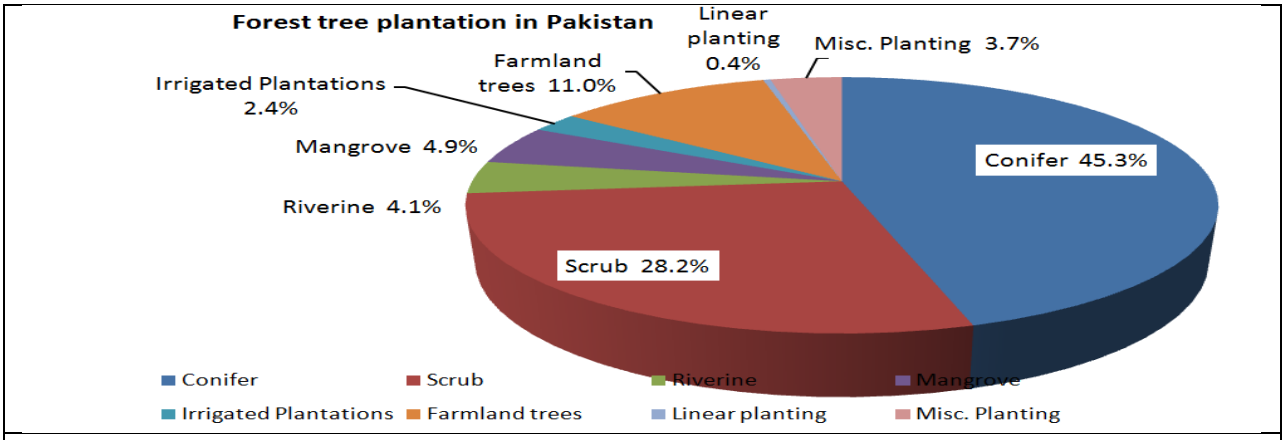


Figure 5.4: Forest tree plantations in Pakistan[27]

Tenure wise, 3.823 million hectares are covered by state owned forests that are legally protected as Reserved, Protected, Un-classed forests and Resumed lands and are managed by the Forest Departments (FDs); and communal, such as Guzara forests and privately owned forests [notified under Pakistan Forest Act 1927's Section 38 Areas and the Land Preservation Act (Chos Act)]. Local people generally do not have rights and privileges in Reserved forests unless specifically recognized by Government notification, but in Protected forests, they have rights and concessions for grazing, grass cutting, collection of fuel-wood, and any other forest produce which is not protected specifically.

The forest resources of Pakistan are deteriorating both qualitatively and quantitatively and the annual change rate during 1990-2000 period was 1.8% and 2.1%, during the period from 2000-2005 The mangrove forests depleted at a rate of 4,900 hectares per annum (2.37%) during the ten-year period from 1992 to 2001, coniferous forests at 40,100 hectares per annum (2.09%) and riverine forests at 2,300 hectares per annum (1.33 %). Further, the quality of forests has been severely affected. The coniferous forests being the most fragile due to their high timber value and mountainous location are rapidly degrading and being deforested. Over 50% of the coniferous forests have tree cover of less than 25% while 22% have tree cover between 25-50%, 14% have tree cover between 50-75% and only 9% have tree cover more than 75%[28].

Low level of public awareness and education, excessive exploitation of forest resources for commercial and subsistence purposes, encroachment and fire, a growing population, insecure land tenure, unplanned

[27] Pakistan's REDD+ Readiness Preparation Proposal; 2013; Ministry of Climate Change, Government of Pakistan, Islamabad submitted to Forest Carbon Partnership Facility; World Bank; Washington; https://forestcarbonpartnership.org/sites/fcp/files/2013/Nov2013/Pakistan's%20REDD%20proposal%208.11.2013%20final%20clean_0.pdf; pages: 43

[28] Pakistan's REDD+ Readiness Preparation Proposal; 2013; Ministry of Climate Change, Government of Pakistan, Islamabad submitted to Forest Carbon Partnership Facility; World Bank; Washington; https://forestcarbonpartnership.org/sites/fcp/files/2013/Nov2013/Pakistan's%20REDD%20proposal%208.11.2013%20final%20clean_0.pdf; pages: 46

urban and industrial expansions, inequity, unemployment and poverty are some of the main reasons why Pakistan continues to have a high deforestation rate today. Pakistan is already suffering from some of the effects from low forest cover in the form of desertification, decreased water quality, and decreased water availability, decreased quality of air, siltation, landslides, and lower capacity of land to hold water.

5.1.3. Existing and potential mitigation technologies in Agriculture, Livestock& LULUCF sector

There are a number of mitigation measures and technologies practiced in Pakistan for reducing GHG emissions in the Agriculture and livestock sector. Prior to identifying the technologies in the Agriculture and livestock sector the priorities of the government of Pakistan and mitigation benefits of the technologies were noted down. Major existing and potential technologies include the following:

Sector	Technology
Agriculture	Conservation tillage
	Appropriate application of fertilizers & soil Carbon management
	Farming practices having enhanced carbon sequestration
	Increasing use of crop varieties having enhanced carbon sequestration
	Rice cultivation by alternate wetting & drying/aerobic
	Off-field crop residue management
	Energy efficiency improvement of tube-well
	Nutrient management: mycorrhiza
Livestock	Enteric fermentation
	Biogas – Compressed bio-methane including Waste & Bagasse
	Manure management
	Genetic modification to produce new breeds which have better digestive efficiency and so better GHG mitigation potential
LULUCF	Social/ Farm forestry as Carbon sink
	Reducing emissions from deforestation, forest degradation & NTFPs
	Sustainable forest management
	Rehabilitation of mangroves
	Fire management in forests
	Land use Planning at local and provincial levels& legal support to implement the plans

Land use management to enhanced carbon sequestration

5.2. Prioritization of mitigation technology needs in the context of national priorities

The government of Pakistan in its Vision 2025 focuses on creating a modern, efficient and diversified agricultural sector – aligned with associated water and energy infrastructure –that can ensure a stable and adequate provision of basic food supplies for the country's population, and provide high quality products to its industries and for export.

The National Climate Change Policy recommends the following priority objectives in the Agriculture and livestock sector:

- Promoting integration of indigenous knowledge and the latest technology with scientific research to spearhead efforts towards an ecologically sustainable green revolution;
- Exploring methods to reduce nitrous oxide release from agricultural soils, e.g.by changing the mix of chemical fertilizers commonly used;
- Managing water in rice paddies to control releases of methane from agricultural soils and introduce low water dependent rice varieties;
- Promoting no till farming for methane abatement;
- Ensuring better manure storage and management;
- Promoting development of biogas and manure digester for methane reduction and energy production through CDM support;
- Developing and adopting new breeds of cattle which are more productive in terms of milk and meat, and have lower methane production from enteric fermentation;
- Encouraging farmers to use appropriate feed mixes and additives to reduce methane production from enteric fermentation/ digestion in cattle;

In the LULUCF sub-sector, the policy recommends the following:

- Stopping conversion of forest land to non-forest uses;
- Aggressively pursue afforestation and reforestation programs with plantation suited to the effects of climate change;
- Ensure documentation and utilization of indigenous knowledge while managing various types of forests in the context of climate change;
- Promote the sustainable management of forests according to national and international norms;
- Create environmental and forest protection clubs at community level for awareness raising.
- Using the vast mass of cultivable wasteland as a carbon sink and to build up organic soil matter;
- Providing incentives and alternative fuel and livelihood options to forest dependent communities to prevent deforestation;
- Promoting farm forestry practices by planting multipurpose fast-growing species to meet the needs for timber, fuel wood and fodder for livestock;
- Establishing linkages with regulated and voluntary carbon markets to promote and encourage forestry mitigation projects in Pakistan;

- Preparing the framework for a national REDD strategy on priority basis and ensure its implementation in accordance with international conventions/processes;
- Explore the use of new planning and decision-making support tools to deal with uncertainty and risk in long-term forest planning;
- Investigate and discover new forest management and adaptive planning options in line with the scientific research on climate change;
- Encourage sustainable use of non-timber forest produce (NTFP)

As per UNDP and UNFCCC guidelines provided in "Handbook for conducting Technology Needs Assessment for Climate Change", the same criteria for TNA along with its weight-age for selecting priority technologies as explained at Section 3.2 for energy and waste sector, was used for Agriculture and LULUCF sector.

5.2.1. Technology Fact Sheets of Shortlisted technologies

In agriculture LULUCF sector following six technologies were selected out of the eight shortlisted by the Consultant through MCDA process:

A. Agriculture

1. Appropriate application of fertilizers & soil Carbon management
2. Rice cultivation by alternate wetting & drying/aerobic

B. Livestock

3. Enteric fermentation
4. Biogas – Compressed bio-methane including Waste & Bagasse

C. LULUCF

5. Social/ Farm forestry as Carbon sink
6. Reducing emissions from deforestation, forest degradation & Non-timber forest products (NTFPs)

5.3. Overview of selected mitigation technology options in the Agriculture, Livestock & LULUCF sector, their mitigation potential and other Co-benefits

An overview of identified mitigation technology options in the Agriculture, Livestock & LULUCF sector, their mitigation potential and other co-benefits are presented in the Table 5.2:

Table 5.2: Description, mitigation potential and other co-benefits of selected technologies (Agriculture & LULUCF)

#	Technology Name	Description	Mitigation potential	Other Co-benefits	Cost	Timeframe
1	Appropriate application of fertilizers & soil Carbon management	Nitrogen fertilizer use in agriculture is associated with water pollution and greenhouse gas emissions. Inefficient application of Nitrogen fertilizer leads to nitrogen losses via leaching, volatilization, and emissions to the atmosphere. By helping to maximize crop-nitrogen uptake, improved nutrient management has a significant and cost-effective role to play in mitigating GHG emissions from agriculture. It includes type of fertilizer, its application rate, timing & placement. The depletion of soil organic carbon (SOC) pool is exacerbated by soil drainage, ploughing, removal of crop residue, biomass burning, subsistence or low-input agriculture, and soil degradation by erosion and other processes. Adoption of recommend management practices (e.g., less-till farming with crop residue mulch, incorporation of forages in the rotation cycle, maintaining a positive nutrient balance, use of manure and other bio solids), conversion of agriculturally marginal soils to a perennial land use, and restoration of degraded soils and wetlands can enhance the SOC pool. Creating a formula to calculate the required amount to avoid over	Reduces nitrous oxide Emissions. Ten per cent reduction has a potential of 7 m tons of CO_2.	Reducing amount of nitrogen applied; cutting material and labour costs in applying fertilizer;	Cost-effective and balance bio-fertilizers can be developed having total NPK of 7-8% with cost of product ranging between Rs. 150-206 per bag of 50 kg.	Long term

		application; fertilizer is applied deep into the soil; winter crops are planted to absorb residual Nitrogen from previous crops. Conservative farming to maintain Soil humidity and prevent soil loss. Sow leguminous plants to increase Soil nitrogen fixation. Appropriate crop rotating techniques to Climate and soil conditions.				
2	Rice cultivation by alternate wetting & drying/aerobic	Most effective option to reduce CH_4 emissions from aerobic rice is to prevent submergence of rice fields and to cultivate upland rice. It neither requires flooded, nor water saturated conditions at any significant period of time. Alternate wetting and drying (AWD) technique in transplanted rice is more appropriate for basmati rice varieties in the traditional rice belt.	Potential is 3 m tonsCO2eq/yr.	Increases yield, and employment opportunities.	Cost of technology is less than cultivating rice in flooded conditions. In basmati rice type, the alternate wetting and drying method saved about seven irrigations over the continuous flooded rice and monitory benefit of nearly Rs9,000/ha.	Long term
3	Enteric fermentation	Enteric fermentation is a digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream of an animal. It is one of the factors in increased methane emissions. Ruminant animals are those that have a rumen. Measures like Diet manipulation can abate methane by decreasing the fermentation of organic matter in the rumen, allowing for greater digestion in the intestines. Increasing animal intake of dietary oils helps to curb enteric fermentation and increase yields by	▪ Reduce methane emissions. ▪ Ten per cent reduction has a potential of 7 m tons of CO_{2eq}/yr.	Increasing the digestion efficiency, enhancing meat and diary production	Cost is Rs.300/tons of CO_2 abatement from use of feed additive monensin premix.	Long term

		limiting energy loss due to fermentation. Use growth hormones such as bovine sometotropin (BST) and anobolic steroid to increase meat and dairy productivity while decreasing methane emissions per product unit. Fodder is processed mechanically (grinding, milling, mixing, etc.) and chemically (fermentation, ensilage micronutrient enrichment, etc.) to accelerate cattle metabolic rates, and thus increase cattle weight per unit of fodder.				
4	Biogas – Compressed bio-methane including Waste & Bagasse	Biogas plants of >6 m^3, bottling of Compressed bio-methane & production of electricity from waste and bagasse	Up to 50% reduction in emissions of GHGs - A 7-cubic-meter constantly used digester can reduce about 4,919 tonnes of CO2e/year in the flat land and 2,205 tonnes of CO2e/year in the mountains. Potential is 120 m CO_2e/yr.	➢ Provides additional hours for income generation or social activities ➢ Health improvement ➢ Increases employment opportunities ➢ Improves quality of life ➢ Helps in restoring forest area ➢ Provides energy for cooking & heating ➢ Slurry from biogas is a good fertilizer for agriculture which leads to food security ➢ Helps in sustainable disposal	➢ Cost of construction of 6 m^3 biogas plant is Rs.50000-60000.	➢ Medium to Long term

				of wastes		
5	Manure management	The technologies for manure management here include: (i) Aerobic digestion of manure and (ii) composting.			Cost of compost Rs.350 per 50 kg.	Long term
6	Social/ Farm forestry as Carbon sink	Agro-forestry, is "a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic, and environmental benefits for land users at all levels". Social forestry means the management and protection of forests and afforestation on barren lands with the purpose of helping in the environmental, social and rural development. Growing trees on steep lands in contour rows prevent soil erosion and keep soil moisture	Every tonne of carbon added to and stored in plants or soils removes 3.6 tonnes of CO2 from the atmosphere.		Average cost of woodlots plantation per acre is Rs.10,000.	Medium to Long term
7	Reducing emissions from deforestation, forest degradation & NTFPs	Emissions of GHGs from forest land are reduced by slowing down the rates of deforestation and forest degradation. Removals of GHGs from the atmosphere can be achieved through various forest management options, such as afforestation on non-forested lands, replanting degraded or deforested areas or enrichment planting in riparian buffer/zones like river banks, streams and wetlands and protection and sustainable harvesting of NTFPs.	Every tonne of carbon added to and stored in plants or soils removes 3.6 tonnes of CO2 from the atmosphere.		Average cost of deforestation is lesser than tree plantation.	Medium to Long term

5.4. Criteria and process of technology prioritization

The MCDA approach as followed in the energy and waste sector (Section 4.4) was adopted for prioritization of mitigation technologies in Agriculture and LULUCF sector. The members of Expert Working Group provided valuable inputs and suggested to include the following additional technologies in the list of technologies suggested by the Consultant:

1. Appropriate diet for reducing Enteric fermentation in ruminant animals
2. Appropriate application of fertilizers & soil Carbon management

The members emphasized that "Appropriate diet for reducing enteric fermentation in ruminant animals" is the major source of CH_4 emission from the livestock sector in Pakistan, and appropriate measures need to be taken in this respect. While CO_2, CH_4 and N_2O emissions from agriculture soils are the major source of GHG emissions in the Agriculture sector. Hence, the members proposed to include technology for "appropriate application of fertilizers & soil carbon management" in the list of technologies for Agriculture sector.

The consequences of each option in Agriculture and LULUCF sector were assessed on the basis of the criteria described in Section4.4.1. Weight-age of different members of the group was adjusted by the consultant after interactive discussion and sensitivity analysis during the meeting. The relative weight-age points were put in the excel sheet programmed for ranking of options. Performance matrix have been developed showing relative scores against each criterion for each selected technology and presented at Annex XX.

5.5. Results of technology prioritization

The options ranked higher and were best in accordance with the national priorities were selected in order of ranking scoring above 55 percent. List in this regard is as follows:

Table 5.3: Aggregated ranking of mitigation technologies by Expert Working Group on Mitigation

#	Sub-sector	Technology	Aggregated score	Rank
1	Agriculture	Rice cultivation by alternate wetting & drying/aerobic	61.7	4
2		Appropriate application of fertilizers & soil Carbon management	60.0	5
3	Livestock	Biogas – Compressed bio-methane including Waste & Bagasse	63.5	3
4		Appropriate diet for reducing Enteric fermentation in ruminant animals	55.7	6
5		Manure management	53.3	7
6	LULUCF	Reducing emissions from deforestation, forest degradation & NTFPs	75.5	1
7		Social/ Farm forestry as Carbon sink	72.0	2
8		Conventional technologies in Agriculture including livestock & forestry sector	24.0	8

The selected six technologies are in accordance with Pakistan's national priorities. Reducing emissions from deforestation, forest degradation & NTFPs was ranked highest. As at present the rate of deforestation is highest which has led to natural disasters like vast floods, natural slides, drought etc.Social/ Farm forestry as carbon sink was ranked second highest. Social forestry and farm forestry is getting popularity in Pakistan because of its environmental and socio-economic benefits. This is one of the best tools to increase area under forest cover which would help in not only mitigating the adverse effects of climate change but also provide a sink for CO_2.Biogas – Compressed bio-methane from dung was ranked third highest. Pakistan has a large number of livestock and poultry and has a large potential for biogas generation. So far small scale biogas fermentation plants of more than 6 m3 have been constructed with the support of donor agencies and NGOs which have been very successful.

The other selected technologies ranked more than 55 percent were: Rice cultivation by alternate wetting & drying/aerobic; appropriate application of fertilizers & soil carbon management; and enteric fermentation. Pakistan's Basmati rice is considered to be one of the best rice varieties in the world. It has a good export potential. Pakistan is the world's 11th largest producer of rice. The technologies selected will reduce methane emissions from rice fields. The GHG emissions from Agriculture soils and enteric fermentation are highest in Agriculture sector. The selected technologies will reduce such emissions.

Finally and based on above process of pre-selection, selection and standardized ranking, six recommended mitigation technologies for short to medium term diffusion and deployment at more large scale are largely feasible in Pakistan. These have been endorsed by the TNA committee. These technologies are in full support with the National Climate Change Policy.

Chapter 6: Technology prioritization for the Transport sector

The transport sector has shown the highest emission growth rate of all sectors since inventory year 1994. Transport contributes about 10 percent to the GDP and accounts for 6 percent of the employment in the country. Similar to the selection of technologies in other sectors, the prioritization of mitigation technologies for transport sector was also carried out as per UNFCCC and UNDP "Handbook for conducting Technology Needs Assessment for Climate Change" together with Expert Working Group on Mitigation through MCDA.

6.1. GHG emissions & existing technologies in Transport sector

6.1.1. Situational Analysis of GHG emissions in Transport sector

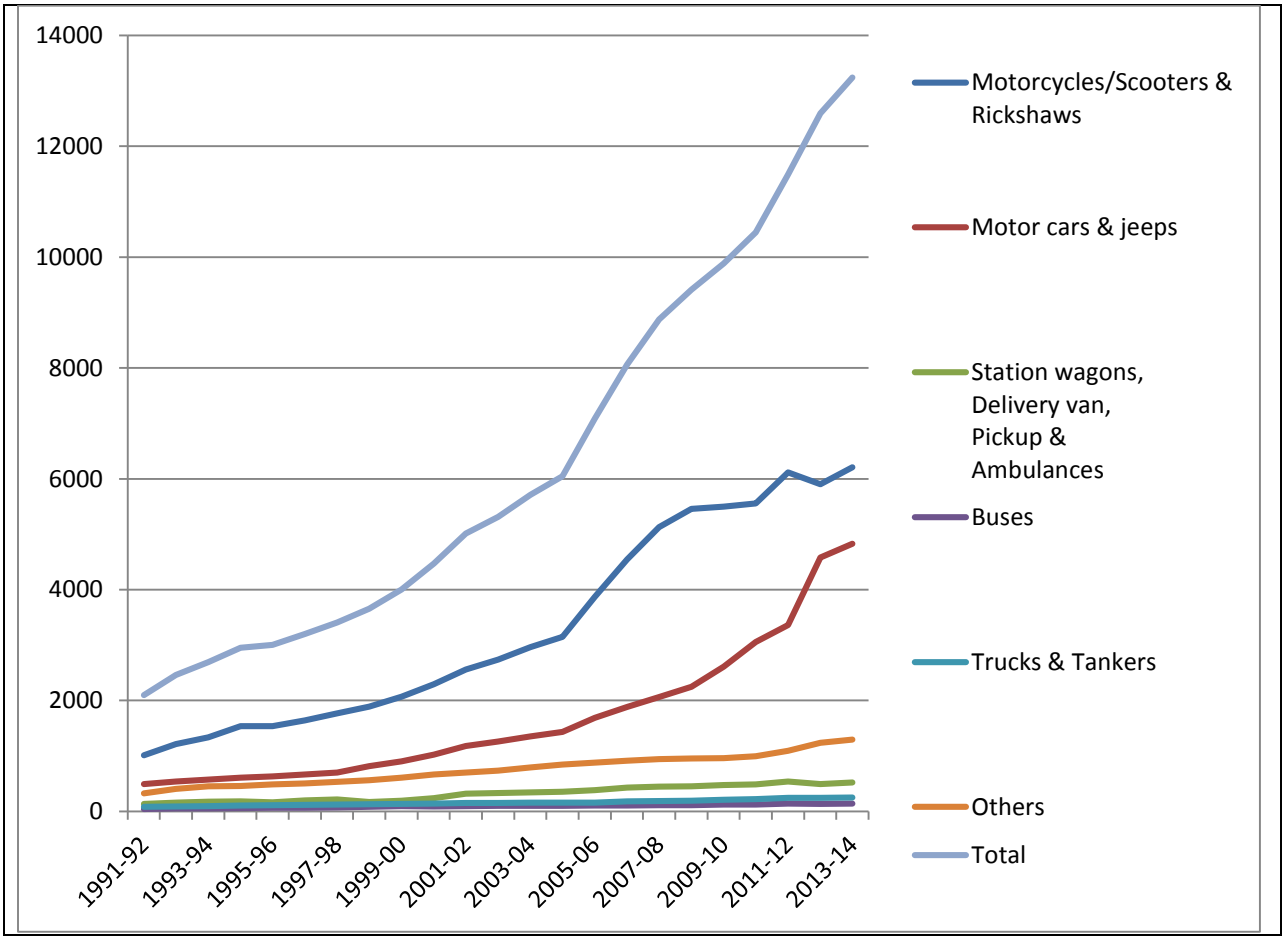
The transport sector consumes more than half of the oil consumed in Pakistan[29]. The transport sector accounted for 19.848, 33.474 and 42.572 million tonnes of oil equivalent to GHG emissions in the inventory years of 1994, 2008 and 2012, respectively. Thus managing emissions in this sector remains crucial for tackling climate change. Within the transport sector, road transport is dominant as it is responsible for carrying 91% of the national passenger traffic and 96% of the freight movement[30], while

[29]Habib-ur-Rehman (2010).'Transport and Communications'. Economic Survey 2009-10. Ministry of Finance, Pakistan. Available at: http://www.finance.gov.pk/survey/chapter_10/14_Transport.pdf

[30]JICA, NTRC, and Ministry of Communications –Pakistan(2006). Pakistan Transport Plan Study in the Islamic Republic of Pakistan.Nipon KOEI CO., LTD., Almec Corporation. Available at: http://www.ntrc.gov.pk/PTPS-reportSDJR06013FinalReport01.pdf

9% of national passengers and 4% of the freight are transported through rail and aeroplanes. As the population and the economy have grown, the numbers of vehicles have drastically increased as shown in Figure-6.1. In 1991-2, Pakistan had 2.096 million vehicles on the road, which increased to 13.24 million by 2013-14[31].The easy availability of credit through banks in the past few years and lack of a proper public transportation system has caused increase in the number of vehicles. In recent past significant number of motor vehicles were switched to CNG largely due to price differentials between oil and gas. The use of CNG in vehicles is less polluting than petrol or diesel as the Carbon mono-oxide (CO) content in CNG exhaust is 90% less than CO found in gasoline (petrol) exhausts. However, reliance upon CNG in vehicles is not expected to continue due to Pakistan's depleting natural gas resources.

There has been a major investment in road infrastructure in Pakistan. Most of the existing railway infrastructure had already been constructed before 1947[32]. However, some extension in the railway network has been carried out, as Mardan to Charsada; and KotAdu to Kashmore. New railway lines are planned, especially to link Gwader and northern areas of Pakistan to the national railway network under Pakistan China Economic Corridor.



[31]Pakistan Economic Survey 2013-14

[32]JICA, NTRC, and Ministry of Communications –Pakistan(2006). Pakistan Transport Plan Study in the Islamic Republic of Pakistan.Nipon KOEI CO., LTD., Almec Corporation. Available at: http://www.ntrc.gov.pk/PTPS-reportSDJR06013FinalReport01.pdf

Figure 6.1: Rise of Motor Vehicles in Pakistan

6.1.2. Existing and potential mitigation technologies in Transport sector

There are number of mitigation measures and technologies practiced in Pakistan for reducing GHG emissions in the transport sector. Prior to identifying the technologies in the transport sector the priorities of the Government of Pakistan and mitigation benefits of the technologies were taken into consideration. Following are the major existing and potential technologies in the transport sector:

- Bus rapid transport
- Metro train
- Railway transportation
- GHG emission reduction through improved railway traffic management
- Inland water ways transportation
- Vehicle tune up
- Engine emission standards
- Hybrid vehicles
- GPS Tracking for traffic management
- Traffic management without GPS
- Increasing road network
- Fuel efficient aircrafts
- GHG emission reduction through improved air traffic management
- Bike ways and promoting bicycle and walking for shorter distance
- Business as usual

6.2. Prioritization of mitigation technology needs in the context of national priorities

The Pakistan Vision 2025 focuses on establishing an efficient and integrated transportation system to ensure reduction in transportation costs that will result into significant emission reduction from this sector and will increase inter intra-city and regional connectivity. The Vision plans to upgrade the railway system including its network connecting North-south and East-west corridors by developing linkages through road and rail for providing quality service for passengers and freight. Public transport including mass transit systems will be carefully devised and implemented.

The National Climate Change Policy recommends the following priority objectives in the transport sector:

- Sensitize the public to the importance of proper vehicle maintenance for fuel efficiency enhancement and reduction of emissions;
- Ensure the provision of a fuel efficient public transport system in the country;
- Set up and strictly enforce vehicle emission standards;
- Plan and develop mass transit systems in metropolitan cities;
- Promote the scope of CDM projects in the transport sector;
- Support the private transport sector by providing incentives for reducing emissions and environmentally friendly transport services;
- Promote the development and adoption of environmentally friendly transport technologies and efficient management techniques;

- Promote greater use of Compressed Natural Gas (CNG) in the transport sector to the extent consistent with the availability of CNG in the market;
- Secure financing for technology innovations for urban planning and the transport sector, specifically to address mitigation issues;
- Encourage the national airline to give due consideration to new fuel efficient aircrafts, causing minimum carbon emissions, while planning fleet up-gradation
- Ensure the provision of an efficient railway system in the country
- Upgrade and expand the railway network in the country, as the advantages of railway over road travel in terms of carbon emissions are well recognized
- Develop and promote inland waterways transportation

Keeping in view the national priorities and the UNDP and UNFCCC guidelines provided in "Handbook for conducting Technology Needs Assessment for Climate Change", the same criteria for TNA along with its weight-age for selecting priority technologies as explained at Section 4.4 for energy and waste sector, was used for transport sector.

6.2.1. Technology Fact Sheets of Shortlisted technologies

The Consultant out of the technologies list mentioned in section 6.1.2, shortlisted and prepared technology Fact Sheets of the following six (6) existing and potential technologies in transport sector. These six fact sheets were presented in the meeting of Expert Working Group on Mitigation for prioritization of technologies through MCDA:

1. Bus rapid transport
2. Engine emission standards
3. Circular Railway
4. Vehicle tune up
5. Hybrid vehicle
6. GPS Tracking

6.3. Overview of selected mitigation technology options in the Transport sector, their mitigation potential and other Co-benefits

An overview of possible mitigation technology options in the transport sector, their mitigation potential and other co-benefits are presented in the Table 6.1:

Table 6.1: Description, mitigation potential and other co-benefits of selected technologies (Transport)						
#	Technology Name	Description	Mitigation potential	Other Co-benefits	Cost	Time frame
1	Bus rapid transport	A bus rapid transit system (BRT) is a high-capacity low cost transport system with its own right of way. The key technology is energy efficient engine, minimum Euro-II/ Pak-II compliant diesel engines which emits less CO2 and has good fuel burning efficiency.	The technology has led to reduce GHG emission by 40,000 tons per year	▪ Provides safe, comfortable & timely mobility to female, children and old-aged passengers' ▪ Reduces travel time which has brought positive psychological impact. ▪ Reduces number of accidents. ▪ Has led to social equality and poverty reduction by providing affordable high-quality transport.	Investment cost for BRT systems per km cost was 11 million per km in Lahore and 20 million per km in Rawalpindi-Islamabad. The BRT system in Rawalpindi is designed keeping in view that in future the structure of the flyover and other portions of the network can be converted to rail transport system which will further reduce GHG emissions and provide other benefits. The operational cost of Metro-bus Lahore was around Rs.60 per passenger in year 2014.	▪ Medium to Long Term
2	Railway transportation	Railway is considered to be the cheapest way of transportation of passengers and freight.	Its GHG emissions are lesser than road transportation .	It is six times more energy-efficient than road and four times more economical. Rail construction costs are approximately six times lower than road for comparable levels of traffic. Railways has served to integrate the fragmented markets and thereby, stimulating the emergence of a modern market economy. It connects industrial production centres with markets and with	Investment cost for construction of a normal railway track is Rs.100 million per km.	Medium to Long Term

				sources of raw materials and facilitates industrial development and link agricultural production centres with distant markets. It provides rapid, reliable and cost-effective bulk transportation to the energy sector, to move coal from the coal fields to power plants and petroleum products from refineries to consumption centres. It links places, enabling large-scale, rapid and low-cost movement of people across the length and breadth of the country. In the process, the Indian Railways has become a symbol of national integration and a strategic instrument for enhancing our defence preparedness.		
3	Vehicle tune up	Engine tuning is an adjustment, modification of the internal combustion engine or its control unit, to yield optimal performance, to increase an engine's power output, economy, or durability. A vehicle needs tune-up when its average fuel consumption drops by 10-15 per cent or after a warm up the vehicle does not pull away	The technology leads to decrease in GHG emission up to 3-5 per cent.	Economic benefits: The efficiency of transport sector is fundamental in bringing down the cost of energy consumption and reducing overall cost of production. Tune up of vehicles saves the fuel consumption. Furthermore, it will also lead to increase in energy and food security and improvement in the balance of payments by reducing imports of fossil fuels. Social Benefits: The margin of savings accrued from reduction in the cost of production will leverage better social security support to the industrial workers and their families. Better care of	Cost of tuning is Rs.500 to Rs.5000 depending on the type of the vehicle and level of tune up.	Short term

				industrial workers will lead to health improvement, increase in work output. In addition, it will lead to improvement in their quality of life and increase in employment opportunities. Decrease in cost of transport sector will result in reduced poverty.		

6.4. Criteria and process of technology prioritization

The MCDA approach as followed in other sectors was also adopted for prioritization of mitigation technologies in the transport sector. The members of Expert Working Group suggested changing circular railway to railway transportation that should include passenger as well a freight transport. The consequences of each option in transport sector were assessed on the basis of the criteria described in Section 4.4.1. Performance matrix have been developed showing relative scores against each criterion for each selected technology and presented at Annex XX.

6.4.1. Results of technology prioritization

The technology options found best in meeting the national priorities were selected in order of ranking scoring above 55 percent. Table 6.2 reflects aggregated ranking of mitigation technologies by Expert Working Group on Mitigation. The three technologies, Railway transportation; Bus rapid transport in urban areas and Adjustment of air-fuel mixture for better ignition, carburetor and other routine check-ups for increasing Vehicle efficiency were selected in the meeting.

Table 6.2: Aggregated ranking of mitigation technologies by Expert Working Group on Mitigation

#	Sub-sector	Technology	Aggregated score
1	Railways	Efficient Railway transportation	75.0
2	BRT	Bus rapid transport in urban areas	69.5
3	Private/ commercial vehicle	Adjustment of air-fuel mixture for better ignition, carburettor and other routine check-ups for increasingVehicle efficiency	58.6
4		Conventional technologies of transport management (Poorly managed railway transportation; in-existing efficient urban transport system, in-efficient tune-up of vehicles etc)	24.0

The technologies selected are in accordance with our national priorities. Railway transportation for movement of passenger and freight was ranked highest. Among the means of transportation, railways are the cheapest and safest mode for passengers and goods. Stretched over 8,800 kilometers and 781 stations[33], Pakistan's railway network constitutes the backbone of its transportation system and plays a pivotal role in the country's economy. Most routes have VHF radio coverage for communication between train dispatchers and trains. Telephone Communication is over wire lines and microwave. Railway is under the administration of Pakistan Government's Ministry of Railways. The government is working on circular railway for cities in Karachi and Lahore.

Bus rapid transport was ranked second highest. It is a vision of the present political leadership of the country to provide transport facilities to the people at par with the developed countries and Metro Bus service is a step towards that goal. Rate of urbanization is very high and Pakistan is going to be pre-dominantly urbanized by the year 2030. Such technologies would help in solving urbanization issues and

[33]PAKISTAN RAILWAYS; From Steam Engines to Fast Track Trains
http://pakistanpaedia.com/comm/railway/pakistan_railways.html

reducing GHG emissions from such issues. Vehicle tune up was also selected as a mitigation technology. The number of private and commercial vehicles are increasing at a very rapid rate and there is a need to educate the people to adopt practices of regular tune up of their vehicles.

Finally based on the process of pre-selection, selection and standardized ranking, three recommended mitigation technologies for short to medium term were prioritized and endorsed by the TNA committee (Figure 6.2). These technologies are in full support with the National Climate Change Policy and Pakistan Vision 2025.

Chapter 7: Summary and Conclusion

Pakistan's Technology Need Assessment (TNA) Project being implemented in Pakistan in collaboration with United Nations Environment Program (UNEP); Technical University of Denmark (DTU); Climate Technology Centre and Network (CTCN); Regional center, Asian Institute of Technology (AIT). The project identified GHG emission reduction potentials in the selected sectors, as well as prioritized technology needs keeping in view the current mitigation potential of the technologies and the national development goals and priority needs identified in National Climate Change Policy and Pakistan Vision 2025. The Vision 2025 aims to double the GDP growth from 4 percent to 8 percent as well as acceleration of huge transportation and industrial activities along the Pakistan China Economic Corridor. The Vision 2025 envisages to double power generation to over 45,000 MW to provide uninterrupted and affordable electricity, and increase electricity access from 67% to over 90% of the population; reduce average cost per unit by improving generation mix and reducing distribution losses; increase percentage of indigenous sources of power generation; and increasing usage of energy efficient appliances/products. As a result the Pakistan's GHG emission will rise from 369 tons of CO_2 equivalent in 2012 to 1046 and 4621 tons of CO_2 equivalent by 2030 and 2050, respectively.

The TNA project implementation is overseen by National Climate Change (CC) Policy Implementation Committee which serves as National TNA Steering Committee headed by the Federal Minister for Climate Change. The Director General (Environment & CC) serves as coordinator and his office is Secretariat of the TNA project and liaise with International Partners and other stakeholders. An Expert Working Group on Mitigation provides technical backup for the TNA process. For implementation of TNA project in Pakistan UNEP engaged the services of two Consultants, one for mitigation and the other for adaptation.

The consultant on mitigation held series of meetings and discussions with the relevant stakeholders and collected relevant information. The Sector Prioritization was carried out in the Inception workshop which included (i) Energy and waste sectors; (ii) Agriculture, land use change and forestry sector; and (iii) transport sector. The information collected was analyzed for carrying out situational analysis of selected sectors and development of priority technologies fact sheets. The technology fact sheets included information related to the characteristics of the technology; its cost; socio-economic and environmental characteristics; institutional capacity; need for capacity building; scale of application; time horizon and local acceptability of the technology.

Technology prioritization were carried out in selected sectors in the meeting of Expert Working Group on Mitigation by using multi-criteria decision analysis based on the explanation of proposed technologies through fact sheets. A uniform criterion for selection of technologies was prepared in consultation with stakeholders for multi-criteria decision analysis. On the basis of this criterion, the technologies prioritized

in the energy sector included (i) boiler and furnace energy efficiency improvement; (ii) energy efficiency improvement in buildings; (iii) solar energy technology; (iv) electricity generation from micro and small hydropower plants; (v) wind generators for electricity generation; (vi) biogas – compressed bio-methane including waste & bagasse; and (vii) using nuclear technologies for electricity generation. Technologies identified in the energy sector have vast potential of GHG emission reduction such as 35 percent through retrofitting, insulation etc. in boilers up to 70 percent through energy efficiency improvement measures in buildings as well as through solar photovoltaic, thermal, micro, mini and small hydropower generation technologies.

The selected technologies in the Agriculture, land use change and forestry sector included (i) reforestation & reducing CO2 emissions from forest degradation; (ii) farm forestry as carbon sink; (iii) rice cultivation by alternate wetting & drying/ under aerobic conditions; (iv) Diet options for reducing Enteric Fermentation in ruminant animals; and (v) Appropriate Application of Fertilizers & Soil Carbon Management. These technologies will significantly reduce rising level of GHG emissions from agriculture and up to 50 percent GHG emission reduction from waste through bio-methane bottling and REDD+ projects. In the transport sector the technologies prioritized included (i) railway transportation; (ii) bus rapid transport; and (iii) vehicle tune up. These technologies will significantly reduce the emission from the transport sector.

The technologies selected and prioritized in the energy including waste, agriculture including land use, land use change and forestry, and transport sectors conform with the technological priorities identified in the national climate change policy as well as in the Pakistan Vision 2025. Hence, the transfer and diffusion of prioritized technologies under TNA project is likely to receive strong support from the Government as well as the funding agencies to implement these technologies on-the-ground in the foreseeable time perspective conforming to Pakistan Vision 2025 and National Climate Change Policy. In addition implementation of these technologies will also put Pakistan to the path to low carbon economic development.

Annex-I

Boiler and furnace Energy Efficiency Improvement

Technology Characteristics:

Different boilers have different efficiency levels depending on the fuel type. Heat losses in the boilers include: dry flue gas losses; heat losses due to moisture and hydrogen in fuel, moisture in air into the combustion chamber; excessive air intake; improper air-fuel mixing resulting in un-burnt carbon and sensible heat in ash; radiation and convection losses occurring from exterior surface of boiler.

Tune up: Boiler and furnace tune-up is the method for determining the lowest practical excess air level at which the boiler can be operated and adjusting the boiler to that condition. Tuning of the combustion system requires a visual check by an experienced boiler or stationary engineer to ensure that everything is in good working condition and set according to the manufacturer's recommendations or the optimum settings developed for the particular boiler. Simple parametric testing may be required, which may involve changes in the key control variables of the combustion system and observation of key parameters such as CO emissions, steam outlet conditions, flue gas outlet (stack) temperature, and NOX emissions.CO level is reduced from 1000-2000 to < 200 ppm and Unburned carbon from 20-30% to 10-15%. It is mostly done by operating the boiler at various firing rates; and excess air levels while recording boiler operating conditions. Parametric testing and stack measurements are done at normal steam pressure. The boiler tune-up will establish the excess air level at some operating margin above the absolute minimum which is at the threshold of smoke or combustion emissions formation. Different burner designs and fuels will have different minimum oxygen requirements. Many burners will also exhibit higher minimum oxygen at lower firing rates. The combustion system of boilers and furnaces may drift over time from its optimum setting or certain controls (e.g., dampers) may not be operational due to wear. One objective of the initial setting of the combustion system is to maximize the combustion efficiency (minimize Unburned carbon and CO emissions), and demands to minimize NOX emissions may require further tuning.

Reducing air leakage: Air leakage or infiltration occurs as a result of the large temperature difference between the hot combustion gases and ambient air temperature, which creates a negative pressure in the furnace. The sources for air leaks can be multiple, ranging from small openings (such as warped doors which deteriorates and fails to provide adequate sealing) to actual cracks in boiler casings or ductwork requiring more significant repairs. Indicators of excessive air leakage include: high O2 levels measured at the outlet of the boiler, as well as fuel consumption and gas temperatures. Depending on the severity and source of the leaks, the solution can be as follows: (i) routine maintenance (e.g., adjust door seals); (ii) more thorough fixes during planned outages (e.g., repair boiler casing cracks); and (iii) adjustment of steam pressure in the steam distribution system of a boiler near to the recommended levels also reduces chances of air leakage.

Air pre heaters: For most fossil fuel-fired heating equipment, energy efficiency can be increased by using waste heat gas recovery systems to capture and use some of the heat in the flue gas. One of the waste heat recovery methods is preheating combustion air. Heat recovery equipment includes various type of heat exchangers including air heaters, typically located after the gases have passed through the steam generating sections of the boiler. Air pre heaters transfer heat from flue gas to the incoming combustion air. Pulverized coal-fired boilers require the use of air pre heaters to evaporate the moisture in the coal and to transport the pulverized fuel to the burners. Stoker-fired boilers typically do not require preheated

air unless the moisture content of the coal exceeds 25 percent. Retrofitting an air pre-heater, to a natural gas-fired 10 MMBtu/hr boiler, operating at an annual capacity factor of 68 percent and with a flue gas temperature of 600 °F, to reduce the temperature by 300 °F, results in an efficiency improvement from about 76 percent to 82 percent.

There are two general types of air pre heaters (APH); recuperator and regenerators. Recuperators are gas-to-gas heat exchangers usually placed on the boiler stack. Internal tubes or plates transfer heat from the outgoing exhaust gas to the incoming combustion air while keeping the two streams from mixing. Regenerators include two or more separate heat storage sections, each referred to as a regenerator. The hot flue gas heats the heating plates; in turn, this heat is transferred to the incoming combustion air.

Blow-down: Boiler blowdown is water intentionally wasted from a boiler to avoid concentration of impurities during continuing evaporation of steam. The water is blown out of the boiler with some force by steam pressure within the boiler. Heat losses in the boilers may be in the following forms: (i) Dry flue gas loss; (ii) heat carried out by water vapors; (iii) unburned fuel and products of incomplete combustion; (iv) radiation and convection heat losses from outside surface of boiler as a result of insulation issues; and (v) heat carried away with the boiler blowdown. Boiler efficiency can be primarily improved through reducing waste heat energy losses in the combustion gases; improving insulation and controlling blowdown (with or without heat recovery from the blowdown). Controlling the level of total dissolved solids within the boiler improves its efficiency. Blowdown lends itself to the recovery of the heat content of the blowdown water. After passing through the blowdown control valve, the lower pressure water flows flash vessel where the steam is free from contamination and is separated from the condensate by plate heat exchanger and can be used to heat boiler feed tank. Old-style boilers has a large water capacity and normally tolerate a high total dissolved solids (TDS) of up to 15,000 parts per million (ppm). The modern boilers has a very limited water space and TDS levels are kept at mostly less than 3,500 ppm depending on the pressure at outlet of steam generating unit. Quantity of blowdown should not exceed the minimum necessary amount and TDS levels should be as per recommendations. Anything in access is a waste of energy.

The dissolved solids in the blowdown should be monitored regularly by a TDS meter. The frequency of blowdown should be controlled to manage the dissolved solids in the boiler to the recommended levels. The quality of make-up water can be improved to reduce the necessary blowdown frequency and heat loss. A blowdown heat recovery unit can be installed on the continuous blowdown line from the boiler. This unit will preheat cold make-up water for the boiler.

Other technologies: Other technologies for energy efficiency include variable frequency drive coupled with O2 trimming system, feed water treatment, and flash steam recovery.

Cost

Costs for a natural gas-fired 10 MMBtu/hr boiler, operating at an annual capacity factor of 68 percent and with a flue gas temperature of 600 °F are as follows:

- Cost of boiler tune-up is very less if done by factories' own experts, If external experts are hired, its cost may be up to Rs.100,000 depending on the size of the boilers.
- Cost of reducing air leakage can be negligible if it sets with routine maintenance or it may be significant amount if boiler repairs are involved.
- Average estimated cost of an air pre-heater system is Rs.4 – 10 million.

- Cost of insulating boiler plant is estimated at Rs.3,000/m2.
- Cost of replacement and up-gradation of burner is Rs.2-5 million.
- Cost of blowdown in terms of equipment is that of TDS meter and blowdown heat exchange system which is Rs. 1.5-2 million.

Safety, reliability & maturity: The technology is comparatively simple, relatively low cost, safe, reliable and easy to adopt. It has been practiced in Pakistan since last 30 years in an unorganized and discontinuous basis. No formal training facilities exist for boiler operators. Boiler inspectors are ill equipped to carryout inspection, monitoring and certification. There are no certification standards.

Potential Development Benefits:

Economic benefits: The efficiency of boiler, furnace & heating system are fundamental in bringing down the cost of energy consumption and reducing overall cost of production. It will also lead to increase in energy and food security and improvement in the balance of payments by reducing imports of fossil fuels.

Social Benefits: The margin of savings accrued from reduction in the cost of production will leverage better social security support to the industrial workers and their families. Better care of industrial workers will lead to health improvement, increase in work output. In addition, it will lead to improvement in their quality of life and increase in employment opportunities..

Environmental benefits: The boiler tune-up will lead to significant decrease in greenhouse gas (GHG) emission up to 3 percent in the industries which use steam or heat for different process applications. Controlling boiler blowdown will lead to significant decrease in greenhouse gas (GHG) emission up to 9 percent in the industries which use steam or heat for different process applications. The boiler air-preheating will lead to significant decrease in greenhouse gas (GHG) emission up to 3 percent in the industries which use steam or heat for different process applications. Replacement and up-gradation of burners will lead to significant decrease in greenhouse gas (GHG) emission up to 6 percent in the industries since an inefficient burner system results in higher CO2, NOx emissions, higher operating costs, lower reliability and reduced output. Providing proper insulation to a boiler will lead to significant decrease in greenhouse gas (GHG) emission up to 7 percent in the industries which use steam or heat for different process applications. Reducing air leakage in a boiler will lead to significant decrease in greenhouse gas (GHG) emission up to 4 percent in the industries which use steam or heat for different process applications. Since an inefficient system results in higher heat rate, CO_2 emissions, operating costs, lower reliability and reduced output.

Application potential:

Institutional capacity: The private sector companies have limited capacity to conduct the tune-ups.

Need for capacity building: There is a need for capacity building of ENERCON as well as the private sector to conduct tune-ups on scientific lines to optimally benefit from the opportunities of CO_2 emission reduction and improving energy efficiency at affordable costs.

Scale of Application and time horizon: Boilers and furnaces are integral part of most of the industries, and these often consume largest proportion of the fuel being used by those industries. Pakistan Vision 2025 envisages fundamental improvements in competitiveness across the industrial and manufacturing, services through achieving efficiency, quality and productivity to enable self-sustaining enterprises thereby increasing output, boosting their share in the international market and raising the overall level of

prosperity and wellbeing of the nation. Innovation, value addition and continuous improvement are keys to improving competitiveness through promoting boiler and furnace tune-up under a well-designed program.

Local acceptability: As there is no negative impact of the technology as well as it is cost effective technology, hence it has high level of local acceptability.

Annex-II

Reducing energy consumption in homes and offices through building design, air conditioning and power factor improvement in warmer areas

Technology Characteristics:

Building design in warmer areas

Building placement and design are important elements in determining how buildings derive maximum advantage from sunlight and air. Building-envelops, act as a thermal barrier in regulating interior temperatures. In hot climate the building envelops can reduce amount of energy required for cooling through insulation.

Kitchens and laundry rooms typically have house heat-producing appliances, so locating kitchens and living areas for northern or southern exposures can provide a lot of natural daylight without a lot of heat gain. Placing the washer, dryer, and freezer outside of conditioned space can reduce cooling loads even further. Supplement a compact house design with porches, patios, or other planned outdoor areas to extend the living space outside the conditioned space.

Materials such as mud plaster; reflective chemicals; thermo-pore, jumbolon for foam insulation, sachal tile, Munawar AC tiles; aerosol, white enamel weather shield, slaked lime, paint insulation can be used for roof, floor and wall insulation. Hallow blocks also improve wall insulation. For false ceiling gypsum board with foil, thermo-pore, and paper board can be used. Use light color for painting inside walls. Such materials help significantly to reduce temperature of the interior of the building. Use Roof hatch windows; double glazed windows and fuel-efficient stoves with water and room warming facilities.

Advanced heating and cooling systems can reduce energy consumption and improve the comfort of the building's inhabitants. For example, programmable thermostats automatically raise or lower temperatures at night or during the day when no one is present. Air-source and geothermal heat pumps can provide both heating and cooling efficiently. Evaporative cooling in dry areas and desiccant cooling in more humid areas are also generally more efficient than conventional cooling systems. Integrated space and water heating systems are often energy efficient in larger buildings. Several methods reduce the need for artificial lighting: proper placement of windows and skylights and use of architectural features that reflect light into a building, such as light shelves. Use compact fluorescent light bulbs or crystal white surface-Mounted-Device Light-Emitting Diode. Task lighting, lighting sensors, and dimmers also reduce the power needed for lighting.

Modern energy-efficient appliances use significantly less energy than older appliances. Energy-efficient appliances, including refrigerators, freezers, ovens, stoves, dishwashers, and clothes washers and dryers with its Energy Star label may be used. Modern power management systems also reduce energy usage by idle appliances by turning them off or putting them into a low-energy mode after a certain time. Use Renewable technologies like solar water heaters, solar photovoltaic, biogas plants etc.

Air conditioner inverter

In traditional air conditioner, compressor periodically works either at maximum capacity or shuts on and off, after desired set temperature is achieved, to regulate the cooling temperature. Starting on and off requires initial torque due to loss of inertia which increases power consumption. These air conditioners use a narrow range of speeds rotary compressor, which contain single phase induction motor that causes the starting current of air conditioner rise very high, often 3 - 5 times to the rated current. Their speed is determined by the constant frequency of the power supply (typically 50 or 60 Hz).

By contrast, Inverter-equipped air conditioners have a variable-frequency drive that incorporates an adjustable electrical inverter to control the speed of the motor and thus the compressor and cooling output. The inverter controls the speed of the compressor motor to drive variable refrigerant flow in an air conditioning system to regulate the conditioned-space temperature. The combination of motor and control unit is then termed "Variable speed drive". The variable-frequency drive uses a rectifier to convert the incoming alternating current (AC) to direct current (DC) and then uses pulse-width modulation in an electrical inverter to produce AC of a desired frequency between 0Hz up to 120Hz (0rpm - 7200rpm). The

variable frequency AC drives a brushless motor or an induction motor. As the speed of an induction motor is proportional to the frequency of the AC, the compressor can run at different speeds. Once desired temperature is achieved a 2 ton inverter ac may work as 0.5 ton ac. A microcontroller can then sample the current ambient air temperature and adjust the speed of the compressor appropriately. Inverter controls are usually used on three-phase AC (alternating current) motors but can also be used on some single-phase AC motors. Filtering harmonics and electromagnetic compatibility are typical issues that need to be taken care of, but modern inverter systems have made significant progress in this respect. The maintenance cost of inverter AC is more than traditional AC.

Power Factor Improvement

Power factor (PF) measures efficiency of use of Alternate Current (AC) electric power drawn from the network. It is the ratio of effective current to apparent current or active (delivered useful) power to apparent power taken from the supply. It is due to inductive loads e.g. induction motors; fluorescent and mercury lamps, transformers and induction generators in an electric system. Active or useful power is the power that equipment needs to achieve the task at hand, measured in Kilowatts (kW). Reactive power is drawn in addition to useful power by a reactive load, measured in Kilo-volt ampere reactive (kVAR). Consumption of reactive power does not contribute to achieving the task. Both useful and reactive powers determine the power drawn from network, i.e. the total or apparent power, measured in kVA. Lessening the effects of reactive power will reduce the current needed from network to complete the same tasks. Poor PF causes energy losses as it: (i) draws more current from the network – costing more to achieve the same tasks; (ii) can incur a 'poor PF penalty' from the supplier; (iii) reduces effective capacity of the electrical supply, the more reactive power that is carried, the less useful power can be carried; (iv) causes losses at transformers and other devices, leading to inefficiency and unwanted heat gains; (v) can cause excessive voltage drops in the supply network; (vi) can reduce life expectancy of electrical equipment.

Poor PF in an inductive load can be corrected by adding (i) proper capacitors in parallel or (ii) synchronous condenser or motor with no load attached to its shaft. Power engineering specialists conduct a survey to check for poor power factor. Only appropriately trained and qualified people should specify or fit PF improvement equipment. The equipment has a finite life – an older installation may not be operating as originally intended.

Fuel-efficient stoves

Fuel-efficient stoves for low income communities are constructed by using a mold. The mold help in producing domestic: 2 + 1 stove (has provision for 2 cooking vessels and 1 heat recovery vessel where the hot gases could be used to pre heat water for cooking, drinking, washing, space heating etc.). The smoke is allowed to move up through a chimney.

To construct energy efficient mud stoves, clay and wheat straw or rice husk is collected and mixed with water. Equipment required are: 20 litre bucket, 5 litre cooking pot, hoe, trowel. Mud mortar mix is prepared by mixing 7.5 kgs clay soil with about 5 litres of water and some quantity of wheat straw or rice husk and sandy or loamy soil. Prepare and level the floor where the fuel-efficient stove is to be located.

The mud mortar mixture is filled in the mold to make raw stoves. The chimney is also installed in the design. These are picked up if constructed on sand or other detachable material from which these can be removed so that these are air dried in sun shade. Otherwise these are dried at their installation place. After drying these are smoothened and polished for final finishing. Sometimes the mud stoves are baked in baking kiln. Another method is to construct the mud stove by using 30 bricks (un-burnt or burnt).

Cost: The cost of building design improvement varies. Many design factors that save energy are virtually free; payback period of other measures is 1-2 years.

Cost of inverter Air-conditioners are in the range of Rs.80,000 – Rs.100,000 for 1.5 tones unit. The initial cost is high as this technology has been recently introduced in Pakistan and used on a limited scale. The price can substantially decrease with the adoption of this technology and mass production.

The cost of power factor improvement varies. If the PF at a site is permanently poor and no single item of equipment is solely responsible, fixed PFC can be employed also. In this case, the PFC capacitors will be connected across the main power supply to the premises, that is, the capacitor banks' terminals are connected to each of the three phase cables as they enter the site. In this case, Automatic PF control panel can be linked with the switchgear. In other case, many machines are switching on/off at various times; the PF may be subject to frequent change. In these cases the amount of PF needs to be controlled automatically – that is, the banks of capacitors need to be selectively switched in and out of the power circuit appropriately. The PF capacitors can also be installed with individual equipment.
Cost of mold ranges from Rs.2000 to Rs.3000. The raw materials for preparing clay and straw mixtures are locally available.

Safety, reliability & maturity: The technology is comparatively simple, safe, and reliable. It has been practiced in Pakistan in an unorganized and discontinuous basis. No formal training facilities exist for construction of energy-efficient building design, air-conditioner inverter, power factor improvement and fuel-efficient stoves. There are no certification standards.

Potential Development Benefits:
Economic benefits: The technology can offer owners economic benefits from lower heating and cooling costs, better comfort, reduced expenses for dealing with complaints and increased asset value. It results in less electricity and natural gas-consumption from the network, saving money on utility bills.
In Pakistan about half of the total energy consumed is used in buildings (residential, commercial and industrial). An energy-efficient building consumed 60 to 70 percent less electricity and natural gas compared with a poorly designed and constructed building with poor insulation and higher energy consuming lights, fans and other electrical appliances.
Social Benefits: Energy efficient building features can promote better health, comfort, well-being, and productivity of building occupants. Margin of savings accrued from reduction in the cost of production will leverage better social security support to the workers and families living in houses, industries and offices. It will lead to health improvement, particularly from asthma, allergy and respiratory diseases and increase in work output. In addition, it will lead to improvement in their quality of life and increase in employment opportunities.
Environmental benefits: The technology will lead to significant decrease in greenhouse gas (GHG) emission (60-70 percent). It results in reducing urban heat island phenomenon and global warming.
Application potential:
Institutional capacity: The private sector companies have limited capacity to design and construct energy efficient buildings.
Need for capacity building: There is a need for capacity building of ENERCON, architects, building designers, and developers to implement the technology. Institutions like Pakistan Council for Architects and Town Planners, Pakistan Engineering Council and Green Building Council may facilitate such trainings
Scale of Application and time horizon: The technology can be applied widely in domestic, commercial and industrial sectors in short span of time.
Local acceptability: As there is no negative impact of the technology hence it has high level of local acceptability.

Annex-III

Fact sheets of Solar Energy Technologies

Solar photovoltaic with SMD-LED lights

Technology Characteristics:

Pakistan, being located in the sun-belt region, has plenty of solar radiation daily available throughout the year. The annual average solar radiation on a horizontal surface varies from 4.7 Kwh/m^2 to 6.2 Kwh/m^2. The number of clear sunny days in the country varies from 250 in the northern region to above 300 days in most part of the rest of the country. Solar power takes lots of daylight and converts it to little bit of energy. Crystal white surface-Mounted-Device Light-Emitting Diode (SMD-LED) use little bit of energy but produce reasonable amount of directed light. The use is where there is presently no light. An efficient 2 W SMD-LED bulb, gives out light only in one direction equivalent to about a 20 watt bulb. Solar photovoltaic (PV) system consists of solar PV panels, charge controller, 12 or 24 volts battery and Direct Current (DC) powered lighting, fan and other appliances. If lighting and appliances are Alternate Current (AC) powered, then a converter to convert 12 or 24 volts DC to 220-230 volts AC is also required in the system. Other solar PV applications include integrated solutions such as solar lantern, mobile charger, torch light, calculator etc. Solar PV cells are of three types i.e. amorphous, mono-crystalline and poly crystalline. Life of amorphous cells is less (5-8 years) while for other types life is more than 25 years. Polycrystalline are suitable for hotter areas.

Cost: The estimated cost of 100 watts solar PV, charge controller, and 12 volts, 200 ampere battery is Rs.80,000. This system can operate two 40 watts DC powered fans and five 5-7 watts DC powered SMD-LED lights for an average size household. For operating other household appliances like fridge, washing machine, electric motor and oven, additional amount would be required based on wattage and hours of usage. Cost required per watt hour would be about Rs.100. Initial average cost of solar PV system required for a household with a maximum load of 10 kilowatt hour per day is Rs.1 million. Cost of batteries of Rs.80,000 would be required after every two years. The tariff of PV system for grid is Rs.19.2 for 1-10 years and Rs.8.6 for 11-25 years.

Safety, reliability & maturity: The technology is simple, safe, and reliable. It has been practiced in Pakistan in an unorganized and discontinuous basis. No formal training facilities exist and there are no certification standards. Life of solar PV is about 25 years.

Potential Development Benefits:

Economic benefits: Pakistani villages not connected to the grid are representing a promising model for rural electrification based on private purchases of clean decentralized photovoltaic technologies. For grid connected areas such systems are being used for load-shedding hours as a replacement of UPS. Provision of electricity will help in investing additional hours for income generation activities.

Social Benefits: The technology provides employment opportunities and improves quality of life. There is learning opportunities for students in the evenings and family members have additional time for social activities. Traditionally families in rural areas use paraffin candles and lamps as source of light. In urban areas, engines using petrol, diesel or natural gas are used for producing electricity during load shedding hours. These sources produce fumes which are harmful to human health. The technology does not emit any pollution as opposed to use of paraffin lamps. The technology helps in achieving energy security.

Environmental benefits: The technology will result into significant reduction of greenhouse gas (GHG) emission depending on the size of the system. The technology does not produce any noise while one of the alternatives of technology i.e. engines using petrol, diesel or natural gas produce lot of noise.

Application potential:

Institutional capacity: The private sector companies have the capacity to install PV systems but do not have the capacity to produce solar cells and panels.

Need for capacity building: Pakistan Council of Renewable Energy Technologies has a unit for producing solar cells and panels but this is not fully functional mostly because of capacity issues. There is a need for capacity building of Pakistan Council of Renewable Energy Technologies, Alternate Energy Development Board as well as the private sector to produce solar cells and panels.

Scale of Application and time horizon: The technology can be applied widely for use in building sector. For areas not connected to the grid, the technology has medium payback period (about 7 - 10 years, depending on size and type of the system). Charges of electricity from national grid are different for household, commercial and industry sector, so payback period is also different for these sectors. Government has installed 100 MW solar PV systems for grid and production of 900 MW solar PV systems is under process with the private sector which will also be facilitated through Clean Development Mechanism. Pakistan Vision 2025 stresses promotion of renewable energy technologies to tackle energy crises.

Local acceptability: As there is no negative impact of the technology hence it has high level of local acceptability.

Solar pump with sun tracking system

Technology Characteristics:

It is a Direct Current (DC) powered submersible pump (positive displacement, low voltage) constructed of high quality marine bronze and stainless steel; these pumps were designed for corrosion free service in clean portable water. They can be installed in a well, cistern or lake. It takes energy from photovoltaic cells, made from silicon and other semiconductor materials that enable direct conversion of solar energy into electricity.

Sometimes, solar panels are mounted on a sun tracking system that rotates the panels along with the movement of the sun. Control panel issued as an interface between the power source and the pump on all systems. It provides much greater pump system efficiency, motor protection, system control features and diagnostics. Most of solar submersible pumps are designed to fit into a 125 mm (5”) inside diameter well casing; 150 mm (6”) with optional sand shroud. The pump requires no lubrication. It operates with DC power source including solar panels, batteries, or a combination of both. Depending on size, ¾”-5” drop pipe is used for water lifting. As there are no running charges of water lifting, so the water lifted from solar pumps can be stored in a storage tank for its use during the hours when there is no sunlight.

Cost: The cost of solar pumps generally ranges between Rs.150,000-Rs.2,500,000 depending on its output capacity, type and groundwater table.

Safety, reliability & maturity: The technology is not so simple, however it is safe, and reliable. It has been practiced in Pakistan in an unorganized and discontinuous basis. No formal training facilities exist and there are no certification standards.

Potential Development Benefits:

Economic benefits:

Initial cost of solar pumps is high, but if calculate the actual investment required for running a diesel pump of the same capacity for 7 years or more, cost of solar pump is less. Water lifted from solar pumps can be used for drinking or irrigating the agricultural fields. If water is applied through improved irrigation methods like drip irrigation, saving is even more. The technology results in increased production of agricultural and horticultural crops, vegetables and forest trees.

Social Benefits: In villages women fetch water from far-off places for household use. Solar pumps can provide water for drinking and household use. Time saved by women can be utilized for other social activities. The technology helps in achieving energy and food security. It results in creating income generation activities, improving quality of life and poverty reduction.

Environmental benefits: The technology will result into significant reduction of greenhouse gas (GHG) emission depending on the size of the pump. The submersible pumps do not produce any noise. If trees are grown with irrigation water from solar pumps, these have lot of environmental benefits and act as sink for CO_2.

Application potential:

Institutional capacity: The private sector companies have the capacity to install solar pumps but do not have the capacity to produce such pumps.

Need for capacity building: There is a need for capacity building of Pakistan Council of Renewable Energy Technologies, Alternate Energy Development Board as well as the private sector to produce efficient solar pumps.

Scale of Application and time horizon: The technology can be applied widely for use in agriculture and drinking purposes. The technology has medium payback period (about 5-7 years, depending on size and type of the pumps). Pakistan Vision 2025 stresses promotion of renewable energy technologies to tackle energy crises and increase production of agricultural crops.

Local acceptability: As there is no negative impact of the technology hence it has high level of local acceptability.

Solar water heating-Domestic

Technology Characteristics: Solar water heating is the most popular applications of solar energy in industrial and domestic uses. There are two main types of domestic solar water heaters:

Flat-plate collectors: The main components of these are a transparent front cover, collector housing and an absorber. The absorber, inside the flat-plate collector housing, converts sunlight to heat and transfers it to water in the absorber tubes. As the collector can reach stagnation temperatures, up to 200°C (i.e. when no water flows through), all the materials used, must be able to resist such heat. Therefore, the absorber is usually made of metal materials such as copper, steel or aluminum. The collector housing can be made of plastic, metal or wood, and the glass front cover must be sealed so that heat does not escape, and dirt, insects or humidity do not get into the collector itself. Many collectors also have controlled ventilation, so as to avoid condensation inside the glass front cover. The collector housing is highly insulated at the back and sides, keeping heat losses low. However, there are still some collector heat losses, mainly due to the temperature difference between the absorber and ambient air.

Evacuated-tube solar collectors: The Evacuated-tube solar collector comprises of following main parts: (i) Evacuated Tube (ET) that absorbs solar energy and converts it to usable heat. Vacuum between the two glass layers insulates against heat loss. (ii) Heat Pipe (HP): Copper vacuum pipe that transfers the heat from within the ET up to the manifold. (iii) Manifold: Insulated box containing the copper header pipe. The header is a pair of contoured copper pipes with dry connected sockets that the heat pipes plug into. (iv)Mounting Frame: Strong and easy to install with various options to match different mounting methods. Evacuated tube solar collector basic system operation consists of: (i) The absorber coating on the inner glass tube absorbs sunlight and converts it into heat; (ii) Steam forms inside heat pipe which transfers heat rapidly up to the manifold; (iii) A pump circulates water or heat transfer fluid through the

header pipe, carrying heat back to the storage tank. Gradually throughout the day the tank is heated up. The tank can be boosted by an electric element, gas/oil boiler, or the solar tank can simply feed an existing water heater tank with solar pre-heated water.

Safety, reliability & maturity: Technology is comparatively simple, relatively low cost and easy to adopt. Solar Water Heater system reduced power bills and the likelihood your property value will increase. Other positives include doing something positive for the environment, setting an example for others to follow & installing technology that will be the standard in the decades to come. The simple payback period in Pakistan is only 7 years.

Price: The price of a family size solar water heater is about Rs.35,000 – Rs.60,000.

Potential Development Benefits:

Economic benefits: Solar water heaters have a significant role in reducing heating energy consumption in public and residential sectors. Water solar heaters can help to reduce the pressure on consumption of natural gas. This technology has a good prospect. As a result, the money saved can be averted to other socio-economic needs.

Social benefits: Solar water heaters are widely used by communities both in the developed and developing countries as it is an environment and user-friendly technology. It can easily be installed on the rooftop. In terms of social benefits, this technology can contribute to the sustainable development, as it is simple enough for local people to carry out with a little training. As a result, it can help provide work, enhance life quality and reduce energy costs and reliance on fossil fuel. The availability of natural gas is rapidly depleting and government is considering importing Liquefied Natural Gas to meet the demand.

Environmental benefits: Solar water heating can reduce fossil fuel consumption and subsequently GHG emissions. If 80% of urban households, equivalent to 10 million households, use solar water heaters by 2030, the emission reduction potential can reach 20 million tones[34] of CO_2.

Application potential:

Institutional Capacity: Pakistan has the capacity to produce flat-plate collectors in the public and private sectors. Pakistan Council for Renewable Energy Technology pilot tested the technology and provided training to public and private sector institutions. The technology is being marketed by private sector.

Need for Capacity Building: There is a need to build the capacity of public and private sector institutions in manufacturing of improved technologies such as evacuated-tube solar collectors.

Scale of Application: Pakistan has an enormous solar energy source. Pakistan is located in the sun-belt region and has rich potential for harnessing solar radiation technology for meeting domestic and industrial needs. In Pakistan the annual average solar radiation on a horizontal surface varying from 4.7 Kwh/m2 to 6.2 Kwh/m^2 and the Annual Direct Normal Solar Radiation for Concentrated Solar Power (CSP) is in the range of 4.5 to 7.5 KWh/m^2/day. The number of clear sunny days in the country varies from 250 in the northern region to above 300 days in most part of the rest of the country. At the present, solar energy can be extracted to heat water in place of natural gas and electric heaters, particularly in urban areas.

Time horizon: The period of adoption of this technology can be reduced if utility companies like Sui Northern and Sui Southern Gas Company Limited markets the products to their consumers and deduct the base price of the products in installments through monthly bills.

Acceptability to locals: The technology has been adopted at a limited scale and is accepted by the society.

Solar dryer

Technology Characteristics:

Solar dryer collects solar energy by heating-up the air volume in solar collectors and conduct the hot air from the collector to an attached enclosure. Solar Cabinet dryer mainly consists of a drying cabinet in the form of a black body. Any black layer on the inside of a solar dryer will improve the effectiveness of turning light into heat. One side of the cabinet is glazed to admit solar radiation, which is converted into low-grade thermal heat thus raising the temperature of the air, the drying chamber, and the produce. The

[34] http://environment.about.com/od/renewableenergy/a/solar_water_hea.htm

material to be dried is placed in shallow layers on trays inside the drying cabinet. Proper air vents are provided for displacement of hot and humid air. Solar greenhouse dryers are characterized by having extensive glazing on their south facing side while the other sides are well insulated. In indirect Solar dryers, the produce is placed on trays inside an opaque drying chamber to which is attached an air type solar collector. The sun does not shine directly on the material to be dried; instead the air heated in solar collector is ducted to the drying chamber for dehydration. Air circulation can be by natural convection; however blowers are often used for forced convection. These dryers result in higher temperature than the cabinet dryers or sun drying, and can produce higher quality product. Design and specifications of different type of dryers vary from case to case in consideration to their specific needs.

Cost: The estimated initial cost of a solar dryer of 50-100 kg is Rs.30,000 – Rs.50,000. Solar dryers are available from 10 kg to 500 kg.

Safety, reliability & maturity: The technology is simple, safe, and reliable. It has been practiced in Pakistan in an unorganized and discontinuous basis. No formal training facilities exist and there are no certification standards.

Potential Development Benefits:

Economic benefits: Pakistan economy is based on agriculture. Due to inadequate post-harvest care, it is estimated that 20-30 percent of the agricultural produce is wasted. Drying with solar dryer is faster than open sun drying and food retains its nutrient value. Solar dryer is very effectively in drying agriculture products and reducing insect infestation in such products, particularly in remote northern mountainous areas. Solar drying of agricultural produce helps in its safe and low cost storage for longer periods. Desired moisture contents depend on type of food, duration of storage and the storage conditions available. Dried fruits are transported and sold later in the urban market, resulting in a positive effect on the economy of the area. Solar dryers could be equally effectively used in the provinces of Punjab and Sindh to dry agriculture products for better market value and generating local employment. Good quality products can be obtained at much less cost, due to savings in cost of electricity or other heating fuels that would have been used otherwise, for the same purpose.

Social Benefits: The technology provides employment opportunities and improves quality of life. The technology saves agricultural produce and helps in achieving energy and food securities. Adequately dried vegetables can be used in off-season and are more hygienic then the vegetables stored without drying.

Environmental benefits: The technology results into significant reduction of greenhouse gas (GHG) emission depending on the size of the system.

Application potential:

Institutional capacity: The private sector companies have limited capacity to produce and install solar dryers.

Need for capacity building: There is a need for capacity building of Pakistan Council of Renewable Energy Technologies, Alternate Energy Development Board as well as the private sector to produce solar dryers.

Scale of Application and time horizon: Due to the lack of logistics and basic infrastructure in the northern mountainous regions of Gilgit-Baltistan and Chitral and areas in Balochistan like Makran Division etc. tons of fruit like apricots and dates go waste every year. Solar dryers are now being used to dry large quantities of such fruits. The technology has medium payback period (about 5 - 7 years, depending on size and type of the system). Pakistan Vision 2025 stresses promotion of renewable energy technologies to tackle energy crises.

Local acceptability: As there is no negative impact of the technology hence it has high level of local acceptability.

Solar thermal electricity – Parabolic Trough

Technology Characteristics:

Generation of solar thermal electricity (STE) from concentrating solar power (CSP) plants has grown strongly worldwide. The CSP plants concentrate solar rays to heat a fluid, which directly or indirectly runs a turbine and an electricity generator. Concentrating the sun's rays allows for the fluid to reach working temperatures high enough to ensure fair efficiency in turning the heat into electricity, while limiting heat losses in the receiver. Predominant CSP technologies are: (i) parabolic troughs (PT), (ii) linear Fresnel reflectors (LFR) and (iii) towers, also known as central receiver systems (CRS) and (iv) parabolic dish, also a CSP plant, usually supporting an engine at its focus.

More than 95 percent of commercially operated solar thermal power plants are parabolic trough systems. Parabolic trough (PT), with oil or molten salt as heat transfer fluid (HTF), is considered to be a mature technology. Parabolic trough collectors are assembled from the following units: (i) concentrator, a mirror trough with a parabolic shaped cross section, (ii) tracking device to track course of the sun, (iii) absorber or receiver tube. The concentrator collectors are mounted in rows on supporting pylons and are connected with one another. Its structure contains drive systems; movable tube connections on the collector ends and absorber tubes. Heat storage system and steam turbine/ generator are connected to the PT system. In Thailand, the 5 MW PT plant dispensed with oil, generating steam directly works at 30 bars and 330°C. Heat storage system balance out fluctuating irradiation and extend the operating time of power plant. Commonly used are storage systems in which molten salt from a cold tank (288°C) is heated to around 390°C in a heat exchanger using heating oil from the solar array and then stored. Reflecting films may replace glass, making troughs lighter and cheaper.

These technologies differ with respect to optical design, shape of receiver, nature of the transfer fluid and capability to store heat before it is turned into electricity. Fixed receivers (Linear Fresnel reflectors and Towers) are stationary devices that remain independent of the plant's focusing device. This eases the transport of collected heat to the power block. Mobile receivers (Parabolic troughs and dishes) move together with the focusing device. Some are full hybrids, as they routinely use a fuel (usually, but not always, a fossil fuel) or another source of heat together with solar energy.

Cost: Cost of the technology is about Rs.30 per kilowatt hour.

Safety, reliability & maturity: The technology is not so simple. Safety parameters are needed for the workers of the technology to protect their eyes and skin from any infection and burning issues. The technology may also affect insects and birds in the eco-system, however, proper measures can reduce such affects. The technology has already been tested in many countries like USA, Spain, and Thailand etc, so it is reliable. There is a PT plant in Electrical and Mechanical College, National University of Engineering and Technology.

Potential Development Benefits:

Economic benefits: By adopting Parabolic trough technology, Pakistan can be one of the pioneers in solar thermal deployment in south east Asia, which could present a unique opportunity for technological and engineering enterprises to position themselves in this new niche in international markets particularly when Pakistan is establishing Energy corridor. The electricity produced will be fed directly to the national grid. There will be substantial savings from replacement of fossil fuel used for generating electricity. Provision of electricity will reduce load shedding and help in investing additional hours for income generation activities.

Social Benefits: The technology will create employment opportunities, improves quality of life and alleviate poverty. The family members will have additional time for social activities and learning. Traditionally families in rural areas use paraffin candles and lamps as source of light which is a source of indoor air pollution which will be reduced due to increased availability of electricity. In urban areas, generators using petrol, diesel or natural gas are used for producing electricity during load shedding hours. These sources produce fumes including greenhouse gases (GHGs) which are harmful to human health. The solar thermal electricity is a clean source of energy, hence does not emit any pollution. The technology helps in achieving energy security and accelerates socio-economic development of the country.

Environmental benefits: The technology will result into significant reduction of GHG emission depending on the size of the system. The technology does not produce any noise while one of the

alternatives of technology i.e. engines using petrol, diesel or natural gas produce lot of noise. The technology has some negative impacts on eyes and skin of the workers. Further birds and insects are also affected by the technology. There are some mitigation measures of these effects, which can reduce the effects.

Application potential:

Institutional capacity: The private sector companies have limited capacity to install and maintain solar thermal electricity units.

Need for capacity building: There is a need for capacity building of Pakistan Council of Renewable Energy Technologies, Alternate Energy Development Board as well as the private sector to produce solar thermal electricity units.

Scale of Application and time horizon: The technology can be applied widely for use in power sector. The technology has long payback period (about 12-15 years, depending on size and type of the system), however it will decrease as the technology will go to scale. Pakistan Vision 2025 stresses promotion of renewable energy technologies to tackle energy crises.

Local acceptability: As this is a clean source of energy and will optimize energy generation mix hence there is a local acceptability of this source of energy.

Annex-IV

Micro and small Hydro

Technology Characteristics:

In hydropower, moving water turns a turbine, the turbine spins a generator, and electricity is produced. It provides an economical source of energy without the use of fossil fuel. Micro, mini and small hydropower technology is the development of hydroelectric power on a scale that serves a small community or an industrial plant. Water from the river is channeled through a settling basin, which helps to remove sediment that could harm the turbine. The water then flows into the Fore bay Tank where it is directed downhill through a pipe called a penstock. When the water reaches the bottom, it drives a specially designed turbine to produce the electricity. The vertical drop (head) creates pressure at the bottom end of the pipeline. The pressurized water emerging from the end of the pipe creates the force that drives the turbine. The amount of power that can be produced by a mini- hydropower plant is determined by the head (the height of power drop) and the flow rate. The higher the head, the smaller the flow rate needed to produce the same amount of electricity. Electrical power output will always be slightly less than water power input due to turbine and system inefficiencies including pipeline diameter. Before designing hydro system or estimating how much electricity it will produce, it is needed to make four essential measurements: (i) Head (the vertical distance between the intake and turbine); (ii) Flow (how much water comes down the stream); (iii) Pipeline (penstock) length and (iv)Electrical transmission line length (from turbine to home or battery bank). The site´s head and flow will determine everything about hydro system—pipeline size, turbine type, rotational speed, and generator size.

Micro, mini and small hydro power plants are best suited for isolated locations where there is no electricity grid. Off-grid power plants need local load controlling to stabilize frequency and voltage supply. For industrial use, the output from the turbine shaft can be used directly as mechanical power, as opposed to converting it into electricity via a generator or batteries. This is suitable for agro-processing activities such as milling, oil extraction and carpentry.

Cost: Cost varies from approximately Rs.40,000 – Rs.300,000 per installed kW, when using appropriate technologies, which are much cheaper than using conventional approaches and technologies. The tariff of electricity production from small hydro ranges from Rs.7.6 to Rs.10.9 per unit (KWH)

Safety, reliability & maturity: The technology is simple, safe, and reliable. It has been practiced in Pakistan in an unorganized and discontinuous basis. No formal training facilities exist and there are no certification standards.

Potential Development Benefits:

Economic benefits: Pakistani villages not connected to the grid and having a source of water flow with a head more than 5 feet can benefit from low cost rural electrification based on micro, mini or small hydropower plants. Provision of electricity will help in investing additional hours for income generation activities.

Social Benefits: Micro-hydro schemes are owned and operated by the communities they serve, with any maintenance carried out by skilled members of that community. So they provide employment in themselves and improve quality of life, as well as providing the power to re-energize entire communities. There is learning opportunities for students in the evenings and family members have additional time for social activities. Traditionally families in rural areas use paraffin candles and lamps as source of light. In urban areas, engines using petrol, diesel or natural gas are used for producing electricity during load shedding hours. These sources produce fumes which are harmful to human health. The technology does not emit any pollution as opposed to use of paraffin lamps. The technology helps in achieving energy security.

Environmental benefits: Unlike traditional power stations that use fossil fuels, micro-hydro generators have practically no effect on the environment, these don't depend on dams to store and direct water, they're also better for the environment than large-scale hydro-electric stations. The technology will result into significant reduction of greenhouse gas (GHG) emission depending on the size of the system. It does not produce any noise while one of the alternatives of technology i.e. engines using petrol, diesel or natural gas produce lot of noise.

Application potential:

Institutional capacity: The private sector companies have the capacity to install micro, mini or small hydro systems. Some of these also have the capacity to produce micro, mini or small hydropower units.

Need for capacity building: There is a need for capacity building of Pakistan Council of Renewable Energy Technologies, Alternate Energy Development Board as well as the private sector to produce micro, mini or small hydropower units.

Scale of Application and time horizon: Potential of the technology in Pakistan is about 50,000 MW, only 14 percent potential has been tapped. It can be applied widely for use in building sector and also at a limited scale in industrial sector. For areas not connected to the grid, the technology has short payback period (about 3-5 years, depending on size and type of the system). Charges of electricity from national grid are different for household, commercial and industry sector, so payback period is also different for these sectors. Pakistan Vision 2025 stresses promotion of renewable energy technologies to tackle energy crises.

Local acceptability: As there is no negative impact of the technology hence it has high level of local acceptability.

Annex V

Wind turbine and windmill

Technology Characteristics:

A wind turbine or windmill is a machine that converts the energy in wind into mechanical energy. A wind generator then converts the mechanical energy to electricity. Wind power is used to rotate blades mounted on a rotating axle, which turn a shaft inside the nacelle (the box at the top of the turbine). In the majority of wind turbines, the shaft goes into a gearbox, which increases the rotation speed enough for the generator, which then uses magnetic fields to convert the rotational energy into electricity. The electricity then goes into a transformer, which converts it into a higher voltage for distribution through the national electricity grid. Wind pump is used to uplift mostly groundwater. The power in the wind is proportional to the wind speed cubed. The wind speed increases the higher up you go, which is why wind turbines are so tall. The power output of the turbine is also related to the swept area of the turbine blades. The greater the area, the larger the amount of power the turbine can convert from the wind. Wind turbines and windmills are generally mounted on towers, mostly more than 40' high. Sometimes wind turbines are attached to a high-rise building instead of mounting on a tower.

Cost: The cost of wind turbine and windmills varies depending on its size and type. The tariff of electricity production from wind generators in Pakistan is Rs.10.6 per unit (KWH). Wind mills used for lifting water from wells and canals are relatively cheaper and costs between Rs.50,000 to Rs.250,000 depending on material used and size of windmill and water head.

Safety, reliability & maturity: The technology is comparatively not so simple, but it is safe, and reliable. It has been practiced in Pakistan in an unorganized and discontinuous basis. No formal training facilities exist for installation, operation and maintenance of wind turbines and wind pumps. There are no certification standards. With the wind turbines specially designed for use in low resource areas, there are good prospects of generating electricity along the 1250 km long coastline of Pakistan where wind blows at a speed of more than 6 knots throughout the year. In addition there are possibilities of locating wind turbines in offshore and mountainous areas. Coastal areas between Garro and Ketibunder in Sindh have more wind speed than other coastal areas of Pakistan and are especially suitable for wind turbine or wind pumps. It is estimated that Pakistan has a capacity of producing about 50,000 MWs of electricity.

Potential Development Benefits:

Economic benefits: Wind energy installations offer economic development opportunities, especially for villages along coastal areas with un-used barren lands. Landowners get better price of their land. Local economic benefits include creation of employment opportunities. Expenditures by the contractors also boost local economy. This renewable source of energy is lesser costly than solar photovoltaic and is therefore more affordable than solar energy. The technology will result in infrastructure development in the area. There is an opportunity to provide electricity in the neighboring communities located in the remote areas where the wind park is located. Development of economic activities in these areas will open the doors of other economical activities and bring prosperity to the local communities. As windmills help in irrigating agricultural lands by water lifting, this results in increased agricultural production.

Social Benefits: With increased economic benefits, social benefits like food and energy security, more employment opportunities, poverty alleviation, increase in educational and recreational activities as well as health improvement are achieved due to provision of electricity. The area will open up for provision of basic infrastructure services and utilities such as clean drinking water, better sanitation conditions, schools, clinics and veterinary health facilities.

Environmental benefits: The technology will lead to significant decrease in greenhouse gas (GHG) emission in the industries and power sectors. The percentage GHG emission reduction depends on electricity production. There are some negative effects of the technology related to disturbance to birds; and low flying aircrafts. By taking proper mitigation measures this situation can be improved.

Application potential:

Institutional capacity: The private sector companies have limited capacity to install wind turbines and wind mills.

Need for capacity building: There is a need for capacity building of Alternate Energy Development Board, Pakistan Council of Renewable Energy Technologies as well as the private sector to install and maintain the technology. Heavy Mechanical Complex, Taxilla and fan manufacturing industries may be provided with the advanced technology to manufacture wind turbines and windmills.

Scale of Application and time horizon: The technology can be applied widely for provision of electricity to the national grid as well as for off-grid applications. The technology has medium payback period (about 5-8 years, depending on size and type of the installation). Pakistan Vision 2025 focuses of increasing the share of renewable energy in the energy mix.

Local acceptability: There are some negative impacts of the technology which can be overcome by taking proper mitigation measures. The technology has high level of local acceptability.

Annex VI

Pulverized coal fired power generation under Super and ultra-supercritical steam conditions

Technology Characteristics

Steam conditions	Pressure (kg/cm2)	Temp.(°C)
Subcritical	157-169	538
Supercritical	246-250	556-566
Ultra-supercritical	270-325	580-620

The pulverized coal-fired power generation system (Fig. 1) is widely used as an established, highly reliable technology. Using the technology under supercritical and Ultra-supercritical steam conditions is a high efficiency, low emission (HELE) technology for coal. The technology coupled with reduction of power consumption within the power plant allow power generators to operate at higher temperatures and greater pressure while at the same time reducing by up to 40% emissions generated per watt of electricity. The Supercritical clean coal technology operates above the temperature and pressure at which the liquid and gas phases of water coexist in equilibrium.

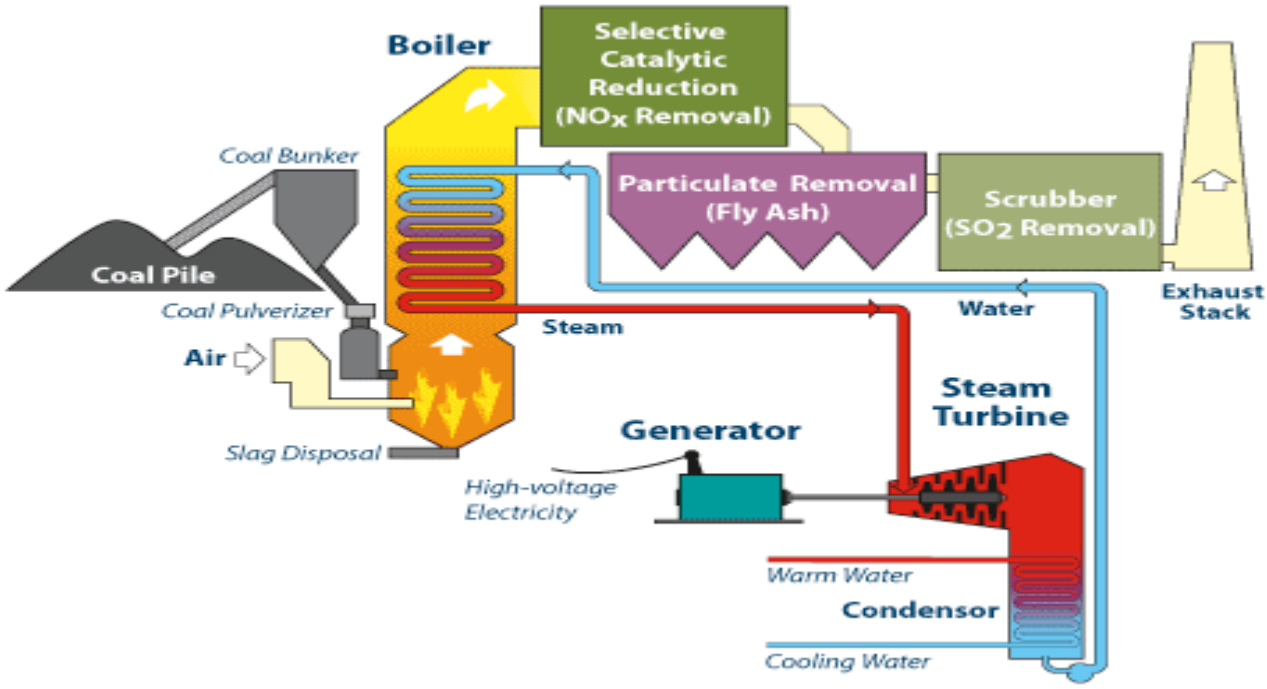


Fig. 1 Pulverized coal-fired power generation system (Rankine cycle)

The SC power plants require less coal per MW-hour, leading to lower emissions (including CO2 and mercury), higher efficiency & lower fuel costs per MW. Figure 2 shows an example of the relationship between the steam condition and the efficiency of a supercritical pressure plant. Responding to the trend of increasing steam temperatures, power companies, steel manufacturers, and boiler manufacturers are promoting the development and practical application of high strength materials with superior high-temperature corrosion resistance, steam-oxidation resistance, and workability.

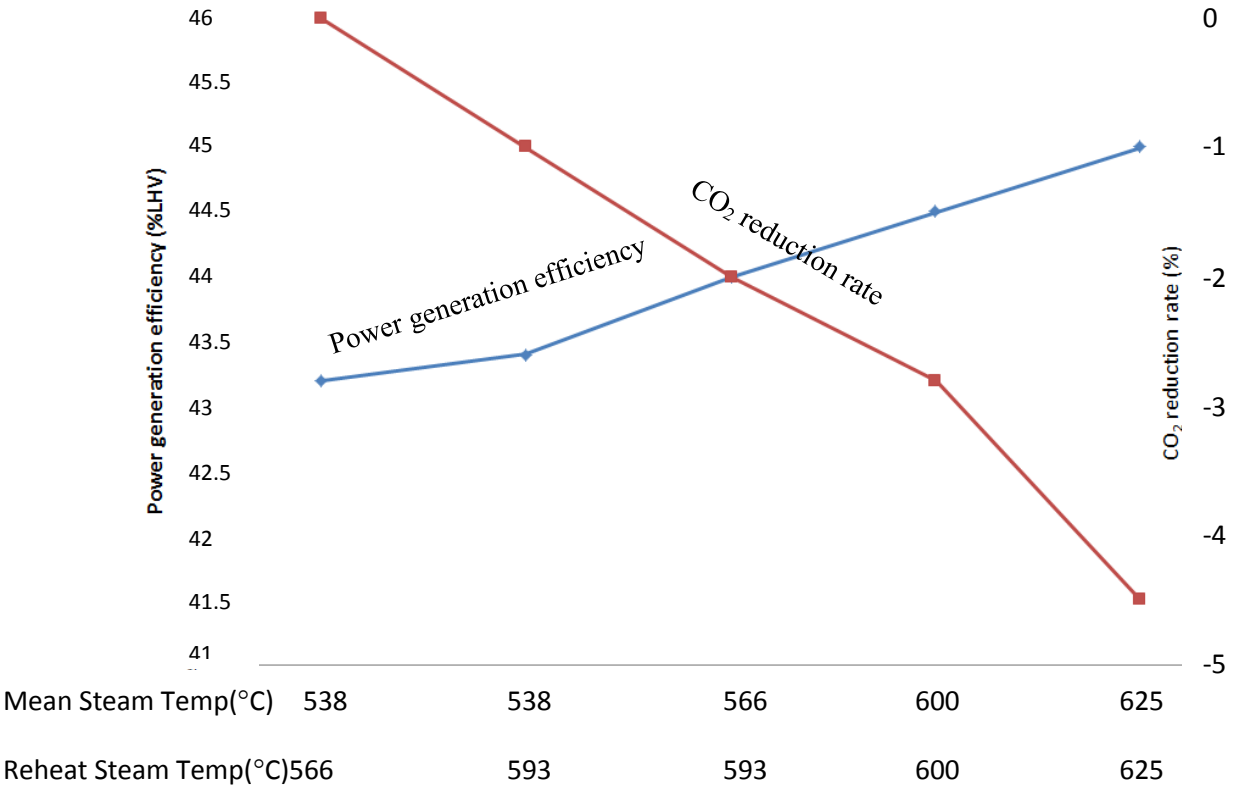


Fig. 2 Power generation efficiency and CO_2 reduction rate for various steam conditions

Annual mean value of	Emission requirements (mg/Nm^3)	Emission from clean Coal Tech.
Particulate Matter	30-50	40
NOx	200 – 800	400
SOx	200 - 510	<400

Treatment of flue gases includes its de-nitration, de-sulfurization and particulate or fly ash removal. For desulfurization, pulverized coal-fired thermal power plants can be equipped with wet limestone and gypsum-based desulfurization systems. Sea or saline water is mostly used for the process. For denitrification, The Selective Catalytic Reduction (SCR) process is used to decompose nitrogen oxides, mainly through the use of ammonia. Electrostatic precipitators remove particulate matter in exhaust gas in accordance with the theory that dust charged by a negative corona at a discharge electrode adheres to a positive dust-collecting electrode.

A by-product of the technology coal ash is recycled as a cement raw material, as civil engineering materials such as concrete admixture, especially with fly ash and landfill material and as a fertilizer raw material. Clinker ash is used for constructing sports grounds and planting beds due to its high permeability and water retention properties. Another by product is slurry.

Efficiency improvement of power generation

Increasing the thermal efficiency of power generation plants is an important issue not only to decrease the power generation costs from an economic standpoint, but also for suppressing CO_2 emissions. In particular, steam temperatures at coal-fired power plants, which are currently the most prevalent among large thermal power plants, have increased.

Cost: Cost of production from coal is Rs.8 per kWh. Tariff for electricity generation from coal is Rs.10.6 for first 10 years and Rs.6.98 for 11-30 years for coal plant of 300-350 MW capacity.

Safety, reliability & maturity: The technology is mature, safe, reliable and easy to adopt.

Potential Development Benefits:

Economic: The technology will stimulate real growth and development of different sectors because of reliable and cheap sources of production of electric power. This will lead to increased business development opportunities. Hence, it will contribute to the overall sustainable economic growth and development.

Social: It will result in employment creation and result into reduction of unemployment – with an emphasis on the lower income communities, empowering and employing them. There may be some inconvenience during the construction period, which may trigger health risks. Awareness creation and skills development of people employed and residing on the site where the power station will be built, monitoring movement of local communities and people, in particular those who live on the site where power station is built, establishing community forums to ensure constant collaboration with local communities will result in minimizing negative social impacts.

Environmental: The technology lead to decrease in greenhouse gas (GHG) emission, about 40 percent as compared to conventional methods of production of electricity from coal.

Application potential:

Institutional capacity: Specialized private sector companies have the capacity to produce electric power from the technology.

Need for capacity building: There is a need for capacity building of private sector and training institutions for imparting training in clean coal technology and measures for installing supercritical clean coal power plants and apply other energy conservation and CO_2 emission reduction measures at affordable costs.

Scale of Application and time horizon: The technology needs to be applied to replace power generation from coal by using traditional methods. Pakistan Vision 2025 stresses promotion of energy efficiency measures.

Local acceptability: The total coal reserves in the country are lignitic and sub-bituminous, so most of the coal has to be imported. As there is lesser negative impact of the technology, hence it has a level of local acceptability.

Annex VII

Appropriate Application of Fertilizers & Soil Carbon Management

Background

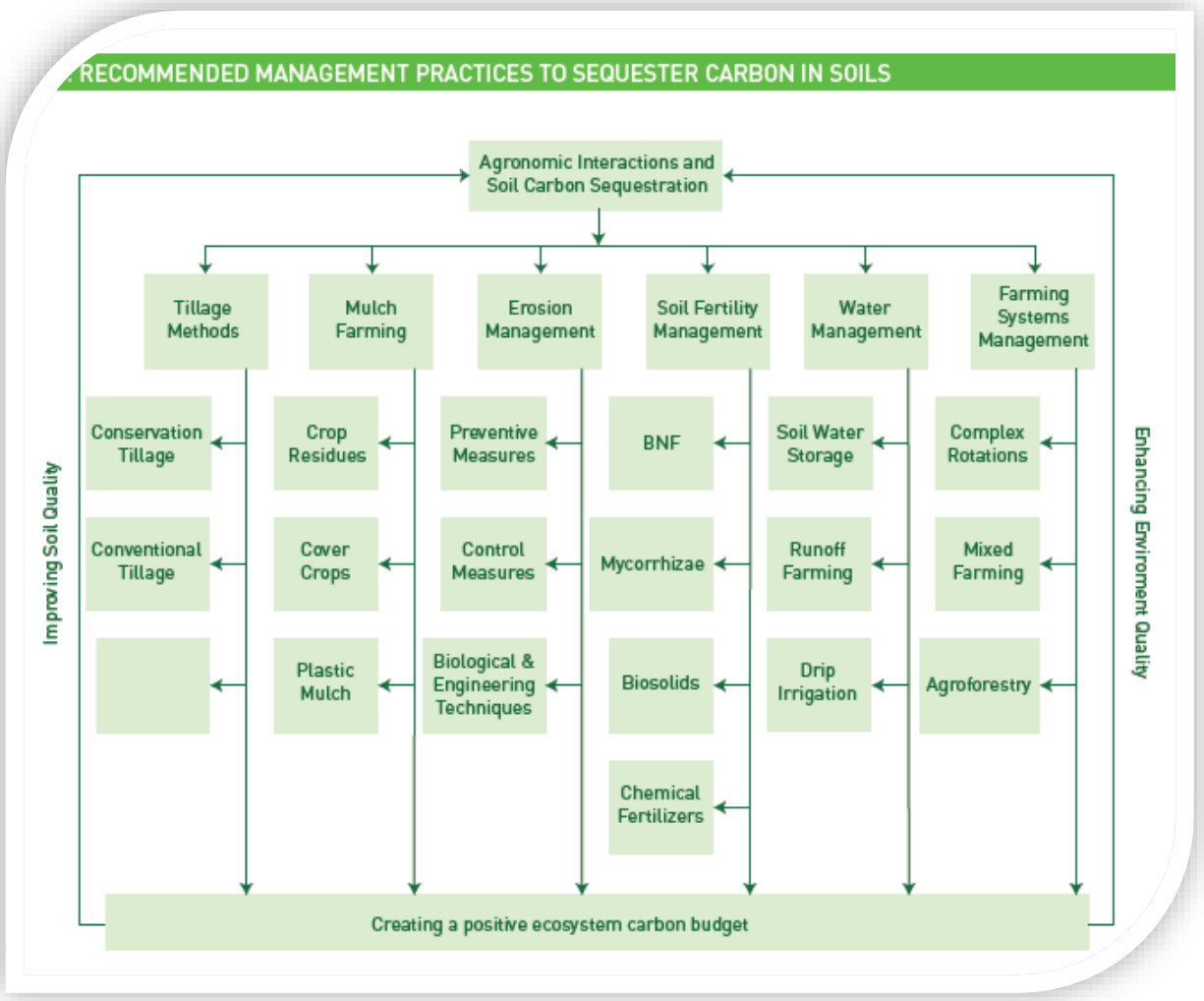
The emissions from agricultural soils are among the highest sources of GHGs in Agriculture sector. This fall in five global carbon pools: (i) oceanic pool; (ii) geological carbon pool, comprising fossil fuels; (iii) soil orpedological ; organic and inorganic; (iv) atmospheric; and (v) biotic pool. The soil organic carbon pool includes highly active humus and relatively inert charcoal carbon. It comprises a mixture of: (i) plant and animal residues at various stages of decomposition; (ii) substances synthesized microbiologically and/or chemically from the breakdown products; and (iii) the bodies of live micro-organisms and small animals and their decomposing products. The soil inorganic carbon pool includes elemental C and carbonate minerals such as calcite, and dolomite, and comprises primary and secondary carbonates. The primary carbonates are derived from the weathering of parent material. In contrast, the secondary carbonates are formed by dissolution of CO_2 in soil air into dilute carbonic acid and its interaction with calcium (Ca+2) and magnesium (Mg+2) brought in from outside the local eco system (e.g. calcareous dust, irrigation water, fertilizers, manures). The SIC is an important constituent of soils in arid and semi-arid regions.

There are three main types of C sequestration: (i) those based on the natural process of photosynthesis and conversion of atmospheric CO2 into biomass, soil organic matter or humus and other components of the terrestrial biosphere; (ii) those involving engineering techniques; and (iii) those involving chemical transformations.

Technology:

Transfer of atmospheric CO2 into the pedologic pools by use of judicious management of soils and vegetation, involves numerous agronomic interactions. Principal agronomic techniques include:

- reduction or elimination of mechanical tillage and adoption of no-till (NT) or minimum till;
- use of crop residues or synthetic materials as surface mulch in conjunction with incorporation of cover crops into the rotation cycle;
- adoption of conservation-effective measures to minimize soil and water losses by surface runoff and accelerated erosion bioengineering;
- enhancement of soil fertility through integrated nutrient management (INM) that combines practices for improving organic matter management (in situ), enhancing soil biological processes involving biological nitrogen fixation (BNF), and mycorrhizae, and additions of organic wastes (bio-solids, slurry) and synthetic fertilizers;
- conservation of water in the root zone to increase the green water component by reducing losses through runoff (blue water) and evaporation (grey water), and increasing use efficiency through application of drip irrigation/fertigation techniques;
- improvement of grazing systems that enhance the diet of livestock and reduce their enteric emissions; and
- better use of complex farming systems including mixed crop-livestock and agroforestry techniques that efficiently use resources, enhance biodiversity and mimic the natural ecosystems.



The objective of these agronomic interactions (Figure 3) is to create a positive C budget, and improve the quality and productivity of natural resources. The overall goal of sustainable management of soil, water and biological resources is to strengthen and accelerate the coupled cycles of H2O, C, N, P, and S. Strengthening of these interlinked cycles enhances the resulting ecosystem services by increasing the soil C pool, improving soil biological activity, increasing net primary productivity (NPP), decreasing losses from erosion and leaching, and increasing the humification efficiency.

Proper types and doses of fertilizers at appropriate intervals according to the soil and crop requirements help in soil carbon management and reduction of GHG emissions from soil. Use of soil micro-organisms like Rhizobium and Azotobacter helps in improving nutrient uptake. Certain plant hormones and hormones precursors like L-tryptophane also helps adjusting plant maturity and in better uptake of nutrients.

Cost: Reducing tillage for crop cultivation reduces its cost from Rs.6000 to about Rs.2000 per acre. Use of crop residues as surface mulch involves only labor cost which is about Rs.1000 per acre. Cost of biological fertilizers is Rs.3000-Rs.5000 per acre. Cost of drip irrigation is Rs.50,000 to Rs.100,000 per

acre. Controlled grazing system can be managed with about Rs.1000 per acre. Cost of hormone precursors is about Rs.3000 per acre.

Safety, reliability & maturity: The technology is safe, reliable and mature.

Potential Development Benefits:

Economic: The technology results into improved production and productivity from Agriculture. Improved production efficiency will reduce the costs of crop production. Pakistan is an agrarian country and the technology would have positive effects on the economy of the country. It will contribute to the overall sustainable economic growth and development.

Social: Increased income from crops will create more employment opportunities with an emphasis on the lower income communities in rural areas, empowering and employing them.

Environmental: The technology will lead to significant decrease in greenhouse gas (GHG) emission. The technology will also assist in reducing water and land erosion.

Application potential:

Institutional capacity: The Government research institutes and educated farmers have the capacity to implement the technology.

Need for capacity building: There is a need for capacity building of Government research institutes, and farmers for the implementation and monitoring of the technology.

Scale of Application and time horizon: The technology can be applied widely in villages in medium to long span of time.

Local acceptability: As there is no negative impact of the technology hence it has high level of local acceptability.

Annex VIII

Reducing Methane Emission from Rice cultivation

Introduction:

A major source of methane emissions is the decomposition of fertilizer and crop residues in flooded rice cultivation. The most effective option to reduce these emissions are to prevent submergence of rice fields and to cultivate upland rice which neither require flooded nor water saturated conditions at any significant period of time.

Technology Characteristics:

Rice is commonly grown by transplanting 30-35 days-old nursery seedlings in well-flooded and puddled fields. In this cultivation system, rice seedlings are raised in a nursery on separate, well-prepared soil and then manually uprooted and shifted to main field. Puddling destroys soil structure and even after paddy harvest, plantation of next crop (wheat) is delayed. Poor soil condition developed after continuous standing water is not favorable for better land preparation and good stand establishment. In addition, manual and random transplantation of seedlings ensures optimum plant population and are labor and water-intensive operations, increasing cost of production and resulting in low yield.

Alternatively, the technology of aerobic rice is a new water-saving cultivation system in which varieties adaptive to aerobic soil conditions are grown like wheat and maize crops. The crop does not need standing water. Usually rice seeds are drilled or broadcast in fine seedbed at field capacity level and subsequent irrigations are applied depending on crop requirement. To avoid weed competition and for vigorous seedling crop stand, seeds soaked in water or primed with $CaCl_2$ may be used. The first irrigation may be delayed until the crop is fully established.

Growing aerobic rice neither needs seed nursery nor transplantation of seedlings. It also does not require puddling operation which reduces cost of production. Alternate wetting and drying (AWD) technique in transplanted rice is more appropriate for basmati rice varieties in the traditional rice belt. AWD is also a water-saving system in which 2-3 weeks old nursery seedlings are transplanted and the field is kept flooded for 35 days and afterwards subsequent irrigation is applied. The field is again kept flooded around flowering. Under the changing climatic and water scenario, farmers can also practice alternate wetting and drying irrigation scheduling in aerobic rice and reduce weed infestation.

Further through a more integrated approach to rice paddy irrigation and fertilizer application substantial reduction in methane emission can be achieved. Many rice varieties can be grown under much drier conditions than those traditionally employed, with big reductions on methane emission without any loss in yield. Additionally, there is great potential for improved varieties of rice, able to produce a much larger crop per acre of rice paddy and so allow for a cut in the area of rice paddies, without a cut in rice production. Furthermore, the addition of compounds such as Ammonium sulphate, which favor activity of other microbial groups over that of the methanogens, has proved successful under some conditions.

Cost of technology is less than cultivating rice in flooded conditions.

Safety, reliability & maturity:

The technology is comparatively simple, safe, reliable and easy to adopt.

Potential Development Benefits:

Economic benefits:

In basmati rice type, the alternate wetting and drying method saved about seven irrigations over the continuous flooded rice and monitory benefit of nearly Rs9,000/ha. The technology conserves about 30 percent irrigation water in rice growing areas and enhances paddy yield to about 1.5 times from existing 26 mounds per acre. The technology helps in planting recommended 80,000 – 100,000 plants per acre. The technology saves labor and water requirements of the crop by 30-40 percent. It saves soil structure, time and improve timely plantation of the following crop, which is mostly wheat, as well as leads to

increased water productivity and nutrient availability. Due to high nitrogen use efficiency up to 50-60 per cent, the next crop is also benefited by residual nitrogen.

Social Benefits:

The technology increases income of the farmers, and saves their time, which they can spend on social activities.

Environmental benefits:

The technology leads to significant decrease in greenhouse gas (GHG) emission due to aerobic cultivation of rice.

Barriers:

The most critical barriers for implementing this technology are technical know-how and availability of required quantity of seed.

Application potential:

Institutional capacity:

The public and private sector have the capacity of introducing the technology.

Need for capacity building:

There is a need of capacity building of farmers, particularly in remote area, in introduction of the technology.

Scale of Application and time horizon:

Research trials at the Nonetheless, aerobic rice can be successfully grown in non-traditional rice belt dominantly with non-basmati varieties on more than 0.9 million hectares. The AWD technology can be applied in more than 1.1 million hectares of land. So the technology has a very wide scale and can be applied in limited time.

The two technologies have been verified over the last 3-4 years and are now being practiced in rice growing areas of Punjab and Sindh. Aerobic or AWD technology is being applied in Guranwala, Okara, Kasur and Jhang districts in Punjab and Thatta, and Larkana in Sindh. The total area under such cultivation is estimated at 200,000 hectares.

Local acceptability:

As there is no negative impact of the technology, hence it has high level of local acceptability.

Annex IX

Diet options for reducing Enteric Fermentation in ruminant animals

Background

Ruminant animals (Cattle, sheep, goat, buffaloes and camel) have a "rumen" – a large fore-stomach with a complex microbial environment, where anaerobic microbes, called methanogens, decompose and ferment food present in the digestive tract producing compounds that are then absorbed by the host animal. Because the digestion process is not 100 percent efficient, some of the food energy is lost in the form of methane. The produced methane is a potent greenhouse gas that contributes to global climate change. Methane is released into the atmosphere from animal effluences. Non-ruminant domesticated animals (e.g., swine, horses, mules) also produce CH_4 emissions through enteric fermentation, although this microbial fermentation occurs in the large intestine, where the capacity to produce CH_4 is lower.

Animal Type	Emission Factors
Sheep	11.0
Goats	11.0
Swine	2.2
Horses	39.6
Mules/Asses	22.0
Buffalo	116.8

Larger ruminants like cattle produce greater amounts of methane than smaller ruminants because of their greater feed intake. The physical and chemical characteristics of the feed, the feeding amount and schedule, the use of feed additives to promote production efficiency, and the activity and health of the animal. Very low quality feeds, such as untreated rice straw or poor rangelands in arid areas, tend to lead to higher emissions per unit of feed intake in ruminant animals. Low levels of feed digestibility (e.g., below 55 percent) or low levels of metabolizable energy content in the feed are often indicators of higher methane emissions per unit of product. Feed intake is positively related to animal size, growth rate, and production (e.g., milk production, wool growth, pregnancy, or work). Therefore, feed intake varies among animal types, as well as among different management practices for individual animal types. It has also been suggested that there may be genetic factors that affect CH4 production. Of these factors, the feed characteristics and feed rate have the most influence.

Technology:

The processes to reduce the CH_4 and N_2O emissions from livestock fall into three general categories:

1) Improved feeding practices and improving pasture quality:

Exploring appropriate feeding strategies that increase productivity while at the same time reduce methane emissions from enteric fermentations. Efforts will be centered around strategies that have shown promise elsewhere including feeding livestock on improve forages; feed supplements. This will involve screening tanniferous herbaceous forages and agroforestry tree species for methane reducing potentials; supplementation using agro-industrial by-products including oilcakes; and integrating these options strategically in ruminant feeding systems or incorporating grain with pastures.

Diet manipulation can abate methane by decreasing the fermentation of organic matter in the rumen, allowing for greater digestion in the intestines—where less enteric fermentation takes place. This inhibits methanogens and limits the amount of hydrogen (H) available for methane (CH_4) production. Alternatively, changing the type of fermentation taking place – by switching ruminants from a cellulosic to a starch-based diet, for example – can increase the amount of fermentation while still decreasing levels of methane production.

Increasing animal intake of dietary oils helps to curb enteric fermentation and increase yields by limiting energy loss due to fermentation. These oils appear to be a viable option because they can be easily substituted into animal diets. It was estimated that with a 1 percent increase in dietary oils decreasing methane emissions by 6 percent. Therefore, whole cottonseed was introduced into the diet of dairy cattle and observed to reduce methane emissions by around 12 percent and increase milk yield by about 15 percent. The introduction of sunflower oil abated methane emissions by 22 percent. Some breeds of cattle emit about 25 percent less methane and require less feed. Exploring manure and pasture management on both small and larger farms reduces CH_4 emissions.

2) The use of specific agents or dietary additives:

Exploring with various feed additives, including plant extracts (condensed tannins, saponins, essential oils) and rumen modifiers (yeast, bacterial direct fed microbials, and enzymes).

3) Longer management changes and animal breeding:

Explore ways to improve feed efficiency through breeding manipulation. Improving feed conversion efficiency (the amount of feed consumed per unit of production) through better breeds, helps to decrease the amount of methane produced since more efficient animals have been shown to produce less methane. This can reduce further CH_4 emissions by giving animals diets that are more highly digestible.

Emissions from enteric fermentation are diffuse and this makes them difficult to measure. Emissions can be measured in vitro, by trying to simulate the rumen in a lab, or in vivo, by measuring emissions directly from an animal. Preference is given to in vivo methods when possible. Current in vivo methods include placing livestock in emissions measurement chambers or using portable sulfur hexafluoride (SF_6) tracers to measure methane emissions from the rumen in the field. Both techniques have disadvantages; the SF6 tracer does not measure emissions from the anterior of the animal and the chamber can be costly and place animals under stress, which could increase emissions. Neither method provides instantaneous data on emissions from the animal.

Studies examining abatement through enteric fermentation mitigation must assume baseline diets and management practices from which reductions are taking place. In reality, farms have many different diets they feed animals that vary with season, price, and availability. Thus, it becomes difficult for farmers to accurately estimate emissions reductions from new management practices because their baselines may be dramatically different than those assumed in studies.

Cost: Diet manipulation options increase 10-15 percent costs of improved feedstock that are subject to feed market volatility. Furthermore, the availability of certain feed or oil types will vary by region and season in some cases, so it would be difficult to assign costs on a national level for diet manipulation. Rather, farmers and ranchers will likely choose to source the lowest-cost dietary supplements available to them at any given time.

Animal	Av. Feed cost per day per animal (Rs.)	Av. cost of improved feedstock per day per animal (Rs.)
Buffaloes	600	800
Cow	400	500
Sheep/goat	100	140

Safety, reliability & maturity: A mitigative diet that is affordable one year may not be the following year, and this will make long term mitigation dynamic in nature as farmers will have to periodically adjust the composition of the diets they are giving animals because of the costs and availability of certain feeds.

Potential Development Benefits:

Economic: Because CH4 emissions represent an economic loss to the farmer—where feed is converted to CH4 rather than to product output—viable mitigation options can entail feed efficiency improvements per unit of beef or milk. Methane emissions reduction from enteric fermentation implies that more energy is available to the animal per unit of feed consumed, improved production and productivity of livestock. Improved production efficiency will reduce the costs of livestock production both in terms of purchasing food additives and reduced losses due to a healthier livestock population. Increases in yield may also be observed when utilizing supplements to mitigate enteric fermentation, and these would act to ameliorate any costs associated with their purchase.

Social: Improved livelihoods, better incomes, and more employment opportunities, and lesser work load for female because livestock handling is mostly done by female in the rural areas.

Environmental: The technology will lead to significant decrease in greenhouse gas (GHG) emission. Reduced emissions from enteric fermentation can improve animal health and thereby reduce livestock loss and increase livestock production. Improved production efficiency in cattle will reduce natural resources requirements for livestock production hence reducing overall environmental impacts. Pasture management practices that increase soil carbon stocks can significantly mitigate CO_2 emissions. Improved production efficiency in cattle will reduce natural resources requirements for livestock production hence reducing overall environmental impacts.

Application potential:

Institutional capacity: The Government research institutes, private sector companies and educated farmers have limited capacity to implement the technology. However, most of the farmers have no knowledge of the technology.

Need for capacity building: There is a need for capacity building of Government research institutes, private sector companies and educated farmers for the implementation and monitoring of the technology.

Scale of Application and time horizon: The technology can be applied widely in villages in medium to long span of time.

Local acceptability: As there is no negative impact of the technology hence it has high level of local acceptability.

Annex-X

Biogas – Compressed bio methane

Technology Characteristics:

Biogas, is a clean-burning methane-rich fuel gas produced through anaerobic digestion of suitable biomass which can be generated from cattle dung, animal wastes etc. In addition to methane, it contains Carbon dioxide (CO_2), Nitrogen (N_2), Hydrogen (H_2), Hydrogen sulfide (H_2S), Oxygen (O_2) and water vapors. Composition depends upon the material fed and process nature. Biogas is produced by mixing dung (Animal waste) and water in the absence of oxygen through fermentation process. During this process pathogen levels are reduced and plant nutrients made more readily available, so better crops can be grown from its slurry. Construction process of Fixed dome type household level biogas digester (Size 6 m^3) consist of: (i) marking a site for construction of inlet tank (2'X2'), digester (circular, 5' dia& 10' depth) and outlet chamber (1'X1'X10' + 1'X1'X2') with overflow hole connected to outlet drain; (ii) excavation of pit for inlet tank, digester and outlet chamber; (iii) Construction of inlet tank, digester and outlet chamber with mortar and bricks with plastering, polishing, and correction of leaking points, inlet tank is connected with digester through 10 cm dia HDPE pipe, digester have 0.5" dia GI dome gas pipe, outlet chamber is covered with RCC slab; (iv) Concreting the cover and (v) Connecting stove with GI dome gas pipe through plastic gas pipe. A diary with 1000 cows would yield a flow rate of approximately 2000 ft^3 raw biogas/hour which are enough to meet cooking and heating requirements of about 500 rural households.

Bio methane is an upgraded form of biogas which has higher heat contents and is produced by removing the H_2S, moisture, and CO_2 for use as a fuel for farm machinery, electricity production and vehicles. It increases concentration of methane from about 68 percent to about 90 percent. Bio methane is stored in cylinders by using compressors, usually as compressed bio methane (CBM) at medium pressure 200 – 250 psi. The CBM can be used to meet energy demand at distant places. For 5 kWh electricity production 1000 ft^3 of bio methane is required. The biogas scrubbing system consists of Steel wool; pure water and adsorbent material (silica gel) units for trapping H_2S, CO_2, and moisture, respectively. The three units are interconnected with plastic hoses.

Cost: The cost of Fixed dome type household level biogas digester is Rs.35,000 - 45,000.

Safety, reliability & maturity: Technology is comparatively simple, safe, and reliable. It has been practiced in Pakistan in an unorganized and discontinuous basis. No formal training facilities exist and there are no certification standards.

Potential Development Benefits:

Economic benefits: Biogas systems offer multiple benefits. Biogas reduces the expenses on fuel for cooking over the long run. Bio-slurry obtained from the plant has proved to be excellent organic manure. This manure is more effective and is of higher quality than traditional manure such as farm-yard manure. Use of bio-slurry as manure reduces the high cost of chemical fertilizers, helps in increasing farm production and the farmer's income. It also reduces the adverse effects arising from their use. Biogas can also provide lighting when used in mantle lamps, providing more time for students to study. Economic benefits can be calculated from saving in use of fuel-wood and kerosene, labor in collecting fuel-wood; and health benefits. It is also used to run farm machinery, pump water, produce electricity production and vehicles

Social Benefits: Biogas provides direct benefits at the household level, especially to rural women. This comes about as a result of the reduction of the firewood collection and dung cake preparation workload when cooking with conventional biomass is substituted with biogas. Users find it much easier to cook on biogas and cooking times are much faster than cooking using solid biomass fuels. Moreover, biogas is smokeless and does not require constant attention while cooking, allowing women to tend to others activities simultaneously. There is less blackening of cooking utensils and kitchen walls Experience from the region shows that on average biogas save approximately 2 hours per day per family mainly due to the reduction in time used for collecting biomass and/or making dung cakes, cooking and cleaning of utensils. This saved time can be used more productively by women for childcare, income generating activities, education, recreation and other social activities. There is reduction in female's health hazards due to

smoke and poisonous gases. In addition, it improves their quality of life. A major problem for the rural people especially to the housewives and small children is indoor air pollution due to exposure to smoke inside the kitchen while cooking with solid biomass fuels. Poor indoor air quality is one of the major risks factors for acute respiratory infections, the leading killer of children under five in developing countries. Use of biogas reduces smoke and significantly improves air quality inside the kitchen reducing the incidences of respiratory diseases, coughing, dizziness and headaches, and eye infections. Biogas is no more just the renewable energy source of rural population but it is also an appropriate source of energy for urban population, having potential to replace fossil fuel. As Pakistan has about 76.8 cattle/buffaloes, 97.8 sheep/goat, 932 poultry birds and organic material from agriculture, kitchen and municipal waste, the biogas produced is not only enough to meet cooking and heating requirements of the whole population but also for generation of electricity.

Environmental benefits: The use of biogas significantly improves the indoor air quality in user' homes. Biogas plants also reduce demand on firewood and hence lower pressure on forests and other biodiversity. One biogas plant of 6 m^3 capacity enables the saving of about 2.0 tons of biomass per year. This mitigates considerable amount of greenhouse gas emissions by reducing the amount of unsustainable biomass that is burned as well as by protecting the carbon sink. The surroundings become clean, healthy and odor-free when a biogas plant is constructed making them more acceptable to the neighbors. Biogas plants can contribute to improved sanitation through utilization of dung, poultry waste and organic waste material in the biogas plants.

Application potential:

Institutional capacity: Public and private sector companies have limited capacity to install low cost biogas plants.

Need for capacity building: There is a need for capacity building of public as well as the private sector to implement the low cost and efficient technology for constructing biogas plants.

Scale of Application and time horizon: The technology can be applied widely for power generation at household and community levels. Savings of fuel expenses as a result of installing biogas plants recovers the total plant investment cost within 4-5 years.

Local acceptability: As there is no negative impact of the technology hence it has high level of local acceptability.

Annex-XI

Social forestry and Agro-forestry

Introduction:

Agro-forestry, is "a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic, and environmental benefits for land users at all levels". Social forestry means the management and protection of forests and afforestation on barren lands with the purpose of helping in the environmental, social and rural development.

Technology Characteristics:

Agro-forestry increases tree cover and sequesters carbon by taking CO_2 out of the atmosphere through photosynthesis and stores it as organic carbon in above-ground biomass (trees and other plants) and in the soil through root growth and the incorporation of organic matter. Thus, the process of release of more CO_2 to the atmosphere can be reversed, at least partially, through growing more trees and protecting of already existing forest cover which serves as a sink for CO_2. Shading crops and the rhizosphere by the trees would significantly reduce evapo-transpiration (ET) of the cropped area. The soil organic carbon content increases in the top 10 cm depth of an improved forestry plantation. The activity addresses both issues of emission reduction and enhanced removal of greenhouse gases.

Cost is variable, depending on the number and type of trees planted along with crops. Agro-forestry, Re-forestation and reducing forest degradation is considered to be one of the most cost-efficient climate change mitigation strategies. . Per acre cost of the technology is about Rs.100. per forest tree.

Safety, reliability & maturity: The technology is simple, safe, reliable and easy to adopt by preserving and growing indigenous plants and avoiding plantation of invasive and alien species.

Potential Development Benefits:

Economic benefits: Trees preserve the dams, roads, and other infrastructure facilities, reduce soil erosion, conserve rainwater, reduce water runoff and sediment deposit after storms and thus increase the economic revenue. Flash flooding is dramatically reduced by a forest or by planting trees. Underground water-holding aquifers are recharged with this slowing down of water runoff. During windy and cold seasons, trees located on the windward side act as windbreaks. A windbreak can lower home heating bills up to 30% and have a significant effect on reducing snow drifts. A reduction in wind reduces the drying effect on soil and vegetation behind the windbreak and helps keeping precious topsoil in place. Trees generate carbon credits through CDM and REDD+. Moreover Real estate values increase when trees beautify a property or neighborhood. Trees increase the property value of homes by 15% or more.

Social Benefits: Tree plantations generate income; provide a livelihood for forest dependent people. They act as live fence and fodder banks.

Environmental benefits: The technology leads to significant decrease in greenhouse gas (GHG) emission. Agro-forestry in semi-arid regions can sequester as much carbon as forests in temperate regions. Every tons of carbon added to and stored in plants or soils removes 3.6 tons of CO2 from the atmosphere. Nitrogen fixing trees improves the soil fertility. This can happen due to controlled grazing, fire management, use of fertilizers, improved cultivars, reduces the water leakage and soil erosion, re-vegetation of reclaimed lands, filters nutrient run-off, acts as buffer against floods and drought and improves water quality.

Application potential:

Institutional capacity: The public and private sector have the capacity to promote the technology.

Need for capacity building: There is a need of capacity building of public and private sector in Agro-forestry, Re-forestation and reducing forest degradation.

Scale of Application and time horizon: Deforestation and forest degradation, through agricultural expansion, conversion to pastureland, infrastructure development, destructive logging, fires etc., account for nearly 20% of global greenhouse gas emissions, more than the entire global transportation sector and second only to the energy sector.

The technology needs to be applied to replace traditional air-conditioners. Pakistan Vision 2025 stresses promotion of energy efficiency measures.

Local acceptability: As there is no negative impact of the technology, hence it has high level of local acceptability.

Annex-XII

Reducing emissions from deforestation, forest degradation & NTFPs

Introduction:

Deforestation is the permanent destruction of forests in order to make the land available for other uses. Forest degradation is broadly defined as a reduction in the capacity of a forest to produce ecosystem services such as carbon storage and wood products as a result of anthropogenic and environmental changes.

Technology Characteristics:

Reforestation and reducing forest degradation practices help in increasing forest cover and sequester carbon by taking CO_2 out of the atmosphere through photosynthesis and store it as organic carbon in above-ground biomass (trees and other plants) and in the soil through root growth and the incorporation of organic matter. Thus, the process of release of more CO_2 to the atmosphere can be reversed, at least partially, through growing more trees and protecting of already existing forest cover which serves as a sink for CO_2. Shading crops and the rhizosphere by the trees would significantly reduce evapo-transpiration (ET) of the cropped area. The soil organic carbon content increases in the top 10 cm depth of an improved forestry plantation. Additionally, degraded lands are used and reclaimed by the plantations of indigenous species and specific trees. Regeneration of forest on degraded or deforested lands are remove CO_2 from the atmosphere through the build-up of biomass, making forest lands a sink of greenhouse gases. The activity addresses both issues of emission reduction and enhanced removal of greenhouse gases. Emissions of greenhouse gases from forest land are reduced by slowing down the rates of deforestation and forest degradation. Removals of greenhouse gases (specifically CO_2) from the atmosphere can be achieved through various forest management options, such as afforestation on non-forested lands, replanting degraded or deforested areas or enrichment planting in riparian buffer/zones like river banks, streams and wetlands. NTFP's are plants that can be used as medicines, crafts, foods, syrups, etc. Sustainable harvesting of non-timber forest products like mazri (*Nannorhopsritchieana*) and production of seed and nurseries of such plants help in sustaining their growth.

Cost is variable, depending on the number and type of trees planted along with crops. Agro-forestry, Re-forestation and reducing forest degradation is considered to be one of the most cost-efficient climate change mitigation strategies. Per acre cost of the technology is about Rs.10, 000.

Safety, reliability & maturity: The technology is simple, safe, reliable and easy to adopt by preserving and growing indigenous plants and avoiding plantation of invasive and alien species.

Potential Development Benefits:

Economic benefits: Trees preserve the dams, roads, and other infrastructure facilities, reduce soil erosion, conserve rainwater, reduce water runoff and sediment deposit after storms and thus increase the economic revenue. Flash flooding is dramatically reduced by a forest or by planting trees. Underground water-holding aquifers are recharged with this slowing down of water runoff. During windy and cold seasons, trees located on the windward side act as windbreaks. A windbreak can lower home heating bills up to 30% and have a significant effect on reducing snow drifts. A reduction in wind reduces the drying effect on soil and vegetation behind the windbreak and helps keeping precious topsoil in place. Trees generate carbon credits through CDM and REDD+. Moreover Real estate values increase when trees beautify a property or neighborhood. Trees increase the property value of homes by 15% or more.

Social Benefits: Tree plantations generate income; provide a livelihood for forest dependent people. They act as live fence and fodder banks.

Environmental benefits: The technology leads to significant decrease in greenhouse gas (GHG) emission. Agro-forestry in semi-arid regions can sequester as much carbon as forests in temperate regions. Every tons of carbon added to and stored in plants or soils removes 3.6 tons of CO2 from the atmosphere. Nitrogen fixing trees improves the soil fertility. This can happen due to controlled grazing, fire management, use of fertilizers, improved cultivars, reduces the water leakage and soil erosion, re-vegetation of reclaimed lands, filters nutrient run-off, acts as buffer against floods and drought and improves water quality.

Application potential:

Institutional capacity: The public and private sector have the capacity to promote the technology.

Need for capacity building: There is a need of capacity building of public and private sector in Agro-forestry, Re-forestation and reducing forest degradation.

Scale of Application and time horizon: Deforestation and forest degradation, through agricultural expansion, conversion to pastureland, infrastructure development, destructive logging, fires etc., account for nearly 20% of global greenhouse gas emissions, more than the entire global transportation sector and second only to the energy sector.

The technology needs to be applied to replace traditional air-conditioners. Pakistan Vision 2025 stresses promotion of energy efficiency measures.

Local acceptability: As there is no negative impact of the technology, hence it has high level of local acceptability.

Annex-XIII

Technologies for Bus rapid transport system

Technology Characteristics: A bus rapid transit system (BRT) is a high-capacity low cost transport system with its own right of way. The key technology is energy efficient engine, minimum Euro-II/ Pak-II compliant diesel engines which emits less CO_2 and has good fuel burning efficiency. External and internal noise levels are Maximum 85 and 80 dBA, respectively. The BRT system has barrier-controlled, automated off-board fare collection, a service interval of less than 2 minutes during peak hours, stations with well-designed signage and information systems and a precision bus docking system.

The technology can change the trend of modal shifts towards public transportation, thereby bringing about a range of benefits, including reduced congestion, air pollution and greenhouse gases and better service to poor people. A BRT system has the capacity to take in one direction approximately 10,000 passengers per hour per direction in peak hours. This is a much higher value than for conventional buses and Mini buses – maximum 5000 passengers per hour in one direction. A BRT system can run at an average speed of 20 km/hour.

In Pakistan, the transport sector contributes 21 percent to the national carbon emissions, and is responsible for more than half of the oil consumed in Pakistan. As the population and economy have grown, the size and number of vehicles too have increased from 2.7 million in 1990 to 9.8 million by 2010. Metropolitan cities are growing so rapidly, that their transport systems are hardly able to keep up pace with emerging urbanization challenges. This has led to increased transport problems. The Bus Rapid Transit (BRT) systems launched in Lahore, Rawalpindi and Islamabad has enabled these cities to optimize their transport infrastructures for local public transport relatively in a shorter span of time.

Cost: Investment cost for BRT systems per km cost was 11 million per km in Lahore and 20 million per km in Rawalpindi-Islamabad. The BRT system in Rawalpindi is designed keeping in view that in future the structure of the flyover and other portions of the network can be converted to rail transport system which will further reduce GHG emissions and provide other benefits. The operational cost of Metro-bus Lahore was around Rs.60 per passenger in year 2014.

Safety, reliability and maturity: The Metro-bus system is safer and more reliable than the conventional urban transport system because of its built in design specifications and dedicated routes. The terminal approach system has escalators and underground, subway-styled approach tubes. Due to these approach tubes, prospective passengers don't have to cross high-speed roads to get to the stations, but go below them instead, an example of a segregated Right-of-way. The stations have parking spaces for motorbikes and cycles while the two terminals provide car-parking facilities as well. The time of travel is followed. The BRT system is about two years old in Lahore and in Rawalpindi-Islamabad it has been introduced recently.

Potential Development Benefits:

a) Social: The Metro-bus system has brought positive impact, particularly in respect of facilitating female, children and old-aged passengers' movement in safe and comfortable manner. This mode has facilitated reducing travel time to their places of work, home and entertainment which has brought positive psychological impact. Furthermore, it reduced the number of accidents. This has led to social equality and poverty reduction by providing affordable high-quality transport.

b) *Economic*: The Metro-bus system is promoting economic activities due to easy and timely mobility of people from one destination to another which promotes business deals as well as has facilitated timely attendance of employees to their work places. There is increase in energy supply security, due to reduction for imported oil and improvement in the balance of payments by reducing imports of fossil fuels.

c) Environmental

Increased usage of high-quality public transport has proved to be a good policy option for Pakistan as it has led to reduce GHG emission by 40,000 tons per year while this sector accounted for 21 percent of the

total GHG emissions of the country. The major environmental benefits include reduction in air pollution particularly very fine Particulate Matters, because pollution level of buses per passenger is less. This results in lesser incidences of lungs and respiratory diseases.

Application potential:

Institutional Capacity: The government has established Punjab Metro bus Authority for operation and maintenance of BRT system in Lahore, Rawalpindi and Islamabad. The authority has entered into a contract with a Turkish company to look after the affairs related to maintenance and operation of bus service. The other matters are being managed by the local authorities.

Need for Capacity Building: There is a need to build the capacity of public and private sector institutions to manage the Metro-bus system.

Scale of Application and time horizon: The BRT system is functional in 3 cities and has also been initiated in four other cities viz. Multan, Karachi, Peshawar and Faisalabad. It is assumed that by 2030, BRT systems will be one of the main sustainable urban transport systems in place in major cities of Pakistan.

Acceptability to locals: The BRT technology has high accepted by the urban society in Pakistan.

Annex-XIV

Rail transport system

Introduction

Railway transport occupies a significant role in the transport system of a country. The development of trade, industry and commerce largely depends on the development of railways. In addition, circular railway is the local commuter rail network that serves the metropolitan areas of big cities. Light rail can play a significant role in a city's transport – offering an effective option that builds on a country's current transport network. In-effective exploitation and utilization of railway system is costing the economy of the country. Simply adding more cars, vans and buses to existing routes only makes a city's roads more congested – particularly in the city center. Circular railway for a city results in speedy, comfortable and economical transport facilities to citizens and revolutionizes the transport system of the city.

Technology Characteristics: A rail transport is a high-capacity low cost transport system with its own right of way. The technology parameters include:

1. **Service integration and improvements**
   It includes introduction of the card, the integrated electronic ticketing system, on light rail to make travelling easier between modes; following of time schedule; cleanliness and hygiene, drinking water and sanitation facilities improvement. The involvement of private sector may also help in improving the services. The system has barrier-controlled, automated off-board fare collection, a service interval of lesser time during peak hours, stations with well-designed signage and information systems.

2. **Modernizing and extending the existing network**
   The existing network for passengers and freight needs to be extended. Other technology measures include energy efficient engine, as per latest Euro/ Pak compliant diesel engines which emits less CO_2 and has good fuel burning efficiency. External and internal noise levels are reduced.

3. **Dedicated lines for rail freight**
   Dedicated lines for rail freight and passenger trains will help in increasing the speed of the system.

The technology can change the trend of modal shifts towards public transportation, thereby bringing about a range of benefits, including reduced congestion, air pollution and greenhouse gases and better service to poor people. About 300 persons are accommodated on a light rail and about 1,200 persons on heavy rail.

In Pakistan, the transport sector contributes 21 percent to the national carbon emissions, and is responsible for more than half of the oil consumed in Pakistan. As the population and economy have grown, the size and number of vehicles too have increased from 2.7 million in 1990 to 9.8 million by 2010. Metropolitan cities are growing so rapidly, that their transport systems are hardly able to keep up pace with emerging urbanization challenges. This has led to increased transport problems. The Bus Rapid Transit (BRT) and circular rail system for cities is a solution of the problem. Intercity passenger numbers are also increasing and introduction of new initiatives like production of electricity from coal also requires more efficient rail system.

Cost: Investment cost for construction of a normal railway track is Rs.100 million per km.

Safety, reliability and maturity: The rail system is safer and more reliable than the conventional urban transport system because of its built in design specifications and dedicated routes. The terminal approach system has escalators and underground, subway-styled approach tubes. Due to these approach tubes, prospective passengers don't have to cross high-speed roads to get to the stations, but go below them instead, an example of a segregated Right-of-way. The stations have parking spaces for motorbikes and cycles while the two terminals provide car-parking facilities as well. The time of travel is followed.

Potential Development Benefits:

a) Social: The Rail system has brought positive impact, particularly in respect of facilitating female, children and old-aged passengers' movement in safe and comfortable manner. This mode has facilitated reducing travel time to their places of work, home and entertainment which has brought positive psychological impact. Furthermore, it reduced the number of accidents. This has led to social equality and poverty reduction by providing affordable high-quality transport.

b) *Economic*: The Rail system is promoting economic activities due to easy and timely mobility of people from one destination to another which promotes business deals as well as has facilitated timely attendance of employees to their work places. There is increase in energy supply security, due to reduction for imported oil and improvement in the balance of payments by reducing imports of fossil fuels.

c) Environmental

Increased usage of high-quality public transport has proved to be a good policy option for Pakistan as it has led to reduce GHG emission by 40,000 tons per year while this sector accounted for 21 percent of the total GHG emissions of the country. The major environmental benefits include reduction in air pollution particularly very fine Particulate Matters, because pollution level of buses per passenger is less. This results in lesser incidences of lungs and respiratory diseases.

Application potential:

Institutional Capacity: Pakistan Railway and Ministry of Railways has limited capacity to manage the improved system. However, efforts are under to up-grade the railway system to meet the future transport challenges.

Need for Capacity Building: There is a need to build the capacity of public and private sector institutions including Pakistan Railway and Ministry of Railways.

Scale of Application and time horizon: It is assumed that by 2030, rail systems will be one of the main sustainable urban transport systems in place in major cities of Pakistan.

Acceptability to locals: The rail technology has high accepted by the rural and urban society in Pakistan.

Annex-XV

Adjustment of air-fuel mixture for better ignition, carburetor and other routine checkups in Vehicles

Technology Characteristics:

Engine tuning is an adjustment, modification of the internal combustion engine or its control unit, to yield optimal performance, to increase an engine's power output, economy, or durability. A vehicle needs tune-up when its average fuel consumption drops by 10-15 percent or after a warm up the vehicle does not pull away or stalls or on observation following engine problems are found: idles fast when warm; stalling; low power; idles rough; knocking; difficulty in starting; misfiring; rough running; engine runs on with key off and black exhaust smoke. ENERCON has set up a number of computerized tune-up centers throughout the country, where through tuning the engine and by good housekeeping of the vehicle, 10% fuel can be saved and noxious exhaust emissions can be reduced by 60%, thus reducing air pollution and greenhouse gases. Tune-up includes: adjustment of carburetor idle speed and the air-fuel mixture; inspection and possible replacement of ignition system components like spark plugs (clean, service & test on a spark plug tester), contact breaker points, distributor cap, distributor rotor; cleaning, replacement or adjustment of distributor contact points by setting the point gap; lubrication of distributor brackets cam; inspection and adjustment of ignition timing; connecting oscilloscope, exhaust gas analyzer and smoke meter and performing a diagnosis; check for composition of omissions, opacity of smoke. Furthermore, it involves adjustment of engine inlet and exhaust valves clearness, if necessary; inspection and diagnosis of faults in battery, crank voltage, drive belt, engine vacuum fittings, hoses, connections, cooling system; fuel pump operation, air cleaner and fuel filters, fuel tank cap, fuel lines and connections for leakage. As well as in the starting system, checking revolutions per minute; generator, diodes and voltage regulator; cleaning the engine oil filter cap; tightening intake and exhaust manifold bolts to the specified torque; checking, cleaning and adjusting positive crankcase ventilation, if necessary; inspection and cleaning of exhaust gas recirculation valve and discharge port. If engine is cold, operate it for 5-10 minutes or unit it reaches operating temperature. Note any operational problems during this warm up time.

Cost of tuning is Rs.500 to Rs.5000 depending on the type of the vehicle and level of tune up.

Safety, reliability & maturity: The technology is comparatively simple, relatively low cost, safe, reliable and easy to adopt.

Potential Development Benefits:

Economic benefits: The efficiency of transport sector is fundamental in bringing down the cost of energy consumption and reducing overall cost of production. Tune up of vehicles saves the fuel consumption. Furthermore, it will also lead to increase in energy and food security and improvement in the balance of payments by reducing imports of fossil fuels.

Social Benefits: The margin of savings accrued from reduction in the cost of production will leverage better social security support to the industrial workers and their families. Better care of industrial workers will lead to health improvement, increase in work output. In addition, it will lead to improvement in their quality of life and increase in employment opportunities. Decrease in cost of transport sector will result in reduced poverty.

Environmental benefits: The vehicle tune-up will lead to significant decrease in greenhouse gas (GHG) emission up to 3-5 percent.

Application potential:

Institutional capacity: The private sector companies have the capacity to conduct the tune-ups.

Need for capacity building: There is a need for capacity building of ENERCON as well as the private sector to conduct tune-ups on scientific lines to optimally benefit from the opportunities of CO_2 emission reduction and improving energy efficiency at affordable costs.

Scale of Application and time horizon: The technology needs to be applied to all the vehicles. Pakistan Vision 2025 stresses promotion of energy efficiency measures in transport sector.

Local acceptability: As there is no negative impact of the technology as well as it is cost effective technology, hence it has high level of local acceptability.

Annex XVI

List of Participants

Inception workshop for conducting Technology Need Assessment in Pakistan

1. Muhammad Irfan Tariq, Director General (Environment and Climate Change), Ministry of Climate Change, Government of Pakistan
2. Dr. Aurangzeb Khan, Director General, Climate Change Department, Government of AJK
3. Dr. Khalid Abdullah, Cotton Commissioner, Ministry of Food Security and Agri. Research ,Government of Pakistan
4. Saad Warraich, Director (UN-II), Ministry of Foreign Affairs, Government of Pakistan
5. Naeem-ul-Haq, Director, Ministry of Foreign Affairs, Government of Pakistan
6. Dr. Hussain Ahmed, Director, Environmental Protection Agency (EPA)-KP
7. Sajjad Haider yaldrum, Deputy Secretary, Ministry of Climate Change, Government of Pakistan
8. Asad Mehmood, Manager (Technical), ECF/ENERCON, Ministry of Water and Power, Government of Pakistan
9. Col. Khalid Mehmood, Director, GCISC, Islamabad
10. Muhammad Fakhar Alam, Director, SDU, P&DD, KP
11. Muhammad Ali, Deputy Director, Ministry of Climate Change, Government of Pakistan
12. Dr. Shahida Waheed, Director Coordination/Chief Scientist
13. Dr. M. Rehan Anis, Senior Scientific Officer, GCISC
14. Fayaz Ahmed, Deputy Director, Ministry of Climate Change, Government of Pakistan
15. M. Azeem Khoso, Deputy Director, Ministry of Climate Change, Government of Pakistan
16. Zahid ullah Khan, Deputy Director, Ministry of Climate Change, Government of Pakistan
17. Navid H. Bokhan, Director, Alternate Energy Development Board, Ministry of Water and Power, Government of Pakistan
18. Mazhar Hayat, Section Officer (CC), Ministry of Climate Change, Government of Pakistan
19. Nagina Tariq, WASH Coordinator, Ministry of Climate Change, Government of Pakistan
20. Imran Khan, Assistant Director, Ministry of Climate Change, Government of Pakistan
21. Rajendra P. Shreshtha, Professor, AIT, Bangkok
22. Muhammad Imran, Lecturer, University of Agriculture, Faisalabad
23. Muhammad Nawaz, District Officer, Environment, Rawalpindi
24. Asiya Noor, Section Officer, Ministries of Industries and Production, Government of Pakistan
25. Imran Muslim Zaidi, Ministry of Climate Change, Government of Pakistan
26. Jamil Ahmed,Ministry of Climate Change, Government of Pakistan
27. Abdul Qadir, Ministry of Climate Change, Government of Pakistan
28. Muhammad Asad, Ministry of Climate Change, Government of Pakistan
29. Dr. Qamar-uz-Zaman Chaudhry, UN-WMO-Consultant-TNA
30. Abdul Rehman, LEAD-Pakistan
31. Nadeem Ahmed, LEAD-Pakistan
32. Harmain Rukh, LEAD-Pakistan
33. Tayyab Shahzad, Consultant
34. Masooma Hassan, Expert Climate Change Adaptation

Annex XVII

List of Participants

Expert Working Group on Mitigation

1. Dr. Arshad M. Khan, Former-Executive Director, GCISC, Islamabad
2. Dr. M. Mohsin Iqbal, Former Head-Agriculture-GCISC, Islamabad
3. Asad Mehmood, Manager (Technical), ECF/ENERCON, Ministry of Water and Power, Government of Pakistan
4. Imran Khan, Assistant Director, Ministry of Climate Change, Government of Pakistan
5. Dr. Saleem Janjua, National Project Manager, Pakistan Sustainable Transport Project, Ministry of Water and Power, Government of Pakistan
6. Dr. Muhammad Parvaz, DG, HDIP, Islamabad
7. Muhammd Irshad Ramay, Coordinator, National Cleaner Production Center, Islamabad
8. Ijaz Ahmed, Deputy Chief Engineer, Pakistan Atomic Energy Commission, Islamabad
9. Dr. Zafar Mahmood Khalid, Professor/ Chairman Biotechnology, International Islamic University, Islamabad
10. Aqeel Jafri, Director, Policy, Alternate Energy Development Board, Ministry of Water and Power, Government of Pakistan
11. Shahbaz Latif, Research Officer, NTRC, Islamabad
12. Nafay Idrees, Research Officer, NTRC, Islamabad
13. Zia-ul-Islam, Research Officer, NTRC, Islamabad
14. Munnaza Naqvi, Program Officer, UNDP, Islamabad
15. Shafiq Ali Siddique, City Planner & Environmentalist
16. Dr. Qamar-uz-Zaman Chaudhry, UN-WMO-Consultant-TNA
17. Jawed Ali Khan, Consultant-TNA
18. Yasmin Jawed Khan, Freelance Consultant
19. Bilal Anwar, COMSATS
20. Masooma Hassan, Env. Policy & Planning Professional, Islamabad
21. Tayyab Shahzad, Consultant

Annex XVIII

Composition of National TNA Committee

1. Muhamad Irfan Tariq, Director General Environment & Climate Change, Ministry of Climate Change, Islamabad (Chair)
2. Ahmed Kamal, Member, NDMA, Government of Pakistan (Member)
3. Syed Naseer Gillani (Chief Environment), Ministry of Planning, Development and Reforms, Islamabad
4. Director General, Pak. EPA, Islamabad
5. Dr. Muhammad Aslam, Food Security Commissioner, Ministry of National Food Security and Research, Islamabad
6. Dr. Javaid Iqbal, Director General, Environmental Protection Department, Government of Punjab
7. Managing Director, Punjab Small Industries Corporation, Industries, Commerce & Investment Department, Government of Punjab
8. Ms. Tanzeel Nazir, Deputy Director (Environment), Sindh Coal Authority, Energy Department, Government of Sindh.
9. Zia-ur-Rehman, Assistant Director (Environment), Directorate of Power Development Sindh, Energy Department, Government of Sindh
10. Shariq Raza, Technical Officer, Energy Department, Government of Sindh
11. Ms. Saira Atta. Director General, Industries Department, Government of Balochistan.
12. Mr. Nusrat Baloch, Director Electricity (North), Energy Department, Government of Balochistan.
13. Mr. Ali Bakhsh Bezinjo,(Director Technical) Environmental Protection Agency, Quetta, Balochistan
14. Dr. Aurangzeb Khan, Director General, AJK-Climate Change Department, Government of Azad Jammu & Kashmir
15. Sajjad Yaldram, Dy. Secretary, MoCC yaldramsajjad@yahoo.com
16. Deputy Secretary (IF), Ministry of Industries & Production, Islamabad
17. Dr. Muhammad Rehan Anis, Senior Scientific Officer, GCISC, Islamabad
18. Irfan Yousaf, Director (CDM), Alternative Energy Development Board (AEDB), Islamabad
19. Dr. ShahidaWaheed, Chief Scientist/ Director Coordination, Pakistan Institute of Nuclear Science & Technology Directorate of Coordination, Islamabad
20. Asad Mehmood, Manager (Tech), ENERCON, Islamabad
21. Ashfaque Ahmed Memon, Dy. Technological Adviser, Ministry of Science and Technology, Islamabad
22. Dr. Afzal Hussain Kamboh, Deputy Director, PCRET, Islamabad

Annex XIX

List of Stakeholders of Climate Change Mitigation

Federal Government (Ministry of Climate Change; Water & Power; Science & Technology; Communication; National Food Security and Research; Petroleum & Natural Resources; Industries & Production; Defence, Planning & Development)

1. Ministry of Climate Change, Government of Pakistan, Islamabad (**For energy and Agriculture sectors**)
2. National Energy Conservation Center (ENERCON), Ministry of Water and Power, Government of Pakistan (**For energy, transport and Agriculture sectors**)
3. Alternate Energy Development Board (AEDB), Ministry of Water and Power, Government of Pakistan (**For energy and Agriculture sectors**)
4. Pakistan Council of Renewable Energy Technology (PCRET), Islamabad (**For energy and Agriculture sectors**)
5. National Disaster Management Authority (NDMA), Government of Pakistan, Islamabad
6. Hydrocarbon Development Institute of Pakistan (HDIP), Ministry of Petroleum & Natural Resources, Government of Pakistan, Islamabad (**For energy and transport sectors**)
7. Pakistan Atomic Energy Commission (PAEC), Ministry of Defence; Government of Pakistan, Islamabad (**For energy sector**)
8. Ministry of National Food Security and Research, Government of Pakistan, Islamabad (**For Agriculture sector**)
9. Ministry of Industries & Production, Government of Pakistan, Islamabad (**For energy, transport and Agriculture sectors**)
10. Ministry of Science and Technology, Government of Pakistan, Islamabad (**For energy, transport and Agriculture sectors**)
11. Ministry of Planning, Development and Reforms, Government of Pakistan, Islamabad (**For energy, transport and Agriculture sectors**)
12. Pakistan Environmental Protection Agency (Pak EPA), Government of Pakistan, Islamabad (**For energy and transport sectors**)
13. National Transport Research Center (NTRC), Ministry of Communication, Government of Pakistan, Islamabad (**For transport sectors**)
14. Pakistan Institute of Nuclear Science & Technology, Directorate of Coordination, Islamabad (**For energy sector**)
15. Global Change Impact Study Center (GCISC), , Government of Pakistan, Islamabad (**For energy, transport and Agriculture sectors**)
16. Pakistan Sustainable Transport Project, Ministry of Water and Power, Government of Pakistan, Islamabad (**For transport sector**)

Provincial Government& Territories

17. Environmental Protection Department, Government of Punjab, Lahore (**For energy and transport sectors**)
18. Punjab Small Industries Corporation, Industries, Commerce & Investment Department, Government of Punjab, Lahore (**For energy, transport and Agriculture sectors**)
19. Sindh Coal Authority, Energy Department, Government of Sindh, Karachi (**For energy sector**)

20. Directorate of Power Development Sindh, Energy Department, Government of Sindh, Karachi (**For energy sector**)
21. Energy Department, Government of Sindh, Karachi (**For energy sector**)
22. Energy Department, Government of Balochistan, Quetta (**For energy sector**)
23. Industries Department, Government of Balochistan, Quetta (**For energy, transport and Agriculture sectors**)
24. Environmental Protection Agency, Government of Balochistan, Quetta (**For energy and transport sectors**)
25. AJK-Climate Change Department, Government of Azad Jammu & Kashmir, Muzaffarabad (**For energy, transport and Agriculture sectors**)

Academia

26. International Islamic University, Islamabad National Cleaner Production Center, Islamabad (**For energy, transport and Agriculture sectors**)
27. Institute of Information Technology (COMSATS), Islamabad National Cleaner Production Center, Islamabad (**For energy, transport and Agriculture sectors**)

Financial Institutions and donors

28. World Bank-Pakistan, Islamabad (**For energy, transport and Agriculture sectors**)
29. Asian Development Bank-Pakistan, Islamabad (**For energy, transport and Agriculture sectors**)
30. UNDP-Pakistan, Islamabad (**For energy, transport and Agriculture sectors**)

NGOs/Civil Society

31. National Cleaner Production Center, Islamabad (**For energy, transport and Agriculture sectors**)
32. NGO Sheher Saaz, Islamabad (**For energy, transport and Agriculture sectors**)

Private Sector

33. Renewable and Alternate Energy Association of Pakistan (REAP), Islamabad (**For energy and Agriculture sectors**)
34. Energy Conservation Fund (ECF),Islamabad (**For energy and transport sectors**)
35. ADMC Consultants, Islamabad (**For energy, transport and Agriculture sectors**)
36. Waqas Electronics, Islamabad (**For energy sector**)

Annex XX

Performance matrix showing scores of selected technologies in Agriculture & Transport Sectors

Performance matrix showing scores of selected technologies in Agriculture Sector												
#	Technology Name	Potential to save usage of fuel	Time saving	Reduction of GHGs	Health benefits	Sustain ability	Initial/ Capital cost	O & M cost	Capacity building is required	safety and reliability	Employment generation & market potential	Social impacts
1	Diet options for reducing Enteric Fermentation in ruminant animals	40	25	70	85	65	40	40	35	75	75	55
2	Appropriate Application of Fertilizers & Soil Carbon Management	40	40	70	60	75	40	40	40	60	65	60
3	Biogas – Compressed bio-methane including Waste & Bagasse	70	80	60	70	60	85	80	80	65	40	75
4	Manure management	50	50	70	85	65	40	35	40	55	60	80
5	Reducing emissions from deforestation, forest degradation & NTFPs	85	80	90	85	85	80	70	60	85	55	75
6	Social/ Farm forestry as Carbon sink	90	80	85	85	90	75	75	70	90	45	70
7	Conventional technologies in Agriculture including Livestock and forestry sector	10	25	25	35	40	30	30	25	25	30	35

Performance matrix showing scores of selected technologies in Transport Sector												
#	Technology Name	Potential to save usage of fuel	Time saving	Reduction of GHGs	Health benefits	Sustain ability	Initial/ Capital cost	O & M cost	Capacity building is required	safety and reliability	Employment generation & market potential	Social impacts
1	Railway transportation	85	70	85	80	80	75	60	60	85	80	80
2	Bus rapid transport in urban areas	80	90	80	85	75	85	60	80	85	70	85
3	Adjustment of air-fuel mixture for better ignition, carburetor and other routine check-ups for increasing Vehicle efficiency	80	80	70	80	70	80	70	70	80	80	75
4	Conventional technologies of transport management (Poorly managed railway transportation; in-existing efficient urban transport system, in-efficient tune-up of vehicles etc)	40	40	50	40	30	20	30	40	40	30	40

Annex XXI

References

1. Alauddin, A. (2009). 'Energy efficiency & Renewable Energy: The key to Sustainable Development'. AEDB
2. Cam W.C. 2012; Technologies for Climate Change Mitigation-Building Sector; UNEP RISO Center; Energy, Climate and Sustainable Development
3. Dhar, S; Desgain, D; and Narkeviciute; 2015; Identifying and prioritizing technologies for mitigation-A hands on guidance to multi-criteria analysis (MCA) UNEP DTU Partnership
4. Government of Pakistan; 1992; Pakistan National Conservation Strategy; Ministry of Environment; Islamabad
5. Government of Pakistan; 2005; National Environment Policy; Ministry of Environment; Islamabad
6. Government of Pakistan; 2006; Renewable Energy Policy for Development of Power Generation; Alternate Energy Development Board; Ministry of Water and Power; Islamabad.
7. Government of Pakistan; 2006; National Operational Strategy for Clean Development Mechanism; Ministry of Environment; Islamabad.
8. Government of Pakistan; 2007; National Energy Conservation Policy; National Energy Conservation Center (ENERCON); Ministry of Environment; Islamabad
9. Government of Pakistan; 2013; Pakistan Vision 2025; One Nation – one vision; Planning Commission; Ministry of Planning, Development and Reforms, Islamabad
10. Government of Pakistan, Ministry of Climate Change; 2012; National Climate Change Policy; Islamabad
11. Government of Pakistan, Ministry of Water and Power; 2014; Improving steam boiler operating efficiency; National Energy Conservation Center (ENERCON)
12. JICA, NTRC, and Ministry of Communications –Pakistan(2006). Pakistan Transport Plan Study in the Islamic Republic of Pakistan.Nipon KOEI CO., LTD., Almec Corporation.
13. Habib-ur-Rehman (2010);'Transport and Communications'. Economic Survey 2009-10. Ministry of Finance, Pakistan.
14. Handbook for conducting technology needs assessment for Climate change; 2010; UNFCCC and UNDP
15. Haselip, J; Narkeviciute, R; and Rogat, J; 2015; A step by step guide for conducting a technology needs assessment; GEF; UNEP and UNEP DTU Partnership
16. Hydrocarbon Development Institute of Pakistan, Energy Yearbook 2013
17. Hydrocarbon Development Institute of Pakistan, Energy Yearbook 2014

18. Khan,M.A.A; 2011; National Economic and Environmental Development Study (NEEDS); Ministry of Climate Change, Government of Pakistan & United Nations Convention on Climate Change (UNFCCC). Page:37, table 9
19. Khan S.R., Khwaja M.A., Khan A. M., Kazmi S. and Ghani H. 1999; Environmental Impacts and Mitigation Costs of Cloth and Leather Exports from Pakistan, SDPI Monograph Series M. 12, Islamabad, Pakistan.
20. Mir, K.A; Ijaz, M (May 2015); Greenhouse gas emission inventory of Pakistan for the Year 2011-2012; Global Change Impact Study Centre, Islamabad, Pakistan GCISC Interim Research Report RR-19 (Interim)
21. Pakistan Economic Survey 2008-9; Economic Advisors Wing; Finance Division; Government of Pakistan, Islamabad
22. Pakistan Economic Survey 2011-12; Economic Advisors Wing; Finance Division; Government of Pakistan, Islamabad
23. Pakistan Economic Survey 2012-13; Economic Advisors Wing; Finance Division; Government of Pakistan, Islamabad
24. Pakistan Economic Survey 2013-14; Economic Advisors Wing; Finance Division; Government of Pakistan, Islamabad
25. Pakistan Economic Survey 2014-15; Economic Advisors Wing; Finance Division; Government of Pakistan, Islamabad
26. Pakistan's REDD+ Readiness Preparation Proposal; 2013; Ministry of Climate Change, Government of Pakistan, Islamabad submitted to Forest Carbon Partnership Facility; World Bank; Washington;
27. Planning Commission of Pakistan, 2015; Working paper for 11th Five Year Plan,
28. Rogat, J; 2015; Identification and engagement of stakeholders in the TNA Process; A guide for National TNA Team; UNEP DTU Partnership
29. Task Force on Climate Change (2010).'Final Report of the Task Force on Climate Change'.Planning Commission, Pakistan.
30. Salter, R; Dhar, S; and Newman, P; 2011; Technologies for Climate Change Mitigation-Transport Sector; UNEP RISO Center; Energy, Climate and Sustainable Development
31. Uprety, D.C; Dhar, S; Hongmin, D; Garg, A; and Upadhyay, J; 2012; Technologies for Climate Change Mitigation-Agriculture Sector; UNEP RISO Center; Energy, Climate and Sustainable Development