Republic of Sudan

TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE MITIGATION

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Supported by:

Disclaimer

This document is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP Risoe Centre (URC) in collaboration with the Regional Centre, Environmental Development Action in the Third World **(ENDA)**), for the benefit of the participating countries. The present report is the output of a fully country-led process and the views and information contained herein are products of the National TNA team, led by the Higher Council for the Environment and Natural resources, Ministry of Environment, Forestry and Physical Development.

Foreword

Technology Needs Assessment for Climate Change (TNA) is a project implemented by the Higher Council for Environment and Natural Resources (HCENR) in collaboration with the United Nations Environmental Program (UNEP) Risoe Centre (URC), Denmark, and supported by the Global Environmental Facility (GEF) grant financing. Project execution is assisted by a national team composed of eleven experts representing different government institutions, research centres and universities.

TNA is considered as a prospect for Sudan to prioritize technologies suitable for Sudan conditions and contribute to reducing Greenhouse Gases (GHGs) emissions and to moderate vulnerability to negative impacts of climate change; these technologies will go in line with the national development priorities of the country.

TNA also allows Sudan to come up with ideas for sound projects on appropriate technologies for both adaptation and mitigation. Hence, Sudan is considered as one of the many vulnerable developing countries around the world due to its fragile ecosystem and its livelihood which is directly affected by the impact of climate change. TNA will also contribute to the success of implementation of the United Nations Framework Convention on Climate Change (UNFCCC) as long as the developed countries take a leading role in providing financial assistance and facilitating technology transfer for developing countries.

TNA is a participatory process; it requires consultation of wide range of stakeholders during different steps of the process. Stakeholders participated in the groundwork of these studies will eventually add more to the preparation and success of the TNA as they have different views, background and experiences in climate change. Identified sectors and sub sectors for the TNA would build upon preceding studies conducted earlier such as the National Adaptation Program of Actions and National Communications.

Sudan has set many goals in its Millennium Development Goals (MDGs). Amongst the most important goals identified are eradication of extreme poverty and hunger, combating HIV/AIDS, Malaria and other diseases and ensure environmental sustainability. Conducting TNA will give Sudan a great opportunity in achieving those goals. Technologies identified through the TNA will assist remarkably in overcoming many challenges that face the country in the context of poverty, hunger, human health and environment in general.

Environment and poverty alleviation have also been recognized as the cross-cutting issues in the Five-Years Strategic Plan of the country (2007 – 2011). Sound, environmentally benign technologies are needed to be incorporated in the improvement of the environment and alleviation of poverty. The government exerts great emphasis on the improvement and development of international relations with environmental development partners, and augmenting mechanisms for benefiting from the latest research, expertise and technologies to enable the country for achieving these goals.TNA in Sudan can go beyond prioritizing technologies to practical approach to spread the use of the technologies identified, as Sudan faces many barriers in the technology transfer such as limited resources, lack of training, poor dissemination tools. In conclusion, TNA will help overcome these barriers.

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List of Abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
CC	Climate Change
CFL	Compact Fluorescent Lamp
CO2	Carbon dioxide
FNC	Forest National Cooperation
Gg	Giga gram
GHG	Greenhouse Gases
GWh	Giga watt hour
HCENR	Higher Council for Environment and Natural Resources – Sudan
ICL	Incandescent Lamp
ICS	Improved Cook Stoves
kW	Kilowatt
LPG	Liquid Petroleum Gas
LUCF	Land use Change and Forestry
MCA	Multi Criteria Analysis
MDG	Millennium Development Goals
MEA	Multilateral Environmental Agreements
MED	Ministry of Electricity and Dams
MO	Ministry of Oil
NG	National Grid for Electricity
PP	Prioritization Process
TFS	Technology Fact Sheet

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Executive Summary

The Technology Needs Assessment Project (TNA) is done based on the agreement signed between the Republic of Sudan represented by the Higher Council for Environment and Natural Resources (HCENR) and the United Nations Environmental Program (UNEP) Risoe Centre (URC), Denmark, and supported by the Global Environmental Facility (GEF) grant financing. The UNEP, through its Division of Technology, Industry and Economics (DTIE) is responsible for the implementation of the project and provide overall project oversight and strategic coordination. Energy, Environment and Development Programme (ENDA) provides technical and process support to the participating countries in Africa.

Technology Needs Assessment (TNA) is a tool through which Non Annex I countries, could assess /identify the most applicable technology required for adapting /mitigating to Climate Change.

The (TNA) project covers two Climate Change Areas: Mitigation and Adaptation. This report is concerned with the mitigation sectors which identify technologies that can limit growth in GHG emissions within the context of sustainable development**.** The main objective of this work is to identify mitigation options that are most applicable and useful in Sudan without affecting /hindering its developmental plans. The work in mitigation sectors has further been divided into two main parts. The first part is to identify the prioritized sectors and sub-sectors. The second part is to identify the most suitable technologies that are most effective in emission limitation.

The first step in this work is to establish project implementation structure including project coordinator, the national team and the stakeholders. Management unit of this project is hosted within the climate change unit of the Higher Council for Environment and Natural Resources (HCENR). Great attention has been given to the continued consultation process with the stakeholders in every step of the project. One of the main outcomes of project methodology is the establishment of a motivated network that can further assist in implementing the outcomes of this study or even any climate change project.

The second step is to set a methodology that allows identifying and prioritizing sectors, sub sectors and areas of interest. The procedure adopted to carry out this selection and identifying processes had to meet (parallel wise) two criteria; reduction of GHG emission or increase of sink in terms of increasing sequestration rate. The second criterion incorporates the contribution to sustainable developmental priorities within Sudan developmental strategic plans. As Sudan is a least developed country then these priorities include issues like poverty eradication, food security and improved social services. Hence, the current situation has been studied for each sector with a focus on its emission and its relationship to current and future contribution to development in Sudan. This has resulted in adopting the following sectors, Agriculture, forestry and other land use (AFOLU). Agriculture comprises livestock, and crop production. The second sector is energy which includes energy production and consumption from fossil fuel. The thirds sector is industry; which embraces GHG emission from both energy sources and process origin. After these steps, specific sub-sectors with high emission, as indicated in the first national communication, have been considered for further analysis. This has resulted in identifying the enteric fermentation, manure management, and forest conservation/management in the AFOLU sector.

For the energy sector, electricity production/consumption, transportation and household have been highlighted as main sub-sectors. Within the industry sector attention has been given also to growing industries that are now not considered as emission sources such as agricultural processing industries. The main current emission sources come from construction industries under the category of mineral and non-mineral products; the cement industry has been recorded as the first emitting source. Further a long list of technologies has been prepared by the national team for each sector/area, special care has been given to short and medium range technologies; considering their degree of compatibility with the technical and economic setup in Sudan.

Ultimately the most efficient technologies (whether currently available or not) have been suggested. Hence a long list has been created. Technology facts sheets (TFS) have been filled for the technologies and presented in the second local workshop with the stakeholders for further discussion. Subsequently, this long list has been shortened through mutual discussion and finally subjected to Multi Criteria Analysis (MCA) procedure by stakeholder using a self-generated, MS excel-based program. The criteria suggested included the GHG reduction potential/high sequestration potential and the developmental criteria which include environmental, social and economic criteria. The main step in this process is proper selection of the most suitable indicator, whereby technologies with the highest ranking have been selected for further analysis (barrier and cost benefit analysis).

The national team and the stakeholders' consultation process has identified the following sectors: Agriculture, Forestry, and other land use (AFOLU), Energy and industry as highest prioritized sectors. The identified priority technologies selected for the AFOLU sector are bio gas unit and improved stoves.

For the Energy sector, mass transportation has been identified within transportation sub-sector and selected as priority one in addition to the Compact Fluorescent Lamps (CFL) for the demand side sub-sector.

In the industry sector, among the identified technologies, Efficient Boilers with dual fuels have been selected as priority technology.

Chapter 1: Introduction

1.1Background

Sudan is the third largest African country with an area of 1,882.00 km2; it extends between latitude 22° N at its northern border and 7 ° N southward. At longitude base it is found between 22°E at its western border and 38°E East. Sudan is a land of multi ecological zones, from desert to rich savannah. Sudan (population ~33 million) is one of the least developed countries. Issues of poverty, food security and low service level are the main developmental challenges.

Developmental priorities

Explained by its under-developed state; Sudan aims towards achieving quicker growth rates. However, its developmental strategic plans do not consider development from the fiscal point of view only, but also put great emphasis on ensuring sustainable developmental mode (conservation of resources, securing biodiversity, reduction of GHG and pollution). These goals are clearly stated in different development planning documents such as the Strategic Plan document 2007-2033. Hence it is very justifiable that objectives like poverty alleviation, food security and provision of adequate services like water, energy, and waste management are given great priority. On the other hand, concerning the strategic and future perspective there is high encouragement for sectors that can contribute more to increasing Sudan's GDP (e.g., export).

Table 1- Summary of developmental priorities

Objective	Poverty alleviation	Food security	Services	GDP Increase	Natural resource management
Indicators	-Increase of Income -Reduction of negative expenses e.g. illnesses	Increase food commodities productivity and production	-Increase of population percentage which have access to each services - Increased service level	Export increase	-Percentage of resource utilization

Source: Compilation of the TNA Team

About the (TNA) Project

This work is done based on the agreement signed between the Republic of Sudan represented by the Higher Council for Environment and Natural Resources (HCENR) and the United Nations Environmental Program (UNEP) Risoe Centre (URC), Denmark, and supported by the Global Environmental Facility (GEF) grant financing. The programme of Energy, Environment and Development (ENDA) provides technical and process support to the participating countries in Africa.

TNA is taking place in 36 different developing countries all over the world and it is a multi-disciplinary work that aims mainly towards addressing both the adaptation/mitigation technology needs of the specific country. It is seen as part of the global effort to respond to climate change phenomena in the context of sustainable development. Furthermore, TNA could be considered as part of the experience exchange and technical know-how provision at the three levels; national, regional and global. The main outcome of TNA is to support the countries in their sustainable development process by providing a Technology Action Plan (TAP) for environmental sound technologies. The project is composed of four parts starting by technology identification/prioritization, followed by barrier analysis and enabling framework needed for developing a technology action plan. Ultimately, these results will facilitate the preparation of profound project ideas.

TNA Project Objectives

To identify and prioritize, on the basis of country-driven participatory processes, technologies that can contribute to mitigation/adaptation goals of the participating countries, while meeting their national sustainable development goals and priorities (TNA).

To identify barriers hindering the acquisition, deployment and diffusion of the prioritized technologies for the mitigation option.

To develop Technology Action Plans (TAP) to that specify activities and enabling frameworks necessary to overcome the barriers and to facilitate the transfer, adoption and diffusion of selected technologies in Sudan.

1.2 Existing national policies about climate change mitigation

Sudan, a least developed country, has a voluntary general obligation for adopting a low carbon development approach. The Republic of Sudan has been among the first countries to ratify the United Nations Framework Convention on Climate Change UNFCCC in 1993 and Kyoto Protocol in 2005. Consequently, Sudan adopted within its national implementation strategy to combat climate change two main pathways namely; adaptation and mitigation (First National Communication, 2003)

Sudan has implemented several activities under the multilateral environmental agreements (MEAs) which have direct relations to climate change adaptation/mitigation and development priorities. The outcomes of these tasks include number of assessment reports, strategies and action plans. The major types of these initiatives are as follows:

- Government Policies and Strategies**:** these are country-driven policy responses to environmental challenges motivated by either commitments under MEAs or national sustainable development objectives;
- National Programs: these are specific measures designed to meet specific needs and objectives of national policies, to be funded by national budget and/or bilateral donors;
- Intergovernmental/Multilateral Processes: these are scoping studies that address critical areas affecting or impeding national development;
- Other Multilateral Activities: these are assorted projects, largely funded through GEF, and focused on capacity building and sector development priorities.

In Sudan there are several government policies and strategies that are complementary to overall climate change goals:

- The Environmental Protection Act has been enacted in 2001 to provide a framework to policies, legislations and executive actions of federal state organs. The objective of the Act is to implement the general policy in collaboration with the governmental departments and the private sector.
- The 25-Year Strategy (2007 – 2033) provides the policy directions to all economic and social sectors, and incorporates the country's environmental strategy, which states clearly that environmental issues must be embodied in all development projects. Examples of key national programs are fuel switching to LPG and solar for cooking in the household sector, dissemination of improved stoves and promotion of water harvesting techniques. Moreover, key intergovernmental/multilateral processes that relates to climate change are: Poverty Reduction Strategy which is linked to climate change mitigation/adaptation issues such as promoting livelihood of the communities.

Chapter 2: Institutional Arrangement for the TNA and the Stakeholders' Involvement

2.1 TNA team, national project coordinator

Overview for TNA organizational setup

The TNA study in Sudan has been undertaken in an interlinked multi-disciplinary mode. This has been translated into various circles, each of specific responsibility as shown below. The details of each circle components are also highlighted.

- **Focal point:** The Higher Council for Environment and Natural Resources (HCENR) acts as a National Focal Point for the UNFCCC and other MEAs and plays an advisory policymaking role with regard to climate-related initiatives within the government. The HCENR hosted TNA in Sudan hosted TNA and its management and coordination including all correspondence and project inquiries through the Project Coordinator.
- **Project Coordinator**. The national coordinator represents the climate change unit in the HCENR and manages the overall process of technology needs assessment.

National Team: Composed of 6 national experts, which work closely with a group of stakeholders thus forming working group for each sector. The national team is representing different institutions related to GHG mitigation efforts in Sudan, namely forestry, technology research, conventional and renewable energy, in addition to environmental economics. The national team is responsible for conducting the technical process including data collection, document revision and facilitating stakeholders' consultation. Within the national team, each member is responsible for one sector depending on his/her experience and specialization working in close collaboration with sectoral core stakeholders. Series of meetings and working sessions have been regularly held at a working group level, mitigation group level and at the whole TNA project level (with the adaptation group). The main duties assigned are studying and investigating the selected sectors with respect to specific points such as GHG emission share, importance and role played in country development, future plans, and existing technologies related to climate change mitigation. Furthermore, the national and sectoral developmental plans have also been revised with the objectives of identifying current and future goals. The designated team leader, with help of team members, is responsible for preparation of documents required for the local workshop, e.g. scoping papers, technology status in addition to assisting project coordinator in preparing regional workshop documents, and finally preparing the project report. The project coordinator and the two team leaders (Adaptation and Mitigation) have attended a regional capacity building workshop organized by the UNEP Risoe Centre and ENDA in Naivasha in June 2011.

The knowledge and the experience gained from the workshop have been shared with the rest of the national team.

Stakeholders: The stakeholders for the TNA project represent a wider group of concerned institutions composed of different bodies including:

- Government institutions.
- University and Research Institutes.
- Private sector
- Non-Governmental Organizations.

The role of stakeholders is to identify and prioritize/select the optimum technology under Sudan's conditions including providing information to prepare the technology fact sheets. Ultimately, they are expected to facilitate the adoption of such technologies within the context of gaining the ownership of the process. A list of stakeholder institutions can be found in Annex II.

2.1 Stakeholder Engagement Process followed in TNA – Overall assessment

The stakeholder engagement process has involved continuous consultation at different phases of the project. The aim is to establish a sense of ownership towards the project. This process has been undertaken in several steps. The first step has been dedicated to sectors selection during a one day inception workshop on 27th July, 2011. The workshop's main objective is to select sectors and sub-sectors which are seen to have higher priority in relation to mitigation of the greenhouse gases emission; this process has taken the stakeholders' views in consideration. The inception workshop has been attended by 110 participants representing 45 institutions from government, academia, research and technology institutes, NGOs and private sector (listed in Annex II). The second step has taken place after the national team has prepared a long list of technologies which has been presented and revised during this workshop on 8th February 2012. The technology fact sheets have then been prepared and a short list for technology selection has been generated.

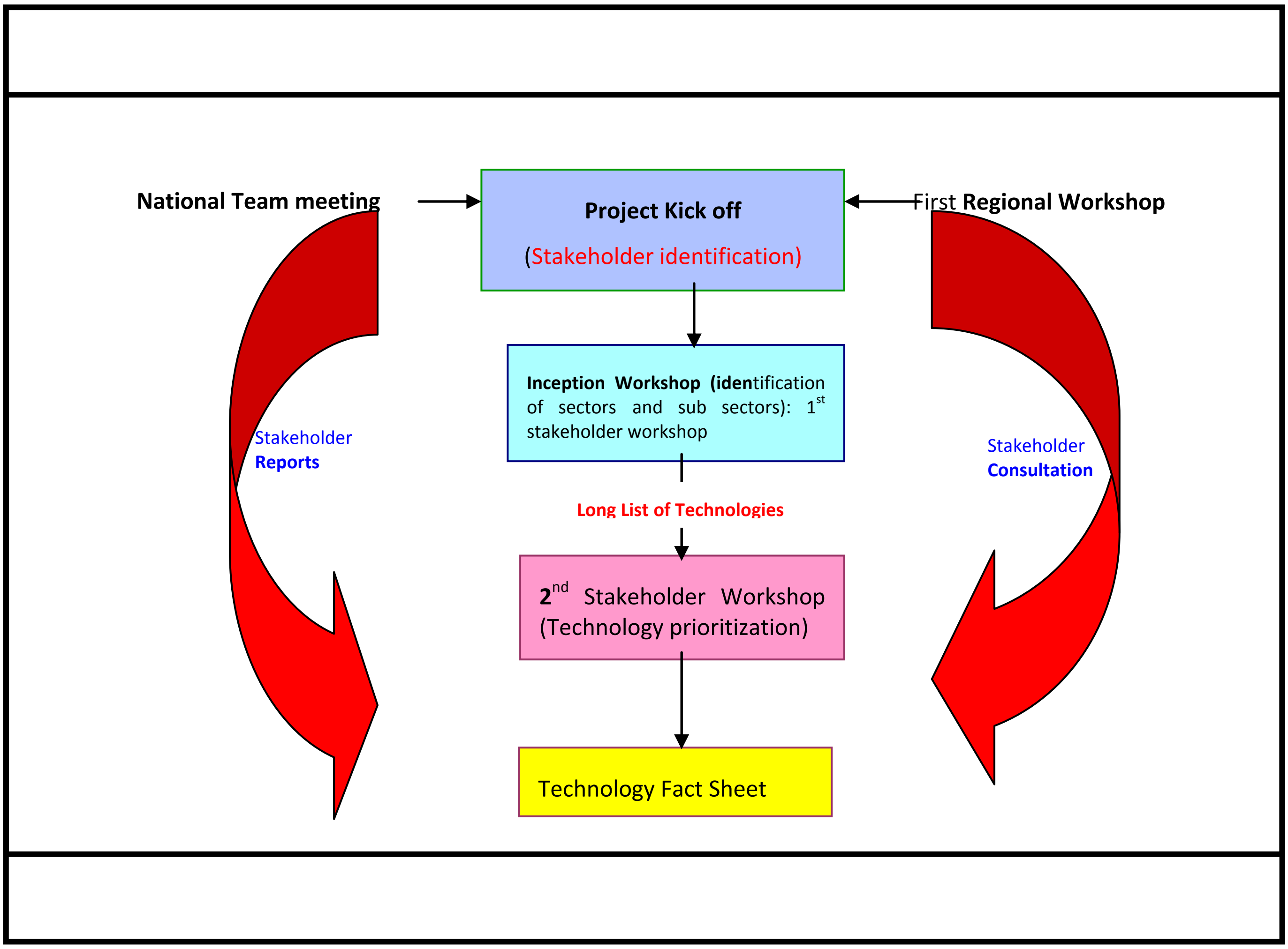

Figure 1 - Graphical representation of TNA project sequences – Sudan

Chapter 3: Sector Selection

3.1 Overview of sectors, GHG emissions status and trends of the different sectors

This chapter is to display GHG sources in Sudan as documented in the First National Communication, analysis of these sources in relation to development and hence expected trend of GHG emission. Also, this chapter is to explain the prioritization process that has been undertaken in order to identify the most prioritized sectors and sub-sectors in terms of potentials for GHG mitigation and development.

The sectors have been identified based on the following:

- Sudan's First National Communication under the United Nations Framework Convention on Climate Change and drafts of the Second National Communication (http://unfccc.int/resource/docs/natc/sudnc1ann.pdf)
- IPCC Guidelines (1996, 2000 and 2003)
- Guidebook for Conducting Technology Needs Assessment for Climate Change
- The development priorities (including the sectoral ones) according to the National Strategic Plan
- Sudan's Millennium Development Goals (MDGs) Document
- National Team members' experience
- Suggestions and confirmations by working groups and stakeholders

Classification of sectors

The Identified sectors that have been considered in the TNA sector prioritization process are as follows:

- Agriculture, forestry and other land use: These sectors are grouped together as technologies used in the agriculture sector could enhance the GHG mitigation in land use change and forestry **(AFOLU).**
- Energy
- Industry
- Waste management

1: Agricultural Forestry and Other Land Use (AFOLU) Sector

Agriculture Sub-sector:

According to the First National Communication, agriculture includes two areas, namely crop production and livestock

a. **Crop Production:** Agriculture productivity is declining in most of the cultivable lands. Soil erosion, loss of soil fertility, flooding and loss of biodiversity are increasing in both irrigated and rain fed areas. The situation will become worse in future due to climate change. Emissions from agriculture originate from burning agricultural residues[1], savannah burning, and soil disturbance, or as a result of applying synthetic fertilizers. Improvements in the agriculture sector through different technologies and practices such as improved seeds or zero tillage is to contribute to both GHG reduction and efficiency improvement of agricultural practices. However, according to the first national communication, emissions from crop production are low compared to those of the livestock, hence crop production has been seen more as an adaptation sector candidate rather than as a mitigation area.

[1] The productivity and production are highly fluctuating every year, hence the rate of carbon sequestration in re-growth is not well proved.

b. Livestock: The largest source of methane in the agricultural sector is an enteric fermentation and manure management. Sudan is famous for its livestock wealth which is estimated at more than 130 million head out of these 30 million is cattle. The dung production is estimated to be 4-5 kg/day/animal in open husbandry; in a closed system by 10 kg /day/animal fresh weight. Main challenges facing the livestock sector are their mobile nature and the continuous conflicts between pastors and farmers. Conflicts are mostly initiated by the dryness of the normal pasture, due to many reasons including low fertility of land. Other dimensions of pastoral life are the very low access to basic services such as potable water and electricity. The development plans have highlighted these problems and any mitigation effort should consider this situation. Within the climate change context two areas are sources of GHG emission, namely manure management and the enteric fermentation:

- **Manure Management**

Besides its GHG emitting issues, manure is also a source of pollution and health hazards. Currently, manure is used in Sudan mainly as

- Building material, which requires dung fermentation in specific processes, therefore it adds to GHG emissions
- For energy provision; this is done through combustion in a very inefficient mode. This process contributes additionally to air pollution.

The suggested solution must inhibit open fermentation and minimize side effects on human beings and environment. This could be met by technologies such anaerobic fermentation (biogas units) which produce heat/electricity, or through compost technology that produces fertilizer. These technologies could reduce GHG emissions and also provide energy, or contribute to improvements of soil characteristics. Both benefits are to positively affect the rural welfare level.

- **Enteric fermentation**

Enteric fermentation is a natural phenomenon. Studies have revealed that this is much related to the genetic formation and the feed rations. In spite of the fact that the open husbandry system is traditionally prevailing in Sudan, the feed control is limited, however, the closed or semi closed system is increasingly growing. Ration and feed control for different objectives such as increasing milk production are already practiced.

Forestry Sub-sector:

Forests in Sudan are seen as a multifunction system, for example income from forest products contributes to food security. Forest revenue makes up about 15% of country's hard currency and forestry sector provides about 15% of employment opportunities in rural areas. Sudan's forests provide all requirements of hardwood and about 70% of the national energy consumption. Additionally, forests play an important role in encouraging ecotourism, sustaining biodiversity and soil fixation. The forest situation in Sudan has witnessed high deterioration especially after separation of Sudan into North and South. Forest cover has been reduced from 46.5% in 1958 to 29.4% in 2005, to reach 11.6% in 2010. The annual removable rate has arisen from 0.74% to 2.2% and the forest density is 200-500 tree/feddan[2]. Forests in Sudan face different challenges in two areas namely, forest management and forest conservation.

- Forest management is concerned with offsetting issues of excessive cutting/destroying forests to satisfy wood need such as energy, furniture etc. as well as to offset activities which affect forest situations such as over-grazing, forests fires etc.

[2] A feddan (Arabic: فدّان, faddān) is a unit of area. 4200 m^2 It is used in Egypt, Sudan, and Syria. The feddan is not an SI unit and in Arabic, the word means 'a yoke of oxen': implying the area of ground that could be tilled by them in a certain time. A feddan is divided into 24 Kirats (175 m^2) (source: Wikipedia)

- Forest conservation includes offsetting the encroachment of local communities into forest areas causing soil erosion, land degradation, destruction of habitats, and contributes to desertification and biodiversity loss. This encroachment is founded/ catalysed by extension of mechanized agriculture area, traditional shifting cultivation and implementation of infrastructure projects.

2. Energy Sector

The mitigation team has agreed on considering these two main sub-sectors within the energy sector:

- Electricity generation and consumption
- Fossil fuel consumption which includes transportation and household

Overview

The electricity service in Sudan is based on two systems; the first system is the national grid that supplies mainly central and eastern Sudan; and the second system is the off-grid system which is composed of isolated small scale thermal power plants that supply remote cities or regions. According to the Ministry of Electricity and Dams (MED) statistics until 2011 only around 27.8% of the population have been able to benefit from the electricity services. The strategy of MED is to concentrate on the household sector and hence to provide access to electricity to over 83% of the population by 2030 and to increase the power usage by 50% in the industrial sector and by 100% in the agricultural sector. The main challenges facing the mitigation measures in the electricity sector are as follows:

- **Expansion need:** The main source for GHG emission in the electricity production area is the burning of fossil fuel (Heavy fuel oil (HFO), Gas oil, Heavy Coke Gas Oil (HCGO), Diesel oil,) in the thermal power plants. Although the electricity demand is increasing, the total CO_2 emissions decreased from 1,027 Gg in 1995 (First National Communication) to 471.096 Gg in 2010 due to the introduction of Marowi dam (1250MW). As the hydroelectric option is limited by seasonality factors (e.g., silt accumulation), other power generation options should be considered. These include clean/renewable energy resources and highly efficient power plants. Additionally in the short run improving maintenance plans and upgrading the operation systems could improve the production conditions increase the energy generated quantity hence kW/Litre will be higher. GHG emissions are expected to be reduced.
- **Electricity distribution:** The National Grid **(NG)** which consists of large hydro power plants and large thermal units has a relatively low emission factor (0.301) due to the significant hydropower contribution. NG covers limited geographical zones mainly in Central and Eastern Sudan. The other parts of Sudan are served by the thermal based off Grid options which have high GHG emissions and higher operation costs compared to NG. Extension of NG is believed to lower the load on the off **Grid**, and thus lowers the GHG emissions.
- **Demand Profile**: MED statistics have revealed that the total consumed power has increased from 5,044.7 GWh in 2009 to 6,026.0 GWh in 2010 (19.5%). The major groups that consume electricity in Sudan are the residential and services sector with around 80% of the total electricity consumed (Table 2). This is mainly utilized to satisfy the lighting and cooling demands. Normal incandescent lamps, that are widely used in Sudan, with an average of 10 lamps per household and therefore lead to an overall high consumption rate although they relatively low consumption (60-100 watt) compared to fans or refrigerators (150-250 watt). According to the MED statistics the number of consumers is estimated at 1.5 million. Considering the use of about 10 lamps per premises for 4.5 hours a day, the total of 2460 GWh per year is demanded. Based on this analysis energy efficiency options should be highly considered. Additional energy efficiency options could be considered for city and house architecture or utilization of efficient appliances. However, these areas have not yet been developed due to lack of specific data and information.

Table 2 – Electricity Consumption by Sectors (2009-2010)

Sector	Consumption (GWh)		Share (%) 2010	Evolution 2009-2010*[1]%
	2009	2010		
Residential	2,595.8	3,093.8	51.3	19.2
Industrial	714.3	888.4	14.7	24.4
Agricultural	**192.8**	978.3	16.3	407.4
Governmental	699.0	841.2	14.0	20.3
(Standardized)*[2]	842.8	224.3	3.7	(73.4)
Total	**5,044.7**	**6,026.0**	**100.0**	**19.5**

*[1]Evolution mean what is the improvement done on each sector in 2010 comparing with 2009, it is the percentage increase from 2009 to 2010.

*[2] standardized include the commercial and light industrial sectors

Source: MED

- **Energy Demand:** Energy Demand incorporates two areas, namely transportation and households.

Transportation area overview: The statistics of the Ministry of Oil (MO) show that fossil fuel consumption in the transportation sector represents about 65% of the total fossil fuel consumption in Sudan (Table 3). The biggest consuming transport mode is road transportation with a share of more than 84% of the total consumption in the transport sector.

Due to the increase of economic activities which enhance mobility, improving infrastructure (paved roads) and the reduction of other modes of transportation like railways, the road transport sector is expected to expand further. Hence, it has been given higher attention.

Table 3 - Petroleum Consumption by sectors in KTOE (2003-2008)

Sector/Years	2003	2004	2005	2006	2007	2008
Transport	2241.7	2042.8	2011.1	2381.7	2534.1	2576.7
Household	143.1	134.4	180.2	208.2	227.0	224.1
Industry	846.0	731.4	919.1	1122.4	1200.8	1276.8
Total	3230.8	2908.7	3110.3	3712.4	3962.0	4077.6

Source: Ministry of Oil

Household area overview: Cooking has been agreed upon to be a major issue in the household consumption of traditional fuels. Currently, in Sudan LPG is encouraged as an alternative to both biomass and kerosene in order to mitigate indoor pollution and safety hazards. Hence, LPG consumption has increased from 127 thousand tonnes in 2003 to 269 thousand tonnes in 2008.

The mitigation team has suggested 3 options for discussion with the stakeholders:

- **Expansion of LPG Stoves**

LPG is a relatively cleaner fuel from the emission point of view than kerosene (107,900 kg CO2eq/TJ for LPG versus 157,400 kg CO_2eq/TJ for kerosene, 112 000 kg CO_2/TJ for wood). Hence expansion programmes have always been encouraged. However, within this context, LPG availability is a controversial issue as some opinions connect it to limited supply of crude oil and limited capacity of the local refineries. This situation can end up in having LPG as an imported commodity. These conditions will have negative implications on its availability and affordability.

- **Expansion of Improved biomass stoves or renewable energy stoves solar cookers (zero emission) or biogas-based burners**

The TNA team has opted to consider this option under the forestry sub-sector rather than the fossil fuel consumption. The main reasons for this are:

- Around 70% of the energy demand in Sudan is covered by biomass. Cutting trees without reforestation constitutes the main reason for lowering the sink level in Sudan. Annual deforestation rate of 0.4 – 0.7 million hectares are stated by various authors such as World Bank 1985, FRA 2005, Daak 2007, Elsiddig *et al*. 2007). Therefore, using improved stoves will respond to the deforestation issue more than the reduction of emissions from the household sector.
- In Sudan the main executive governmental body responsible for managing improved biomass stoves is the Forests National Corporation (FNC).

- **Changing cooking practices;**

Cooking practices include factors such as meal times, cooking time and type of meals. This option has not been seen to be applicable as it includes cultural issues such as changing meal time and type of food which require long term behavioural and perception changes.

Therefore, the stakeholders have not given the household sector under energy a higher priority as TNA candidate and as result of stakeholders' consultation has not been subjected to further analysis.

3: Industry Sector

Overview

Industrial production in Sudan contributes to food security, employment opportunities, GDP increase, and export earnings and to the diversity/comprehensiveness of national production. Its growth rate has increased from 7.9% in 2009 to 8% in the end of 2010. Revenues from the manufacturing industry production amounted to US $2.958.5 million corresponding to 9.45% of GDP. Mining production earnings have grown from 7.69% of GDP in 2006 to 8.89% in 2008. Within this framework, the contribution of large-scale enterprises is 82%. The food and beverage industry contributes 55% to Sudan's GDP. Industry has to overcome many hurdles (e.g., obsolete/archaic equipment and inefficient process designs). This results in exploiting unnecessary energy and raw materials. This situation is intensified by the low level of technical know-how in relation to process optimization. At the institutional level there is an absence of regulation that mandates energy, resource audit or control of equipment standards. Therefore, mitigation efforts in the industrial sector have to be directed to fill these gaps.

GHG emissions sources in industry

GHG emissions in the industrial sector are due to two main sources, namely:

- Energy: Especially at off grid/self-status, energy is the main source for GHG emissions, whether for electricity heat or steam/hot water satisfaction. According to the Forest National Corporation in 1994 the industrial sector has utilized 7.6% of the total biomass specifically fuel wood (1,050,174 m^3) and charcoal (11,673 m^3). In addition, MED has estimated that in 2010 14.7% of the electricity consumption in the county has been used in the industry sector with an increased rate of 24.4% compared to the previous year. Regarding fossil fuels, according to MO statistics, industrial consumption can be estimated at around 30% of total consumption (e.g., in 2008 it was 1276.8 out of 4077.6 million tonnes). This type of emission is a cross-cutting issue for all industries but for the sake of this work, further analysis is only to be undertaken for growing industries.

- Process: The specific process/step production (e.g., during cement formation) has been considered as the main source of GHG emissions. Although they are lower compared to other sources of emissions in Sudan, but these types of industry are growing and are anticipated to further growth in the future. Below is an overview of the main industrial activities in Sudan.

Food Industries

This sector is continuously growing and the increase is expected to continue in the future as a result of population increase and *comparatively* \`encouraging investment\` process. This sector is generally characterized by inefficient production systems e.g. old boilers, high losses throughout the different processes e.g. non-insulated pipes and very poor housekeeping. A special criterion for the food sector is its relatively high need for steam and hot water which calls for special consideration at the energy side. This could include better housekeeping and introduction of renewable energy sources. Currently, many industries are considering the use of LPG as an alternative since it does not require major modifications to the existing plant. This alternative is especially attractive when combined with more efficient boilers that use dual fuel. The dual characteristic will minimize the risk of LPG scarcity.

Minerals and Non-Mineral Product Industries

- **Cement Industry:** This has been one of the most rapidly growing industries in the last few years. The production has increased from 621.7 thousand tonnes in 2009 to 2,112.6 thousand tonnes in 2010. Accordingly, investment in the cement industry is estimated at US$ 1,995 Million. Cement industry is interlinked with all infrastructure projects and housing strategies. By definition, the cement industry is energy consuming; it contributes to GHG emissions during the production process itself. The main mitigation options involve energy reforms such as energy saving techniques or using less polluting fuels like waste tyres and process modification, e.g. by using pozzolans[3].
- **Other Industries:** This includes ceramic, gypsum and brick industries. The main emission sources in these industries are fossil fuel combustion to satisfy their energy needs. Currently, energy supply in the ceramic industry is satisfied through LPG and electricity. LPG consumption is estimated to be about 1500-1800 tonne/month. The main problem that this sub-sector faces is the high prices of electricity and LPG. Within the gypsum industry, the main GHG emission comes from the energy side. Currently, the industry uses fossil fuel and wood for the heating step (one of the steps in the gypsum making process), hence alternative heat sources are encouraged. Again, here LPG seems to be a suitable option from a technical point of view. Considering the building brick industry, there are about 800 traditional units and four factories with a total production of 455 million blocks/ year. However, in 2002 the demand is estimated at 1500 million blocks/ year. Therefore, energy is required in this industry to satisfy the demand gap. The common energy forms used include firewood for traditional brick and fossil fuel for factories. The factories need is estimated at 2000 tonnes/ factory in

[3] A pozzolan is a siliceous or siliceous and aluminous material which, in itself, possesses little or no cementitious value but which will, in finely divided form and in the presence of water, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. The broad definition of a pozzolan imparts no bearing on the origin of the material, only on its capability of reacting with calcium hydroxide and water. (source: Wikipedia)

addition to about 40 thousand litre of oil for ignition. The main mitigation options considered are utilizing alternative fuel or substituting the fire brick with other products such cement blocks.

GHG emission Status in Sudan

The main reference used in preparing this part is the First National Communication (2003) in which an inventory has been carried out using 1995 as the base year. It indicated that the total national emissions amounted to 89,220 Gg CO_2 equivalents. Table 4 shows the summary emission levels, by sectors and gases, for the national GHG inventory in the year 1995.

Table 4 - Greenhouse Gas Emissions: Sudan; 1995 (Gg)

GHG Source & Sink Categories	Net CO_2 Emitted	CH_4	CO	N_2O	Others (NO_x, NMVOC, HFCs)	Total CO_2-eq (Gg)
Energy	4,328	150	2,104	1	323	16,706
Industrial Processes	173	0	0	0	16	173
Agriculture	0	1,713	388	30	46	50,083
Land-use change & Forestry	15,577	90	787	1	23	21,184
Waste	0	33	0	1	1	1,055
Total National Emissions and Removal	20,077	1,985	3,280	33	409	89,220
Total CO_2 **emissions from biomass**	21,936	0	0	0	0	21,936

Source: Sudan's First National Communication under UNFCCC – Sudan (HCENR), 2003.

Analysis of GHG emission by Gas

Figure 2 reveals that the main gas emitted is carbon dioxide (CO_2) (20,077 Gg) which constitutes more than 75% of the 1995 total GHG emission, followed by carbon monoxide (3,280 Gg, 13%) and methane (1,985 Gg, 8%). Small amounts of other gases such as NMVOC, NO_x, N_2O, have also been recorded.

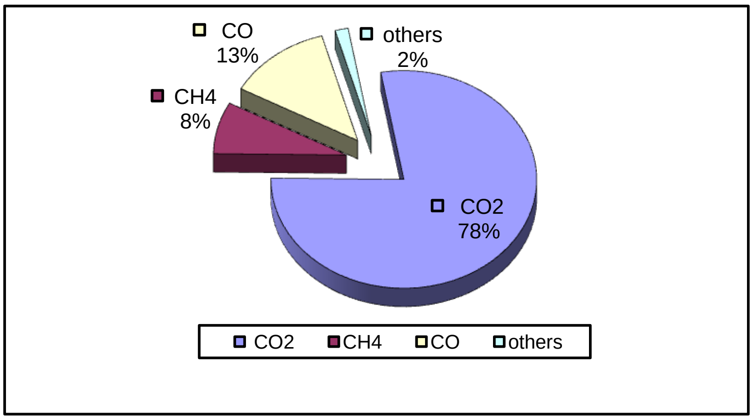

Figure 2 Percentage Contribution by Gas to the Total GHG Emissions in terms of CO_2 equivalents in 1995

Analysis of GHG emissions by Sector

In Figure 3 it is clear that the contribution of the sectors considered in the inventory study varies considerably.

Land-use change and forestry, instead of constituting a CO_2 sink, are found to be the main emitter of CO_2, that mounted to 15,577 Gg or more than 75% of total CO_2 emitted. In turn, they are the second contributor for the aggregated GHG emissions in CO_2 (equivalent 24%, 1995).

In the energy sector, CO_2 emissions from fossil fuels are estimated at 4,328 Gg – about 22% of the CO_2 total. The energy sector emits the major share of CO_2 and NMVOC (3280 Gg and 274 Gg respectively). Its share contribution in the aggregated GHG emissions in CO_2 equivalent in 1995 is 20%. It is important to note that biomass energy is estimated to emit about 21,936 Gg of CO_2, constituting more than 80% of total CO_2 emitted in the energy sector, which is consistent with the energy balance of the inventory year. However, emissions from biomass energy have not added to total energy emissions, because it accounts, instead, to the land-use change and forestry sector.

Agriculture is the dominant sector in CH_4 emissions; it is estimated to contribute 1,713 Gg, or more than 86% of total CH_4 emissions in Sudan. Its share in the aggregated GHG emissions in CO_2 equivalent in 1995 is (56%), and it is the largest contributor.

GHG emissions from the industrial process sector are mainly CO_2. Their contribution to the aggregated GHG emissions in CO_2 equivalent in 1995 is less than 1%.

The results of GHG emitted from different types of waste management in Sudan showed that Methane is clearly the most important gas. The key waste sources are solid waste, domestic/commercial wastewater and industrial waste water and sludge. However, their contribution in the aggregated GHG emissions in CO_2 equivalent in 1995 is only about 1%.

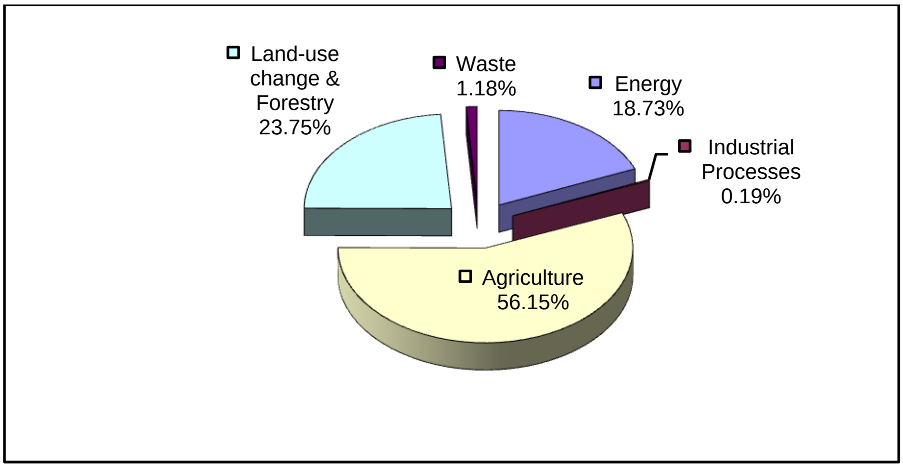

Figure 3 Percentage Contribution by Sector to the Aggregated GHG Emissions in CO_2 equivalent in 1995 (Inventory)

Source: First National Communication (2003) and compiled by the National Mitigation Team Analysis of Sectors in relation to Development priorities

The next step after identifying sectors with high GHG emission is to carry out an analysis of these sectors from the development point of view. The analysis includes assessing their social and environmental benefits which include issues such as contribution to basic needs (food, welfare services).

Following these criteria and considering the above selected sectors it could be seen that energy contributes much to services by providing electricity which is a crucial need for the different aspects of development.

Contribution to GDP in terms of export increase or providing employment is relatively low. Forestry, agriculture and other land use (AFOLU) provide more than 70% of Sudan's employment chances and produce major exports commodities. Furthermore, development of the AFOLU sector is highly connected to food security. Therefore; Sudan's National Strategic Plan calls for giving special attention to the AFOLU sector after the oil boom and many projects have been rehabilitated or established with special emphasis on environmental conservation and substantial natural resource management. In this context, forests and other wood land areas that help combat desertification and sustain biodiversity have been given considerable attention.

On considering industry and waste sectors, it has been found that although both have minimum contributions to GHG emissions, industry plays an important role in the economics by encouraging export, providing food commodities, support employment etc. Under Sudanese conditions, it could be fairly stated that in spite of the negative aspects associated with waste management such as health and environment hazards and the economic and environmental benefits of some waste technologies such as recycling, industry should be given higher priority when considering the comparative importance of the two sectors.

Table 5 provides an overview analysis of the developmental aspects of each sector.

Table 5- Developmental Analysis of Main GHG Emission Sectors

Sector	Share in Emission (Inventory data)	Contribution to Socio-/Environmental Benefits	Level of Economic Benefits	
			Employment	GDP
Energy	High	Services	Low	Low
Agriculture, Forestry and Other Land Uses	Very high	Food security, biodiversity, densification,	High	High
Industry	Low	Food security	Low	Moderate
Waste	Very low	Pollution, health hazard and resources conservation	Very low	Very low

3.2Process criteria and results of sector/sub-sector selection

Prioritization Process (PP):

The process started by consulting the relevant documents, followed by identifying development priorities with focus on potential benefits to the specific sectors and sub sectors. This step followed discussions within the mitigation team and consequently agreeing on the relevant criteria for the sectors prioritization. The second level of prioritization has been done to select (sub-) sectors. The overall objective of this step is to identify areas where intervention would make a strong contribution in meeting the identified development priorities beside its ability to reduce GHG emissions/increase sink. The final decision on the sectors has been taken in close consultation with the stakeholders during the inception workshop.

Criteria used

The criteria used for identifying a TNA candidate sector are as follows:

- Contribution to greenhouse gas emission.
- The role in meeting the development priorities in the context of sustainable development in Sudan.
- Future development and GHG emission projection.

Results of Sectors/sub-sectors selection

The above analysis (table 5) resulted in identifying the following sectors:

- Agricultural, Forestry and Other Land Use (AFOLU)
- Energy
- Industry

An overview of the sectors and sub-sector selection procedure can be seen in figure 4 which shows the steps followed in the selection process.

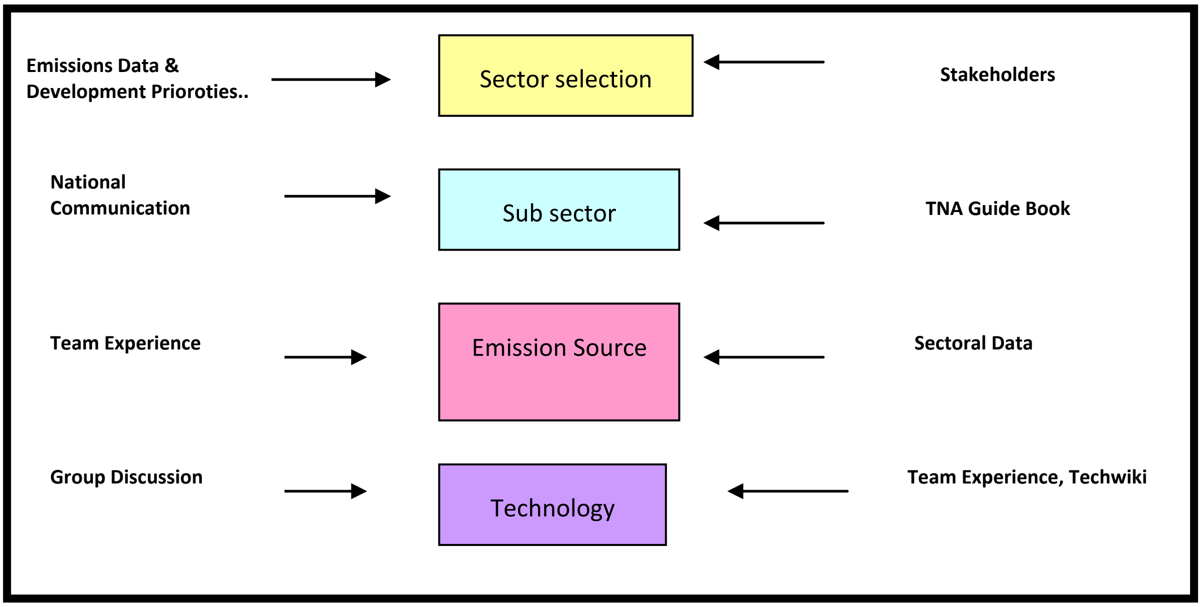

Figure 4 Sector Selection Process

The results of the prioritization process are summarized in table 6 which shows the sector, sub-sectors and areas of much consideration.

Table 6 - Summary of the prioritized sub-sectors/ areas

AFOLU Sector			
Sub-Sector: Agriculture		**Sub-Sector: Forestry**	
Livestock		Forest Conservation	Forest management
Manure management	Enteric fermentation		

Energy Sector	
Sub-Sector: Energy Generation and Consumption	**Sub-Sector: Fossil fuel consumption**
Thermal power generation and demand management	Transport

Industry Sector	
Sub-sector : Mineral (cement and other construction material industry) and construction industries	**Sub sector**: Food industry

Chapter 4: Technology Prioritization for Energy Sector

4.1 GHG Emissions and Existing Technologies of Energy Sector

The main GHG emission sources in this sector are the energy industries with 1,027 Gg of CO_2 and transport with 1,923 Gg of CO_2. Other consumption area includes residential energy consumption which produces 617Gg of CO_2.

The main existing technologies are the use of renewable energy-based technologies especially in the electricity production and consumption sub-sectors.

4.2 An overview of Possible Mitigation Options in the Energy Sector and their Mitigation Benefits

Electricity Production and Consumption

For the supply side the main goal is to reduce the consumption of the fossil fuel used in thermal power plants. This could be achieved through utilization of renewable energy technologies such as hydro, solar, wind and geothermal. On comparing solar and wind to geothermal, we could find that geothermal has higher plant availability and shorter transformation cycles, thus higher efficiency. Specifically (MED) calculation assumes 90% availability for geothermal, and an average of 29-30% for wind and solar (photovoltaic and CSP). From the potential point of view, geothermal potential in Sudan is estimated to be 500 MWe until 2030 (according to Kema Study). On the other hand, wind profile in Sudan is not favouring large power plants (limited areas of wind speed 7m/s and above). For solar energy, in spite of high solar radiation 6.4kW/m^2/day, but the high ambient temperature of >35°C is a limiting factor for photovoltaic systems. Another factor is the scattered solar radiation caused by atmospheric dust which reduces solar system efficiency up to 40%. For real development, this is very expensive and to a great extent is still a new technology. In general, the stakeholders opinion is that MED can be considered for building demonstration plants for solar and wind but these projects are rather limited. Instead, real reduction in GHG (alternative to thermal) can only be achieved through bigger projects such as geothermal. For stakeholders geothermal is a commercial technology with extensive technical know-how. Yet, the high production expected can counter the high costs for connection to NG.

Considering the demand side it has been concluded that that the residential sector is the major consuming sector for electricity. The consumption is projected to increase as more people are using more appliances. A large share of this consumption can be identified as unnecessary, due to the use of inefficient appliances. In addition, the stakeholders have mentioned that the city and house design is affecting the consumption especially at cooling and lighting systems. However, improvement of `city and house architecture` is looked into as a vague and not specific option. As a result of hard discussions, about reducing demand versus increasing supply, the main mitigation options considered is labelling the appliances. This system is envisaged to control the import of high energy consuming devices. Given the high electricity consumption for household lighting, special emphasis has been put on lamp bulbs (lighting). Ii has been calculated that if the CFL lamps were replaced for only 6 million lamps then a saving of 835,200.00 MWh equivalents to 251,395.20 GHG reduction (CO_2/year) could be attained.

Transportation

Transportation is a very crucial service in a vast country like Sudan. The main option for transportation is fossil fuel vehicles. One of the main consuming sectors is private transportation which is mainly done through cars or small buses, which leads to high emissions per person per km. The major mitigation options have been looked into as follows:

- Fuel switch: This option affects GHG emitted/m^3 of fuel. It requires switching/blending of fossil fuels with cleaner fuel such as bio- fuel or LPG with the objective of reducing the total GHG emissions from the vehicle. In this context, another factor that encourages the utilization of bio-fuel in Sudan is the establishment of the national project for bio- fuel with the overall objective of replacing the politically sensitive petroleum products. However, this option still needs extensive research programmes directed towards identification of the local values required for adopting a feasible implementation plan.
- Mass transport: This option (Vehicle type) affects fuel consumption/person, hence, the total GHG emitted for group of people. It involves encouraging the utilization of mass transport system verses private cars. It is found that the most common vehicles used in big cities of Sudan for person transport are either private cars or small buses with the capacity of less than 25 persons. This situation results in higher emission of GHG than that is expected when big buses of 60 + are used. It could be estimated that buses had 1/60 of the private car's emission per passenger/km, if fully occupied. A mass transportation system seems to be a very applicable and feasible option as it reduces pollution. In addition, mass transportation is expected to reduce road congestion and save travel time.
- Road building and design and driving mode: This factor includes in turn different sub factors such as driving style, traffic rules and road design which affects fuel consumption/km of roads. Some sub-factors are identified as more or less vague and not well defined such as driving style, and some issues such as traffic laws and street modification are expected to require complex financial and legal measures. As a result, the sub-factor **road design** has been considered for the ranking process. It has been identified as a long term but effective factor. Considering a current average mileage of about 5 km/litre then any improvement towards attaining the car industry mileage of 50-70 km/gallon will have positive similar effects on GHG.

4.3 Criteria and process of technology prioritization

Multi-criteria analysis has been used as a tool for prioritizing the suggested technologies. This has been done using an excel sheet provided by the team members. The criteria of selection adopted have been similar for all sectors and included the technology GHG reduction potential and second group of criteria related to developmental aspects (i.e., environmental, social and economic) . Any technology is scored from 0 to 10 for GHG reduction and from 0 to 15 for the development criteria (i.e., 0 to 5 for social; 0 to 5 for environmental and 0 to 5 for economic). The total is therefore equal to 25.

In the second workshop, the stakeholders agreed on indicators that are most suitable for each criterion. The ranking process in the energy sector has been undertaken according to the following indicators. As of result of absences of quantitative values for the different criteria more emphasis has been given to stakeholder's opinion based on their experience.

In electricity generation the indicators used are as follows:

- For GHG reduction potential

Criterion 1 (Cr 1): GHG emission reduction

This criterion deals with how much GHG is expected to be reduced on applying the specific technologies at a reasonable scale. In this context, geothermal has been given higher priority as it provides nearly zero emission and has high replacement potential. CFL has also been highly ranked as it highly reduced amounts of GHG emitted

- Environmental criteria

Criterion 2 (Cr 2): Pollution minimization

This criterion relates to the overall pollution level resulting from the power plant. Hence, due to hot water pollution, geothermal has been ranked lower in this criterion. On the demand size, it is connected to health hazards associated with utilization; hence, cooling system (e.g., Air Conditioning) has been ranked lower as a result of health hazards with which is associated (e.g., respiratory system dieses).

- Social criteria

Criterion 3 (Cr 3): Contribution to services

On the supply side, this criterion deals with the contribution to increased generation (service level increase). So, geothermal has been ranked higher due to its high availability factor. On the demand side, lighting has been looked into as an important factor in family welfare so CFL is highly ranked.

- Economic criteria

Criterion 4 (Cr4): Contribution to the reduction of State expenses by erecting high profitable power plants

On supply side, technologies that provide a long lifetime span and low costs are encouraged. All technologies have equally ranked because there is no significant difference between them to stakeholders.

On the demand side, the effect of the technologies on electricity bill reduction has been considered as an important indicator. The stakeholders have concluded that the high numbers of lamps/household in Sudan compared to the number of Air conditioning system results in equal electricity cost.

In Transportation the indicators are as follows:

- GHG reduction potential/Criterion 1 (Cr1)

Fuel switch, in particular bio fuel, is highly ranked due to its biomass sequestration nature.

- Environmental criteria criterion 2 (Cr2): Pollution minimization

Within this criterion it is clear that mass transport always generates less pollution per km compared to the car, even if car consumption of fuel/km is lower than the bus, the pollution per person remains high. Thus, Bio-fuel technology has highly been scored as it contributes to the environmental conservation.

- Social criteria/Criterion 3(Cr3): Contribution to services

The cost of private car is relatively high in Sudan, and hence, mass transportation facilitates the public mobility. In this context, stakeholders have highly scored the bio-fuel in this criterion for its contribution to employment.

- Economic criteria/Criterion 4 (Cr 4): Total cost needed and profit expected (investment, O&M, profit etc.)

Mass transport is cheaper compared to road design and building and to fuel switch.

Bio-fuel based transportation is considered a new technology therefore requires additional economic efforts compared to the two other options.

After scoring the technologies against the 4 criteria and during the stakeholder consultations, the standardization and the weighting steps have been undertaken and led to the results presented in tables 7 and 8 below.

Table 7 - Multi - Criteria Analysis for Electricity generation and consumption sub-sector– Sector Energy

MCA Energy
Electricity generation and consumption

Scoring

		Criteria 1	Criteria 2	Criteria 3	Criteria 4
		Cr 1	Cr 2	Cr 3	Cr 4
Tech 1	CFL	9	4	4,5	4
Tach 2	Geo	9	2	5	4
Tech 3	Wind	8	3	4	4
Tech 4	AC	8	3	3	4
Tech 5	CSP	8	3	3	4
Tech 6	SPV	8	3	3	4

Standardization

		Criteria 1	Criteria 2	Criteria 3	Criteria 4
		Cr 1	Cr 2	Cr 3	Cr 4
Tech 1	CFL	9	4	4,5	4
		1	1	0,75	1
Tach 2	Geo	9	2	5	4
		1	0	1	1
Tech 3	Wind	8	3	4	4
		0	0,5	0,5	1,00
Tech 4	AC	8	3	3	4
		0	0,5	0	1
Tech 5	CPS	8	3	3	4
		0	0,5	0	1
Tech 6	SPV	8	3	3	4
		0	0,5	0	1

Weighting

		Criteria 1	Criteria 2	Criteria 3	Criteria 4		
		Cr 1	Cr 2	Cr 3	Cr 4	Total	
Weight - Absolute		10	5	5	5	25	
Weight - Relative		0,4	0,2	0,2	0,2	1	
Tech 1	CFL	1	1	0,75	1		Ranking
		0,40	0,20	0,15	0,20	0,95	1st
Tach 2	Geo	1	0	1	1		
		0,40	0,00	0,20	0,20	0,80	2nd
Tech 3	Wind	0	0,5	0,5	1		
		0	0,10	0,10	0,20	0,40	3rd
Tech 4	AC	0	0,5	0	1		
		0	0,10	0,00	0,20	0,30	4th
Tech 5	CPS	0	0,5	0	1		
		0	0	0	0	0,30	4th
Tech 6	SPV	0	0,5	0	1		
		0	0,10	0	0,20	0,30	4th

Where: **CFL** = Compact Fluorescent Lamps; **GEO**= Geothermal '; **Wind** = Wind Turbines; **AC**= Energy Saver Air Conditioner Systems; **CSP** = Concentrated Solar Power; **SPV** = Solar Photovoltaic

Table 8 - Multi - Criteria analysis for Transportation – Sector Energy

Transport

Scoring

		Criteria 1 Cr 1	Criteria 2 Cr 2	Criteria 3 Cr 3	Criteria 4 Cr 4
Tech 1	MS	8	4	4	5
Tach 2	FS	8	5	4	3
Tech 3	RBD	6	3	5	4

Standardization

		Criteria 1 Cr 1	Criteria 2 Cr 2	Criteria 3 Cr 3	Criteria 4 Cr 4
Tech 1	MS	8	4	4	5
		1	0,5	0	1
Tach 2	FS	8	5	4	3
		1	1	0	0
Tech 3	RBD	6	3	5	4
		0	0	1	0,5

Weighting

		Criteria 1 Cr 1	Criteria 2 Cr 2	Criteria 3 Cr 3	Criteria 4 Cr 4	Total	Ranking
Weight - Absolute		10	5	5	5	25	
Weight - Relative		0,4	0,2	0,2	0,2	1	
Tech 1	MS	1	0,5	0	1		
		0,4	0,1	0	0,2	0,7	1st
Tach 2	FS	1	1	0	0		
		0,4	0,2	0	0	0,6	2nd
Tech 3	RBD	0	0	1	0,5		
		0	0	0,2	0,1	0,3	3th

Where MS=Mass Transport (buses); **FS**= Fuel Switch; **RBD**= Road Building and Design

4.4 Results of technology prioritization

Electricity

The MCA resulted in selecting the compact fluorescent lamps technology (CFL) as a priority within electricity production and consumption area.

Transportation

The results of the MCA place the mass transport technology (buses; 60+) as the first priority within the transportation sub sector. Therefore the two technologies selected in the energy sector are the CFL and the Mass Transport/Buses (+60).

Chapter 5: Technology Prioritization for AFOLU Sector

5.1 GHG Emissions and Existing Technologies for AFOLU Sector

The main emission sources in the agricultural sub-sector are enteric fermentation and manure management in the livestock, representing 1,632 Gg and 62 Gg of CH_4 respectively amounting to 34,272 Gg CO_2eq and 1,302 Gg CO_2eq respectively.

Within the forestry sector, a total of 15,577 Gg of CO_2 have been emitted as a result of change in forests and other woody biomass stock and forests and grassland conversion. Emissions from forestry represent 75% of total CO_2 emitted in Sudan. The main current technology involves afforestation and proper land management.

5.2 An Overview of Possible Mitigation Technology Options in AFOLU Sector and their Mitigation Benefits

Forestry

The mitigation options technologies can be classified into two main groups:

Technologies related to the afforestation option aim at increasing the sequestration rate. This option includes the application of mechanized systems to replace the manual-labour system used in the different steps of land preparation, tree plantation etc. Alternatively, planting fast growing species with higher sequestration rate is an option to reduce CO_2 emissions. However, the introduction of new suitable species with high sequestration rate is a complicated option and requires considering different aspects such as water requirements, soil type, matching to the ecosystem, socio economics benefits, etc. Hence this option has not been favoured.

The other options is related to the management technologies which tend to reduce the GHG emissions resulting from the forest utilization such as establishing fire line to control haphazard forest fires or utilization of improved stoves to reduce forest cutting. Considering the energy issues main fuel wood consumption sector, it has been found that most traditional stoves are inefficient because of their improper design and material selection. Improved stoves that have better efficiency or stoves that use other fuels such as agricultural residues have been suggested. In addition, biogas based burner or solar cooker have also been considered. As result of stakeholders consultation, preference has been given to the commonly known "improved mud stove" (Butana) due to its simplicity and wide utilization in the rural and semi urban areas of Sudan.

Livestock

The mitigation technology available for manure management includes aerobic or anaerobic fermentation processes and biogas or compost reactors that prevent releasing fermentation gases (mainly methane) to the open air. Both processes reduce GHG emission and produce fertilizer. The biogas provides an extra clean energy source that contributes to the provision of light, heat and the reduction of fuel wood uses.

Regarding the enteric fermentation which is a natural process, the mitigation options available are either feed change or improved digestion process by modifying the genetic formation through breeding and inter crossing. However, within the Sudanese context, improved feeding practices (ration changes) or the use of specific additives that suppress methanogenesis (the chemical process that creates methane) will be only more suitable than breeding for closed husbandry systems. When dealing with open systems, breeding can be more suitable as the interference only occurs once; then it *goes by itself*. However, from an application span and technical know-how perspective, ration change has been considered for application as presented in the fact sheet.

5.3 Criteria and Process of Technology Prioritization

Forestry

The designed methodology as explained in the energy sector has also been adopted in the AFOLU, hence, the criteria is the increase of GHG sequestration/reduction of GHG emission and developmental criteria namely social, economic and environmental. Under these criteria the following indicators have been selected.

In forestry the criteria and related indicators are as follows:

- GHG reduction potential/Criterion 1: GHG emission reduction/carbon sequestration
- For this criterion the Improved Stoves (IS) is firstly ranked because it saves existing sink in immediate term. Other technologies tend to establish new forest stands which needs time. Tractor technologies have secondly been ranked due to the fact that they enhance forest operation and practices in a relatively short time.
- Environmental criteria/Criterion 2: forest environmental benefits (non forest products, pollution reduction, sustaining biodiversity)
- Within this criterion, IS has highly been ranked because it conserves trees immediately and hence sustains the forest function. The tractors come second as they have relatively quicker effects than the other technologies. Water technology has highly been ranked as it improve the overall environment of the region.
- Social criteria/Criterion 3: Contribution to improved livelihood patterns and welfare of local communities stakeholders consider that supporting rural communities can be accomplished by increasing non-wood benefits, (e.g., gum, fibre, dye, medicine and food). Keeping forest stands will partially contribute to rainfall pattern and soil fertility. This results in local people having higher levels of welfare. However, tractors have low been ranked as they are likely to reduce employment. In addition, water collection points resulting from water technology may attract outsiders thus initiating conflicts so it has lower been ranked.
- Economic criteria/Criterion 4: Total cost of establishing the project without considering the technology itself.

According to the discussions carried out, this issue can be tackled as follows: All four chosen technologies, except the water harvesting technology are already known in Sudan’s forestry sector. In fact, several projects using these technologies have already been established. Thus the costs to establish a new project are relatively low and hence highly ranked; only the water shed technology is a new project and needs more effort when establishing it.

In livestock the criteria and related indicators are as follows:

- GHG reduction potential/Criterion 1: GHG emission reduction
- Anaerobic fermentation has highly been ranked as it is a proved technology which reduces the GHG significantly while the others are more or less under research.
- Environmental criteria/Criterion 2: Minimization of pollution and health risks
- Anaerobic fermentation will reduce the health risks caused by the untreated dung. The side effects of ration change and breeding technologies are not well known so they may cause health risk.
- Social criteria/Criterion 3: Contribution to local community welfare and services level

It is the stakeholder agreement that erecting biogas units for anaerobic fermentation to produce combustible gas can support the provision of electricity and cooking fuel for the community.

- Economic criteria/Criterion 4: Contribution to the local economy in terms of improving local economy and jobs creation.

It has been agreed upon that provision of services such as energy from anaerobic digesters, compost from aerobic digesters will improve the local economy so they have highly been ranked. The same thing for the Improved feed ration technology because it incorporates other feed additives that would improve the livestock health and growth.

Forestry

Table 9 - Multi - Criteria Analysis for Forestry Category - AFOLU sector

Scoring

		Criteria 1	Criteria 2	Criteria 3	Criteria 4
		Cr 1	**Cr 2**	**Cr 3**	**Cr 4**
Tech 1	**AUM**	8	4	2	4
Tach 2	**WHSWT**	4	3	2	3
Tech 3	**MFSDF**	5	4	3	4
Tech 4	**Compost**	2	3	4	4
Tech 5	**IS**	9	5	5	4

Standardization

		Criteria 1	Criteria 2	Criteria 3	Criteria 4
		Cr 1	**Cr 2**	**Cr 3**	**Cr 4**
Tech 1	**AUM**	8	4	2	4
		0,86	**0,5**	**0**	**1**
Tach 2	**WHSWT**	4	3	2	3
		0,29	**0**	**0**	**0**
Tech 3	**MFSDF**	5	4	3	4
		0,43	**0,5**	**0,33**	**1**
Tech 4	**Compost**	2	3	4	4
		0	**0**	**0,67**	**1**
Tech 5	**IS**	9	5	5	4
		1	**1**	**1**	**1**

Weighting

		Criteria 1	Criteria 2	Criteria 3	Criteria 4		
		Cr 1	**Cr 2**	**Cr 3**	**Cr 4**	**Total**	
Weight - Absolute		**10**	**5**	**5**	**5**	**25**	
Weight - Relative		*0,4*	*0,2*	*0,2*	*0,2*	*1*	
Tech 1	**AUM**	**0,86**	**0,5**	**0**	**1**		**Ranking**
		0,34	**0,10**	**0,00**	**0,20**	**0,64**	**2nd**
Tach 2	**WHSWT**	**0,29**	**0**	**0**	**0**		
		0,11	**0,00**	**0,00**	**0,00**	**0,11**	**5th**
Tech 3	**MFSDF**	**0,43**	**0,5**	**0,33**	**1**		
		0	**0,10**	**0,07**	**0,20**	**0,54**	**3rd**
Tech 4	**Compost**	**0**	**0**	**0,67**	**1**		
		0	**0,00**	**0,13**	**0,20**	**0,33**	**4th**
Tech 5	**IS**	**1**	**1**	**1**	**1**		
		0,4	**0**	**0,2**	**0**	**1**	**1st**

Where **AUM** =Afforestation Using Machines; **WHSWT**= Water Harvesting &Soil Working Techniques; **MFSDF**= Mobile Fencing for Sand Dune Fixation Compost = Composting of Forest Residues; **IS** = Improved Stoves

Table 10 - Multi - Criteria Analysis for Livestock Category – AFOLU

Scoring

		Criteria 1 Cr 1	Criteria 2 Cr 2	Criteria 3 Cr 3	Criteria 4 Cr 4
Tech 1	**IF**	8	3	4	4
Tach 2	**DA**	4	2	3	2
Tach 3	**Breed**	5	3	3	3
Tach 4	**ANT**	9	4	4	4
Tech 5	**AT**	6	3	3	4
Tech 6	**Compost**	7	3	4	4

Standardization

		Criteria 1 Cr 1	Criteria 2 Cr 2	Criteria 3 Cr 3	Criteria 4 Cr 4
Tech 1	**IF**	8	3	4	4
		0,8	0,5	1	1
Tach 2	**DA**	4	2	3	2
		0	0	0	0
Tech 3	**Breed**	5	3	3	3
		0,2	0,5	0	0,5
Tech 4	**ANT**	9	4	4	4
		1	1	1	1
Tech 5	**AT**	6	3	3	4
		0,4	0,5	0	1
Tech 6	**Compost**	7	3	4	4
		0,6	0,5	1	1

Weighting

		Criteria 1 Cr 1	Criteria 2 Cr 2	Criteria 3 Cr 3	Criteria 4 Cr 4	Total	
Weight - Absolute Ponderation		**10**	**5**	**5**	**5**	**25**	
Weight - Relative Ponderation		**0,4**	**0,2**	**0,2**	**0,2**	**1**	
Tech 1	**IF**	0,8	0,5	1	1		**Ranking**
		0,32	**0,1**	**0,2**	**0,2**	**0,82**	**2nd**
Tach 2	**DA**	0	0	0	0		
		0	**0**	**0**	**0**	**0**	**6th**
Tech 3	**Breed**	0,2	0,5	0	0,5		
		0,08	**0,1**	**0**	**0,1**	**0,28**	**5th**
Tech 4	**ANT**	1	1	1	1		
		0,4	**0,2**	**0,2**	**0,2**	**1**	**1st**
Tech 5	**AT**	0,4	0,5	0	1		
		0,16	**0,1**	**0**	**0,2**	**0,46**	**4th**
Tech 6	**Compost**	0,6	0,5	1	1		
		0,24	**0,1**	**0,2**	**0,2**	**0,74**	**3rd**

Where **IF** = Improved Food Ration; **DA** = Dietary Additives; **Breed** = Breeding Technologies; **ANT**= Anaerobic Fermentation; Aerobic Fermentation; **Compost** = Compost of Animal Dung

5.4 Results of Technology Prioritization for the AFOLU sector

Forestry

The results show that improved stoves technology has the higher priority. This selection also fills the gap within the energy sector and household category, in particular energy used for cooking.

Livestock

Within this category the anaerobic fermentation technology, biogas unit, has been given the highest grade. Therefore, it has been selected to be the highly prioritized mitigation technology option.

Chapter 6: Technology Prioritization for Industry Sector

6.1 GHG emissions and existing technologies of Industry Sector

The main sources of GHG emission in the Industrial sector considering process side is estimated at 173 Gg of CO_2eq mainly from mineral industries (cement industry, road paving and lime production). Food industries such as sugar, and food and drinks emit 11Gg NMVOCs. Considering the energy utilization component, the industrial sector has recorded 586 Gg of CO_2 eq.

6.2 An overview of Possible Mitigation Options in Industry Sector and their Mitigation Benefits.

The mitigation option in industrial sectors could be classified into two main options: One is concerned with the increase of energy efficiency through using more efficient boilers or using less polluting energy sources such as tyres, bio-diesel, LPG or through the introduction of renewable energy technologies. The other option for GHG reduction involves a change of process or introducing alternative products. This is specifically applicable in categories like cement through using pozzolans which is a material that can reduce the GHG emitted during cement formation process, or shifting to stabilized bricks rather than the fired bricks.

6.3 Criteria and Process of Technology Prioritization

The designed methodology as explained in the energy sector has also been adopted in the industry sector. Consequently, the criterion used reduces the GHG emission. On the other hand, the developmental criteria include social, economic and environmental factors. Under these criteria the following indicators have been selected:

Industry criteria and related indicators are as follows:

- GHG reduction: Within this criterion the GHG reduction with efficient boilers is greater than without upgrading the boilers (2^{nd} option). Replacement of bricks will highly reduce the GHG pollution; however some energy is needed to run the stabilizing machine. Hence, score 9 is given.
- Environmental criteria/Criterion 2: It contributes to the pollution reduction and the degree of being environmentally friendly
- Social criteria/Criterion 3: It adds to services with special emphasis on housing and food security; it also contributes to better work environment.
- Economic criteria/Criterion 4: It deals with cost effective project establishment and rewarding revenue.

Table 11 - Multi -Criteria Analysis for Industry Sector

Scoring

		Criteria 1 **Cr 1**	Criteria 2 **Cr 2**	Criteria 3 **Cr 3**	Criteria 4 **Cr 4**
Tech 1	**EB**	9	5	4	5
Tach 2	**WU**	8	5	5	4
Tech 3	**CSEB**	9	5	3	4
Tech 4	**Pozz**	8	4	3	2

Standardization

		Criteria 1 **Cr 1**	Criteria 2 **Cr 2**	Criteria 3 **Cr 3**	Criteria 4 **Cr 4**
Tech 1	**EB**	9	5	4	5
		1	**1**	**0,5**	**1**
Tach 2	**WU**	8	5	5	4
		0	**1**	**1**	**0,67**
Tech 3	**CSEB**	9	5	3	4
		1	**1**	**0**	**0,67**
Tech 4	**Pozz**	8	4	3	2
		0	**0**	**0**	**0**

Weighting

		Criteria 1 **Cr 1**	Criteria 2 **Cr 2**	Criteria 3 **Cr 3**	Criteria 4 **Cr 4**	**Total**	
Weight - Absolute Ponderation		**10**	**5**	**5**	**5**	**25**	
Weight - Relative Ponderation		***0,4***	***0,2***	***0,2***	***0,2***	***1***	
Tech 1	**EB**	**1**	**1**	**0,5**	**1**		**Ranking**
		0,4	**0,2**	**0,1**	**0,2**	**0,90**	**1st**
Tach 2	**WU**	**0**	**1**	**1**	**0,7**		
		0	**0,2**	**0,2**	**0,13**	**0,53**	**3th**
Tech 3	**CSEB**	**1**	**1**	**0**	**0,7**		
		0,4	**0,2**	**0**	**0,13**	**0,73**	**2nd**
Tech 4	**Pozz**	**0**	**0**	**0**	**0**		
		0	**0**	**0**	**0**	**0**	**4th**

Where as EB = Efficient boilers With Dual Fuel LPG/Traditional Fuel; WU= Waste Utilization, Energy Efficiency and Saving for Cement Industry; CSEB= Compressed Stabilized Earth Blocks; Pozz = Pozzolans Substitute for Clinker Formation in Cement industry

6.4 Results of technology Prioritization and Ranking

The process of the technology prioritization resulted in having efficient boiler with dual fuel (LPG and Diesel/furnace) as the highest prioritized technology

Chapter 7: Summary & Conclusion

The Technology Needs Assessment Project (TNA) is performed based on the agreement signed between the Republic of Sudan represented by the Higher Council for Environment and Natural Resources (HCENR) and the United Nations Environmental Program (UNEP) Risoe Centre (URC), Denmark, and supported by the Global Environmental Facility (GEF) grant financing. The UNEP, through its Division of Technology, Industry and Economics (DTIE) is responsible for the implementation of the project and provides overall project oversight and strategic coordination. The technical and process support to the participating countries in Africa have been provided through the Environmental Development Action in the Third World (ENDA).

Technology Need Assessments (TNA) is executed in 36 countries on two rounds. In the first round the project has been executed in 15 countries, in its second round the project has been executed in 21 developing countries in Asia, Africa and Latin America. The main objective of the TNA project is to identify suitable technologies in each country that can contribute to the local efforts paid to mitigate and /adapt to climate change phenomena.

The (TNA) project covers two Climate Change Areas: Mitigation and Adaptation. This report is concerned with the mitigation options which identify technologies that can limit growth in Greenhouse Gases (GHG) emissions within the context of sustainable development.

The first step in this work is to establish project implementation structure including project coordinator, the national team and wide spectrum of stakeholders. The Management of this project is hosted within the climate change unit of the Higher Council for Environment and Natural Resources (HCENR). Great attention has been given to the continued consultation process with the stakeholders in every step of the project. This has been possible by different ways of communication including; two national consultation workshops, a series of sector meeting and working sessions. One of the main outcomes of project methodology is the establishment of a motivated network that can further assist in implementing the outcomes of this study or even any climate change project. Additionally, two regional workshops have been held in order to facilitate capacity building and experience exchange.

The methodology adopted in the identification process is composed of four consecutive steps. The first step (sectors/subsectors identification) has been undertaken by the national team and presented to discussion in the first consultation workshop. This step has been conducted to identify, rank and select the main sources of GHG emissions in the country as reported in the Sudan’s First National Communication under the United Nations Framework Convention on Climate Change (UNFCCC). Secondly the developmental plans and strategies, whether at a macro or sector level, have been thoroughly studied with the aim to identify and classify the developmental priorities in Sudan. Further, modifications of the sector content to match the TNA guidelines have been carried out. Lastly, a process of subdivision into the sub-sectors has been undertaken. Two combined criteria have been taken into consideration for assessing the technologies; contribution to development and to reduction of GHG emissions. The highest prioritized sectors have been chosen for further investigation. Further on, main emissions sources have been identified in each sub-sector. The activities responsible for these emissions have been highlighted and their contribution to the sustainable development has been assessed. This sector/sub-sector identification process resulted in identifying the following sectors:

- Agriculture, Forestry and Other Land Use sector (AFOLU) which includes agriculture, livestock, and crop production, in addition to forest and other land-use such as range.
- Energy sector which is composed of; (i) electricity production and consumption (ii) household and transportation energy demand.

- Industry sector is where GHG emissions have been studied from both energy demand and the industrial process perspectives.

The second step involves the process of technology identification. This process started by holding a set of meetings between the stakeholders and the national team members who coordinated this sector. It resulted in the preparation of a long list of technologies; each technology has been described according to Technology Fact Sheet requirements. The third step has taken place during the second national workshop; a process of multi criteria decision analysis (MCDA) has been conducted. The adopted criteria are as follows: High GHG reduction potential/high sequestration potential as main criteria, the second criterion is the developmental criterion which includes environmental, social and economic criteria. The MCDA process starts by agreeing upon the suitable indicator for each sub-sector. Ultimately, ranking process took place and short list of technologies has been created. As result of consultation and information obtained in the second regional workshop, the list has further been refined. The final selected technologies are; for the AFOLU sector/livestock subsector the manure management technology through installing biogas units has first been selected. The use of improved stoves has been identified as the highest ranking technology in the forest subsector. For the energy sector, mass transportation has been identified within the transportation sub-sector. For energy sector, electricity production and consumption, Compact Fluorescent Lamp (CFL) has been selected as the technology of highest priority. In the industry sector efficient boilers using dual fuel has been selected as the highest prioritized technology.

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Annexes

Annex 1 Technology fact sheets

Sector: Energy.

Sub sector: Energy supply

Technology: Geothermal power technology

A.1 Introduction

Geothermal energy originates from the high-temperature aquifers inside the Earth's crust at depths of between 1-4 Kilometres. These aquifers are surrounded by porous, soft rocks and/or sand and are heated by the Earth's heat. Hot water or steam within the aquifers could reach temperatures of over 300oC. This heat can be used for heating of buildings and/or production of electricity.

A.2 Technology characteristics

Geothermal electricity can be delivered to large grids and mini-grids. Large-scale plants are grid-connected and deliver power for base load purpose. A large-scale geothermal flash plant of (50 MW) capacity could have a load factor of 90%. Geothermal power is a reliable source of energy and commonly has high capacity factor of between 70 and 90% of installed capacity.

A.3 Country specific / applicability

Sudan has geothermal resource in different parts of the country which lead to facilitate the applicability of those technologies e.g. (Beoda desert, Red sea, Jabal Mara in western Sudan). The suggested Geothermal project 100MW will reduce 237,300 tonnes of CO_2 per year per megawatt hour of installed capacity, 2010 grid emission factor 0.301tonnes CO_2 per MWh how much potential

A.4 Status of technology in country

Geothermal is unexploited resource in Sudan. Recently Potential studies have been carried and a power project with total of 100 MW (location not identified) is now under study in Beoda desert (North West of Sudan). There is well organized administrative layout for all renewable energy technologies such as renewable energy Directorate at Ministry of Electricity and Dams (MED), Energy Research Centre and different universities but the status of technical know-how is limited.

A.5 Barriers

- High initial capital cost due to high exploration cost. ; Lack of private sector investment.
- Limited technical Know- how
- The exploration of the geothermal energy systems could be complex.

A.6 Benefits to economic / social and environmental development

Economic:

- Contribute to poverty reduction (provide jobs),
- Low operation & maintenance cost.
- Geothermal energy is an indigenous source of energy and reduces the need to import fossil fuels.

Social

• Social investment activities. Such as employment increase, upgrading of services level at project areas

Environmental

• Clean technology but some pollution due to hot water at rejects point is expected. Waste management issue is to be considered as some chemical may be used to prepare the extracted steam to the turbine quality.

A.7 Costs

Generally the capital cost of geothermal is very high comparing with conventional thermal plant, the capital cost of a MW of geothermal installation approximately about 4, 000,000 USD /MW (Energy Information Administration November 2010) (EIA). The advantage of this technology that it has low operation and maintenance cost. The exploration stage could take about 25% of the total investment costs.

Sector: Energy.

Sub sector: Energy Supply

Technology: Wind Energy on-Shore Technology

A.1 Introduction:

Wind energy is site specific technology depending mainly on local wind speeds. A large wind turbine primarily consists of a main supporting tower upon which sits a nacelle (the structure containing the mechanical to electrical conversion equipment). Extending from the nacelle is the large rotor (three blades attached to a central hub) that acts to turn a main shaft, which in turn drives a gearbox and subsequently an electrical generator

A.2 Technology characteristics

Sites in Sudan are grouped into classes based on the yearly average energy available ranging from 1 to 7; class 5-7 is classified as most suitable for electricity generation. However, only limited areas satisfy this condition namely at red sea cost, Doungla area- North Sudan and Nyla area- West Sudan. The primary perceived problem with wind energy is related to the intermittency of supply, the variability of wind on any given day, week or month means that the amount of power that is produced can change significantly accordingly and a stand by energy sources is thus required. Wind levels and thus power generation can be estimated or forecast from meteorological reports with a reasonable degree of accuracy. However, site readings with specific precautions and arrangement is required before final decision could be made.

A.3 Country specific / applicability

Sudan has wind potential for electricity generation in different parts of the country especially at red Sea coast and north Susan areas, as in Sudan wind atlas 2012.

A.4 Status of technology in country

Different academic and research institution had considered wind energy with some demonstration projects. Basic know how-how is available. Currently MED is erecting some wind energy projects with total of 120 MW: (Dongola 100MW& Nyala (west Sudan) 20MW) and other projects of 180 MW under study (Red sea).

A.5 Barriers

• Limited wind areas in Sudan

• High initial capital cost.

• Lack of skilled man power.

• Lack of private sector investment.

A.6 Benefits to economic / social and environmental development

Environmental

• Wind is zero air pollution systems however through study concerning effect on biodiversity and the ecological habitat in Sudan is not available

• Reduction of GHG; Dongola 100MW& Nyala 20MW wind farm can prevent the emission of approximately 76,500 & 15,300 tonnes of CO_2 per year with 29% plant factor and 0.301 t CO_2/ year Grid Emission Factor.

- Social

It will increase electricity production thus improving the services level, and enhance development.

Economic: Contribute to poverty reduction (provide jobs

A.7 Costs:

The capital cost of a MW of wind energy installation about 2, 130,000 USD /MW. The level cost of electricity from wind in 2009 (accounting for capital costs, lifetime O&M and typical financing costs) ranges between US$50 to 100/ MWh at good to excellent sites (IPCC, 2010).

Sector: Energy.

Sub sector: Energy Demand

Technology: Compact Fluorescent LampsA.1 Introduction

Compact Fluorescent Lamp (CFL) are lamps that provide low energy lighting service through the use of a compact fluorescent light bulb (7-20 W) which replaces the normal Tungsten filament light bulb (60-100W). Replacement of incandescent lamps by CFLs is seen as efficient technology for reducing both electricity demand and GHG emission.

A.2 Technology characteristics

• CFL contributes to energy security as they reduce the electricity demand.

• Calculations show that CFLs pay back the initial investment within 900 hours of operation and also contribute to a reduction in the electricity bill over the lifetime of the bulb.

• They have a variety of shapes and end fittings for use in all types of uses.

A.3 Country specific / applicability

The most prevailing lamps in Sudan are tungsten lamps. Savers lamps are of limited use although they can fit well to all electric systems applied.

A.4 Status of technology in country

Different effort are paid by different groups in this issue e.g. Ministry of Electricity and Dams (MED), is planning to replace Incandescent Lamps (ICLs) with high quality, long life (10,000 hours) energy efficient Compact Fluorescent Lamps (CFL)

A.5 Barriers

• Lack of Consumer Information, Consumer bias towards ICLs,

• Availability of CFL especially at poor, remote and rural areas

• High Price of CFL for consumer

• Absence of policy and regulation that encourage /enforce autonomous replacement.

A.6 Benefits to economic / social and environmental development

• The savings in energy can be in the order of 10-20 times the initial costs over their lifetime and provide a reliable lighting service. Reducing power consumption for lighting by up to 80% is estimated. CFLs last up to 10 times longer than ICLs. The ICLs collected will be destroyed according to the highest environmental standards, energy saving from replacing 6,000,000 ICLs (100W) by CFL (20W) will be 835,200 MWh annually, and thus this amount of electricity will be available for further expansion hence energy security level will increase.

• Support Poverty alleviation efforts

• Reducing energy bill for families by replacement of (60 W and100 W) (ICLs) by 20 w (CFL)

• Generate jobs in the local manufacturing project

• Introducing concept of Energy Efficiency to households in Sudan by providing them with first-hand experience of cost savings through reduced electricity bills alternatively providing them with extra electricity amount at no additional cost

• Replacing 6,000,000 ICLs (100W) by CFL (20W) will reduce (GHG) emissions by 251,395 tonne CO_2 annually and other pollutants.

A.7 Costs

The price of integrated CFL is typically 3 to 10 times higher than the incandescent lamp. The cost of the CFL is approximately 2 USD.

Sector: Energy.

Sub sector: Transport

Technology: Mass Transport (Buses 60+)

A.1 Introduction

Mass or Public transport is a shared passenger transportation service which is available for use by the general public, as distinct from modes such as taxi, car-pooling or hired buses. Public transport modes include buses, trolleybuses, trams and trains, rapid transit (metro/subways/undergrounds etc.) and ferries. Beside economic benefits, concern about air pollution and traffic congestion are the main driving forces for such technology

A.2 Country specific/ applicability

Mass transport or public transport started in Sudan before the 1950s, particularly in Khartoum the capital. The governmental owned company of mass transport appeared in Khartoum during the seventies and early eighties. During the late eighties and nineties the small scale private mode of transport dominated especially in Khartoum. Recently, a lot of buses are operating in Khartoum State, but still, there is a need to increase the number of buses.

A.3 Status of technology in country

The technology is well known and there is enough know how about it. The country’s national strategies are supporting the expansion in the mass transportation system.

A.4 Barriers

- Lack of transportation policies which encourage mass transport
- High upfront cost.
- Lack of hard currency to import the required buses
- Need for more road and re- structuring of existing roads
- Cultural aspects; people prefer to use small mass transport vehicles.

A.5 Benefits to economic / social and environmental development

- Safety and security as mass transportation is generally safer than private cars
- Reduction of air pollution
- Enhance mobility Equality by providing means of transport for disabled, children, elderly etc.
- Create jobs at bus system e.g. drivers, collectors, etc.
- Reduce country consumption on fossil fuel

A.6 Costs

The average price for the bus (60+) is about 175,000 USD

Sector: Energy.

Subsector: Transport

Technology: Blending Fossil Fuel with Biodiesel

A.1 Introduction

Biodiesel blend is a well-known technology worldwide it comprises blending of the vegetable oil especially the non-edible oil such as Jatropha oil with diesel fuel with different ratios to make a homogeneous blend that can be used in the diesel engines without any modification to the engine.

A.2 Technology characteristics

The main characteristic of this technology is that it does not need any modification to the original diesel engine (at specific blend ratio), and it is widely applicable in many countries. The technology also uses a renewable source of energy (Jatropha oil) thus emission sequestration state is attained

A.3 Country specific / applicability

The blend biodiesel technology can be applied in the country because of simplicity of the technology. The Jatropha tree is planted in Sudan as a pilot project and it shows good growing characteristics.

A.4 Status of technology in country

The technology is not applied yet but still under research.

A.5 Barriers

• Technical know- how especial in issues of converting to biodiesel and blending

• Lack of local values required to design a sustainable project

• There are no legislations that regulate the application of the technology.

• No investment in the technology yet.

• The cost may be higher.

• There is no enough awareness to use the technology.

A.6 Benefits to economic / social and environmental development

• Income generation to the producers.

• Create new jobs opportunities.

• Reduces pollution due to better combustibility.

• Contribute to the economic development of the country by saving hard currency for diesel importation.

A.7 Costs

The cost of using the bio fuel is not estimated yet in Sudan.

Sector: AFOLU.

Subsector: Forestry

Technology: Afforestation Using Machines (Tractors)

A.1 Introduction:

This technology is concerned with machine utilization like tractors in afforestation of extensive areas. This technology has the merits of fastness, time saving and minimization of labour cost.

A.2 Technology characteristics:

The technology is simple, not complicated and characterized by having more effective results than man power. The main challenge is to manage its scope and coverage. Main issues involve selection of the suitable machine grade and accessory to match the soil and the process.

A.3 The country specific applicability:

In Sudan this technology was applied in pilot scales (small scales) for carriage, pulling, road construction and fire lines clearing, seeding/planting, and transportation in difficult roads and during the rainy seasons in different mechanized agricultural schemes.

In Sudan the annual deforestation rate is estimated to be 2.4%. This gap could never be filled by labour work, especially under the rural – urban migration state. Additionally there is some difficult soil which could only be prepared through machines. The available technical Know-how available in the forestry sector and other sectors such as agriculture make its expansion a very feasible option.

A.4 Status of technology in country:

The technology is applied in limited forest areas in Sudan. Hence there is reasonable know how and experience. The main envisaged obstacle is to set up a solid maintenance program and to ensure the availability of spare part.

A.5 Barriers:

• High cost for the machine and high operation cost for fuel, maintenance etc.

•Carbon release, GHG emissions through Soil disturbance and Diesel fuel consumption.

• Limited know-how in some specific areas e.g. Advanced maintenance or computer based operation

A.6 Benefits to economic / social and environmental development:

• Increase of carbon stock through quicker afforestation rate

• It contributes to food security as it improves and protects soil, ameliorates climate, protects water sources and supports livestock and wildlife.

• Contribute to wood products satisfaction such as energy satisfaction (70% of energy in Sudan is forest dependent).

A.7 Costs

The cost of the tractor is approximately 31,000 USD.

Subsector: Forestry

Technology: Improved Cook Stoves (Mud Stoves)

A.1 Introduction:

Most of households in the rural, urban and semi urban areas use the traditional three stones open fire stoves to prepare their food. Some public institutions, especially khalwas, prisons and army camps also use the same stoves to prepare meals. It is recognized that the efficiency of the traditional stoves used are extremely low; hence a lot of fuel wood is burnt unnecessary leading to loss of forest cover which is an important sink for GHGs.

Over-reliance of biomass-based fuels and inefficient technologies such as traditional stoves has placed great pressure on local forests. According to National Forests Inventory the annual clearance of forest area in Sudan is about 36,975 Hectares. This has led to a tangible deficit between the annual consumption of forest products, 21 million m^3, and the annual growth rate and reforestation. The later produces only about 10 million m^3 annually. The result of such a non-sustainable exploitation of forest resources is continuous depletion of forest area. The share of the population with access to modern fuels in Sudan in 2007 was 7%, and made up of 6% LPG and 1% kerosene in absolute terms.

The intensive dependence on fuelwood (firewood and charcoal), in addition to decreased rainfall and land clearance for agricultural use, has led to an increasing depletion rate of these non- renewable natural resources, and has resulted in almost complete desertification in some parts of the Sudan (e.g., Eastern)

The total wood fuel consumed annually in Sudan is estimated to be over 4.4 Million tonnes (Forest Products Survey in Sudan, 1995). The traditional stoves cannot achieve complete combustion. Reason being, *first*; the physical design of these stoves is such that the fuel cannot vaporize and mix sufficiently with air, which is a requirement for complete combustion (Bailis, 2004). *Second*, the stoves have poor heat transfer efficiency to the cooking pot (Mark *et al.*, 2007), and *thirdly*, even though these stoves are individually small, they are usually numerous.

Improved cook stoves both for household and institutional uses are available in Sudan and produced locally by a limited number of trained artisans. The improved stoves are 35 % more efficient than the traditional three stone open-fire stoves. The improved *Badia* stoves proved to be the simplest, efficient, and easy to manufacture by rural artisans using locally available materials (clay, animal dung and locally available metal sheets for lining).

Improved Cook Stoves (ICS) reduce the rate of desertification as it uses small amount of fuelwood compared to traditional stoves. The average annual per capita consumption of fuel wood in Sudan was approximately 24.3 kg and 10.1 kg for rural and urban households, respectively.

A.2 Technology characteristics

Improved Cook Stoves (ICS) can be designed and built in various ways, depending on the local conditions. At their simplest, ICS provide an enclosure for the fire to reduce the loss of radiant heat and protect it against the wind. In addition, attention can be given to methods controlling the upward flow of the combustion gases, so as to increase the transfer of heat to the cooking pot. Many of these stoves are made of mud or sand since both are almost free and readily available. The design of the stove incorporates, among others, use of proper insulating material for insulating the combustion chamber to minimize heat loss and ensure high temperature inside to promote complete combustion. Limiting, limiting the amount of fuel inside the combustion chamber, preheating of combustion air.

A.3 Country specific / applicability

Key economic drivers of deforestation include

- High domestic fuel wood consumption; about 69.5 % of the wood consumption,
- The relative high cost of fuel wood and charcoal in comparison to household energy budget ;
- Minimum change for cooking behaviour.

A.4 Status of technology in country

Different institutions have worked on this issue, since mid-eighties, this include research institutes such as energy research centre, government institutes such as Forest National Cooperation, and NGOs such as Sudanese Environmental Conservation Society. Hence a relative basic state of know-how and experience exists. Improved cook stoves both for household and institutional uses are available in Sudan and produced locally by a number of trained artisans. On strategic level, lowering the deforestation is the main issue in all developmental plans.

A.5 Barriers

- Low budget for dissemination and training
- Administrative and organizational procedures in establishing production units
- Needed Budget to further optimize the design parameters
- Relative high cost of the ICS

A.6 Benefits to economic / social and environmental development

• Minimize the pressure on forests to provide wood fuel for cooking

• Improve economic situation through Job creation; improving house energy budget

• Improve the health conditions delivered from cooking with relatively a clean smokeless stove

• Saving time for women and children in collecting firewood, and reduce the burden of carrying wood long distances are also avoided

A.7 Costs

Main cost of the improved stoves is fixed cost (7 UDS) but the running cost is expected to be less than the traditional stoves.

Sector: AFOLU.

Sub-sector: Agriculture, (Manure Management)

Technology: Anaerobic fermentation (Biogas) technology

A.1 Introduction

Biogas technology is process through which animal dung could be processed an aerobically to produce flammable gas that be used in the different energy purpose. The dung sludge could also be used as fertilizer. The main merit here that the dung is not left to decompose (production of methane) and thus GHG reduction is attained. This is estimated by about 60% /kg VS of manure and further 21 %.which is warming potential percentage of Methane to CO_2

A.2 Technology characteristics

The technology takes place in a specific reactor that can have different designs and sizes; the process is highly affected by both intrinsic factors such as carbon /nitrogen ratio or external such as temperature. A limiting factor is the availability of water as biogas is a water based technology as generally the feed is only about 15% dry matter and the rest is water.

A.3 Country specific / applicability

Sudan has a high potential of animal dung resulting from livestock population which is estimated by 130 million and dung production up to 10 kg /animal /day and average methane content is 0.24 m^3/kg.

A.4 Status of technology in country

The technology is known in Sudan, different organizations and institutions have built and operate biogas units. The energy research centre had a research unit. Hence the basic know how is available. There is a plan now to disseminate the biogas units to 22,000 families in Sudan

The technology depends on self-built system which is high cost and requires a lot of time and effort. Recently a readymade unit project is being established.

A.5 Barriers

•Availability of the readymade biogas units

• Social acceptance

• Relative high cost of the unit

• Absence of encouraging political and legal framework

A.6 Benefits to economic / social and environmental development

• Enhance the employment at local level (dung collection and unit management) beside the provision of energy source for other needs e.g. cooking, lighting, electricity

• Left over dung is a pollution source and health hazard, Improvement of environment is expected as result of manure management

• Households no longer need to obtain wood for cooking, which can reduce deforestation levels

• Buying fuel e.g. kerosene, LPG, charcoal or fuel wood is no longer needed

A.7 Costs

Manufacturing or acquisition costs (production costs): all expenses and lost income which are necessary for the erection of the plant. In Sudan One unit of biogas reactor cost about 2000 USD

Operation and maintenance costs (running costs): acquisition and handling of the substrate (feedstock), if not acquired externally, feeding and operating of the plant; supervision, maintenance and repair of the plant; storage and disposal of the slurry; gas distribution and utilization;

Sector: AFOLU

Sub sector: Livestock (Enteric Fermentation))

Technology: Ration Modification for Livestock

A.1 Introduction

Ruminant animals have a unique digestive system. Ruminants possess a rumen, or large fore-stomach, in which microbial fermentation breaks down coarse plant material for digestion. Enteric fermentation enables ruminants to eat plant materials, but also produces CH4. During digestion, microbes present in an animal's digestive system ferment food consumed by the animal. This microbial fermentation process is referred to as enteric fermentation and produces CH4 as a by-product, which can be exhaled or eructated by the animal. The amount of CH4 produced and excreted by an animal depends primarily on the animal's digestive system and the amount and type of feed it consumes. Modified Ration feed is a technology that can reduce the methane production in the natural enteric fermentation process through Inhibition of methanogenesis stage in the digestion process or through reducing methane emission per kg of animal. This material includes:

• Halogenated compounds inhibit the growth of methanogenic bacteria (the bacteria that produce the methane), but their effects can also be transitory and they can have side-effects such as reduced intake.

• Condensed tannins, saponins, or essential oils. However, adding such compounds may have the negative side-effect of reduced digestibility of the diet.

• Hormonal growth implants do not specifically reduce methane emissions in itself, but by improving animal performance, they can reduce emissions per kg of animal product.

A.2 Technology characteristics

An animal's feed quality and feed intake affect CH_4 emissions. In general, lower feed quality or higher feed intake lead to higher CH_4 emissions. 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. As CH_4 emissions represent an economic loss to the farmer—where feed is converted to CH_4 rather than to product output then mitigating this emission is also farmer interest. This can take place either through replacing forages with the feeding which reduce quantity of gas emitted or through concentrates which may reduce the daily methane emissions /kg of animal. Feeding concentrates' benefits depend on whether the number of animals can be reduced or whether slaughter age can be reduced. In addition, it is important to consider how the practice affects land use, the nitrogen content in the manure and the emissions from transporting and producing the concentrates in the first place. In general the technology requires control over feed rations so it is more applicable to closed systems.

A.3 Country specific / applicability

Sudan has large wealth of livestock estimated to be 130 million head, out of which is 40 million head of cows. The contribution of enteric fermentation is significant estimated by 1,713 Gg of CH_4.

A.4 Status of technology in country

Ratio control is practiced for different purposes such as increasing dairy production but there is no significant application targeting reduction of GHG.

A.5 Barriers

• Limited Technical know –how

• High upfront Cost

• Open husbandry system which is prevailing in Sudan

A.6 Benefits to economic / social and environmental development

From the literature the socio-economic development and environmental protection contributions are as of yet not clearly quantified. However in the IPCC (2007) it appears that there is an economic benefit of improved feeding practices as efficiency increased in the livestock management system. The other aspects are uncertain and require more investigation.

A.7 Cost

It is difficult to enumerate the cost of mitigation because the diet manipulation options to reduce CH_4 emissions from enteric have costs that are subject to feed market instability. Furthermore, the availability of certain feed or oil types will vary by region and season in some, so it would be difficult to assign cost on a national level for diet manipulation.

Sector: Industry

Sub sector: Energy Industry

High Efficient Boilers for Steam Generation Using Dual Fuel.

A.1 Introduction

A boiler is a closed pressure vessel in which a fluid is heated for use external to itself by the direct application of heat resulting from the combustion of fuel (Solid, liquid, or gaseous) or nuclear energy. Energy efficiency in industrial power house depend on four factors, fuel type, combustion system limitations , equipment design and steam system operation requirements. The boilers should be designed in low maintenance and high efficiency; the burner should be compatible with boiler.

In Sudan we classified boilers as follows:

Fire –tube boilers, which are includes:

a) Locomotive fire-box boilers.

b) Vertical tubular boilers.

c) Horizontal multi-tubular boilers (used in a wide range).

60% out of the total number are using fuel oil which leads to pollution and production of CO_2 due to improper combustion control. Type (a) and (b) are using coal, but not widely. Majority of boilers used in Sudanese industry is old in design and inefficient.

Technology improvements for boilers focus on efficiency and low-cost design while giving increasingly more attention to air pollutant emissions which are carbon monoxide, hydrogen chloride , mercury as well as GHG such as CO_2 and No_x. The emission depends on fuel type (solid, liquid, gaseous). CO_2 emissions are based on input fuel emission factors corrected for boiler efficiency. Basic fuel emission factors are 50.29 kg CO_2/TJ for natural gas, for distillate fuel oil 69.33kg CO_2/TJ, for residual fuel oil 74.69 kg CO_2/TJ, for coal 89.08kg CO_2/TJ.

A.2 Technology characteristics

Improvement of efficiency of industrial boilers can be attained by adding advanced heat recovery and controls measures to the boiler system. Boiler units with high efficiency should have Maximum Continuous Rating (MCR) The technology involve replacing fuel oil and coal by LPG which has heating value of 32000kJ/kg. The burners should be upgraded by suitable dual burners system to LPG or for fuel-oil. Emission reduction in boilers depends on boiler efficiency and fuel type.

Using LPG with (different) efficiency boilers will reduce the CO_2 emission compared with other fuel Table 1.

Table 1 The relation between Boiler Thermal efficiency and CO_2Emission for different fuel

Boiler Thermal efficiency.	Emission preheat output(kgCO2/mm Btu)			
	Natural Gas(NG)	Distilled fuel oil	Residual fuel oil	Coal
80%	66.3	91.4	98.5	117.5
85%	62.4	86.1	92.7	110.6
90%	59.6	81.3	87.6	104.4
94%	56.4	77.8	83.8	100.0

Source: Climate leaders' greenhouse gas inventory protocol offset project

A.3 Country specific / applicability

Using high efficiency boilers will contribute positively in saving energy and consequently is saving money and using LPG as alternative fuel in steam generation has potential in Sudan, in spite of the fact that there is scarcity in the availability, some private gas company start to import mainly for industrial sector demand.

A.4 Status of technology in country

Majority of boilers used in industries are low efficient very few industries uses high efficient boilers. Less than 2% of industries are using LPG as fuel for boilers ignition, there is problem in burners that designed mainly for LPG it is expensive.

A.5 Barriers

• Specification of high efficiency boilers needs technical know-how with reference to type of industry.

• LPG fuel is flammable and toxic; it is proven to be extremely dangerous, leakage makes cause fire or explosions,

• Special requirement are needed to be transported to industrial sector.

• Scarcity of LPG in market for industrial sector, Household sector is given higher priority.

• Efficient and dual burner boilers are expensive.

A.6 Benefits to economic / social and environmental development

Environmentally: clean technology reduces the CO2 emission more 70 % in the case of complete combustion.

Economical: Low cost compared with fuel oil.

A.7 Costs

LPG is less in cost compared to Fuel- oil.

Tonne of LPG is 1200 SDG; Tonne of Fuel –oil is 2000 SDG, considering the Energy content of LPG to be 46.1 GJ/t and of fuel oil to be 42.5 GJ/t. Then the LPG cost is 26 SDG/GJ and fuel oil cost is 47 SDG/GJ

Burner cost 40000-80000 SDG depending on the capacity of the burner.

High Efficiency boiler cost depends on the type and size of boiler.

A.8 Others

The cost of the Fuel oil in the industrial sector is high and unavailable, so introducing LPG as alternative fuel will be solution for the industrial sector.

Sector: Industry

Sub-sector: Cement

Technology: Energy Efficiency and Saving in Cement Industry

A.1 Introduction:

The utilization of Waste Materials including the Scrapped Tyres (calorific value 35.6 MJ /kg) have been used for more than 20-years worldwide as alternative (secondary) fuel in the cement kilns.

Cement kilns are well suited for waste-combustion because of their high process temperature and because the clinker product and limestone feedstock act as gas -cleaning agents.

Used tyres, wood, plastics, chemicals and other types of waste are co-combusted in cement kilns in large quantities.

Plants in Belgium, France, Germany, the Netherlands and Switzerland have reached average substitution rates of from 35% to more than 70%. Some individual plants have even achieved 100% substitution using appropriate waste materials. (Energy Efficiency & Saving in the Cement Plants at http://ClimateTechwiki.org website).

The utilization of scrapped tyres as alternative fuel in cement kiln is a proven safe and effective technology that has already been used in some cement plants in USA, Germany, Japan and Egypt.

The cement industry in the United States burns 53 million used tyres per year, which is 41% of all tyres that are burnt and is equivalent to 0.39 Mt or 15 PJ. About 50 million tyres, or 20% of the total, are still used as landfill (Energy Efficiency & Saving in the Cement Plants at http://ClimateTechwiki.org website).

So, the scrapped tyres as alternative fuel is one of the most recommended types of waste that can be used as a secondary fuel in cement kilns - besides the fossil fuel. Since it has a high calorific value (32 MJ/kg) compared to other wastes and even the Coal (28 MJ/kg).

Besides, it is the safest method of disposal due to its considerable reduction and control in the generated amount of pollution emissions and especially the toxic gases like dioxin, due to kiln high temperature (900 – 1450 degree centigrade) and short time taken for complete combustion.

So, one metric ton of scrapped tyres can produce in average 6.5 – 8.2 tonnes of cement, and its utilization can represent 20 – 50% from the total amount of fuel been burnt in a kiln. And accordingly, it will reduce our usage of fossil fuels (Heavy Oil) which automatically reduce the extra CO_2 emissions generated from fossil fuels – compared to the amount of CO_2 generated by scrapped tyres. Besides, a considerable reduction (more than 50%) in the energy (fuel) cost.

Cement manufacturing produces CO_2 as it requires very high temperatures to burn raw materials and give the clinker its unique properties.

$CO_2$is generated from three independent sources: de-carbonation of limestone in the kiln (about 525 kg CO_2 per tonne of clinker), combustion of fuel in the kiln (about 335 kg CO_2 per tonne of cement) and use of electricity (about 50 kg CO_2 per tonne of cement).

There are three central measures by which the cement industry may save direct CO_2 emissions in the immediate future:

Improvement of energy efficiency (a maximum of 2% is still feasible),

Reduction of clinker/cement ratio, and

Increase in the use of waste as alternative fuel (national initiatives, adequate national implementation of certain directives regarding specific waste)".

A.2 Technology characteristics

The scrapped tyre can be used as a whole piece or in shredded forms – including or excluding (after the removal of) the steel wires. The usage of shredded scrapped tyres without the steel wires is most preferable option.

Firstly, the scrapped tyre should be properly classified and verified. Secondly, they need to be shredded into 25 – 50 mm chips, and then the steel wires will be removed. The third step is to feed the chips through the feeding belt and dosing system into calciner and/or kiln for combustion.

The high temperatures of the Kiln (1400 – 110 degree centigrade) and the calciner (1000 – 900 degree centigrade) will secure complete combustion free of toxic emissions like the generation of dioxin gases.

The combustion parameters & conditions need to be monitored and controlled effectively and carefully to secure complete combustion of tyres chips and to maintain the emissions within the acceptable limits.

Table (1): Estimated Cement Production per tonne of Fuel used

Fuel Type	Approximate CV"(MJ/kg)	Cement (Tonne)
Furnace Oil	40	**11**
Coal	28	**7.2**
Tyres	**32**	**8.2**

A.3 Country specific / applicability

Last year the Global demand for cement grew by 17% by the end of year 2011 to reach 3.8 billion metric tonnes – as per worldcement.com.

In Sudan, as per Ministry of Industry Records, the demand for cement and the design capacity of the cement plants during the previous three years – from beginning of year 2009 to end of year 2011, have been increased by almost 500%, reaching 3 million tonnes as consumption by end of year 2011, and 6.97 millions of metric tonnes as a total design capacity.

In Sudan the annual imported amount of tyres for different applications is estimated last year by 20,000 tonnes, and expected to reach 40,000 tonnes by end of year 2012.

Generally the new tyres lose about 20% of its weight before it has been scrapped. The steel wires represent about 15 – 25% of the tyre weight which encourage some people to burn the tyres in open areas to get use of the steel wires which has a considerable value.

A.4 Status of technology in country

This technology is of shredding & burning tyres is not introduced in Sudan yet.

A.5 Barriers

• Inaccurate dissemination of information; increases the worries of public and governmental authorities about managing (controlling & monitoring) pollution emissions; especially the toxic emissions like dioxin gas.

• The scrapped tyres are spread into wide areas all around the country, so it will be a difficult job to collect, classify and storing them properly, considering all the necessary precautions especially fire.

• The feasibility study will cost about 50,000 Euro, while the tendering, selection and purchase of equipment like shredding system, fuel handling and dosing system and the minor modifications need to be made in the cement kiln will cost about 1.6 million Euro in addition to 1.6 million Euro for civil work, erection, installation, commissioning, project management fees, consultancy fees and site preparations, etc.

• The duration for the execution of the project including the preparations of the pre-feasibility, comprehensive feasibility study will take about one year, including 7 months for supply and manufacturing of equipment.

A.6 Benefits to economic / social and environmental development

• The plan is to shred 25,000 tonnes/ year of scrapped tyres during the first four years of production to produce 5,000 tonnes/year of steel wires which cost more than 650,000 Euro per year. Moreover it produces about 150,000 tonnes of cement which will save about 15,000,000 SDG per year.

• The high revenue of the project will encourage the usage of other waste besides the scrapped tyres. The collected house hold waste in Khartoum state only is above 2,000 tonnes/ day, considering that the five big cement kilns located at 320 km north Khartoum can burn the majority of waste types and all the quantities available in Sudan.

A.7 Costs

A. Shredding System

• Equipment Cost = 1,000,000 Euro

• Other Costs = 1,000,000

B. Fuel handling & dosing System

• Equipment Cost = 600,000 Euro

• Other Costs = 600,000 Euro

C. Operational Cost

• Cost for 25,000 tonnes of scrapped tyres = 12,500,000 SDG (500SDG per tonne)

Other Costs = 7,500,000 SDG (General Estimation)

Sector: Industry.

Sub sector: Building

Technology: Compressed Stabilized Earth Blocks (CSEB)

A.1 Introduction

A compressed stabilized earth block (CSEB) is a new product, made of soil and stabilizer. The soil, raw or stabilizer, is slightly moistened, poured into a steel press (with or without stabilizer) and then compressed either with a manual or motorized press in the desired shape and size. This technology allows building of thin, water resistance and high walls which have high compression strength. Equipment for CSEB is available from manual to motorized tools ranging from village to semi industry scale

A.2 Technology Characteristics

It is a simple technology that doesn't requires previous skills; efficient training centre can transfer the technology in a week time. CSEB allow unskilled and unemployed people to learn a skill, get a job Since then, the production is made on the site itself or in the nearby area and utilizes local material then transportation chain will be shorter. The technology is more environmentally friendly by using bio-degradable material, parallel it doesn't consume fuel wood as the traditional bricks.

A.3 Country specific/applicability

There is good potential for the stabilizer material in different areas of Sudan. Explained by its technical characteristics the products have low technical performances compared to fired bricks is limited. Since the majority of the family houses in Sudan are single story building then the technology will have social acceptance. According to the local context (materials, labour, equipment, etc.) the final price will vary, but in most of the cases it will be cheaper than fired bricks. Furthermore, it will reduce imports of expensive materials or transport of heavy and costly building materials over long distances.

A.4 Status of technology in country

Different programs for CSEB building had been applied in different states in Sudan and proved to be appropriate and acceptable. The National Centre for Research had modified different types of machine and extended training programs for private sector and organizations (UN-HABITAT). Additionally, different machines had been designed and manufactured locally.

A.5 Barriers

• Lack of awareness among stakeholder and absence s of promotion programs.
• Limited technical know –how
• Proper soil identification is required.

A.6 Benefits to economic/ social and environmental development

- This technology reduced of pollution and GHG emission compared to fired bricks.
- Pollution emission (kg of CO_2 /m^2): 2.4 times lower than *wire cut* bricks and 7.9 times lower than *fired bricks*
- Energy consumption (MJ): 4.9 times lower than wire cut bricks; 15.1 lower than fired bricks

A.7 Costs

The main cost factors are distributed as follows: Labour: 20 - 25 % Soil & sand: 20 - 25% Cement: 40 - 60 % Equipment: 3 - 5 %,

Sector Industry

Sub sector industrial process- cement

Technology: Using Pozzolans in Cement Industry

A.1 Introduction

Pozzolan is a material which when combined with calcium hydroxide, exhibits cementitious properties. Pozzolans (the technical term is cement extender), are commonly used as an additive to Portland cement concrete mixture to increase the long term strength and to reduce the material cost of concrete.

Pozzolan is a siliceous or aluminosiliceous material which is highly vitreous. Pozzolans materials can be added to cement to extend its volume without a significant loss of properties .Generally Pozzolans materials do not require pre-processing and therefore can save very significant quantities of energy and lower CO2 emissions when supplementing regular cement.

Modern use:

Modern pozzolanic cements are a mixture of natural or industrial pozzolans and clinker of Portland cement, the high alkalinity of pozzolans makes it especially resistant to common forms of corrosion from sulphate. Once fully hardened it may be stronger than Portland cement only, due to its lower porosity, which also makes it more resistant to water absorption.

Some laboratory tests were carried out in Italy and industrial testing took place in Africa and India to Pozzolanic Material Activators (PMA's)

Low dosage (LD) of PMA between 300-500g/t

High dosage (HD) of PMA between 800-1200g/t

The results of industrial tests in the Table (1)

Table (1) : Industrial Trials, Pozzolan and fly Ash base cements-strengths MPA

Time	30% of Pozzolana in Africa			26% of Pozzolana in India		
	Blank	LD	HD	Blank	LD	HD
24 hr	12.1	14.8	16.2	14.3	17.4	19.2
2 days	17.5	20.0	22.4	24.7	27.3	29.9
28 days	34.1	38.6	40.1	45.9	50.4	52.0

Source: J. Bogerd, Italy (2011)

A.2 Technology characteristics

The availability of clinker substitutes is sufficient to allow the cement –to- clinker ratio to be reduced to 0.7 globally, theoretically enabling a saving of a further 15 tonnes of thermal energy. The global intensity of cement production could be reduced by 0.9GJ/t of cement produced, with significantly higher saving possible in many countries and regions (IEA2010). As calculated by the IEA2008 in total the savings potential for blended cements amounts to 300 Mt CO_2 to 450 Mt CO2 by 2050.

A.3 Country specific / applicability

Pozzolana is found in Sudan in Bayoda desert in north Sudan and Darfur in west Sudan. So the technology could easily be applied due to presence of natural material. The Pozzolana should be grinded and added to clinker after the ignition of lime stone and the added per cent could be 15- 35%. To be applied in building sector

A.4 Status of technology in country

The technology is new and has not been properly introduced in Sudan.

A.5 Barriers

•lack of research to know the specification of type of Pozzolana that exist in Sudan

• lack of awareness within the private sector mainly the cement factories, to use Pozzolana to reduce cost and emission.

• Lack of information regarding its applicability in building in Sudan compared to normal cement.

A.6 Benefits to economic / social and environmental development

This Pozzolanic cement is more environmentally friendly, it reduces GHG emissions and it also reduces the cost of industry.

A.7 Costs

Adding Pozzolana is assumed to reduce the cost in cement industry but exact information was not available

A.8 Others

Generally using Pozzolana will lead to huge saving in terms of costs and CO_2 emissions, thus generating vast opportunities business to create long-term growth in competitive and sustainable setting.

ANNEX II: List of Stakeholders Participating in the Inception and the Second Workshop

NO	Name	Institute
.1	Somaya Alsayid	Ahfad University for Women
.2	Nawal Hussain	Sudan Academy for Communication Sciences
.3	Nazik Hassan Ali Alawad	Ministry of Electricity and Dams
.4	Nuraldin Ahmed Abdalla Saaid	Meteorological Authority
.5	Nouralla Yassin Ahmed	National Energy Research Centre
.6	Iman Alrashid Diab	National centre for Research
.7	Sawsan Abdalla Ali	Forests National corporation
.8	Issam Aldin Ibrahim Abdalla	Ministry of Agriculture
.9	Haythum Kamal Aldin Abdalla	Kenana Sugar Company
.01	Almothana Saad Mohamed	Kenana Sugar Company
.11	Igbal Salah Mohamed Ali	Ministry of Water Resources
.21	Widad Motwakil Saadalla	Ministry of Water Resources
.31	Tarig Algamri Atta Almanan	National Centre for Research
.41	Hassan Wardi Hassan	Ahlia University
.51	Mona Mahjoub Mohamed Ahmed	Institute of Environmental Studies
.61	Aboubaida Alboukhari Ibrahim	Sudanese Industrial Chamber Association
.71	Abdelrahman Altahir Ahmed	Kenana Sugar Company
.81	Salah Aldin Ali Mohamed Nour	Ministry of Petroleum
.91	Abdelazim Widaa	Ministry of Petroleum
.02	Alrabia Mohamed Altahir	Ministry of Petroleum
.12	Mostafa Mohamed Altahir Atti	Ministry of Electricity and Dams
.22	Ikhlas Abdelaziz	Industrial Research Centre
.32	Sayed Hajalnour Ahmed	Ministry of Environment , Forestry & Physical Development
.42	Thuraya Najib	Practical Action
.52	Ahmed Sulaiman Alwakeel	Free Lance
.62	Arig Jaafar Mohamed	National Energy Research Centre
.72	Taghrid Abdelrahim Mohamed	Ministry of Water Resources
.82	Alwalid Abas Mohamed Alsaid	National Energy Research Centre
.92	Ali Omer Ahmed	National Energy Research Centre
.03	Hanadi Attaalfadil Mohamed	Ministry of Industry
.13	Amani Abdelmahmoud Ali	Ministry of Environment , Forestry & Physical Development
.23	Ismail Fadlalmoula Mohamed	Sudanese Meteorological Society
.33	Quosay Awad Ahmed Babiker	University of Khartoum, Petroleum Department
.43	Mohamed Saad Ibrahim Abdellatif	Ministry of Animal Wealth
.53	Najla Mahgoub Hamadain	Forests National corporation
.63	Awatif Abdalla Mohamed	Ministry of Animal Wealth
.73	D.Suad Ibrahim Jalalaldin	Ministry of Agriculture
.83	Naima Abedlgadir Hilal	Industrial Research Centre
.93	Farough Ismail Abdeljalil	Ministry of Industry
.04	Salah Yousif Mohamed Ahmed	Forests National corporation
.14	Amira Hasan Alam	Salam Company for Cement Production
.24	Ahmed Amer Mohamed	Shamal Company for Cement Production

.34	Abdelazim Yasin Abdelgadir	University of Khartoum, Faculty of Forestry
.44	Alyas Ahmed Alyas Ahmed	University of Khartoum, Faculty of Forestry
.54	Mohamed Ali Hamed	United Nations Development Program
.64	Osman Taha Alzaki	National Centre for Research
.74	Hayfa Hasan Fadul	Ministry of Science and Technology
.84	Omayma Mohamed Ahmed	Ministry of Agriculture
.94	Donya Hasan Khalafala	Ministry of Agriculture
.05	Somaya Ahmed Alzaki	Institute of Environmental Studies
.15	Asya Adlan Mohamed Abdalla	Institute of Environmental Studies
.25	Ali Mohamed Korak	Sudanese Association for Rural Afforestation
.35	Mohamed Yousif Mohamed Adam	Institute for Water Harvesting Research
.45	Sawsan Khair Alsid Abdelrahim	Range and Pasture Administration
.55	Alamin Sanjk Mohamed	University of Khartoum, Faculty of Forestry
.65	Mirghani Abnauf	Free Lance
.75	Dawoud Abas Osman	Sudanese Industrial Union
.85	Imadaldin Ahmed Ali Babiker	Agricultural Research Authority
.95	Abedlrahman Khidir Osman	Free Lance
.06	Mawahib Altayeb Ahmed	National Centre for Research
.16	Alfadil Biryma Hamed	National Energy Research Centre
.26	Salahaldin Hasab Elgabo	Ministry of Electricity and Dams
.36	Adam Musa Mohamed	Uinversity of Neelain
.46	Adel Abdalla Rabih	Ministry of Electricity and Dams
.56	Osama Salah Mohamed Ibrahim	Ministry of Electricity and Dams
.66	Zuhair Mohamed Alsheikh Dafalla	Ministry of Electricity and Dams
.76	Samya Yousif Idris Habani	National Council
.86	Amiral Elnour	Ministry of Industry
.96	Abdelrahman Altahir Ahmed	Kenana Sugar Company
.07	Mustafa Mohamed Salih Agha	Ministry of Electricity and Dams
.17	Dirar Hasan Nasr	University of Red Sea
.27	Ali Mohamed Ali	Higher Council for Environment & Natural Resource
.37	Mutasim Bashir Nimir	Higher Council for Environment & Natural Resources
.47	Amal Abdelgadir Hasan	Ministry of Agriculture
.57	Mahasin Balla Ahmed Babiker	Ministry of Agriculture
.67	Alawiya Yousif Mohamed	Ministry of Agriculture
.77	Maha Ali Mohamed	Ministry of Agriculture
.87	Ayman Mohamed Abdin	Ministry of Agriculture
.97	Dirar Ibrahim Dirar	Ministry of Agriculture
.08	Khalid Ahmed Ali	Ministry of Agriculture
.18	Asma Abobakr Ismail	Higher Council for Environment & Natural Resources
.28	Adel Mohamed Ali	Higher Council for Environment &Natural Resources
.38	Yasir Alzain Ahmed	Higher Council for Environment & Natural Resources
.48	Mohamed Ahmed Yousif Hamad	Higher Council for Environment & Natural Resources

.58	Mohamed Yousif Mohamed	Technology Transfer and Agricultural Extension
.68	Amani Abdelmahmoud Ali	Ministry of Environment , Forestry & Physical Development
.78	Nadir Mohamed	Sudanese Environmental Conservation Society
.88	Taysir Ismail Idris	Ministry of Agriculture
.98	Howida Mirghani Almrdi	Ministry of Agriculture
.09	Wigdan Mohamed Ibrahim	Higher Council for Environment & Natural Resources
.19	KhadijaYounis Abdelmawla	University of Bahri
.29	Hasan Bashir Nimir	University of Khartoum, Petroleum Department
.39	Nagmaldin Goutbi Alhassan	Higher Council for Environment & Natural Resources
.49	Ahmed Mohamed Abdelkarim	Meteorological Authority
.59	Hiba Mahjoub Hasan	Higher Council for Environment & Natural Resources
.69	Mohamed Altahir Mohamed	Higher Council for Environment & Natural Resources
.79	Dinan Babiker Elkhalil	Higher Council for Environment & Natural Resources
.89	Mahjoub Hasan	Ministry of Environment , Forestry &Physical Development
.99	Ahmed Ibrahim Ahmed	Ministry of Transportation
001	Abdelrahmen Elamin	EWASCO Company
101	Hana Hamadalla Hamad	Higher Council for Environment & Natural Resources
201	Fathalrahman Ahmed Mohamed	Ministry of Agriculture
301	Daoud Abbas	Sudanese Industrial Chamber Association
401	Mohamed Aljak Sulaiman	Industrial Research Centre
501	Seif Eldin Abdalmageed	Ministry of Labour
601	Alam Sighayroun Mohamed	Sudanese Industrial Chamber Association
701	Yasir Abdelkarim Abdelaziz	Sudanese Industrial Chamber Association
801	Salwa Hamza Ali	Sudani Newspaper
901	Ishraga Alhilo	Sahafa Newspaper
011	Shza Alrhma	Alray Ala'am Newspaper