Opportunities for Low Carbon Investment in Tanzania

An assessment of future emissions growth and low carbon reduction potential

Submission to the Development Partners Group, December 2010

Global Climate Adaptation Partnership

SEI Stockholm Environment Institute

DEW Point Development Resource Centre Environment – Water – Sanitation

For

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Development Partners Group

Summary

The development partners group, with funding from UK (DFID) Government, are funding a study on the '*Economics of Climate Change in Tanzania*'. The work is led by the Global Climate Adaptation Partnership, together with the Stockholm Environment Institute, working with other international and local partners, and is assessing the impacts and economics costs of climate change, the costs and benefits of adaptation and opportunities for low carbon investments for the United Republic of Tanzania.

This report focuses on the potential for low carbon opportunities and the financing that could flow from such projects. Tanzania needs additional investment to facilitate growth that is more sustainable than the current pathway. This could be achieved through using financing mechanisms that provide funding for projects and programmes where greenhouse gas (GHG) emissions reductions can be demonstrated. In addition to reducing carbon, many of these options could lead to more sustainable growth through protecting natural resources, improving environmental quality, delivering economic opportunities and reducing reliance on fossil imports.

The analysis focuses on the following:

- The future emission profile for Tanzania and the key opportunities for investment in low carbon technologies or options across different sectors;
- Consideration of carbon finance and co-benefits with other policies;
- The opportunities and barriers for financing and accessing low carbon funds;
- The linkages between low carbon investments and climate resilience.

A summary of the findings are presented below.

GHG emissions and projections

- Investing in low carbon technologies and programmes has strong synergies with a more sustainable economic and development strategy and is strongly in Tanzania's self interest. Low carbon opportunities have the potential to provide Tanzania with additional carbon finance to help invest for economic growth that is more sustainable whilst benefiting many other key policy aims.

- Sustaining year-on-year GDP growth rates of 8-10%, as set out in the Vision documents will be a significant challenge, and is likely to be impeded by unsustainable resource use and increasing reliance on and inefficient use of fossil fuels. Emerging problems are likely to become more acute, as a result of near term economic growth and rapidly rising population.

- To determine the current or future role carbon financing could play in providing funding for investment in the economy it is important that the level of GHG emissions is assessed through the development of a current year inventory and projections.

- Tanzania currently has relatively low emissions of Greenhouse Gas (GHG) Emissions, in total and per capita terms. However, these are set to increase significantly over the next 10-20 years, in line with economic and population growth.

- The published inventory for 1994 puts GHG emissions per capita (excluding those from the LUCF sector) at 1.3 tCO_2e. Current estimates, from CAIT (for 2005), are broadly similar. However, when land use and forestry are included, the per capita emission estimates increase to 2.7 tCO_2e.

- The key emitting sectors are forestry, due to deforestation and degradation, and agriculture, primarily from livestock (CH_4 from enteric fermentation) and agriculture soils (N_2O from fertilisers, animal manure etc). These two sources accounted for 93% of emissions in 1994 (forests 70%, agriculture 23%).

- Emissions from the energy system are low (based on inventory accounting) due to the very high prevalence of biomass, accounting for up ~90% of final energy consumption. However, this biomass is not carbon-neutral because it is sourced from unsustainable resources, the emissions of which are captured in the forestry sector estimates, accounted as removals.

- In future years, emissions of greenhouse gases in Tanzania will increase under the planned current development baseline.

    - Excluding LUCF emissions, emissions are set to more than double by 2030 (48 Mt to 110 Mt CO_2e), with per capita emissions rising from 1.15 to 1.5 tCO_2e.
    - Including the LUCF sector, emissions are set to rise from 110 to 250 Mt CO_2e by 2030, while emissions per capita increase from 2.7 to 3.4 tCO_2e.

- Emissions from the consumption of fossil-fuel consumption are also estimated to increase significantly, particularly in the transport sector. Increase switching to more modern cooking fuels in the household sector will lead to increases, as the carbon emissions associated with biomass use are accounted for in the LUCF sector. Moreover, even in the electricity sector, which currently has a high share of renewables (hydro), the current plans for coal and gas development will increase the carbon intensity of generation.

- The future emission projections (excluding LUCF sector) are shown in Figure Es1 below

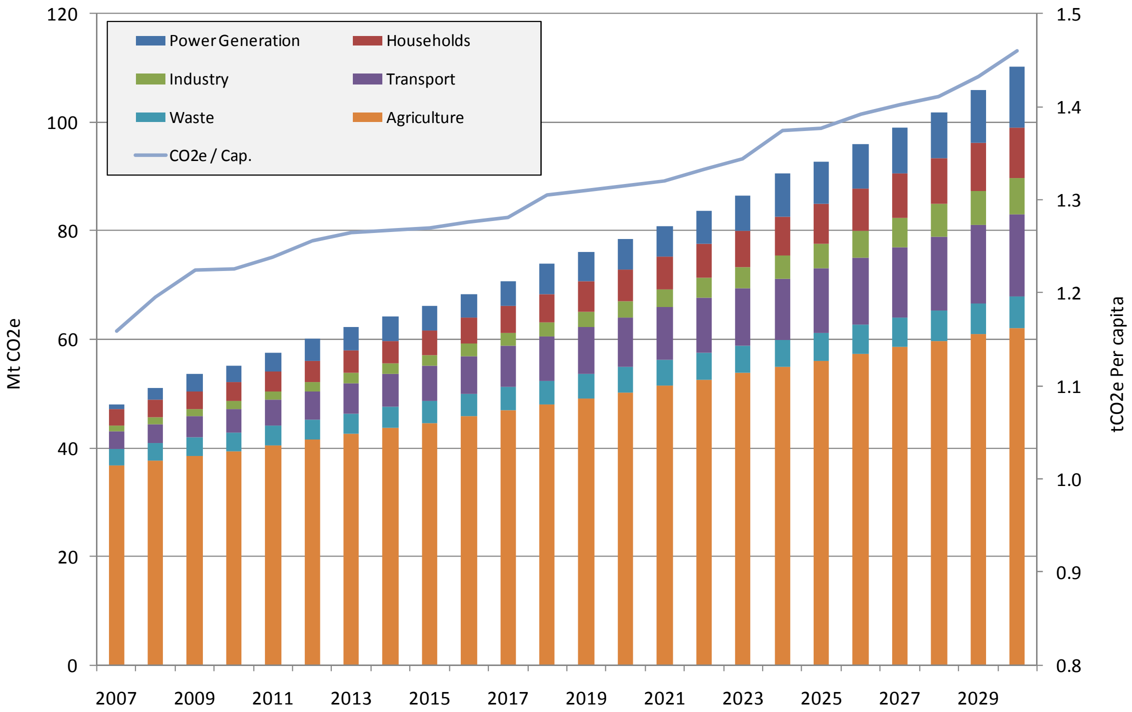

Figure Es1. GHG emission projections for Tanzania (excl. LUCF), MtCO_2e, 2007-2030

Low carbon investment opportunities

- The future emissions pathway illustrates that greenhouse gas emissions are likely to increase significantly over the next twenty years. This is illustrative of some of the aspects of unsustainable growth including continued unsustainable use of natural resources, and increase dependence on and inefficient use of fossil energy. Tanzania, however, could look to adopt a more sustainable growth strategy, reducing future emissions, and benefiting from carbon financing and the many associated co-benefits.

- Four broad drivers that illustrate why investments in low carbon projects could be in the interest of Tanzania.
    - *Carbon financing* opportunities, providing investment and financing from projects or programmes that reduce CO_2 emissions
    - Strong *policy co-benefits,* where low carbon investments are aligned to current or planned policies
    - *Strengthening development and growth,* where low carbon investments could actually stimulate new economic sectors and reduces costs e.g. through energy efficiency measures.
    - A*daptation synergies,* where these investments align with actions needed to enhance climate resilient growth.

- Tanzania is already carrying out a range of low carbon projects. However, there is scope to do more, as illustrated in this analysis, in particular take advantage of carbon financing opportunities. Key opportunities include:

    - Improved production and use of biomass energy to safeguard forest resources. Linked to REDD funding, the economy wide benefits of such a move could be significant. It would also have strong co-benefits such as reducing health impacts to households, saving fuel costs, developing the local manufacturing economy and safeguarding biodiversity and associated forest industries.

    - Switching to modern fuels in the household sector. Due to forecast demand growth, switching to modern fuels such as LPG is an important part of the solution for safeguarding forests, and reducing emissions. Co-benefits include cleaner, modern energy for cooking particularly for a growing urban population.

    - Forestry management and protection. An integrated approach to forestry management and protection, including the agriculture and energy sectors, could reduce emissions significantly. Tanzania is in a good position to benefit from the emerging REDD scheme as one of the leading countries in taking this initiative forward.

    - Biofuels. As an alternative to transport fuels, biofuels have the potential to reduce reliance on expensive imported fuels, develop new export markets and stimulate the rural economy. However, how the industry is structured to realise benefits to rural communities is critical, as would its perceived sustainability and necessary positive co-existence with food agriculture production.

    - Energy efficiency. There is significant potential across all sectors to realise energy efficiency improvements, often resulting in significantly reduced fuel costs. This is particularly true in the transport sector and probably in the industry sector (although this has not been fully assessed for this sector).

    - Renewable generation (including SHS). Tanzania has long invested in renewable generation through the development of hydro generation. There is now the potential to assess opportunities for other renewable including wind, solar and geothermal. However, investors will need to be incentivised through the tariff structure and be able to effectively use the carbon financing mechanisms. Promotion of solar home systems is already being developed; mitigating the problems of affordability will be key to seeing this technology disseminated widely in rural areas.

    - Agricultural measures. These are important where they also enhance productivity, and provide the potential for financing. Ensuring food security is paramount now and in future years.

    - Sustainable urban planning. Promoting a low carbon climate resilience agenda in urban planning could enhance future sustainability of urban areas, by ensuring integration of different departments (transport, buildings, utilities etc), recognising future pressures, developing public transport systems, and designing communities with climate impacts in mind.

- An assessment of the cost of these options through the use of a MACC analysis show that many are cost-effective even without the associated carbon financing benefits. A MACC of selected measures assessed is shown below in Figure Es2. The selected measures could achieve up to 20% reduction of the baseline estimate in 2030, based on a relatively strong but not unrealistic take-up of different options.

- An important insight is that many of the measures are low or negative cost, meaning that even a modest carbon price could cover the investment made. This is important as it suggests that for a more sustainable investment, the additional costs can be covered by a modest carbon price. Where cost are negative, this implies that such investments should be made irrespective of whether carbon finance is available, as over their lifetime such investments save money.

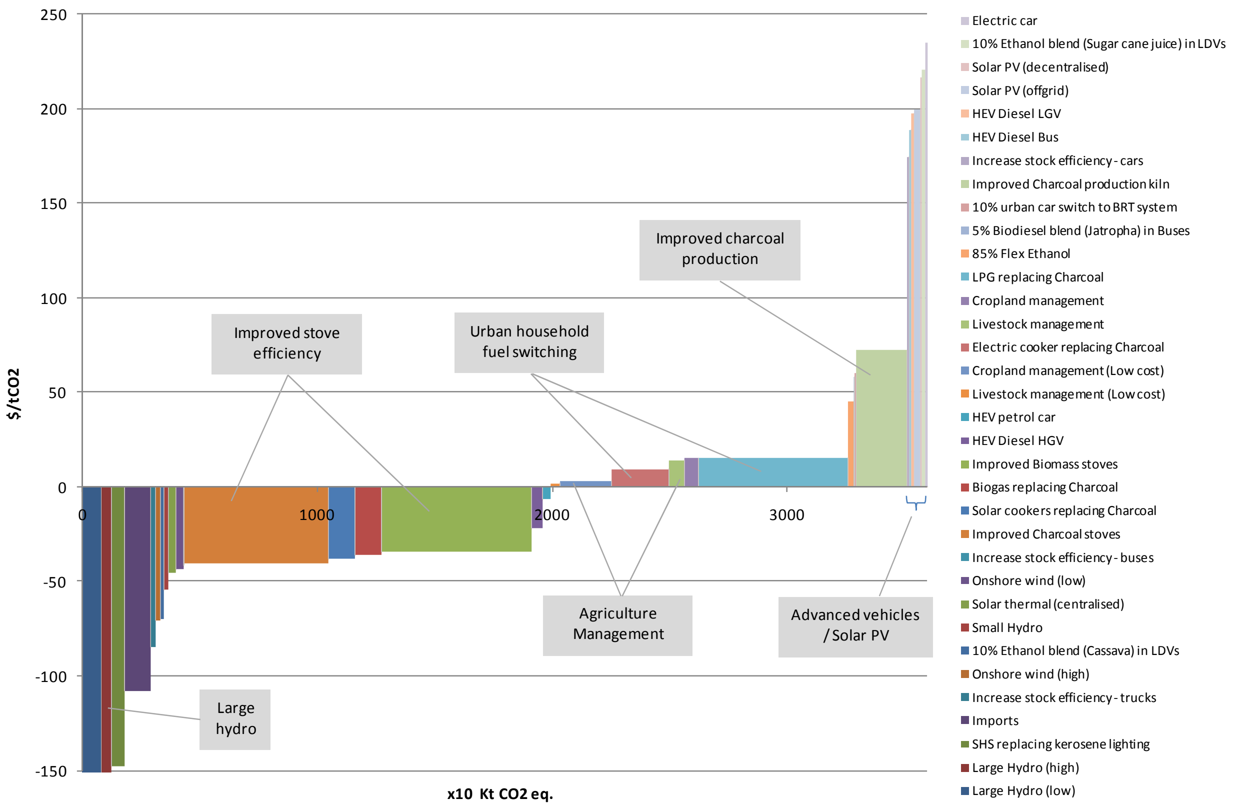

Figure Es2. Illustrative marginal abatement cost curve for Tanzania in 2030

Implementation challenges

Implementation of the identified options is predicated on overcoming significant regulatory, institutional and financing barriers, many of which have prevented large scale uptake of low carbon technologies to date. These barriers are present across all sectors reviewed, and include:

- Economic / market barriers (e.g. no finance, poor commercial case): Tanzania has been slow in accessing the international carbon finance markets to date, with only one project registered under CDM and only recent uptake of voluntary credit schemes in the forestry sector. Commercial banks seem currently unwilling to lend to low carbon projects due to the track record in implementation to date. There is also a mismatch between the short term domestic deposit base and the long term tenor required for capital intensive projects, creating a role for international financial institutions.

- Low levels of information / awareness: The relatively low levels of absolute and per capita emissions, lack of track record in low carbon development and competing priorities of poverty alleviation have resulted in low levels of awareness. Climate change continues to be seen through a development aid perspective, rather than from the perspective of domestic led economic restructuring or growth.
- Policy / regulatory framework: The development of a coordinated climate policy framework is at an early stage. The fiscal framework to support low carbon options remains under-developed. For example, utilities pricing supports traditional fossil fuel generation at the expense of other renewables, with limited use of technology specific tariffs;
- Technical problems of use in-country: Tanzania lacks the necessary operation and maintenance infrastructure to support complex technologies. Solar PV, however is building economies of scale and may be the first break through technology:
- Lack of skills / know-how: This is particularly pertinent to technical and financial project preparation, and acts as a barrier under CDM applications. Skills and training are of particular importance for those areas where behaviour is a significant element in emissions, such as forestry and agricultural soil management practices
- Limited institutional capacity: Multiple institutions play a role in low carbon policy development with a clear need for streamlining roles and responsibilities. This is particularly true of Forestry management and transport planning, which account for the bulk of forecast growth in Tanzania's GHG emissions

Despite the challenges, there are positive signs that Tanzania is beginning to embrace low carbon options both through its policies and regulatory structures, although these would benefit from further alignment. There are also clear signs of growing momentum within the private, voluntary and education sectors which are crucial to creating the implementation capacity required, and which may serve as a basis for scale-up of low carbon options over coming years.

Linking low carbon and climate resilient growth

- In terms of the linkage between low carbon investments and climate resilient growth, the study finds a mix of potential synergies and conflicts. A number of areas are highlighted:
    - The impact of climate change will affect the energy system of Tanzania, and is important in considering the potential development of current and also low carbon growth pathways.
    - The climate model projections for Tanzania indicate future increases in average minimum temperature of 1 ºC to 3ºC above the baseline by the 2050s (years 2046 -2065) with greater warming in the north and northeast. Temperatures will rise further in future years without a global deal on emissions.
    - These increases in temperature will increase demand for cooling, which will in turn increase energy demand through air conditioning, unless alternatives are sought. These changes could be very significant in terms of the electricity sector, because it is likely to increase peak demand requirements on the system. These future changes need to be built into future electricity planning and demand forecasts. The available climate data indicates a 25 to 100% increase in likely cooling demand from climate change by the 2050s. This also needs to be considered in the context of rising future cooling demand from socio-economic change. There is also a need to look at low carbon development in the context of building design to provide alternatives to air conditioning.
    - The changes in precipitation are more uncertain: while all climate models show changes to rainfall, these vary with season and region. Many climate models project increases in rainfall in the north, while there is more disagreement on whether increases or a decreases will occur in the south of the country. The combined effects of changes in future temperature and precipitation will affect the electricity supply industry, particularly given the high proportion of hydro power, and should be considered in future scheme development. However, these changes in rainfall and in climate variability (particularly droughts) will also

impact on fossil generation due to cooling water demands, thus a move to fossil generation may not necessarily reduce the impacts of current and future climate variability.

- There are also potential changes in the frequency and duration of extreme events (floods and droughts). The future climate projections vary widely on the changes likely in future years, though these have implications for hydro and fossil supply, as well as risks to energy infrastructure. Some models indicate an intensification of heavy rainfall, particularly in some regions and thus greater flood risks. Droughts are likely to continue, and some (but not all) models project an intensification of these events, particularly in some regions.
- Future climate change could have important impacts on agro-ecological zones, affecting forests. This is a key point in relation to REDD+. The limited studies that are available indicate potentially large threats to current zones, which could affect the viability of current afforested areas and thus the viability and revenues from such schemes. This issue is highlighted as a priority for consideration in the context of REDD development. The most immediate response needed is to increase monitoring programs to study response of forest and tree species to climate change. The additional stress of climate change is also likely to mean a greater focus on reducing and managing existing stresses, such as stopping fragmentation, pollution, population encroachment, habitat conversion, etc. Finally, additional measures are likely to be needed, which include forest buffer zones and increasing ecological zone connectivity. Given the irreversibility of land-use change, these are an early priority.

Conclusions and recommendations

- Tanzania is a growing economy, aiming for strong economic development over the next 10-20 years, as it seeks to raise standards of living and address high levels of poverty. However, there are significant risks associated with the current growth pathway due to the unsustainable use of natural resources and the increasing reliance and inefficient use of fossil fuels. A more sustainable pathway should be adopted, to ensure that Tanzania can become a middle income country whilst protecting its natural assets and environment.

- The opportunity to access carbon financing could help Tanzania to invest in more sustainable technologies, and ensure that some of the current problems can be addressed. This could raise much needed finance while at the same time supporting domestic priorities and moving towards a more sustainable pathway.

- Reducing the reliance on wood fuel energy and protecting the forests will promote sustainable resource use, protecting biodiversity and economic sectors relying on forest resources. It also reduces household exposure to pollution and promotes a move towards more modern energy forms. Developing a sustainable transport system can help reduce reliance on oil imports, protect urban environmental quality, enhance urban infrastructure and potential help develop a sustainable biofuel sector. Promoting renewable electricity generation, both grid and household-based further strengthen energy independence so long as it is carefully planned, and doesn't increase vulnerability.

- Tanzania is and has already implemented many lower carbon opportunities. However, a more strategic approach by Government could ensure that all public policy is considered in the context of low carbon, climate resilient growth. The extent to which Tanzania can develop low carbon opportunities is dependent on a number of things – first, confidence that carbon finance mechanisms will be there in the long term and can be accessed. Second, as discussed above, the policy co-benefits need to strengthen the domestic policy agenda. Third, low carbon opportunities need to be progressive, bringing benefits to lower income groups, and not further entrenching poverty. Fourth, there needs to be strong synergies with the adaptation agenda, to ensure not only low carbon but climate resilient growth.

- Overall, the study concludes that because of its location, availability of resources and socio-economic conditions, there are significant benefits for Tanzania in promoting low carbon projects to ensure a more sustainable growth pathway. Such a pathway appears strongly in the country's self interest, providing potential extra investment from carbon financing and numerous policy co-benefits. However, further assessment of the relative economic, social and environmental benefits and costs would be needed to further quantify the extent to which Tanzania should or could move in this direction. Focus needs to be given to assessing the macro-economic impacts of such investments, including the distributional impacts, to better identify the opportunities. Further assessment of the social and environmental benefits could also be developed e.g. quantifying health and environmental benefits.

- **A key recommendation is the need for Tanzania to get ready and act now.** Key elements are to improve estimates, advance institutional and policy development, undertake investment analysis, revisit Vision 2025, to advance a more sustainable (and low carbon) path (in parallel to climate resilient growth) and to enhance regional co-operation.

- Specific recommendations include:

    - Improving the estimates. Further work is needed to improve these initial estimates and to give a degree of confidence in the analysis. A more comprehensive analysis of future emission projections and potential opportunities, with full marginal abatement cost curves and analysis of urgent priorities across all sectors, as well as on the links with climate change impacts. Further work should also be undertaken on the potential macroeconomic impacts, and more detailed assessment of the costs to different sectors / stakeholders.
    - Building Capacity. Access to substantial adaptation funds must be assured. However, mechanisms, institutions and governance systems for effective use must be developed to allow Tanzania to access these funds. This requires early and concerted action to build capacity across stakeholders and with the affected communities themselves. This is an early priority.
    - A more sustainable and lower carbon pathway. There are many benefits if Tanzania switches to a more sustainable and lower carbon pathway. However, this will not happen on its own and steps are needed by Government, business and civil society to realise these benefits and to maximise the potential flow of carbon credits under existing and future mechanisms. Specifically, i) low carbon plans should cut across all sectors and mainstreamed into sector plans, ii) areas of development increasing future threats to climate obligations in future years should be identified, iii) linkages between adaptation and low carbon development (especially in finance) should be further explored.
    - National policy and Vision documents. Planned revision of national policy should examine the potential effects of climate change and the potential for adaptation and low carbon growth. There is also a need to build on existing government and donor activities. There is a need to develop a new strategic vision for Tanzania that addresses these areas, for example, with further development of the Vision 2025 document, including both domestic and international aspects.
    - Regional collaboration. There is also a need for regional collaboration and co-operation across the areas of low carbon growth and adaptation, to benefit from economies of scale and to enhance regional resilience.

- The steps above would provide national action on a low-carbon, climate resilience investment plan and would help Tanzania in negotiations and in securing finance.

A summary of key next steps is presented in the table below.

Strategies	Recommended Actions
Low-Carbon Investments	• Full analysis of baseline projections, low carbon options, impacts of climate change on energy and low carbon options, costs and potential for prioritisation and development of strategy for mechanisms. • Develop national strategies to mainstream LCG in planning. Build into long-term vision (e.g. Vision 2025), including potential effects from international action. • Facilitate carbon finance opportunities in voluntary and compliance carbon markets (VCM, CDM) and in REDD • Prioritize forestry, agriculture, transport and electricity generation low carbon measures, considering short-term opportunities but also longer-term areas where potential 'lock-in' and identify alternatives. Improve sectoral co-ordination. • Look for synergistic adaptation – low carbon project opportunities, e.g. agro-forestry and sustainable land-use
Climate resilience & co-benefits	• Climate risk screening of low carbon growth pathways • Consideration of energy demand (cooling) and supply (hydro, fossil stations) effects from climate change, with associated adaptation (diversity, demand management). • Analysis of potential impacts of climate change on forestry (REDD) and introduction of monitoring and move towards early adaptation. • Explore opportunities in case studies of major low carbon strategies such as geothermal, biofuels and on-farm carbon management and how they might be scaled up to achieve both reductions in future emissions and adaptive development.

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Disclaimer

This report is commissioned under DEW Point, the DFID Resource Centre for Environment, Water and Sanitation, which is managed by a consortium of companies led by Harewelle International Limited[1]. Although the report is commissioned by DFID, the views expressed in the report are entirely those of the authors and do not necessarily represent the development partners group or DFID's own views or policies, or those of DEW Point. Comments and discussion on items related to content and opinion should be addressed to the authors, via the "Contact and correspondence" address e-mail or website, as indicated in the control document above.

[1] Consortium comprises Harewelle International Limited, NR International, Practical Action Consulting, Cranfield University and AEA Energy and Environment.

Abbreviations

CAIT	Climate Analysis Indicators Tool (from the World Resources Institute)
CAMARTEC	Centre for Agricultural Mechanization and Rural Technology
CBFM	Community-based Forestry Management
CCGT	Combined Cycle Gas Turbine
CDD	Cooling Degree Days
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions
CHP	Combined Heat and Power
DFID	(UK) Department For International Development
DNA	Designated National Authority (under CDM)
EE	Energy Efficiency
EWURA	Energy and Water Regulatory Authority
ESMAP	Energy Sector Management Assistance Programme (World Bank)
FAO	Food and Agriculture Organization of the United Nations
FITs	Feed in Tariffs
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GoT	Government of Tanzania
HEV	Hybrid Electric Vehicle
HGV	Heavy Goods Vehicle
ICE	Internal Combustion Engine
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPPs	Independent Power Producers
JFM	Joint Forestry Management
LCG	Low Carbon Growth
LDV	Light Duty Vehicle
LGV	Light Goods Vehicle
LPG	Liquefied Petroleum Gas
LUCF	Land Use Change and Forestry (sector)
MACC	Marginal Abatement Cost Curve
MEM	Ministry of Energy and Minerals (Tanzania)
MIC	Middle Income Country
NGO	Non-Governmental Organisation
NSGRP	National Strategy for Growth and Reduction of Poverty
PFM	Participatory Forest Management
R&D	Research and Development
RE	Renewable Energy
REA	Renewable Energy Agency
REDD	Reducing Emissions from Deforestation and Forest Degradation
REF	Rural Energy Fund
SADC	Southern African Development Community
SHP	Small Hydro Power
SHS	Solar Home Systems
SMEs	Small and Medium sized Enterprises
SPPAs	Small Power Purchase Agreements
TANESCO	Tanzania Electric Supply Company Limited
TASEA	Tanzania Solar Energy Association (now TAREA, Tanzania Renewable Energy Association)
TaTEDO	Tanzania Traditional Energy Development and Environment Organization
TCCIA	Tanzanian Chamber of Commerce Industry and Agriculture
TPDC	Tanzania Petroleum Development Corporation
TPSF	Tanzania Private Sector Organisation
TRA	Tanzanian Revenue Authority
UNFCCC	United Nations Framework Convention on Climate Change

VCS	Voluntary Carbon Standard
VERs	Verified Emission Reductions
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organisation

1) Introduction

Background and Objectives of the study

The development partners group, with funding from UK (DFID) Government, are funding a study on the *Economics of Climate Change in Tanzania*. The work is led by the Global Climate Adaptation Partnership, together with the Stockholm Environment Institute, working with other international and local partners, and is assessing the impacts and economics costs of climate change, the costs and benefits of adaptation and opportunities for lower carbon growth for the United Republic of Tanzania.

The key aims of the study are to:

- Assess the impacts and economic costs of climate change for Tanzania, considering key sectors of the economy and non-market sectors such as health and ecosystems;
- Analyse the costs and benefits of adapting to these effects over different timescales;
- Assess the potential for low carbon financing to help support a more sustainable growth pathway, necessary for Tanzania to become a Middle Income Country (MIC) ;
- Use the results to enhance the evidence base to inform and guide the negotiation position for COP 16, as part of a regional approach to negotiations and promoting dialogue on shared challenges;
- Inform decision-making at domestic, regional and international level on the economics of climate change in Tanzania, and the region as a whole; and
- Highlight areas where further work is required to understand impacts and policy responses to climate change.

This report focuses on the potential for low carbon opportunities and the financing that could flow from such projects. Tanzania needs additional investment to facilitate growth that is more sustainable than the current pathway. This could be achieved through using financing mechanisms that provide funding for projects and programmes where greenhouse gas (GHG) emissions reductions can be demonstrated. In addition to reducing carbon, many of these options could lead to more sustainable growth through protecting natural resources, improving environmental quality, delivering economic opportunities and reducing reliance on fossil imports.

It is the potential for carbon financing to provide additional investment needed for economic growth whilst also helping ensure more sustainable growth that make such opportunities important for consideration. The issue is illustrated in Figure 1 below.

This report very much focuses on the opportunities for reducing GHGs rather than prescribing a specific pathway for low carbon or more sustainable growth (although such concepts could be usefully integrated into current strategy documents). Economy wide opportunities are considered, both in the near and longer term, to assess technical potential for, and costs of, emission reductions. This is a broader assessment than would be achieved by focusing only on current financing mechanisms, as it is uncertain how much carbon financing will be available and how mechanisms will evolve. Similar studies have been undertaken for many countries, and are often labelled as *low carbon growth* assessments (SEI 2010).

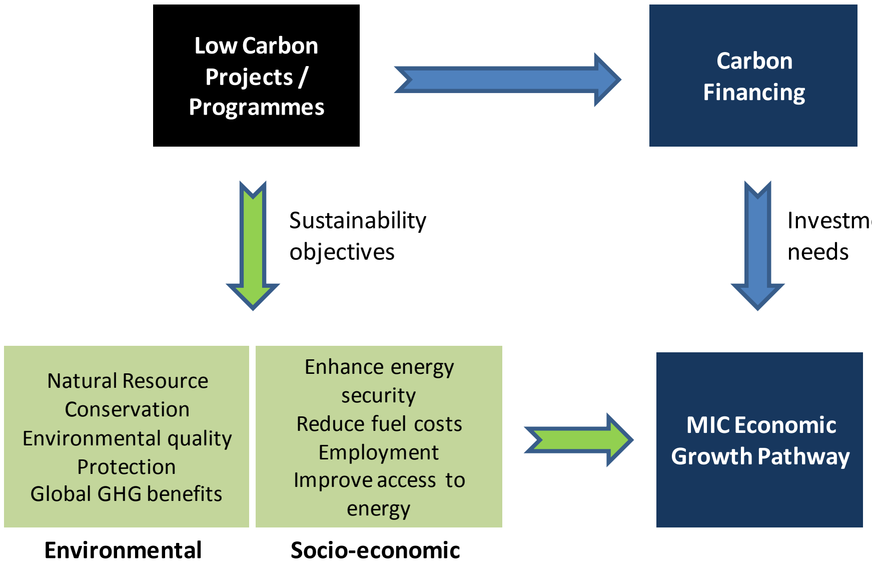


Figure 1. Low carbon opportunities can help deliver more sustainable growth

Country Context

Tanzania is one of the poorest countries in the world, ranked 185 (out of 213) in terms of gross national income per capita (PPP metric)[2], and despite relatively strong economic growth between 2000-2008, poverty levels remain high and relatively unchanged (GoT 2010). Robust and rapid development is vital to increase economic productivity and to reduce the high levels of poverty being experienced. The Government has therefore set out a strategic vision that seeks to accelerate economic growth, reduce poverty levels and increase standards of living for the population. Such objectives are set out in the National Strategy for Growth and Reduction of Poverty (MKUKUTA II) (GoT 2010), incorporating the aspirations of the Vision 2025.[3]

Sustaining year-on-year GDP growth rates of 8-10%, as set out in the Vision documents will be a significant challenge, and is likely to be impeded by unsustainable resource use and increasing reliance on and inefficient use of fossil fuels. Emerging problems are likely to become more acute, as a result of near term economic growth and rapidly rising population. Specific problems are described below.

Deforestation and degradation of forests

High rates of deforestation leading to significant reductions in forestry cover. The FAO (2006) have estimated deforestation rates of 412,000 ha per year since 1990, In 2005, this deforestation rate translated to an annual loss of forest stock of 1.2%. This results in Tanzania being ranked globally at 6th (and 3rd in Africa after Sudan and Zambia) in terms of annual net loss of forest. Whilst these rates are uncertain, they do reflect the impacts of extensive fuel wood use for energy (accounting for over 90% of primary energy needs), and the clearance for agricultural land.

The FAO (2009) states that deforestation rates are likely to remain at the same level in Africa (under a business as usual case) in future years. Specifically for East Africa, *high population densities and high land dependence coupled with land-use conflicts and limited opportunities for economic diversification are likely to reduce forest area further.*

The continued loss of forests will impact on growth through reduced income from associated industries (wood products, tourism), reduction in ecosystem services provided, and higher costs through the provision of alternative energy types.

[2] See World Bank *World Development Indicators*, http://siteresources.worldbank.org/DATASTATISTICS/Resources/GNIPC.pdf
[3] The Tanzania Development Vision 2025, http://www.tanzania.go.tz/vision.htm

Unreliable and limited access to electricity

Electricity supply has been unreliable in recent years. This is due to a combination of factors, including hydro plants coming off line due to low water availability, and the very high losses due to poor system maintenance resulting from lack of investment in infrastructure. This has a number of impacts affecting growth:

- Outages disrupt business activities. The World Bank (2008) estimates that businesses in Tanzania experience outages equivalent to 63 days of the year. Costs are incurred due to equipment damaged by outages but also the need to switch to higher cost own generation. In Tanzania, 60% of firms own generation equipment (supplying about 12% of electricity needs). The costs of own generation tend to be higher than public supply, estimated at 29 c/kWh compared to 9 c/kWh.
- Outages result in higher costs of generation due to the use of rental capacity, and the lost revenues from consumers. The World Bank (2008b) estimated that the value of lost load or unserved energy cost the economy 4% of GDP. In addition, emergency capacity required due to near term shortfalls and provided through oil-fired rental units, are estimated to cost 1% of GDP in Tanzania.
- Higher costs of generation and lower revenues for TANESCO mean that levels of investment drop, and the risk of future outages increases. The situation is compounded by high system losses and inefficient tariff structures that do not necessarily take account of historic investment (despite having low production costs due to hydro generation).

Current access to grid electricity is extremely low in Tanzania, reducing the availability of modern energy services for households and businesses. The access rate is about 12% of the population overall, and 1% of the rural population. This is reflected in the by the low consumption levels, around 85 kWh per capita, below the sub-Saharan average (excluding South Africa) of 124 kWh.

Increasing reliance on fossil fuels

Tanzania's reliance on fossil fuels is increasing, as the energy system diversifies away from dependency on hydro generation for electricity and biomass for non-commercial sector energy needs, and fossil intensive sectors grow, in particular transport. Some of this diversification could be met by indigenous resources but not all, in particular oil, for which Tanzania is import-dependent. This could have two consequences – firstly, increased imports could reduce energy security, and secondly, Tanzania will become increasingly exposed to the fluctuations international energy commodity markets and forecast increases in prices in the medium term. In 2007, high oil price increases led to a significant increase in the value of imports (by over 26%) (GoT 2008). In addition to the economic impacts, adverse environmental impacts will also arise from increased use of fossil fuels, in particular air pollution.

The increasing reliance on fossil fuel use is compounded by inefficient use of energy. There are very low levels of awareness concerning energy efficiency, much of the equipment used in the industry and transport sector is second-hand (imported from Europe and Japan), and maintenance of equipment is often limited. In terms of lighting, CFLs are only used in a small percentage of households and business premises[4]

Rapid urban expansion and transport sector growth

High population growth and the continuing rapid rate of urban growth have put significant pressures on existing urban infrastructure and resulted in significant unplanned development, in particular in Dar Es Salaam. For example, by 1992, it was estimated that out of the 170,000 housing units of Dar es Salaam, approximately 75% were located in informal settlements.[5] This has implications for provision of basic services, such as water supply, waste disposal, electricity provision, public amenities and road networks. The UN projects that the urban population will grow from 9.4 million in 2005 to 29 million by 2030, increasing the challenges to urban planning.

The problems are evident in terms of urban road congestion, where the number of vehicles required to meet demand exceed the capacity. Dar Es Salaam has 50-60% of the vehicles in Tanzania on its roads. These roads are said to have been designed to support a population of about two million people, and actual holding

[4] See information from the TREESPA project at the following website - http://www.treespa.eu/

[5] From Lupala, J., (2002), Urban Types in Rapidly Urbanising Cities: Analysis of Formal and Informal Settlements in Dar es Salaam, Tanzania, KTH, Stockholm.

capacity for the vehicles is said to stand at 15,000 cars, while at the moment there are more than 135,000 vehicles travelling on the same infrastructure on daily basis.

A study by the Centre for Economic Prosperity (CEP) indicates that a motor vehicle often spends up to two hours to cover a 16- kilometre trip, a distance which could have spent only 15 minutes if there was no traffic congestion. This is at relatively low levels of per capita ownership. Another survey conducted by the Confederation of Tanzania Industries (CTI) has established that traffic jams in Dar es Salaam costs about 20% of annual profits of most businesses. Dar es Salaam Rapid Transit Agency (Dart) Chief Executive Mr Cosmas Takule was recently quoted by the local media saying that around 4bn/- loss was being incurred every day in the city due to the persistent jams.[6]

As road transport increases, air pollution is likely to worsen. Kanyama et al (2004) reviewed the existing studies which indicated very high levels of harmful pollutants in areas with dense traffic. The correlation between traffic and pollution is also strong according to these studies, showing that the transportation sector is an important contributor to the air pollution in Dar-es-Salaam. As the population grows and incomes increase, the level of urban travel demand will increase significantly, making the congestion and pollution problems worse.

Synergies between lower carbon investments and broader development objectives

The current problems, as described above, need to be addressed if Tanzania is to ensure strong growth that can be sustained in the near to medium term. Low carbon projects and programmes, whilst generating financing for much needed investment, also support greater sustainability, and could help address the problems outlined above. These synergies are shown in Table 1.

Whilst the synergies are strong, there are also concerns about access to carbon financing (discussed in section 4 of this report) and a perceived risk that low carbon projects / programmes may in fact affect growth. Issues include:

i. Higher investment requirements above a business as usual situation. For example, renewable sources of generation (excluding hydro) tend to be more expensive (before carbon credits are gained) than conventional coal or gas generation. Many energy efficiency opportunities also require significant upfront capital investment, despite the net cost being negative over the technology lifetime (the reason why they have not already been implemented, even though they save money).

ii. Potential conflicts may arise with other policy objectives. For example, reducing domestic natural resource extraction (for example in forests or indigenous coal reserves, due to a shift to lower carbon energy) could be seen as higher cost options – but this fails to recognise the full costs of current resource exploitation (e.g. the wider economic costs or environmental costs that are not currently included in the price of these goods or services). Intensification in some sectors which are key to development (e.g. agriculture) may increase carbon intensity as well, and thus there is a need to highlight that low carbon alternatives allow similar growth pathways.

iii. Lack of synergies with the necessary investment for adaptation to future climate impacts, to enhance climate resilience.

[6] Information on traffic problems in Dar es Salaam from article in Daily News *Dar es Salaam traffic congestion begs solutions* by Abduel Elinaza (20th October 2010) found at http://dailynews.co.tz/feature/?n=13937&cat=feature

Table 1. Potential synergies between lower carbon investments and broader development objectives

Benefits of Low Carbon Investments	Policy Objective Supported	Description
Access to finances	Raise capital for investment in economy	Low carbon projects provide the potential to raise carbon finance, and much needed capital for investment. This could reduce donor-dependency.
Reduce energy costs	Increase competitiveness of economic sectors	Reducing energy intensity of economic production through energy efficiency can reduce energy costs, thereby increasing competitiveness.
Enhance energy security	Reduce reliance on fossil fuel imports	By improving efficiency or switching to renewables / alternative fuels, reliance on oil imports can be reduced, improving energy security and reducing foreign exchange payments.
Promote renewable decentralized energy technologies	Enhance access to modern energy services, particularly in rural areas	Renewable technologies provide significant potential for delivering modern energy services to rural populations.
Developing 'green' sector	Economic development and job creation	A low carbon focus could hold opportunities for developing sustainable energy technologies, and establishing a strong regional position in associated markets
Improve environmental quality	Reduce health impacts from indoor and outdoor air pollution	Reducing reliance on or use of fossil fuels in transport sector and biomass in rural areas could significantly reduce impacts on health.
Habitat protection	Safeguarding forest areas and associated economic sectors	Opportunities for carbon finance through REDD+ provide an incentive for safeguarding forests, in turn protecting important economic sectors e.g. wood products, tourism and maintaining important ecosystem services.
Promoting regional co-operation	Improving regional economic links, and co-operation	Linking up energy infrastructure could have significant benefits for energy security and the supply of clean, reliable electricity.

To exploit the opportunities for carbon finances, it will be imperative for the above benefits to be clear, for project developers and policy makers to be clear how to access funding and for stakeholders not to view this as an agenda for pushing Tanzania down a low carbon pathway. In conclusion, it is important that:

- The future potential for and current possibility of carbon finance is clearly demonstrated
- Wider synergies of such investments with development goals and the need for more sustainable growth need to be identified. In other words, low carbon investments need to be shown to be in Tanzania's self interest, supporting objectives beyond simply raising finances.
- Investment is made in institutional capacity so that financing can be accessed, and Tanzania is well positioned to access mechanisms being developed.

Structure of report

This main focus of this report is a technical assessment of the near and medium term potential of Tanzania to invest in lower carbon projects and programmes that are needed for development and growth but which can pay for themselves through the carbon finances generated. We argue that not only will this generate some of the funding necessary for investment going forward but will also promote a much more sustainable growth pathway, where Tanzania can conserve its significant natural resource base whilst reducing future reliance on fossil fuels. In other words, a more sustainable growth path is also likely to be lower carbon.

Section 2 estimates the strong growth in greenhouse gas emissions to 2030, underpinned by strong economic growth and population increases. The high emissions growth is indicative of an unsustainable pathway, with significant loss of natural resources and increasing reliance on and inefficient use of fossil fuels. Section 3 explores the types of low carbon opportunities, by sector that could generate carbon finance whilst at the same time delivering a more sustainable growth pathway. This includes both current projects, of which there are many, and future potential in the longer term.

Section 4 considers the current carbon financing opportunities and challenges for Tanzania. Section 5 explores the need to consider climate resilience in project investments, due to future climate impacts. This is important again for ensuring climate resilience is a key part of sustainable growth. Section 6 summarises the key findings of the analysis, and recommends a range of actions in order to exploit low carbon financing opportunities and promote more sustainable growth.

2) GHG emission and projections

Determining the potential for low carbon investments i.e. investments that could generate or be supported through carbon financing, requires that a *business as usual* baseline be established from which to estimate potential savings, now and in future years. This has been done through an assessment of current emissions, building on the 1st National Communication (GoT 2003) and by developing emission projections. Once these emission estimates have been established, it is then possible to review sector-based opportunities for low carbon investments.

Current GHG emissions

The most recent Tanzanian GHG inventory was reported in the 1st National Communication (GoT 2003). This provides emission estimates for years 1990 and 1994. Total emissions excluding the Land Use Change and Forestry (LUCF) sector total are estimated at 39 $MtCO_2e$. Emissions are dominated by agriculture emissions (see Figure 2), primarily methane (CH_4) emissions from enteric fermentation and nitrous oxide (N_2O) emissions from agricultural soils. Each of these categories accounts for ~30% of total emissions. CO_2 emissions are very low, due to the low utilisation of fossil fuels in the energy system and an extremely high reliance on biomass for energy.[7]

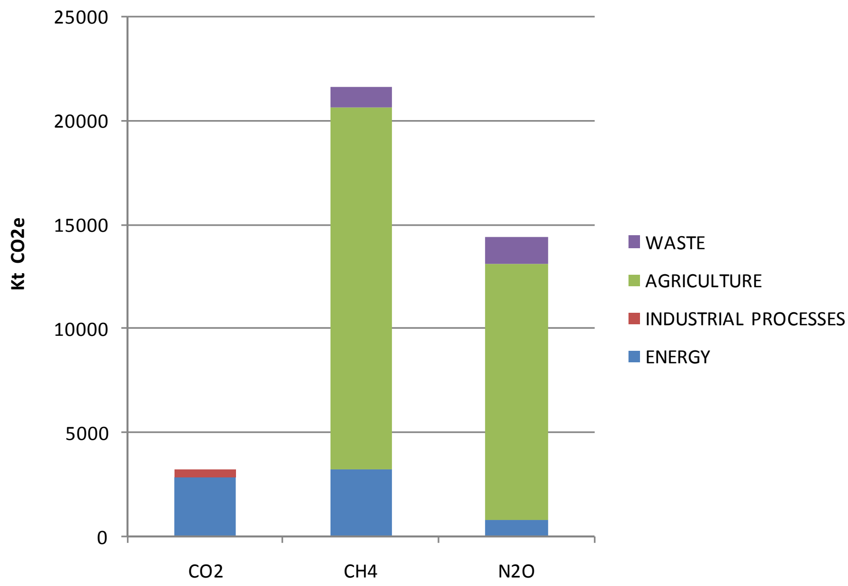


Figure 2. Tanzanian GHG Emissions in 1994, excluding Land Use Change and Forestry (LUCF)
(Source: GoT 2003)

Emissions (excluding the LUCF sector) are very low given the population of Tanzania, as shown by per capita estimates (emissions divided by population, expressed as tonnes of carbon dioxide or all greenhouse gases per capita, i.e. tCO_2 or tCO_2e). Based on the 1994 inventory estimates, CO_2 emissions per capita are estimated at 0.1 tonnes whilst GHG emissions are 1.3 tonnes. More recent estimates for 2005, from CAIT, estimate that emissions per capita are still relatively low, at 0.1 tCO_2/capita and 1.5 tCO_2e/capita (all GHGs).[8] For CO_2 emissions only, this ranks Tanzania as one of the world's lowest emitters (ranked at 171 out of

7 CO_2 emissions from biomass energy consumption are not accounted for in these estimates. The Revised 1996 Inventory guidelines from the IPCC state that *biomass fuels are included in the national energy and emissions accounts for completeness. These emissions should not be included in national CO_2 emissions from fuel combustion. If energy use, or any other factor, is causing a long term decline in the total carbon embodied in standing biomass (e.g. forests), this net release of carbon should be evident in the calculation of CO_2 emissions* in the LULUCF sector.
8 Climate Analysis Indicators Tool (CAIT) Version 7.0 (Washington, DC: World Resources Institute, 2010), see http://cait.wri.org/cait.php

186). Including all GHGs (excluding LUCF), Tanzania is ranked higher at 155, due to the significant N_2O and CH_4 emissions from the agriculture sector. A comparison of per capita emissions with other countries is provided in Figure 3, illustrating the very low levels for Tanzania.

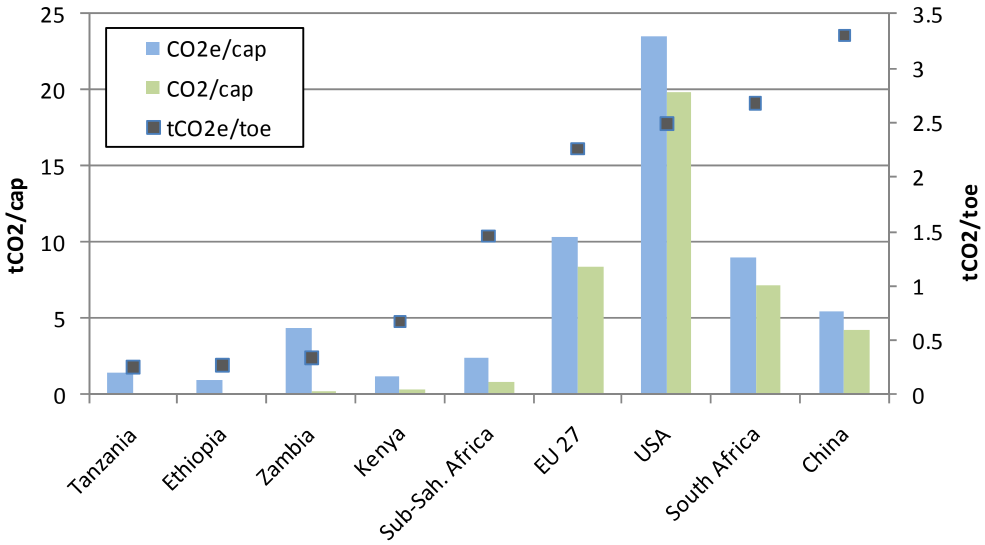


Figure 3. GHG emissions per capita (excl. LUCF emissions) and per unit of energy use in 2005 for selected countries (Source: Climate Analysis Indicators Tool (CAIT))

However, the inclusion of land use change and forestry (LUCF) emissions changes this picture, significantly increasing overall emissions of greenhouse gases in the 1994 inventory by almost 2.5 times, from 39 to 91 Mt CO_2e. CO_2 emissions dominate the LUCF contribution and are primarily due to forest removals, whilst CH_4 emissions are largely due to flooding of lands for hydro generation and water supply.[9] [10] According to the inventory, forestry emissions (due to removals) are primarily due to the harvesting of wood for fuel.

Based on this study, estimated per capita emissions for 2005 are significantly higher once the LUCF sector is included – rising to 1.65 tCO_2/capita (CO_2 only) and 2.67 tCO_2e/capita (all GHGs). (Using LUCF estimates from the 1994 inventory, per capita emissions are higher than calculated in this study due to differences in estimates between studies. These estimates are therefore not presented here).

[9] The estimates for LUCF are based on a review of the text on pages 101-118 in the 1st National Communication (GoT 2003). This annex includes some improved estimates from what is seen in the main body of the report e.g. CH_4 arising from flooded lands is much higher in the Annex text. However, a significant error seems to be apparent in Table 36, showing CO_2 emissions at 757 MtCO_2. The main body of the text indicates a figure closer to 9.6 MtCO_2; therefore this sector estimate should be cross-checked. This 'error' appears to be reflected in the data held by UNFCCC, at http://unfccc.int/ghg_data/ghg_data_unfccc/ghg_profiles/items/4626.php

[10] The authors consider the emissions of CH_4 from flooded land (27 MtCO_2) in the 1st National Communication to be much too high, and have not included such estimates in the projections described later in this report.

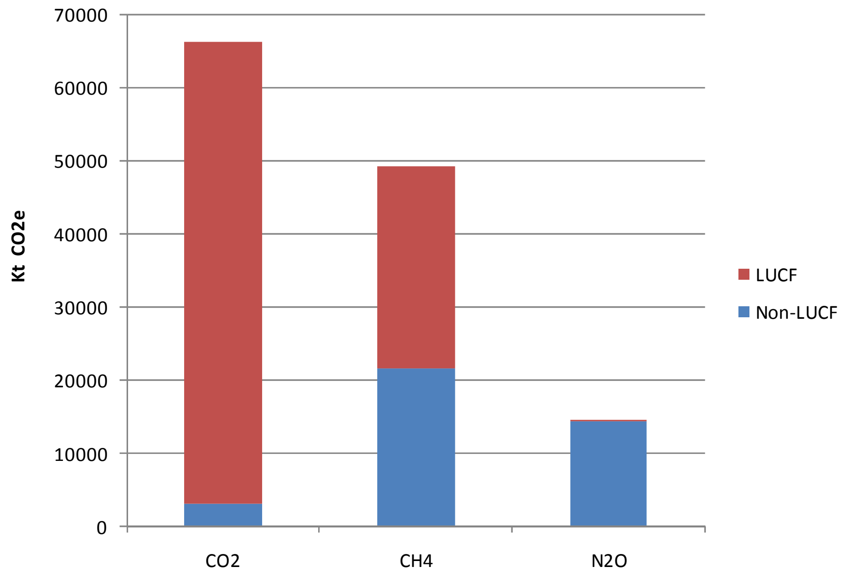


Figure 4. Tanzanian GHG Emissions in 1994, including Land Use Change and Forestry (LUCF)
(Source: GoT 2003)

Whilst current emissions are low, it is likely that as Tanzania's economy grows and as incomes rise, this situation will change. The future is likely to lead to increasing reliance on fossil energy resources, an increased need for agricultural output and greater pressures on forest resources. These changes match the historic pattern of growth versus CO_2 emission levels (shown below in Figure 5), which provides an indication of how higher growth in Tanzania over recent years has matched higher emissions, in this case CO_2 due to higher fossil fuel use.

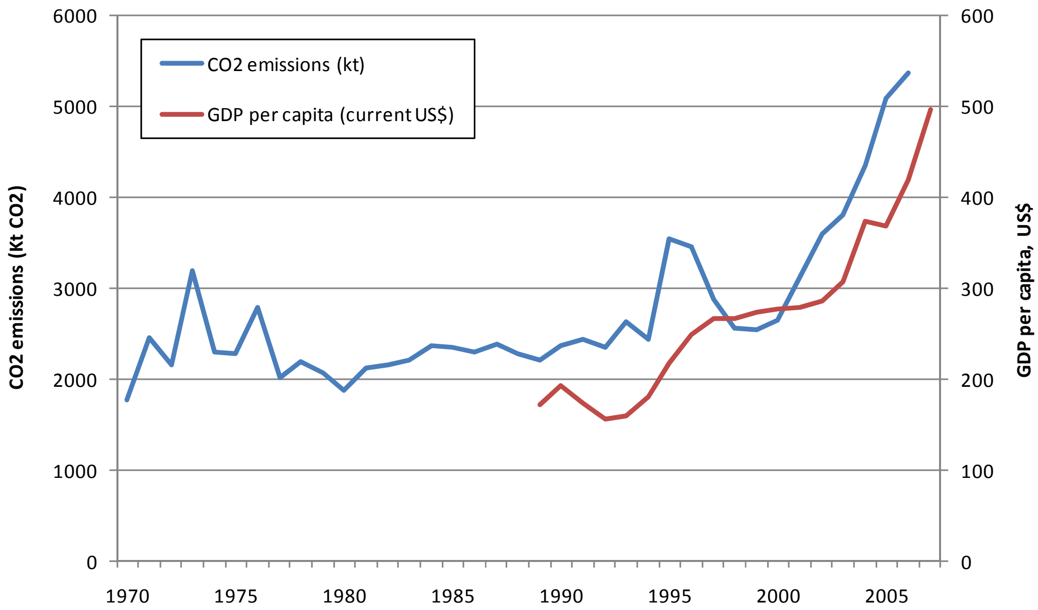


Figure 5. Historic trend of CO_2 emissions, and GDP per capita levels in Tanzania, 1970-2005
(Source: World Bank Development Indicators[11])

[11] World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators

Given the near to medium term growth forecasts for the country (see next section), under a business-as-usual case, emissions will grow rapidly.

Drivers of emission growth in future years: Population and economic growth

The key drivers of future emissions include population growth and economic development. Historic and projected population growth for Tanzania is shown in Figure 6, split by rural and urban populations. Population is forecast to grow significantly from just under 40 million in 2005, to 75 million by 2030, and 110 million by 2050 (Source: UN, 2010). There is a significant shift from a rural-dominated population to one with a large urban population. These rapid demographic changes will be important in changing patterns (both spatial and temporal) of future demand for energy and transport services, and will in turn affect GHG emissions.

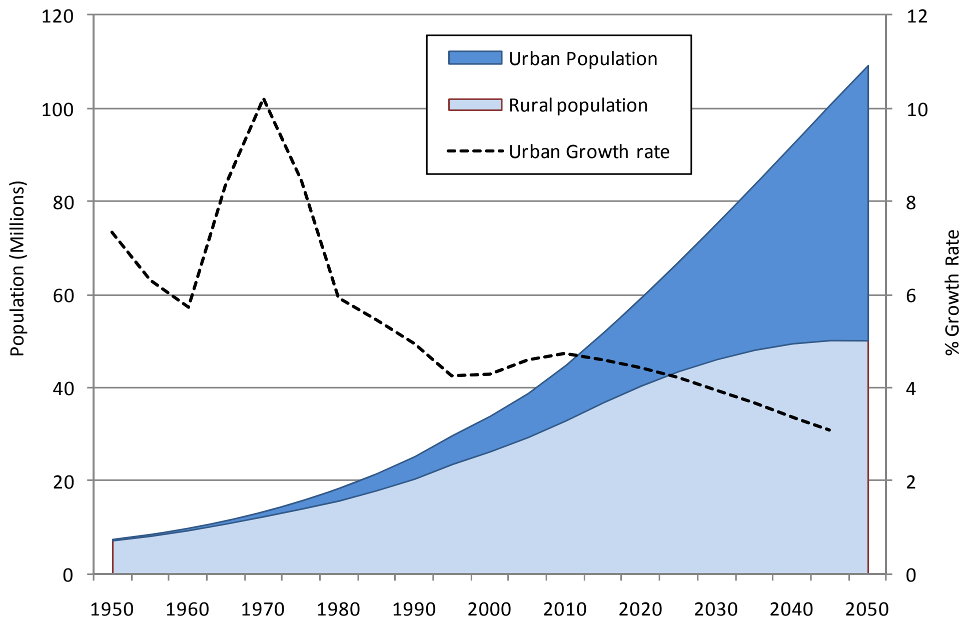


Figure 6. Growth in population in Tanzania between 1950-2005 (historic) and 2005-2050 (projected)
(Source: World Population Prospects, United Nations)[12]

GDP is also an important driver of emissions growth, due to the linkage between energy demand and growth. An objective of the National Strategy for Growth and Reduction of Poverty (NSGRP II or MKUKUTA II) (GoT 2010) is for GDP growth to be between 8-10% per annum by 2015. This is in line with the earlier Vision document (GoT 1999), which also had an objective of an 8% annual GDP growth rate.

These growth rates are forecast to lead to an increase in total GDP from US$ 15 billion (in 2005)[13] to over US$ 90 billion by 2030, based on the assumed growth rates described above (see Figure 28 in Appendices). Such growth will require significant increases in demand for energy services, and under a business as usual path, higher GHG emissions.

The contribution of different sectors to GDP is critical to understanding how sectoral emissions growth may change over time. In 2005, the contribution of the agriculture sector was 47% for agriculture, [14] with an

[12] Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision, http://esa.un.org/unpp, Accessed April 27, 2010
[13] World Bank Development Indicators, http://data.worldbank.org/country/tanzania
[14] World Bank Development Indicators, http://data.worldbank.org/country/tanzania. Note that the Economic Survey 2007 states that the contribution of agriculture activities to GDP was 25.8% in 2007, a much lower value than provided in the above. This difference needs to be understood – although is unlikely to materially change the projections.

assumption of a reduced share of 30% by 2030 (value added, % of GDP). This reduction is in line with NSGRP, which foresees an economy reducing its reliance on the agriculture sector. Industry and service sectors have shares of 14.5% and 38.4% respectively, and are assumed to increase to 25% and 45% respectively by 2030.

These drivers form the basis for projecting future emissions, and allow us to develop a reference case or baseline, from which to assess emission reduction potential, and lower carbon investment opportunities. It is important to highlight that no explicit account has been taken of how unsustainable resource use will impact on future growth (as has been inferred). This is a shortcoming of the analysis, in which no additional macroeconomic assessment of these factors has been undertaken.

Reference case projections

Energy sector overview

Energy sector emissions are currently low in Tanzania due to the limited use of fossil fuels. Most energy requirements are met through the use of biomass, the contribution of which is 89% of final energy consumption (see Figure 7). This is primarily used in the residential sector, to provide energy for cooking. Electricity consumption is extremely low, accounting for less than 2% of final energy requirements. This reflects low grid access rates of 14% for the population as a whole,[15] and around 1% in rural areas (GoT 2003b).[16] Petroleum products, all of which are imported, make up the balance.

Due to the very high biomass component of the system, the carbon intensity of energy used in Tanzania is extremely low compared to other countries (see Figure 3).

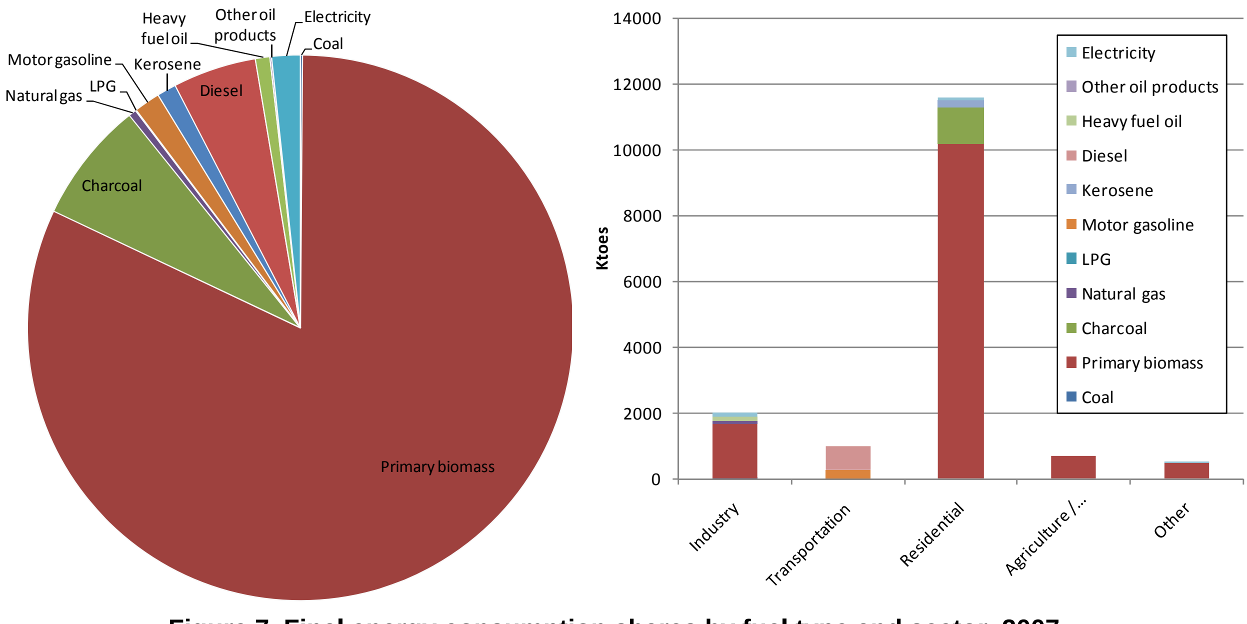


Figure 7. Final energy consumption shares by fuel type and sector, 2007
(Source: IEA 2009)

Whilst biomass is the primary energy resource, the rate of use is not sustainable i.e. annual consumption exceeds forest stock growth. In addition, the overall forest stock is declining due to deforestation, estimated

15 Overview of Energy Sector, Document downloaded from Ministry of Energy and Mines website, http://www.mem.go.tz/energy/index.php
16 A specific agency, the Rural Energy Agency (REA)[16] was set up in 2007 to ensure modern energy services, particularly electricity, would be provided to rural communities, breaking the dependence on biomass. A Rural Energy Fund is used to fund rural energy projects.

in the FAO's Forest Resource Assessment (FAO 2006) to be as high as 412,000 ha/year.[17] Hence, whilst the energy system currently appears to be 'low carbon', this is simply a function of how the inventory accounting has been done. The loss of carbon through unsustainable use for wood fuel is captured in forestry emissions, as described later.

In terms of other indigenous resources, Tanzania has significant hydropower potential, estimated at 4.7 GW (current level is about 0.55 GW). Fossil resources include coal reserves, estimated at about 1,200 million tonnes, of which 304 million tonnes are proven, whilst proven reserves of natural gas are estimated at 45 billion cubic metres (from Songo-Songo and Mnazi Bay).[18] Natural gas reserves were also discovered at Mkuranga in 2007, and are being assessed to determine whether they are of commercial value or not.[19] Renewable resources such as wind, solar and geothermal are potentially significant sources of energy although have yet to be systematically assessed.

The evolution of the energy system towards a more modern and sustainable energy system is set out in the National Energy Policy of Tanzania (GoT 2003b). The Strategy's priorities include the need for affordable and reliable supplies, greater use of indigenous and renewable resources, reform of energy markets, energy efficiency and environmental considerations. It recognizes the importance of the energy system for economic growth and development. Given the drivers described in the previous section, it is likely that the energy system will grow significantly, and will evolve in respect of energy mix, particularly as more modern energy services are provided e.g. expanding electricity system and alternatives to household biomass.

Electricity generation and distribution

In 2007, the capacity of the electricity generation system was approximately 1000 MW, over 50% being hydro generation plant, with the remainder broadly split equally between gas and oil. In terms of generation, over 60% of electricity was provided by hydro power, and 37% from gas generation.

Historically, electricity generation levels have been relatively low although they have increased rapidly post-2000 (see Figure 29, Appendix 2). In addition, distribution losses have also been historically high, at over 20%, meaning that for every five units of electricity generated only four units are supplied. The low levels of generation (and therefore consumption) are reflected in Tanzania's per capita consumption levels[20]. In 2007, the level was below the average for sub-Saharan Africa, at 81 kWh / capita compared to 151 kWh in Kenya and 4985 kWh in South Africa.

Prior to 2005, the system was almost totally reliant on hydro generation, leaving it vulnerable to outages during low rainfall years. This was seen particularly in the mid-1990s and 2006 (illustrated in Figure 30, Appendix 2), when serious load shedding problems arose.[21] Post-2005, significant additional thermal generation capacity has come online, reducing this vulnerability in dry periods (although not removing it completely).

The baseline projections for the electricity generation system (see Figure 8) are based on the Power System Master Plan Study (GoT 2008b).[22] The Master Plan is an outlook by TANESCO to inform planning in future years based on demand growth. A range of options have been considered that would meet future demand but also that ensure a given reserve capacity (to safeguard against outages, maintenance, etc), that are economically attractive and that do not lead to over-reliance on hydro power.[23] It is important to recognise

[17] We recognise there are other lower rates quoted in other documents, highlighting the uncertainty in this area, and the need for further assessment, as being undertaken in the REDD baseline development activities.

[18] Overview of Energy Sector, Document downloaded from Ministry of Energy and Mines website, http://www.mem.go.tz/energy/index.php

[19] EWURA website, http://www.ewura.com/naturalgas.html

[20] The indicator *per capita consumption* is estimated by dividing total population by total electricity supplied

[21] Load shedding can have significant impacts on economic activity, as loss of supply can result in manufacturing or operations or commercial services to temporarily shut down. It can also disincentivise expansion of the manufacturing sector, slow consumption rates and new connections in other end use sectors, reduce revenues for generation / distribution companies and increase costs for consumers who need to purchase and run expensive diesel generators.

[22] Forecasts of system capacity can be found in Appendix 1.

[23] The key criteria in the long term are: - 1) meet the load forecast with an appropriate level of reserves to guard against unforeseen events such as a failure of generating units or sharp increases in demand, 2) use the least cost (in terms of unit costs of average energy

that the Master Plan is only one outlook (amongst a number of other alternatives), and is from the perspective of TANESCO. As the role of IPPs (private sector generation) increases (promoted through the Electricity Act 2008), this outlook could change. However, as current outlook that has been well thought through, it seems reasonable to use this as the basis for a Reference projection.

Box 1. Current projects likely to be developed in the near term (~2016)

Near term capacity additions may include:

* Kiwera Coal. To be developed in two phases of 200 MW
* Singida-based wind project. Starting at 50MW and scaling up to 200MW
* Expansion of the existing Mtwara Energy Project (MEP). Currently generating 10MW for an isolated grid in Mtwara and Lindi Regions, but with plans to expand to 300MW and connect to the national grid
* Chinese developer in partnership with the Rufiji Basin Development Authority (RUBADA). Two projects, one 165MW hydro at Mpanga to cost $202 million, and a second at Kilombero, exploiting the Kinganse and Shuguhli Falls for 464MW and costing $955 million.
* Kinyerezi gas to power project. Near the current Sango Sango site, would generate 240 MW
* TANESCO to add 100MW of gas at Ubungo in Dar es Salaam and 60MW of diesel in Mwanza
* TANESCO to buy 70% (70 MW) of the existing Dowans generation facilities (currently not operating and under considerable political scrutiny)
* Ruhuji Hydro in Iringa Region, near Kilombero, 358MW

The above list does not include the small (<10MW) "flagship" renewable energy power projects that are being supported by the World Bank and Sida through the Rural Energy Agency (e.g. 4MW hydro in Mufindi, 1MW biomass power project on Mafia Island)

Source: Communication between CAMCO and the Ministry for Energy and Minerals

Based on the projections in the Master Plan, the system becomes much more diversified. Although hydro remains a critical generation source, significant increases in domestic gas and coal-based generation can be observed, increasing the carbon intensity of the system. Losses (the difference between total generation and sales (red line)) are assumed to reduce from 24% in the base year to 15% by 2030.

Generation levels are projected to increase by over 7 times to meet demand, resulting in consumption levels of around 300 kWh per capita, which is still relatively low compared to middle income countries. However, this consumption value is based only on centralised electricity generation, and does not take into account decentralised systems that Tanzania will have in place in 2030, back-up diesel generation (to address load shedding problems), or captive (self) generation in the industry sector.

Future emissions (measured in kilo tonnes of carbon dioxide, $ktCO_2$) from the centralised generation system are estimated based on the mix of new plants (see Figure 9), and are approximately 10 times higher in 2030, relative to 2005. The carbon intensity (the emissions of carbon per unit of electricity supplied, measured as kilogrammes of carbon dioxide per kWh) shows a significant rise from ~0.3 $kgCO_2$/kWh in 2005 to over 0.6 $kgCO_2$/kWh in 2009/10 as coal generation comes online. This decreases to 0.45 $kgCO_2$/kWh by 2014, due to increased imports and additional hydro capacity. These estimates do not take account of back-up generation from diesel generation sets, which can be significant during load shedding periods. However, the assumption is that additional capacity in the near term will reduce current load shedding problems.

over the life of the plant) options first and 3) maintain a hydro: non-hydro ratio of about 50% so as not to be overly dependent upon hydrologic uncertainties

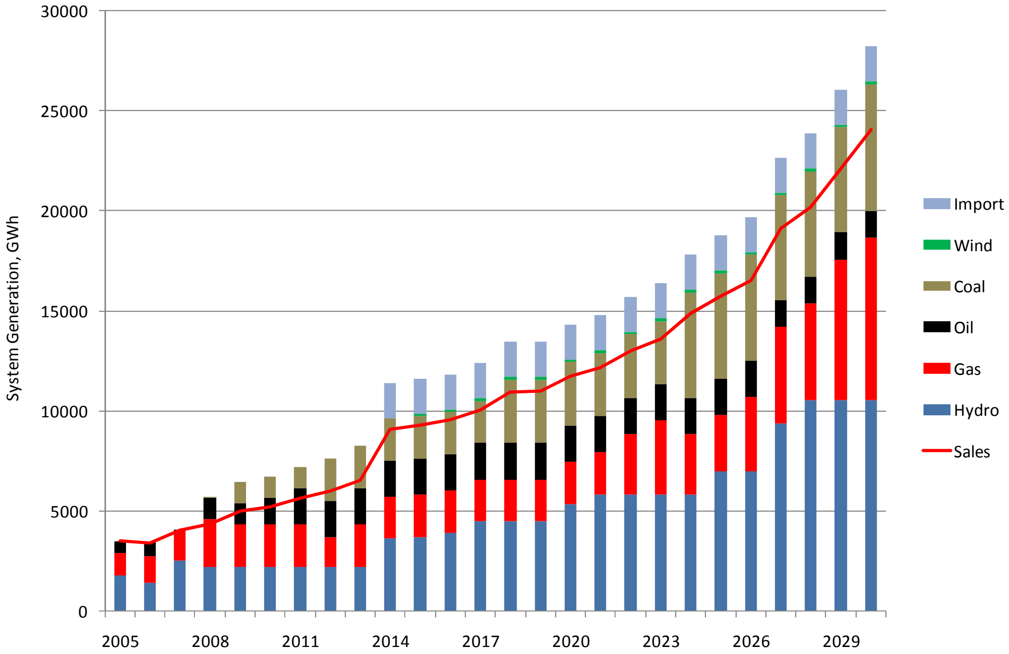


Figure 8: Forecast electricity generation (GWh) for Tanzania, 2008-2030
(Source: GoT 2008b)

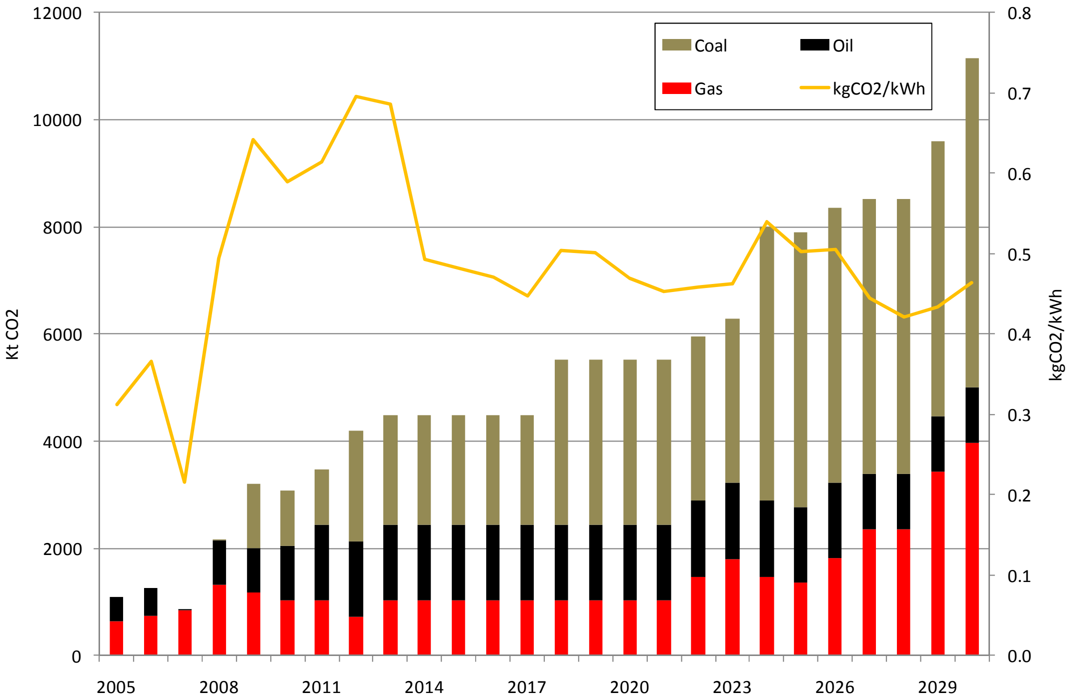


Figure 9: CO_2 emissions from electricity generation sector, Kt CO_2 and carbon intensity of generation (kgCO_2 per kWh generated)

Household energy consumption

The household sector is the largest consumer of energy in Tanzania, the main sources being primary biomass and charcoal (see Figure 7). Biomass is used in rural households for cooking (in the main) and heating. Urban households tend to use charcoal for cooking. Other fuels have achieved limited penetration to date, primarily due to affordability and access. Kerosene is used for lighting (and cooking) in both urban and rural households, whilst some limited LPG use (mainly for cooking) can be observed but is primarily limited to urban areas. As stated in the previous section, levels of electricity use in the household sector remain low.

Projecting future household energy consumption needs to take account of a number of factors including population / household growth, rate of switching to modern types of energy (based on increasing income), household energy intensity (again correlated to income), how efficiently energy will be used in future and changes to energy access and price. It is therefore a complex sector to develop projections for. Note, as discussed in the later section on climate resilient growth, climate change may actually lead to changes in energy supply and demand as well.

Biomass and charcoal consumption

Estimates of biomass and charcoal consumption for the projection base year (2007) have been derived using a bottom-up methodology. For charcoal estimates, the following assumptions have been made:

- 85% of the urban population use charcoal as their primary household fuel (SADC 2005). An additional assumption is that 5% of urban and rural households also use charcoal on an adhoc basis (20% of primary use levels)
- Annual consumption per household is approximately 1.08 tonnes / yr (or 3 bags of about 30 kg each per month) (SADC 2005).
- Production efficiency of charcoal has been taken as 14% based on IEA statistics (commonly used simple earth kilns have efficiencies of 10-15%). This is the conversion rate of tonnes of firewood to tonnes of charcoal.

For fuel wood the following assumptions have been made:

- 95% of the rural population and 5% of the urban population use fuel wood as their primary household fuel. A further assumption is that 5% of urban and rural households also use charcoal on an adhoc basis (20% of primary use levels)
- Annual consumption of fuel wood per household is approximately 3.1 tonnes / yr (or approximately $4.3m^3$), based on the use of a simple three-stone fireplace (SADC 2005).

The above assumptions result in the estimates shown in Table 2.

Table 2. Estimates of charcoal and biomass consumption in 2007, kilo tonnes of oil equivalent (ktoes)

Fuel category	Bottom-up estimate	IEA (2009)
Primary biomass	4644	10156
Biomass for charcoal production	3559	3242
Charcoal	1303*	1135
Total primary biomass	8204	13398

* Equivalent to 1.85 million tonnes. This compares well to the estimate of 1.6 million tonnes in SADC (2005) for 2002.

A key issue from a comparison of the bottom-up estimates versus the IEA statistics is that primary biomass consumption levels are significantly higher under the IEA statistics, resulting in high per household consumption levels.[24] It is clear that these statistics are uncertain, with biomass consumption extremely difficult to estimate. In this project, we have decided to base our estimates on the bottom-up approach, as the assumptions behind such estimates are clear, and based on referenced assumptions.

[24] It may be that the IEA figures also include institutional and small industrial activates such as tobacco curing, brick making, school cooking. However, if assumed only for households, per capita consumption levels would be unrealistic i.e. much too high

By 2030, the percentage of urban households using charcoal reduces from 85% to 70%, while those using fuel wood remains constant at around 8%. However, the amount of charcoal energy consumed per household increases by 10% as average incomes increase (in view of experiences in other countries and historic consumption). Due to the very high growth rate of the urban population, this results in more than double the number of households (in absolute terms) using charcoal. Fuel alternatives for cooking include LPG and for higher income households, electricity. The number of households using biomass in rural areas is estimated to reduce slightly, due to a small amount of uptake of alternatives by higher income groups (LPG) and use of small-scale renewable technologies (e.g. biogas, solar). The energy intensity of biomass use per household remains the same in each projected year.

Other household fuels

The other household fuels considered in the projections include kerosene, LPG and electricity. The energy balance values from the IEA (2009) have been used for the projection base year. It is very difficult to predict (in the absence of more detailed economic modelling) how the penetration of these fuels in the household energy mix will change. If they can be accessed, their uptake is a function of rising incomes, affordability and convenience relative to other alternatives.

Electricity consumption is based on the projections from the previous section, with some limited growth in rural decentralised generation. By 2030, this results in 50% urban and 15% rural households with access to electricity, up from 25% and 3% respectively (in the base year). Electricity consumption per household is estimated to have increased by 30% in 2030. The growth in electricity is due to increasing demand across a range of energy services – lighting, cooling, cooking, refrigeration and other appliances (TVs, computers etc). This is consistent with the demand projections for electricity in the TANESCO Master Plan.

Kerosene used in households declines, as increased electricity consumption provides a higher percentage of lighting demand. Finally, the percentage of households using LPG increases due to growth in incomes and resulting increased demand for cleaner, more convenient energy types. We have not assumed any potential for natural gas supply to household customers, with this resource assumed to be used exclusively for power generation. Even if available, high infrastructure costs and low heating demand probably make such an option uneconomic.

Projections

The projections for household energy consumption have been split into rural and urban areas. The aggregated projections are shown in Figure 10 below. The fuel wood for charcoal production is not shown in the figure; however, if plotted, it would double the total energy presented in the graph.

Biomass and charcoal remain the most important fuels for the provision of cooking services, both in urban and rural areas. This projection would lead to increased levels of forest degradation, and further reduce the sustainability of biomass resources, particularly in the context of ongoing deforestation driven by agricultural sector activities.

Modern types of energy increase from 5% to 15% of final energy consumption. However, in reality they are providing a much more significant share of energy services (heating, cooking, cooling etc) because they tend to be used much more efficiently than fuel wood and charcoal i.e. biomass may be used in appliances that have efficiency values of 15%, relative to LPG used at 60% efficiency. Therefore, in useful energy terms (or for cooking, ‘energy in the pot’), modern types of energy provide (approximately) 18% of energy services in 2007, rising to 42% in 2030.

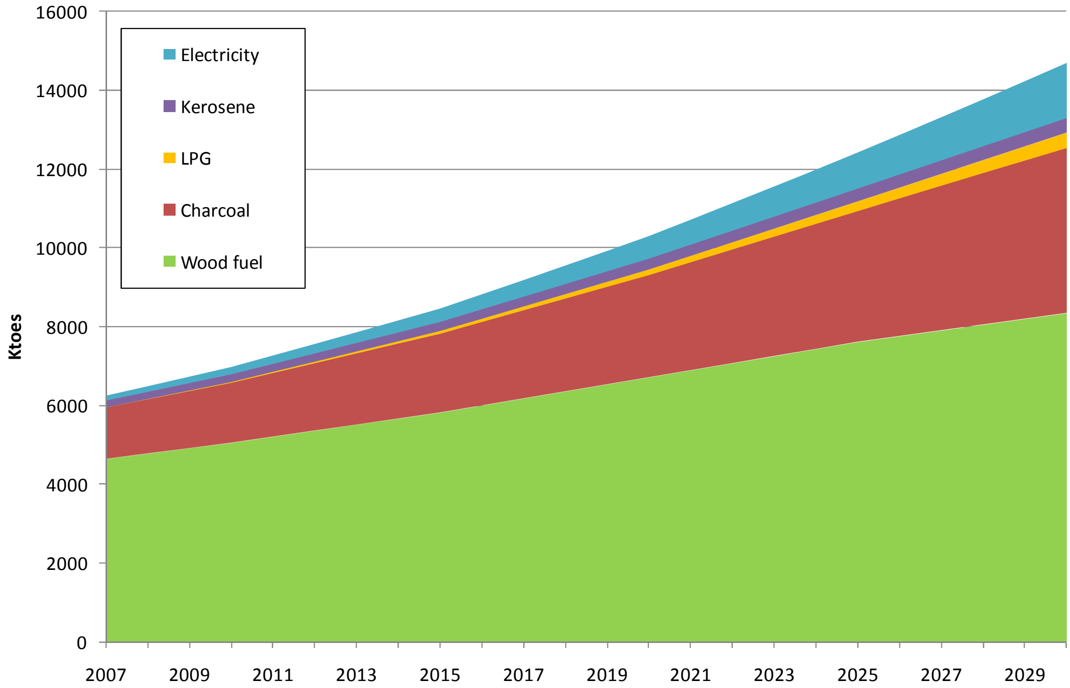


Figure 10. Projections of household final energy use in Tanzania, Ktoes

Based on the above projections, biomass consumption (including wood fuel and biomass used for charcoal production) more than doubles to 62,000 ktonnes in 2030 (from 28,000 ktonnes currently). This equates to 87 million m^3 (from current level of around 39 million m^3).[25] The removal of wood stocks from forests is taken into account in the forestry emission projections below.

As illustrated in the projections, it is really the wood energy demand that is driving the emissions from the forestry sector. Mwampamba (2007) notes that significant impact of charcoal consumption in particular, assessing a range of scenarios. In conclusion, the paper suggests that forests on public land could be fully depleted by 2028, under a median consumption level scenario, and assuming low kiln efficiencies and low replenishment of harvested forests.

Industry

Energy consumption in the industry sector in 2007 was dominated by biomass energy, based on the IEA statistics. It is assumed that this is primarily consumed in small-scale and cottage industries. For the manufacturing sector, the projected energy demand is shown in Figure 32 in Appendix 1.

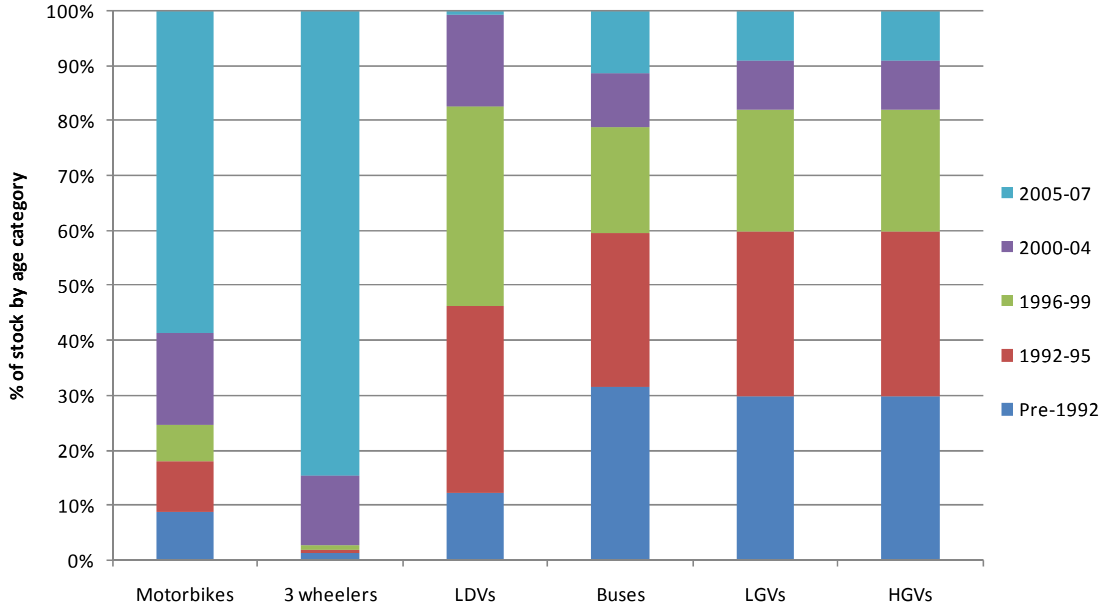
The driver for projecting future energy consumption is growth in GDP contribution from the industry sector. The same fuel mix is assumed as currently observed, and industry is classified as general manufacturing. Consideration of autonomous energy improvement over time is also factored into the projections. Understanding of how industry may re-structure over time is also important for estimating energy intensity of output, particularly if a more service-based economy is foreseen as opposed to more energy-intensive manufacturing. However, relevant strategy documents do not provide a level of detail that would allow for improved understanding of how the subsectors may evolve.

[25] Total current consumption across all sectors is 50 million m^3. This compares well to other estimates, such as that cited in GTZ (2009), estimating fuel consumption in Tanzania in 2005 at 46.2 million m^3 of solid round wood.

Transport

Tanzania currently has a relatively small transport sector, accounting for around 6% of final energy consumption. However, the sector is growing at a rapid rate. Consumption of road transport fuels, all of which are imported, increased from 400 ktoes in 2000 to 1000 ktoes in 2007.

Road vehicle numbers (based on vehicle registrations from the Tanzanian Revenue Authority) are also rising rapidly. Figure 11 provides stock information for road vehicles (sourced from the TRA (Tanzania Revenue Authority)), illustrating the mix of vehicle ages across the fleet. The older age of the stock illustrates the large market in second-hand vehicles in Tanzania. However, it is understood that this registration database does not fully account for deregistered vehicles so could well be overestimating older vehicle levels.



Vehicle Type	Motorbikes	3 wheelers	LDVs	Buses	LGVs	HGVs
Stock (000s)	76	1.10	172	27	44	44
Fuel Use (Ktoe)	11	0.21	160	207	129	496

Figure 11. Split of road transport stock by age group

The benefit of using stock data, disaggregated based on age, is that a more accurate characterisation of fuel consumption by vehicle can be developed, based on different efficiencies. Bottom-up estimates have been developed, and are comparable with the published aggregate fuel consumption values. These 2007 estimates provide the basis for the projected estimates.

The main drivers for projecting vehicle types are GDP (for freight –based vehicles) and income per capita (for passenger vehicles). The drivers are taken from the IEA/SMP model, published on the World Business Council for Sustainable Development (WBCSD) website.[26] Demand elasticity factors, which reflect the strength of the driver in projecting a given demand, are taken into account. Improved efficiency of vehicles purchased in future years is also accounted for. Another important assumption made is that the above stock profile (in Figure 11) changes over time to reflect that, as incomes increase, an increasing number of new (or newer) cars, as opposed to second hand cars are purchased. This has the impact of making the relative stock efficiency higher in future years.

Projected fuel consumption levels by vehicle are shown in Figure 12. This represents the Reference case, assuming no significant uptake of biofuels or advanced vehicles (e.g. hybrid electric, electric).

[26] WBCSD website, www.wbcsd.org

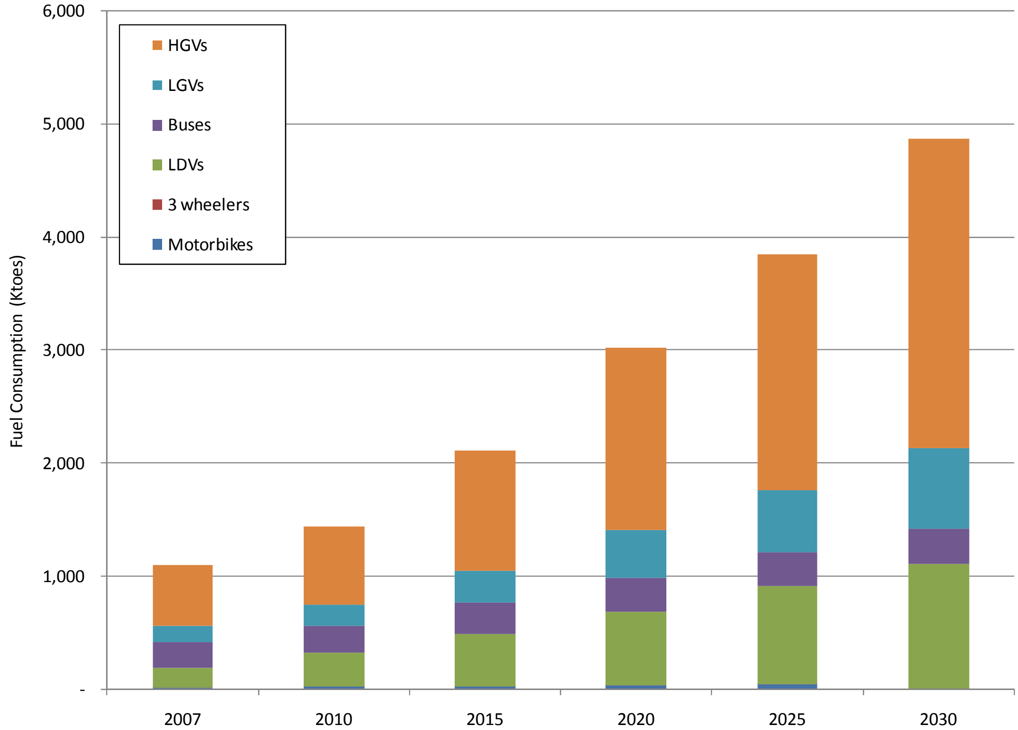


Figure 12. Projected fuel consumption for the road transport sector, Ktoes

Despite more efficient vehicles in the fleet in future years, fuel consumption in the road transport sector will have increased by almost 5 times. From a current level of 171,000 cars, this is project to increase to 1.5 million cars by 2030. Goods vehicles are projected to increase from current levels of 80,000 to 550,000 vehicles over the same period. These estimates assume similar vehicle speeds and effects on efficiency, and do not account for any increase in fuel that would occur with increasing congestion. This is already an acute problem for Dar es Salaam, and one likely to increase with the rising vehicle projections here. SEI (2009) cited evidence that 1.26 litres of transport fuel were wasted for every hour spent in congestion. The economic costs of congestion are extremely large and can be important at the macro-economic level, as described in the introduction. This is supported by evidence from Kenya; in its Vision document,[27] poor urban transport systems in Nairobi and the resulting congestion are estimated to cost 2% of GDP (NB. Nairobi accounts for 40-50% of national GDP).

Agriculture

The agriculture sector dominates the Tanzanian economy, as measured by contribution to GDP and in terms of employment. The World Bank estimates that in 2006, the agriculture sector contributed 45% (based on the *valued added* metric),[28] and the 2007 Economic Survey (GoT 2008) put agricultural sector employment at 77% of total workforce in 2006 (compared to 84% in 2000/01).

Out of the estimated 44 million hectares (ha) of land suitable for arable cultivation, 10.1 million ha are currently being cultivated. 26 million ha are used for livestock farming. Farming is generally on a small-scale, with 85% of arable land used by small-holders, at an average plot size of 0.12 ha. Mechanisation of farming and fertiliser input is limited, affecting levels of productivity (GoT 2001). Most small-holders use hand hoes as the primary agricultural tool for tilling. Irrigation levels are also low, with most agricultural systems primarily rain-fed. Only 1% of potential irrigable land (29.4 million hectares) is irrigated.

[27] GoK (2007), Kenya Vision 2030, Government of Kenya, Ministry of Planning and National Development and the National Economic and Social Council (NESC)
[28] See World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators

The earlier goal for this sector, as set out in the sector strategy (GoT 2001), was *that by the year 2025* [the sector] *is modernised, commercial, highly productive and profitable,* utilising natural resources sustainably.[29] Such a strategy could have the following impact on emissions:

- Increased inputs of fertiliser and energy resulting in higher emissions as productivity per ha increases. However, this does not necessarily translate into higher emissions per unit of output.
- Increased export market, as non-domestic markets are sought, potentially resulting in higher processing sector and transport-based emissions.
- Less spread of cultivated land, as agriculture modernises, potentially moves to larger scale farms and increases productivity per ha. Such a move could have positive implications for the rate of deforestation, as small scale cultivation is the most important driver.

The more recent Kilimo Kwanza document updates the agricultural sector policy, summarised in the box below.

Box 2. The Agriculture Sector Strategy in Tanzania

The Kilimo Kwanza document outlines that the transformation of Tanzania's agricultural sector must be the foundation of the country's socio-economic development, and that the country must achieve food self sufficiency for its continued stability and development. It sets out the acceleration of the agricultural sector transformation, with agriculture as an economic priority. While it builds on the existing strategy, it has a stronger private sector lead, and sets out a number of pillars, covering financing, governance, production (food crop priorities), tenure, incentives, value addition, resources and infrastructure development.

The Mkukuta document reports that the real growth of agriculture sector in the medium-term between 2010 and 2015 is projected at an average rate of 5.3% a year compared to average growth rate of 3.9% in the 2005 – 2009 period. The sector will be strongly recovering from a low growth rate of 2.7% in 2009 and is expected to pick up to 4.0% in 2010 before jumping to 6.3% by 2015 mainly on the assumption that world economy recovers. The growth in the production of crops is expected to pick up as the increased productivity in the agriculture due to government efforts of boosting production capacity by providing agricultural inputs like fertilizers, tractors and technical assistance, under the Kilimo Kwanza initiative.

The Mkukuta key interventions (also articulated in Kilimo Kwanza strategy) include:

- Improving existing and expanding agriculture irrigation infrastructure, and developing rain water harvesting infrastructure, including water for livestock
- Increasing proportion of small holder farmers using mechanization and improved seeds and implementing contract-based farming model and out-grower schemes.
- Strengthening physical infrastructure to support growth of employment generating and profitable agriculture, including small scale agriculture
- Introducing and strengthening investment incentives in agriculture, including mechanization, firm level irrigation facilities, and farm level agro-processing, and large scale crop storage facilities.
- Strengthening agro-processing, and service sector and marketing baseline information to support agricultural growth
- Promoting and adopting the use of science and technology in agriculture, including R&D for quality and nutritious food crop, high value cash crops, as well as ICT to provide information on prices and markets, advisory services
- Promoting measures to cushioning farmers from famine/droughts impacts, including piloting and scaling up farm crops/livestock insurance.
- Increasing proportion of exported processed agricultural commodities

Developing agriculture projections is extremely difficult, and the estimates used in the emission projections should be considered preliminary, and an initial basis for discussion with stakeholders. The approach to projecting livestock numbers (and emissions) used here has been to use the population growth rate, as an indicative central estimate. The use of this driver looks reasonable based on comparable growth rates for

[29] An important initiative in recent years has been Kilimo Kwanza, a strategy focused on reducing poverty, particularly in rural areas, through social and economic development driven by the agriculture sector. For more information, see *Accelerating pro-poor growth in the context of KILIMO KWANZA*, Paper Presented to the Annual National Policy Dialogue On 23rd November, 2009, Produced by Joint Government and Development Partners Group

livestock numbers and population between 1990 and 2007. This implicitly suggests that livestock farming is providing food products primarily for the domestic market.

Arable emission projections are even more difficult to estimate, particularly N_2O emissions from soil. Even using an IPCC Tier 1 methodology to derive current year estimates is complex, due to the number of inputs and uncertainty of how these will change in the future.[30] The default approach used here has been to use the population growth rate, with limited account of factors such as changing land use practices and rates / levels of fertiliser application.

Land use change and forestry (LUCF)

Tanzania has significant forest cover of 35.3 million ha, out of a total land area of 94.5 million ha. 16 million ha is reserved (or gazetted) forests (managed), 2 million ha are forests in national parks and 17.3 million ha are unprotected forests. The unprotected forests are the most heavily degraded and subject to deforestation. These are often characterised *by insecure land tenure, shifting cultivation, annual wild fires, harvesting of wood fuel, poles and timber, and heavy pressure for conversion to other competing land uses* (GoT 2009b). The 2005 Forest Resource Assessment (FAO 2006) estimated deforestation rates of 412,000 ha per year since 1990, leading to forest cover reducing from 41.4 mill. ha in 1990 to 35.3 mill. ha in 2005. For the purposes of the forestry projections, this deforestation rate has been used. However, we are aware that there are a number of other deforestation rates cited in different publications, illustrating the uncertainty of this type of statistics.[31] Based on the FAO statistics, Tanzania is globally ranked 6th (and 3rd in Africa after Sudan and Zambia) in terms of annual net loss of forest. (For comparison, Brazil is ranked 1st with a net loss of 3 million ha per year). Note that work is ongoing to establish this baseline, funded by the Norwegian Government (GoT 2009b, see below).

Degradation of different forest type is also significant, particularly due to the extraction of wood for use as energy, and is therefore an important source of emissions from this sector. [32]

Box 3. Drivers of deforestation in Africa

A report for the European Commission (EC 2010) states that the key **direct** drivers of deforestation in Africa (ranked based on relative importance) include:

- Small-scale permanent agriculture (deforestation), accounting for up to 60%;
- Large-scale permanent agriculture (deforestation), accounting for up to 10%;
- Fuel wood consumption (degradation);
- Commercial logging and timber production (degradation);
- Illegal logging (degradation); and
- Infrastructure development (deforestation).

Blaser and Robledo (2007) provide some quantification of the importance of different drivers. They estimate higher numbers for large scale agriculture (20%) and 50% for small scale agriculture. Wood extraction from forests (through logging and for fuel wood) account for around 20%.

Indirect drivers, which often underlie the direct drivers mentioned above include:

- Demographic – rapid population growth and increasing population density
- Economic – economic growth increases the pressure on forest resources
- Technology – agrotechnology could increase intensification, reducing agriculture land expansion. However, due to slow rate it allows for continuing deforestation.

[30] The input data needed for this methodology include synthetic fertiliser use, manure-N used as fertiliser, edible crop production of N-fixing crops and non-N-fixing crops, and area of cultivated organic soils in the country (see Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual).

[31] GoT (2008c) states the following, estimating a much lower deforestation rate - *The overall tree planting throughout the country is, on average, rated at 25,000 ha per year. When this is compared with the national deforestation rate of about 92,000 ha per year it implies a net deforestation rate of about 67,000 ha annually.*

[32] FAO definitions (EC 2010) - **deforestation** is the conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum of 10 %. **Forest degradation** concerns the changes within the forest class which affect the forest stand, quality or site negatively. Reduction of the tree canopy above the original threshold of 10 % is classified as forest degradation

- Governance – weak institutional capacity, land tenure issues and low priority for forest policy relative to other Government policies
- Socio-cultural – diseases such as HIV/AIDS can have a significant impact on the protection of natural resources due to impact on financial resources, workforce, dependency on wood fuels etc.

It should be noted that considerable uncertainties exist concerning the area of cover of different types of forest, and the loss being incurred in each (deforestation and degradation). According to an article on the Tanzanian REDD programme in TFCG (2009), uncertainties due to lack of or incomplete data are significant. Knowledge of these different forest types is key as all have different levels of carbon per hectare, a key assumption when estimating emissions (or the potential benefits of a REDD programme).

The UN Reduced Emissions from Deforestation and Forest Degradation (REDD+) scheme[33] could offer significant incentives to reduce deforestation rates. Tanzania is a UN-REDD Programme pilot country, and has published its National REDD Framework (GoT 2009b). Work is ongoing to establish the baseline, funded by the Norwegian Government, against which reduced emissions from deforestation and deforestation can be assessed.

For the purposes of this study, a first attempt has been made to update the 1990 emission inventory estimates presented in the 1st National Communication (GoT 2003), and develop estimates for 2005 and 2010 (see Figure below).

It is highlighted that these estimates are very uncertain due to the input data assumptions. They have been estimated to illustratively reflect the increasing problem of deforestation, its impact on emissions and opportunities for reducing such emissions under a scheme such as REDD.

Whilst there are significant uncertainties, the estimates highlight some important issues. Firstly, emissions from this sector have been and are predicted to rise rapidly over the next two decades. 76% of forestry emissions are a result of extraction of wood from the forest stock (degradation), primarily for fuel wood but also for other wood products. 24% of carbon release is due to conversion of forest and grass use to other land use types (deforestation). These removals are of course counterbalanced to some extent by forests acting as carbon sinks. However, there is some discussion amongst inventory experts about whether all annual forest re-growth should be counted or just plantations and newly planted trees. Therefore, we have presented both in the Figure below.

Excluding the possible impact of natural re-growth on carbon sequestration, net emissions from LUCF are estimated to rise from around 10 MtC (37 $MtCO_2$) in 1990 to around 40 MtC (147 $MtCO_2$) in 2030. Natural re-growth (excluding decay) is optimistically estimated at about 40 MtC removals in 1990, reducing to only 24 MtC removals in 2030 due to deforestation[34]. This results in net emissions of -32 MtC (-117 $MtCO_2$) in 1990 to around 12 MtC (44 $MtCO_2$) in 2030.

Based on the estimates including natural forest re-growth in the calculation, Tanzania's biomass consumption is unsustainable beyond 2020 as extraction (of wood fuel and timber) out-strips re-growth/regeneration at an accelerating rate to 2030 and beyond, driven primarily by wood fuel demand. Under the case (as presented in the 1st National Communication) where natural forest re-growth is not considered, biomass use is already beyond unsustainable levels.

It is important to state that these estimates do not take account of any action to address the problems of deforestation and degradation in the future and present a *no action* scenario. They do account for some switching to alternative fuels away from biomass. However, the net effect is still rapidly increasing biomass consumption due to strong population increase.

[33] Reducing Emissions from Deforestation and Forest Degradation (REDD) is a mechanism to create an incentive for developing forested countries to protect, better manage and wisely use their forest resources, thus contributing to the global fight against climate change. "REDD+" goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. REDD+ strives to make forests more valuable standing than cut down, by creating a financial value for the carbon stored in standing trees. In the long term, payments for verified emission reductions and removals, either market or fund based, provide an incentive for REDD+ countries to further invest in low-carbon development (UN 2009).
[34] Based on current annual deforestation rates assumed in the FAO (2006) of 412 kha/yr

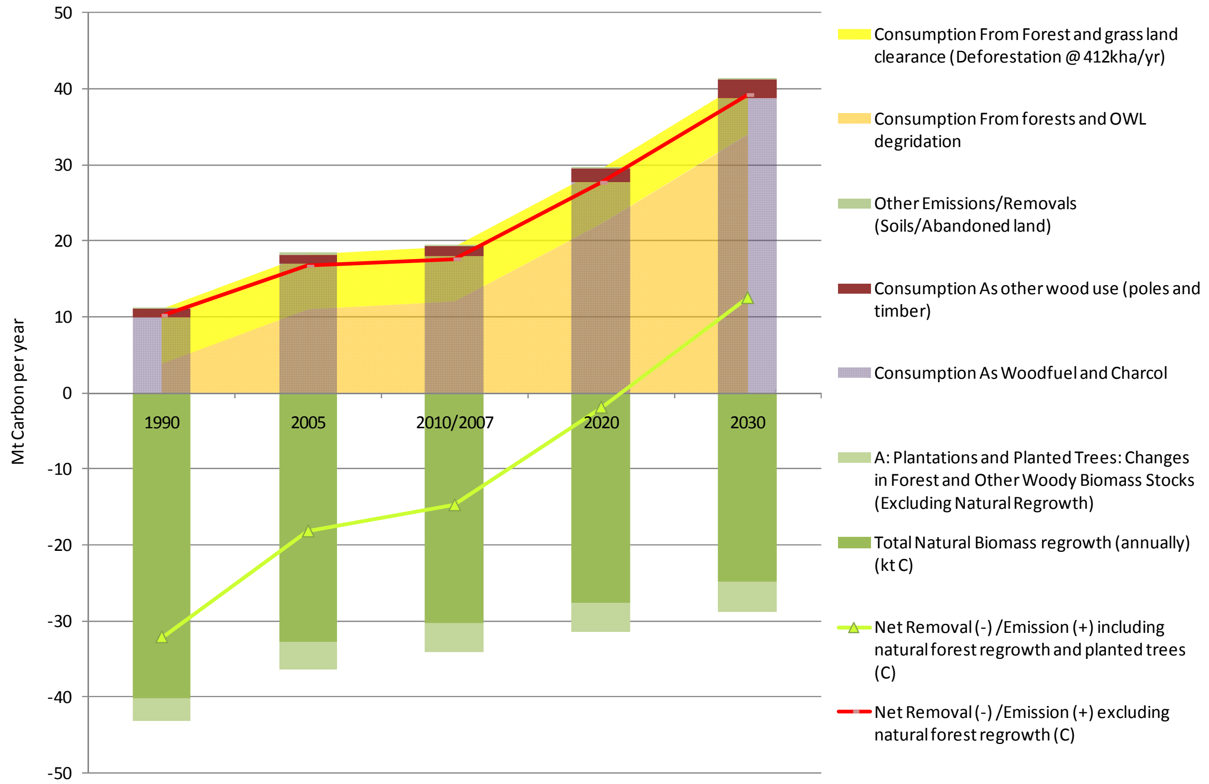


Figure 13. Land Use Change and Forestry (LUCF) sector emissions and removals, 1990 – 2030
(see below on how to read this graph)

The purple columns, red line and yellow and orange area above the zero line (x-axis) are increases in emissions. Emissions are being presented in two ways:

- Emissions by source - carbon removals from forest and grassland clearance (yellow area), and biomass extracted from existing forests and wooded areas (orange area)
- Emissions by consumption type - the use of the biomass for wood fuel and charcoal (purple bars) in households and industry, and the consumption of timber and round-wood in agriculture and industry (dark red/brown bars).

The green columns and lines (below the zero line) are reductions in emissions (removals). Removals are due to natural forest re-growth (dark green bars) and newly planted trees and managed plantation (lighter green bars).

The net emissions are represented by the red and green trend lines. The red trend line represents the net emissions/removals (in ktC) only including removals from forest and tree planting (light green bar). The green trend line represents the net emission/removal including all natural and anthropogenic- related forest planting and re-growth (both green bars).

Where the trend line is above the x-axis, this represents a situation where emissions are greater than removals. The key factor is whether natural re-growth can be accounted as a sink. If not, as we have assumed in the rest of this analysis, forestry resource use is already at an unsustainable level, and the situation is projected to get worse.

Data sources and assumptions used for the above estimates are detailed in Appendix 3.

Given the challenges of estimating even current emissions from the forestry sector, moving to the estimation of future emissions is extremely difficult. The recent EC report (2010) discussed briefly the outlook for deforestation in different regions, including Africa. The report makes the following points why reducing rates of deforestation will be extremely challenging:

- Increasing population putting additional food and fuel demands, increasing demand for forested land
- Growing economies requiring more wood products, and also growing wood export markets
- Fuel wood is likely to remain an important affordable fuel in the near to medium term
- Potential pressure on land from biofuel production, including from the international market
- Given the low levels of governance in the region, biodiversity protection and enforcement of any types of forestry policies will likely remain very difficult

The FAO (2009) states that deforestation rates are likely to remain at the same level in Africa (under a business as usual case) in future years. Specifically for East Africa, *high population densities and high land dependence coupled with land-use conflicts and limited opportunities for economic diversification are likely to reduce forest area further.*

GHG emission projections

Projected total GHG emissions (excluding LUCF) are shown below. According to the Reference case estimates, GHG emissions per capita increase from around 1.15 tCO_2e to 1.45 tCO_2e per capita by 2030[35]. In absolute terms, emissions more than double.

Even with the modest assumptions on future growth, the agriculture sector continues to be the highest emitting sector, increasing in future years due to increasing population growth and demand for food. However, the highest growth in emissions relative to the base year is due to the projected increases in fossil energy use, particularly in the transport sector. Higher demand for personal travel is foreseen as incomes rise, based on historical observations in other countries. For other sectors, lower emissions growth is estimated but still amounts to significant increases. Large uncertainties remain due to data gaps and limited information concerning the future evolution of different sectors. However, these projections provide a useful starting baseline from which to assess future opportunities for low carbon investments.

[35] Per capita CO_2 emissions rise from 0.15 to 0.45 tonnes, reflecting the growth in fossil energy consumption.

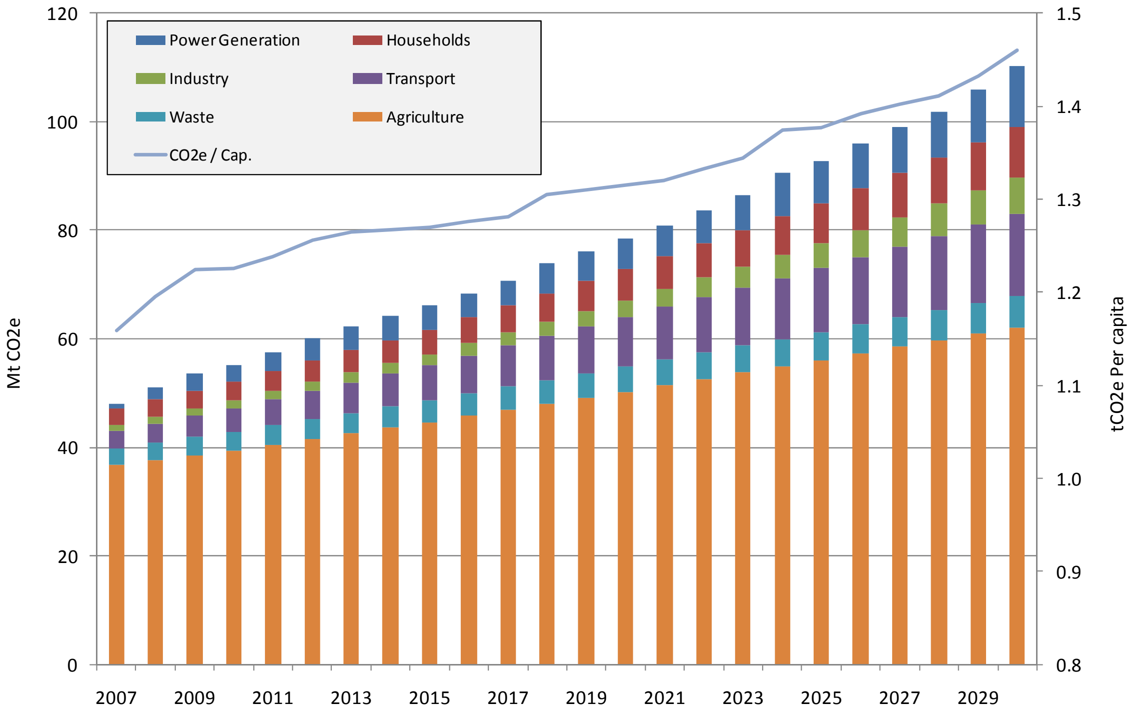


Figure 14. GHG emission projections for Tanzania (excl. LUCF), $MtCO_2e$, 2007-2030

The above projections exclude the Land use change and forestry (LUCF) sector. The importance of this sector, as shown in Figure 15, is that it more than doubles total emissions. Including LUCF increases per capita emissions from 2.6 tCO_2e in 2007 to 3.4 tCO_2e in 2030. (The forestry estimates below do not take account of the impact of natural forest re-growth, and its impact in storing carbon, as discussed in the LUCF section above).

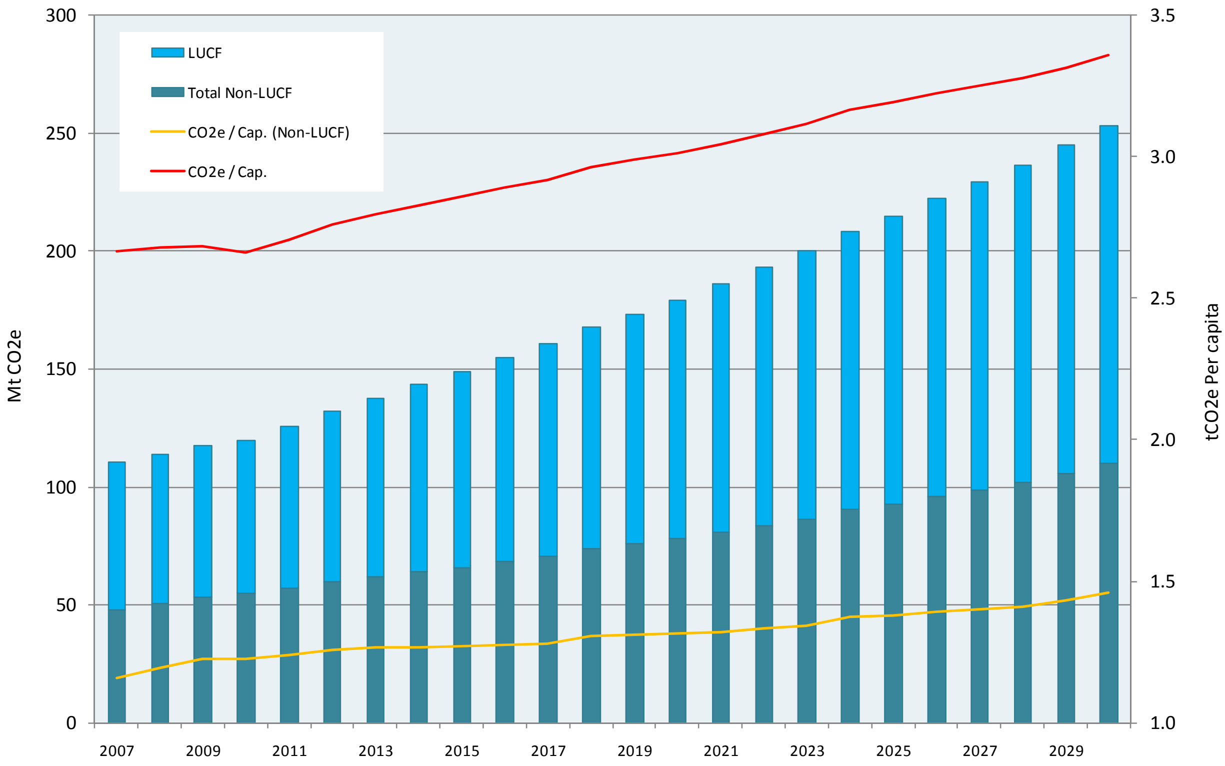


Figure 15. GHG emission projections for Tanzania (incl. LUCF), $MtCO_2e$, 2007-2030

3) Opportunities for Tanzania: Towards a more sustainable growth pathway

Introduction

The future emissions pathway presented in the previous section is based on many different assumptions and is uncertain, particularly in the longer term. However, its main purpose it to illustrate that greenhouse gas emissions are likely to increase significantly over the next twenty years. This growth in emissions is indicative of strong population growth and rapid economic growth, and reflects the increasing demand for energy, both biomass and fossil-based sources, transport services and agricultural production.

From these projected increases in emissions, this analysis now focuses on exploring opportunities for low carbon investments that could both generate carbon finances and promote a more sustainable growth pathway that is in Tanzania's self interests. We have identified four broad drivers that illustrate why investments in low carbon projects could be in the interest of Tanzania, shown in Figure 16. This is even in the absence of any international obligations on Tanzania

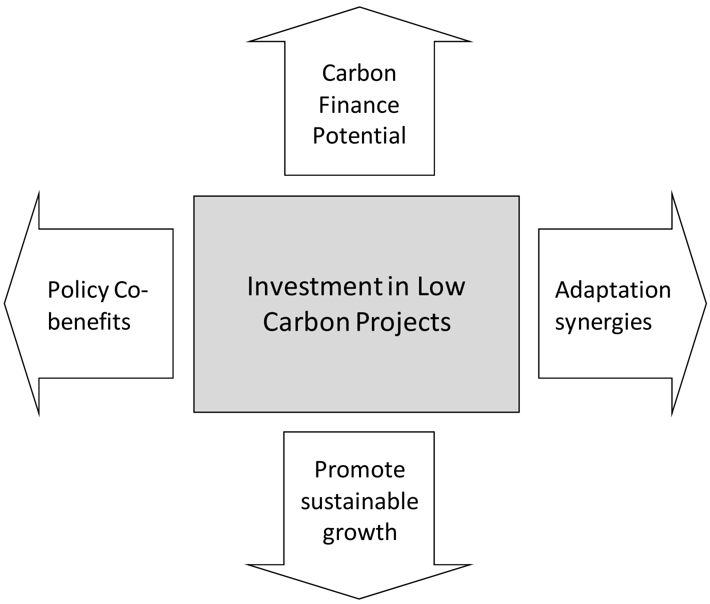


Figure 16. Drivers for investments in low carbon projects

Policy co-benefits are where low carbon investments are aligned to current or planned policies. *Strengthen development and growth* are where low carbon investments could actually stimulate new economic sectors and reduces costs e.g. through energy efficiency measures. *Carbon financing* opportunities reflect investment and financing that leads to projects or programmes that reduce CO_2 emissions. Finally, *adaptation synergies* are where these investments align with actions needed to enhance climate resilient growth.

Of course, the (likely) relative positive and / or negative impact of all of these drivers will determine the exact level of investment in low carbon projects and programmes. Tanzania is of course making investments that are low carbon. These provide practical demonstrations of the benefits of such a policy. A selection of projects is provided in Appendix 4.

This section of the report provides an overview of the key opportunities by sector, and their associated co-benefits. The economics of these are assessed, and presented in term of cost-effectiveness for reducing carbon, using a marginal abatement cost curve, or MACC (described in the next section). In addition, the importance of assessing the challenges of implementation of these opportunities is highlighted, rather than simply technical costs, as implementation challenges and barriers can often make technical options much less cost-effective.

Using a MACC-based approach

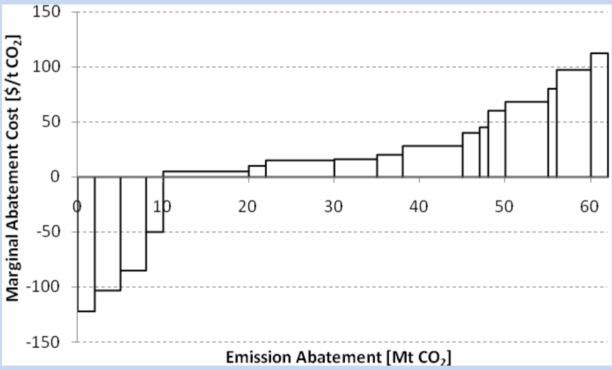
A marginal abatement cost curve (MACC) provides a basis for prioritising possible investments in low carbon technologies. It both shows the emission reduction potential, important for understanding potential for carbon credits, and the cost to reduce emissions, important for assessing whether investment in a given measure will deliver a return based on a specific carbon price. A brief guide to MACCs in provided in the Box below.

Box 4. A brief guide to Marginal Abatement Cost Curves (MACCs)

Many of the studies on low carbon analysis use a Marginal Abatement Cost Curve (MACC)-based approach. A MACC is a graph that is used for usefully highlighting the 'best' or most cost-effective options for reducing emissions across the economy, as well as the total emissions achievable for different levels of costs. They present the marginal cost of emission abatement for varying amounts of emission reduction. This is shown in the graph below.

Each bar on the graph represents a specific measure, with the vertical axis indicating the costs that each of these measures can reduce a tonne of CO_2 at (the cost-effectiveness of abatement). Thus the costs of reducing emissions increase from the individual options (the bars) from left to right. The width of each bar on the horizontal axis indicates the total potential reduction associated with each measure (in tonnes of emissions), thus wider bars represent options that can reduce more emissions than narrow bars. The total cost of each measure if fully implemented is therefore the marginal cost (y-axis) multiplied by the abatement potential (x-axis).

The cost curve therefore presents the possible options in terms of their cost-effectiveness. It orders these in terms of attractiveness or cost-effectiveness from left to right, thus the most favourable options are those in the bottom left of the graph, i.e. that can reduce carbon emissions at negative cost. These negative cost measures represent options that will result in financial savings, not costs. This is typically observed for efficiency measures that reduce fuel consumption, and therefore costs. By reading off the graph, it is possible to see the amount of emissions that can be abated for different cost levels.



MACCs always consider cost-effectiveness in a specific year, and against a baseline in that year. The baseline is critical for informing what the potential abatement is e.g. if there is significant coal generation assumed in the baseline, there will be greater potential than if generation was predominantly gas-based.

According to the underlying methodology, MAC curves can be divided into expert-based and model-derived curves. Simply put, expert-based MAC curves assess the cost and reduction potential of each single abatement measure, while model-derived curves are based on the calculation of partial- or general-equilibrium models. Most of the MACC approaches are expert-based.

Source: Updated from SEI (2010)

These types of assessments provide an important indicator as to whether a given investment might be cost-effective, and what the overall investment requirements might be. However, the evaluation of such measures needs to be broader than simply costs – there are many political, institutional and social issues that also need to be considered.

This study has undertaken a rapid assessment to provide an indication of some of the most promising options. However, it should not be viewed as comprehensive (not all options have been considered) nor as a substitute for a full integrated assessment of the potential opportunities. It should also be interpreted in view of the implementation challenges highlighted.

Prior to reviewing the MACC information in this chapter of the report, it is important that some key issues are highlighted to aid interpretation.

- In the main, all of the cost and potential assumptions used in the MACC are Tanzania specific.
- Each option in the MACC is appraised against the *standard* technology that would likely be invested in under the business as usual case.
- For these MACCs, a default discount rate of 10% has been used although this can be changed for sensitivity analysis. MACCs can be reported for 2015, 2020, 2025 and 2030 – although all those presented here are for 2030.
- A carbon price is not included in the MACCs presented below, although can be for further sensitivity analysis.
- In many cases, the metric of cost-effectiveness is sensitive to fuel prices, and in the longer term, these of course become more uncertain. In all cases, fossil fuel prices have been projected using assumptions from WEO 2009 (IEA 2009b). Current household fuel prices are based on retail prices (including all taxes) from in-country sources and EWURA. Road transport fuels do not include taxes to enable comparison with biofuel production costs. Power sector fuel prices are from the PSMP (GoT 2008b).
- The costs of renewable and other advanced technologies decrease over time. For the power sector, technology learning rates are taken from ESMAP (2007) while for transport, IEA (2008) has been extensively used.

The analysis is presented by sector below.

Electricity generation

Tanzania has historically had a very low carbon-intensive system (low emissions per kWh of generation) due to the dominance of hydro power. However, this has caused significant supply problems during low rainfall years. In future, the electricity supply system is projected to expand significantly (moving from 81 to 300 kWh/capita); to ensure reliability it cannot be over-reliant on hydro generation and will need to diversify. The sector Master Plan therefore proposes increased use of coal and natural gas in future years, utilising domestic resources.

In this context, the uptake of low carbon technologies therefore needs to be balanced against energy security, supply reliability and system operation, as well as cost.[36] In addition, climate resilience of the system will need to be fully considered, in view of future climate impacts. An analysis for hydro generation in Tanzania was provided in ECA (2009), reflecting higher costs due to possible extreme low rainfall in future years (see section 5 for more information and a critique). Against this, it is also important to recognise the potential issues with higher fossil use, particularly in relation to environmental factors (from extraction and air pollution) but also possible constraints in extreme low rainfall years due to the demand for cooling water.

Low Carbon Investment Opportunities

Key opportunities include the development of 'new' renewable sources including solar, wind and geothermal, improved transmission and distribution to reduce losses (and therefore CO_2 intensity of electricity), demand side management and efficiency, and improved interconnection with neighbouring countries.

Renewable micro and mini-grid generation options also have an important role to play in providing access to clean, affordable and modern energy in rural areas. Such opportunities are already being considered and realised by the REA, and under World Bank (2007) projects such as TEDAP.[37] This is particularly important

[36] Note that assessing these factors would be best undertaken in an integrated planning framework, provided by models such as MARKAL-TIMES or LEAP. This would allow assessment of both supply, generation and demand sectors in an integrated way.

[37] Tanzania Energy Development and Access Project (TEDAP), funded by the World Bank, to improve the electricity generation system and off-grid generation. An important environmental objective is to abate greenhouse gas emissions through use of renewable energy in

in the context of large rural areas with low population density for which centralised distribution does not make economic sense.

Hydropower

The level of large-scale hydro capacity in Tanzania is significant, currently at 560 MW. In terms of the future projected potential, there is approximately between 3-4,000 MW that has been subject to feasibility studies, such as Ruhudji and Rumakali. In the projections for this work, an additional 2000 MW of large hydro by 2030 has been assumed, as per the TANESCO Master Plan (GoT 2008b).

There is approximately 315 MW of potential small hydro in Tanzania, of which 8 MW has been exploited (GTZ 2009). Examples of smaller scale projects being developed including Kinko[38] and various projects developed by the Njombe Diocese Catholic Church Mission (with donor support) providing electricity to rural communities. There is SHP potential in the southern highlands and Tanga and Kilimanjaro Regions. Two thirds of the REA flagship SPPA projects are mini hydro, ranging from 1 to 10MW. A 4MW project in Mufindi District will connect 11 new villages.

Compared to small-scale diesel generation, micro-hydro is cost competitive in generation terms (ESMAP 2007). However, capital costs also vary depending on location and labour costs. In a paper published on the Practical Action website *Micro-hydro power: an option for socio-economic development*, a cost range of $655-5630 per kW ($US 1998) was suggested. Other important factors include whether local labour from the village has been used as part of the agreement to install the technology, reducing costs. In addition, there are issues around finding suitable locations that offer relatively secure running water all year round. This also has an impact on the costs.

As implied above, Tanzania needs to ensure reliability of supply and cannot be over-reliant on hydro resources, particularly due to concerns over water availability in future years (as experienced in recent years). In addition, some of the yet-to-be exploited potential is likely to be less cost-effective, and in more problematic areas to develop e.g. in National Parks, such as Steigler's Gorge. However, hydro generation is clearly one of the most cost-effective sources of generation (see Figure 17), with other benefits, such as water storage, and providing balancing for other intermittent renewable sources.

Wind energy

There is no proper assessment of wind energy potential in Tanzania. There have been some assessments made in specific regions – the Singida region and Makambako in the Iringa region have measured wind speeds of more than 8 m/s, a resource at which electricity generation can be produced at reasonable cost. Other areas with wind speeds of more than 4.5 m/s are Mkumbara, Karatu and Mgagao (GTZ 2009). There may also be coastal potential, and this is of potential interest to the tourist sector that experiences frequent power outages. Small or micro wind is at very early stages. It could grow, however, with the cultural connection between Tanzania and India, where wind technologies are under rapid development. Therefore, it is difficult to assess what the future potential might be for this type of technology.

Biomass

Tanzania's first IPP has been generating power from the waste of the wattle tree (TANWATT) for approximately 10 years. Cogeneration from bagasse (sugar factories) and timber waste make up a third of the Small Power Purchase Agreement (SPPA) projects. In terms of Biogas, there are plans to expand the existing 200kWp generated from digested sisal waste to 10MW, 1MW at each of ten sites. Initiatives that support expansion to other areas and other waste (i.e. oil palm waste in Kigoma) might also be considered. The 1 MW fuel switch from diesel to biomass (dead coconut) on Mafia Island is one of the SPPA flagship projects. Africa Biofuels, a US company is looking to produce vegetable oil from indigenous Croton tree for sale to TANESCO and Barrick in Kagera Region. Currently, the Kagera Region runs on an isolated TANESCO diesel generator and it would be cost effective to power could be produced and sold at the higher tariff of $0.30/kWh.

rural areas for provision of electricity. An important part of the project is the off-grid component which is looking for opportunities for technology scale-up to increase rural electrification in association with the REA.

Geothermal
Geothermal resources do exist in Tanzania although the available potential is unknown in the absence of any detailed surveying. According to GTZ (2009), a geological survey of Tanzania has been conducted since June 2006 in collaboration between the Ministry of Energy and Mines and the Federal Institute for Geosciences and Natural Resources (BGR) of Germany. Geothermal potential at Songwe is being assessed, with 60 MWe currently estimated.

One of the most significant costs associated with exploiting geothermal resources is the pre-exploitation drilling to assess the steam resources. Once the resource has been assessed and deemed commercially viable, geothermal plants can be competitive with other thermal generation plants. Kenya is actively developing geothermal power generation (150MW installed and another 150MW under construction), with 18MW over the border in Lake Natron.

Solar PV systems
There is a significant solar resource in Tanzania due to the high insolation rates. Whilst the potential is significant, installed capacity of small-scale systems in 2008 was approximately 1.8 MW (GTZ 2009). However the recent rate of growth has been fast. According to TASEA, the solar energy association, just over 100kWp of solar systems were sold in 2005, whilst in 2006, the market more than doubled to 204 kWp, with more than 4,000 systems installed.[39] Recent figures put the market at 1.5 MW in 2009. The growth rate in suppliers has also increased significantly.

There are about 12 importer/wholesalers and 150 retailers around the country. This private sector growth has benefited from donor fund market development projects (Sida, UNDP, World Bank) in association with the Ministry of Energy and Minerals (MEM). Half of the market is for small home systems (less than 50Wp) while the other half is for institutional systems (telecoms, TRA, etc.). There are good incentives in place at REA to encourage use of solar technology for social infrastructure or APEX organizations. Residential PV systems of up to 100Wp are subsidized at $2 USD per Wp by the Rural Energy Agency through the Rural Energy Fund. More than 300 technicians have already been trained in installation and after sales service.

Small-scale solar systems for households and other buildings are used for the provision of lighting and electrical appliances. The typical PV modules of 50 Wp (watt-peak) generate around 45 kWh per year, with excess electricity stored in a rechargeable battery. Costs for a 50 Wp system are typically between $400-600 depending on the country in question.[40] For a smaller system (~15-20 Wp), the cost is approximately $200. The potential can be thought about in terms of the non-electrified households and premises that could benefit from solar PV systems, which in Tanzania includes much of the 5.8 million rural households, most of which have no electricity provision.

A case study outlining the potential for solar systems, including how they can be funded, can be found in Appendix 1. One of the key issues is funding the upfront capital costs, and therefore the provision of credit for householders is critical to enable uptake. While the upfront costs are high, this does not mean that such systems are not cost-effective. A case study on Zara Solar in Tanzania by the Ashden Awards suggests that a smaller system (14 Wp) could be paid off within two years, where it replaces costly kerosene lighting.[41] This is of course dependent on the local cost of kerosene, and the conditions of any loan repayment. However, other benefits also need to be considered, such as the provision of electricity for other purposes, including commerce. Other social benefits include reducing indoor air pollution, facilitating education at home and allowing for other social activities, through reliable lighting, running of appliances etc.

Solar lanterns are also a potential technology for providing lighting, and are cheaper than a full solar home system, at between $25-90.[42] A lantern has a lamp and battery combined in one portable unit, with a 1-10 Wp PV module sometimes integrated, but often detachable.

[39] See TASEA website, http://www.tasea.org/news.php?id=42&page=1
[40] Solar technology information from Ashden Awards site, http://www.ashdenawards.org/solar
41 Providing affordable solar systems in Northern Tanzania, Zara Solar Ltd. For a typical family using 6 – 9 litre/month (as found in a UNDP survey) this represents a monthly cost of 12,000 to 18,000 Tsh http://www.ashdenawards.org/files/reports/Zara_2007_Technical_report.pdf.
[42] Ashden Award case study - *http://www.ashdenawards.org/winners/REF10*

Table 3. Low carbon electricity generation options

Option	Cost-effective?*	Adaptation synergies	Other benefits	Barriers
Centralised				
Hydro	Yes. Long plant lifetime / no fuel costs relative to fossil generation incurring high fuel costs	May lower climate resilience of system under current and future changes in pattern of average or extreme precipitation	For all renewables: Reduced reliance on fossil fuels, with - Air quality improvements. - Reduced fuel imports - Reduced sensitivity to fuel price shocks - Greater energy diversity and security	Capital intensive Sustainability issues Competing with irrigation demand
Geothermal	Yes as baseload plant. Some evidence from Kenya that is C-E, but due to drilling risks offset by ArcGeo project.	Resilient to future climate impacts		Capital intensive
Wind	Depends on wind speed and consistency of resource. Some evidence from NW Kenya that could be C-E although high costs of connection due to remote area	Likely to be resilient to future climate impacts (though estimates of climate change on future wind speeds are highly uncertain)		Capital intensive Tariff certainty required Grid infrastructure costs (due to remote location) Intermittent
Decentralised (Micro / Small grid)				
Hydro	Yes, if reasonable annual availability (reliable flow)	May not be as resilient to climate impacts (due to potential changes in average and extremes) as other options	As above. Reduced reliance on biomass gathering due to alternative energy source Low maintenance requirements	Need reliable hydro source
Solar PV	Not generally as PV costs currently very high		However, cost-effective relative to other options in remote areas – due to high solar resource and very expensive alternative	High costs
Wind	Not generally unless extremely good wind resource			High costs, Intermittent

* Cost-effective means 'no regrets / negative cost, or very low cost (<$10/t$CO_2$). Cost-effectiveness will be dependent on the alternative option. In the comparative work in Kenya, we have tended to compare options against diesel generation, which has relatively high fuel costs.
Source: Adapted from SEI (2009)

Transmission and distribution

A number of options relate to the technical improvement of the transmission and distribution network to reduce losses, and expanding regional connections with neighbouring countries. Reducing technical losses effectively means increasing supply with the same system capacity, thereby reducing carbon intensity of electricity supplied. Current losses amount to over 23% although are forecast to reduce to 15% by 2030 in the Reference case. It is worth noting the significant investment in the grid infrastructure under the Backbone Transmission Investment Project, led by the World Bank. The development objective of this project, only recently agreed, is to increase availability, reliability, and quality of grid based power supply to northern regions of Tanzania.[43]

Regionalisation of the grid is another option for sourcing renewable electricity from other countries (reducing emissions from the system) and potentially reducing risks of load shedding through increasing supply options. A connection with Zambia and Kenya (ZTK Interconnector) under discussion could supply Tanzania with an additional 200 MW (GoT 2008b).

[43] Further information can be found at the World Bank's website, http://go.worldbank.org/TZE5269DG1

Fuel switching
Another option for reducing the grid intensity of the system is by moving to lower carbon generation options e.g. gas instead of coal generation. The ability to do this in Tanzania will depend on the gas resource availability and the economics of the resource versus availability of cheaper indigenous coal. Carbon financing through CDM could be an option for incentivising such switching, in addition to the co-benefits (reductions in air pollution).

Assessing the costs and co-benefits of power sector options

The cost-effectiveness of electricity generation options are calculated based on based on the technical cost of producing a unit of electricity and the emissions of that unit of electricity generated. The relative costs of a range of selected options are shown in Figure 17. Hydro generation is the least cost option, followed by gas CCGT and coal plant (both using domestic fuel resources). The order of options will change in the future, as fuel prices increase and the costs of renewable technologies decrease. The carbon intensity of electricity, the other variable in the cost effectiveness calculation, is shown by the estimates of thermal plant if a $30 carbon tax was imposed. It illustrates that coal plant levelised costs would increase by 40% and gas costs by 20%.[44]

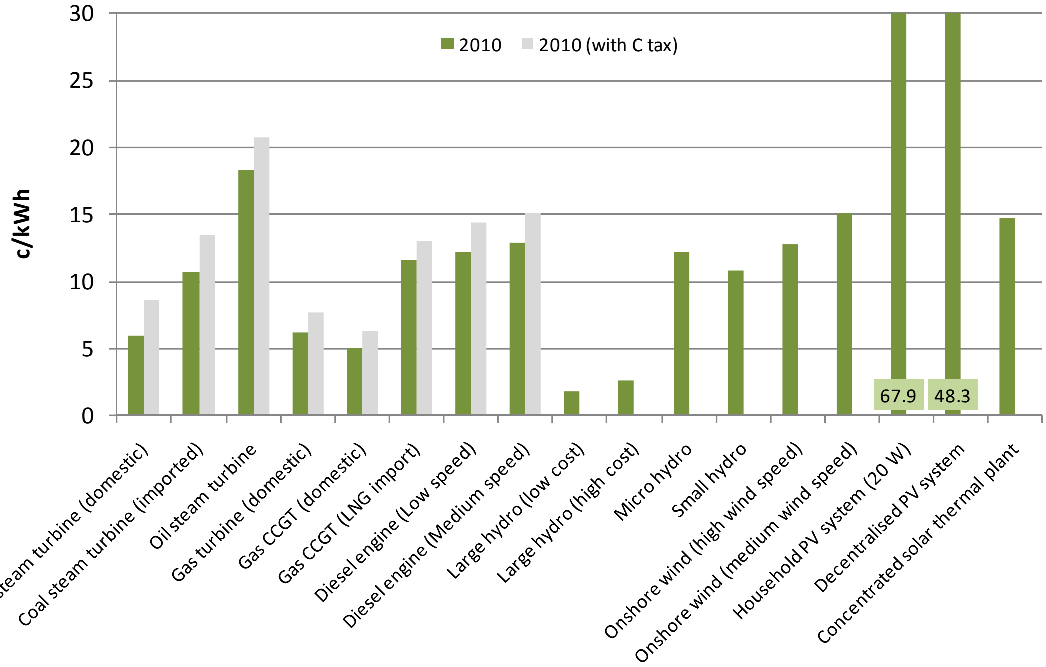


Figure 17. Levelised cost of selected electricity generation options in 2010, c/kWh

The costs provide the basis for the cost curve analysis (as shown in Figure 18). The thermal and hydro generation assumptions are taken from the Power System Master Plan Study (GoT 2008b), whilst the renewable generation options are primarily taken from ESMAP (2006). The options shown below are being evaluated against a baseline (or marginal) technology that could be selected based on cost. In Figure 18, a gas turbine plant (using domestic gas) is the technology against which all options are compared. This is a useful marginal technology to use, as it closely represents the intensity of grid-based generation in the Reference case. All of the measures shown below are much more cost-effective against oil generation plant, due to the relatively higher price of this type of generation and the higher carbon intensity of oil-fired generation.

[44] Carbon intensity of electricity measures the emissions associated with the fuel required to generate a kWh of electricity. Therefore plant efficiency is critical. Typical factors (as used in this analysis) include (units kg/kWh): Coal plant 0.91, Diesel engine 0.74, Gas turbine 0.51, Gas CCGT 0.44. Using a life cycle approach, renewable technologies would also have emissions assumed due to those associated with materials used and construction (as would thermal plant). However, in this instance, such emissions have not been accounted for. Other emissions also include CH_4 from flooded land, associated with hydro generation.

In addition, solar home systems have been added, and compared against mini-grid diesel generation. Again, such technologies are actually cost-effective if compared to a less efficient off-grid household sized generator.

Some key observations include:

- The MACC below represent a situation where over 25% of emissions from grid-based generation are reduced based on a selection of measures. No carbon tax / credit has been added to any of the estimates (which would increase cost-effectiveness of lower carbon options).

- The mix represented means increased investment in hydro (400 MW) by 2030, increasing hydro capacity by a further 15%. Such an increase would need to be further tested to ensure climate resilience. This hydro capacity could be more expensive than suggested below as the most cost-effective hydro would have already been exploited under the Reference case.

- Unlike hydro power, other renewable generation options are likely to require further incentives to develop. This is where carbon finance needs to play a strong role through whatever mechanisms are in place in future years. A differentiated tariff system for renewables would also allow for higher cost renewable to be invested in. These issues are explored in more detail in the next section.

- Solar home systems (SHS) in the graph below are assumed to be in 4 million households. Significant emission savings could be realised under such a scenario, while providing affordable electricity plus other benefits.

- Fuel switching could also be important as shown by the combined cycle gas turbine (CCGT) option. This type of plant is more efficient than a gas turbine plant, therefore using less gas per kWh generated, resulting in lower emissions. The cost-effectiveness is a function of the gas fuel price; if it is high enough, the efficiency saving results in generation being cheaper, therefore becoming a negative cost option.

- Further analysis is needed to test this mix in its ability to meet the changing demand load, particularly the peak demand. If the system is running to a tight reserve margin (particularly due to a low rainfall year in a system with significant hydro capacity), increased renewable generation could make the system more vulnerable to intermittency effects.

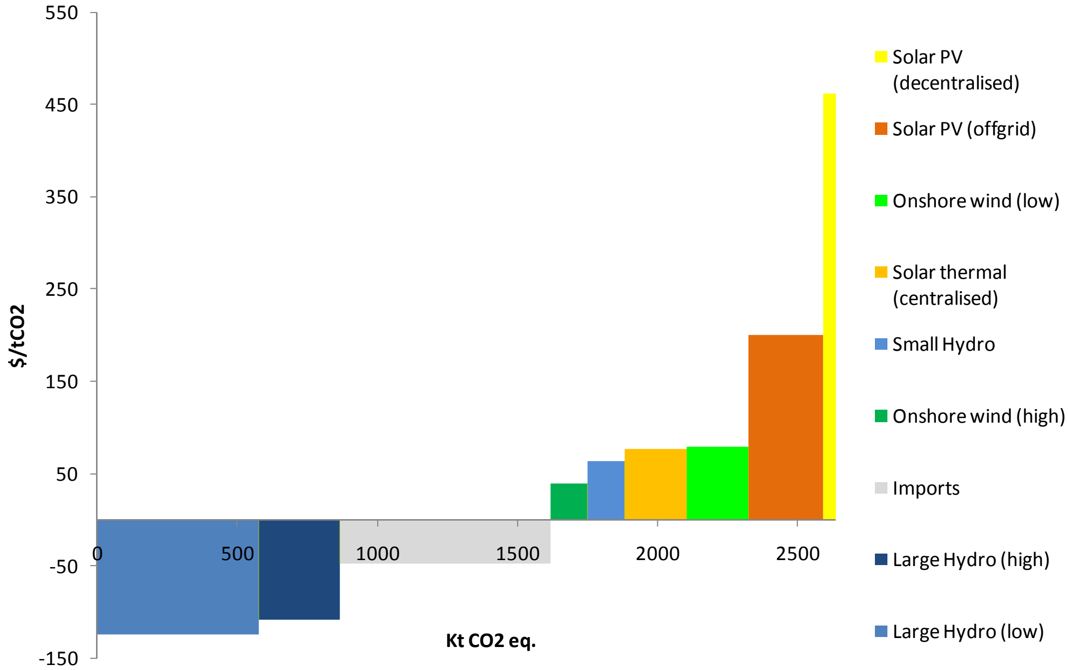


Figure 18. Marginal abatement cost curve for the electricity generation sector in 2030 (compared to gas turbine technology, except solar PV - offgrid)

For comparison, evaluated against oil-based generation, an option that has been particularly used for short term rental contracts, the options are shown to be much more cost-effective due to the higher emissions from oil generation, and the relatively higher fuel costs.

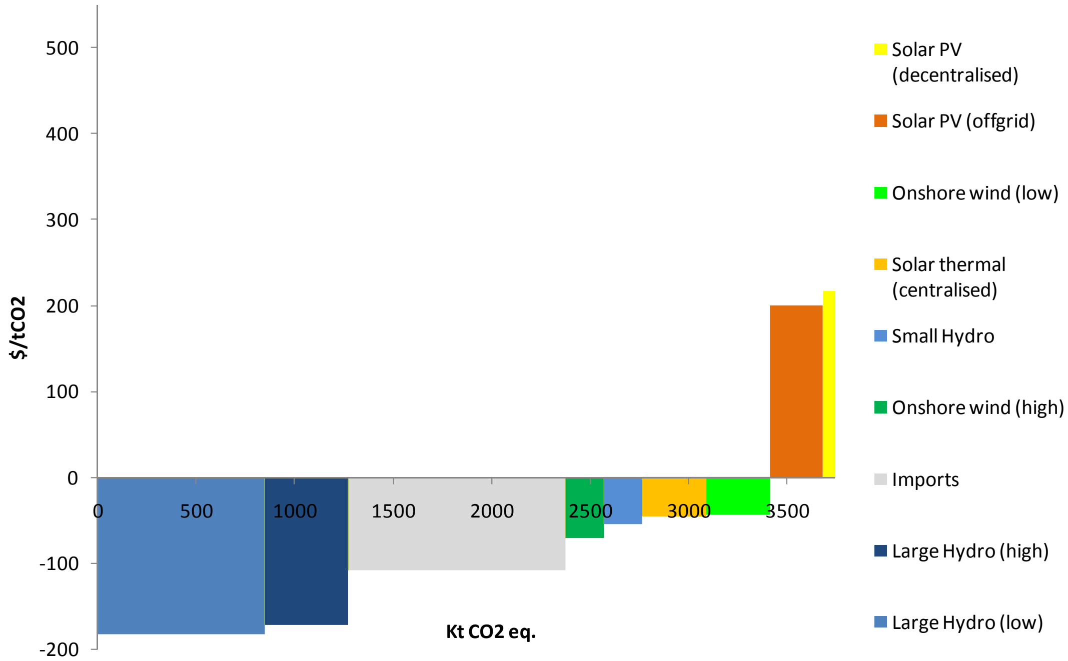


Figure 19. Marginal abatement cost curve for the electricity generation sector in 2030 (compared to diesel engine technology)

Implementation issues

Institutional set up

The Government of Tanzania is committed to facilitate the increased use of renewable energy as an important source in the energy mix and a major means to support the national development goals. Therefore, a number of legal framework measures, policies and strategies have been formulated and enacted to provide a constructive atmosphere for industrial growth.

Energy planning is guided by the national energy policy formulated 1992 and revised in 2003. The national energy policy formulated in 2003 supports research and development of renewable energy and also promotes the use of efficient biomass and end-use technologies. The objective is *"to provide input in the development process of the country by establishing a reliable and efficient energy production, procurement, transportation, distribution and end-use system in an environmentally sound manner and with due regard to gender issues".* Key objectives are to avoid deforestation, and to promote lowest cost energy solutions.

The Ministry of Energy and Minerals (MEM) is responsible for coordinating and putting in place appropriate policies, laws and regulations. The Assistant Commissioner's Office for Renewable Energy at MEM coordinates sustainable energy activities. The Rural Energy Agency (REA) established under the Rural Energy Act of 2005 also undertakes sustainable energy activities. The Act established the Rural Energy Board, Fund and Agency responsible for promotion of improved access to modern energy in rural areas. The MEM is proposing to attract other institutions, such as NGOs, businesses, entrepreneurs, municipalities and Community Based Organisations (CBOs), which will ultimately own and manage projects developed under the REA diversifying away from reliance on TANESCO to promote rural energy access.

The Rural Energy Fund (REF) is intended to provide capital subsidies to bring down the cost of energy services and thereby reduce the risks to project developers envisioned to include communities, companies, local governments and others that are ready and capable of investing in the provision of modern energy services. The REF receives a levy of 1% of TANESCO billing plus significant donor contributions. There are no Value Added Tax (VAT) and custom duties on solar and wind technology products. Other products and appliances are subject to a VAT rate of 20%, while custom duties range from 20-30%. The regulator, the Energy and Water Regulatory Authority (EWURA) established in 2005, also has a mandate to take account of the impact of the energy sector on the environment.

Tanzania Electric Supply Company Limited (TANESCO) is the sole public utility responsible for the generation, transmission and distribution of grid electricity. There are several IPPs involved in power generation. At present TANESCO is vertically integrated but there are plans for unbundling with separation of the functions of generation, transmission and distribution of electricity. Tanzania Petroleum Development Corporation (TPDC) spearheads, facilitates and undertakes oil exploration and development in the country. The natural gas company, Songas, is jointly owned by Globeleq, TANESCO, TPDC, Tanzania Development Finance Company Ltd. (TDFL) and Finance for Development.

Sector development issues

There are a number of issues that may affect the development of a low carbon power sector, based around the scale up of renewable technologies. At a macro-level, it might be argued that access to power is more important than low carbon generation in a developing country context such as Tanzania with significant levels of poverty and climate stress. However, against this, fossil fuels often have much higher external costs that are not included in current prices and thus distort the relative attractiveness of these plants (this in includes air pollution as well as carbon emissions, but also impacts from mining, extraction and transportation). The current power strategy is oriented towards lowest cost solutions, and given the current low levels of electrification, the net increase in emissions may be relatively small in relation to the development impact that can be achieved through the deployment of efficient fossil fuel systems, particularly based on indigenous fossil resources. Access to power will also be important to mitigating the effects of climate change in supporting economic diversification and resilience away from climate sensitive sectors such as agriculture, forestry and tourism.

Currently, there is limited interface between power sector policy and plans relating to national economic planning. Although the National Policy for Growth and Reduction of Poverty does make references to energy investments, the procedures and institutional capacity to handle that are not yet in place. For example, although energy is a critical element in the implementation of activities in the agriculture, health, education, water and ICT sectors, none of the policies in these sectors considers the energy required to achieve their objectives. There is a growing recognition in Tanzania that the implementation of the energy policy and plans must be synchronized with the policies, plans and strategies of the other sectors if they are to reach their development goals.

TANESCO faces significant operating challenges. Of the roughly 1 GW of installed capacity (50% hydro-electricity 50% fossil fuels, primarily diesel oil and natural gas), only 500 MW is ever operational at any given time. Over the past few years the country has experienced severe blackouts and power rationing in urban areas due to drought and subsequent low-water levels. The peak load on the TANESCO grid is at least 20% higher (probably more) than 500 MW, leading to continuous load shedding. There is substantial suppressed demand (with tens of thousands of diesel and petrol generators independently operated throughout Tanzania). It is estimated that about 20-30% of power generated is lost in transmission due to poorly maintained power lines. TANESCO sells power at about $0.10 per unit (kilowatt hour/kWh), though it costs TANESCO more than $0.14 per unit to generate and deliver. These issues provide significant challenges to the expansion of the grid to a wider population.

The relatively high cost of grid extensions and connections has a negative impact on the extension of grid services especially to communities in rural areas. GTZ (2009) estimates that it costs more than 10,000 USD per kilometre to extend a high transmission line of 132 kW. The total number of customers connected to the grid is about 701,000. New connections are still limited to 3,255 connections per month. Regardless of connection bureaucracy at TANESCO, there are more than 100,000 applications for new connection per annum, which suggest an existence of a strong and suppressed demand for the service.

Small scale renewable energy is under active development in Tanzania. Standardized Small Power Purchase Agreements (SPPAs) have been designed. Currently Feed in Tariffs (FITs) for RE and IPPs are technology neutral and set at the wholesale grid price of $0.10. The tariffs are three times higher if feeding an isolated diesel-powered mini grid as opposed to main grid ($0.30). While the main grid tariff is too low to stimulate investment in all but mini-hydro and biomass cogeneration, the framework is in place to begin offering technology specific FITs (needed particularly for wind) for supplying the main grid. The introduction of SPPAs has resulted in about a dozen projects, however, none of these are CDM registered. Despite its overarching roles, the Rural Energy Agency still faces the challenge of enhancing the participation and capabilities of local communities in rural energy projects.

To date, carbon finance (revenues from greenhouse gas emission reductions, whether UN or voluntary) has not provided any significant contribution to investments in renewable energy and emission reductions. Renewable energy developers cite a bias in terms of financing and regulatory approval towards existing sources of power generation, even where these may be sensitive to shifts in the climatic baseline such as hydro, or to fluctuations in world commodity prices, such as gas and diesel imports. Certainly, the current wholesale pricing regime and lack of differentiated FITs does not support a rapid shift to renewable power generation, and the costs of carbon are not reflected in the fiscal support structure.

Too many agencies may be involved in approvals for renewable energy development in relation to resource or property access rights, permitting and siting conditions. Long lead times can be experienced for licensing, grid access and EIA procedures. Public private partnership legislation remains under development, but has yet to be agreed. Transmission access and pricing rules may create onerous connection conditions that penalise smaller producers. Access to debt finance remains challenging given the potential implementation risks for RE projects.

More broadly, there remains a capacity deficit at the industry level, both in terms of production, and installation and service infrastructure for renewable energy technologies. There is currently no manufacture of RE products in Tanzania. REDCOT and the College of Engineering and Technology at the University of Dar el Salaam have recently begun to develop educational facilities for entrepreneurship in the production of RE technologies (wind turbines, solar water heaters, micro-hydro). The Tanzania Bureau of Standards currently has no testing facility for most RE products. There are a number of other institutions that have courses on RE technologies, in particular Solar PV.

As a result, the development of renewable energy (with the exception of small scale solar PV) has been relatively flat. Each technology has its own issues:

- Hydropower: For SHP, local investors and project developers often lack the finance and acumen to develop mini-hydro projects, while the investor climate frustrates foreign development of the identified potential.
- Solar PV: However, the distribution of fake products and an absence of enforcement of quality standards threaten the market, and service infrastructure in rural areas remains relatively weak.
- Wind: The costs of wind development, coupled with low main grid FITs, is preventing development. Banks are unwilling to lend large sums based on the current tariff structure, and technology specific FITs would be required (see case study in Appendix 1).
- Biomass: Potential sources of biomass, such as sugar companies could become important power producers, but are themselves largely inefficient, and lack capacity to implement projects.
- Geothermal: The technology is regarded as relatively expensive, capital intensive and the current tariff structure does not make it economic. Poor levels of resource knowledge significantly increase risks when drilling.

Summary

The generation system is likely to expand rapidly over the next few years. It will remain relatively low carbon (compared to systems in other countries) due to the continuing use of hydro generation. However, renewable opportunities remain – although more work is needed to understand the resource and structure the tariff system to incentivise investors. Incentives may also come through the CDM mechanism although Tanzania needs to demonstrate that such a mechanism can be effectively used in this sector.

The MACC analysis demonstrates that low carbon options can be cost-effective. With carbon finance incentives, they become even more competitive. In addition, further use of indigenous generation sources reduces Tanzania's exposure to international fuel price increases and fluctuations. A more strategic risk in the context of fuel prices and evolution of carbon financing is that investments now in fossil-based generation could lead to technology *lock-in.* This is because generation plants typically have lifetimes of 30-40 years meaning that they will be used to pay-back any investment made. This could well be in spite of high energy prices and significant opportunity cost relating to carbon financing.

This raises an associated issue in the context of negotiation discussion on programmatic CDM and the Registry of Nationally Appropriate Mitigation Actions (NAMAs). A move towards fossil based generation could have implications for sector based programmes in the energy sector, or even national level financing in the context of NAMAs.

Increased reliance on renewable sources, however, must take account of climate resilience issues (discussed in section 5), including water availability for hydro generation and the changing demand load for electricity, as cooling demand increases for example. Note that this also potentially applies to fossil stations, not least because of their relatively high water demands. Tanzania is going to need to ensure it balances its system so that it has generation options that can guarantee contribution to peak demand.

Using higher cost generation sources could also potentially lead to increases in the cost of electricity (depending on how the market and tariff structure evolves) and impact on affordability. Increasing access is an important objective that must not be compromised by higher prices; such adverse impacts would need to be mitigated.

Increasing decentralised and off-grid generation is also going to be important for provision of electricity to rural communities. This appears to be the most important household technology that could be scaled. There is also the benefit of a buoyant and rapidly expanding private sector that could help deliver this. However, access to credit is going to be critical to ensuring affordability obstacles can be overcome. In addition, product quality needs to be ensured to avoid undermining the technology in the eyes of the consumer. Opportunities for programmatic CDM in this area should be explored, to see what carbon financing opportunities exist.

Some types of enabling measures in this sector are provided in the box below.

Box 5. Enabling activities to deliver low carbon measures in the Electricity Generation sector

A number of enabling activities might help low carbon deployment in the electricity sector. These would need consideration in the context of sector policy, thus they are not recommendations, but highlight some of the potential activities to overcome barrier effects

- Introduce utility efficiency program to reduce technical and economic losses from existing power generation and transmission, including load management and DSM approaches
- Development of technology specific Feed in Tariffs (FITs) to reflect levelised costs of individual generation technology plus private sector investor return (WACC), and removal of subsidies for existing wholesale power.
- Greater urgency in the application of CDM and support for voluntary financing mechanisms for Renewable Energy development
- Introduction of targeted fiscal mechanisms (tax exemptions, rebates) for support of RE product imports and local manufacturing capacity
- Strengthen grid access and licensing regulations
- Set medium term national targets for installed capacity and output by individual RE technology
- Improve information on the potential for renewable energy e.g. wind atlas, geothermal feasibility
- Support R&D and adoption of established RE technology (e.g. from India). Local manufacturing of low cost small scale systems. Operation and maintenance structures. Resource mapping.
- Work with existing large scale consumers of Renewable Energy (Tanzania Telephone Company Ltd, Mobile companies, Tanzania Railways Corporation, Tanzania-Zambia Railway Authority, Tanzania-Zambia Mafuta, Tanzania Harbours Authority) to promote further deployment and to engage with government.

Household energy

The household sector is the most significant user of energy in Tanzania, through consumption of fuel wood and charcoal. The baseline projection illustrates that these will remain important sources in the near and medium term. These are affordable, indigenous sources of energy, and whilst modern energy forms will become more prevalent as incomes increase, they will probably only replace a fraction of the households using wood fuel and charcoal.

However, the rate of biomass consumption is unsustainable, driven by population growth and a rapidly dwindling forest resource (as illustrated in the forest sector projections above). Therefore, opportunities for funding to promote more sustainable resource use through low carbon projects should be considered. In addition, account needs to be taken of affordability, with few alternatives for the rural poor.

Low Carbon Investment Opportunities

In this section, consideration is given a range of opportunities for reducing the consumption of biomass and charcoal, or providing alternatives to it, thereby reducing GHG emissions – and realising other co-benefits. Options are also considered for how energy can be used more efficiently for growing energy service demands such as lighting and appliance use. Options are listed in Table 4 below.

Table 4. Low carbon options for households

Energy Service	Option	Cost-effective?*	Adaptation synergies	Co-benefits (additional to GHG benefits)	Barriers
Cooking	Improved efficiency of stoves	Yes (high)	Lower reliance on increasingly scarce or stressed resource	Reduced fuel costs Improved combustion – lower indoor air pollution levels (health benefits) Less pressure on local forestry Increase economic time (particularly for women)	Initial investment Lack of information / awareness
Cooking	Improved efficiency of charcoal production	Yes	Lower reliance on increasingly scarce or stressed resource	Less pressure on local forestry Reduced costs Employment opportunities to manufacture / sell technology	Initial investment Lack of information / awareness
Cooking	Switching to alternative fuels (away from biomass)	Fuel / technology dependent	Lower reliance on increasingly scarce or stressed resource	Lower indoor air pollution levels (health benefits) Less pressure on local forestry More convenient	No access to electricity Investment and higher fuel costs
Cooking	Biogas	Fuel / technology dependent	Lower reliance on increasingly scarce or stressed resource	Lower indoor air pollution levels Less pressure on local forestry More convenient Slurry by-product has high nutrient content, used for fertiliser	Upfront costs Lack of awareness Ongoing maintenance
Cooking	Solar cookers	Where alternative time is of lower value (in refugee camps)	Lower reliance on increasingly scarce or stressed resource	Lower indoor air pollution levels (health benefits) Reduced fuel costs Reduced fuel wood use	Initial investment Time consuming to operate
Lighting	Solar home systems	Yes compared to kerosene and off grid diesel		Lower indoor air pollution levels from avoiding kerosene (health benefits) Social benefits from lighting	Initial investment Ongoing maintenance and access to spare parts
Lighting	More efficient lighting e.g. CFLs (electric)	Yes		Reduced energy costs Reduced pressure on electricity system	Lack of information / awareness
Appliances	More efficient appliances (electric)	Yes		Reduced energy costs Reduced pressure on electricity system	Cheap price of less efficient appliances

* Cost-effective means ‘no regrets / negative cost, or very low cost (<$10/t$CO_2$).
Source: Adapted from SEI (2009)

It is worth highlighting that emission reductions from improving efficiency of biomass use or using alternative fuels can be significant, as demonstrated in the cost curve analysis presented later in this section. This is because biomass use is not sustainable, and therefore cannot be deemed a carbon neutral fuel. In appraising the above options, CO_2 emissions from charcoal and biomass have been included in the estimations of carbon reduction potential. In the projections developed for this sector, only the non-CO_2 emissions from biomass energy consumption were captured (following best practice in inventory development). The CO_2 emissions from unsustainable use were allocated to the forestry sector.

Increased penetration of improved stoves

Increasing the efficiency of household biomass consumption is an important energy policy objective, reducing demand for wood fuel and charcoal, and thereby easing the pressure on forest resources. Improved stoves can significantly reduce fuel consumption. In addition to the benefits of reduced supply side pressures, socio-economic co-benefits can also be significant. These include the reduction in fuel payments and / or time spent gathering wood fuel, increased cooking speed and improving indoor air quality, reducing negative health effects.

Improved stoves have been promoted in Tanzania for more than 15 years. However, the penetration of improved stoves is not well known, whilst many of the improved stoves that have been introduced, particularly for charcoal burning, are low quality and do not necessarily provide the benefits. CEEST (1999) states that in 1990 only 4.9% of urban households had improved charcoal stoves. A recent article put the penetration of improved charcoal stoves in Dar-Es Salaam at 60%.[45] Others claim that 40% of households that rely on charcoal use improved stoves in urban centers. A survey conducted in 2007 is less optimistic, indicating market penetration rates closer to 20% (Palmula and Beaudin 2007, cited in World Bank 2009).

The ProBEC baseline survey (SADC 2005) stated that improved wood fuel stoves were estimated to be in 10-15% of rural households. It is not clear how successful scaling up of improved stove dissemination has been since 2005, under this SADC programme.[46] GTZ (2009) stated that there were around 15,000 improved stoves produced and sold per month in Tanzania. Given the low levels of historic penetration of improved technologies, there are significant opportunities for reducing demand through stove programmes.

Typically used three stone wood fuel stoves are fairly rudimentary, achieving efficiencies of between 7-12%. Improved stoves (such as Rocket Lorena stove) can achieve efficiencies of over 20%, reducing annual fuel wood consumption from 3000kg (based on 4.2 m^3 annual consumption) to 1500kg. Where wood fuel is purchased, this could halve the fuel expenditure. If gathered, this saves significant time, which can be spent on other activities. Improved charcoal stoves can also lead to significant savings in fuel consumption. A typical metal charcoal stove (jiko) operates at around 12% efficiency, while an improved stove with ceramic liner can improve the efficiency to 25%. Again, this can halve fuel consumption.

Box 6. Local scale initiatives: Kisangani Smith Group (Ashden Award Winners, 2005)[47]

A group of local blacksmiths in Tanzania have developed two types of fuel efficient stoves. This was born out of the use of charcoal in their furnaces, and the need for increased efficiency. One stove is for burning wood (sawdust) and crop residues as an alternative to charcoal (costing 35,000 TSh) while the other is a efficient wood stove for rural households, costing 30,000 TSh. Kisangani Smith Group have manufactured and supplied approximately 1,400 sawdust stoves and 2,100 wood stoves since 2005.

A family cooking with charcoal typically uses about two standard 70 kg sacks per month, costing 5,000 TSh each. Sawdust (in this case study) replaces virtually all this use (of course an alternative fuel has to be available), leading to an extremely short payback period of ~2 months. The efficiency benefits of the wood stove are as yet untested although informal feedback suggests they are significant.

The economics of improved stoves appear attractive where fuel is purchased, leading to relatively short pay-back periods. Including co-benefits in the appraisal of this option in relation to health improvement further illustrates the cost-effectiveness of this measure (see example below).

Box 7. The impacts of indoor air pollution from biomass fuel stoves

The World Health Organization (2006) estimates that 396,000 people died from diseases caused by indoor air pollution in 2002 in sub-Saharan Africa. The primary cause of these deaths is exposure to particulate matter, emitted into the home as a result of wood fuel and charcoal burning. The effects are not evenly distributed in society, with poorer households more exposed due to greater reliance on biomass fuels and less advanced technology, and women and children most exposed due to being in the home for longer periods and engaged in cooking activities.

Switching to moderns fuels such as LPG and biogas brings about the greatest reductions in indoor air pollution, whilst reducing GHGs, although the costs may well be prohibitive without additional financial help.

Cost benefit analysis has been conducted by the WHO that demonstrates that fuel switching and improving stoves results in benefits far exceeding the costs (WHO 2006).

[45] Inter Press Service website, www.ipsnews.net, Addressing Energy Crisis Through Alternatives and Efficiency at Household Level
[46] For further information on the SADC Programme for Biomass Energy Conservation (ProBEC), see website http://www.probec.org/displaysection.php?czacc=&zSelectedSectionID=sec1194880064
[47] More information on this case study can be found at the Ashden Awards website: http://www.ashdenawards.org/files/reports/ksg_case_study_2008_0.pdf

> *Making improved stoves available, by 2015, to half of those still burning biomass fuels and coal on traditional stoves, would result in a negative intervention cost of US$ 34 billion a year as the fuel cost savings due to greater stove efficiency exceed the investment costs. This generates an economic return of US$ 105 billion a year over a ten-year period (Table 5). Time gains from reduced illness, fewer deaths, less fuel collection and shorter cooking times, valued at Gross National Income (GNI) per capita, account for more than 95% of the benefits. When time gains are conservatively valued at 30% of GNI per capita for adults and 0% of GNI for children, the economic payback decreases to US$ 33 billion a year for improved stoves.*
>
> This analysis shows the important of full policy appraisal to identify the full benefits and costs of an option, particularly for a measure such as this that has such multi-policy benefits.[48]

However, a range of barriers include the upfront cost of purchasing a new stove and perceptions that such technologies don't work. Tsephel et al (2008) has undertaken some work to look at stove and fuel choice. Some interesting observations emerge concerning why different income groups do not always go for improved stoves or cleaner fuels. For example, lower income groups view higher upfront costs as more of a barrier and are less concerned about indoor smoke pollution. This type of work, based in Ethiopia, is being extended to other studies, including Tanzania, and is critical for understanding the barriers that make wider uptake of these technologies difficult.

Improving efficiency of charcoal production process

A market of over 1.6 million tonnes of charcoal per annum requires significant wood fuel resources. It is estimated that for every tonne of charcoal, approximately 11 m^3 or 7.8 metric tonnes of wood fuel is required. Therefore, sustaining the charcoal market at this level requires significant forest resources. On the demand side, more efficient appliances can be used (as discussed above). However, on the supply-side there are significant opportunities for reducing fuel wood consumption by improvements to the charcoal production process.

Currently, most charcoal production is highly inefficient, using earth mound or pit kilns, and requiring significant amounts of wood fuel per tonne of charcoal produced. Technologies such as Casamance kiln and Half-Orange kiln can significantly improve production and thermal efficiency of the process, reducing wood fuel requirements (see Table 5).

Table 5. Characteristics of different charcoal production kilns

Kiln type	Traditional kiln	Improved kiln	Efficiency (%)	Remarks
Earth Pit Kiln	X		10-15	Lowest efficiency, unpopular and labour intensive in digging and covering the pit
Portable Steel Kiln		X	20-25	Unpopular due to high initial investment (TSh 3,000,000 per unit)
Half Orange Brick Kiln		X	25-35	Improved charcoal quality. Not movable. High initial cost (TSh 300,000 per unit)
Cassamance Earth Mound kiln		X	25-30	Unpopular. High initial cost. Tedious.
Earth Mound Kiln	X		10-20	Most popular in Tanzania
Improved Earth Mound Kiln		X	15-25	Has a chimney. Improved carbonization time. Improved charcoal quality

Source: van Beukering et al (2007), cited in Malimbwi et al (2007)

Initiatives are being undertaken to promote sustainable charcoal production. However, the challenges to scale this type of production up are significant, due to the informal nature of this sector and the higher costs of sustainable production, where the costs of re-planting and forest resource use are borne. A case study

[48] The World Bank guidance for undertaking cost-benefit analysis is provided in document *Guidelines for conducting cost–benefit analysis of household energy and health interventions*, http://www.who.int/indoorair/publications/guidelines/en/index.html

exploring the issues relating to sustainable charcoal production can be found in Appendix 1 of this report. Further discussion of implementation issues can be found later in this section.

Switching to alternative, modern energy
The promotion of cleaner, modern but affordable energy services is an important objective for Tanzania. This promotion of energy sources for households as an alternative to cooking with wood fuel or charcoal is consistent with a low carbon strategy. For example, while kerosene and LPG are fossil-fuels, the GHG emissions to cook a meal are much lower than found for charcoal (see Bailis et al (2004) for further information). This is on the basis of only accounting for emissions of CO_2, CH_4 and N_2O, not other gases also emitted that have a global warming effect. One tonne of charcoal consumed equates to approximately 9 tonnes of CO_2, due to the amount of fuel wood required to produce charcoal very inefficiently.

An option that could become interesting to consider as an alternative cooking fuel if large scale domestic production takes off is ethanol gel fuel. Ethanol gel fuel, which is currently imported, has got a small market penetration in Tanzania. Domestic production would probably lower the prices and may through lower prices achieve a more important market penetration.

Alternative fossil fuels, such as indigenous brown coal, would certainly not fit into a low carbon strategy. This fuel is not only extremely carbon-intensive but also very harmful to human health due to the high levels of air pollutants emitted.

A key issue related to switching to modern fuels is affordability, particularly the relative price of different household fuels but also the cost of the cooking appliance. This is discussed in more detail later in this section.

Other household energy technologies
Other options in the household sector include the use of more efficient technologies, particularly for electrical appliances and lighting, and alternative cooking fuels, such as biogas.

Biogas can meet both cooking and lighting needs of a household and generates high value fertilizer that can be used in improving farm outputs. The current penetration of biogas stoves for households is low, with around 6,000 small residential biogas plants in operation. The low penetration is similar to that observed in other East African countries, and is due to maintenance costs, upfront capital requirements and problems of collecting enough animal dung. More promising is their application at the institutional scale (see section on *Other end use sectors*), particularly as a means of generating energy and treating human waste.

Lessons from household biogas from Zimbabwe show that there are a range of conditions needed to help successful introduction - zero grazing is practiced so that collection of dung does not require a lot of time; sufficient amounts of water are available to mix the dung with; at least six cattle are available from which to take dung; there is support for transferring know how about how to construct a biogas dome and operate it or an organisation/company to pay to construct the biogas dome; capital is available to invest in constructing the dome ($US 700 – 1000).

In addition to increasing electrification in Tanzania, demand side measures should also be considered to ensure that the electricity supplied is used as efficiently as possible. As the consumption of electricity grows in future years, the benefits of nearer term action will be relatively higher. It will also be important for moderating peak demand, as the demand for lighting and air conditioning increases in future years, and during specific periods of the day, the load is significantly higher (for example, during hot evenings). The issue of air conditioning is particularly important due to the likely increase in demand with socio-economic growth (air conditioning penetration is primarily a function of income) and cooling demand in future years due to climate change itself (see later section on climate resilience), and the load that such devices can put on the system. This highlights the potential importance of passive measures (building design) that could reduce the cooling load in future years.

Many of the electrical appliances currently in the market are likely to be low efficiency. Significant potential is likely to be available through the promotion of more efficient appliances (through appliance standards or subsidies) and lighting devices, such as CFLs as replacements for Incandescent light bulbs.

Assessing the costs and co-benefits of options in the household sector

The cost curve below (Figure 20) illustrates the significant emission reduction potential from the household sector. The potential savings below includes CO_2 from biomass and charcoal use, and from charcoal production, based on the assumption that all biomass used is unsustainable. Therefore, 1 kg of charcoal not consumed in a more efficient stove will have the all GHG emissions (including CO_2) from its production and consumption accounted for.

In the inventory and projections, such CO_2 was accounted for in the LUCF sector. So the unsustainable use of wood to produce the same 1 kg of charcoal would have associated carbon allocated to forestry removals. However the accounting is done, it is imperative that the benefits of measures on the demand side (households in this case) and supply side (forests) are not double counted.

Some key observations include:

- The measures selected in the MACC below could realise savings of up to 20% of 2030 emissions from the forestry sector, relative to the Reference case. Much more optimistic rates of improved stove uptake and switching to alternative fuels could see much higher savings.

- SHS are extremely cost-effective when measured against kerosene or dry cell battery consumption for lighting. This reflects the very high price of kerosene and dry cells, particularly in rural areas, making the payback time on such systems relatively quick. This of course does not take account of the benefits of providing small levels of electricity for other appliances.

- Improved stoves (charcoal and biomass) are both cost-effective due to the relatively low upfront costs of an improved stove and the significant fuel savings. The economics of this option are of course dependent on purchasing wood fuel rather than sourcing it free. However, even for households that gather free biomass, the cost savings could be thought of in terms of time saved from gathering wood. There are also the real benefits from improving indoor air pollution usually associated with an improved stove.

  As discussed in this report, there are some real economic barriers, in addition to the socio-cultural ones, including upfront costs for an appliance that may never have been purchased before, and for households with very low incomes.

- There are a number of alternatives to cooking with charcoal that have been assessed. Solar cookers and biogas are cost-effective because the cost savings associated over the technology lifetime is greater than the upfront capital investment. However, their uptake is probably going to be limited, hence their reduction potential is shown at a lower level.

  Interestingly, electricity and LPG are fairly low cost, low carbon measures. Their relative efficiency compared to standard charcoal stove means that their fuel costs are lower although the investment is significantly higher. These calculations are sensitive to the price of charcoal assumed. In recent years, the costs of charcoal have increased dramatically in Dar es Salaam, from around TSh 5000 per bag (30 kg) in 2004 to over TSh 20,000 in 2007 (World Bank 2009). With increasing demand and pressure on wood fuel supply, it would not be surprising to see these prices continuing to increase in future years.

  We are aware that other barriers, such as upfront capital for investment in new appliances are very important. In addition, other barriers may exist around the purchasing of fuel. The World Bank (2009) provides the example of LPG and charcoal, noting that charcoal can be purchased incrementally (each week) while higher one-off costs are incurred for the purchase of an LPG cylinder that could last a month. Such issues can be prominent barriers for lower income households.

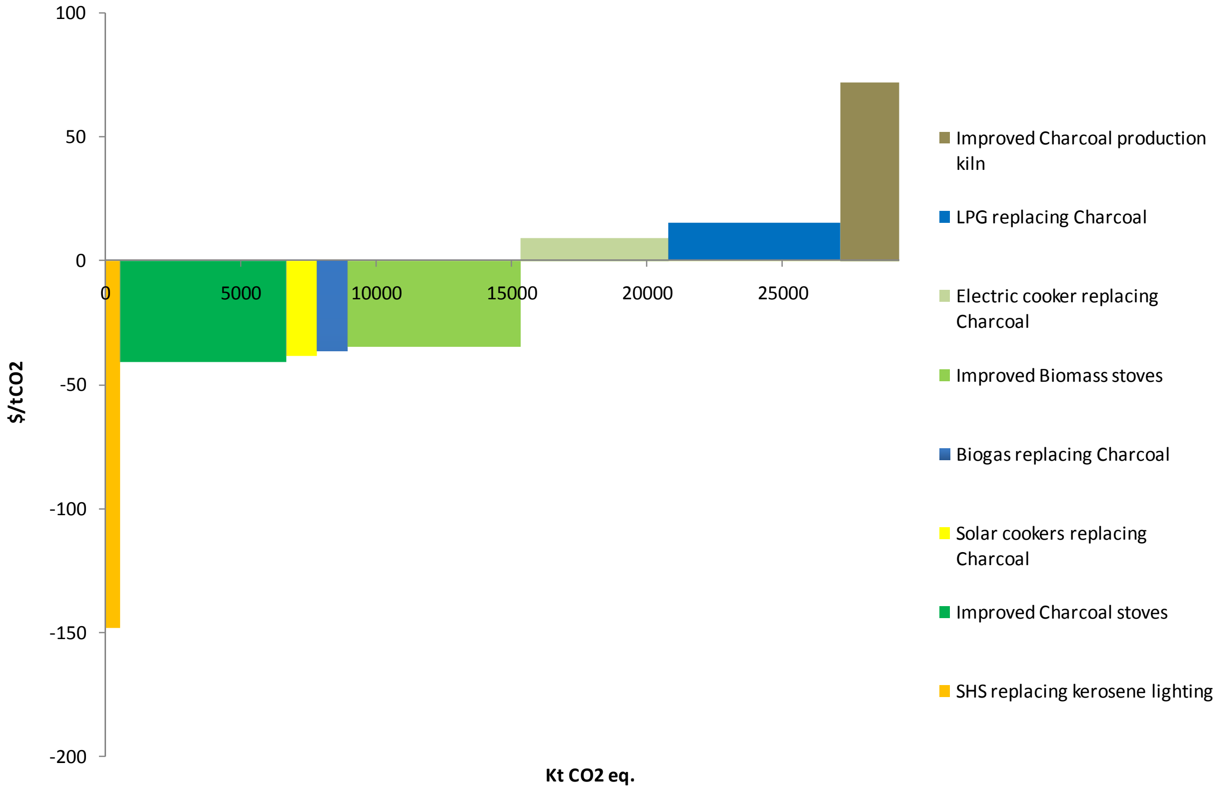


Figure 20. Marginal abatement cost curve for the household sector in 2030

- Improved charcoal production option has been included here because it provides charcoal primarily for the household sector. This option is the use of an improved half-orange kiln instead of an earth mound process. The emission savings represent the reduced level of biomass required to produce a tonne of charcoal. This measure is least cost-effective primarily because we have assumed that the more efficient producer is also investing finances into growing and cultivating biomass for use in the kiln, while the producer using the standard production process essentially get free biomass for fuel off common land (as is the common practice). If both producers (low carbon and traditional) both paid, then this option would be cost-effective.

  Importantly, if this measure was widely taken up, the emissions savings associated with improved charcoal stoves and charcoal replacement would be lower, as these measures assume inefficient charcoal production.

Implementation issues

There are major obstacles to achieving widespread penetration of clean cooking fuels in Tanzania and other developing countries. Some of these barriers are presented in the Box below.

Box 8. Barriers and issues to consider in achieving widespread penetration of clean cooking fuels

- The "natural" evolution in cooking fuel usage with growing income follows an "energy ladder": fuel wood → charcoal/brown coal → kerosene → LPG/electricity. The ladder also progressively leads to increasing energy efficiency and decreasing pollution. The poorest households, which account for the majority of the population, who depend on biomass fuels, lack the purchasing power needed to climb the ladder.
- Many households at the bottom end of the energy ladder obtain their cooking fuels at "zero" private cost (e.g. from deforestation). Thus, clean cooking fuels must compete with "free" fuels. Health, social, and environmental costs associated with collection and use of these fuels are externalities that are not reflected in the private cost.
- On the other hand, many households spend a substantive share of their disposable income on "low-end" cooking fuels due to lack of access to cleaner alternatives, even when these could be afforded.
- Many rural households receive a large share of their cash income through the production or provision of charcoal or other "dirty" fuels. Substitution of these fuels by clean fuels would eliminate an important source of livelihood for these households.
- The tasks related to cooking, including collection of fuel wood, are by and large the responsibility of women. But, women are generally not the decision-makers in the matter of investments in the energy sector relating to cooking fuels. Women and children also suffer disproportionately in terms of some of the external costs of low end fuels, notably in terms of health impacts.
- The government of Tanzania recognizes that the high rate of deforestation due to charcoal production is something that needs to be addressed but it has had difficulty finding the right solutions (Palmula and Beaudin 2007, in World Bank 2009).The complexity of the cooking fuel issue, and the public cost associated with a traditional top-down investment programme, is a daunting challenge to a government.
- Decision makers in industrialized countries are generally not aware of the links between continued use of dirty fuels (including nominally "renewable" fuels such as wood) in developing countries and their own economic, political, and environmental interests, or they have not accepted the idea of good health as a basic human right, the universal achievement of which should be supported by all countries of the world.
- The poorest countries may have increasing difficulties competing in the global market for fossil oil derivatives.

Improved cooking stoves

Despite the numerous benefits associated with cleaner alternatives, the transition to improved cooking stoves and fuels has largely stalled in Tanzania and many other countries in sub-Saharan Africa. Why is it that, efficient and clean stoves fail to penetrate the market, as expected?

Economic and financial analyses of energy use and fuel switching also frequently mention that charcoal is not as cost-efficient as LPG and other alternative fuels. These analyses, however, are over simplistic in that they rarely look beyond simple economic factors. It is known that there are a wide range of other factors that affect people's choices when selecting fuel types beyond simply price and efficiency.

In order to design effective policies and programs to promote the use of cleaner cooking alternatives, the barriers to improved cooking technologies must be understood at the household level. To date, research regarding the determinants of stove choice at the household level has focused mainly on socio-economic factors, such as income, age, gender and education, while the role of product-specific factors, such as safety, indoor smoke, usage cost and stove price, have been largely disregarded.

Attributes raised by end users in a survey carried out by SEI in September 2009 in Dar es Salaam presented in Table 6, indicate that there are a range of factors that affect people's choices when selecting fuel types – beyond simply price and efficiency. Understanding the product specific factors that household consumers value is a key factor in predicting and growing the market for clean cooking fuels.

Table 6. Key factors affecting choice of household fuels and appliances

Attribute Group	Attributes
Economy	Lasts long, Durability of the stove, How long the fuel lasts - efficiency
Health	Risk of explosion, Inhaling poisonous gases, Smoke, Risks that other family members may be exposed to
Convenience	Easy to procure, Easy to use, Reliability, How to stop Soot, Smell (of kerosene) Start up time, How much handling is required to keep burning/heating, Speed it takes from lighting to heating things to cook
Reliability	Minimum number of dependable variables to keep stove going, The combined reliability of stove and fuel supply and number of service providers to keep both going.
Family and living condition situation	The kind of food you prepare and the size of the family, Dependant on the type of food you are cooking, You can't leave the cooking with Moto Poa to a house girl. It has to be under your control. What space and where I can cook, Fuel storage ability Building design can restrict what fuels you can use Who is handling the stove. Who is going to use the fuel
Externalities	Deforestation,

Simon (2010) highlights the following requirements for effective delivery of stove programmes:

- Deliver technologies for which there is some demand, and that are compatible with household specific cooking and heating habits, food preferences and domestic architecture. Technologies should also reduce fuel requirements and render the indoor environment less polluted.
- Establish supply chains that maximize the number of households receiving new technologies.
- Disseminated stoves should be durable and supported by periodic monitoring activities in order to discourage early abandonment.
- Improved cook stoves programmes must ensure that stoves remain affordable for all members of the targeted development community.
- Improved cook stoves should support pre-existing artisan networks through training courses while also generating new employment opportunities.

Cook stove programmes can bring development benefits in addition to the environmental (forestry and GHG) benefits. However, the challenges to realising such development and carbon financing benefits can be significant, and while effective design of a programme is key (as described above), barriers also specific to Tanzania need to be considered. These could include:

Barriers to development benefits	Barriers to GHG accounting for carbon finance
Lack of supplementary financial provisions such as access to low interest credit	Measurement and verification issues due to large numbers of stove
Inadequate local support to ensure the impetus from different NGOs / Agencies, capacity in the local economy and consumer awareness	Inclusion of non-CO_2 gases which are often difficult to verify in the field
Market opportunism by local players could mean the economic benefits from such initiatives are not distributed	Calculating non-renewable biomass, particularly where some biomass sources are sustainable
Stove design not being tailored to local conditions, both cultural and physical	Leakage issues due to savings in use of renewable biomass meaning more non-renewable biomass is used elsewhere
	Longevity of carbon finance and climate policy, particularly with uncertainty about financing mechanisms and the role of voluntary credits

Improved charcoal production

It is estimated that Tanzania consumes nearly 2 million tonnes of charcoal annually and this figure is expected to grow. Valued at $350 million, the charcoal sector is the country's 3rd largest, after gold mining and tourism. The industry creates income for the rural producers. Tens of thousands of rural Tanzanian micro- entrepreneurs depend on the revenue resulting from charcoal production and trade for their subsistence. An estimated 2 million man hours are devoted to charcoal production, transport, trade and retail in Tanzania (WB, 2010). Of these about 100,000 man hours are for the actual charcoal production (WB 2010) Local councils report that at least 70% of their revenues are derived from taxes on charcoal production and distribution. However, the industry is underpriced due to the lack of pricing on wood fuel obtained from the forests.

In theory, charcoal could be a renewable resource if properly managed – nurseries, tree planting, managed harvesting, efficient wood-to-charcoal conversion, marketing, etc. However, the sector is entirely informal and difficult to reform. A case study example of sustainable charcoal production can be found in Appendix 1. One of the key challenges is developing the market for the sustainable product when cheaper, non-sustainable charcoal is available. This involves trying to raise consumer awareness about the benefits of the more sustainable model, and trying to offset additional costs of producers with carbon finance.

Policy and regulation on Charcoal production and sustainable biomass management remain under development, and the government has yet to legislate to formalise the industry structures. There is no specific bio-energy component to the National Energy Policy (2003). The Forest Policy (1998) establishes private woodlots and plantations for wood fuel production, and allows forest reserves to be managed at village level. The Land Policy (1997) and Environmental Policy (1997) set out the need for biomass conservation priorities. There is a lack of baseline data for policy formulation. The sector also suffers from limited capacity and political will to organise the charcoal production sector.

The World Bank has under taken a comprehensive review of the policy barriers and opportunities relating to domestic charcoal use and production (World Bank 2009). The report describes the benefits of sustainable charcoal industry, such as a diversified tax base, and reduced environmental degradation.

The report identifies the low costs, resulting from a weak fiscal and regulatory regime as undermining incentives for producers or traders to pay levies or invest in efficiency savings. Attitudes among regulators towards charcoal use by regulators tend to focus on prevention, rather than attempts to develop and regulate a sustainable and profitable industry. Policy proposals include:

- Ensuring that charcoal revenue collection responsibilities of local governments are matched with an ability to retain a higher share of revenue collected, to fund resources for local level regulation and enforcement.
- Supporting local governments in reinvesting charcoal income (as is done with the Road Fund), with the objective to further improve revenue collection and promote sustainable forest management, rather than recycling revenue into wider development objectives such as health, infrastructure and education.
- Introducing fiscal incentives that reward sustainably produced charcoal and place additional costs on that which is illegally produced to balance.

The report recognises that currently, monitoring and enforcement capacity is not adequate to policy the transport and trade of charcoal. Increased capacity for Forest Surveillance Units would be required, as would collaboration with other agencies, such as TANROADs.

Bringing charcoal into the regulated economy would not only challenge existing vested interests, it would also result in the unit costs of charcoal rising. The report recognises that such price rises would need to be offset by improvements in demand side efficiency to ensure that vulnerable groups do not experience price shocks. While increased costs would drive the market for efficient production (efficient kilns), conservation (tree planting, participatory forest management) and consumption (efficient stoves), they would need to be accompanied by a number of reforms

- Development of harvesting plans for forest areas administered by central or local governments to ensure that accurate data is available for strategy development;
- Scaling up community-based forest management (CBFM) to help secure tenure for rural producers, although this is likely to require substantial external financing and capacity building support;
- Establishment of private or group-based small-scale plantations and woodlots to meet increased demand, although this would likely require initial subsidy support and incentive payments;
- Improve take up of efficient kilns, partly driven by increased input prices for semi-industrial kilns and via capacity building for small scale producers;
- Incentivise purchase of efficient stoves to help offset impact of charcoal price increases;
- Introduction of fuel switching policies aimed at higher income consumer groups (electricity/gas), particularly in urban areas;
- Explore integration of REDD financing mechanisms to promote sustainable charcoal production.

Summary

The household sector is the largest consumer of energy, and source of emissions (through the unsustainable use of forestry resources). Low carbon projects could help promote more efficient (and sustainable) use of indigenous biomass resources, as well as promoting access to more modern fuels[49]. The co-benefits of the measures described i.e. beyond carbon finance opportunities, are significant, and strongly align with Tanzania policy objectives.

Key options highlighted include:

- **Solar household systems** are an important technology for rural electrification; bringing lighting services and provision of electricity for electrical appliances. Such technologies can be cost-competitive relative to alternatives, including kerosene for lighting and small scale diesel generators for electricity. They also have important socio-economic benefits – promotion of local commerce, lighting to help facilitate learning and other social activities, and reducing indoor air pollution.

  Access to affordable credit is key to ensuring this technology can be rapidly scaled. There are now REA/REF subsidies to support solar PV systems, but whereby all small rural PV systems need to be installed by a developer. The subsidy is limited to up to 100 Wp for residential systems and 300 Wp for Institutions. System subsidy is 2 USD per Wp (GTZ 2009).

[49] Tanzania has a Millenium Development goal to replace 50% of traditional biomass cooking fuels with modern fuels.

Importantly for Tanzania, there is a buoyant private sector market that could realise such scaling. In addition, ensuring the quality of technology is critical for ensuring that SHS delivers the benefits and customer expectations are met.

- **Improved biomass / charcoal stoves** could realise significant cost savings to households across Tanzania, and lead to significant benefits for reducing depletion of forest resources. In addition, the health benefits through reducing indoor air pollution could also be considerable.

  However, as with SHS, ensuring quality of these technologies is important. Many improved technologies in the existing stock are not delivering the savings or retaining their quality over the specified lifetime (Malimbwi et al 2007). The barrier of cost also needs to be addressed, particularly to enable low income households to access such technologies. Finally, better understanding of consumer behaviour is critical to increasing uptake rates through new stove programmes.

- **Improved charcoal production** is another important opportunity to promote sustainability in the use of biomass resources. Significant savings could be achieved through reduced use of wood fuel, and greater emphasis on forest replenishment. This could also safeguard the longer term viability of the industry. However, rapidly growing demand due to population growth is going to make this challenging; therefore, switching to alternative fuels away from charcoal is also important.

- **Fuel switching (from charcoal to modern energy sources)** will inevitably happen as incomes increase. However, the rate of switching required to significantly reduce charcoal demand needs to be much more rapid. Challenges include meeting supply requirements and ensuring affordable access.

Some of the activities that might enable the uptake of these low carbon opportunities are highlighted in the Box below.

Box 9. Enabling activities to deliver low carbon measures in the Household Energy sector

- Further develop bio-energy policy relating to biomass production at the level of MEM. Forest Division should work closely with the Energy Department and other stakeholders to enhance sustainable management of natural resources for charcoal production.
- Support further R&D, distribution channels and (micro) finance for more efficient charcoal stoves and production kilns.
- Diversification of fuels, sourced from tree-felling, timber processing and other agricultural residues, such as rice husk and coconut shells and sawdust briquettes.
- Develop sustainable community and private forestry management practices promoting managed woodlots for charcoal production, selective and sequential harvesting, and regeneration of felled areas, particularly for peri-urban and rural areas close to cities.
- Improve capacity, provide training and promote consolidation within charcoal industry, particularly in relation to production techniques, transportation and marketing, sustainable certification and reforestation
- Establish commercial nurseries, tree growing and environment conservation.
- Devise an effective method of charcoal revenue collection and hypothecate for charcoal industry development and sustainable land management practices.

Other end-use sectors

Industry
Accounting for about 22.6% of GDP, Tanzania's industrial sector is one of the smallest in Africa. It is, however, expected to grow with increased population growth and demand for goods. The main industrial activities are dominated by small and medium sized enterprises (SMEs) specializing in food processing including dairy products, meat packing, preserving fruits and vegetables, production of textile and apparel, leather tanning, and plastics. A few larger factories manufacture cement, rolled steel, corrugated iron, aluminium sheets, cigarettes, beer and bottling beverages, fruit juices, and mineral water.

Industry represents a relatively small end user of energy, using approximately 10% of the national energy balance. This mostly consists of some coal use in cement production (80000t pa in Kiwira and Mbeya cement), non-wood renewables (the majority of energy) and natural gas displacing heavy fuel oils (Twiga cement, Tanzanian Breweries, Aluminum Africa, Karibu textiles). SMEs continue to use significant amounts of biomass at the level of cottage industries.

Key options associated with the industry sector include:

- General energy efficiency improvements. Industry audits can lead to efficiency improvements of up to 20%. The subsequent fuel savings can often payback the cost of undertaking efficiency improvements.

- Move to or optimisation of renewable co-generation. Tanzania has the power capacity for cogeneration of more than 200 MW from sugarcane residues (bagasse) in the four sugar factories of Mtibwa, Kilombero, Kagera and Tanzania Planting Corporation (TPC). Mtibwa currently generates 7 MW although it has the capacity to generate 15 MW. TPC has invested in the power plant generating 15 MW of which 7 MW will be fed into the national grid (GTZ 2009).

  Depending on the tariff agreed, the supply of excess electricity can be extremely cost-effective because the cogeneration plant is being run anyway for sugar production, and because the fuel input is completely free.

- Other companies using biomass fuel for captive generation (and in some cases supply to the grid) include: TANWAT (wood/forestry, generating 2.5 MW), Sao Hill (wood/paper, generating 1.0 MW), Mufindi Paper Mills (generating 15 MW) and Hale Sisal Estate (sisal waste biogas, generating 300 kW) (GTZ 2009). Two biomass-based generation plants are in the validation stage of CDM; CHP plant at Sao Hill Sawmill, and biomass power plant at Mufindi Paper Mill.[50] Both illustrate low carbon projects being developed to provide captive power, whilst at the same time raising carbon finance.

A number of options were cited in the 1st National Communication:

Cement production

- Production management, introducing control systems for reducing the amount of fuel used and improving production efficiency
- CO_2 recovery system using CO_2 for other applications.
- Fuel switching, moving to natural gas away from fuel oil
- Production mix, using different blends to reduce amount of fuel used for calcination and the amount of lime used per unit of cement produced
- Recovery of waste heat

In addition, if appropriate, retrofitting the cement kiln type to dry multi-stage type could further reduce energy requirements and combustion emissions.

[50] Projects listed at UNEP Risoe CDM/JI Pipeline Analysis and Database, May 1st 2010, http://cdmpipeline.org/

Pulp and paper

- Efficiency improvements, to Optimize the recovery boiler in order to reduce both the amount of lime and energy used
- Recovery of CO_2 from calcination by the absorption of CO_2

Other Industries

- Energy efficiency improvements. Improve efficiency in existing plants through maintenance, improved steam production and management, improvements to motor drive systems, cogeneration, and power factor correction

The above options have not been included in the MACC analysis due to the uncertainties around how the industry sector will develop in future years. This does warrant analysis in future assessment, notably in relation to the key carbon emitting sub-sectors, and the areas where expansion is most likely, e.g. agricultural processing.

Commercial / Public Sector

Options for this sector have not been assessed in detail, as many of the options are similar to those listed for the household sector, except on a larger scale (for example, schools are likely to invest in 300 Wp systems while household systems are usually between 20-50 Wp).

Potential savings in future years has not been assessed in detail. However, the commercial sector is considered to be the fastest growing sector; its energy demand is likely to be primarily for electricity, which is captured in the electricity supply projections.

Key energy requirements for this sector in future years are likely to be electricity for cooling, appliances and lighting. In urban areas, this demand is likely to be met by grid-based sources for larger enterprises. Solar systems will be particularly important for smaller-scale commerce, particularly in rural communities without access to grid-based electricity.

A number of public sector institutions, particularly school, hospitals and prison will also have a significant demand for cooking energy. Currently, such demand is met primarily by wood fuel. Two potentially important options for reducing reliance on biomass include improved efficiency stoves and biogas, managing human waste whilst producing gas for cooking. An important provider of such technology has been the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC). According to information from CAMARTEC, the fixed dome technology can significantly reduce wood fuel consumption, treat faecal waste and provide fertiliser as a by-product. The technology for a prison would cost around $135,000. Lasting 20 years, significant emission savings can be realised, with a potential to produce carbon finance. In addition, significant fuel cost savings are achieved (40% a year) and human waste is treated safely.

In addition to be demonstrated at the institutional level in Tanzania, particular successes have been observed in Rwanda. A case study example (from SEI 2009b) is provided in the Box below.

Box 10. Introduction of biogas digesters in Rwandan prisons

The successful implementation of biogas digesters in Rwandan prisons was recognised by the Ashden Awards for Sustainable Energy in 2005 (http://www.ashdenawards.org/winners/kist05). This programme run by the Kigali Institute of Science, Technology and Management (KIST), has developed and installed large-scale biogas plants in prisons in Rwanda to treat toilet wastes and generate biogas for cooking. After the treatment, the bio-effluent is used as fertiliser for production of crops and fuelwood. This not only provides a sustainable cooking fuel but reduces problems associated with sewage. As of 2005, biogas plants were running in six prisons with a total population of 30,000 people.

Technology:

Biogas systems take organic material such as manure into an air-tight tank, where bacteria break down the material and release biogas - a mixture of mainly methane with some carbon dioxide. The biogas can be burned as a fuel, for cooking or other purposes, and the remaining material can be used as organic compost. The systems installed in Rwanda are based on an original design from China, modified by GTZ, and finally scaled up and refined by a Tanzanian engineer working in Rwanda.

The biogas system uses a number of individual digesters, each 50 or 100m3 in volume and built in an excavated underground pit. Toilet waste is flushed into the digesters through closed channels, which minimise smell and contamination. The digester is shaped like a beehive, and built up on a circular, concrete base using bricks made from clay or sand-cement. The sides taper gradually and eventually curve inward towards a half-metre diameter man-hole at the top. It is crucial to get the bricks laid in exactly the right shape, and to make the structure water-tight so that there is no leakage of material or water out of the digester. Biogas is stored on the upper part of the digester. The gas storage chamber is plastered inside with waterproof cement to make it gas-tight. On the outside, the entire surface is well plastered and backfilled with soil, then landscaped.

A particular feature of the plant design is a compensating chamber that acts as a reservoir of methane bacteria for enhanced gas generation. At first, gas pressure displaces the liquid to the compensating chamber. Consumption of gas leads to backflow of the waste from the compensating chamber into the bio-digester; this agitates the waste, circulates the bacteria, and releases trapped gas.

The scale of these biogas systems is enormous: a prison with a population of 5,000 people produces between 25 and 50 cubic metres of toilet wastewater each day. Using a 500m3 system (five linked digesters), this produces a daily supply of about 250m3 of biogas for cooking.

Cost:
The cost of a 500m3 plant is ~50 million Rwandan francs (£50,000). A system of phased payments is used, with the final 5% paid only after 6 months of satisfactory operation.

Benefits:
- Sustainable technology, with training provided to prisoners on how to maintain
- Improved sanitation due to waste treatment
- Forest protection
- Renewable, cheap fuel provision
- CO_2 savings from reduced fuelwood use and sewage treatment
- Skills training for prisoners

Source: Ashden Awards Case Study *Biogas plants providing sanitation and cooking fuel in Rwanda* (http://www.ashdenawards.org/)

Implementation issues in industry / commercial sectors

Poor infrastructure in water and electricity supply systems continues to hinder factory production. Many industrial enterprises operate backup diesel generation due to the lack of grid reliability. These have high carbon intensity (per unit of energy delivered), as well as increasing air pollution and increasing reliance on non-indigenous fuel supplies. In general, Tanzania's manufacturing sector targets primarily the domestic market with limited exports of manufactured goods. Most of the industry is concentrated in Dar es Salaam.

There is some activity to promote industrial energy efficiency. A limited number of energy audits have been undertaken, identifying potential savings of between 15-40%. Dar es Salaam Water supply system energy audit which indicated a potential saving of up to 40% of the total annual bill on adoption of energy efficiency (EE) recommendation measures. Energy savings in most industries can be achieved through improved combustion efficiency in boilers and furnaces; steam and condensate management and efficient utilization of electricity. There are some discussions about training in energy management.

Currently, there is little evidence of an active energy efficiency or cleaner production policy at government level. There are no minimum energy efficiency product standards, and limited fiscal incentives to purchase efficient equipment. The EU Tanzanian Renewable Energy and energy Efficiency project to Sustain Poverty Alleviation (TREESPA) has reported that there are relatively low levels of awareness among industrial energy users of energy efficiency potential within their businesses.

There is also limited energy service provision, and financing of upfront capital investment costs is problematic, particularly for smaller companies. Banks tend not to undertake project finance assessments for small companies, lending on the basis of corporate credit risk only. The cash flow benefits of energy efficiency projects are therefore rarely assessed in any lending decision. The IFC is introducing energy efficiency financing credit lines and technical assistance through the Climate Change Investment Program for Africa (CIPA) program in neighbouring Kenya to address this barrier. Agence Française de Développement (AFD) is working through the Kenyan Association of Manufacturers to establish a regional sustainable energy financing facility to include Tanzania. Smaller companies may also struggle to access technologies at low cost due to limited purchasing power and lack of distribution networks.

Tanzania has relatively low levels of large scale commercial and public sector building infrastructure. However, this sector is expected to grow rapidly in line with rapid growth in GDP and mass urbanization. Under projections, the service sector is expected to account for up to 45% of GDP by 2030. Air conditioning and ICT are expected to represents an increasing share of energy costs in relation to buildings operation. This is a particularly concern because of the projected increase in demand with climate change itself (e.g. with increasing temperatures, see the climate resilience section).

There is currently no evidence of energy efficiency regulations relating to new buildings under the National Energy Policy. A number of government buildings have been audited to create awareness among planners and decision makers.

National standards for energy consuming equipment have also yet to be put in place. Ensuring high efficiency cooling and other technology appliances could help moderate energy demand growth not only in the commercial and public sectors, but also in the domestic sector.

Finally, there is a low level of energy service company provision, particularly in relation to the retrofit of existing commercial or public buildings. Financing of upfront capital investment costs is problematic in this regard, despite building efficiency being a relatively low net cost opportunity.

Summary

It is clear that additional data are required to better understand the current and future energy requirements of these sectors in order to determine the potential for emission reduction, and associated finance and co-benefit opportunities. Key opportunities in industry include general energy efficiency improvements, improving competitiveness through reduced fuel costs, biomass-based cogeneration (where the biomass fuel is sustainable e.g. bagasse in sugar industry) and industry specific measures e.g. waste heat recovery in cement sector.

Key opportunities in the commercial and public sector include those discussed for households, particularly use of improved stoves and decentralised electricity (SHS) for smaller commercial units. Biogas is also a technology that holds significant potential opportunity for emission reduction, whilst saving fuel costs and treating waste. An area of key importance for further assessment will be the demand for electricity in future years, and efficient use through the use of improved appliances.

Some of the activities that might enable the uptake of these low carbon opportunities are highlighted in the Box below.

Box 11. Enabling activities to deliver low carbon measures in the Industry / Commercial sectors

Industry

- Develop energy efficiency policy for industry to include minimum standards, fiscal incentives, and system of audits for large energy consumers.
- Build awareness amongst industrial enterprises of economic and quality assurance benefits of improved energy practices and fuel switching
- Build upon the aggregate technology identification and purchase structures developed by TREESPA (lighting, welding, electric motors).
- Encourage local banks to provide dedicated EE finance lines for industry through concessional finance and technical assistance in audits, product design and marketing
- Work with TANESCO and EE Equipment distributors to promote uptake of energy efficient equipment to customer base

Other Sectors

- Minimum efficiency standards for new and retrofitted buildings to include insulation and HVAC, potentially integrated into wider building standards
- Introduction of national EE product import standards for key groups of energy consuming equipment (A/C, ICT) and potential adoption of EU/US energy standard labelling schemes.
- Assessment of capital investment financing routes for public building retrofit, in relation to budget costs

Transport sector

An efficient and reliable transport system is vital for ensuring future economic development. With rapid urban population growth predicted, effective planning of transport infrastructure and systems is needed, particularly to ensure the objectives of efficiency and reliability, and maintain urban environmental quality.

Dar es Salaam already has acute congestion problems, and these are projected to increase in line with rising income growth and vehicle numbers. The economic costs of rising congestion can be very significant, as well as leading to additional external costs in the form of health impacts and lost time. There is also a feedback effect on carbon emissions: vehicles travelling at very low speeds have much higher emissions per km travelled – thus increasing carbon and air pollution emissions further. However, the often chaotic evolution of urban areas and the rapid growth in transport demand often makes robust integrated planning extremely difficult.

The National Transport Policy aims to develop *efficient and cost-effective domestic and international transport services to all segments of the population and sectors of the national economy with maximum safety and minimum environmental degradation*.[51] Low carbon investments in the transport sector have strong synergies with the development of efficient, reliable and clean transport system, particularly in urban areas. This is because lower carbon options include the promotion of public transport, more efficient vehicles, alternative modes of transport, and alternative fuels (see Table 7).

[51] National Transport Policy, http://www.tzonline.org/pdf/nationaltransportpolicy.pdf

Table 7. Policy synergies associated with a lower carbon transport system

Low carbon growth promotes......	Co-benefits (Transport policy synergies)	Challenges
Public transport systems	* Reduced congestion (efficiency / urban environmental quality) * Reduced air pollution (urban environmental quality) * Reduced road traffic accidents (fatalities and injuries) * Access to transport services (Transport provision to wider socio-economic groups) * Reduced reliance on fossil imports	* Large capital investment requirements * Planning in rapidly growing urban areas * Preference for private transport * Behavioural change
Energy efficiency in vehicles	* Reduced fuel costs for consumers * Reduced reliance on fossil imports (enhance energy security) * Improved air quality due to newer vehicles / lower fuel consumption (urban environmental quality) * Safer vehicles (reducing road traffic accidents)	* Additional upfront investment costs * Access to more advanced vehicles * Availability of maintenance services for more advanced vehicles * Disincentivising 2nd hand car markets
Alternative transport modes e.g., cycling	* Reduced congestion (efficiency / urban environmental quality) through increase cycling / freight to rail * Social benefits of using non-motorised modes	* Large capital investment requirements (for expanding rail systems) * Preference for private transport (versus cycling)
Alternative fuels	* Reduced reliance on fossil imports (enhance energy security) * Agriculture sector investment and employment (economic development)	* Competition for land / water with other sectors, particularly agriculture * Increased food prices
Driving behaviour	* Reduced fuel costs for consumers * Reduced reliance on fossil imports (relatively) * Improved road safety (reducing road traffic accidents)	* Entrenched driving behaviour

A key issue to establishing a more sustianable transport system requires early planning to ensure that transport systems can meet the needs of an expanding urban population and rapidly increasing vehicle population (as illustrated in the transport projections), and indeed shape the evolution of transport systems to achieve a more sustainable model. This early planning needs to be integrated to take account of the many other services urban areas have to provide (housing, provision of utilities etc), increasing the challenge.

Sperling and Salon (2002) highlight the problems that face many developing countries (in the absence of robust early planning): *Rapid motorization is creating major challenges in the expanding "megacities" of the developing world. These cities face stifling traffic congestion, huge expenses for road infrastructure and worsening air pollution. Many have much more severe traffic congestion and air pollution than U.S. cities. Bangkok, Thailand is the best known example, but there are numerous others. What is surprising and troubling is that these car-induced problems occur even though vehicle ownership rates are still far lower than those in more developed cities.*

The National Transport Institute of Tanzania has developed an integrated transport plan (GoT 2009), to identify the opportunities for developing a more effective transport system that is *not unimodal in character*. Whilst recognising the issues concerning urban transport (particularly from an infrastructure and mode perspective), it does not clearly define how such problems should be overcome. Key issues not identified include rapid projected growth in passenger (particularly private) and freight, which is going to be the most significant factor in planning. However, it does highlight the need for coordination with land use planners, and the potential risks from climate change impacts.

Low Carbon Investment Opportunities

A summary of low carbon options for the transport sector follows:

Public transport systems
Public transport systems in urban areas are important for providing access to transport services for urban populations and reducing the volume of traffic on roads, particularly in urban centres. An example of such a system is the Dar es Salaam Bus Rapid Transit system (DART)[52], being implemented primarily through World Bank funding although subject to significant delay. This is likely to have low carbon benefits through reducing private vehicle usage and replacing older minibuses vehicles currently used. When designing such schemes, other low carbon transportation can be encouraged through increasing cycle lanes (as in the case of the DART scheme)[53] and making areas more pedestrian friendly. Cost-effectiveness of reducing carbon emissions is extremely difficult to determine, as these are all scheme specific. For illustrative purposes in this analysis, costs used in the MACC analysis have been taken from Kahn Ribeiro (2007), citing Wright and Fulton (2005), of around \$60/tCO_2.

Increasing vehicle energy efficiency
There is significant potential for efficiency improvements in the transport sector, particularly due to the high uptake of second hand vehicles. Technical efficiency improvements can be achieved by reducing the age of the vehicle stock, increasing uptake of improved conventional (internal combustion engine (ICE) vehicles or moving towards more advanced technologies. More advanced technologies, such as electric vehicles, could be described as 'leap frog' technologies, which could allow for a country to 'leap frog' the fossil-intensive, mass combustion engine-based vehicle systems experienced in most developed countries.[54] Sauter and Watson (2008) provide a useful discussion of the different issues related to technology leap frogging.

Characteristics of different technology types for LDVs are shown in Table 8.

Table 8. LDV technologies for improving energy efficiency[55]

Technology type	Description
New conventional vehicles	Tanzania has a relatively old road vehicle fleet. Historic data shows that a new petrol or diesel car now is at least 30% more efficient than a comparable vehicle in 1990. Conventional ICE vehicles are likely to increase in efficiency over time due to non-engine improvements (by between 20-30%, relative to current new vehicles
Advanced gasoline / diesel vehicles	Such options include improvements to vehicle powertrain systems (direct injection, variable transmission, turbo charging, improved combustion efficiency)
Hybrid electric vehicles	These are vehicles that incorporate an electric motor, running off a battery that recharges while the gas engine is being used and also through regenerative braking. The electric motor is used whilst the vehicle is moving slowly or cruising, and power requirements are less. This combination allows for a much more efficient use of the internal combustion engine, allowing it to operate steadily at near-optimal loads. This is a fully commercialised technology, although penetration in developed world markets is currently limited. (Hybrid technologies can be categorized into partial or full hybrid systems; we have used a generic (no distinction between series or parallel) full hybrid system here). The cost increase for hybrids is based on IEA (2008), as is the typical efficiency improvement of between 46-48%. Future cost reductions are based on improved and more cost-effective battery technologies. Plug-in hybrid vehicles are not specifically included in this analysis. These vehicles

[52] Overview of BRT can be found at http://www.itdp.org/index.php/projects/detail/dar_es_salaam_brt/
[53] Personal communication with UWABA, www.uwaba.or.tz
[54] A comparable example is the adoption of mobile phone networks in developing countries instead of extending fixed cable-based networks seen in many developed countries.
[55] Due to the very high cost of hydrogen fuel cell vehicles, and associated infrastructure issues for private vehicles, these have not been considered in this analysis.

	allow charging from the grid rather than the internal recharging system, and therefore improve energy use per km.
Electric vehicles	These vehicles have no internal combustion engine, relying entirely on an electric system. Such vehicles are up to 4 times more efficient that a gasoline car. The main challenge of commercialisation and large-scale uptake of this technology is battery range and cost. Charging infrastructure is also an issue. The cost-effectiveness of this option as a low carbon measure depends on the carbon intensity of grid-based electricity.

For private car usage, a significant challenge is affordability. Improved vehicles cost more, particularly compared to a second hand conventional vehicle. Additional upfront costs are a significant barrier, particularly as financial savings (through reduced fuel costs) accumulate over the lifetime of the vehicle. The distributional impacts of restricting older vehicles on the road need to be carefully considered, so as not to make private passenger travel prohibitively expensive, thereby restricting access for lower income groups.

Vehicle efficiency can also be improved by better vehicle maintenance. Simple measures such as ensuring proper tyre inflation and regular vehicle servicing can significantly reduce fuel consumption.

Alternative fuels

An important low carbon fuel alternative to conventional transport fuels (gasoline and petrol) are biofuels - biodiesel and ethanol. There has been real interest in the use of biofuels in Tanzania in recent years for the following reasons (as summarised in GTZ (2005)):

- Agricultural / rural development, leading to the creation of new jobs and income opportunities. FAO (2010) also notes potential benefits to increasing crop productivity
- Reduction of oil imports, resulting in foreign exchange savings
- Enhance energy security through increased indigenous energy production. This could also lead to a new export commodity for the international market
- Creation of new industries associated with biofuel sector
- Reduction of GHG emissions, leading to opportunities for CDM and carbon trading
- Reduction of air pollution associated with fossil fuels (Lead, SO_2, CO)

However, there are specific concerns associated with biofuel production. First, development of land for energy crops could affect available land for the expansion of food production, particularly with a growing population. This could lead to increased food insecurity, increasing food prices. Second, specific crops could increase the pressure on water resources and affect natural biodiversity (due to expansion of agricultural land). Third, depending on the structure of the industry, limited benefits could be seen by the rural poor, if indeed they are ‘by-passed’ by large producers. Fourth, the production system employed could result in higher carbon emissions from the agricultural sector, offsetting any potential carbon benefits.

Whilst Tanzania does have a small, emerging biofuel industry, it has not grown significantly in recent years as the Government decides on a biofuel policy.[56] Most of the current biofuel investors are developing jatropha projects for biodiesel production. There is also increasing interest in sugar cane for ethanol production. A report by IIED (Sulle and Nelson 2009) states that over 4 million hectares of land have been requested for biofuel investments, particularly for jatropha, sugar cane and oil palm, although only 640,000 ha have so far been allocated and of these, only around 100,000 ha have been granted formal rights of occupancy. Some companies are proposing biofuel projects involving initial investments of up to US$ 1 billion, or several billion US$ over the next 10-20 years.

Recently the FAO (2010b) have undertaken a detailed study of Tanzania’s potential to develop biofuels. The study underlines that the development of biofuels could be important for increasing investment into the agriculture sector, raising food production levels and developing the rural economy through employment and

[56] A National Biofuel Policy is currently being developed by the National Biofuel Taskforce. Interim guidelines are in place whilst the policy is being developed (Guidelines for sustainable liquid biofuels investments and development in Tanzania, Ministry of Energy and Mineral, January 2010). Whilst policy development is being progressed, there have been restrictions on new investments.

increase small holder incomes. The FAO assessment shows that bio energy could do much for agriculture provided the sector is carefully managed.

A summary of the main findings from the study are provided in Table 9 below.

Table 9. Key findings from the FAO BEFs study for Tanzania

Analysis	Description
Biomass Potential	Based on current agricultural practices (rain-fed, low input tillage systems), there is high land suitability across the country for cassava and sunflower, some suitability for sweet sorghum and limited suitability for sugar cane and palm oil. Increasing bioenergy production requires a change in agricultural practice towards conservation agriculture in the medium term and with the application of high level inputs in the long term. These improvements will influence the performance of the whole agricultural sector. Large scale increase could be possible under conservation agricultural production with low input levels.[57] The suitable area for cassava production could be increased by more than 9.5 million hectares providing 26.6 million dry-tons of cassava, an near threefold increase compared to the baseline. Palm oil and sugar cane expansion require additional water resources and therefore have less large-scale potential. Jatropha potential is uncertain due to no evidence for significant scale-up (currently it is grown on a smaller scale, often on marginal land).
Biofuel Chain Production Costs	Technological capacity and human capital is limited to develop the sector, requiring significant investment. The lowest production costs for ethanol are from sugar cane juice ($0.5-0.7 / litre) and cassava ($0.35-0.5 / litre). (In the most established market (in Brazil), ethanol is produced for $0.27-0.3 / litre). The study recommends production from cassava because it permits the inclusion of smallholder farmers (outgrower) in production. Biodiesel production from palm oil is not economically viable as it places too much risk on palm oil uses for food. The lowest cost for biodiesel is from jatropha ($0.7-0.9 / litre), The study notes that jatropha-based biodiesel development poses many risks because of the many uncertainties in jatropha productivity. Therefore, the study recommends exploring other oilseed crops for biodiesel production such as moringa, castorbean, and cotton.
Agriculture Markets Outlook	A range of scenarios were considered to explore the impact of expanding biofuel markets, including if there was no expansion of agricultural land for biofuel production and if there was expansion into currently unutilised land (314,000 ha). Under the no expansion case, the analysis suggests that there will only be limited national level impacts on food security. Under the land expansion case, ethanol production reaches 818 million litres by 2017, with only 81.6 million litres going to domestic blending (10% with gasoline), resulting in potential for large export market (737 million litres). Similar levels would also be seen for biodiesel, based on domestic blending of 5% with diesel. The outlook highlights both the opportunities and risks. Opportunities lie in accessing other markets, where biofuel use is mandated, generating potential export earnings. Risks emerge where the policies in different regions change, reducing market demand. The oil price is also important as it both determines the profitability of biofuels, and impacts on feedstock prices. Too low a price results in lower demand for biofuel. (Lower oil prices also reduce crop production costs, leading to increased global production, and reduced crop prices).
Economy-wide effects in Tanzania (also discussed in IFPRI (2010))	Importantly the study suggests that there is limited shifting away from food production and therefore limited trade-off with biofuel production. This is in part due to the large size of Tanzania's agricultural export sector that prevents food production from contracting. The land displaced by biofuel feedstock is smaller than the area released by declining traditional export crops. As a result, food production increases slightly under most biofuel investment scenarios. Overall, national GDP rises and new employment opportunities are created in biofuel sectors, leading to welfare gains throughout the income distribution (with a possible adjustment period to new new market conditions.

[57] Conservation agricultural production is low tillage, an important option in the agriculture sector for reducing soil carbon emissions.

	The most effective model for raising poorer households' incomes is the outgrower schemes, especially for typical smallholder crops such as cassava and jatropha. The study therefore suggest that Tanzania should explore opportunities to engage smallholders in the production of biofuels. Given its strong pro-poor outcomes and greater profitability, the study findings favour a cassava-based biofuel industry for Tanzania.

In conclusion, Tanzania has enormous potential to develop a bioenergy sector. Biofuel sector development could be an important vehicle for helping regenerate the agricultural sector by bringing in new private, as well as public, investment, increasing productivity. It could provide an important income source for poorer rural populations but this depends on how the industry is developed and structured. It is also possible that biofuel production need not necessarily compete with food production by increasing land productivity and using unutilised lands. Increasing productivity could also promote greater food self-sufficiency.

In the cost curve analysis that follows, low blend levels that require no vehicle retrofit have been assumed – as per the mandates discussed in FAO (2010) – Ethanol 10% and biodiesel 5%. In Brazil, typical ethanol blends are ~25% but require vehicle manufacturers to make modifications, the cost of which is included in the vehicle price (GTZ 2005). A flex-ethanol vehicle has also been included for comparison, which can take an 85% ethanol blend. Costs of biofuel production are taken from the FAO (2010) study.

Current commercial biofuel production in different countries is known as first generation, using conventional technology to produce biodiesel through esterification of plant oils and ethanol from sugar, maize and other starchy crops. Second generation techniques, using advanced techniques such as Fischer-Tropsch processes, for example) are not currently commercially viable. Using first generation techniques, net emission reductions (relative to fossil fuel equivalent) are assumed to be in the order of 80% for ethanol and 70% for biodiesel. Obviously, the net benefit could be significantly lower depending on the production process, and agricultural method (e.g. tillage, fertiliser inputs).

According to GTZ (2005), different studies indicate up to a 40% net reduction from grain ethanol versus gasoline (as seen in North America), a significantly higher 92% net reduction for ethanol produced from sugar cane in Brazil and up to a 70% reduction from biodiesel relative to diesel fuel.

Assessing the costs and co-benefits of transport sector options

A selection of transport options has been assessed to see how they rank in cost-effectiveness terms (for reducing carbon emissions) and their potential to reduce emissions. In general, measures in this sector tend to be less cost-effective than observed in the power generation and household sectors. However, they often have ancillary benefits (e.g. lowering air pollution, improving congestion) that would have wider economic and social benefits which are not included in the cost-effectiveness calculation (i.e. they may therefore be more beneficial in benefit to cost terms, even though there specific cost-effectiveness for carbon emission reduction is lower).

There are four main categories of measures represented in the MACC below:

- Alternative fuels (shaded green)
- Public transport measures (shaded orange)
- Advanced vehicle technologies (shaded blue)
- Efficiency standards (shaded red)

One set of measures not included but often considered cost-effective are demand-side based, focused on changing driving behaviour e.g. through education to improve driving, road pricing etc. Such measures are very difficult to cost or assess the effectiveness of, and of course are usually extremely location specific.

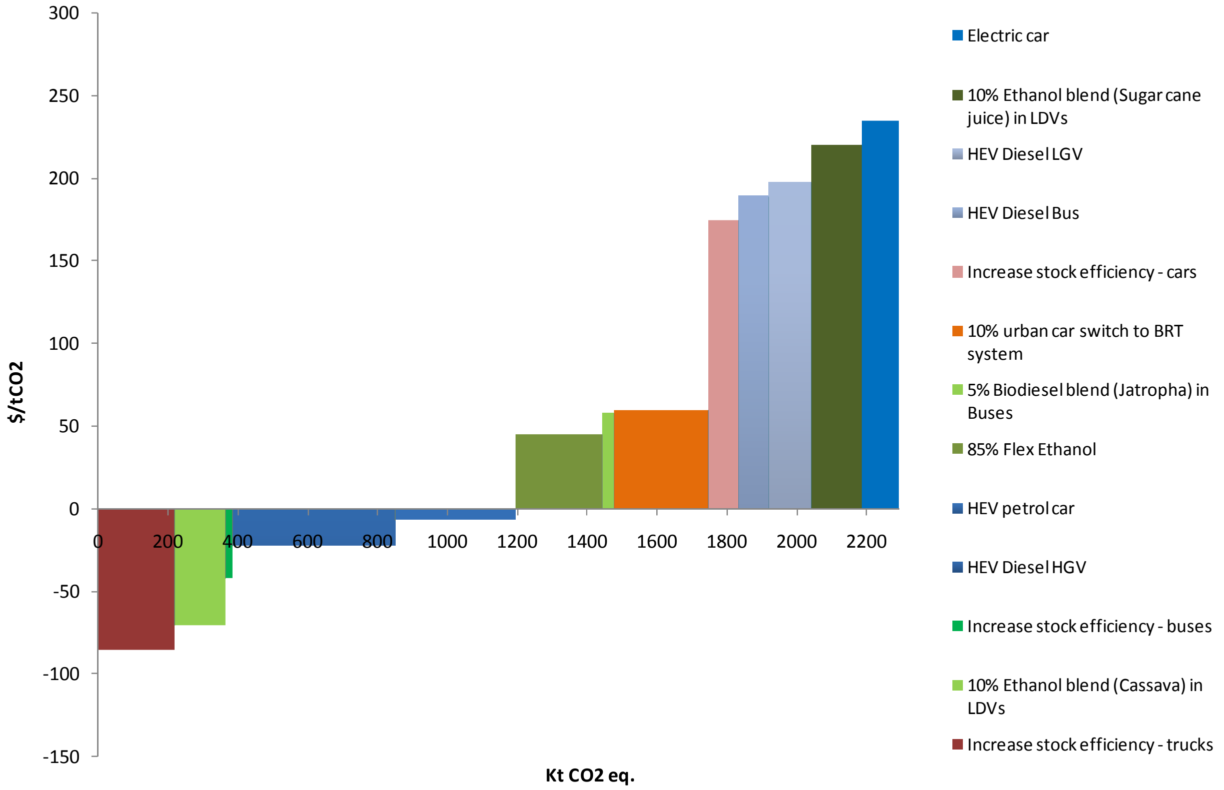


Figure 21. Marginal abatement cost curve for the transport sector in 2030

Key observations from the MACC analysis include:

- The low carbon options shown in the MACC curve could realise emission reductions of nearly 20%. However, many of the advanced vehicle options shown are significantly more expensive than the comparable conventional vehicle.

- The difference in the cost-effectiveness of different biofuel blends illustrates that production from some feedstocks is not as competitive against the international oil price (based on data from the FAO (2010) analysis, and the assumed fossil prices).[58] However, the use of cassava (based on the oil price in 2030) as a blend is cost-effective (The ethanol blend option produced from sugar cane juice is included below for comparison but cannot be counted towards total savings represented by the MACC).

  An E85 flex-ethanol car technology has also been included but is likely to have limited take-up in a small market, particularly if much of the fuel produced is for export. Less flexible vehicles e.g. E25 would be lower cost, and therefore more cost-effective.

- A Bus Rapid Transport (BRT) option, has been included in this analysis although does not use Tanzania-specific information for costs. The costs, which are primarily illustrative to indicate where such a measure might rank, are taken from Kahn Ribeiro (2007), citing Wright and Fulton (2005), of around $\$60/tCO_2$. Potential is premised on 15 cars being taken off the road for every bus in the scheme. Note as highlighted above, this only considers the carbon benefits, and does not factor in other economic and social benefits from such schemes.

- Advanced vehicles (hybrid electric, electric) are important to consider in the time frame of this analysis. By 2030, it is likely that vehicles such as hybrid electric and electric vehicles will be the

[58] The transport fuel prices used are excluding taxes and duties.

norm internationally. Based on the cost reduction assumed in this analysis, which are extremely uncertain and will be dependent on market evolution, HEV cars and trucks are negative cost, whilst LGV and buses are more expensive. The differential of a HEV car by 2030 from that using conventional ICE technology is not significant, which is not unreasonable given that this is already a commercial technology. This is not the assumption for other vehicle types, although in the case of the HGVs, the relative fuel savings (particularly due to high assumed annual mileage) make this specific technology more cost-effective.

Electric cars are more expensive. While significant reductions in battery costs and range performance are envisaged by 2030, this type of vehicle is still more expensive. Effectiveness as a low carbon option is dependent on the carbon intensity of grid electricity, used for charging.

The typical efficiency improvements for advanced technologies are from the recent EU Transport GHG: Routes to 2050? Project[59], whilst cost assumptions are primarily from IEA (2008).

- Increasing stock efficiency means an incentive or standard that would take older vehicles off the road, reducing their potential lifetime, and replacing them with a new vehicle. The cost of this measure is based on the additional cost of a new car which has a relatively shorter life time. The principle is that older cars will be used for longer, making them cheaper in effect due to their higher utilisation (capital costs are annualised over a longer time period).

Implementation issues

The National Transport Policy (2003) aims to develop "efficient and cost-effective domestic and international transport services to all segments of the population and sectors of the national economy with maximum safety and minimal environmental degradation (p1). The focus on the Policy has been lowest cost options aimed at delivering socio-economic development. The strategy emphasises the road sector, with 70% of freight and 90% of passenger movement. One of the key programme outputs of Tanzania rural transport policy is the Village Transport and Travel Programme (VTTP).

Significant donor funds are being invested into Tanzania's transport infrastructure. This finance is primarily aimed at expansion and upgrading of the country's road and airport infrastructure. The World Bank is a major donor. However, political, regulatory and financial structures are currently not well suited to monitoring, controlling and pricing GHG emissions from transport and urban infrastructure.

Use of biofuels in transport sector

There has been rapid growth in Tanzania's demand for petroleum products for transportation and significant foreign investment interest to develop biofuels in Tanzania, both for the domestic market and export. In 2006, the Biofuels Task Force was established to oversee development of the sector. In the absence of specific regulation, a number of pieces of legislation touch upon the sector including the National Energy Policy, the Transport Policy, Land Policy, the Agriculture Sector Development Strategy and National Forestry Policy. Each sets out certain elements either indirectly promoting or constraining the development of the industry.

In the absence of defined guidelines, and against wider international concerns over the equity and environmental sustainability of biofuels production, the development of the industry within Tanzania has encountered a number of issues. Several foreign investors targeted coastal forest areas for replanting with jatropha. Rural communities were offered as little as $8 per hectare for coastal forest land. A WWF-sponsored study identified potential threats and recommended a biofuels investment moratorium to which the GoT agreed. Investment and government support has dried up as a result. At the same time, the EU began to remove support from many projects due to concerns over community and food production impacts.
Another potential project is the production of ethanol from cashew apples, technology currently under consideration in Kenya and India by UNIDO. Tanzania is currently Africa's second biggest cashew producer, and ethanol could contribute to the transport sector in the Mtwara and Lindi Regions (South)

[59] EU Transport GHG: Routes to 2050? Project website, http://www.eutransportghg2050.eu/

A project to invest in a new sugar factory from sugarcane is looking to get financial closure in the second quarter of 2011. Current plans are to produce sugar, ethanol from the molasses and electricity from the bagasse and from biomass from production forests. Tanzania currently has a production of 280 thousand tons of sugar per year and a total demand of about 500 thousand tons which is expected to grow with economic development. The existing sugar factories have little scope for increasing production without green field expansion. Therefore there is a big interest from many actors around additional sugar production capacity. This project is the only new sugar project in the pipeline and has a total area of 25,000 hectares (ha) of which 7,700 ha are planned for sugarcane cultivation and the rest for production forest to add additional biomass to power a co-generation power plant designed to export 75,000 MWh to the grid per year. The environmental impact assessment was approved in 2009 but the project stalled due to difficulties in finding capital for the investments.

The FAO, through the Bio-energy and Food Security Project (BEFS) has sought to address some of the ethical and economic concerns relating to bio-fuel production in Tanzania (see FAO 2010b). The project has undertaken an analysis of the economic and food security implications of expansion of bio-fuel production. As described above, the report sets out the tradeoffs between bio-fuel crops (primarily cassava, sugar cane, palm oil, jatropha, sweet sorghum and sunflower) and the key food security crops (maize, cassava and rice). The report concludes that food security concerns have been driven primarily by low food crop yields in Tanzania, rather than competition for land. The analysis indicates that there are potential gains from pursuing a targeted bio-fuel strategy, both in terms of increased agricultural outputs (associated with higher levels of investment in productivity) and economic benefits from recycling of revenues into poverty reduction and food security. Small-scale cassava production is identified as the optimal bio-fuels path. It is important that the Government of Tanzania selects a bio-energy pathway that is consistent with existing plans for energy, poverty reduction and food security to avoid misallocation of public funds.

The lifting of moratorium is contingent on publication of “Biofuels Investment Guidelines”, which have been approved by Cabinet but which have not yet been issued.

Promotion of public transportation systems

The expansion of low carbon public transport systems offers another route to decoupling transport growth from emissions. Currently, in major urban centres, the quality of public transport is regarded as relatively poor, and does not serve as an adequate alternative for private vehicle use.

Two studies have identified the lack of a well-defined authority and administrative system with the responsibility for formulation and implementation of a coordinated strategy for public transportation, either at the city level, and particularly for Dar es Salaam. These studies also identify a general lack of adequate traffic management principles, management of the road-based transport system that includes policies and measures for the transport system as a whole (see Saiwo 2008, Kanyama et al 2004), Nonetheless, Tanzania is recognised as having a relatively strong rural transport policy infrastructure, as demonstrated in the Village Travel and Transport Programme (VTTP).

Infrastructure development needs to be combined with the introduction of fiscal and administrative incentives, elimination of price fixing and licensing constraints. Clear legal responsibilities are required for institutions.

Upgrading the public transport infrastructure would carry a cost that would unlikely be met by a large proportion of low income users who dominate the system. Low fares currently result in owner operators maintaining minimum financial reserves for maintenance and upgrade. Alternative routes to financing are required, that can be coupled with central government transfers. Past focus has been on the allocation of donor funds for capital works, but there is a need to establish steady finance streams going forward. Currently, there is little emphasis on charging road users for road use or parking that might allow transfer to lower carbon forms of public transport.

The Dar Rapid Transit Agency is potentially a good example of integrated urban transport planning that will slow the expected growth in transport related GHG emissions. Using buses with EURO III engine standards, the 140 passenger capacity buses will run on dedicated lanes. A single DART bus is expected to displace 10 minibuses, resulting in the removal of the estimated 8000 minibuses in the city. There are expected to be significant health and air quality benefits. Financing agreements have been signed with the World Bank, and the scheme is expected to be ready by 2012.

Improved vehicle maintenance and fuel quality
In Tanzania, large numbers of relatively inefficient vehicles are imported for private use, and to operate on the public transport network. The Surface and Marine Transport Regulatory Authority (SUMATRA) has indicated the need for better coordination among regulatory bodies in relation to environmental issues. Currently these issues are dealt with by a range of institutions, including Bureau of Standards (TBS) for buses, police for vehicle inspection and enforcement, NEMC for environmental protection and SUMATRA for regulation of surface and marine transport. There is a lack of an independent and mandatory vehicle inspection regime. There is little control over the age or emissions quality of vehicles imported into Tanzania. The government could pursue a differentiated import tariff to discourage the import of older, more polluting vehicles with larger more inefficient engines.

The current police vehicle inspectors lack the necessary technology to measure the roadworthiness and monitor emissions from vehicles and to check imports. The Government has a petroleum bill to oversee the management of management of specified standards for the petroleum product imports. Fuel storage standards also need to be taken into account under inspection regimes.

Urban infrastructure and transport infrastructure planning
Cities in Tanzania are undergoing a rapid rate of urbanization, leading to a proliferation of unplanned settlements. This process not only makes larger segments of the population vulnerable to climate impacts, it also makes the process of decarbonisation more complex as these settlements become more formal and develop their own infrastructure.. A 2009 report by UN HABITAT documents the issues that have accompanied urban planning in Dar es Salaam, A lack of investment over a number of years has been compounded by poor coordination between the Dar es Salaam City Council and Central government. Transport infrastructure planning was neglected for a number of years, resulting in poor road networks, insufficient traffic signs and lights, and inadequate/ dangerous public transport serving only a small percentage of the population. The report estimates that 33% of all movement is done on foot within the city, but that the necessary infrastructure (walkways, bicycle paths, zebra crossings, footbridges, and pedestrian signs and markings are absent from city streets (UN HABITAT 2009).

A number of legislative measures are in place relating to urban planning. These measures include the Master plan, 1979, Strategic Urban Development Planning Framework, (SUDPF), 1992, Kinondoni Coastal Area Management Project (KICAMP), Sustainable Coastal Communities and Ecosystems (SUCCESS) among others. There are however a number of institutional issues, with responsibilities split between the Ministry for Transport, Works, Home Affairs, Regional Administration, Local Government and Finance. Enforcement of planning regulations also remains an issue.

Summary

Demand for transport is predicted to increase significantly over the next twenty years. With the projected rapid expansion of urban centres, the challenges of maintaining urban movement (avoiding congestion) and maintaining urban environment quality are significant. Low carbon options could help manage transport growth, ensure sustainable urban areas, reduce demand for transport liquid fuels and importantly generate carbon financing opportunities, and is consistent with similar objectives for efficient and effective transport systems.

Development of the biofuel market could offer significant benefits for Tanzania through generating rural employment, providing agriculture sector investment, reducing reliance on fuel imports and creating a new export commodity. Recent analysis suggest that, depending on the crop grown, this need not compromise food production or water resources but could actually lead to increasing food productivity through additional sector investment. To realise economic benefits to rural communities, the sector model taken forward will be key to ensure small holders can supply energy crops. The international community also needs to buy in to the sustainability of such an industry to ensure that any export markets are sustainable in the longer term.

Development of carefully planned public transport provision will be critical for provision of transport services to a rapidly growing urban population. This planning will need to be integrated with other service provision to ensure that transport systems can meet the evolving urban area, and its associated demographic characteristics. Significant challenges include raising the capital investment required, co-ordinating with different planning agencies, implementing and enforcing spatial planning policies, promoting a shift away from private car use and ensuring that the type of scheme developed is affordable for lower income groups. The benefits in terms of lower pollution levels (and reduced GHGs) could be significant, particularly if schemes also introduce more advanced vehicle types (e.g. hybrid or electric buses).

Key issues of affordability remain with promoting advanced vehicle types and restricting lower efficiency vehicles. As incomes increase, purchasing of newer vehicles will become more the norm (as opposed to second-hand vehicles). A move to more advanced vehicles will be dependent on their wider global commercialisation (potentially allowing leap frogging) and the price differential versus a conventional vehicle. It is therefore partly a function of timing.

Introducing enforced maintenance or restricting the older vehicles on the market needs to be carefully thought through in terms of impacting on affordability of transportation, required for a growing economy. For larger commercial operators, such internal measures could have the potential to lead to significant cost savings.

Limited focus has been given to non-transport modes. Further consideration could be given to the use of the railways for freight and passengers as a means of reducing road transport-based emissions. However, it is likely that significant investment and incentives will be required to reduce recent decline in the use of rail infrastructure. Air emissions are likely to increase in future years as Tanzania increases its export markets, and higher levels of international investment flow into the country. Currently, international emissions, whilst subject to estimation, are not accounted for nationally under current international agreements. This could change in the future, and therefore it is in the interest of Tanzania to assess future risks under future international obligations associated with increasing emissions from this sector.

Some of the activities that might enable the uptake of these low carbon opportunities are highlighted in the Box below.

Box 12. Enabling activities to deliver low carbon measures in the Transport sector

Biofuels

- Issue clear bio-fuels guidance that sets out land use constraints, feedstock and food security, community protection, as part of an integrated land use management plan;
- Undertake further analysis on a crop by crop basis, building on work undertaken for the FAO BEFS project
- Establish strategy for use of biofuels within Tanzanian transport sector, including blending and potentially targets for use. Consideration of fuel duty level will also be important.

Public transport

- Realignment and consolidation of transport planning authorities
- Build upon Dar Es Salam DART scheme for dedicated transport networks

Vehicle maintenance and fuel quality

- Introduce fiscal incentives to discourage the import of low quality second hand vehicles
- Introduced improved vehicle testing, maintenance and fuel quality assurance system

Transport infrastructure planning

- City and municipal governments need to implement and enforce regulatory frameworks integrating climate screening into urban master-planning, and at the building level.
- Better address rural development problems in order to alleviate problems in urban areas.

Agriculture

A key domestic policy objective is for Tanzania to modernise the agriculture sector and improve productivity, particularly to ensure food self-sufficiency. This will be particularly important in a situation where the agriculture sector becomes more vulnerable to climate change impacts. For Tanzania, projects that can generate carbon finance will have to complement (but not compromise) agriculture sector priorities like food security, land productivity and rural economic growth. Another important issue to highlight is that agriculture is a very climate sensitive sector and will be affected by climate change. The consideration of options to reduce emissions in this sector must be undertaken alongside consideration of the potential effects of climate and enhanced resilience.

Alongside the exploitation for wood fuel and charcoal energy, the sector is also an important driver of deforestation. Therefore, introduction of low carbon approaches need to take account of impacts on the forestry sector. For example, whilst a more intensive farming system has increased energy and fertiliser inputs, which in turn increase GHGs, it could also mean less land utilisation by the sector (or at least reduce current rates of increase) and the ability to increase productivity and develop export markets. Therefore, potential trade-offs exist.

Low Carbon Investment Opportunities

There are a range of low carbon measures that could be considered, with potential for generating carbon finance. They are primarily based around:

- Cropland management;
- Grazing land management and pasture improvement;
- Livestock management.
- Other management activities

The key measures cited in the IPCC 4th Assessment report are listed in Table 10.

Table 10. Low carbon options for the agricultural sector

Option category	Option
Cropland management	Nutrient management, particularly with respect to method and timing of fertiliser application, to improve N use efficiency
	Reducing or no tillage farming practices. Soil disturbance tends to stimulate soil carbon losses through enhanced decomposition and erosion; reduced tillage can avoid / reduce losses
	Water management. Increased or more effective irrigation can enhance carbon storage in soils through increased yields and residue returns [-ve: potential gains offset by energy for pumping, increased emissions from fertilisers]
	Rice management. Reduce CH_4 emissions through various practices including draining and using alternative rice varieties.
	Agro-forestry is the production of livestock or food crops on land that also grows trees for timber, firewood, or other tree products. [+ve: strong synergies forest protection, and adaptation; -ve: lower intensity of yields]
	Returning cropland to another land cover, increasing the carbon storage in soils / vegetation
Grazing land management and pasture improvement	Grazing intensity (and timing) can influence the removal, growth, carbon allocation, and flora of grasslands, and therefore affecting level of carbon accrual in soils
	Increasing productivity e.g. fertilisers. Application can increase yields and carbon storage. However, it can also lead to N_2O emissions thereby offsetting some of the benefits.
	Nutrient management – as mentioned above for croplands
	Reducing biomass burning, as this can lead to CH_4 emissions from combustion, reduce the albedo of the land surface, plus contribute to climate change through different indirect ways.

	Species introduction: Introducing grass species with higher productivity, or carbon allocation to deeper roots, has been shown to increase soil carbon.
Livestock management	Improved feeding practices, for example, feeding more concentrates, normally replacing forages. Although concentrates may increase daily methane emissions per animal, emissions per kg feed intake and per kg-product are almost invariably reduced.
	Specific agents and dietary additives. A wide range of specific agents, mostly aimed at suppressing methanogenesis, has been proposed as dietary additives to reduce CH4 emissions.
	Longer-term management changes and animal breeding. Increasing productivity through breeding and better management practices, such as a reduction in the number of replacement heifers, often reduces methane output per unit of animal product.
Other	Management of organic/peaty soils. Due to the high storage of carbon in such soils, use of these soils for agriculture can lead to CO_2 / N_2O emissions in particular. This is because soils are drained, which aerates the soil, favouring decomposition. Emissions can be reduced by practices such as avoiding row crops and tubers, avoiding deep ploughing, and maintaining a shallower water table. The most important mitigation practice is avoiding the drainage of these soils in the first place or re-establishing a high water table
	Restoration of degraded lands, which may lead to enhanced carbon storage. Such measures have strong synergies with adaptation.
	Manure management. Animal manures can release significant amounts of N_2O and CH_4 during storage, but the magnitude of these emissions varies. Methane emissions from manure stored in lagoons or tanks can be reduced by cooling, use of solid covers, mechanically separating solids from slurry, or by capturing the CH4 emitted. The manures can also be digested anaerobically to maximize CH_4 retrieval as a renewable.

Source: Primarily from the IPCC 4th Assessment Report WG3 (Smith et al. 2007)

A recent study by the FAO (2010c) under their Mitigation of Climate Change in Agriculture (MICCA) Project reviews some of the mitigation projects currently underway. Many of the projects covered include restoring degraded soils and agroforestry. Importantly, most of the projects are aimed at and are resulting in productivity gains, which is critical for a country such as Tanzania. The survey highlights that many of the projects hold benefits for mitigation, adaptation and productivity. However, it highlights some of the challenges for generating carbon financing including number of agricultural holdings in developing countries, and the modest amount of carbon accumulated in small holdings.

Work undertaken for the low carbon study by Sokoine University (see impacts report) highlights the potential for low carbon options in the agriculture sector, noting that many options, particularly those that involve soil carbon sequestration, generate co-benefits for adaptation, food security and rural development.

Benefits can also be seen for the forestry sector. Poor agricultural practices including shifting cultivation and extensive pastoralism are among the major causes of deforestation and hence GHG emissions. Better land management to reduce GHG emissions particularly through soil management to maximise carbon storage and reduce N_2O and CH_4 should therefore be promoted. Improved practices can result into better water and plant nutrients utilization for increased crop yield and reduce the need for shifting cultivation. Tanzania is the third largest country in Africa in terms of livestock population. Most of these livestock are kept by pastoralists/agro-pastoralists and are the major contributors of deforestation (see separate agricultural report on impacts and adaptation). Therefore, there is a need to address animal husbandry issues through improved rangeland management, reducing grazing pressures.

Sokoine University highlight the following low carbon opportunities that are currently not fully exploited or utilized at all. It is important that such options are incorporated into regular farm operations and practices so that GHG can be displaced at a relatively low cost.

- **Multipurpose gardens**: Traditionally known as ‘coffee-banana’, the system has worked well and sustainably for hundreds of years in different regions of Tanzania. Livestock are zero grazed with manure recycled in the multipurpose gardens where several crops are grown, e.g. coffee-banana-beans-yams-vegetables-fruit -and forage trees. Leguminous crops fix nitrogen and thus improve soil fertility. Fodder plants incorporated into the system are predominantly leguminous with beneficial effects on soil fertility. To a large extent, this is organic agriculture with no external inputs. Coffee husks are used in the farm and only coffee beans are marketed. Since most of the crops (coffee, fruit trees- mango, and avocado, citrus) are perennial, they conveniently serve as carbon sinks.

- **Use of animal power for field operations**. The large number of livestock population available in the country could be utilized as a source of power for most field operations. This could significantly reduce the GHG emissions from fossil fuel (tractors) in the agricultural sector. Use of oxen carts could also facilitate the transportation manure the crop fields. When manure is applied on land as a soil conditioner and organic fertilizer, replacing synthetic fertilizer, it has the effect of reducing erosion, sequestering carbon and improving soil fertility as well as increasing the water holding capacity of the soils.

- **Use of biogas**. Use of manure in the production of biogas for energy reduces emissions as methane is burnt instead of being released into the air. Since many livestock keeping communities do not utilize the manure and most of their surroundings are already degraded, significant potential to adopt use of biogas exists. The potential problems of biogas digesters is discussed earlier in the report.

- **Creation of carbon sinks that assist to remove emissions**. The main potential for mitigation lies in enlarging carbon sinks (IPCC, 2007). One approach is to increase biomass by incorporating trees and bushes in different farming systems. Opportunities in Tanzania include (i) trees in tea and coffee production (ii) agroforestry within the coffee banana farming system. Coffee plantations in Iringa, Tanga, Mbeya, Arusha, Kilimanjaro and Kagera Regions have trees that provide shade and improve soil fertility through leaf fall and Nitrogen fixation.

- **Restoration of degraded soils.** Restoration of degraded land takes many forms. Controlling of activities that cause degradation naturally restores the vegetation cover. This is especially in vast grassland and grazing lands, by regulating animal numbers and pasture improvement resulting in the improvement of soil carbon sequestration rate. Several soil and water conservation projects have been implemented in the country and different degrees of success registered. The projects include HADO, HASHI and HIMA in Dodoma, Shinyanga and Iringa Regions. Through these programs degraded land has been restored through destocking, replanting of native vegetation, mechanical conservation works, and rainwater harvesting. In Mvumi and Kondoa in Dodoma Region the success in the restoration is such that natural vegetation is back even water is flowing once again in the streams that had dried up. It should however be emphasized here that these projects addressed development needs and had no clear connection or agenda to climate change mitigation.

Assessing the costs and co-benefits of agriculture sector options

Agriculture projections are extremely uncertain, particularly because the inventory estimates are not recent and incomplete (compared to other country inventories). A simplified approach, due to high uncertainty of agriculture sector emissions, has been to use mitigation cost and reduction potential estimates for Africa from the comprehensive USEPA study (2006) on non-CO_2 mitigation options and apply them to the Tanzania situation. Options for livestock management, particularly focusing on enteric fermentation, could reduce emissions by 2.1% at $15/t$CO_2$ or by 0.5% at $0/t$CO_2$. For cropland management, to reduce N_2O emissions in particular, we have used the following % reductions: 13.5% at $15/t$CO_2$ or by 10.6% at $0/t$CO_2$. These measures are shown in Figure 22.

Whilst this approach is basic, it has been used provide some preliminary understanding of the extent of reduction potential at given costs for generic agriculture emission categories. At higher costs, mitigation does not increase significantly; and other analysis supports this finding by estimating average abatement costs of around $5-10 for agriculture sector in Africa (Grantham Institute 2009). On mitigation potential, it is difficult to compare the Grantham analysis with that produced by the USEPA due to different baselines and different analysis years.

As discussed in the next section, whilst measures are low cost, there are often major issues with implementation, particular across a sector that is often fragmented, with many smaller farms and small-holdings. This inevitably makes policy implementation more problematic.

Implementation Issues

Agriculture constitutes the most important sector of the Tanzanian economy, providing about 27% of GDP and 80% of employment. Cash crops, including coffee, tea, cotton, cashews, sisal, cloves, and pyrethrum, account for the vast majority of export earnings. Much of the stated policy architecture in Tanzania is focused upon improving the intensity of agriculture, and increased mechanisation, such as the use of power tillers. GoT and DFID are also focused on moving Tanzanian agriculture up the value chain through increased domestic agri-processing and improved storage and transportation systems. All of these aspects have the potential to increase GHG emissions from the sector, particularly in terms of fertiliser use and fuel inputs, In addition, increases in GHG emissions are likely to be driven by rising food demand and population growth.

Emission reduction projects could still have a role to play, where they can increase productivity, and take account of the need for climate resilience (due to current and future climate impacts). Given the structure of the agriculture sector, involving many small holders with very low incomes, carbon finance could be an important source of additional income. However, with large numbers of small holders, implementing such projects is challenging. Project opportunities may therefore be more efficiently targeted at larger agro-forestry companies where intensive systems and heavy fertiliser use are in place, resulting in poor soil carbon management techniques and intensive livestock practices.

Carbon finance in the agriculture sector is a reality today. For example, a project called *Emiti Nibwo Bulora* (translated as Trees Sustain Life) in Tanzania's Kagera region, developed by Vi Agroforesty, is promoting agro-forestry techniques (FAO 2010c). The project involves integrating tree planting into the agricultural area through boundary planting, dispersed interplanting, fruit orchards and woodlots. Whilst only in the implementation phase, this project is expected to benefit over 1000 households over the next few years through voluntary carbon financing. Further work by Vi Agroforestry is described in SEI (2009).

Another interesting recent example is the Kenya Agricultural Carbon Project, located on 45,000 hectares in the Nyanza Province and Western Province of Kenya, which aims to reduce emissions through cropland management whilst also improving yields.[60] This is the first project of its kind, to generate finance from reducing soil carbon emissions through techniques such as covering crops, crop rotation, compost management, and agro-forestry, and is being supported by the World Bank BioCarbon Fund and implemented by Vi Agroforestry. The direct benefit to local communities is over $350,000 with an initial payment of $80,000 to be made in the first year, 2011.

One significant challenge involves constructing effective metrics for GHG credits in agriculture. Creating these metrics will require institutional innovation and creative work to better understand and collect the necessary technological and economic information needed to measure GHG emissions in agriculture. Recognition of the importance of off-site impacts of changes in farm practices increases the complexity of measurement, reporting and verification of GHG impacts.

Innovation in the agriculture sector and the dissemination of low carbon technologies is crucially dependent on institutional capacity, regulation and policy. Some of these will be related to biotechnology developments, and as such Tanzania should ensure robust biosafety and traceability frameworks are in place.

Much agricultural innovation relating to water use efficiency, reduced inputs, and more stress tolerant varieties, are derived from R&D in the developed world. Nonetheless, there is a clear need for Tanzania to ensure that national research capacity is effective, providing sufficient infrastructure and attracting high quality research staff. The CGIAR system can continue play a facilitating role in this regard, and may provide a model for non-agricultural technologies. Local focus should be upon leveraging research from developed countries and identifying complementarities. International funding for mitigation and climate resilient agricultural research will be dependent on demonstration of such capacity. A role may also be identified for the private sector, both in upstream R&D and downstream trials, with the public sector concentrating on those areas where property rights and return on investment opportunities are constrained.

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[60] The World Bank website, http://go.worldbank.org/WIWKCYP9T0

Summary

The key objective for Tanzania is the development of a modern, more productive agriculture sector that ensures food self-sufficiency and can help develop the rural economy. Low carbon options have been shown to enhance productivity, increase resilience to climate change and provide opportunities for climate financing. They also tend to be low cost and have significant benefits for wider environmental sustainability, including reducing deforestation.

However, there are issues of scale with only a limited number of relatively small scale projects. These are of course important for local communities, and demonstrating the benefits of approaches such as agroforestry. A question will be whether such initiatives can be scaled and integrated into Tanzania's evolving agriculture sector, delivering significant emission reductions and significant levels of carbon finance.

Some of the activities that might enable the uptake of these low carbon opportunities are highlighted in the Box below.

Box 13. Enabling activities to deliver low carbon measures in the Agriculture sector

- Implement programme of negative and low cost mitigation practices among farmers for carbon management in soil and livestock where financing opportunities can be identified and captured
- In adaptation strategies, identify climate resilience activities that have mitigation co-benefits within the Tanzanian agricultural sector;
- Advisory to large scale agro-processing companies on low carbon agricultural practices, inputs and supply chain management techniques;
- Promotion of domestic R&D in mitigation technologies, and identification/adoption of international best practices
- Assessment of viability of certain areas of agriculture from a resilience perspective under shifting climate baseline, prior to large scale mitigation efforts
- Integration of mitigation requirements into agricultural insurance products

Forestry

Protecting forests through improved management not only reduces the emissions associated with deforestation but has the significant co-benefits of ecosystem protection, and sustaining associated industries (timber, tourism, energy). Through REDD+, which Tanzania is heavily engaged, significant opportunities for raising carbon finance exist in future years.

Key low carbon options listed by the IPCC are shown in Table 11 below.

Table 11. Low carbon options for the forestry sector

Option	Co-benefits	Barriers
Reducing deforestation and degradation	Maintain livelihoods using forest resource Biodiversity preserved Maintain ecosystem services	Pressures for alternative land uses e.g. agriculture Domestics energy needs Timber export market
Afforestation / reforestation	Reduce soil erosion Improve water and soil quality Enhance biodiversity and wildlife habitat improve the aesthetic / amenity value of the area New economic resource	Pressures for alternative land uses e.g. agriculture

Forest management to increase stand- and landscape-level carbon density		
Increasing off-site carbon stocks in wood products and enhancing product and fuel substitution	Energy conservation through the use of (sustainable) bioenergy	

Source: IPCC 4th Assessment Report – mitigation (Nabuurs et al. 2007)

Assessing the costs and co-benefits of LCG Opportunities

In Africa, options for mitigation are viewed as relatively cost effective. The IPCC's 4th Assessment report (Nabuurs et al. 2007) cites estimates from forestry modelling that indicate that 70% of the mitigation potential can be undertaken at \$1-20 /tCO_2, and near 90% between \$20-50/tCO_2. The cost curve analyses (under Project Catalyst) that have been done for Brazil and Indonesia, which focus on forestry, support this finding – although debates continue as to the opportunity cost of foregoing the use of land for non-forestry activities. Changes in agricultural commodity prices or land rent rates could dramatically change such opportunity costs.

Many of the costs of implementing forestry management or protection programmes are generally not included in widely cited abatement costs. These can be significant, and will depend on the scheme introduced and the area covered. The costs of monitoring and verification (to avoid leakage) are also generally not included.

The projected CO_2 emissions from this sector are significant due to assumed high deforestation rates, and the use of biomass-derived fuels for energy. The projections described earlier in this report show that forestry sector emissions account for over 50% of total emissions. Significantly reducing rates of deforestation and forest degradation could lead to large reductions of emissions and potential for carbon financing; hence the significant interest in REDD in Tanzania.

For example, if extraction of biomass for energy was reduced by 30% in 2030, assuming the same rates of deforestation, this could reduce emissions by 25%, and lead to significant payments under a proposed REDD+ scheme.[61] The additional co-benefits from forest protection are also considerable (although unquantifed) and include biodiversity protection, ecosystem services and safeguarding forest-based economic activities (including biomass for energy).

However, implementation issues are significant, as discussed below.

Implementation issues

A detailed overview of the current status of REDD in Tanzania is provided in Case Study 4 in Appendix 1. The key issues concerning implementation are summarised in the section below.

Background / existing policy
Avoided deforestation and reforestation has the potential to cut emissions at low cost within a short time frame. Encouraging sustainable forestry has a number of co-benefits including poverty alleviation, improved governance, biodiversity conservation, and the development of an environmental services economy. Tanzania has been an active member in developing 'Reducing Emissions from Deforestation and forest Degradation (REDD) and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks'. The process of REDD+ implementation has started in the country through national planning processes and the development of pilot projects, giving some sense of what REDD+ might look like in practice to the wider region.

[61] It is important to highlight that if carbon emissions are saved from the forestry sector, this reduces the potential of measures in the household sector, which count the benefit of emissions saved from reducing use of unsustainable biomass.

Under REDD+, Tanzania will implement policies to address the drivers of deforestation and degradation. Examples of policies include enhancing community based forest management, developing 'payment for environmental service' schemes and changes to agricultural and energy policies. Financial support is already being given to Tanzania to develop national REDD+ plans, and to start implementing projects. The innovation in REDD+ is that financial support from the international community to implement these policies is likely to be linked to performance in reducing deforestation and degradation rates.

The existence of community based forest management means that Tanzania is potentially well placed to implement REDD. Policy reforms in forestry management mainly through the National Forest Policy in 1998 and the subsequent Forest Act of 2002 facilitated community engagement over 15 years ago. This community participation in forest management created knowledge of the value of conservation and facilitated the sense of ownership and collective responsibility in managing forests (Tanzania-REDD, 2010). The use of Participatory Forest Management (PFM) strategies is important for the REDD initiative which relies on community engagement. PFM in Tanzania builds off of the country's local government institutional framework, which gives local communities a legal mandate through elected Village Councils and Village Assemblies. Equally important is the country's policy framework for land tenure, which vests these village bodies with responsibility for managing the lands ('village lands') within the boundaries of villages. As of 2008, PFM covers extensive areas, including about 1.7 million ha under Joint Forestry Management (JFM) and 2.4 under Community based Forestry Management (CBFM). This means that about 13% of all the forest in Tanzania is under PFM arrangements, involving over 2,300 villages across the country.

Existing local governance and land tenure framework, and track record of developing PFM in concert with those other policy factors means that Tanzania is well placed to demonstrate how local involvement in forest management and global climate objectives under REDD can be practically integrated. Tanzania's experience on implementing PFM demonstrates how empowering local communities to manage forests, through secure mechanisms for tenure and a clearly developed policy and legal framework, is key to reversing forest loss and degradation in rural areas.

Whilst having strong experience in community based forest management, significant challenges exist in developing REDD into a national scheme that significantly addressed the problems of unsustainable forest resource use.

Barriers

There are a number of risks and barriers for local communities to benefit from REDD+ which are becoming apparent in Tanzania:

- Strong linkages in socio-ecological systems that may be disrupted by change in forestry management policy and regulation. Conflicting interests among various stakeholders in developing and implementing REDD initiatives. Existing conflicts may be exacerbated. Care will need to be taken in ensuring that REDD schemes are integrated properly into existing PFM structures.

- Although, forest legislation (mainly the 2002 Forest Act) provides a clear and unambiguous legal basis for the management of forests on village lands at individual, group and community levels, implementation of JFM for instance has been more uncertain (even though legalised through the signing of JMAs). Despite the overall success of PFM in Tanzania, these approaches continue to face several key challenges which may also be a constraint to REDD implementation. One challenge to PFM has been developing flows of local benefits from forests under local management. Despite many years of developing PFM, and the presence of valuable stocks of timber on many areas under PFM, there is very little revenue being captured at the village level from these resources. By contrast, levels of illegal timber harvesting in Tanzania in recent years have been high (see for example TRAFFIC report, 2006), but this trade has generally bypassed local communities. Although PFM has had many successes in improving forest conservation and community tenure security, which REDD can further, there are still uncertainties which can either be partly resolved or further exacerbated by REDD, depending on its design and execution. Therefore, current structures need to be assessed as fit for purpose and strengthened where necessary, if to provide the main vehicle for REDD implementation.

- Poor governance and local law enforcement, e.g. in preventing illegal logging;

- Insecure tenure is a major issue, which makes it difficult to ensure emissions reductions are permanent, and may therefore make investment unattractive;

- Lack of regular, reliable, specific and accurate data for computing baseline emissions, and therefore expensive survey work. The inclusion of forest degradation and forest enhancement in REDD, implies that countries will need to carry out forest inventories on a regular and systematic basis in order to quantify forest carbon stock changes. This would be an expensive undertaking if professional surveyors are employed; skills capacity could be a serious issue (Skutsch et al, 2009). Hence, while the focus of REDD is mitigating emissions, alleviating poverty and provide livelihoods alternatives among the poor, much finance could eventually be diverted to employing technical staff for estimating carbon stock.

- Leakage has also become very challenging in the implementation of REDD initiative, because local projects, albeit successful, might fail to deliver any net emission reductions from reduced deforestation in the aggregate. Even if strategic planning can favour the monitoring of activities such as illegal logging, strategic conservation projects will not on their own satisfy the energy needs of Tanzania's rural population. This is why, in the final analysis, leakage can be brought to tolerable levels only with the implementation of practices such as sustainable charcoal production (UN-REDD, 2009).

- Very high deforestation rates make large scale implementation critical. However, the scale of the problem makes the challenge of addressing the issue through REDD significant.

- REDD+ could create incentives for government or investors to occupy poorly defined 'surplus' land. In addition, lack of clarity over rights to carbon and lack of access to legal systems even where rights are well defined may exclude poor people. The creation of new flows of revenue based on forests' carbon values could result in weakening local rights to use and manage forests; as forests commercial values rise as a result of carbon market trends, many parties such as individual elites or private investors may try and obtain forests that communities have yet to clearly secure their rights over.

  Thus the carbon market and REDD might prompt a rush for control over forests similar to the recent rush for control over lands in Tanzania's coastal areas that has occurred as a result of the growth of the biofuels market. If REDD results in outsiders claiming control over forests that were previously used by local communities, such developments might undermine the very objectives of REDD in Tanzania. Furthermore, if communities lose access to land or resources it will also weaken their capacity to adapt to climate changes. Developing REDD in a way that helps communities to secure tenure over forests, and integrates REDD with PFM, is therefore also important to the aim of integrating the climate change mitigation and climate change adaptation agendas (Tanzania-REDD, 2009).

- Establishing and maintaining benefit sharing systems will require significant government capacity. Another legal challenge has been attributed to the fact that the Current forest laws are not clear on how the benefits of forest management particularly in forest reserves managed for timber production purposes can be equitably shared with participating communities. In many cases, benefit-sharing arrangements remain in a legal limbo with *de facto* management at the local level taking place, in return for vague promises about benefits at a later date. Clearly, this is a situation that cannot be sustained indefinitely. Without benefits reaching a level that equal or exceed the costs being borne, in terms of local forest management, the long term future of PFM through JFM and CBFM remains uncertain. With the increased discussion in Tanzania over revenues from carbon financing, particularly under REDD; the question of sharing of these revenues is likely to be rekindled (Blomley and Idd, 2009).

- High transaction costs of implementing REDD+ in areas where forests (or their ownership) are fragmented, may exclude communities from REDD+ schemes.

Whether REDD+ strategies are able to take advantage of the opportunities and mitigate the risks identified is yet to be determined. There has been little discussion to date of linkages between REDD+ and the wider policy changes required to reduce deforestation and degradation rates as set out in this report. For example, energy policies and agricultural policies will need to be integrated into the overall REDD+ framework and will demand much more effective cross-sector coordination at national and local levels. These policies may have implications for different stakeholders, which need to be better understood.

Another set of issues that have not yet been fully analysed are the distributional effects and benefits of for communities. In Tanzania it is hoped that REDD+ will deliver pro-poor Community Based Forest Management approaches (as discussed above). However, while such policies to date have been relatively successful at delivering environmental benefits, they have not been of specific economic benefit to more marginal communities. However, it is still far from clear whether the scale of benefits from REDD+ can help to overcome such issues, or in fact whether REDD+ may actually result in new pressures that exacerbate existing inequalities.

Finally, any implementation of REDD needs to take account of alternative energy sources. As a key driver of deforestation and degradation, unless energy needs of the population are addressed, enforcing forest protection is going to be increasingly difficult. Where REDD affects fuel wood and charcoal availability, this could also have significant distributional impacts on low income households who cannot afford any alternatives.

Summary

It is clear that carbon finance offers the opportunity to reduce deforestation and protect forest stocks. In addition to the many implementation challenges, the drivers of deforestation and degradation (wood fuel for energy and deforestation through agricultural activities) also need to be tackled. Hence, the strategy for forestry protection and sector growth also needs to be integrated with action in the forestry and energy sectors.

Some of the activities that might enable the uptake of these low carbon opportunities are highlighted in the Box below.

Box 14. Enabling activities to deliver low carbon measures in the Forestry sector

- Further progress on land reform processes will be needed in order for REDD+ benefits to accrue to areas and stakeholders that currently have insecure tenure. Safeguards may be needed to ensure that such reforms are not orientated towards benefitting elites and REDD+ may need to be developed with a specific ‘pro-poor’ mandate;
- Accountable and transparent financial systems need to be developed for benefit sharing, including processes for conflict resolution;
- Guidelines for negotiating participatory forest management approaches need to be developed and support is required to implement such guidelines properly;
- Voluntary approaches to REDD+ should be tested alongside government initiated pilots, as these offer a different model for implementing REDD+;
- Cross-sector coordination will need to be enhanced, with financial support from REDD+ used to support policy changes in much broader areas than those typically under the jurisdiction of forestry departments.
- Developing regional strategies based on agriculture and forest losses in relation to climate change
- Ensure that forestry initiatives are pro-poor and consider crop production and food security issues, recognising that the poor depend on forests for their livelihoods
- Promote market-based REDD initiatives, rather than fund-based. This will help avoid the complexity of managing and distributing funds at the government level.

Future potential for low carbon projects in Tanzania

This section of the report has illustrated the potential for low carbon projects that could help Tanzania move towards a more sustainable growth path, in addition to generating carbon finance to support such investment. Low carbon projects can help safeguard forests, reduce reliance on energy imports, provide more access to modern energy services, promote more sustainable biomass use, promote efficient and clean transport systems, and enhance economic competitiveness.

The potential is across all sectors of the economy, as shown in the MACC in Figure 22. The characteristics of these measures are listed in Table 12. An important insight is that many of the measures are low or negative cost, meaning that even a modest carbon price could cover the investment made. This is important as it suggests that for a more sustainable investment, the additional costs can be covered by a modest carbon price. Where cost are negative, this implies that such investments should be made irrespective of whether carbon finance is available, as over their lifetime such investments save money.

Due to the stove efficiency measures, the overall investment requirement shown in the MACC example is in fact net negative. Importantly, such cost estimates only take account of technical costs; introducing policy and transaction costs would reduce this savings figure significantly.

More work is needed to explore the uncertainties around such cost estimates, particularly because they are driven in large part by a limited number of large potential measures, particularly in the household and forestry sectors. In addition, this economic estimate of costs is very narrow as it only focuses on technical costs. Of particular interest is how these different options would affect the wider economy, and the implications for GDP growth.

Table 12. Selected low carbon options for Tanzania

Sector	Option	Policy driver	Policy Co-benefits	Climate resilience	Implementation concerns
Electricity generation	Renewables: * Wind farms (grid) * Large hydro plant (grid) * Small scale hydro (mini-grid) * Solar PV (grid) * Solar thermal (grid) * Household solar (off-grid)	Expansion of electricity generation system, increasing consumer access	* Carbon finance opportunities * Lower reliance on (and payments for) imported fossil fuels, increasing energy security * Reduced air pollution * Increased diversification away from hydro	* Potential competing uses of water (hydro) * Reduction in water resources	Additional costs of renewable generation (excl. hydro) Ensuring technology quality for decentralised RE e.g. SHS
Household energy	Introducing improved stoves	Reduce primary biomass / charcoal demand	* Reduce indoor air pollution, & health impacts * Reduce fuel costs * Reducing pressure on forest stocks / safeguarding biodiversity * Save economic / leisure time (wood collect.)	Reduced pressure on forests enhances resilience to climate change and provides greater buffer zones and connectivity.	* Access to stove technology * Ensuring stove quality to deliver savings
	Improving efficiency of charcoal production	Reduce primary biomass demand	* Reduce fuel costs for producers * Reducing pressure on forest stocks / safeguarding biodiversity	As above	Establishing market for more expensive charcoal
	Promotion of alternative fuels to charcoal (urban areas)	Reduce charcoal demand and increase use of modern fuels	* Reducing pressure on forest stocks / safeguarding biodiversity * Increase access to cleaner fuels * Reduction in urban air pollution	As above	Upfront costs of appliances and / or fuel
Industry	Tackling energy inefficiency in SMEs	Reducing industry fuel costs, increasing competitiveness	* Reduce fuel costs, enhance competitiveness * Enhance energy security * Reduce air pollution		Upfront costs with limited awareness of potential savings
Transport	Improving efficiency of road transport fleet (conventional technologies)	Reducing reliance on fossil fuel imports	* Reduce reliance on / payments for foreign fossil imports * Reduce costs of vehicle use * Reduce air pollution * Reduce road accidents (due to newer cars)		Additional upfront cost of more efficient vehicles
	Increased uptake of advanced technologies	Reducing reliance on fossil fuel imports	* Reduce reliance on / payments for foreign fossil imports * Reduce air pollution		* Additional upfront cost of more efficient vehicles * Avail. of technical services for advanced vehicles
	Alternative transport fuels	Reducing reliance on fossil fuel imports	* Reduce reliance on / payments for foreign fossil imports * Increasing energy security		Competition with other land uses
	Public transport systems	Meeting urban transport demand	* Reduce congestion * Reduce air and noise pollution levels * Save travel time / enhance productivity * Reduce road traffic accidents		* Large upfront investment costs * Incentivising shift away from private vehicles
Agriculture	Improve livestock and cropland management	Improveproductivity & reduce land degradation	* Protect / enhance arable land quality * Safeguard rural livelihoods * Increase economic productivity of sector	Significant synergies with adaptation, establishing more resilient systems	Cultural issues concerned with changing farming practices
Forestry	REDD+ / Afforestation	Protect forestry-dependent economy and energy supply security	Protect biodiversity, and dependent sectors Ensure security of wood fuel supply	Reduced pressure on forests enhances resilience to CC and provides greater buffer zones & connectivity.	* Tenure issues * Enforcement * Permanence of savings * High transaction costs

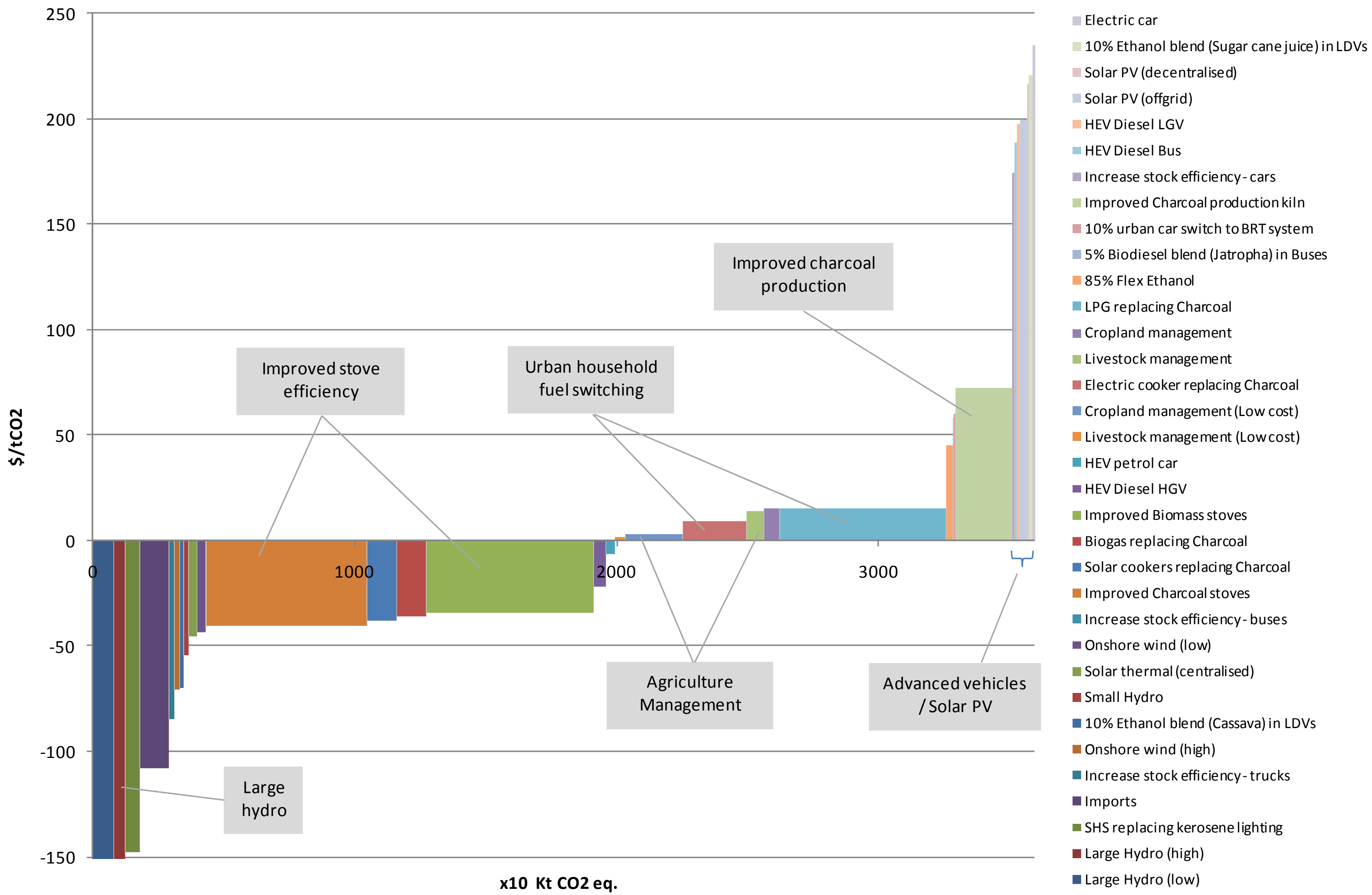


Figure 22. Illustrative marginal abatement cost curve for Tanzania in 2030

As described in this section of the report, Tanzania has already introduced low carbon growth in specific areas, particularly in electricity generation using renewable technologies. However, as illustrated, there is considerable scope to go further, as illustrated by Figure 22. In summary, the key opportunities emerging from this analysis include:

- Improved production and use of biomass energy to safeguard forest resources. Linked to REDD+ funding, the economy wide benefits of such a move could be significant. It would also have strong co-benefits such as reducing health impacts to households, saving fuel costs, developing the local manufacturing economy and safeguarding biodiversity and associated forest industries.

- Switching to modern fuels in the household sector. Due to forecast demand growth, switching to modern fuels such as LPG is an important part of the solution for safeguarding forests, and reducing emissions. Co-benefits include cleaner, modern energy for cooking particularly for a growing urban population.

- Forestry management and protection. An integrated approach to forestry management and protection, including the agriculture and energy sectors, could reduce emissions significantly. Tanzania is in a good position to benefit from the emerging REDD scheme as one of the leading countries in taking this initiative forward.

- Biofuels. As an alternative to transport fuels, biofuels have the potential to reduce reliance on expensive imported fuels, develop new export markets and stimulate the rural economy. However, how the industry is structured to realise benefits to rural communities is critical, as would its perceived sustainability and necessary positive co-existence with food agriculture production.

- Energy efficiency. There is significant potential across all sectors to realise energy efficiency improvements, often resulting in significantly reduced fuel costs. This is particularly true in the transport sector and probably in the industry sector (although this has not been fully assessed for this sector).

- Renewable generation (including SHS). Tanzania has long invested in renewable generation through the development of hydro generation. There is now the potential to assess opportunities for other renewable including wind, solar and geothermal. However, investors will need to be incentivised through the tariff structure and be able to effectively use the carbon financing mechanisms. Promotion of solar home systems is already being developed; mitigating the problems of affordability will be key to seeing this technology disseminated widely in rural areas.

- Agricultural measures. These are important where they also enhance productivity, and provide the potential for financing. Ensuring food security is paramount now and in future years.

- Sustainable urban planning. Promoting a low carbon climate resilience agenda in urban planning could enhance future sustainability of urban areas, by ensuring integration of different departments (transport, buildings, utilities etc), recognising future pressures, developing public transport systems, and designing communities with climate impacts in mind.

A significant challenge associated with many of the measures is their effective implementation through well designed policies and incentives. Many of the measures have key implementation challenges and considerable barriers (adding to costs). Effective and robust policies will be critical to realising these measures. A key concern, particularly for low income groups, is affordability. Even if technologies are cost-negative over their lifetime (i.e. payback their investment), it is often the upfront costs that will restrict access to lower income groups. It is not only affordability but the possibility to benefit from economic opportunities e.g. improved stove programmes, biofuel sector development etc. that need to be safeguarded. Policies should not be regressive but promote benefits to lower income groups.

To justify the introduction of these options and realise the many co-benefits, access to carbon financing will be key. If this cannot be accessed or the barriers are too significant, then stakeholders will disregard such investment due to lack of opportunity or incentive. The following chapter reviews this critical issue of financing opportunities.

4) Financing Challenges

There are significant opportunities for pursuing low carbon investments in Tanzania. However, as described in the previous chapter, each sector faces a number of implementation barriers that may restrict the level of investment in low carbon options, the resulting potential to access carbon finance and the benefits for more sustainable growth. These implementation barriers typically include:

- Economic / market barriers (e.g. lack of access to capital, affordability for low income groups, poor commercial case)
- Low levels of information / awareness
- Inadequate policy / regulatory framework
- Technical problems of use in-country
- Lack of skills / know-how
- Limited institutional capacity

These barriers can result in the actual costs of implementation being significantly higher than the technical costs identified in the previous chapter. Analysis undertaken by Project Catalyst indicates that these transaction and policy costs, associated with implementation, can be as high as $5/t$CO_2$e (McKinsey 2009a). In practice, such barriers can be sufficiently challenging to prevent the realisation of policy aspirations.

This chapter assesses the potential barriers to financing low carbon investments in Tanzania. It begins with a review of the investment environment, assesses some of the relevant governance issues, and reviews potential public and private routes to finance.

General investment environment

Despite Tanzania's political stability, the investment climate has not led to high levels of foreign investment. The Government of Tanzania (GoT) has undertaken a number of steps to improve the business climate (many with DfID support). These have included redrawing tax codes, liberalising the financial sector, and cutting red tape. However, the World Bank 'Review of Doing Business' Report continues to identify Tanzania as a relatively complicated country in which to do business, and ranks it below most of the neighbouring countries of the region. This has implications for private sector involvement in clean technology markets, and the challenges faced by potential entrepreneurs looking to drive growth. Of particular concern are issues relating to permitting and property rights, which are usually vital to low carbon infrastructure activities. Figure 23 sets out Tanzania's overall ranking at 131 of 183 countries, based on the 10 key indicators used.

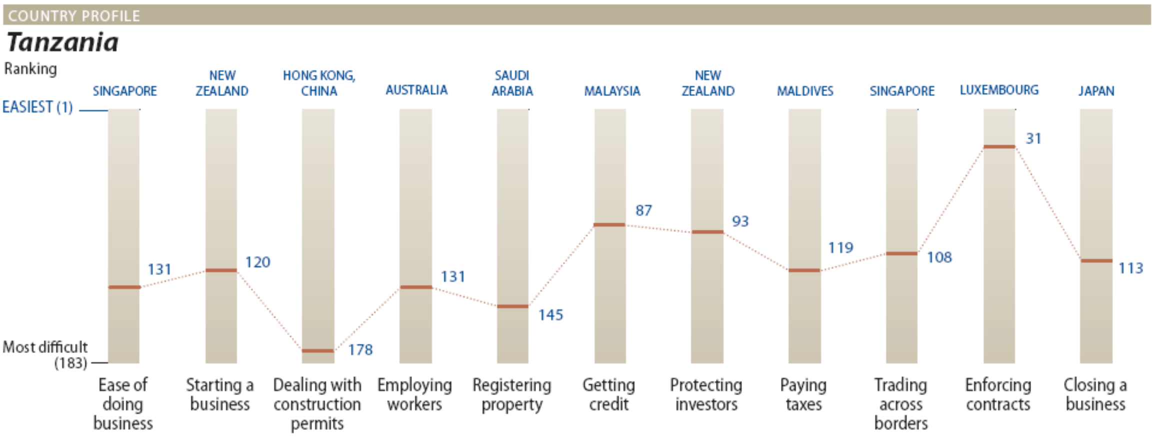


Figure 23. Tanzania Ranking in Doing Business Report (2009), The World Bank

Climate change regulation and governance

The increased uptake of low carbon investment in Tanzania – as in other country - requires an effective institutional and regulatory framework. The success of delivering low carbon projects and programmes and achieving the associated economic benefits is therefore largely dependent on effective governance and the role of policy makers.

The review here has identified some potential lessons that explain the relatively low level of climate finance - though many of which are common issues for Africa and explain the relatively low level of climate finance compared to other world regions:

- Fragmented low carbon plans, and low levels of integration between sectors (renewable energy, end use energy efficiency, transport, forestry and agriculture);
- Multiple ministries and agencies dealing with low carbon policy development and enforcement, and low levels of coordination among them;
- The slow pace of policy implementation in relation to carbon finance under the UNFCCC and Kyoto Protocol, resulting in limited investment/financial flows and no effective carbon price support for renewable energy or end use energy efficiency;
- The social complexities of introducing mitigation measures in agriculture and forestry, which remain the key emitting sectors in Tanzania (and most of Africa);
- A prevailing view of climate change mitigation and adaptation as donor-driven and government-owned, rather than as opportunities for private sector and NGO innovation.

DfID has recently completed a separate parallel review into the governance and political economy of climate change in Tanzania (Thornton et al, 2010). Its assessment of the issues is broadly in line with the above conclusions. However, rather than identifying reform of the central institutions and mechanisms as the main response, the report leans towards a more diversified set of approaches, rather than the institutional and technocratic agenda. The report suggests that the promotion of climate change as a overarching issue have been hampered as it is seen locally through a number of sub-sectoral lenses (water, food, natural disaster), rather than as an integrated issue in its own right. The report places a clear focus on the need to overcome the contradictory layers of accountability, *clientelism* and patronage that define the Tanzanian political system, and in particular the 'gate-keeping' of power and resources. It proposes this can be changed by channelling donor support towards the more informal elements of the political economy, changing attitudes and behaviours, widening the focus of stakeholder engagement away from national government towards NGOs, media, the private sector and district level authorities. Finally, the report advocates support for linkages and accountability rather than direct capacity building for central institutions.

However, while this provides an interesting alternative approach, given the structures of international climate finance and the need to mobilise resources at scale, a core approach of institutional reform and political capacity building must form the basis of any low carbon investment agenda moving forward. Moreover, the structures for climate mitigation and adaptation finance in the region will continue to be structured for delivery primarily through national governments by IFIs, who remain best placed to address issues that relate to public goods and poverty related agendas. Indeed, there is evidence that the various Ministries within Tanzania are already addresses climate change through the revision of existing policies and regulations, and better definition of the role of government and other stakeholders.

Despite certain regulatory and market difficulties, the private sector is also relatively active in low carbon projects, particularly in the provision of bio-energy (biogas, biodiesel), solar energy, wind, and water use. Zara Solar has developed into a large regional distributor of PV systems. Mafuta Sasa Biodiesel Ltd in Keko Mwanga, Dar es Salaam is commercially refining discarded cooking oil into biodiesel. Nonetheless, many of the large scale projects relating to other technologies have been slow to develop and receive finance. The Tanzania Private Sector Organisation (TPSF) and the Tanzanian Chamber of Commerce Industry and Agriculture (TCCIA) are mainstreaming climate innovation and entrepreneurship into their institutional programmes, including supporting proposals, and providing training. Further details are provided in the sector analysis and in Annex 3.

In terms of NGOs and the voluntary sector, organisations such as SURUDE, TaTEDO, TASEA, ZASEA and ZALWEDA are actively engaged in programmes promoting climate change projects and entrepreneurship. Programmes include biogas plant installation, economy stoves manufacture and utilization, solar energy installation, and agricultural programmes. International donors including SIDA, DANIDA, and GTZ are supporting biogas utilisation and associated training programmes.

R&D Institutions have also become active in the sector. Examples include the University of Dar Es Salaam College of Engineering and Technology (ISCP/PACF), Institute of Resource Assessment (REDD Programme), Tanzania Industrial Research Organisation – TIRDO (design and prototype manufacture of solar dryers for fruits and fish), Centre for Agricultural Mechanisation and Rural Technology – CARMATEC (design, development and installation of biogas plans, solar cookers and solar heating systems.

There is therefore growing momentum to address sustainability in development within the NGO, educational and private sectors. These activities, which are further elaborated in Appendix 4, provide a solid base from which to further extend the uptake of low carbon technologies at national level. However, they remain relatively fragmented and small scale. Achieving the mitigation potential identified in Chapter 3 will require concerted regulatory and policy support, and in particular a more streamlined access to finance private and public sector finance as described in the following sections,

Financing low carbon projects

The United Nations Framework Convention on Climate Change (UNFCCC) Report on Investment in Renewable Energy and Energy Efficiency states that the private sector is and is likely to remain the main source of financing for renewable energy and energy efficiency across the developing economies. Many low carbon technologies remain of higher cost than their carbon intensive alternatives. Even where payback periods are short, and the costs of abatement are negative due to increased efficiency and lower input costs, such technologies may require high upfront capital investment. These incremental costs and capital requirements are unlikely to be fully met from government funds in a resource constrained economy such as Tanzania, where there are competing high-priority social and economic programmes. The international carbon markets and targeted use of donor funds to leverage the private sector are likely to play a large role in bringing capital into the sector.

As a result, low carbon markets have tended to grow most rapidly in those countries with developed financial markets and active private investors. The relative lack of progress in Tanzania reflects the significant role played by the state and the difficulties in securing private capital to invest under current regulatory structures. The extent to which private funding might operate in low carbon technology sectors is not yet defined in regulation or in practice in Tanzania. This in part reflects the relatively limited extent of sector development and small numbers of projects with private sector capital.

Accessing Private Sector Finance

Tanzania has a significant number of commercial banks (approximately 25), three financial institutions, and a number of local Microfinance Institutions (MFIs), savings and credit organizations. The participation of local financial entities in the promotion and support of low carbon activities, however, has been limited. Likewise, international financial participation has been restricted to date.

Lack of familiarity with low carbon technologies and investments, unfavourable project economics and high levels of perceived risk are cited as the key barriers to private sector lending. Commercial investors base their investment decisions on the risk/return profile of potential projects. In particular, the higher costs and limited track record of many low carbon technologies, combined with regulatory systems that support higher carbon alternatives, can make private sector investment unattractive. Smaller scale projects face additional barriers deriving from the transaction and due diligence costs being relatively large in relation to the overall project size.

Local financial institutions can play a crucial role in low carbon development, particularly in relation to project finance for renewables and clean technologies. The can also help facilitate market entry for international partners. They can support local currency based lending, and act as a conduit for international banks by acting as senior borrower, taking local project risk and undertaking due diligence. However, there can be a number of issues. Many local financial institutions are not familiar with emerging low carbon technologies. In Africa such institutions generally do not have access to large dollar reserves, resulting in local currency risk and exposure to base interest rates. This can result in very expensive long term financing in local currency terms, which is highly exposed to the effect of government demand for foreign currency on short term 90 day interest rates.

Additionally, local institutions are often reluctant to provide long tenor financing required for infrastructure projects, with a minimum 15 year tenor required for most renewable and conventional power projects. This creates an obvious mismatch with the short term deposit profile of most institutions. Even though Tanzania has an active bond market, currently liquidity does not extend beyond 5 years. As a result, elements of public finance and donor support will be important in scale up to deliver those opportunities with longer pay back and higher capital intensity.

Public policy frameworks play a key role in enabling confidence among private sector investors. Public risk mitigation tools, such as Power Purchase Agreements, are central to enabling private sector participation. Private sector investors and lenders look to a broad range of enabling environment indicators, including clear policy objectives, transparent planning and permitting processes, regulations for grid and market access, enforcement, and policy time horizons that match investment financing and depreciation needs.

Public Sector Finance

In the absence of commercial private sector finance, national financing structures, such as national development banks, or targeted development funds such as the Renewable Energy Fund (REF) in Tanzania, can provide enabling finance to bridge potential shortfalls of mitigate risk. The REF has been the most active targeted form of support in Tanzania within the low carbon sector, funded by government budget, donor contributions and levies on conventional power generation. However, the relatively small size of such funds and the narrow sphere of their application (rural energy access) can limit their potential for leveraging private sector investment. There is a clear need to engage with private sector to build a broader clean-tech venture fund capacity that can partner with national development finance mechanisms.

From an international perspective, even with strong domestic policies and the prevailing capital flows to emerging markets, risk perception among many potential inward investors may still be too great. In this regard, there is a clear role for the International Finance Institutions (IFIs), and Credit Guarantee Agencies (CGAs) to play a role in supporting scale up and mitigating risk. This can be done through the provision of soft loans, or the use of targeted risk mitigation products (credit guarantees, political risk guarantees). The role of these institutions has grown recently, partly as a response to constraints in the international capital markets and partly in recognition of their increased role in scale up of low carbon economies. However, the scale of support offered does not currently reflect the scale of financing required under climate mitigation scenarios.

Public funds may target the bundling of smaller scale projects where there are issues of access to finance and economies of scale, developer support, and the commercial scale up of key technologies and delivery infrastructure. Greater integration between national policy development and availability of well-designed public risk reduction tools for commercial investment (e.g. around PPA payment security) is required. Board level mandates are likely to be required for public institutions in order to provide longer-term, more strategic provision to this sector. In particular, the IFIs can help support the commercialisation and transfer of low carbon technologies to developing country contexts, drive down the costs of technology deployment and ensure development of infrastructure that does not result in high carbon lock-in.

In Tanzania, as with many other countries in Sub-Saharan Africa, simply finding bankable projects can be a challenge in itself. Given the absence of commercial banks ready to invest, the role of public finance is necessarily more prominent that one might expect in other regions. In this area, the Private Infrastructure Development Group, a coalition of donors is seeking to mobilise private sector investment through the provision of long term finance (both hard and local currency), project preparation capacity (understanding and allocating risk), project development (engineering, contracting, financing), and revenue certainty and payment security (creating reliable PPAs and using commercially attractive tariffs).

Public Private Partnerships (PPP)

Given the institutional scale of low carbon development needs, particularly in the delivery of large scale low carbon infrastructure, there is an argument for the more systematic deployment of project finance mechanisms and public-private partnership (PPP) models. This allows a higher degree of certainty for private sector investors. This would take the form of standardised PPP manual, regulatory framework and operating provisions.

There are many types of PPP regulation/models, but the most effective are Standard Concession Agreements (allocating responsibility and risk between the government and private parties), Operating Leases, Management and Service Contracts.

While there is scope for selection of the most suitable model, any PPP structure should focus on the fair allocation of risk. PPP structures should be designed to allow competition between different private sector investors for particular concessions. Government support is required on issues such as resettlement, community disruption and land issues, for both small and larger investors.

Given the absence of venture capital finance and other forms of equity, debt finance is important for PPP development, and banks are keen to see government assume risk in relation to off-grid solutions.

Clean Development Mechanism (CDM)

Tanzania is classified as a non-Annex I country under the Kyoto Protocol without emission reduction obligations. As such, it is able to access carbon finance for low carbon development through the Clean Development Mechanism. Carbon finance (CDM and other voluntary initiatives) was designed to provide additional financial incentives for the development of project with associated emission reductions, particularly renewable energy initiatives. Tanzania has very good potential for development of CDM and related mechanisms, particularly in relation to renewable energy and rural electrification.

The Designated National Authority is the Vice President's Office, Division of Environment. Tanzania has issued a CDM guide for investors, setting out a list of approved interim CDM projects. Such projects must meet sustainability objectives including environmental and social, poverty alleviation criteria, and be based on in-country partnerships. To date, energy projects in rural areas have been accorded highest priority.

At the current time, there have been a number of CDM projects submitted to the Tanzanian DNA at various stages of preparation. Tanzania was among the first African countries to register a CDM project. Projects under development have included landfill gas, wind, methane capture, bagasse cogeneration, natural gas fuel switch, and forestry. A number of other potential areas have been identified by the DNA, including coal mine methane, process industry fuel switching, and renewable biomass.

However, despite an early start, progress has been relatively slow, with only one project - a relatively small landfill methane flaring project – having been registered with a value of 202,000 CERs. There have been no CDM projects in the power generation sector, and no CERs have actually been issued as yet. A number of issues have been identified:

1. The CDM process is long and requires a high level of expertise, particularly in relation to the preparation of Project Design Documents (PDDs), where a thorough understanding of the different approved methodologies is required before applying them to a specific project. Some donors, such as Sweden are providing technical assistance to project developers in Tanzania in this respect. In addition, Tanzania has not yet submitted its national grid emission factors to the UNFCCC, creating the need for project developer to calculate and monitor emission factors throughout the course of a project as the national energy mix develops.

2. The transaction costs associated with CDM are relatively high in relation to the size and nature of potential projects in Tanzania. Hiring external consulting support can be expensive (up to 100,000 Euro), particularly for local project developers and smaller projects. Potential projects in Tanzania are generally too small (typically 4MW hydro, 1MW biomass) to cover the high cost of developing carbon finance and bundling projects is problematic under current CDM processes, although this may be reformed in the emerging post-Copenhagen framework. Monitoring and verification can add significant additional costs over time.

3. The length of time from project development to approval has been very long, creating high levels of risk perception among potential investors. The process of project approval by the DNA, and receiving a letter of no objection (LoNO) is regarded as slow compared to other countries. There have been major capacity building and technical assistance programs (Swedish Sida, World Bank, DfID, Austria, Netherlands, etc.), the results of which remain inconclusive.

4. The price of CERs generated under the CDM has been volatile, reflecting both fluctuations in buyer demand (driven by projected shortfalls and surpluses in schemes such as the EU ETS) and the perceived approval and implementation risk of individual projects. The final price ultimately reflects the outcome of a negotiation between project developer and carbon credit purchaser. Projects that have not yet achieved DNA approval (as is the case with the majority of Tanzanian projects), are unable to sell their CERs at a potentially higher rate. The DNA has identified the issues of securing buyers who are willing to provide up-front payments without project registration and consider security based on an African insurance firm/ bank, as key barriers.

5. Eligibility criteria for CDM financing sets limits on profitability not exceeding 15%. This may limit the development of new projects in Tanzania where market and regulatory risk, combined with high costs of finance, may mean that investors require a higher rate of return. Tariff structures also mitigate against CDM projects for Renewable Energy. The existing tariff levels for small power projects in Tanzania (up to 10MWe) remain below cost price for many emerging technologies. The tariffs are paid in Tanzanian Shillings, while project finance may be mostly in foreign currency, creating an additional financing risk with potential hedging costs. As a result of the above, CDM funds may be needed simply to make some projects financially viable, rather than creating projects that are particularly attractive to investors.

6. The availability of DOEs (Operational Entities) in Tanzania for project validation is relatively limited. They are only allowed to validate certain sectors and therefore finding a DOE for a specific sector in terms of timing and availability is difficult, often with a 6 month lead time. The cost is prohibitive for most Tanzanian companies, and therefore buyers or financiers may pay this additional cost in exchange for the CERs.

Box 15. Enabling activities to deliver low carbon finance measures

- Implement Public Private Partnership (PPP) legislation to formalise private sector finance participation and reduce risk;
- Building public and private sector awareness of opportunities within the CDM market;
- Institutional review of the current DNA process to identify barriers to project approval;
- Encourage DOE verification and monitoring capacity in Tanzania/East Africa that can be shared between project developers in a timely manner;
- Explore options for accessing the voluntary market under current economic conditions;
- Map barriers to debt finance for EE and RE, and propose innovative risk sharing structures (first loss guarantees, partial risk guarantees) to encourage additional bank risk exposure;
- Review opportunities for equity finance and venture capital investment

Voluntary Carbon Markets

Voluntary Carbon Markets offer the potential for additional finance routes to support low carbon growth. A relatively vibrant global market had developed by 2008, particularly in response to the expectation of carbon regulation in the United States and Australia, and an increase in corporate social responsibility. This has been supported by the adoption of registry standards that allow greater transparency with regards to the quality of the offsets involved, such as the Voluntary Carbon Standard (VCS), Climate Action Reserve (CAR), CCX and Gold Standard. However, the voluntary carbon markets have remained small (1%) in relation to the size of the regulated markets. REDD remains in the voluntary sector until it is formally adopted as a mechanism under the UNFCCC.

According to a recent report by Bloomberg Finance and Ecosystem Marketplace (Hamilton et al. 2010), the Voluntary markets proved very susceptible to economic recession with reduced spending on offsets in recent months. In 2009, there was a 26% decline against 2008 in the overall value of the global voluntary offset markets (to 93.7 $MtCO_2e$), also driven in part by uncertainty about domestic emissions regulation following the failure to agree a binding deal in Copenhagen. While methane capture projects represent the bulk of the voluntary markets (41%), forestation (24%) and renewables (17%) represent significant opportunities, both of which are relevant for Tanzania. Popular forestry projects included afforestation/reforestation (10%), reduced emissions from deforestation and degradation (7%) and improved forest management (3%). The increasing consensus around forest carbon protocols and growing recognition of avoided deforestation as a developing country financing mechanisms has supported the increase in forest related credits.

The report indicates that the five most cost-effective project types (based on their average credit price per tCO_2e were mostly renewable energy activities: solar ($33.8/ tCO_2e), biomass ($12.3/ tCO_2e), methane—other ($9.6/ tCO_2e), energy efficiency ($9.2/ tCO_2e) and wind ($8.7/ tCO_2e). These project types traditionally earn above average prices because of their high costs of production and particular appeal to voluntary market buyers. Credits originated in Africa tend to have a relatively high value, in relation to those sourced in Asia, the United States or Latin America. This was due to the increase in offsets certified to the Gold Standard and boutique forestry standards such as Plan Vivo and the Climate Community and Biodiversity Standard (CCB). Overall, the value of voluntary credits was between 50-75% lower in the voluntary market, than found under CDM or JI in the regulated market.

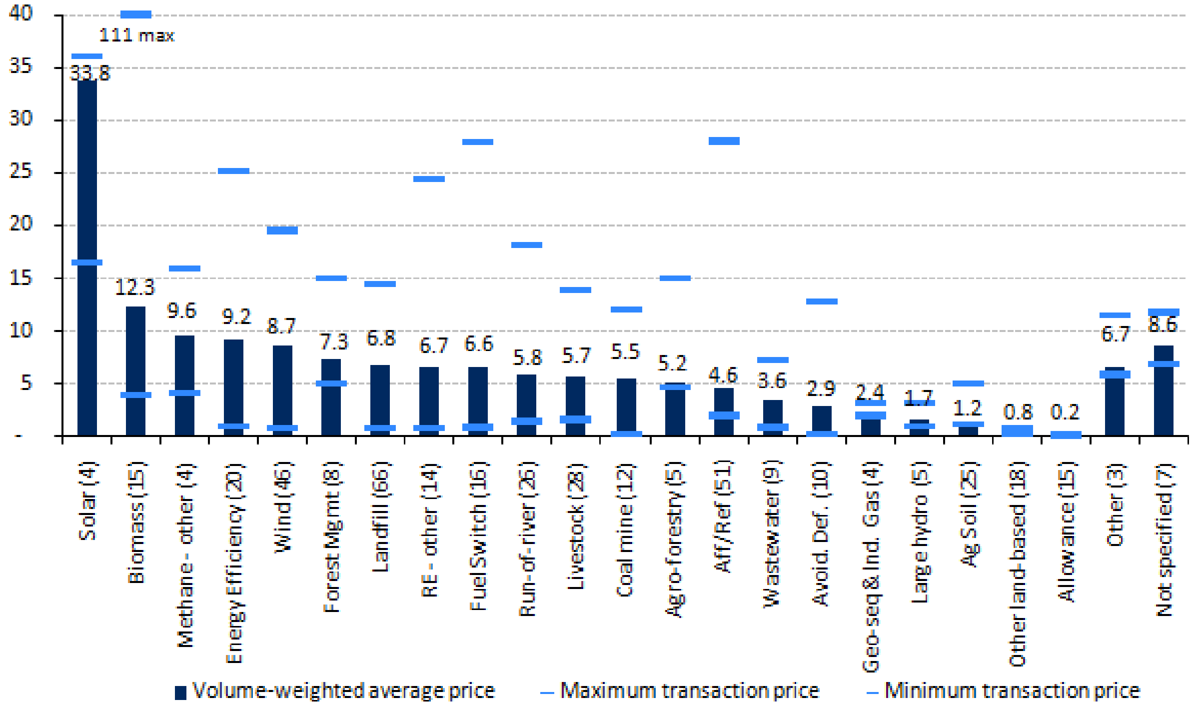


Figure 24. Average credit price for Voluntary Carbon Markets 2009 by project type.

Africa has been slow to take advantage of the voluntary market to date. In 2009, only 2% of all transaction volumes were originated in Africa for OTC offset transactions. This, however, represented a gain in both volume and market share, as voluntary buyers sought sustainable development benefits, alongside NGO and international agency investments. This growth coincided with increased volumes from African CDM projects which doubled their market share to 7%. In 2009, 90% of African VERs were sourced from forest carbon projects ranging from micro (< 5,000tCO2e/year) to very large (>500,000tCO2e/year) projects. REDD was the dominant project type, although other A/R and Forestry management projects were represented. Most demand for African VERs originates in Europe, although it is expected that there will be growing demand for domestic offsets on the continent. The regions governments are beginning to foster the conditions for carbon project investment and to country the sovereign risk associated with African projects.

There are plans for a regional registry – the Africa Carbon Credit Exchange (ACCE). The ACCE has received funding from USAID and the Government of Norway that will facilitate the transfer of both CERs and voluntary credits launched in 2010. ACCE was launched is focused on creation of a trading platform for African-generated CERs and voluntary market credits. Currently the Exchange is working with brokers in Uganda, Rwanda, Kenya, Togo, Senegal and Zambia to establish a pan-African network that will develop a steady supply of credits for the trading platform. To further support offset development, ACCE is creating the Green Knowledge Institute for building of technical and financial expertise, as well as a "Low Carbon Africa Fund" that will provide financing and technical expertise to jump-start low-carbon projects with offset potential. The current pipeline includes mini-hydroelectric, power, bio-fuels, agro forestry, biomass energy generation and industrial emissions reduction projects awaiting implementation.

Within the region, Tanzania has been relatively slow to mobilise the use of voluntary markets, however this is changing, with a number of voluntary market projects emerging in the Forestry and Land Use Sectors. This is due to increased investor expectations that credits will be accepted under the UNFCCC in future. Examples include:

- In September 2010, Tanzania was the country to see carbon credits from a land-use project verified and issued under the Voluntary Carbon Standard (VCS). The Uchindile-Mapanda project takes degraded grassland and converts it into sustainably harvested forests that sequester carbon emissions from the atmosphere and generate carbon credits. Some 40% of the credits have been set aside – a world first – to mitigate against the risk of "non-permanence", such as the forest burning down. The project will also ensure that 10% of the carbon credit revenue is invested in the community, including the building of school classrooms, teachers' houses, dispensaries and roads. The project was developed by Norwegian company Green Resources.

- Carbon Tanzania is currently partnering with the Mpingo Conservation Development Initiative (MCDI), one of Tanzania's leading community-based forestry NGO's, on a pilot initiative in Kilwa District, where MCDI has been based since its establishment in 2004. The project will aim to extend MCDI's work, which facilitates villages to establish sustainable forest management plans based around harvesting high-value hardwoods such as Mpingo (*Dalbergia melanoxylon*), in extensive Village Land Forest Reserves. All of these offsets will be certified and validated through the Climate, Community and Biodiversity Alliance standards and the Voluntary Carbon Standards, and will thus be premium offsets in terms of their social and environmental co-benefits.

In the medium term, it is likely that much of the proposed voluntary activity associated with forestry will come within the regulated market either through increased use of the CDM (or successor) for Afforestation and Reforestation (A/R), or from approval of the REDD+ mechanisms within the UNFCCC process. Indeed the World Bank has just completed its first purchase of temporary AR CERs in Africa (Ethiopia) in October 2010 at an estimated price of \$4/ tCO_2. While the voluntary markets have served a useful purpose in developing some of the standards associated with forestry credits, there remain concerns over monitoring and verification. To date, the price of voluntary credits has been relatively low and the volumes small in comparison with the regulated market. It would be therefore in the interests of the GoT to promote use of the regulated markets across a range of sectors, rather than to build policy around expansion of voluntary markets. This will allow it to access the major markets (such as the EU ETS), and avoid the exposure to economic growth than can affect the buyer demand in voluntary markets much more severely than that within regulated markets.

5) Linking low carbon – climate resilient growth

As well as promoting more sustainable growth through low carbon investment, there is an emerging issue of how to achieve climate resilient growth, such that patterns of development help build the Tanzanian economy's resilience to a future changing climate. This is the subject of the impacts and adaptation report as part of the wider study.

However, in the context of this document, a key emerging question is whether low carbon investments are aligned with the need for increased climate resilience i.e. whether they will involve doing similar things or can easily be linked together, or whether they may involve conflicts or trade-offs.

In the shorter-term, there are a number of immediate issues on the links between low carbon investments and adaptation policy (see box below).

Inter-relationships between adaptation and mitigation

Chapter 18 of IPCC WGII (Klein et al, 2007) addresses the inter-relationships between adaptation and mitigation and identifies four relevant areas:

- Adaptation actions that have consequences for low carbon growth,
- Low carbon actions that have consequences for adaptation,
- Decisions that include trade-offs or synergies between adaptation and low carbon development,
- Processes that have consequences for both adaptation and low carbon development.

For this analysis here, a number of specific issues are relevant:

i. How future climate change may affect future socio-economic change and particularly how it may affect future energy demand.

ii. Whether the effectiveness of low carbon options will be affected by climate change, from future long-term trends and also changes in extreme events (shocks). i.e. in relation to changes in efficiency, robustness of options, as well in terms of the vulnerability of options (i.e. climate resilience).

Both of these potentially affect the marginal abatement costs, There is therefore a need to try and build these factors into the analysis, something that has not been done to date even within developed country assessments.

Finally, there is another issue:

iii. How planned adaptation measures or policies taken to respond to climate change might affect greenhouse gas emissions, especially in cases where adaptation options increase emissions.

Projections of Future Climate Change in Tanzania

Tanzania has a complex existing climate, with wide variations across the country and very strong seasonality. It is also affected by strong patterns of climate variability and extremes, not least due to the periodic effects from ENSO: El Niño and La Niña, which are associated with extreme rainfall and flooding and droughts (respectively).

The study has considered statistically downscaled climate projections of future climate change from a suite of models for Tanzania. Full details are provided in the impacts report and the separate climate projections report. The findings are:

- *Temperature*. The projections indicate future increases from climate change of around 2 ºC (with a range from 1 ºC to 3ºC) above the baseline period from the range of models by the 2050s (2046 -2065) with greater warming in the north, and in particular the northeast. By the end of the century – under an unmitigated high emission scenario – the increase expected is in the range of around 4°C (with a range from around 3°C to 5°C compared to the baseline period).

- *Rainfall*. The changes in precipitation are more uncertain. All the climate models show that rainfall regimes will change but these vary with season and region, and there is disagreement amongst the model whether there will be increases or a decreases in precipitation over most of Tanzania (but particularly in the south). For the north of the country around three-quarters of the models project an increase in precipitation, though this still means significant uncertainty.

- *Extreme events*. The information on extreme events (floods and droughts) is much more variable and future projections vary widely. Many models indicate an intensification of heavy rainfall, particularly in some regions and thus greater flood risks. Droughts are likely to continue, and some models project an intensification of these events, particularly in some regions, though other models indicate reductions in severity.

The study has examined the potential effects of these changes in the context of the low carbon work.

Effects of climate change on energy demand

Cooling demand and its impact on energy services

Climate change affects energy demand, as outside temperature drives heating and cooling requirements. Energy demand increases with colder temperatures (heating in homes, offices and factories) and with higher temperatures (cooling), though these are conditional on technology penetration rates.

The first finding is that the rise in temperatures from climate change will have some benefits in Tanzania, in reducing heating demand in colder seasons, which will reduce heating needs. However, it will also increase the demand for cooling in hotter months and regions (an impact, itself an adaptation), though the scale of these effects is strongly determined by the climatic zone and socio-economic conditions. On top of the pattern of average warmer temperatures, climate models also project increases in the number of heat extremes (heat-waves), which can drive peak demand for cooling.

Space cooling is already the major source of energy demand in tropical and subtropical cities, even for middle income countries. Mechanical cooling (air conditioning) is strongly linked to wealth, showing rises with income levels. This becomes important in relation to the Vision baseline and growth rates, and in terms of some of the key economic sectors of future growth, e.g. tourism. The likely effect is an increase in electricity use, with associated costs. The use of conventional electric powered air conditioning to meet this cooling demand involves a trade off between climate resilience and low carbon growth, as the autonomous adaptation response (cooling) increases energy use and greenhouse gas and air pollution emissions (a form of mal-adaptation).

The study has investigated the potential scale of cooling demand changes for Tanzania. In terms of analysis, studies of climate change use the metric of cooling degree days, see the Box below.

Box 16. Cooling degree days

Cooling degree days (CDD) can be estimated by climate models. They represent the exposure (burden) of future temperature on cooling demand. They are an annual measure of the frequency and extent to which days have a mean temperature above a threshold (ºC), and thus will require some form of air conditioning to be used (noting that the use of AC is conditional on having the technology installed, and being able to afford to run it, thus there are very large differences between the potential effect, as measured in cooling degree days, and the actual impacts, measured in additional kWh of energy use. Note however that if future cooling demand is unmet, then it leads to alternative economic costs in the form of comfort levels, productivity, risks of health impacts, etc).

To derive CDD, the number of degrees Celsius that the mean temperature is above a given threshold (ºC) is calculated for every day of the year (ignoring negative numbers, that is, when the mean temperature is below the threshold) and this is summed for all days of the year, thus Σ(daily mean temperature – threshold) for Tmean > threshold.

The threshold temperature used varies between studies, which has a large effect on the cooling demand. In many global studies, a daily mean temperature of 18 °C is used. However, studies in the US have worked with 21 °C based on observational information, and UK analysis often uses a threshold of 22 °C.

Due to data limitations on the CCE data, the analysis here has not been able to derive the necessary data to allow derivation of absolute CDD, but to indicate the scale of change, the data for the maximum temperature has been used with a threshold level of 22 °C to provide an indication of the relative level of change.

There are a number of issues here which are of importance and relevant for this analysis:

- Future cooling demand will alter the demand balance, and increase the capacity needed in future years, for energy (across the year) but also for peak demand (to address extreme temperatures).
- It will also lead to an increase in greenhouse gas emissions above the baseline projections, the degree of increase depending on the future generation mix for electricity and the increase in air conditioning versus alternative options for cooling.
- Future increases in energy demand will lead to higher economic costs from increases in demand (an impact of climate change). Previous studies have shown that the economic costs of additional energy demand are amongst the largest effects of climate change in net economic terms.

There is some analysis of the potential effects on cooling demand in neighbouring East African countries under the SEI East Africa analysis of the economics of climate change (Watkiss et al. 2009). Under model-simulated baseline conditions, the rise in cooling degree days in Mombasa was projected to rise to by an average if 300% in terms of the cooling burden (cooling degree days). Note that this is a rise in the 'burden' or 'exposure' – it will only be accompanied by a rise in electricity demand if there are the air conditioning units and installed capacity, as well as income levels.

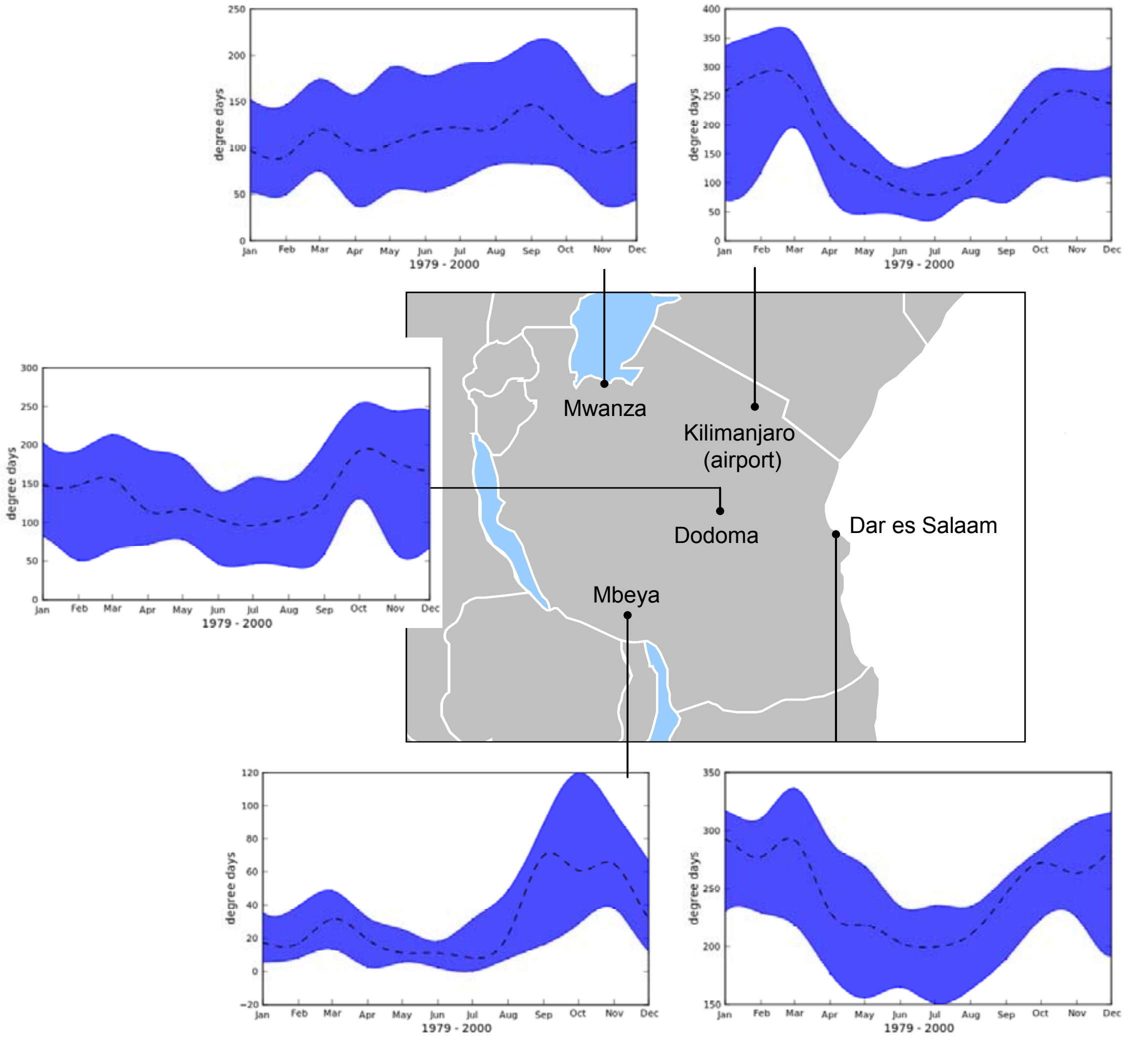
To undertake a similar analysis for Tanzania, the study has first assessed the past observational data to look at cooling degree days (Jack, 2010[62]), however, due to the data available, the study has had to look at maximum temperature thresholds (rather than mean temperatures) looking at cooling degree days. Cooling degree days (CDD) are used as a proxy for the amount of energy required to cool buildings when the temperature rises above a certain level. The threshold used in this study is 22°C. A simple version of the calculation is used in this study that just uses the difference between the daily maximum temperature and the threshold temperature. The calculation is as follows:

$$CDD = \sum (Tmax - Tthreshold)[for\ all\ Tmax > Tthreshold]$$

The data for key met stations are shown in the figure below[63].

[62] Climate Projections for United Republic of Tanzania. Chris Jack, Climate Systems Analysis Group, University of Cape Town. Available on the study website.

[63] It must be noted that the use of the daily maximum temperature is not accurate and other more sophisticated methods can be used given more data for the location. Minimum temperature is available for these locations but the timing of the measurements is suspect and hence the values are not reliable. The method used here primarily provides a baseline climatology with which to compare future projections.



Monthly climatology of cooling degree days (22°C daily maximum temperature threshold)

Figure 25. Observed climatologies of cooling degree days (22°C threshold) for selected stations between 1979 and 2000. Blue envelope represents the range between the 10th percentile values and the 90th percentile values for each month. Dashed line represents the median value for each month

Most the results are as expected with high cooling demand in warmer locations such as Dar es Salaam and Kilimanjaro. Cooler locations such as Mbeya and Mwanza show much lower levels throughout the year.

The analysis has also looked at the future CDD as a result of climate change. This is shown for each of the met stations below, using downscaled data. In each case, the top figure presents the CDD over the year for the modeled baseline for recent years (in grey) and the future period with climate change (red). The bottom graph shows the net change between the two, i.e. the increase from climate change. The data shows the information for the A2 scenario for the 2050s – note that the changes are less under the B1 scenario.

The results show significant increases in CDD across all regions and seasons. The figures show relatively consistent anomalies through the seasons. This is most likely because of the 22°C threshold used. For most locations during most seasons daily maximum temperatures exceed this threshold. The index therefore largely resembles temperature anomalies. The only locations that show significant seasonal variations are the cooler locations such as Mbeya and Mwanza.

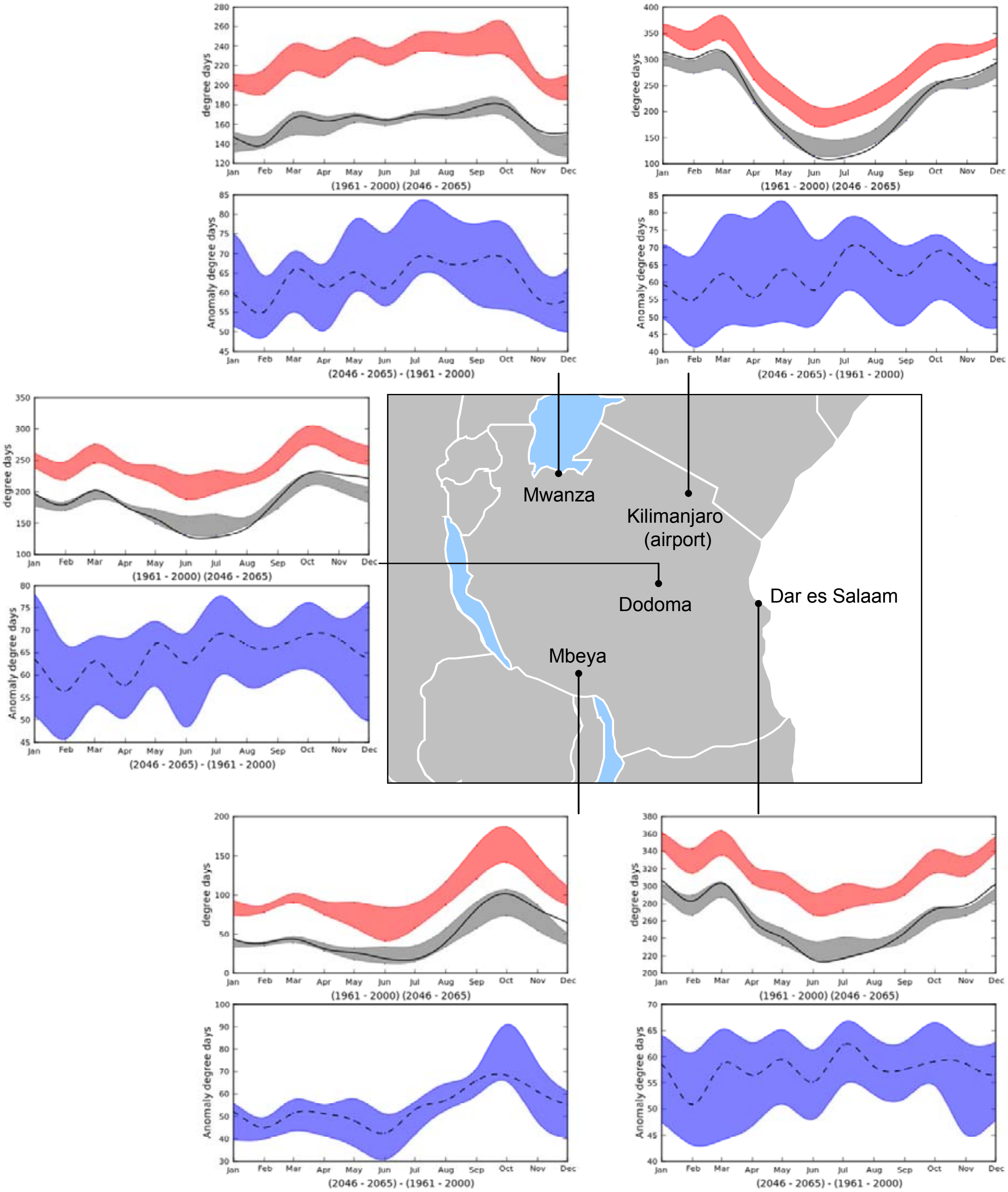


Figure 26. Projections and anomalies of monthly cooling degree days (2046 - 2065) A2 Scenario,

Top figure. The black line represents the multi-model median, the grey envelope represents the 20th century period and the pink/red envelope represents the future period (2046-2065). Bottom figures show the net change compared to the baseline period from climate change. The figures above show one future scenario and period – the underlying modelling report includes estimates for alternative scenarios and other time periods.

These increases will significantly increase potential cooling demand, putting pressure on future cooling and electricity use. The data above indicates a 25 to 100% increase in likely cooling demand by the 2050s (under the A2 scenario, and only slightly lower increases under the B1 scenario).

The study also considered an analysis of the potential impacts of these changes. To do this requires a number of steps.

- First to look at existing relationships between temperature (CDD) and cooling related energy demand (kWh). This requires regression equations for the present climate, but these have not been possible to derive, due to the lack of data that allows a comparison of daily demand levels and daily temperature or CDD data.

- Second, to estimate the future baseline increases in cooling demand, i.e. in the absence of climate change. This is extremely important, because demand for air conditioning in Tanzania will increase in future years due to socio-economic change, notably income growth. Therefore, the level of current cooling demand is not a good predictor of likely levels of demand in twenty or more years time. Penetration rates for cooling equipment shows a strong link with per capita income.

- Third, to look at the marginal increase from climate change on cooling demand, on top of socio-economic demand projections.

Such an analysis is highlighted as a priority for future analysis. It is expected that this effect could be considerable. It could also lead to large peak demand on the electricity system during heat extremes (note the main study has looked at the potential increase in incidence in very hot events).

Note that while the effect on air conditioning demand is the principle effect, demand also increases for energy use in refrigerators and freezers with higher temperatures, and there is also greater energy use for cooling of electrical devices, notably computers and IT.

In some sectors, such as high value tourism, it would be expected that these future cooling burdens would be met – most likely through mechanical (electric) air conditioning. It would also likely be an important factor in the service sector and for middle and high income groups. For the more vulnerable, lower income groups, there will not be access to cooling options, and thus they have a much higher risk to higher temperatures, both in relation to the potential health impacts of extreme events (and health risks) but also in terms of lower productivity.

Low Carbon Climate Resilient Options

In relation to the low carbon – climate resilient pathway, there is a need to avoid mechanical air conditioning whilst meeting future cooling demand needs. This can be achieved through alternatives (e.g. passive ventilation, building design, green roofs, etc). However, these require a greater planned response (including building or planning regulations) and are most cost-effective (or only applicable) at the construction stage. They are particularly important given the long life-time of buildings.

The previous SEI Kenya study (SEI, 2009) undertook surveys on energy use and air conditioning and found some recognition of these future problems by environmental designers/architects in East Africa, who are already considering:

- Orientation of buildings in the East-West direction for optimization of sun shading.
- Natural ventilation of buildings to allow air movement. This involves glazing of one part of the building which forms cooler and warmer sides thus creating pressure which allows hot air to escape.
- Use of wind catchers which trap cool air from outside, which then drops into the building by gravity.

Some of the possible adaptation options suggested though the surveys to reduce air conditioning demand in buildings included:

- Use of passive devices, e.g. air fans that are less energy intensive.

- Change of partitioning of buildings.
- Introduction of sun-shading elements.
- Restructuring of buildings (internal walls) to increase air circulation.

Implementation is likely to be made more challenging by the necessary legislation and policies to support design, the lack of awareness on the need to design these options into buildings, even among the architects (including of the economic benefits compared with the use of air conditioning) and the lack of knowledge on building related fuel consumption and greenhouse emissions.

A number of key future steps are highlighted.

There is a need to plan for demand increases from additional air conditioning in energy demand projections for Tanzania. The analysis above shows strong increases are likely in AC demand in future years. This will increase even more rapidly with income growth and wider penetration rates. Further work is needed to assess likely future demand for cooling (without climate) as well as the additional marginal demand that will be needed because of future climate change. This could have very significant implications, especially as it is likely to increase peak demand, and thus require more network capacity.

There is also a need to look at low carbon development in the context of building design to provide an alternative to air conditioning. Given building lifetimes, this is an early priority.

Energy requirements for water supply

Another potential area for climate change and energy relates to the potential increase in energy use for water (pumping, desalination, recycling, water transfers), especially in areas where water availability is declining due to climate change. These issues are potentially important in the future socio-economic baseline (even without climate change). In some cases they could become very important with future climate change.

As well as changing the energy demand levels, they are also likely to increase future emissions where fossil fuel generation is used to provide energy, e.g. for desalinisation plants, etc.

There is little information about these effects as yet, but they are strongly related to other sectors (cross-sectoral linkages between water availability, domestic supply, agriculture, tourism, etc) and are a major evidence gap.

Effects of climate change on energy supply

Hydro generation

Tanzania has a large proportion of hydro capacity in the electricity generation system mix (see earlier section). This makes the system potentially vulnerable to potential changes in precipitation from future climate change. These changes arise from any trends in water resource availability, but also from any potential changes in variability from extreme events, notably droughts and floods.

A study by the Nile Basin Initiative explored this issue. The main findings are in the Box below.

Potential impacts of climate change on future hydro potential in the Nile Basin

There has been some detailed regional assessment of the potential effects of climate change on future hydro potential as part of the Nile Basin Initiative regional hydro study (2006). This considered the 62 MW proposed (2012) Rusumo Falls project on the Kagera river Burundi/Rwanda/ Tanzania) and Ruhudji river project (358 MW, planned 2015) and Rumakali river project (222 MW, planned 2020) in Tanzania. The study also looked at run-off and storage-yield. The analysis considered two future scenarios of climate change (for the socio-economic A1B and A1FI scenarios) to represent a central and high projection of future changes in temperature and in precipitation. It also used seven GCM model outputs, rather than using single model projections.

For Southern Tanzania, all the models projected an increase in temperature (in 2050 and 2100). For the A1B scenario, the wettest and driest models gave a wider range of change in temperature because such models in this region are also the coolest (least warming) and warmest (most warming). The model average is a small increase in precipitation, but the dry model projects a decrease in precipitation. Furthermore, the dry model projects a reduction in precipitation in 3 of the 4 three-month periods. The study then used a hydrological model to consider potential effects on run-off.

In general, the climate scenarios project an increase in runoff. The exception is the dry scenario for the Nyasa (Southern) Region, under which a decrease in runoff is projected. Furthermore, the model averages for the A1B and A1FI scenarios in Nyasa involve virtually no change in runoff. However, the report does highlight the absolute changes should be interpreted with caution.

The study also looked at storage-yield curves, to show the amount of water storage necessary to provide, or yield, a "reliable" amount of water in each time period. Reservoir storage is less effective in providing firm yield at lower storage levels, due to changes in seasonal runoff, so even for some increases in annual runoff, reservoir storage in less effective. The results show that increases in variation change the shape of the storage-yield curve and in this case reduce reservoir effectiveness at lower storage levels in the Southern region.

Overall, the study finds that the model average climate change scenario for 2050 results in significant increases in runoff for the Tanganyika region for both A1B and A1FI – 23 and 42% respectively. For 2100 there is a larger increase in runoff for the Tanganyika regions for both A1B and A1FI – 55 and 107% respectively. For the Nyasa region, the model average changes in 2050 and 2100 result in no change in runoff for both A1B and A1FI – 1 and 0% respectively. These findings are driven primarily by the climate change scenarios, but also from the responsiveness of hydroclimatic system of each region.

The storage-yield analysis shows that for all regions and all scenarios except A1B model average, the storage-yield curve shape does not change but is shifted up and down in relationship to the change in mean annual runoff. However, under the A1B scenario, where the seasonal changes in climate differs, the storage-yield curve changes shape so that a portion is below the base curve and a subsequent portion is above the base curve. This means that for reservoirs with relatively small storage, firm yield would be less than base climate even in cases where the average annual yield increases. For reservoirs with relatively large storage, yield could increase. This suggests that an increase in climate variability with no change in annual runoff would decrease reservoir performance. This can be offset where runoff increases. If there is no change in variability, yield would rise with increasing runoff and decrease with decreasing runoff. The result suggests that larger reservoir capacity can better cope with increased variability or increased runoff, but not decreased runoff. Increased variability in runoff is most evident in the southern Tanzania region. It is relatively modest in the northern and central west regions.

For the Tanzanian projects there appears to be some potential for average annual runoff reduction, however only assuming validity from the results of the "dry" model. If "dry sequence" scenario was used for a risk analysis, sensitivity tests with average runoff reduced to 23 to 42 % of the base or historic runoff then these projects would not be selected for the plan, and would be replaced by thermal (next stage of Mchuchuma and imported coal) if Tanzanian replacement generation is assumed, or less socially/environmentally acceptable hydro if this generation would be provided from other hydro options in the region. For the southern region there is a high likelihood of changes in seasonality of runoff, resulting in lower effectiveness for flow regulation in any smaller reservoir.

An additional concern (not included in the analysis) is the potential for more extreme events, particularly greater rainfall intensity, which would necessitate some planning for greater flood control for future projects.

Results show that for all regions flood flows may increase significantly, thus designs for flood discharge during construction and over a permanent spillway should take this potential into account. Project costs would also be affected. Similarly the identified trend towards larger floods, suggests that project planning and environmental assessments for multipurpose specifically take into account this hydrologic risk in assessing project benefits from flood control.

The World Bank study did capture the uncertainty across the models.

Other studies have applied a simpler approach, looking at extreme events (droughts), though these studies need to be taken with extreme caution, due to the uncertainty in the projection of extreme events from the models (see later).

The Economics of Climate Adaptation Working Group (ECA, 2009) undertook a study on the power sector focusing on the 2030s. The study used the University of Cape Town projections. The team interpreted these findings for the central region (Dodoma, Singida, and Tabora) under the moderate change scenario reporting a 10% decrease in the amount of annual rainfall, and 25% increased variability in the amount of annual rainfall, which would affect the potential for drought periods (though note these changes contradict the more considered envelopes shown below). For the high change scenario, rainfall was interpreted to decrease by 20% and variability increase by 50%.

The central region is important for hydropower generation, with major dams on the Rufiji River (Kidatu and Mtera dams), which are located in or near the central region. The study reports that these contribute 50% of Tanzania's hydropower production capacity (and then in 2030, Tanzania will rely on hydropower for >50% of capacity, with 95% of this hydro situated in the central region).

The ECA study assumed increased droughts in 2030, associated with decreased water flow in rivers and lower availability of hydropower, but does not use an analytical assessment of temperature, water run-off, storage yields, etc as with the Nile Basin study. Note also that the climate models cannot accurately project the changes in extreme events, such as extreme droughts in far future periods (2050s and 2080s) where the climate signal is significant, let alone for short-term (2030), and the available models show a very wide range of potential changes that include both increases and decreases. It therefore provides an over-simplified link between climate data and consequences. Nonetheless, it concluded that Tanzania Electricity Supply Company (Tanesco) would need to use thermal (natural gas and coal) sources more frequently and at higher cost than for hydropower (and which would also result in an increase in global greenhouse gas emissions) or to reduce electricity supply (demand management).

The study also assessed the impact of droughts on power generation, by correlating historical rain with historical power production at Kidatu – reporting 1 GWh can be produced for every 2mm of rain in the central region. This was extrapolated to all hydro plants in central Tanzania. It was estimated that although the energy reserve margin by 2030 could be as high as 26 percent with no climate change, it could fall to 12 percent under moderate climate change, or 0 percent in the high climate change scenario – compared to a typical reserve margin risk threshold of 15%. The study reported that in the high climate change scenario the expected losses would lead to a 1.7% decrease in national GDP in 2030 – and in the moderate climate change scenario, GDP will decrease by 0.7%, as a result of the climate-change induced droughts. Again, the confidence in these reported results contrasts with the analysis in this study.

Finally, the ECA study used a marginal abatement cost (MAC) curve for the power sector to look at adaptation – looking at the options for meeting the shortfall projected under the study (note this is not a full energy sector wide MAC curve). This showed that most of the expected shortfall in power production could be met with energy efficiency measures, including demand reduction (residential and commercial sectors) which were actually negative cost (no regret). Also it identified reducing spillage at hydro stations and improving the load factor of hydropower could increase power supply for almost zero cost. Finally, it identified building new power plants and reducing losses associated with the transmission, though these were higher cost options.

The current study has assessed the potential changes in precipitation, looking at the climate projections (see earlier and also the main impacts report). It is stressed that the projections of future precipitation are very uncertain in Tanzania, and the predictions of changes in extreme events (floods and droughts) even more so. The figures below show the changes in monthly precipitation, with an example for the 2050s for the A2 scenario.

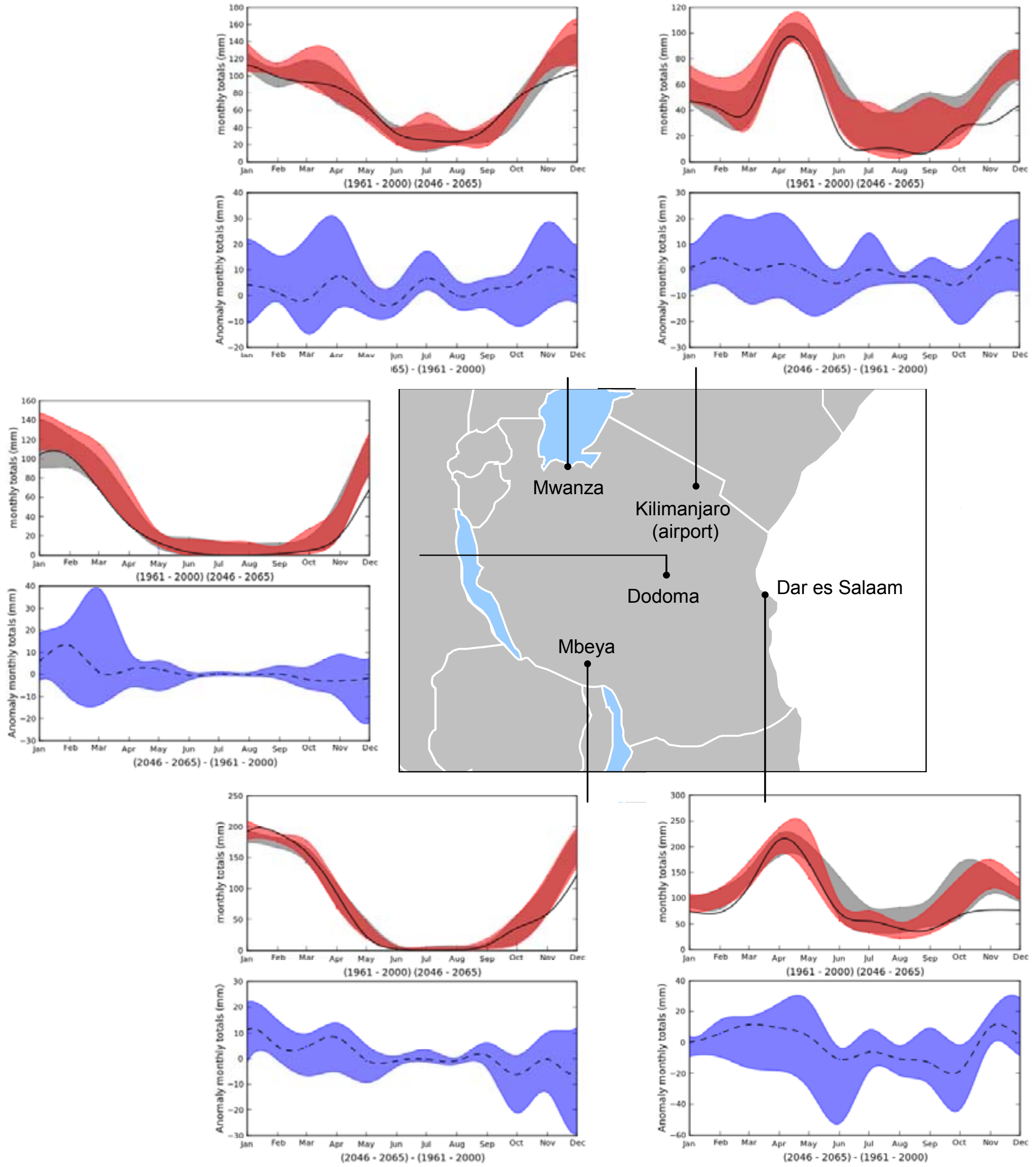


Figure 27. Projections and anomalies of monthly precipitation (2046 - 2065) A2 Scenario,

Top figure. The black line represents the multi-model median, the grey envelope represents the 20th century period and the pink/red envelope represents the future period (2046-2065). Bottom figures show the net change compared to the baseline period from climate change. The figures above show one future scenario and period – the underlying modelling report includes estimates for alternative scenarios and other time periods.

For each met station, the graphs show the downscaled projections, with the projected rainfall over the year (top, in red) and the changes in precipitation from the modelled control period (bottom, in blue). The key finding is that in all cases the climate envelopes show very wide variation, which spans both negative and positive changes (i.e. the different models used across the envelopes show both decreases and increases in rainfall). The changes also show wide variations with location and with season.

Overall, there is some agreement that precipitation will increase in the future during the late part of summer with some very slight signs of drying during the early summer. Such changes are indicative of a seasonal shift with weaker early season rains and stronger later season rains. Other changes are important, however, including temperature and humidity. The increase in precipitation is often related to increases in atmospheric moisture content. Interestingly, the results do not indicate much greater changes in the later time period.

Finally, the study has considered the potential changes in extreme events, notably droughts, which are a source of current problems for the hydro sector. These are reported in the main impacts report. In southern Tanzania, droughts are projected to increase in severity in some (but not all) models. Changes in the rest of the country are more uncertain.

Given the uncertainty above, there is caution needed when interpreting the current modeling results. The key conclusion is to move away from central projections of change – which are shown above to be highly misleading – and move to future resilience to address potential uncertainty. There is also a need to build such an analysis around current climate variability. Clearly, energy diversity offers one approach that will reduce the current risks to the electricity sector as well as building resilience for the future. However, given the likely increases in energy demand, demand side measures may be just as important.

Climate change impacts on thermal generation (cooling and efficiency)

The generation of electric power in thermal (particularly coal-fired) power stations often relies on large volumes of water for cooling. Climate change can have a negative impact on the thermal power production as reductions in precipitation or any changes in intensification or frequency of droughts could limit the availability of cooling water. Such considerations are important given the potential use of fossil (coal or gas) fired generation in Tanzania, i.e. a move to fossil generation may lead to similar problems in drought years, thus reducing the potential for this option to increase resilience.

It is therefore stressed that climate variability may also have similar effects on reducing availability of fossil generation due to cooling water demands, thus a move to fossil generation may not reduce the impacts of current and future climate variability. These may be compounded by limits on water abstraction in the future, due to multiple and competing pressures (e.g. drinking water, irrigation).

In addition, rising temperatures and lower river levels may combine to result in a lower efficiency of thermal power plants, due to higher power demand for pumps to maintain desired condensing temperatures and due to changes from wet to dry cooling towers (Eskeland et al, 2008).

Other impacts on energy supply

Electricity transmission and distribution: Climate change is also likely to result in (albeit limited) electricity transmission losses due to higher average temperatures. Increased temperature and heat waves may increase the resistance of power lines. The vulnerability of electricity transmission may vary across regions depending on the age of this infrastructure, the nature (e.g. overhead or underground cabling) and the remoteness of regions.

Risks to power infrastructure: There is also the potential for infrastructure risk to flooding, either rivers affecting plant and supply stations, or from sea-level rise and storm surge in relation to coastal flooding. The location of power infrastructure is known, and this could be further mapped against these risks.

Impacts on renewable generation: The efficiency of photovoltaic plants could slightly be reduced due to higher temperatures, particularly during heat waves, though climate could also have other effects (e.g. increased or decreased cloud cover at different times). Increasing average wind velocities improve the electricity output of wind converters. However, the extent of increasing wind velocities is still unknown.

Biomass / biofuels: Higher temperatures and atmospheric CO_2 concentrations in moderate climates may be beneficial for the growth of biomass. This may favour electricity/fuel generation from agricultural crops, manure and wood chips. However, reduced water availability or extreme events in some regions might have detrimental effects on crop yields and therefore the potential for growth of biomass for energy purposes.

Other linkages on Low Carbon - Climate Resilience

Forestry sector

One of the key areas of focus for Tanzania is the potential for the UN Reduced Emissions from Deforestation and Forest Degradation (REDD+) scheme. An issue that could affect the future benefits of such a scheme is the impacts of climate change on forests.

The 1st National communication (GoT 2003) reports on modelling studies which look at the projected changes in forests with climate change. This reports climate change will shift forests across Tanzania towards drier regimes: from subtropical dry forest, subtropical wet forest, and subtropical thorn woodland to tropical very dry forest, tropical dry forest, and small areas of tropical moist forest respectively. The analysis predicted that subtropical thorn woodland will be completely replaced. Subtropical dry forest and subtropical moist forest will decline by 61% and 64% respectively. It also reports an increase in tropical very dry forest, tropical dry forest and tropical moist forest, which are likely to replace the current zones. The analysis highlighted some species will be more vulnerable to climate change particularly those: that are drought/heat intolerant; with low germination rates; with low survival rate of seedlings; and with limited seed dispersal/migration capabilities.

The OECD (2003) study reports on the risk of enhancement in the intensity and risk of forest fires on Mount Kilimanjaro as a consequence of the increase in temperatures and a concomitant decline in precipitation. Continuation of these trends could result in the loss of most of the remaining subalpine Erica forests in a matter of years and the effective water catchment.

This area of analysis is key to any assessment of REDD, i.e. whether future forest stocks are sustainable in the face of future climate change. The indicative studies that are available indicate potentially large threats, which would affect the viability of current afforested areas. This is highlighted as a priority for consideration in the context of future REDD development. It is possible that to maintain REDD revenues, active adaptation measures will be needed.

The most immediate response needed is to increase monitoring programs to study response of forest and tree species to climate change. The additional stress of climate change is also likely to mean a greater focus on reducing and managing existing stresses, such as fragmentation, pollution, population encroachment, habitat conversion, etc.

Additional measures could include creating forest buffer zones, increasing ecological zone connectivity. Given the irreversibility of land-use changes, these are highlighted as an immediate priority for consideration.

Transportation and urban areas

One of the key sectors likely to see increases in future greenhouse gas emissions is the transport sector. There are low carbon options to address this, either through technological approaches, or through non-technical approaches, the latter including behavioural change (planned or through economic incentives), public transport, urban planning, etc.

Many of these non-technical approaches are most effective and efficient in less carbon intensive cities, achieved through higher density of people and economic activity (and away from urban sprawl). However, such policies may have counter-productive effects by increasing some of the effects of climate change, e.g. through intensifying urban heat island effects and reducing infiltration capacity (which in turn could have greater feedback to energy and cooling demand). This therefore requires consideration in ensuring that options are introduced in a way that addresses both low carbon and adaptation objectives.

Agriculture sector

The final sector likely to see increases in future greenhouse gas emissions is the agricultural sector. This is due to the planned intensification of the agricultural sector in Tanzania. Note that a discussion on the links with agriculture was presented in the early sector.

One of the additional effects maybe any changes in yield levels that arise as a result of climate change (see the main impacts report, which indicates that under certain scenarios, there may be reductions in yields compared to the business as usual pathway). Any reduction in yields (in the absence of planned adaptation) that would mean more land was needed to produce the same relative increase, resulting in higher greenhouse gas emissions, or would involve adaptation measures that might have knock on effects on other sectors on on low carbon options

Wider economy-wide (macro-economic) considerations

At the macro-economic level, achieving low carbon and climate resilient patterns of growth could involve much more than just introducing abatement options or 'climate proofing' investments. It could involve sectoral shifts away from highly emitting sectors and away from climate sensitive areas (such as agriculture), the latter being consistent with development, though challenging to achieve.

At the aggregate and macro-economic level, it is not yet clear whether the combination of low carbon and climate resilient patterns of growth will align. Some macro-economic shifts which enhance climate resilience may lead to economic structures with lower carbon intensity, though this will not always be the case. Such effects will also vary on a geographical basis. Similarly major planning changes towards low carbon development may sometimes reduce vulnerability, but in other cases will not (e.g. higher building / population density in major cities to reduce private transport demand will increase heat island effects and increase the health related vulnerability to higher temperature).

Implications of climate resilience linkages for analysis of low carbon opportunities

Based on above, we conclude that climate change might have large effects on the future greenhouse gas emission profile and also on the marginal abatement cost curves. These issues are potentially important.

In future analysis, and in the move towards national strategy, a number of points are highlighted.

- First, the need to examine the potential increase in electricity demand from cooling. This will affect the future emissions as well as future capacity and reserve margin needed on the system.

- Second, in terms of supply, the need to consider how large the potential effects of climate change on hydro, fossil fuel, could be.

- Third, to consider how future climate change itself might affect forests, and thus the potential for REDD in Tanzania, as well as moving towards early adaptation activities.

- Fourth, to screen low carbon options to ensure these do not inadvertently increase vulnerability to climate change – and detailing the risks where these may exist - an example being the screening of future hydro power projects against future climate projections of rainfall.

6) Conclusions and Recommendations

Tanzania is a growing economy, aiming for strong economic development over the next 10-20 years, as it seeks to raise standards of living and address high levels of poverty. However, there are significant risks associated with the current growth pathway due to the unsustainable use of natural resources and the increasing reliance and inefficient use of fossil fuels. A more sustainable pathway should be adopted, to ensure that Tanzania can become a middle income country whilst protecting its natural assets and environment.

The opportunity to access carbon financing could help Tanzania to invest in more sustainable technologies, and ensure that some of the current problems can be addressed. This could raise much needed finance while at the same time supporting domestic priorities and moving towards a more sustainable pathway.
Reducing the reliance on wood fuel energy and protecting the forests will promote sustainable resource use, protecting biodiversity and economic sectors relying on forest resources. It also reduces household exposure to pollution and promotes a move towards more modern energy forms. Developing a sustainable transport system can help reduce reliance on oil imports, protect urban environmental quality, enhance urban infrastructure and potential help develop a sustainable biofuel sector. Promoting renewable electricity generation, both grid and household-based further strengthen energy independence so long as it is carefully planned, and doesn’t increase vulnerability.

Tanzania is and has already implemented many lower carbon opportunities. However, a more strategic approach by Government could ensure that all public policy is considered in the context of low carbon, climate resilient growth. The extent to which Tanzania can develop low carbon opportunities is dependent on a number of things – first, confidence that carbon finance mechanisms will be there in the long term and can be accessed. Second, as discussed above, the policy co-benefits need to strengthen the domestic policy agenda. Third, low carbon opportunities need to be progressive, bringing benefits to lower income groups, and not further entrenching poverty. Fourth, there needs to be strong synergies with the adaptation agenda, to ensure not only low carbon but climate resilient growth.

Overall, the study concludes that because of its location, availability of resources and socio-economic conditions, there are significant benefits for Tanzania in promoting low carbon projects to ensure a more sustainable growth pathway. Such a pathway appears strongly in the country’s self interest, providing potential extra investment from carbon financing and numerous policy co-benefits. However, further assessment of the relative economic, social and environmental benefits and costs would be needed to further quantify the extent to which Tanzania should or could move in this direction. Focus needs to be given to assessing the macro-economic impacts of such investments, including the distributional impacts, to better identify the opportunities. Further assessment of the social and environmental benefits could also be developed e.g. quantifying health and environmental benefits.

A priority area for further assessment should also be the potential for regional cooperation in this area. There is a growing recognition that co-operative regional (East African) responses could enhance opportunities for carbon credits. They could also provide greater resilience through shared networks, as well as providing examples of best practice and sharing.

In addition, the potential effects of international climate change policy on Tanzania need also to be assessed. Key concerns are over certain areas of existing economic activity, which also have high planned growth in Vision 2025. This includes the international tourist sector, and potential higher value added agricultural products. However, these are reliant on international transport. The action taken to address greenhouse gas emissions in developed countries could have knock-on effects to these sectors in Tanzania, for example, in relation to the additional costs of carbon. This could affect demand or comparative advantage. Given their importance to the economy, export earnings, balance of trade, etc. it is considered a priority for Tanzania to consider the implications of international climate policy on it’s domestic growth plans.

A number of recommendations and future priorities can be proposed.

A key recommendation is the need for Tanzania to get ready and act now. Key elements are to improve estimates, advance institutional and policy development, undertake investment analysis, revisit Vision 2025, to advance a more sustainable (and low carbon) growth path (in parallel to climate resilient growth) and to enhance regional co-operation.

Specific actions are outlined below.

- Improving the estimates. Further work is needed to improve these initial estimates and to give a degree of confidence in the analysis. Such a follow-on phase might include:
    - A more comprehensive analysis of future emission projections and potential opportunities, with full marginal abatement cost curves and analysis of urgent priorities across all sectors.
    - Analysis of the costs, including to government, the sector and individuals. This step could include an investment and financial flow analysis (by sector). Matching the costs against the wide range of potential finance is a prerequisite for a viable investment plan.
    - An analysis of the synergies and conflicts between low carbon and climate resilient growth, and to consider areas where climate change may have material impacts on the energy sector (e.g. cooling), access to finances (e.g. impacts on forestry and REDD) and on synergies with climate resilience and adaptation.
    - To bring together in an expanded climate strategy that links national policy to sectoral objectives and targets, with effective mechanisms for implementation, monitoring, reporting and verification across both low carbon growth and adaptation.
- Building Capacity. Access to substantial adaptation funds must be assured. However, **mechanisms, institutions and governance systems for effective use must be developed** to allow Tanzania to access these funds. This requires early and concerted action to build capacity across stakeholders and with the affected communities themselves. This is an early priority.
- A more sustainable and lower carbon pathway. There are many benefits if Tanzania switches to a more sustainable growth pathway. However, this will not happen on its own and steps are needed by Government, business and civil society to realise these benefits and to maximise the potential flow of carbon credits under existing and future mechanisms. Specifically:
    - **Low carbon plans** should extend beyond the power generation sector. This will necessitate a greater focus on transport, forestry and agriculture. Low carbon options need to be mainstreamed into sectoral plans
    - There is a particular need to **consider areas of future development** that might 'lock-in' Tanzania into higher emissions pathways, notably in energy, transport and urban environment. It would be useful to specifically address these threats and to identify alternatives.
    - All future plans and policies, including low carbon investment, should consider future climate change, which necessitates **climate risk screening in future low carbon plans across all sectors. Potential linkages between adaptation and low carbon development (especially in finance) should be further explored.**
    - There is a need to link lower carbon and climate resilient growth, noting the conflicts as well as synergies identified.
- National policy and Vision documents. Planned revision of national policy should **examine the potential effects of climate change and the potential for adaptation and low carbon growth**. There is also a need to build on existing government and donor activities. There is a need to develop a new strategic vision for Tanzania that addresses these areas, for example, with **further development of the Vision 2025 document**, including both domestic and international aspects.

- Regional collaboration. There is also a need for **regional collaboration and co-operation** across the areas of lower carbon growth and adaptation, to benefit from economies of scale and to enhance regional resilience.
- The steps above would provide national action on a low-carbon, climate resilience investment plan and **would help Tanzania in negotiations and in securing finance.**

A summary of key next steps is presented in the table below.

Strategies	Recommended Actions
Low-Carbon investments	• Full analysis of baseline projections, low carbon options, impacts of climate change on energy and low carbon options, costs and potential for prioritisation and development of strategy for mechanisms. • Develop national strategies to mainstream LCG in planning. Build into long-term vision (e.g. Vision 2025), including potential effects from international action. • Facilitate carbon finance opportunities in voluntary and compliance carbon markets (VCM, CDM) and in REDD • Prioritize forestry, agriculture, transport and electricity generation low carbon measures, considering short-term opportunities but also longer-term areas where potential 'lock-in' and identify alternatives. Improve sectoral co-ordination. • Look for synergistic adaptation – low carbon project opportunities, e.g. agro-forestry and sustainable land-use
Climate resilience & co-benefits	• Climate risk screening of low carbon growth pathways • Consideration of energy demand (cooling) and supply (hydro, fossil stations) effects from climate change, with associated adaptation (diversity, demand management). • Analysis of potential impacts of climate change on forestry (REDD) and introduction of monitoring and move towards early adaptation. • Explore opportunities in case studies of major low carbon strategies such as geothermal, biofuels and on-farm carbon management and how they might be scaled up to achieve both reductions in future emissions and adaptive development.

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Appendices

Appendix 1. Case studies illustrating low carbon opportunities in Tanzania

Case Study 1: The Challenge of Sustainable Charcoal

Charcoal is the single most important energy source for millions of urban dwellers in Tanzania with an estimated annual charcoal consumption of 1.6 million tonnes, requiring approximately 15 million cubic meters of wood. Since the wood is harvested unsustainably (and mostly illegally), without tree planting to offset the lost resources, the production of charcoal results in significant degradation of forest land. An estimated 100,000 – 125,000 hectares of lost forest area may be attributed to charcoal production (WB, 2010).


Unsustainable charcoal production is a major cause of deforestation

The lost forest negatively affects Tanzania's biodiversity, as indigenous fauna and flora have to move, adapt or perish. Lost tree cover leads to falling water tables and shifting river flows, the latter of which is believed to be contributing to reduced hydropower capacity and repeated electricity crises. Negative impacts on agricultural productivity from erosion prone landscapes and lowered water tables is also a risk when forests are degraded or removed. Additionally, according to the Edinburgh Centre for Carbon Management, a tonne of unsustainable charcoal produced and consumed translates into nine tonnes of CO_2 emissions.[64]

Even if all charcoal production is assumed to be produced sustainably so that the CO_2 is recycled and summing the other pollutants weighted by 20 year global warming potential, Tanzania's current charcoal use translates into almost nine million tons of CO_2 emissions (Kammen et al, 2003).

Addressing the problem of unsustainable charcoal is quite complicated, primarily due to the fact that Tanzanians need charcoal. Thousands of poor rural farmers resort to charcoal production as a result of clearing new land under slash and burn agricultural practices and to complement the meager incomes that they derive from agriculture. The annual charcoal market in Dar es Salaam alone is valued at approximately \$350 million[65], making it one of the biggest business sectors in the country. Though the lion's share of this revenue is taken by middlemen transporters/wholesalers, the small percentage that falls to the rural charcoal producer is vital to his or her economic survival. Being a highly informal sector, with unclear or poorly enforced regulations, it is estimated that a potential government revenue loss of USD 100 million is incurred every year. This lost income could be used for reinvestments into sustainable charcoal production or promoting transitions to alternatives fuels.

Millions of urban consumers also depend upon charcoal for the energy required to prepare their meals. Over 90% of urban Tanzanians use charcoal as either their primary or secondary source of domestic energy. Alternatives, such as electricity, LPG (liquefied petroleum gas) or biomass briquettes, are either perceived as too expensive or hampered by undeveloped distribution and marketing networks. The cost of electricity is roughly US\$ 0.10 per kWh, and a household will spend about US\$ 32 per month on cooking using electricity,

[64] It takes approximately 6 kg of wood to produce 1 kg of charcoal. 1 kg of wood contains approximately 1.3 kg of CO_2. Feasibility studies in Kisarawe and Rufiji Districts confirmed that the carbon emissions that may be avoided by producing one (80kg) bag of charcoal sustainably are equivalent to 0.728 tCO_2

[65] Charcoal is the 3rd biggest business in Tanzania, after mining and tourism. A kilogramme of charcoal in Dar and other secondary towns is between 0.35 – 0.5 US\$

as compared to about US$25 per month if using charcoal primarily. For LPG, a typical household can use a 6kg cylinder, and monthly refills of the cylinder cost around US$ 20. Biomass briquettes are a better substitute for charcoal and have been demonstrated to be cheaper than traditional charcoal. In Dar es Salaam, the retail price for briquettes is approximately US$ 0.4 per kilo, as opposed to sometimes US$ 0.5 per kilo for charcoal. In addition, LPG and electricity consumers have to invest in buy cooking appliances (stoves and a start-up gas cylinder).

The main trends show that the traditional biomass based fuels, charcoal and wood fuel have increased in use, whereas the modern cleaner energy carriers, electricity, and kerosene have decreased. LPG consumption, although low has increased in use.

The trends that can be seen are directly counter to the targets of the Government of Tanzania to reduce the share of traditional biomass based cooking fuels. By 2010, the Tanzanian Ministry of Energy and Minerals aims to increase, on a national level, the number of grid connected households to 20% and to decrease charcoal and firewood usage to 80%. At present, 14% of urban and 2% of rural households are connected to the grid.[66] The figure for Dar es Salaam is the highest at 54,3%[67].

Despite having a higher average income and a higher electrification rate, even Dar es Salaam has not met the above target to reduce traditional biomass reliance. There are yet major changes in fuel consumption that need to be seen before the target is met at a national level. In the 2009 Joint Energy Sector Review it was stated that: *"The main energy challenge is to reverse the reliance on firewood and charcoal as the source of energy as this is unsustainable."*[68]

Previous attempts to address the problems associated with unsustainable charcoal (including bans, tree planting campaigns, fiscal incentives for alternatives, etc.) have failed in the absence of government coordination and common strategies. Government finds it nearly impossible to regulate the industry due to its informal nature.

The Dar Charcoal Project

The Dar es Salaam Charcoal Project, funded by WWF and carried out by CAMCO, aims to address the environmental problems resulting from charcoal production and consumption by promoting sustainable charcoal production and gradual switching to alternative fuels. The project duration, as originally drafted, was designed as a five-year intervention, ideally targeting eight districts[69] around Dar es Salaam. The three overall components of the project are sustainable charcoal production,[70] fuel switching/alternative fuels and improved charcoal sector coordination.

The sustainable charcoal production component of the Project would work with rural communities involved in producing charcoal, but currently doing it in an unsustainable fashion. The component involves elaborating village land use plans, forming and training charcoal producer groups in governance, establishing nurseries and woodfuel plantations, teaching local masons to make and producers to use efficient kilns for wood to charcoal conversion, local government enforced sustainable charcoal certification, and sustainable charcoal marketing and distribution.

When charcoal is produced unsustainably (and illegally) the raw material (the wood from the forest) costs nothing. It is then converted from wood to charcoal through carbonization. Studies in Tanzania have shown that the efficiency of traditional kilns ranges between 10 – 20%. Sustainable charcoal producers invest in nurseries, seedlings and tree planting, whereas traditional unsustainable charcoal producers avoid these costs. The traditional conversion technology, the kiln, is also very inexpensive as compared to the Half

[66] Report from Joint Energy Sector Review Workshop 2009, A. Arvidson, J. Senyagwa and L. Nilsson, Stockholm Environment Institute, October 2009

[67] Household Budget Survey 2007, Dar es Salaam January 2009, Ministry of Finance and Economic affairs, National Bureau of Statistics, Tanzania

[68] Report from Joint Energy Sector Review Workshop 2009, A. Arvidson, J. Senyagwa and L. Nilsson, Stockholm Environment Institute, October 2009, p. 15

[69] Districts are Handeni and Kilindi (Tanga Region); Morogoro rural (Morogoro Region); Kibaha, Kisarawe, Bagamoyo, Mkuranga, Rufiji, (Coast/Pwani Region). These districts are the principle charcoal producing areas serving the Dar es Salaam market

[70] Sustainable charcoal is charcoal that is produced in a sustainable and efficient manner with minimum environmental impact.

Orange Brick Kiln or other more modern technologies. The Half Orange Brick Kiln has an efficiency of around 35%. Marketing of sustainable charcoal, to create awareness and differentiate the product from its unsustainable competition, also involves incurring costs. For these reasons sustainable charcoal is 40% more expensive to produce that unsustainable charcoal. However, urban charcoal consumers are not willing (nor able) to pay an additional 40% for "green" charcoal. This cost gap needs to be filled for sustainable charcoal to be able to compete on the market.

A Half Orange Brick Kiln constructed in one of the villages under the Dar Charcoal Project

The Dar Charcoal Project employs two strategies to overcome this cost gap. First, through local government certification of sustainable charcoal, the "green" product is exempted from taxes.[71] The second strategy involves awarding sustainable charcoal producer groups with voluntary carbon credits. The Tanzanian Carbon Initiative (TCI) is designed to broker voluntary carbon credit financing between institutions (private sector, diplomatic missions, government ministries, etc.) that want to offset their greenhouse gas emissions and rural communities producing charcoal in the correct sustainable manner.

A partner in the Dar Charcoal Project, Tujijenge Tanzania Limited (a local microfinance organization) has signed on to manage TCI and the carbon financing transactions between sellers and buyers for a small administration fee. At $16 per credit (nine credits per ton of sustainable charcoal produced[72]) the $144 per ton of sustainable charcoal more than compensates for the additional cost of producing charcoal in the correct manner (and leaves room to negotiate prices) and in fact provides a clear incentive for producers to switch to "clean" techniques and technologies.

The alternative fuels component of the Project targets urban Dar es Salaam, encouraging a gradual shift away from charcoal dependence towards green energy sources. It would conduct marketing and awareness campaigns of domestic energy fuel switching alternatives to charcoal, including biomass briquettes, ethanol gel and LPG.[73] An important part of the marketing would be to improve the current distribution channels of those alternatives, while ensuring their cost competitiveness (as Tanzanians are extremely cost sensitive).

Research on the factors influencing transitions from traditional to modern cooking fuels in developing countries has since the 1970s largely focused on socio-economic factors such as income, age, gender and education, while the product specific factors such as safety, indoor smoke, usage cost and stove price have largely been ignored. Product-specific factors are as important as socio-economic factors to create a market for clean cooking stoves, and future research should strike a balance between both types of factors.

Finally the charcoal sector coordination component of the Project brings together the critical stakeholders in a Steering committee and a wider group to Project update workshops. Stakeholders include the three relevant Ministries (Ministry of Energy and Minerals, Ministry of Natural Resources and Tourism and the Vice President's Office – Division of the Environment), charcoal producers and consumers, private companies trading in charcoal or commercializing alternatives, as well as academics and NGOs working in the sector. This is an important component of the Project, as historically the charcoal sector has fallen somewhere between the Ministry of Natural Resources (who sees itself on the supply side of the charcoal market) and the Ministry of Energy (who sees itself on the consumption or demand side of the market). The lack of any coordination between these Ministries has allowed the sector to virtually escape any form of monitoring and regulation.

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[71] Charcoal traders currently pay for a license and fees to the district government for the right to trade charcoal. Most traders, however, avoid these costs by corrupting local authorities and officials manning road check points.

[72] A tonne of sustainable charcoal should generate nine carbon credits, because it offsets 9 tonnes of CO_2 emissions. While sustainable charcoal is "carbon neutral", unsustainable charcoal results in 9 tonnes of CO_2 emissions. The $16 price is given as an example. The current price of voluntary carbon credits internationally is practically zero.

[73] Liquefied petroleum gas, though a petroleum product, is considered by many to be clean source of energy because its combustion results in only modest levels of CO_2 emissions.

The Dar Charcoal Pilot Project

The Dar Charcoal Project finally began in late 2009, albeit on a very small scale relative to the initial project design and scope of the unsustainable charcoal problem. WWF secured internal funding as well as support for the Project from Barclays Bank UK. Additionally, Camco secured funding from USAID.

The WWF and Barclays support targets introducing the Project's first component, sustainable charcoal project, in twelve villages, six in Kisarawe and six in Rufiji Districts. This is to expand to fifteen villages in late 2010 or early 2011.[74] To date, land use plans have been developed in the villages, 50 charcoal producer groups have been formed and trained in governance and the principles underlying sustainable charcoal, sustainable charcoal certification guidelines have been agreed upon with the district governments, nurseries have been established, and efficient kilns constructed. The marketing of the first production of sustainable production is scheduled for the last quarter 2010.

Simultaneously, USAID has supported a two-year campaign to market biomass briquettes as an urban domestic energy alternative to charcoal. Camco and East African Briquettes Company (EABC, a briquette manufacturer) implement this project component. Though Dar es Salaam is the country's largest city, its economic capital and largest charcoal market, East African Briquettes manufacturing facility is located in Tanga town, some 400 kilometers away. EABC did not have the capacity to develop a distribution network and market briquettes in Dar, and at the onset had zero market penetration in the city.[75] The Project's marketing activities including supporting new wholesalers, establishing new retail distribution points, conducting physical demonstrations at institutions (i.e. schools and barbeque kiosks) and public areas, and advertising the product through various media (print, radio, billboards, etc.). From a baseline of zero tonnes per month, EABC is currently selling over 60 tonnes of briquettes each month in Dar es Salaam.

Barriers and/or Challenges to Expanding the Dar Charcoal Project

If successfully implemented, the Dar Charcoal Project will result in a great number of positive environmental and socio-economic impacts. In addition to reducing emissions from deforestation and forest degradation, biodiversity and watersheds will be protected. The forest resources currently under threat will remain a heritage of future generations of rural Tanzanians, and thus the Project also addresses climate change adaptation issues. Formal sector employment will be created along the value chain, from producers to wholesalers to retailers, in addition to services that support the sector, such as marketing and microfinance. The project will result in improved domestic energy security. Lifting the entire industry out of the informal sector, through greater monitoring and coordination, should lead to greater and more consistent tax collection on traditional charcoal.

But the project is far from achieving these goals. The scale of the pilot project (12 villages) is far too small compared to the scope of the problem; at least 300 villages in eight districts produce significant quantities of unsustainable charcoal for the Dar es Salaam market. The initiative is currently inadequately funded. The Project doesn't even attempt to address the charcoal problems in other important Tanzanian cities, such as Arusha, Mwanza and Dodoma.

The pilot project is still in its infancy. To date, no sustainable charcoal has hit the market. Raising awareness among consumers, building distribution channels and marketing the product will raise an array of challenges that the Project has yet to confront. And there is currently no budget for marketing and raising awareness.

The carbon finance component of the project, the Tanzanian Carbon Initiative, is still but a concept. Tujijenge needs support to develop the principles and procedures required of a Tanzanian-specific voluntary carbon market. The credits have yet to be market to, and thus attract interest from, institutional buyers. This carbon finance is critical if sustainable charcoal production and commercialization is to survive and thrive in the absence of donor funding.

[74] The "full" Project design targets 300 villages in eight districts.
[75] EABC was primarily selling briquettes in Tanga and Arusha towns.

Case Study 2: Off-grid Solar Electricity in Tanzania

Tanzanians want electricity, but are faced with major power crises. Only 10% of Tanzanians have access to electricity from the national power company, and electrification rates are far less than that in the countryside, where 80% of the population lives. Only 2% of rural households receive power via the Tanzania Electricity Supply Company (TANESCO) grid. Generally in rural areas, electrification is largely limited to district headquarters. However, electricity is needed for a basic quality of life, for providing energy for lighting, and for employment and social activities.

In order to access electricity in rural area, options include establishing community-based mini-grids (with, for example, micro-hydro or biomass supply systems), waiting for the national grid to come to their vicinity, or installing solar electric systems. It is the Government of Tanzania's policy to promote the use of personal solar home (or business) systems for rural off-grid electrification, instead of continuing to use kerosene and batteries indefinitely.

Solar Home System on a house in Zanzibar

Rural homes use kerosene lanterns for lighting, in spite of the poor quality of light, fumes, fire hazard and the cost of kerosene. This is an expensive and poor quality solution. For appliances such as radios, people use dry cell batteries, purchasing replacements regularly and at great cost. The reality for almost all rural Tanzanians is that, after sunset, activities slow down due to no lighting or electricity for motive power. Students cannot do their homework and almost all economic activities stop until the next day. The productive hours of the day are limited and the quality of life is impaired.

Solar home systems (SHS), or solar business systems, are an important option for rural Africa. Given the highly dispersed population base, with 80% of the population living in small rural villages and individual homesteads, grid electrification is expensive and will take years (decades), if ever, to reach the bulk of rural households and villages. Moreover, national electricity grids, such as that operated by TANESCO, are stretched to their limit, cannot even service urban populations (for example, over 50% of Dar es Salaam's population is not connected to the grid), and are in debt and unable to invest in expanding access to electricity. Their expansion to rural villages with small populations is not economically feasible given the cost of transmission and distribution and the limited purchasing power of rural people.

Nonetheless, rural homes want electricity. In fact, their desire for lighting, cell phone charging, radio and television is so strong that the national market for solar home systems in Tanzania has multiplied by a factor of fifteen in the last five years, from 100kWp in 2005 to over 1.5MW in 2009.

In addition to the national energy crisis (beginning seriously in 2006), donor-funded projects to support private sector solar companies have been major drivers of the industry's growth. One of the first initiatives was the UNDP/MEM Mwanza Solar PV Project.[76] This now-completed project initially targeted Mwanza Region, but was intended to expand to all of the Lake Zone (Kagera, Mara, and Shinyanga Regions). The project's focus was on building up the technical and marketing capacity of new and existing solar companies through training and awareness raising campaigns. Additionally, through this project national solar equipment standards were developed. Unfortunately, the project faced management difficulties in the later half of the five-year project and expansion to the additional three Lake Zone regions did not take place.

A second solar project, the Sida/MEM Solar PV Project, started a year after the Mwanza PV Project and is still ongoing.[77] The project is similar in design to the Mwanza Project, but larger in scale, targeting sixteen regions countrywide. (There are currently twenty regions in Tanzania). The project components include (1) business development services for solar companies (which is basically technical and marketing training for solar retailers, technicians and vocational school instructors), (2) marketing and awareness raising, (3) network building amongst solar industry stakeholders, and (4) policy and institutional support for the implementation of national quality control standards.

The combined effort of these two projects has resulted in a massive increase in national solar technology awareness and a 15-fold increase in the size of the Tanzanian solar market. Two retailers supported by the projects have transformed into two of the country's major importers/wholesalers. Through support from these projects, the Tanzanian Renewable Energy Association (formerly the Tanzanian Solar Energy Association) has grown to become a dynamic group bringing together stakeholders from the Government, private sector, academia and non-governmental organizations who lobby for the industry's interests, including successfully lobbying for complete tax exemptions for all solar products entering the country. There are currently nearly a dozen Tanzania solar importers/wholesalers and over 200 retailers in the regions and districts around the country. There are an even greater number of trained rural solar electricians.

As impressive as these results appear, the market penetration of solar systems still remains small and limited relative to need, for a number of reasons.[78] Though solar awareness nationally is fairly high, up-front costs (most retailers sell on only a cash basis)[79], excessive margins, lack of credit and inconsistent quality (including fraudulous solar products such as panels) continue to limit the growth and economic efficiency of Tanzania's rural solar market. Many consumers end up paying too much for a solar home system composed of a miss-matched set of components: battery bank too large for the solar array, or an inverter with exaggerated capacity, etc.

A new solar project looms and aims to address these remaining barriers. The Clusters Solar PV Project is implemented by Camco Tanzania through the Rural Energy Agency (REA) and in collaboration with the Ministry of Energy. "Clusters" is funded by the World Bank. The project is structured to provide standardized high-quality solar systems, bulk purchases to reduce cost, credit financing and subsidies. The project concept was borne out of the realization that project-oriented, social sector solar projects continued to fail, due to inexistent ownership and maintenance of systems. This project focuses on private sector involvement, driven by successfully established farmer or worker cooperatives, corporations, companies providing solar PV products on a wholesale basis, and micro-finance. Under this model, Tanzania's Rural Energy Agency provides a small 20% subsidy for systems procured. Farmers pay for 80% of the systems that they receive, split as 20% down payment and 60% on credit (over three years).

The Clusters PV Project is currently benefiting cashew, tea and coffee farmers in Southern Tanzania. It is a model with enormous extension and replication capacity. In fact, in 2010 this project is going to provide solar systems to over 1,000 homes, in its first year. These procurements and servicing also become sustainable - through the capacity building and training provided by the project - enabling this number to continue

[76] Undertaken between 2004-2009
[77] This project is managed by Camco Advisory Services Tanzania on behalf of the Ministry of Energy and Minerals (MEM), with funding from the Swedish International Development Agency (Sida).
[78] There are approximately 5.8 million rural households in Tanzania, and last year about 20,000 purchased solar home systems, a third of one percent.
[79] Solar home systems from 30 to 80Wp cost Tsh 250,000 (US$167) to over Tsh 1 million (US$667), in a country with a per capita income of less than Tsh 380,000 (US$253). Most cannot afford to pay cash for their systems. However, Tanzania's rapidly expanding cash-crop farmers who grow coffee, cashew nuts, sugar, tea, tobacco, and cotton, can buy these systems, if the systems are available and marketed efficiently.

multiplying yearly for several years to come. This project will lead to multiple megawatts of off-grid green energy, procured and managed by farmer groups. Additional funding to the already existing Clusters PV Project will enable the project to work in new sectors (tobacco, cotton and sugar, for example) and in new regions.

Camco Tanzania is attempting to develop four separate Clusters PV Projects, one each for the South, North, Central and Lake Zone of Tanzania. These separate projects would target different farmer and worker groups, given that each zone has different specialties. There are more tea growing and some tobacco groups in the South. There are miners, farmers raising livestock and producing honey, coffee and tobacco growers in the Lake Zone. The North focuses on coffee, sisal and livestock. And the Central zone has sugar cane out growers, rice, sisal and tobacco farmers. Everywhere in Tanzania there are dynamic teacher associations that can form Cluster Groups. Teachers are ideal targets for the Cluster Project model, as there are thousands of them living in rural areas, without electricity but with salaries. Their Savings and Credit Cooperative Societies (SACCOS) are perfect microfinance clients. Clusters Projects should work with ten to twenty groups in each of the four zones, leading easily to 40,000 new rural solar home systems annually.

The objective of the Clusters Solar PV Project Lake Zone is to improve access to affordable and good quality solar electric systems for rural households and businesses. The model involves market and partner analysis and identification, marketing and awareness-raising, establishing project management and Steering Committees, procurement (which includes drafting business plans), capacity building training for managers, technicians and quality control agents and microfinance.

Each individual Cluster Project is “owned” by its Cluster Group sponsor. Sustainability of each Cluster Group’s project is ensured through capacity building training. Project managers assume their role through initial management training and through the practical experience of implementing the project. Rural electricians assume their role as area technical experts and agents of the private sector solar equipment suppliers through the training that they receive and via practical experience. Additionally, quality control agents ensure that the solar equipment received corresponds with the required specifications and that the equipment is properly installed.

The major risks associated with the project revolve around Cluster Group identification, management capacity and financing. Cluster Groups selected must have membership large enough to achieve scale in order to receive good wholesale prices. The must have strong leadership and management, and the trust of their membership. They need to be credible financially with experience in banking and with loan practices. The Groups need physical assets in order to guarantee loans. The absence of any of these elements could hamper the implementation of a Cluster Project, or at a minimum slow down implementation.

The Tanzanian solar market has benefited greatly from donor-funded projects supporting private sector development. There is still a long way to go, as the current supply meets a miniscule share of real need and demand. As grouped procurements improve affordability and quality, market growth will continue on its current steep exponential curve.

Case Study 3: The potential for Wind Power in Tanzania

Background

Tanzania has abundant renewable energy resources, much of which can be developed at relatively low cost. Electricity generation from new small and medium-sized hydropower projects combined with generation from timber and sugar biomass is central to plans for the development of the power sector.

To be viable, developed power projects have to be able to sell electricity profitably to TANESCO (Tanzania Electricity Supply Company) at that company's "avoided cost". In addition to the principal national grid, which is powered by a combination of large hydropower and thermal sources (oil and gas), TANESCO operates about twenty isolated diesel generators to supply power in far away rural regions and districts. For example, Kagera, Kigoma and Ruvuma Regions are largely powered from diesel generators. Currently, TANESCO can generate and deliver a unit (kilowatt hour) of electricity on the national grid at US$ 0.07, while its avoided cost on isolated grids is US$ 0.24.

Small power projects (of less than 10MW) that want to sell electricity to TANESCO through the country's standardized power purchase agreements (SPPA) are paid the avoided cost. The Electricity and Water Utility Regulatory Authority (EWURA) calculates the avoided cost and it is adjusted annually.

National grid-connected power projects need to be able to generate and sell power to TANESCO profitably at US$ 0.07 a kilowatt-hour. That is a fairly low tariff and therefore only fosters the development of very inexpensive renewable energy resources. The Southern Highlands of Tanzania (including Iringa, Rukwa, Mbeya and Ruvuma Regions) have such inexpensive renewable energy resources. In these regions there are dozens of small hydropower sites that have been identified.

The Southern Highlands is also home to the country's timber industry, which results in large quantities of waste biomass that are increasingly being used for power generation. Tanzania's first renewable electricity Independent Power Producer (IPP) has been generating electricity from black wattle (*acacia mearnsii*) waste (used for producing tannin) at the CDC-supported Tanganyika Wattel (TANWATT) facility in Njombe District (Iringa Region) since 2002. Though not part of the Southern Highlands, just North of Iringa, Morogoro Region is the center of Tanzania's sugar industry. Mtibwa and Kilombero Sugar Companies could become important power producers using bagasse.

Prospects for wind

The Southern Highlands is the cradle of Tanzania's cheap renewable energy sources. But the Southern Highlands is very far from the country's major electricity consumers. TANESCO's biggest clients (and the country's biggest consumers of diesel fuel for back-up power generation) are the gold mines in the northwest Lake Zone. Each of the eight principal gold mines in the Lake Zone represent a power load of approximately 20 MW. But this major load on the national grid could hardly be farther away from the renewable energy sources in the Southern Highlands. Actually, they can be. This gold sector is even farther away from the natural gas extracted in Lindi and Mtwara Regions. The huge distances between the site of the power generation and its use leads to grid instability and important transmission losses.

There is recognized wind power potential at three areas in Tanzania – Singida, Makambako and Same. All three areas are in proximity to the main grid, and, at the moment, can currently only seek the national grid tariff ($0.07/kWh), unless they could "wheel" (send their electricity along the national grid) to major customers. Of the three areas with confirmed reliable wind resources, Singida is geographically close to the gold mines in the Lake Zone.

The expense of wind development, coupled with the low main grid tariff, currently prevents the development of new projects. Two 50 MW initiatives at Singida have been unable to progress for three years. An investment of greater than US$130m to sell power at $0.07/kwh does not attract banks. It has been estimated that these projects need a tariff of US$ 0.12 to be viable. Of course, they could receive that, as they are both larger than 10MW and therefore not bound by the SPPA tariff fixed by EWURA. They could negotiate their tariff independently. But if TANESCO's avoided cost on the national grid is US$ 0.07, is it in the company's interest to agree to purchase power at US$ 0.12, especially given TANESCO's current perilous and well-documented financial situation?

Scoping out a prospective wind generation opportunity
There is no such company called Singida Windpower (TZ) Limited, but let's suppose there was. What might its project be like?

The Singida Windpower project would comprise the construction and operation of a grid connected wind farm in Singida. Singida is in Central Tanzania about 400 km west of Dar es Salaam and is a low-income area with little technological development. The nominal power capacity of the wind farm would be 50.4 MW, comprising 24 wind turbines each with a rating of 2.1 MW. Once completed, the project would be generating 263 GWh/year, which would be fed into the Tanzanian national grid that passes within less than 1km of the project site. Output from the wind farm would supplant thermal generation, which would result in environmental benefits and also reduce the impact of the vagaries of international oil prices on electricity bills in Tanzania.

If the project cost US$ 130m to develop and sold power to TANESCO at the grid's avoided cost of US$ 0.07, the project's payback period would be just over seven years (though not without substantial risk of not being paid). Approximately 30% of the project's investment will flow to local suppliers.

Tanzania's electricity generating system has been predominantly hydroelectric, until the recent growth in demand and vagaries of weather required the installation of thermal generating systems. Tanzania's electricity demand has been growing at rates exceeding 10% in recent years, and the installed capacity has not been able to keep pace with the demand, particularly in the face of varying hydrological conditions. Currently, the generating system had a total installed capacity of 979 MW, fairly evenly split between hydro and thermal sources. However, the available hydro capacity had been compromised by adverse weather, which had resulted in low water levels since 2005.

In addition to helping to meet the growing demand for electricity, the Singida Windpower project would also increase the share of renewable energy on the grid. Wind speed data displays inverse correlation with hydrology, which means that enhanced output from the wind facility would be available during periods of poor hydrology, thereby increasing security of the country's power supply.

Skills would be transferred from Europe to Tanzania, both at a national and at a local level. The project would generate opportunities for new renewable electricity technologies to be utilized in Tanzania. Singida Windpower would have a major demonstration effect and would go far towards encouraging other investments in clean electricity generating technologies. Capacity will be built in wind turbine installation, project design and management, and in installation, maintenance and operation of wind farms. Through technology and skills transfers from Europe and Asia, parts of the wind turbines would be manufactured in Tanzania. During the 25-year life of the project Singida Windpower would create about ten to twenty permanent jobs.

Singida Region is a very disadvantaged and economically depressed part of Tanzania. During the12-15 month construction period, the project would contribute to increasing economic activity in the area by creating up to 300 jobs in the local area, which would increase local revenue generation and stimulate the local economy. This would be achieved through employing local contractors, suppliers, engineers, surveyors, construction equipment, maintenance personnel, and local support businesses in order to involve the community in the project to the greatest extent practical. Local personnel would be trained to perform turbine maintenance and operation to develop and enhance local participation.

Assuming that the current national electric grid has a greenhouse gas emissions factor of 0.5 tons of CO_2e (carbon dioxide equivalent) per megawatt hour – a fairly safe estimate – the generation of 263 GWh of green power would result in annual carbon emissions reductions of 131,500 tons. At current prices for Certified Emissions Reductions (CERs) of approximately US$ 16.8 (euro 14) the value of those CER is US$ 2.2m annually, and US$ 46m over 21 years (a 3 X 7 years CDM period).

Perhaps, however, the most important consideration, from TANESCO's standpoint, on whether or not to purchase electricity from Singida Windpower (TZ) Limited is the additional capacity that the project brings to the grid, and geographically at a strategic location. If the Singida Windpower project could be gradually scaled up to 200MW, it would go a long way to supplying the load of the entire gold mining sector in the Lake Zone. Current transmission losses on the grid are estimated at 25%, and perhaps higher when power is generated in Dar es Salaam for use in the Lake Zone. These losses could be largely avoided if wind power was generated in Singida. 200MW of power generation in Singida are practically the equivalent of 250MW generated in Dar es Salaam. This translates into greater energy security and grid stability.

What would be the financial implications of the project to TANESCO? If TANESCO purchased wind power at US$ 0.12, ¢5 above the current avoided cost, it would spend US$ 31.5m, and US$ 13 million more than if it was purchasing an equivalent volume of small hydro or biomass generated power from the Southern Highlands.

Case Study 4: REDD+ Opportunities for Tanzania (based on paper by Pius Yanda, Institute of Resource Assessment (IRA), University of Dar es Salaam)

Introduction

Several studies have established that forestry endowment in Tanzania, which is approximately 34.6 million ha of forests and woodland habitats (UN-REDD, 2009; Zahabu, 2008 and Blomley et al., 2008); are currently facing alarming rates of deforestation due to demand for biomass fuel and other income generation activities. It has been estimated that Tanzania has lost an average of 412,200 ha of forests per annum in the 1990s and early 2000s; this amounts to a destruction of 14.9% of its forest cover in the period 1990-2005 alone (UN-REDD, 2009).

Deforestation has been related to population dynamics, poverty among rural communities, inadequate energy substitutes and limited technology to better utilise the available natural and energy resources (UN-REDD, 2009). Biomass demand among rural and urban populations has made deforestation worse, partly due to heavy dependence on firewood and charcoal for cooking and heating as well as unreliable electricity. Forests provide over 90% of the national energy supply through fuelwood and charcoal, and 75% of construction materials (Milledge *et al*. 2007; Miles et al., 2009).

Population growth in major towns, such as Dar es Salaam, has caused significant deforestation in adjacent regions and forests. Dar es Salaam, for example, had a population of 396,000 inhabitants in 1972 while today it is estimated to have grown to 3 million. This rise in population makes Dar es Salaam the 9th fastest expanding city in the world, and is undoubtedly connected to rates of deforestation (UN-REDD, 2009).

Poverty has also been historically related to deforestation; 50% of Tanzanians live below the poverty line and the country as a whole is 90% dependent on biomass for its energy needs with only 1% of its rural population having access to electricity in the rural areas (URT, 2005). One of the national strategies that were established to reverse this deforestation trend was the introduction of participatory forest management about few years ago. Participation of communities in forestry management operates in two major forms; Joint Forest Management (JFM) and Community Based Forest Management (CBFM). CBFM concerns forests situated on village or general land while JFM relates to those on reserve land. Despite these participatory forms in the management of forests, there are claims central government still has extensive powers in the management of forests in the village, general or reserved land.

REDD has received considerable attention and identified as one critical approach that will address deforestation trends and facilitate poverty alleviation in Tanzania. REDD is also an important global step towards climate change mitigation by reducing the levels of greenhouse gas emissions. Some studies have established that 15-20% of global GHG emissions are attributed to deforestation and forest degradation. As shown in the table below, Tanzania stands as the key stakeholder in the REDD initiative, partly due to extensive forest cover, increased threats to forests degradation and the establishment of PFM strategies that provide the basis for the implementation of REDD.

Forest Ecosystems in Tanzania: Location, Threats and Characteristics

Ecosystem / forest type	Extent /location	Main Deforestation and Degradationdrivers and threats	Other considerations
Miombo Woodlands	≈ 220,000 sq km, about 2/3rds total forest, esp. west & south: Tabora, Morogoro, Iringa, Manyara, Tanga regions	Medium level pressure from agriculture (e.g., tobacco in Tabora area) and charcoal	Mostly outside forest reserves or other protected areas; valuable timber spp.
Coastal Forests (excluding mangroves)	≈ 8,000 sq km in 50-200 km coastal belt - Dar es Salaam, Tanga, Lindi, Pwani & Mtwara areas	High pressure from illegal logging, charcoal, biofuel plantations and agriculture.	High levels of biodiversity and endemism (except thicket forest); tends to be small isolated patches, especially hilltops, islands

Eastern Arc and other Montane Catchment Forests	Eastern Arc ≈ 3,500 sq km; mainly found in national forest reserves (NFRs) and Nature Reserves at top of mountain blocks in Iringa, Morogoro, Tanga & Kilamanjaro regions	High pressure from fire, encroachment, illegal logging for valuable timber spp., slash & burn farming	Very high levels of endemism and biodiversity; high tourism potential
Mangrove Forests	≈ 1,150 sq km located in NFRs along coastal strip.	High pressure for poles, timber, boat building (especially near towns), shrimps & salt pans	High carbon levels and critical role for climate change adaptation
Wetlands (non-marine)	≈ 2,000 sq km, mainly found mainly in Morogoro, Iringa and Tabora regions	High pressure from irrigated rice, livestock grazing	Important water catchment functions; high carbon levels
Acacia Savanna woodlands	≈ 175,000 sg km in north & central Tanzania, mainly in protected areas (including game reserves)	Medium-low pressure from woodfuel, poles, subsistence farming, grazing	Game parks – tourism; livestock a key component of ecosystem
Guinea – Congolean lowland forests	≈ 6,700 sq km in Kagera & Mwanza regions in NW Tanzania (Lake Victoria Basin); mainly National Forest Reserves	Medium-high pressures from agriculture, esp. livestock, charcoal, near urban areas	High biodiversity values; includes Podocarpus swamp forests

Source: UN-REDD (2009)

REDD+ opportunities

Extensive forest cover and alarming deforestation have been established as the key drivers for the establishment of REDD initiatives, with the potential to reduce human intervention in forests through financial compensation for avoiding deforestation and thus contributing to their conservation. Other drivers of the REDD programme include policy reforms in forestry management (mainly through the National Forest Policy in 1998 and the subsequent Forest Act of 2002) that facilitated community engagement over 15 years ago. The participation of communities in forest management created knowledge of the value of conserving resources and facilitated the sense of ownership and collective responsibility in managing forests, conditions that are likely play an essential role in the implementation of REDD in Tanzania (Tanzania-REDD, 2010).

The use of PFM strategies is important for the REDD initiative which is based on the reality that the interests and incentives of local forest users and resident communities often are the key determinants of whether or not forests are used sustainably or unsustainably. Traditional forest management approaches based on central government protection and regulation of use failed to adequately protect forests, as shown in many forested countries throughout the world. PFM in Tanzania builds off of the country's local government institutional framework, which gives local communities a legal mandate through elected Village Councils and Village Assemblies. Equally important is the country's policy framework for land tenure, which vests these village bodies with responsibility for managing the lands ('village lands') within the boundaries of villages.

Since PFM was first developed in the 1990s, both JFM and CBFM arrangements have spread rapidly. As of 2008, PFM covers extensive areas, including about 1.7 million ha under JFM and 2.4 under CBFM. This means that about 13% of all the forest in Tanzania is under PFM arrangements, involving over 2,300 villages across the country. Therefore, PFM strategies will provide an opportunity for the engagement of communities in the conservation of forest resources under REDD.

Generally, the Government of Tanzania is committed to ensuring that Tanzanian forest-adjacent communities can voluntarily participate in and benefit from REDD as a way of enhancing forest conservation outcomes and reducing poverty (Tanzania-REDD, 2009). Besides the government commitment, it has also become widely recognized that local communities who control forest uses, formally or informally, must be key beneficiaries of funds under REDD if these new global payment schemes are to be successful in reversing existing rates of deforestation and forest degradation.

Existing local governance and land tenure framework, and track record of developing PFM in concert with those other policy factors means that Tanzania is well placed to demonstrate how local involvement in forest management and global climate objectives under REDD can be practically integrated. Tanzania's experience on implementing PFM demonstrates how empowering local communities to manage forests, through secure mechanisms for tenure and a clearly developed policy and legal framework, is key to reversing forest loss and degradation in rural areas.

REDD, in essence, presents an opportunity to create a new flow of benefits from forests to local forest managers, creating even stronger incentives for communities to conserve forests in exchange for carbon derived revenues. PFM therefore provides the institutional foundation for REDD, while carbon markets provide a source of new potential economic benefits which can build on existing forest values to create even stronger incentives for local people to manage forests sustainably (*ibid*).

REDD+ barriers

Climate change mitigation through the forestry sector has received considerable attention for addressing poverty, reducing deforestation and forest degradation and promoting conservation processes. Its implementation has also been grounded on extensive experience of promoting community based conservation in forestry and wildlife sectors; the initiative which will facilitate engagement of communities in REDD. Since early 1990s, Tanzania has made significant steps towards improvement of management of its forest resources; some important steps being the implementation of Community Based Forest Management (CBFM) and Joint Forest Management (JFM) (Blomley and Idd, 2009).

Whilst PFM provides a useful framework for helping implement REDD+, there are a number of key challenges that will need to be overcome:

The high rate of deforestation. Despite being well positioned, the rate of deforestation is going to be difficult to address. The main direct causes of deforestation are clearing for agriculture, overgrazing, wildfires, charcoal making, persistent reliance on wood fuel for energy and lack of efficient production and marketing, over-exploitation of wood resources and lack of land use plans and non adherence to existing ones. The underlying causes of deforestation are rapid population growth, poverty, policy and market failures (*ibid*). It has also been documented that deforestation is taking place in both reserved and unreserved forests but more so in the unreserved forests. This is partly due to inadequate resources to implement active and sustainable forest management, deforestation through encroachment and over-utilisation in forest reserves which are under the jurisdiction of the central or local governments (Blomley and Idd, 2009).

The legal dysfunction in forestry management. Although, forest legislation (mainly the 2002 Forest Act) provides a clear and unambiguous legal basis for the management of forests on village lands at individual, group and community levels, implementation of JFM for instance has been more uncertain (even though legalised through the signing of JMAs). While the law allows for a wide range of partnerships within a JMA, and option for delegated management where management rights can be devolved from government to a third party agency (such as an NGO, a community group, a private company or a local government body), there are no known cases of this happening on the ground. In addition, while several hundred villages have been supported to develop JMAs around a range of forests managed by central or local government, only a limited number of these agreements have been signed by the government (Blomley and Idd, 2009).

Challenges to PFM. Despite the overall success of PFM in Tanzania, these approaches continue to face several key challenges which may also be a constraint to REDD implementation. One challenge to PFM has been developing flows of local benefits from forests under local management. Despite many years of developing PFM, and the presence of valuable stocks of timber on many areas under PFM, there is very little revenue being captured at the village level from these resources. By contrast, levels of illegal timber harvesting in Tanzania in recent years have been high (see for example TRAFFIC report, 2006), but this trade has generally bypassed local communities. Although PFM has had many successes in improving forest conservation and community tenure security, which REDD can further, there are still uncertainties which can either be partly resolved or further exacerbated by REDD, depending on its design and execution.

Summary of Tenure/Institutional Systems for Forest Management

Institutional / Tenure basis	Main characteristics	Implications for carbon finance
Customary CBFM on village or private land	Forest areas managed for traditional, customary or sacred reasons. Managed via traditional institutions and norms. Tend to be small patches and localized in areas where traditional management is strong.	Good, although lack of formalised ownership means that permanence cannot be assured. Fragmented and small forest blocks means that aggregation is needed to reduce transaction costs.
Community Based Forest Management (CBFM) on village land	Responsibility for forest management on village land delegated to village governments, groups or individuals. Widespread, with forest areas per village varying from a few hectares to tens of thousands of hectares. Concentrated mainly in miombo, coastal and acacia woodlands.	Good. Legally defendable rights to trees, land and carbon. Fragmented nature of village forests means that aggregator is necessary to reduce transaction costs. High demand for timber, land and charcoal close to urban areas makes site selection critical.
Wildlife Management Areas (WMAs) on village land	Allows an elected CBO known as the Authorised Association to manage wildlife resources on village land and obtain a share of hunting revenues. WMAs are large, but only 16 legally established to date due to high establishment costs and delays.	Quite good, e.g. large forest blocks and well-defined management bodies. But procedures and institutions for forest management are different to village wildlife management: clarification is urgently needed.
Joint Forest Management (JFM) in National Forest Reserves (NFRs)	Legal agreements between the state and local user sharing management responsibilities and returns. But failure to agree national guidelines on benefit sharing has constrained its spread and adoption.	Moderate. Forests contain high carbon values, but failure to clarify and legalise revenue sharing is a critical weakness, and means that carbon property rights are unclear.
Forest Nature Reserves (with no or minimal co-management)	Highest protection status under the Forest Act. Very limited local use is allowed, so limited for JFM. More nature reserves could be established in Morogoro and Iringa Regions.	Good. Tenure and protection are clear, and carbon values are high. Mixed picture for co-benefits: high biodiversity & hydrological benefits, low social/livelihood benefits.

Source: The Katoomba Report, 2009

Sharing of forestry benefits. Another legal challenge has been attributed to the fact that the forest law remains silent on how the benefits of forest management particularly in forest reserves managed for timber production purposes can be equitably shared with participating communities. In many cases, benefit-sharing arrangements remain in a legal limbo with *de facto* management at the local level taking place, in return for vague promises about benefits at a later date. Clearly, this is a situation that cannot be sustained indefinitely. Without benefits reaching a level that equal or exceed the costs being borne, in terms of local forest management, the long term future of PFM through JFM and CBFM remains uncertain. With the increased discussion in Tanzania over revenues from carbon financing, particularly under REDD; the question of sharing of these revenues is likely to be rekindled (Blomley and Idd, 2009).

While policy and legal frameworks in the management of forests seem to provide considerable conditions for its implementation, benefit sharing mechanisms have yet provided systematic financial flow channel and assess cultural and economic aspirations of major forest dependents, mostly the rural poor communities. The challenge may also be extended to the evaluation on how differentiated contribution of forest resources to households will be adequately covered through finance. This is due to the fact that forest contribution, demands and preferences can be different even at individual household level.

Key differences between forest and wildlife management. The highly sectoral nature of natural resource legislation constrains opportunities for communities to obtain multiple benefit streams from the management of forest and wildlife resources on village land. The highly sectoral nature of forest and wildlife laws means that the process for establishment of community based forest and community based wildlife management differs markedly. Although they do not necessarily conflict, a number of legal “grey areas” constrain community level managers wishing to manage both forest and wildlife resources in a given area of village land. As a result, the possibility of obtaining multiple revenue flows from wildlife and forest harvesting is being lost, which significantly reduces local incentives for long term natural resources management (Blomley and Idd, 2009).

Long term viability of JFM. Despite the major efforts of government to support JFM over the past 15 years, its long term viability remains in the balance. Firstly, given the high conservation status of many of the forests under joint management arrangements, the total level of permitted benefits that may be legally harvested from the forests is very low (and may be significantly less than the range of benefits people obtained prior to JFM being established, albeit illegal in nature). Secondly, even where opportunities exist for extractive use of forest reserves (such as in production forests where timber harvesting is permitted), the relative share (and type) of benefits that can be captured by communities has yet to be agreed on and the mechanism for sharing of benefits is not yet in place (*ibid*).

Issue of leakage. Leakage has also become very challenging in the implementation of REDD initiative, because local projects, albeit successful, might fail to deliver any net emission reductions from reduced deforestation in the aggregate. The Tanzanian case proves the verity of the statement that leakage can never be completely overcome. Yet it also suggests some ways in which leakage can be minimized. Even if strategic planning can favour the monitoring of activities such as illegal logging, strategic conservation projects will not on their own satisfy the energy needs of Tanzania’s rural population. This is why, in the final analysis, leakage can be brought to tolerable levels only with the implementation of practices such as sustainable charcoal production (UN-REDD, 2009).

Technical costs. The inclusion of forest degradation and forest enhancement in REDD, implies that countries will need to carry out forest inventories on a regular and systematic basis in order to quantify forest carbon stock changes. This would be an expensive undertaking if professional surveyors are employed, and there may be serious manpower shortages (Skutsch et al, 2009). Hence, while the focus of REDD is mitigating emissions, alleviating poverty and provide livelihoods alternatives among the poor, much finance will eventually be diverted to employing technical staff for estimating carbon stock.

Enforcement of the scheme. The REDD initiative may also face critical challenge in enforcing rights over forests among rural communities. Even though forest law, policy and other supporting measures such as the Village Land Act give communities clear rights over forests, enforcement often proves challenging. One concern that has arisen globally with regards to REDD is if the creation of new flows of revenue based on forests’ carbon values will result in weakening local rights to use and manage forests. This concern is based on the fact that as forests commercial values rise as a result of carbon market trends, many parties such as individual elites or private investors may try and obtain forests that communities have yet to clearly secure their rights over.

Thus the carbon market and REDD might prompt a rush for control over forests similar to the recent rush for control over lands in Tanzania’s coastal areas that has occurred as a result of the growth of the biofuels market. If REDD results in outsiders claiming control over forests that were previously used by local communities, such developments might undermine the very objectives of REDD in Tanzania. Furthermore, if communities lose access to land or resources it will also weaken their capacity to adapt to climate changes. Developing REDD in a way that helps communities to secure tenure over forests, and integrates REDD with PFM, is therefore also important to the aim of integrating the climate change mitigation and climate change adaptation agendas (Tanzania-REDD, 2009).

Current REDD projects

The Norway’s International Climate and Forest Initiative was launched in 2007, with a global commitment towards REDD efforts at international and national levels. Drawing from this initiative, in April 2008, Norway and Tanzania signed a letter of Intent on a Climate Change Partnership; with a focus on supporting REDD pilot activities in the field, capacity building, national strategy development and implementation. The Government of Tanzania has therefore embarked on developing a National REDD Strategy which will be the basis for implementation and management of REDD activities in the country. Moreover, there are other REDD initiatives, which include UN-REDD, Forest Carbon Partnership Facility (FCPF) and Clinton Foundation Climate Change Initiative (CCI) in which Tanzania is participating.

REDD pilot activities that have been supported by Norway and Tanzania Climate Change Partnership are listed in the table below.

Ongoing REDD projects in Tanzania

Project name	Description	Region	Budget	Expected outcomes
Tanzania Forest Conservation Group and MJUMITA	Making REDD work for communities and forest conservation in Tanzania	Montane and lowland coastal/miombo forest in the Eastern Arc Mountains and Coastal Forest	USD $5,9 mill. over 5 years	50,000 ha. of conserved forest, sequestering approx. 110,000 t CO_2, and providing economic benefits to approx. 20,000 people. Establishment of a community carbon cooperative.
The Jane Goodall Institute (JGI)	Building REDD readiness in the Masito-Ugalla Ecosystem Pilot Area. Support of Tanzania's National REDD Strategy	Western Tanzania, working in 15 villages	USD $2,76 mill. over 3 years	70,000 ha. of conserved forest, sequestering 55,000 t CO_2
Mpingo Conservation Project (MCP)	Combining REDD, PFM and FSC certification in South-Eastern Tanzania	Southern Tanzania, working in 12 villages	USD $1,95 mill. over 4 years	50 000 ha. of conserved forest, sequestering 50,000 t CO_2, and providing economic benefits to approx. 18,000 people
TaTEDO	Community-Based REDD Mechanisms for Sustainable Forest Management in Semi-Arid Areas	Northern/Central Tanzania, working in 10 villages	USD $2,1 mill. over 4 years	2,500 ha. conserved forest, 108,285 t CO_2, 6,000 beneficiaries
African Wildlife Foundation (AWF)	Advancing REDD in the Kolo Hills Forests	Northern/Central Tanzania, working with 15 villages	USD $2.06 mill. over 3 years	18,000 ha. of conserved forest, 15,000 beneficiaries
CARE Hifadhi ya Misitu ya Asili (HIMA)	Piloting REDD in Zanzibar through Community Forest Management	Unguja and Pemba islands, Zanzibar	USD $5.5 mill. over 4 years	60,000 ha. of forest, 16,000 rural households

The impact of REDD on fuel wood

Wood-fuel, mainly firewood and charcoal, account for over 97% of the total wood products consumed in Tanzania. However, percentage of dependence has been increasing overtime, partly due to population dynamics and quantity of agricultural produce, such as tobacco that require semi-processing. For instance, in 2003 alone, the total consumption was around 44.8 million m3: 55.7% of this was used as firewood for domestic cooking and heating; 39.7% was employed for the production of charcoal; 2.9% was used by rural industries; and 1.6% was used for processing agricultural crop (URT, 2005).

In general, Tanzania relies on biomass as the source for 91% of its energy supply (ibid). Arguably, the biggest driver of deforestation in Tanzania is the harvesting of wood for fuel and charcoal production. Populations in rural areas rely heavily on firewood for their energy (primarily for cooking), while urban populations use charcoal. According to the literature, high dependence of households on firewood and charcoal relates to the inability of some households to access alternative sources of energy due to low income. Often fuel wood is cheaper than alternative forms of fuels such as biogas and kerosene (Leach and Mearns, 1988; Hosier and Milukas, 1989; Boahene, 1998). A study by Boahene (1998) ascertains that even if the price of fuel wood were to increase, demand would not be drastically reduced due to the unavailability of substitute energy sources like electricity.

Although rural households account for 75% of the population, urban households use more biomass in relative terms, as they account for about 40% of total wood-fuel consumption (URT, 2005) Therefore, in forests surrounding village areas, deforestation have been occurring partly due to the heavy demand for fire-wood. High demand for charcoal in the cities (for example, Dar es Salaam accounts for 50% of national charcoal consumption), enhances widespread deforestation, in particular in areas surrounding the cities (UN-REDD, 2009).

The market price for charcoal remains competitive relative to other energy sources, even when it is transported from regions far from the cities. Small quantities of charcoal are produced locally by individuals in forests surrounding their villages and sold on the roadsides, but commercial quantities of charcoal are usually produced by non-local individuals or groups, who often move around the country, and transport the charcoal to the cities. As urban centres expand, so does the demand for energy, and thus for charcoal, as it remains the most viable and economically competitive source of energy for cooking purposes.

A key challenge for REDD in facilitating forest conservation will be how to adequately provide alternative energy sources for cooking and heating; and income generation sources among rural and urban communities. This is due to the fact that proper operation of REDD will basically depend on the capability of communities to avoid deforestation or even substituting their energy and production sectors. The substitution however will be accompanied by technological and economic costs, which some communities may not be able to cover. Also, the success of REDD framework in reducing deforestation, an immediate consequence will be the reduction of biomass available for energy generation.

Reducing biomass availability could substantially impact living standards in a negative manner. If utilisable biomass is further reduced through REDD policies, without simultaneously providing alternative sources of energy and income, there could be a number of negative social effects. In many areas, women and children already spend several hours a day fetching fire-wood, thus taking away from children the opportunity to attend school, and from these women the ability to engage in direct income generating activities.

Furthermore, scarcity of fire-wood forces some households to cook fewer meals per day, as well as to change their diets, thus having a detrimental impact on their health and nutrition. Also, in cold areas where fire-wood is used for heating, its scarcity can create health problems for children and elderly people (URT, 2005). Finally, charcoal production is one of the main sources of income for many rural communities. If REDD further adds to the scarcity of utilizable biomass (both for satisfying energy needs and generating income), then these social problems will be exacerbated to a large extent and accompanied by a potential fall in income, unless relevant countermeasures are taken (UN-REDD, 2009).

It is unlikely that Tanzania, in the absence of widespread commercial energy availability, will be unlikely to move quickly away from wood fuel for domestic cooking, which in 2014 is still likely to account for over 80% of total energy use (URT, 2005). The high annual rate of forest depletion in Tanzania should urge policy-makers to reform the energy sector. Although using more efficient stoves can reduce biomass energy demand, such stoves are still a large investment for the poor, and there is no incentive to make that investment while charcoal prices remain low.

Even though stoves investment could be promoted through a series of subsidies and the contribution of REDD funds and eventually contribute to the reduction of demand for biomass; limited provision of technologies and awareness among rural communities is still very low. Potentially due to increasing scarcity of wood fuel, people will shift to other opportunities for reducing consumption of wood fuel through the improvement in kitchen management, through using firewood to increase burning efficiency and extinguishing firewood and charcoal immediately after cooking (UN-REDD, 2009).

An interesting alternative solution for producing charcoal for cooking purposes is the one developed in Senegal, where the increasing scarcity of forest resources, due to soaring population and economic growth, pushed local communities to take countermeasures. In 2004, PERACOD[80] started a project of diversification

[80] *Programme de Promotion de l'Electrification Rurale et de l'Approvisionnement en Combustible Domestiques*

of sources of energy supply for domestic fuels in the city of Saint Louis, Senegal. The pilot project explored and developed techniques of agglomeration of the fine carbon dust (originating from charcoal) into carbon briquettes. The technology developed by PERACOD consists of a “Rotor Press” that makes possible the valorisation of biomass carbon dust by blending it into a mix of grass and clay. The rotor press is able to create a surrogate of bio-carbon that can reutilize carbon dust and diminish deforestation originating from charcoal production (UN-REDD, 2009). This innovation could indeed be explored in Tanzania as a viable, albeit temporary, solution for charcoal substitution. At the national level, the debate revolves around the choice to build a national grid or to continue with off-grid rural electrification projects. However, given the limited financial resources of Tanzania, it is unlikely that the government will be able to provide the whole country with such an investment in infrastructure.

Although alternative energy sources such as hydropower and natural gas are available in Tanzania, relatively cheaper than charcoal; however, there are several problems with the use of these alternatives at the moment. The first is that, while the stream of energy of these alternative sources may be cheaper, and sufficient infrastructure already exists in some cases, the household installations and appliances needed to use these energy sources are too costly an investment for most families. A second problem is that the units in which these energy sources are sold (e.g. gas cylinders) are often too large, requiring a large monetary payment at once, while charcoal can be bought in small quantities and the payments thus divided and dispersed.

The size of charcoal bags is becoming smaller and smaller to accommodate the consumers’ needs. The price of charcoal is such that it is more convenient for a family to purchase it instead of gas canisters. With a 30kg charcoal bag, an entire family (the average Tanzanian household is formed by about 5 members) can cook up to a month. Gas canisters are too expensive to justify the higher investment of buying gas stoves (URT, 2005). It is also essential that the carbon emissions of these alternatives are accounted for when assessing the role of REDD program in climate change mitigation. An additional problem is market price distortions caused by the government taxing these energy sources, especially electricity, at high rates.

Co-benefits of REDD to the Economy and Environment

Co-benefits, often called multiple benefits, are the positive impacts of Reducing Emissions from Deforestation and Forest Degradation (REDD) that are additional to emissions reductions. These include ecosystem and social benefits such as biodiversity and non-timber forest products. Potential co-benefits from REDD are widely relevant in Tanzania, where forests and woodlands support the livelihoods of 87% of the rural poor (Milledge *et al*. 2007).

The key benefit is the conservation of forests and enhancement of natural carbon stocks. Conserving forests also promotes the continued provision of wood and non-wood benefits under environmental change, thus increasing resilience to climate change for both natural ecosystems and communities (Campbell *et al*. 2009). Important consideration in the implementation of REDD is that co-benefits generated will differ depending on where and the type of ecosystem under management.

Furthermore, a recent study by Kareiva (2009) has shown that poverty reduction projects linked to conservation objectives have proved successful than projects solely focused on poverty alleviation. Further evidence has pointed to the tendency towards an inverse relationship between rural income and deforestation rates, whereby a rise of the former (after a certain threshold) is generally correlated with a reduction in the latter (Culas, 2004). This evidence makes a case for attaching REDD initiatives to as many pre-existing development projects, as well as for the inclusion of poverty alleviation and development measures in climate change mitigation.

The economic and environmental benefits of carbon trading are particularly relevant for Tanzania due to the fact that there have been high demands of sustainable forest management and poverty alleviation. The strategies are also grounded from the heavy dependence on land and forests for subsistence and growing threat of widespread forest resource degradation. Hence, successful implementation of REDD, carbon trading in particular, can inject in money to sustain forests management, raise local incomes and other forest related livelihoods as well as creating alternative development and energy sectors. The analysis further show that alternative development and livelihoods options are necessity under the current and projected climate change impacts.

Despite potential successes in the implementation of REDD, there have been concerns that leakage may reverse the conservation outputs; because while some areas may prove successful, might fail to deliver any net emission reductions from reduced deforestation in the aggregate. This is linked to the pattern of deforestation in most general lands. Almost half of Tanzania's forested lands fall under the general land category, and the general land is "open-access" for everyone; already forests in this category of land are characterized by "insecure land tenure, shifting cultivation, annual wild fires, harvesting of wood fuel, poles and timber, and heavy pressure for conversion to other competing land uses, such as agriculture, livestock grazing, settlements and industrial development (Zahabu et al., 2008).

Likewise, it has been estimated that the majority of deforestation in Tanzania takes place on general land (*ibid*), partly due to the fact that general land (with its open-access feature) is subject to a classic *tragedy of the commons*, where undefined user rights have been leading to over-exploitation of the resources. This case is not solely for Tanzanian case, the same tragedy can be assumed to take place in other countries with open-access lands characterized by insecure land tenure, even though some differences may be observed. As a global lesson, REDD initiatives are unlikely to work well at a national level as long as vast areas of a country are open-access, as severe deforestation leakage can occur in these lands. Again, the Tanzanian case-study is not only indicative of a common problem but also points to a potential solution (*ibid*).

There has been evidence on the ground as in many instances, local communities in Tanzania stopped harvesting forests unsustainably "as they realized it's *their* resource" (UN-REDD, 2009). This highlights the need of expanding community-based forest management to larger sections of general land, spreading "rights, responsibilities, and revenue" to local communities for a more effective management of common forests (Sumbi, 2009). Therefore, REDD initiatives can provide the presently-missing monetary incentives for local communities to bring open-access forests under a regime of commonality and sustainable forest management.

In addition, REDD initiatives both be *affected by* and be an *agent of change of* land tenure systems. Insecure land tenure can lead to the failure of REDD, but REDD can also help define and secure land tenure rights, providing the incentive for communities to do so. Generally, effective monitoring of REDD projects and sustainable forest conservation (e.g. sustainable charcoal production and consumption) can prove REDD initiative in Tanzania a reality, and bring leakage to tolerable levels. This should be complemented by the enhancement of alternative sources of energy.

Furthermore, successful implementation of REDD initiative will depend on the ability to ensure that the price per ton of carbon sequestered will be high enough to prevent the proprietors of the forests from using the forests for other purposes, including but not limited to agriculture, industrial development, commercial harvesting, firewood collection, and cultivation of alternative crops such as those used for bio-fuels (UN-REDD, 2009). This is associated with the fact that, very often the owners/users of forest resources have little option besides cutting down the forests to satisfy their basic needs. This is why initiatives such as UN-REDD will be successful only if it will be integrated in a strategy of overall development, whereby the energy and agricultural needs of developing countries are given the same consideration as the global benefits deriving from the conservation of the world's forests (UN-REDD, 2009).

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Appendix 2. Additional supporting graphs for emission / projections estimates

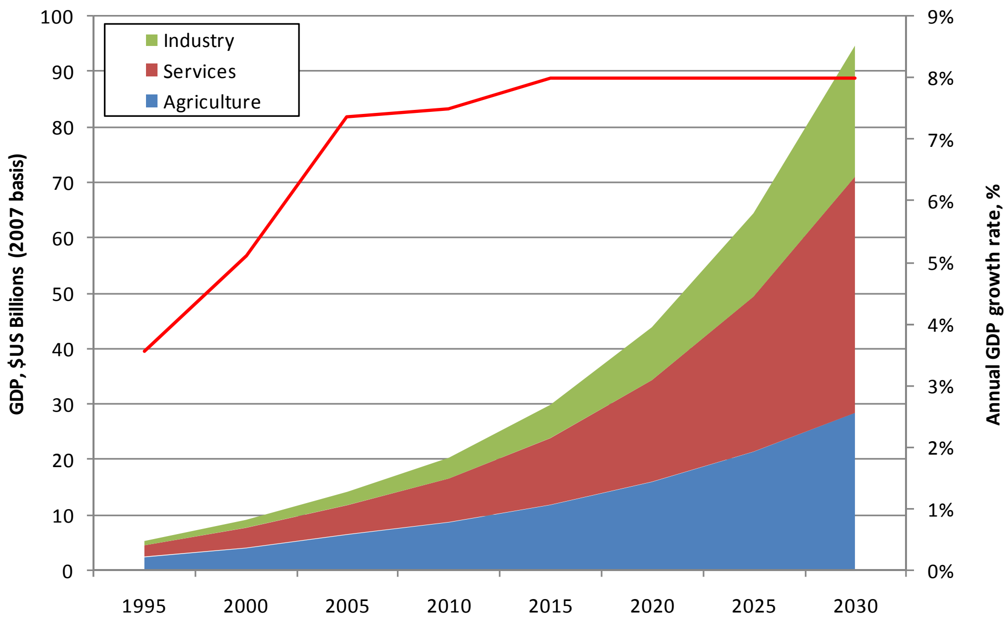

Figure 28. Historic (1995-2005) and forecast (2010-) GDP for Tanzania, US$ billion, and annual GDP growth rate
(Source: Historic GDP and sector shares from World Bank Development Indicators[81])

[81] World Development Indicators (WDI), http://data.worldbank.org/data-catalog/world-development-indicators

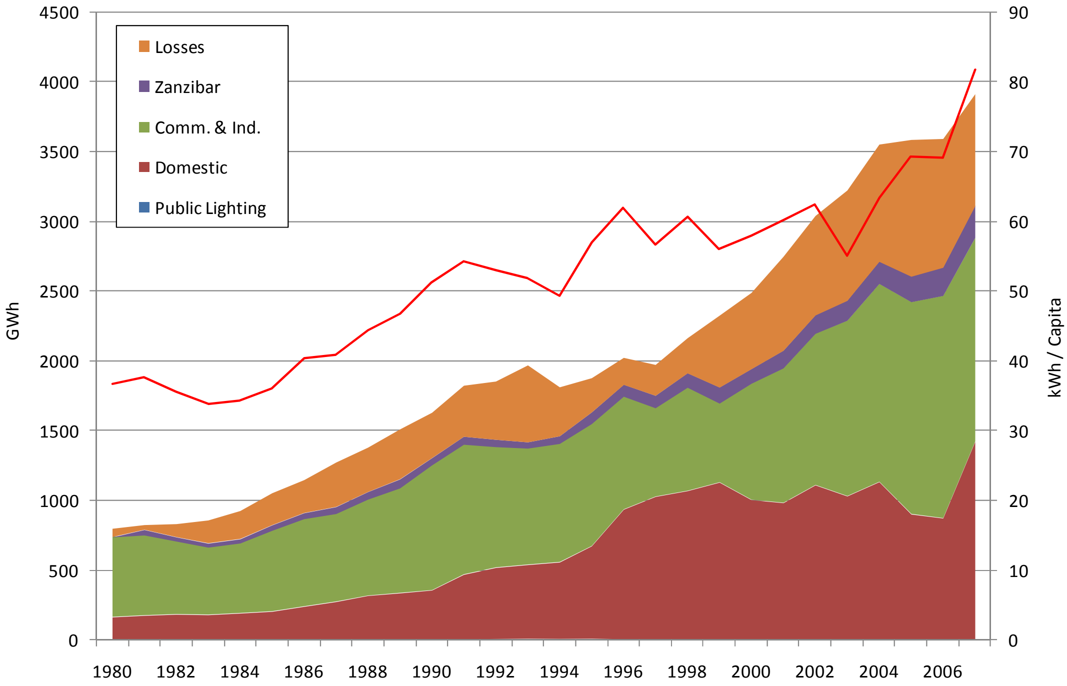

Figure 29. Historic levels of electricity generation and sales by sector (GWh), and electricity consumption per capita (kWh per capita)
(Source: GoT 2008; Per capita estimates from World Bank WDI)

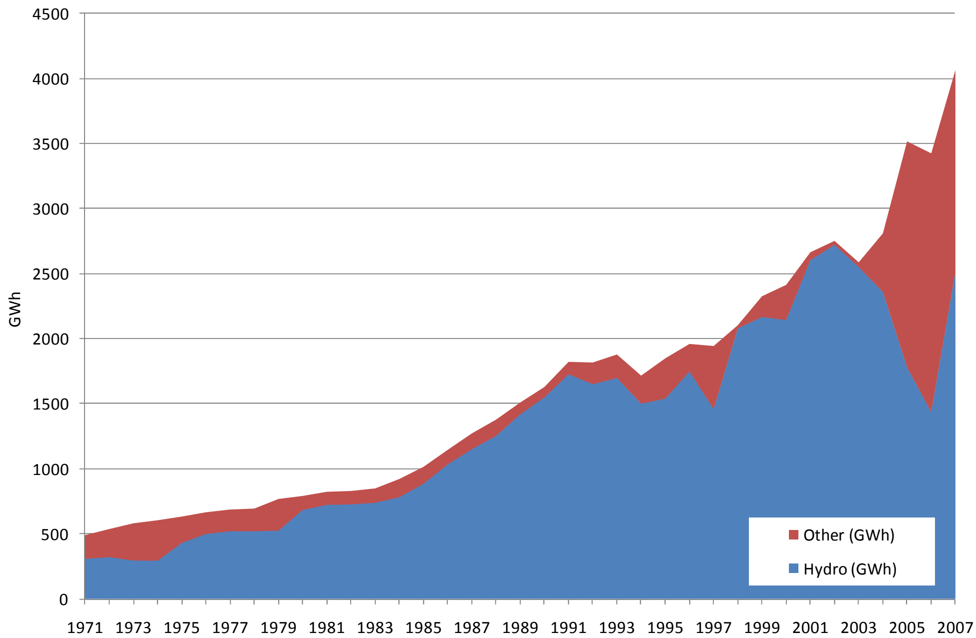

Figure 30. Hydro generation as a proportion of total generation, GWh
(Source: IEA 2009)

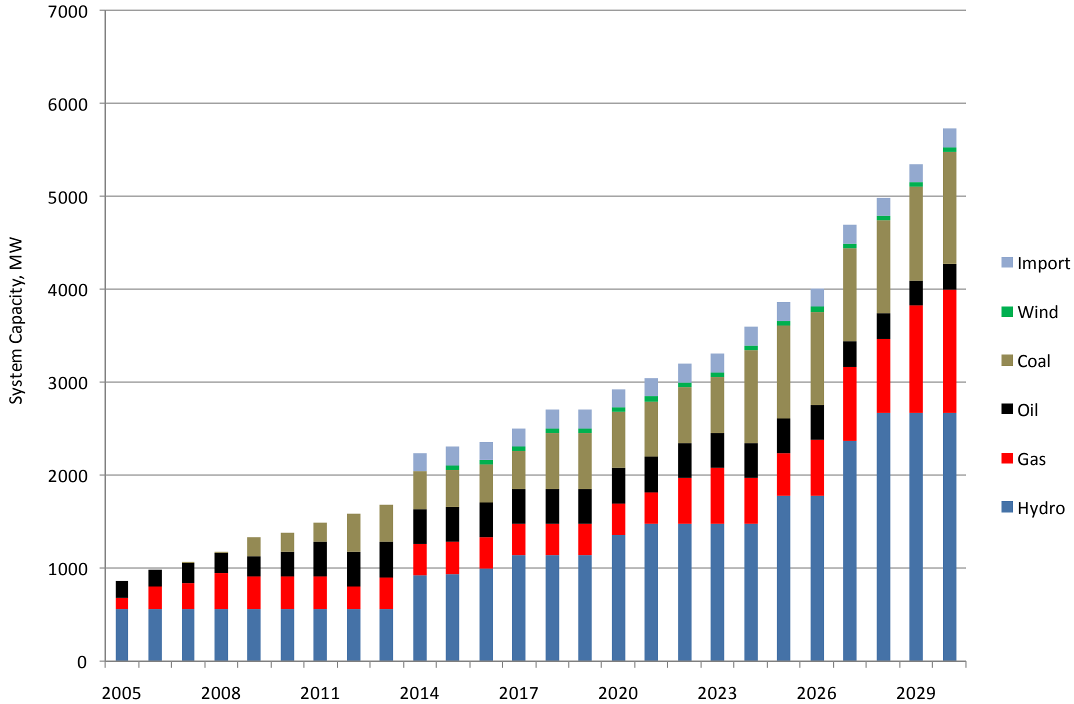

Figure 31: Forecast electricity system capacity for Tanzania, 2008-2030
(Source: GoT 2008b)

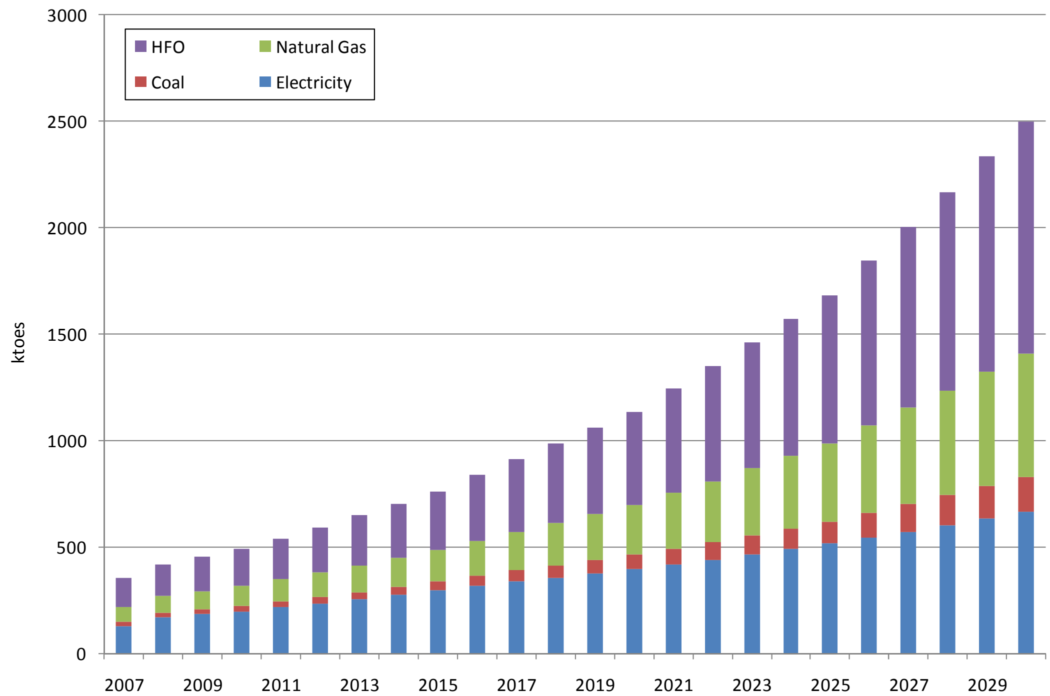

Figure 32: Projected energy consumption in industry sector, 2007-2030

Appendix 3. Data sources and assumptions used for LUCF sector emissions and projections estimates

Emissions have been estimated based on a number of datasets as presented in Table 13 below. The key documents have been the 1st National Communication (GoT 2003) and the FAO (2010). Details of the projection parameters used are presented in Table 14 and are based on IEA wood fuel estimates, FAO (2010) on deforestation rates (412kha/yr), FAO assumptions of forest planting and GDP growth rates for agriculture and industry.

Table 13. Description of data sources for LUCF estimates

LUCF Sector	Historic Estimates (2005 – 2010)	Projections
A Changes in Forest and Other Woody Biomass Stocks (Excluding Natural Re-growth)		
A: Plantations and Planted Trees: Changes in Forest and Other Woody Biomass Stocks (Excluding Natural Re-growth)	Based on 1NC 1990 data and FAO FRA 2010 planted forests stats and assumptions: 4.3.1 Estimation and forecasting FAO FRA 2010. Note that 1NC also has other estimates totalling ~418kha in 1990. Assumed these "non forest trees (5-1s1 row 38 & 39) are also included but not in FAO data.	Based on projection from 2010 using assumptions on plantation and planted from FAO expert judgement FAO_FRA2010 4.3.1 (10,000ha over 2005 - 2010). See projection parameter no 5
A: Total Biomass Consumption From Stocks: Changes in Forest and Other Woody Biomass Stocks (Excluding Natural Re-growth)	Based on woodfuel and charcoal consumption split from 1NC and re-estimates of total consumption from IEA Energy Balance Biomass, Roundwood and timber based on FAO-FRA-2010 T11: CO2 release from woodfuel & Charcoal CO2 included in this LULUCF estimates and not in energy.	Woodfuel based on projections to 2030 developed under this project (Projection parameter 7). Timber and roundwood projected on agriculture and industry GDP (Projection parameter 8)
B Forest and Grassland Conversion		
B: Onsite Burning: Forest and Grassland Conversion	Factored 1NC 1990 data Based on area of forest cleared from stats in World Bank tanzania_en.xls	Based on projected deforestation rates (assumed to be 412kha/yr) see Projection parameter 1)
B: Onsite Decay: Forest and Grassland Conversion	Factored 1NC 1990 data Based on area of forest cleared from stats in World Bank tanzania_en.xls	Based on projected deforestation rates (assumed to be 412kha/yr) see Projection parameter 1)
B: Offsite consumption of cleared forest and OWL (Burning assumed to be all accounted for under energy): Forest and Grassland Conversion	Factored 1NC 1990 data Based on area of forest cleared from stats in World Bank tanzania_en.xls. Note: Estimate excluded from 1NC all estimates as assumed to be included in Energy. However as all CO2 is excluded from energy sector it is included now in LUCF estimates.	Based on projected deforestation rates (assumed to be 412kha/yr) see Projection parameter 1)
Excluded:------B: CH4 from Flooded land (1NC table 36)	Not sure this number is correct (= 1284.66 * 21 to convert to CO2) Estimate is based on 1NC which assumes 1t/CH4/ha/day while 1996 IPCC has about 2.21 (0.31+1.9) kg/ha/day and recalc of 1NC conversion on p 116-117 = 1kg CH4/ha/day	Excluded

C Abandonment of Managed Lands	Assumed constant from 1NC data	Assumed constant
D CO2 Emissions and Removals from Soil		
D: Total Net Change in Soil Carbon in Mineral Soils: CO2 Emissions and Removals from Soil	Factored from 1NC Based on World Bank (% Arable Land)	Factored from 2010 based on area of arable land calculated from cumulative deforestation rates @ 412kha/yr assuming all deforestation is for arable land. (see projection parameter 3)
D: Total Net Carbon Loss from Organic Soils: CO2 Emissions and Removals from Soil	Factored from 1NC Based on World Bank (% Arable Land)	Factored from 2010 based on area of arable land calculated from cumulative deforestation rates @ 412kha/yr assuming all deforestation is for arable land. (see projection parameter 3)

A Changes in Forest and Other Woody Biomass Stocks (Natural Forest and OWL regrowth)	Based on >20 years old growth uptake assumed from p111 of 1NC for all forest and wooded land as harvested for fuel wood and need to assume regrowth. Growth assumed to be proportional to forest area as in FAO FRA 2010 Area (1000 hectares) 1.4 T1	Factored on forest area in 2010 based on cumulative deforestation rates @ 412kha/yr. (See projection parameter 2)

Note: CH_4 from flooded land is excluded. 1st NC estimates suggest emission is similar to emission from deforestation (27mt CO2 equiv.) which seems too high.

Table 14. Basic Projection parameters used

no	*Projections*	1990	2005	2010	2020	2030	*Description and Reference*
1	Deforestation rate (Forest clearance)	412	412	412	412	412	Assumes no increase or decrease in deforestation rate
2	Area of natural forest available for re-growth (kha)	59678	48705	45048	40928	36808	Estimates of forest land based on deforestation rate on World bank stats and FAO
3	Area of arable land kha	9000	9500	9000	13120	17240	Assumes all deforestation is for agriculture (arable land)
4	additional planting kha/yr		2	2	2	2	Based on FAO expert judgement FAO_FRA2010 4.3.1 (10,000ha over 2005 - 2010)
5	Plantation and planted forest area of stock (kha)	413	493	503	523	543	Based on Annual rate of plantation ha per year above Based on FAO expert judgement FAO_FRA2010 4.3.1
6	Area of abandonment of managed lands >20 yrs			240	240	240	Assumed constant.
7	Woodfuel consumption rate kt dm/yr	32,223	54,861	58,426	81,402	103,900	Based on study estimates for projected biomass energy use
8	GDP (Agri + Industry)			12.47	17.84	25.51	GDP for Agri and Ind sectors

Appendix 4. Inventory of lower carbon growth opportunities already being pursued

Sector	Sub-Sector	Programme / Project Name	Location	Low Carbon Option	Option type	Implementation mechanism	Challenges / barriers to implementation cited	Carbon Benefits	Other cited benefits	Synergies / conflicts with adaptation	Funding type / organisation
Electricity Generation	Centralised	New 100 MW Gas Based Power Plant at Ubungo, Dar es Salaam	Ubungo, Ilala District - Dar es Salaam	To generate power using natural gas to increase generation capacity in the grid network, will be connected to the National Grid Control Center (GCC) at Ubungo, Dar es Salaam.	N/A			Not diesel or HFO	Increase availability of electricity	Likely to increase carbon emissions	Government of Tanzania
	Centralised	100MW Independent Power Tanzania Limited (IPTL) Power Plant - Conversion	Tegeta, Kinondoni District, Dar es Salaam	To convert 100 MW IPTL plant from using expensive Heavy Fuel Oil (HFO) to using cheap natural gas.	Fuel Switching	Donor-supported		Switch from HFO to Gas	Reduce emissions	Still a fossil fuel	World Bank IDA
	Centralised	Rumakali hydropower Plant - 222 MW	Makete District, Iringa region	To generate power using Water (Hydro) to meet the growing power demands in Tanzania, will contribute to the National Grid System, injecting 222 MW.	Renewable Energy	Donor-supported		Negligible emissions	Increase availability of electricity, promote economic development		World Bank IDA
	Decentralised	TEDAP	Nationwide								
	Decentralised	1 MW power project on Mafia island	Ngombe	1 MW hydroelectric	Renewable Energy			Negligible emissions			
	Centralised	Singida wind farm	Singida region	200MW+ wind farm	Renewable Energy	Foreign private sector investors		Negligible emissions	Increase availability of electricity, promote economic development		
	Decentralised	Catholic mission	Njombe	10 MW hydroelectric dam	Renewable Energy			Negligible emissions			
	Decentralised		Mbinga	1 MW hyrdoelectric	Renewable Energy			Negligible emissions			
	Decentralised	Product and Market Development for Sisal and Heneque	Hale, Tanga	300KW pilot, possible scale-up to 10x1 MW	Renewable Energy	NGO support for startup of private enterprise		Reduced reliance on grid or self-generated diesel power	Increase availability of electricity, promote economic development		UNIDO, CFC, FAO
	Centralised	Mwenga hydroelectric project	Mufindi								
	Decentralised	Clusters PV project		Deployment of home-based PV systems to generate up to 130KW	Renewable Energy						

Sector	Sub-Sector	Programme / Project Name	Location	Low Carbon Option	Option type	Implementation mechanism	Challenges / barriers to implementation cited	Carbon Benefits	Other cited benefits	Synergies / conflicts with adaptation	Funding type / organisation
Industry	e.g. Cement	Mbeya cement		Partial conversion to biogas from Coal	Fuel Switching	Private sector					
		Tanga Cement		Partial conversion to biogas from Coal	Fuel Switching	Private sector					
		Kilombero Sugar		Feasibility study for using "bagasse" (cane waste) for cogeneration – current process is not efficient enough for self-sufficiency	Fuel Switching	Private sector	Not implemented	Reduced reliance on grid or self-generated diesel power	Reduced energy cost		
		TPC	Kilimanjaro region	Possible bagasse cogeneration – CHP	Fuel Switching	Private sector		Reduced reliance on grid or self-generated diesel power	Reduced energy cost		
		Sao Hill Industries Ltd.	Njombe	Cogeneration from timber waste -CHP	Renewable Energy	CDM		Reduced reliance on grid or self-generated diesel power	Reduced energy cost		
		Kioo Ltd. (glass bottle manufacturer)	Dar es Salaam	Converted 2x1.5 MW HFO generators to natural gas	Fuel Switching	Private sector	Completed.	Reduced GHG emissions	Reduced energy cost		
Residential	Urban										
		Switch from lump charcoal to ethanol gel/LPG			Fuel Switching	Market-based (not a formal project)	Financial capacity of consumers – lump charcoal is still cheaper for some people				
	Urban	British High Commission	Dar es Salaam	Increase efficiency of diplomatic residences	Energy Efficiency/emissions reduction	Purchase of local goods and services to the extent possible	Cost, time	Lower carbon footprint		Very small-scale project	Diplomatic mission
	Rural	Tanzania Domestic Biogas Programme	Nationwide	Promote development of small-scale biogas plants in rural areas, then encourage people to use biogas as cooking fuel rather than unsustainably-harvested wood	Renewable Energy; reducing deforestation	NGO support for startup of private enterprise	Biogas digesters can cost up to $1,000; per-captia GDP at PPP is approx. $1,400.	Reduce GHG emissions; maintain arboreal carbon sinks			
Commercial / Public Sector	Public sector	UDSM has banned lump charcoal; substituted with briquettes	Dar es Salaam	Switch to briquettes	Fuel Switching						
		UNDP	Dar es Salaam	Carbon footprinting of office	Energy Efficiency/emissions reduction						
Agriculture	All	Agricultural Sector Development Programme	Nationwide		Implied reduction of agricultural emissions via "sustainable development results"						
Forestry		Participatory Forest Management Programme	Nationwide	Empower communities to financially benefit from managing sustainable wood harvesting from local forests.	Reducing deforestation	Market-based		Maintain arboreal carbon sinks	Promote sustainable economic development		Government of Tanzania
		Green Resources, Ltd. - Fox family		Sustainable forestry and agriculture	Reducing deforestation	Private sector					
		Norgesvel REDD pilot projects		Sustainable forestry	Reducing deforestation	Market-based					
		TATEDO	Shinyanga	Sustainable forestry	Reducing deforestation	Foreign government (Norway) funded					
		Dar Charcoal Project	Dar es Salaam	Sustainable forestry	Reducing deforestation	Market-based					
		Angai PFM and REDD/REDD+ p	Angai, Tanzania	Sustainable forestry	Reducing deforestation	Market-based	Sustainability of behavior change	Maintain arboreal carbon sinks	Increase incomes for people in surrounding areas		
Transport		TPDC conversion of government vehicles to CNG	Nationwide		Fuel Switching	Government		GHG reduction	Secondary effect: Increased household access to CNG for cooking		
		Dar es Salaam Bus Rapid Transit system	Dar es Salaam			Government					