Smith School of Enterprise and the Environment

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Cities and the Built Environment Sector Working Paper

Appendix B

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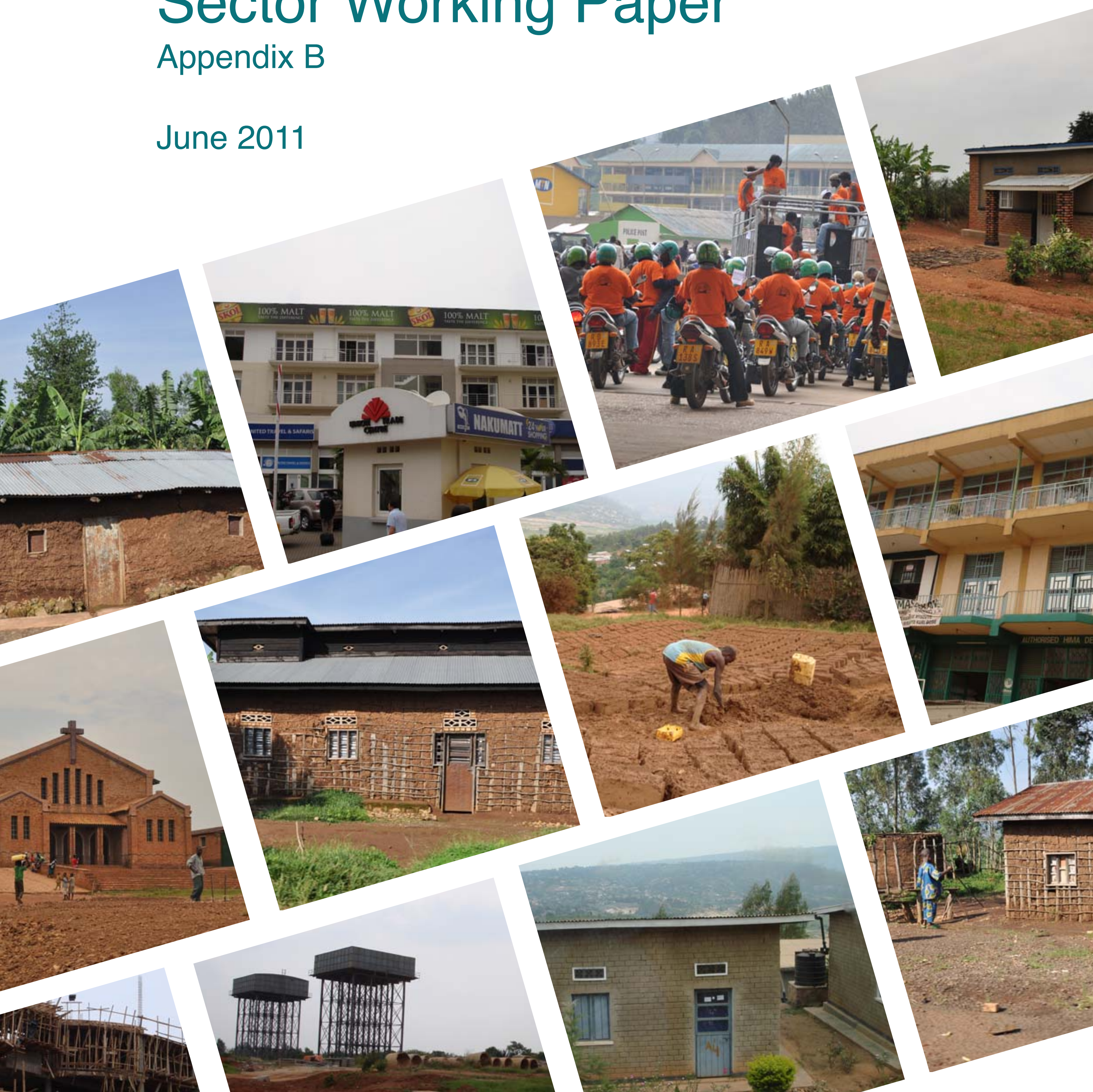

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Executive Summary

This paper is one of a series of papers, which form an initial discussion point in the development of a National Strategy on Climate Change and Low Carbon Development for Rwanda. It should be read in conjunction with the 'thinkpiece', which proposes a vision for 2050, objectives and guiding principles and strategic pillars for the national strategy. This paper reviews the 'Cities and the Built Environment Sector' covering the technology and operation of built areas in Rwanda. The paper concentrates on global best practise and covers the various policy levers that can be implemented in order to facilitate a change in the current system.

This working paper shows a number of opportunities in the built environment in Rwanda that are significant portions of developing a sustainable city. Improvements to the built environment, by passive and active systems, should be considered for all new build systems as they will reduce demand for energy supplies, reducing the cost of living in both economic and environmental terms. Integrated mass transit systems likewise offer the opportunity for low cost mobility answers, while enabling economic growth. Waste management is also a key factor and a growing issue with expanding populations. Waste should also be considered a resource, not a burden to be disposed of. These options need to supported by an increase in capacity, in terms of information, finance and human capacity.

The sector is at a critical stage of development. It is currently characterised by impermanent and unplanned structures, but an increasing level of investment is being realised, increasing the value of the embedded infrastructural making any delay in the implementation of sectoral change increasingly expensive.

Contents

Acronyms and Abbreviations

BedZED	Beddington Zero Energy Development
BNR	National Bank of Rwanda
BRT	Bus Rapid Transit
CapEx	Capital Expenditure
CDCF	Community Development Carbon Fund
CDM	Clean Development Mechanism
CDM EB	Clean Development Mechanism Executive Board
CER	Certified Emission Reduction
CO_2	Carbon Dioxide
CO_2e	Measurement of greenhouse gases global warming impact equal to that of one tonne of carbon dioxide
CPT	Cable Propelled Transit
DNA	Designated National Authority
DOE	Designated Operational Entity
EWSA	Energy, Water and Sanitation Authority
FONERWA	Rwanda Fund for the Environment
GHG	Greenhouse Gases
GoR	Government of Rwanda
KCC	Kigali City Council
LED	Light Emitting Diodes
MINECOFIN	Ministry of Finance and Economic Planning
MININFRA	Ministry of Infrastructure
NEMA	Uganda Natonal Environment Management Authority
NGO	Non-Governmental Organisation
NO_x	Nitrogen Oxide
pCDM	Programmatic Approach to the Clean Development Mechanism
PoA	Programme of Activiities
R&D	Research and Development
RDB	Rwanda Development Board
REMA	Rwanda Environment Management Authority
SSN	SouthSouthNorth
tCO_2	tonnes of carbon dioxide
TK	Bangladesh taka
UK	United Kingdom
USD	United States Dollars

Introduction

This paper is one of nine sector working papers written as part of the process of developing a National Strategy on Climate Change and Low Carbon Development for Rwanda. It follows on from the Baseline Report produced in February 2011, which provides the local context for each sector, including current programmes and development plans. This paper focuses on Cities and the Built Environment while the other working papers cover Energy, Water, Agriculture, Land, Forestry, Transport, Mining and Finance. The paper should be read in conjunction with the 'thinkpiece', which proposes the Strategic Framework including a vision for 2050, objectives, guiding principles and enabling pillars. The aim of each paper is to identify the vulnerabilities and opportunities facing the sector, to review global best practice and relevant case studies, and to propose an action plan for

Box 1: Vision – a visionary aim for the built environment in Rwanda by 2050

As a forward-looking document the following vision is presented as a guiding statement:

In 2050 urban areas within Rwanda will be low energy, socially inclusive, affordable system, with open spaces, civic buildings and effective commerce space. The basic needs for Rwandans, such as housing, education and employment opportunities, transport, sanitation and healthcare will be met, raising the quality of life. This will be achieved by:

- A well planned and developed urban areas, both in Kigali and in secondary urban centres taking into account the current needs and future desires of Rwanda
- Consisting of energy efficient passive structures taking full advantages of natural energy to reduce demand for electricity and associated emissions
- A green domestic construction, maintenance and service industry
- Integrated transport solutions involving multi-modal approach
- Comprehensive waste management minimising inputs and outputs to the urban area, encompassing, energy, liquid and solid wastes
- Socially inclusive system encompassing the entirety of the Rwandan nation
- A system robust in terms of adaptation to climate change and future demand
- Sufficient access to capacity, in terms of finance, knowledge and governance

In comparison with this the current system is:

- Characterised by unplanned and impermanent structures
- Limited connectivity to services
- Little waste management and sanitation services
- Ad-hoc transport systems powered by fossil fuels

Box 2: What could happen

Numerous other counties have undergone rapid rates of urbanisation that has resulted in increasing urban areas. One example is Bogotá, the capital of Columbia, which in 1964 constituted 9.4% of the population (1.7 million in a country of 18 million), and by 2010 this has doubled to 20%, 9.6 million of 46 million. Where this same ratio to be applied in Rwanda, Kigali could be a city of 4.4 million, which were it constrained to its current footprint of 365.5km^2 would equate to a city of 12,000 people per km^2. And where it allowed to spread unchecked? The same population could take up to 5000km^2 of urban area at the cities current density of 3000 people per square kilometer. These calculations are rough approximations, with some wide-ranging assumptions and discount the differences in push-pull factors for urbanisation in Rwanda and Colombia. They are only an illustration of what could occur not a prediction of what will.

addressing climate change and low carbon development in the short, medium and long term. This action plan is put forward to stakeholders in Rwanda for review and comment. As the title suggests, the working papers are aimed at prompting discussion with stakeholders, rather than being the final word. The sector working papers, thinkpiece and stakeholder input will be used to compose the final Strategy in July 2011.

1.1 Overview

Cities, and the built environment are what characterise current human settlement. The provision of affordable shelter is a basic human right, and is recognised as such by the Government of Rwanda. Globally, urbanisation levels have grown from 13% of total population in 1900 to 49% in 2005, which is matched by a related growth in energy use and emissions from urban areas. Unchecked and unplanned, rapid urbanisation can lead to rambling unplanned cities that bring with them issues of energy use, social desperation and health problems.

There are a number of options to develop sustainable and resilient cities, from land use planning to building technologies and transport systems. The main challenge is deigning and implementing systems that not only cost many millions of dollars and take years to construct, but in some cases will dictate the structure of the city for the next hundred years.

Rwanda is at an early stage in this urbanisation. Currently the built environment is characterised by unplanned and impermanent structures, particularly in rural areas. The government of Rwanda has an opportunity to lay the foundation for a modern, efficient built environment in Rwanda which is not only suitable for the current needs and desires of the Rwanda populous, but also flexible to future demands and challenges, particularly climate change.

Opportunities and Vulnerabilities

There are a number of opportunities and vulnerabilities facing the built environment sector in Rwanda, identified during the stakeholder engagement process in Rwanda during the baseline stage. These cover all issues and opportunities raised, whether relevant to low carbon growth and climate change or not. These vulnerabilities and opportunities are summarised in table 1.

Table 1: Vulnerabilities and Opportunities Matrix

	Economic/ Finance	Social/ Capacity	Technology/ R&D	Political	Legal/ Institutional	Environment/ Climate	Communication/ Information
Vulnerability	Low CapEx Availability Financial resources for resettlement Lack of financial resources Weak household incomes No local construction industry	Increasing Population Huge need for access to housing Inadequate human resources Lack of planning and management tools Professional bodies	Informal Structures Little or no access to services Lack of human and material resources High urban spread Little or no waste management	Planning structure Issues with project continuity	Small percentage of registered land owners Lack of town planning Capacity in district offices	Land use – high competition Access to sanitation Landfill – wasted resource Natural Disasters – Earthquakes Terrain – challenging build	Lack of basic urban data
Opportunity	Built Environment is in CDM – renovation? Development of a construction industry Private Sector investment	Provides employment Health impacts of service provision Improved quality of life Large labour force Development of Social housing	Green construction industry Passive structure lower energy demand Walk-able existences Mass transit Decentralised energy services Energy efficient 'white goods' Lack of intrinsic stock	Lead by Example Energy Security by reducing demand Housing Agency Decentral-isation Villagisati-on	Master-plans – strategic view	Terrain - distributed urban centres	Education of behavioural demand

Sectoral Overlap

Due to the nature of the urban areas, this sector overlaps with all other sectors. Urban areas consume and produce a number of resources, including land, water, energy, agricultural products and service industries such as transport and industry. Any action within the urban area will have a significant impact on the demand for these other sectors, either positively or negatively, and must be fully considered.

Focus Areas

The Government of Rwanda is undergoing a drive to improve access to and quality of urban structures in Rwanda, through policy actions, as detailed in the baseline study. The aim of this working paper is to present the various options available to produce a climate resilient and low carbon sector through innovative technology and methods, supported by the relevant policy levers. Table 2 identifies the various focus areas and options for cities and built environment. These focus areas were defined through discussion with stakeholders regarding the issues and opportunities for the sector. These were summarised as access to structures and services, improving the efficiency of the sector and the challenges of planning and implementing the desired options in the sector. These are covered in more detail in the following section, which introduces the various options and policy levers for achieving these aims.

Table 2: Focus Areas for sector

Focus Area	Option 1	Option 2	Option 3	Option 4
Access	Sustainable housing	Universal transport systems		
Efficiency	Household services and goods	Passive buildings	Integrated waste systems	
Implementation/ Planning	Finance	Capacity	Institutional Framework	Data

Global Best Practice

Due to the combined nature of cities and the built environment the following section discusses the various technical and policy options for sustainable urban areas.

5.1 Land Use/Urban Planning

The initial phase of any urban area is the land use and planning phase. This initial process can give the urban area is physical shape and main characteristic for many hundreds of years. There are a number of integrated options that should form the basis of a sustainable urban area.

5.1.1 Terrain

The terrain of urban areas is one of the key aspects that characterises an urban area. Not only does it affect the design and construction of the city, but also the operation. These effects need not be negative. Intelligent design and planning can utilise the natural environment to produce and attractive, efficient and sustainable city. Land use planning should take advantage of the natural terrain to define the density of population and the routes and flows of services and infrastructure.

Box 3: Case Study - Integration of Land Use and Bus System in Curitiba, Brazil

Since 1974 Curitiba has implemented an integrated land use and transport program with its world leading bus rapid transit system. The highest levels of residential and commercial development are concentrated in the two blocks either side of the trunk route, with diminishing densities in the blocks to either side, thus preserving large areas for low-rise residential development in the sectors between routes. The road network is centered around the trunk routes of the BRT scheme flanked by low speed local routes. To either side of this (one block away) are single direction express routes for private vehicles.

5.1.2 Ecosystem Services

Nature provides a number of services that should be fully utlised in a sustainable, efficient city. These focus around the uses of natural water flows and treatment systems (marshes and wet lands) to process liquid waste and green spaces, from natural wetlands to roof gardens and living walls. These provide low cost services that are fully sustainable. A key aspect of green spaces is urban agriculture that can supply a significant proportion of an urban areas needs within its urban boundaries. This not only reduces transportation costs for produce, but also offers some reliance to events as the cities food source is relatively close at hand.

5.1.3 Public Realm

The public realm consists of open spaces such as parks, plazas, and pathways. While often overlooked they give form and quality to urban areas. These areas promote social interaction and offer entertainment that helps give life to a city area. They must be defined at the earliest opportunity, as space that is developed for another purpose, will never become the envisioned open space.

5.1.4 Clustering

The density of the urban realm is a key characteristic for efficient cities. Not only do densely clustered developments minimise the impact of the urban area on the local environment, but also they promote efficient use of expensive infrastructural investments and services, such as mass transit systems and health centres. Similarly mixed-use and co-location developments reduce travel requirements, thus reducing energy consumption and have societal and health benefits from residents interactions and the localised nature of services which promote walking.

5.1.5 Land Use and Transportation

Transport is what allows cities to exist and it is necessary that during planning, transit orientated developments are promoted. Transport is an infrastructurally heavy, and therefore costly, system to implement and operate. Any such investment should be carefully considered to ensure maximum utilisation, often by matching the highest density occupancy to the location of transport nodes. Street design should also focus on developing as pleasant, liveable, functional and sustainable environments. Be they ‘complete streets’, which take a multipurpose view, ‘living streets’ which promote individuals access or ‘green streets’ take advantage of ecosystem services, streets should cease to be a space between buildings.

5.1.6 Liveability

It is easy to think of a city simply as a physical design exercise. But cities must work not only in terms of energy use but also in human terms, hence liveability. A key factor for liveability of urban area is its neighbourhoods. These are family focused areas, which cater for all aspects of society and are fully inclusive. Based around small mixed-use centres, neighbourhoods should promote civic engagement, the use of the public realm and provide the daily necessities of life.

5.2 Building Structures

A significant and growing proportion of anthropogenic emissions is emitted by the built environment. By careful design and construction, buildings can be constructed that have minimum energy requirements. This can be achieved in two ways, with active or passive systems. Active design uses of solar power through mechanical means, such as photovoltaic and ground source heat pumps. They are employed to convert solar energy into usable light, heat, cause air-movement for ventilation or cooling, or store heat for future use. They are usually regulated by computer-controlled systems, to maximise their efficiency. Any system that utilises external energy supplies, such as pumps or fans is considered an active system. Passive building design is the application of good design principles to utilise solar radiation for climate control without the mechanical methods found in active systems. There are six primary passive configurations[1]:

- Direct solar gain
- Indirect solar gain
- Isolated solar gain
- Heat storage
- Insulation and glazing
- Passive cooling

Direct solar gain is the control of the amount of direct radiation reaching the living space, by utilising both man made and natural systems, such as white reflective roofs and landscaping, to cool and selectively heat a building. Orientation and sighting of the building is particularly important in terms of

Box 4: Case Study - BedZED, Zero Energy Development, London, United Kingdom

Beddington Zero Energy Development (BedZED) is an environmentally friendly housing development in England. The 99 homes and 1,405 square meters of workspace, were built between 2000 and 2002. The development follows the design principles of zero energy, high quality, water and waste efficient, utilising low impact materials and encourage eco-friendly transportation. It has utlised both passive and active measures resulting in in 88% reduction in heating requirements, 57% reduction in hot-water, 25% reduction in electricity, 50% reduction in mains water consumption and 65% reduction in vehicle mileage when compared to the average UK citizen.

direct solar gain, as houses in shade, either from trees or slopes will suffer from poor polar gain, particularly in winter, when the sun is lower. The location of neighbouring buildings can also reduce the direct solar gain. In warmer climes, such sighting and orientation techniques can be used to reduce the overall solar gain, managing the temperature of the building. Direct solar gain can be stored using thermal masses (such as water tanks and masonry walls) to provide indirect solar gain through conduction and convection, helping regulate the building temperature without external energy. Solar gain can also be utlised to passively transfer thermal energy, though either natural or forced convection of liquids and gasses, in a process called isolated solar gain. Heat storage, via thermal masses is a key aspect to keep buildings heated during cooler periods, as is insulation than limits unwanted changes in temperature. A key aspect of insulation is the location and type of glazing allowing the desired solar gains and maximising natural light, whilst preventing energy loss. Passive cooling is the slow heat transfer of heat into and out of building and is achieved by shading and ventilation. The local climate defines the design criteria of the structure, in terms or required shading etc, these are detailed in figure 1. Rwanda, while equatorial in location, has a more temperate climate due to its altitude, so will require a specific set of design criteria.

5.3 Energy efficient consumer goods

As well as the ability to reduce energy consumption by altering the physical fabric of buildings, the utilities used with the structures, such as lighting, heating and other services can be made more efficient. Good housing design can limit the amount of heating, lighting and cooling, but some energy consuming systems will always be required, and as countries develop demand for labour saving devices grows. This is achieved by a number of routes including power management and replacement technologies, such as compact fluorescent lamps. For example 2006 model refrigerators use 40% less energy than 2001

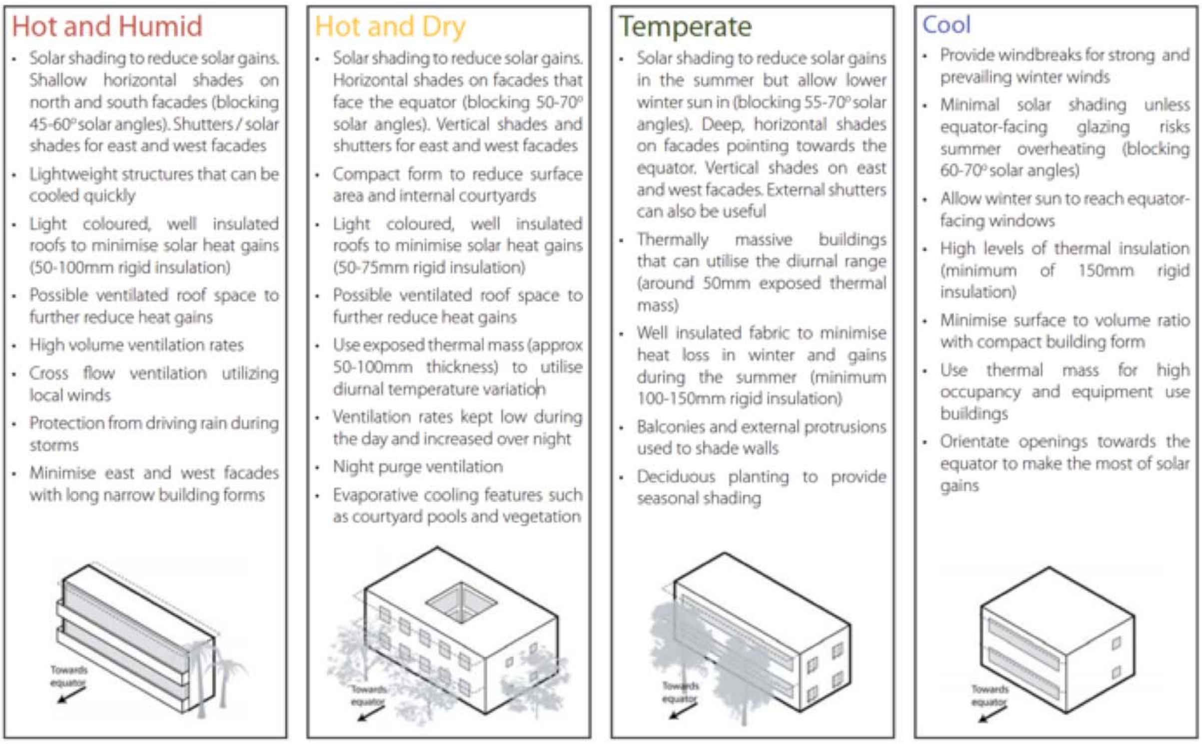

Figure 1: Passive deign critera for differing climatic zones
Source: XCO2Energy.com

models[2]. The power supply for these goods is also a key aspect, and is discussed in more detail in the energy sector working paper.

5.4 Transport

Transportation is both a key aspect of the urban landscape and major challenge. Transport systems providing necessary social and economic connections but have a significant impact on the environment, through local and global emissions, on the social fabric, through accidents and physical inactivity and economy of the city, through costs and congestion. Cities formed around a car-based system are the least sustainable. Energy use and therefore emissions are increased with the U.S. urban dweller, a nation with cities design around personnel vehicles, use 24 times more energy than the average Chinese urban dweller[3]. There are a number of options for sustainable transport systems, mainly based around non-car based technology.

5.4.1 Mass transit

The cornerstone of most sustainable urban transport systems is based around a mass transit or public transport system. These are shared passenger transport systems, which can be hired by private arrangement, such as taxis, or general access, such as busses and rail systems. These systems can be defined by the mode of transport used and have a variety of methods of operation.

All modes of transport can be utilised as public transport. Air and maritime travel is mainly restricted to international travel, though some cities uses maritime ferry systems, such as New York, and air taxi services between airports and urban centres. More common technology in urban areas is bus and rail systems, while cable systems and waterborne transport is also used in specific cases.

Bus and Coach

Bus and coach services play a major role in urban transport around the globe. With origins based in the horse drawn omnibuses of 17th century Europe, busses are a flexible, relatively inexpensive, low capacity system, which utilises the existing cities infrastructure. Bus services can be classified according to route length, frequency purpose and type of bus. Urban and surburban service, the most common system, are usually based around a network service, operating from dedicated stations and roadside stops. The size of vehicle depends on the demands of the individual route with multiple stops. Express service are a similar, often operating the same route, but service a limited number of stops and/or taking advantage of express route, such as free ways. Bus Rapid Transit (BRT) is a specialised version of an express service where high capacity busses operate on dedicated routes between a limited numbers of locations[4]. The system was first applied in Curitiba, Brazil and has since been applied in many locations globally. This system offers an increased vehicle velocity, and thus load capability, improved customer service and experience over systems that use a non-dedicated right of way[5]. This comes at a higher cost and complexity to create the system. If operating on a trunk route model is it often, but not always, utilised with feeder systems, regular busses

Box 5: Case Study - Integrated Transit, Bogota, Columbia

With a population of 7.5 million people spread over 1,600km^2 the design and implementation of this Bus Rapid Transit (BRT) system has important lessons for Rwanda. This development resulted from three visionary mayors who reformed the cities financial structure (Jamie Castro 1992-1995), civic society (Antanas Mockus 1995-1997) and then finally, under Enrique Peñalosa (1998-2001) the infrastructure of the city including transportation.

Based on the successful Curitiba model Peñalosa introduced a dedicated right of way bus system working on a hub and spoke model with feeder routes. This is linked to a bicycle lane network which provides not only routes but secure parking at BRT transit points but facilities such as showers etc.

At a cost of approximately 5.5 million USD per km it is not a cheap option but compares well with other dedicated right of way options. By 2009, 1.4 million people were using 81km of trunk system daily.

that collect from a certain locality to deliver to an interchange with the trunk system. Feeder systems can also be used with other mass transit systems, increasing the populace served by the system. Park-and-ride systems operate from out of town parking areas to urban centres, either point-to-point or a very limited stopping service, reducing vehicle numbers in city centre locations, as well as freeing central parking areas for other uses. Bus vehicles are usually fuelled by diesel, though due to their size other energy sources, such as gasses and electricity, are viable options as the low energy density and the required specialised refuelling requirements can be based at the central depot. Another option is the use of trolley busses; these are electrical powered vehicles that instead of carrying electrical charge in storage devices, are connected directly to a power source by overhead cables. These have the advantage of a domestically secure, low-carbon (depending on electricity generation mix), low emission, low noise system at a lighter weight than battery vehicles. The disadvantage include fixed routes due to overhead structures (though this is negated to an extent in BRT schemes), the higher initial unit costs compared to diesel bus systems[6].

Rail

Rail systems, which utilise steel wheels on steel rails, are a high capacity, high efficiency transport system. They can be defined by the volume of traffic as heavy or light rail system. Passenger heavy rail systems, designed to carry heavier loads, tend to be commuter, intercity and high-speed rail systems, operating over longer distances and higher speeds on dedicated right-of-way routes. Commuter systems are part of an urban transport system operating between a central urban area and outlying suburban and secondary urban centres, stopping at multiple stations. Intercity and high-speed systems operate over much greater distances, usually between major urban centres and internationally. They operate over fewer stops to ensure the rapidity of the service and high-speed rail operates on dedicated rights-of-way.

Box 6: Case Study - MetroCable Transit System, Medellin, Colombia

Metrocable is a gondola lift system implemented by the City Council of Medellín, Colombia with the purpose of providing a complementary transportation service to that of Medellín's Metro. It was designed to reach some of the least developed suburban areas of Medellín and is largely considered to be the world's first Cable Propelled Transit system. The initial conception of this system was indirectly inspired by the Caracas Aerial Tramway (also known as the Mount Avila Gondola) which was designed primarily to carry passengers to a luxury hotel. It consists of three lines (J,K and L) which operates over 4.5km of cable infrastructure. Line K cost 26 million USD and is 1.8km in length. gondolas used as transit offer many advantages such as cost-effectiveness, low emissions and energy efficiency, one of the disadvantages of gondolas is the risk of power outages. In case of a hazard or an emergency it is not possible to exit the cabins. Medellín Metro is ameliorating this problem by providing a communication system in every vehicle should an emergency occur.

Light rail systems are a lower volume systems running either on dedicated rights-of-way (true light rail) or in mixed traffic (tram systems). They are slower than heavy rail and cover smaller distances with more frequent stops but still offer higher capacity than bus systems. Another wheel-on-rail system is rapid transit or metro systems. These can be either heavy or light rail and operate on dedicated rights of way, on above and below ground routes. Above ground systems can be operated on either diesel or electrical energy, with electrical systems having a higher initial cost, but lower operating costs, were as below ground systems rely solely on electrical power due to ventilation needs.

All these systems offer high levels of transit capacity, but at a higher infrastructure requirement and capital costs. The efficiency of rail systems is highly dependent on load factor, with under utilisation negating the inherent efficiency of the system. Rail systems are also highly sensitive to

Box 7: Case Study - Compressed Natural Gas Busses in Delhi, India

The Indian City of Delhi is part of the national capital region with about 14.3 million inhabitants. Due to the rapid increase in vehicle kilometres driven and the poor technical conditions of the vehicles, the load of ambient air with automobile pollutants is extremely high. Between 1998 and 2002 all busses and 12,000 taxis and 13,500 three-wheelers were converted from diesel to compressed natural gas. This was achieved by a variety of policy options from intervention (provision of infrastructure) and regulation (banning of older vehicles and new diesel vehicles) and financial incentives (supporting vehicle replacement).

changes in elevation, requiring significant civil engineering to ensure minimum gradients.

Personal Rapid Transit[7]

Personal Rapid Transit or Personal Automated Transport is a transport system based around small, automated vehicles that operate on rails or automated guide ways. It operates a point-to-point service, with individuals or small groups travelling directly to their desired destination. To facilitate this all stations are on sidings off the main routes allowing units to by-pass stationary traffic. The main benefit of this system is its comparison to private transport in a point-to-point operation and its automated nature allows a highly reduced headway allowing a high unit capacity on a given section of the route. Due to the dedicated nature of the routes and the technology of the system the initial installation costs are high but operating costs are predicated to be low.

Cable Transit[8]

Cable Propelled Transit (CPT) is a technology that moves people in motor-less, engine-less vehicles that are propelled by a steel cable, which is powered by stationary equipment. There are two sub-groups of CPT - Gondola lifts and Cable car (railway). Gondola lifts are supported and propelled from above whereas cable cars are supported and propelled from below. The system has a highly specialised use in accessing steep and unplanned areas where ground level access is difficult if not impossible. The technology has been applied in Medellin and Caracas in Venezuela, allowing access from the steep and inaccessible ‘barrios’, which ring the city centre, or between vertically separated metro systems. The technology is low cost, fast and safe and eliminates topographical challenges. The stationary nature of the power units mean that connection to a grid or alternative power system is straightforward.

5.4.2 Alternative Energy

Another method to make urban transport sustainable is the use of alternative, low-carbon energy sources such as biofuels, electricity and gaseous fuels. While these systems reduce the environmental impacts of transport, they do not affect the congestion effects of private transport, a key issue in urban transportation.

Biofuels are produced by converting biomass (plant matter) into liquid fuels by a number of different of processes. Biofuels can be broadly split into three generations: first generation, which encompasses feedstock’s such as sugars and oils; second generation which is the conversion of waste biomass, such as lignocelluloic matter; and third generation which is produced industrially through algae bioreactors. Combustion of the biofuels can be achieved in standard engines or more efficiently in specifically modified engines, which allows these fuels to be a ‘drop-in’ solution to low carbon transportation. There are a number of issues with biofuels, which include food and land security for first and second generation, as well as technical issues with the mass manufacture of third generation biofuels. For all biofuels, their low-carbon, and therefore sustainable credentials rely on the production cycle. Land use change and refinement processes can turn a supposedly zero-carbon fuel source into one that emits more than gasoline[9]. An issue with all biofuels is the production level, first and second generation biofuels require significant land area to produce the necessary volume for global fuel supply and algal (third generation) require a breakthrough in mass production techniques[10, 11].

Another option is to move away from liquid fuels to other forms of energy. Electricity is an obvious choice and to reduce emissions to the absolute minimum, it is necessary to remove the combustion of carbon-based fuels from generation, by the use of renewables energy sources. The use of electricity to power transport hinges on providing a method for the vehicle to access power, either through permanent connection to the transmission grid, via over-head power line or induction technologies, or by converting it into transportable forms, such as chemical or potential energy. There is also a significant efficiency to be gained by electric motors as they are approximately 90% efficient[12]. Vehicle using a battery system rely on a on having internal battery systems, which are then re-charged or re-placed when discharged, providing energy to propel vehicles. There are a number of differing battery technologies from mature Lead-acid systems to lithium-ion which is a promising technology under development. Another option is a hydrogen fuel cell. These high tech systems convert the chemical energy stored in the hydrogen (and other fuels) into electricity by reacting it with oxygen. They are experimental systems and face issues with cost, durability, reliability and the hydrogen supply. Another option is hybrid and plug-in hybrid vehicles. Theses are a combination of electric and fossil fuel vehicles, were the fossil fuel engine is either assisted by or generates electricity for the electric motor. Regenerative braking can also be used to recover energy normally lost on deceleration. Plug-in systems have charge from a grid system, which reduces the amount of fossil fuel used as purely electric energy is used on short journeys.

Both liquid petroleum gas and natural gas can be burnt in internal combustion engines as a replacement for gasoline and diesel in regular vehicles with little alteration to the vehicle technology. Both offer lower emissions over gasoline and diesel but require specialised storage equipment both at refuelling and on vehicle. Other options include compressed air and flywheel storage, which offer emission free (at source) transit, but have limited range and are consider experimental.

All alternative energy sources have common issues, centred around low energy density (which reduces range for a given mass of energy supply), infrastructure requirements, generation or production (particularly third generation biofuels), cost and acceptance in the eyes of the consumer. All these require significant developments or investments to overcome.

5.4.3 Labour intensive transport

Often dismissed as ‘backward’ or ‘un-developed’ labour intensive transport, walking, cycling etc. are seeing a huge increase in use in developed countries. They are cheap, highly accessible and flexible systems that have health and social benefits, in addition to the transportation benefit. Many global cities, including London, Bogota, Paris, Amsterdam and Beijing are either attempting to increase or have increased the level of journeys taken by these modes. London, Paris and Beijing, the later once famous for the huge number of bicycles, amongst others, have introduced rental schemes to increase the number of bike users within the city[13]. Investments include hire systems, infrastructure (both in terms of transport corridors and end of journey facilities) and bike friendly policies such as education, tax breaks and legal support. A number of project around the world are promoting bicycles as a solution to low carbon mobility, not just within the developed nations, but within newly industrialised, emerging and less developed economies[14-17]. And bicycles need not be solely for personal transport, globally, cargo-bikes are used to transport significant cargo loads in urban and rural areas[18-20].

5.4.4. Car Sharing[21]

Another option is car sharing were consumers ‘rent’ vehicles for short periods, from commercial, public and co-operative bodies. This model has a number of advantages over traditional private owner model. Users have access to a vehicle when necessary, for out-of-town journeys, and rely on labour intensive or mass transit for the day-to-day activities. This takes away the need for owning, and therefore the argument for using at all times, private vehicles, thus reducing an individuals number of journeys by private vehicle. This reduces traffic levels, parking demand and also offers an opportunity for alternative power source vehicles. As the system is based around returning vehicles to a dedicated parking area, charging and refuelling systems can be provided for alternative (such as electric or hydrogen systems) energy source, centralising the infrastructure requirements thus lowering cost. It also lowers the cost to access of private vehicles. Car ownership is mainly focused around sunk costs, in the value of the vehicle, insurance and maintenance. Car clubs, particularly those based around a distance travelled charging system, turn that into a prospective cost, dependent on the action, i.e. number and distance of journeys etc., which also acts as a demand restrictor, informing the user of the total cost of the journey.

Box 8: Case Study - Viability of Small-scale Plastic Recycling Business, Penang, Malaysia

ABADI Plastic Industry Sh. Bhd. was established in 1996 to recycle plastic scrap. On 1,500m^2 of land with 14 staff and processes waste into new raw pellets for re-manufacturing. The process reduces disposal costs for consumers and processing to pelletised form more than doubles (from 126 to 380 USD per tonne).

Supply security is a key aspect for such businesses as is strong linakges between the upstream processes (waste collection) to downstream process (re-manufacturing).

5.5 Waste management

A key aspect to the sustainability of a city is its waste output. Waste consists of: solid, household waste; liquid, effluent and industrial outputs; gas, CO_2, NO_x and other emissions; and energy, in the form of heat, light and noise. All these outputs can be reduced by a combination of 'hard' solutions, such as technology and 'soft' options such as demand management (through efficient systems) and knowledge processes, supported by both 'command-and-control' and 'incentive-based' policies to enable the desired behavioural change.

Energy and gas emissions are dependent on the built environment, consumer goods, transport and energy generation, which are covered in other sections or under the relevant sectoral paper and is difficult to reuse or recycle. The production of both solid waste and liquid waste is dependent on the population and economic activity, and while it can be reduced through efficient it can also be reused and recycled, much more effectively than waste energy and gasses.

5.5.1 Solid Waste

Solid waste consists of everyday items that are consumed and discarded during the course of time. It predominantly includes food wastes, yard wastes, containers and product packaging, and other miscellaneous inorganic wastes from residential, commercial, institutional, and industrial sources which can be defined as one of the following classes of waste:

- **Biodegradable** – food, green and paper
- **Recyclable** – glass, metals, and certain plastics
- **Inert** – construction and demolition waste, soil
- **Composite** - clothing, packaging, plastics such as toys
- **Domestic hazardous and toxic** - e-waste, chemicals, consumer goods

This waste is usually collected in a mixed form, sorted and separated to varying degree and placed into landfill.

There are three options, which will result in a more sustainable waste operation: reduce, reuse and recycle. Reduction centres around minimising the waste produced, and would seem the most straightforward and promising option. Rwanda has taken a step in this direction by banning plastic bags, which as an inorganic material is difficult to process sustainably. Other options to reduce waste is to focus on the longevity and quality of consumer products, reduce packaging, consumer awareness and economic drivers, such as increased cost which incentivises consumers to repair and reuse goods, rather than to throw away[22]. Reuse is defined as the reapplication of products with little or no reprocessing, reusing the intact item, minimising the energy use, and therefore emissions, for the production of a given product. The most common example being deposit systems for drinks bottles. Other reuse options include: waste exchange, where companies sell waste materials as a raw material for use by other companies, and repurposing, where the product is used for a purpose unintended by the original designer and remanufacturing, were worn items are repaired, for example engine blocks and jet engines. Recycling is the processing of used materials into new products (as opposed to reusing the original product). The most common consumer products that are recycled are metals, paper, wood and some plastics. Also the recovery of valuable materials (such as lead from lead acid batteries) is classed as recycling. For reuse and recycle there must be a business case for the product produced. While composting biomass is not considered recycling the use of organic waste to produce fertilizer can be an efficient use of organic waste. Anerobic decomposition of the organic fraction of municipal solid waste has been found to be more environmentally effective, than landfill, incineration or pyrolysis, assuming the methane emissions are captured and used for energy generation[23]. Reuse, recycling and composting rely on sorting of waste into a processaeble form. This can be achieved by the consumer, at the source or at dedicated collection or buy-back centres, or by the processor at a central collection centre (either manually or automatically) or at a dump site by 'scavangers'. All these sorting processes have benefits and challenges. At source sorting relies on consumer acceptance of the process, and also complicates the transport process, with household collection, the advantage being low cost of sorting. Dedicated collection centres and buy-back operations help concentrate the collection process, but with obvious demands on land use and expense, particularly the buy-back option. Sorting by the processor, has increased economic costs, particularly with automated centralised centres, but as the difference to the consumer is minimal, the volume of recycling increases.

After the removal of all useable items from the solid waste the remaining waste must be disposed of, by incineration or landfill. Landfill has the advantage of low cost, but has environmental issues if not correctly managed, particularly with attracting vermin, leachate and health problems for the local populace. Incineration has the advantage of reduced volume of waste after processing, and the heat generated can be used for electricity generation but has an added complexity and cost, and a disposal concern for the 'fly-ash', which contains various toxic elements which can have health implication[24].

5.5.2 Liquid Waste

Liquid waste or wastewater consists of greywater and blackwater. Blackwater is wastewater, which contains faecal matter and urine, greywater is the remainder which is generated by domestic activities. If separated from blackwater at the source greywater can be used without reprocessing for agricultural activities such as

Box 9: Case Study - Innovate Ways to Promote community-based composting in Dhaka

Dhaka is a city of 5.4 milllion people producing 4,000 metric tonnes of waste daily. Waste Concern, an NGO developed, a waste composting the project 1995 on 1000m^2 of land. The drivers were the increasing volume of waste a demand for fertilizer. Sorted domestic organic waste was collected door-to-door and composted using an aerobic method. After 40 days of composting and 15 days maturing 500kg of compost is produced daily from 2000kg of waste using six works. The compost is then bagged for local sale or collected for distribution via a national fertilizer company. The pilot scheme results in earnings of 317,000 TK a year.

irrigation and domestic systems such as toilet flushing. Greywater can also be processed to become portable. As blackwater contains pathogens it requires significant processing to return to portable use. This is a multistage process including physical, chemical and biological

Table 3: Blackwater processing options[26]

Type	Operation	Infrastructure	Costs		Benefits	Issues
			Installation	Operation		
Unimproved Pit	Pit	Low	Low	Low	Cheap	Capacity, Waste needs processing
Chemical	Standalone chemical filled receptacle	Low	Low	High	Clean, easy to install	Expensive operation, chemical waste needs processing
Bucket	Removable receptacle	Low	Low	Low	Cheap	Capacity, waste needs processing
Ventilated improved pit	Ventilated pit system	Low	Low	Low	Cheap	Capacity, Waste needs processing
Ventilated improved double pit	Double ventilated pit,	Low-Medium	Medium	Medium	Capacity, waste allowed to compost	Higher cost
Composting/ urine diversion	Sealed pit, separate urine so fecal matter kept dry	Medium	Medium	Medium	Composting value	Control of moisture, manual involvement in composting process
Pour-flush	Lined pit with water trap and manual filled flush	Medium	Medium	Medium	Water flushing	User education, waste needs processing
Aqua-privy and soak-away	Water-sealed toilet with digester	Medium	Medium-High	Medium	Reduced waste processing required	User education, increasing structure
Conservancy tank	Sealed storage tank using flush system	Medium	Medium High	Medium	Insensitive to geological issues	Cost, processing and collection of waste
No Water Consumption	Closed loop water system use anaerobic and settling filtration	Medium	Medium-High	None	No water closed loop system with no operating costs	Complicated construction
Full bore waterborne sewerage	In house full flush system with centralised processing	High	High	Medium	High capacity system, centralised processing, aspirational	High water, cost and infrastructure requirements
Septic tank with soak-away or	Full flush system with septic tank to collect solids and soak-away for liquid	Medium	Medium	Medium	Higher capacity, lower waste processing	Waste handling, infrastructural requirements
Solid-free sewer	Full flush septic tank for solids and centralised liquid processing	High	High	Medium	High capacity system lower infrastructural requirements	Maintenance of system, waste handling
Shallow sewerage	Full flush centralised processing and surface level sewers	High	High	Medium	Lowe cost and easier maintenance than full bore system	Cheaper construction than full bore system

processes to produce environmentally safe fluid and solid waste. The fluid requires further processing to produce portable water, though advanced systems, such as Singapore's NEWater system, which uses dual-membrane and ultraviolet technologies in addition to conventional water treatment to produce a high purity, portable water[25]. These processes however are highly energy intensive, and have high capital and operating costs. The solid waste retained after processing can either be combusted in an incinerator or composted (which after approximately a year is safe for use). There are a number of options for blackwater processing summarised in table 3.

Policy Options

There are five categories of policy instruments, which may be used independently or as a combination to enable the desired change.

- Information
- Intervention
- Economic
- Regulation
- Market-based

6.1 Information

Information based policies are based on the provision of information, education and advice services and are aimed at increasing government involvement in decision-making. This can vary between providing information or increasing access to information to changing peoples preferences and attitudes, the various options are discussed in table 4.

These policy options generally leave the decision on behaviour on the consumer and the effectiveness of such policies relies on the consumers' capacity and incentives to act on the information and alter their behaviour accordingly. Another issue is the method of information delivery which depends on the messages target, timing and done in a credible way. Examples of information policies are the US Energy Star programme, which is expected to save 833Mt CO_2eq. by 2010[27], voluntary Climate Change Agreements in the UK[28] and public leadership programmes, such as executive orders which mandated the federal agencies to cut energy use by 35%[29].

6.2 Intervention

By providing or commissioning goods/services the government can intervene directly in the system. Financing can either be through direct taxation or by private sector funds under Private Finance Initiatives

Table 4: Types of Information Policies

Option	Description
Provision of Information	Information is provided to the public.
Public Education Campaign	These are often used to raise awareness of particular issues and present basic information.
Reporting and disclosure requirements	Government imposes regulations, which require agents to provide information. These regulations may cover issues about the information including frequency and detail.
Labeling	Manufacturers are required to state information on products in a particular format.
Advisory Service	An expert provides information and advice to a person or business.
Representation Service	An expert is appointed to act on behalf of a person or business.

Table 5: Types of Intervention Policies	
Option	Description
Direct Provision of Service	Government directly provides service in the public sector
Commissioning of Service	Government contracts the non- public sector (e.g. firms, charities) to build/operate particular services.

or Public Private Partnerships. The advantage of direct intervention is that it ensures service provision, but can result in a distortionary impact of the taxes required to support it. Commissioning services can result in the private sector provider not acting the way the government requires. Though this can be controlled to some extent through contract and regulation application, but these may result in perverse incentives and incur significant costs in monitoring and enforcement. By involving private finance, some of the risk of provision is removed from the government.

6.3 Economic Instruments

Economic instruments can be defined as either changing the prices/costs faced by agents or changing the budget within which agents operate. As with information policies, economic policies are decentralized actions, leaving the option to take action with the user, often leading to a more efficient outcome.

There are a number of key aspects of these economic policies that should be considered:

- Cost of administration – all economic policies must be administered and the cost for this should be carefully considered
- Excess burden of taxation – taxes collect less revenue than the loss in welfare to the consumer of the product being taxed
- Unproductive activity – taxation may lead to activity, such as lobbying and accounting loop holes to reduce or avoid the tax completely

Table 6: Types of Economic Policies	
Option	Description
Taxes	The government raises the price paid by the consumer or costs faced by industry.
Charges	Government charges for services that are consumed
Subsidies and Vouchers	The government reduces the price paid by the consumer or the costs faced by industry.
Tax Credits	The government reduces the cost of an activity at the margin.
Benefits and Grants	Similar to subsidies but used when the emphasis is on who receives the subsidy rather than the goods/services that are being promoted
Tradable Permits and quotas	Systems under which a right to produce a good/service (or by- product) is created and a market is created to allow companies to buy or sell these rights.
Franchises and licenses	Awards and auctioning of the right to produce a good/service is sold.
Government loans, loan guarantees and insurance	Government directly provides loans and/or provides a subsidy for the loan (e.g. through guarantees or insurance).

Table 7: Types of Regulation Policies	
Option	Description
Price and market regulation	Laws or rules that set out the prices companies can charge for particular goods/services and/or how companies can organise themselves and their relations with other companies.
Product and consumption regulation	Laws or rules relating to how products are produced – these can cover: characteristics of product/service, how the product/service is produced, who can produce a product/service etc.
Standards	Rules which set minima/maxima for particular characteristics of goods/services and production techniques.
Prescription and prohibition legislation	Rules which state what an agent must/must not do.
Rights and representation legislation	Rules which provide agents with rights and/or representation.

- Elasticity – the degree of behavioural change depends on how responsive agents are to changes
- Incidence of taxation – who bears the burden of taxation
- Costs of taxation – none taxation options have additional costs in terms of the cost of taxation raised to finance them
- Additionality – some of those receiving subsidies, grants, etc. may have behaved in the same way without the incentives. This problem can be overcome with careful targeting (e.g. means testing), although this can raise costs
- Competition – subsidies, tax credits, vouchers, benefits and grants can distort competition
- Length of concession/franchise – there is a trade-off between problems of monopoly associated with long concessions and lack of investment associated with short franchises. Some of these problems can be overcome with regulatory review and provisions in regulatory contracts (e.g. monitor price).
- Numbers of suitable bidders – there must be enough companies interested in the franchise/license for there to be a successful bid.
- Barriers to entry – this is created by the expertise of the existing contractors and the insider knowledge that they have making it more likely that existing contractors will win future contracts. Disclosure requirements may help to alleviate the problem but could enhance ability of firms to collude.
- Size and liquidity of market for permits – the potential benefits from trading permits and quotas will depend on the permit/quota market operating efficiently

Examples include energy taxes which are almost universally applied, and tax exemptions or reductions such as the US Energy Tax Act of 1978 which offered 15% tax credit for residential energy saving measures.

6.4 Regulation

Regulation is the restriction of actions, either positively (you must do) or negatively (you cannot do). Regulation is a common response of government, but they have a number of issues to consider:

- Information requirements – As a centralized process that forces consumers to act in certain ways governments need considerable information of the costs and benefits of alternative actions

- Costs – these include the costs of compliance and monitoring compliance, and costs of lobbying against regulation.
- Inflexibility – it is difficult to design regulation that is sensitive to different individuals and circumstances.
- Time – regulation takes time to develop, bring into force and administer effectively, by which time the problem may have disappeared or changed.
- Limits to regulation – to prevent excess regulation, government has imposed limits and developed processes for developing regulation that policy makers must comply (e.g., Regulatory Impact Assessment).

Examples of regulation include the 'Top Runner Programme' of Japan, which required all new products to react predetermined efficiency levels, and appliance standards found in the US and other countries[30].

6.5 Market-based solutions

These policies rely on 'soft' intervention to encourage markets to resolve problems for themselves, most importantly through self-regulation by codes of practice and accreditation schemes. The self-regulation options are detailed in table 8.

All these policy options are relevant for varying sections of the cities and the built environment. Examples include informative policies such as energy efficiency rating of buildings[31], intervention in the form of transport infrastructure (Transmilenio BRT in Colombia), economic polices such as incentives to install energy efficient goods, regulation in the form of housing standards, both voluntary (Passivhaus standards[32]) and regulatory (building regulations), and self regulation be applying codes of practice for construction industry. When a desired action is identified a full policy assessment analysis the options and therefore defining the most efficient course of action.

6.6 Institutional and Regulatory Framework[33]

The institutional and regulatory frameworks in which planning systems are situated vary enormously, derived as they are from the wider governance context and its particular history. The purposes of planning and how it is undertaken are shaped by the wider context of governance. This wider context reflects the way a society thinks about issues such as: how urban areas should develop; how the benefits of urban development should be distributed; and what the balance between individual rights and collective concerns should be as development proceeds. There are usually substantial tensions and conflicts between different sections of any society about these issues. Urban planning institutions and practices are themselves often-active players in such struggles.

Table 8: Types of Self-regulation

Option	Description
Voluntary agreement	These are rules which a community agrees to abide by – often there are no formal sanctions
Codes of Practice	Codes of practice are similar to voluntary agreements in that they are agreed within communities (usually industries) – codes of practices tend to be consumer focused and can be certified by a central agency
Co-regulation	Between the extremes of voluntary agreement and regulation there are points in between – Co-regulation is voluntary codes of practice with significant Government involvement

The institutional context for urban planning has a significant effect on its forms and outcomes. Hence, in 'learning from the experience of others', it is important to appreciate local specificities. With this in mind the following general policy lessons may be highlighted:

- Initiatives to improve planning systems need to pay careful attention to the specific institutional dynamics of particular nations, regions and cities. It is important to consider how planning agencies are related to formal and de facto government structures, and in particular the degree of decentralized power and the potential for horizontal and vertical policy coordination.
- Planning systems need to be surrounded by checks and balances on the use of investment and regulatory resources, to limit the arbitrary use of planning measures by powerful groups.
- While planning systems need the support of a legal framework, which defines rights and responsibilities, it is helpful to resist over-legalization and the rigidities and time-consuming processes which accompany this.
- Planning measures, where they have material effects, play a significant role in shaping land and property market behaviour.
- Planning systems' regulatory power needs to be combined with investment power, in an integrated and pro-active way, to release the potential of many different kinds of actors to contribute to the urban development process.
- Where planning systems and practices lack strength, respect and trust, it is helpful to focus initially on actions which bring clear benefits to many and build the ground for greater respect in the future.

Analysis

7.1 Access

Land use and planning is a key aspect of the built environment and national planning guidelines should be developed, for a variety of urban types, a basis for this could be the conceptual masterplan for Kigali as developed by Oz architecture. Sustainable housing provided through market based systems (economic incentives or regulation) or government intervention (social housing). Sustainable urban transport, centred on an efficient mass transit system, is a key aspect of a sustainable, low carbon city. The technological options should be assessed along with operational systems to choose the methodology required for successful application in Kigali. With Rwanda's resources it is expected to be an electrically powered system, and with Kigali's terrain, a rubber-wheel-on-road system, possible based around a BRT approach. It is key that personal transport; particularly labour intensive systems should be wholly integrated into the citywide transport system. This allows for socially inclusive system with minimum barriers to access. Careful consideration should be taken to ensure the inclusion of current transport operators and other key stakeholders.

7.2 Efficiency

Energy efficient consumer goods also should be utilised to reduce energy demand. Consumer goods should be assessed for efficiency gains and key options, once identified (such as solar hot water heating) should be supported by a mixture of policy levers, such as economic incentives and regulation of undesirable alternatives. Both active and passive technologies should considered, depending on the individual requirements of the site and structure. By mainstreaming energy efficiency into the building regulations this should ensure that all new build structures should be of a minimal energy requirement, these could be based upon the Passivhaus standards. While application of these technologies can result in zero carbon housing a target of low carbon should be chosen to enable an eventual transition to a zero carbon system. The ability to construct such buildings domestically would promote a domestic 'green' construction industry. Whilst improvements are currently being developed in Kigali's waste management system, the value of the product should be fully realised with a system tailored to Rwanda's needs. This should take into full account the cross-sectorial needs, such as fertilizer demand in agriculture.

7.3 Implementation and Planning

A key aspect for the implementation is the government structure and framework. It should be taken in the context of the wider governance and societal issues. In the design and reconfiguration of planning systems, careful attention should be given to identifying investment and livelihood opportunities that can be built on, as well as pressures that could lead to the subversion and corruption of planning institutions. Urban planning can and should play a significant role in overcoming governance fragmentation in public policy formulation and decision-making, since most national and local development policies and related investments have a spatial dimension. To command legitimacy, regulatory systems must adhere to the principle of equality under the law, and must be broadly perceived as doing so. The protective as well as developmental roles of planning regulation must be recognized in redesigning urban planning systems.

7.4 Climate Adaptation

Current Rwandan urban structures, both permanent and impermanent are poorly prepared for climatic variation due to climate change. Planned structures are designed to a building code that doesn't take into account the possible variations in the future, where as impermanent, unplanned structures are hardly prepared for current climatic variation. The effects climate change on the built environment can be broadly defined as temperature and precipitation changes. Variation in temperature causes challenges in producing a comfortable environment, without resorting to energy intensive cooling. This can be prevented by the application of carefully designed passive housing designs. Passive houses have a much greater ability to thermally regulate themselves, reducing the demand for mechanical cooling systems. Even when mechanical cooling is required, sustainable systems, such as photovoltaic methods should be used. Variation in precipitation is a greater challenge. Greater volumes of water result in challenges in the design of infrastructure, associated groundwork's and drainage as well as water management challenges. Reduction in precipitation can lead to water starvation preventing service provision as well as issues with building stability due to shrinkage and settling. This results in greater demands on the planning of urban areas and the management of water based service, such as sanitation. Planning systems that understand and focus on the effects of climate change are a major step towards reducing the impact of climatic events and developing resilience in the system. These can take the form of regulations, such as banning construction on flood plains and steep slopes, as well as building codes that support applicable technologies in terms of slope stabilisation, foundation characteristics and drainage systems. Water management must also take into account the demands of the built environment, providing resilience and flow management using a mixture of infrastructure and eco-services.

By utilising a combination of the technical aspects presented here, and appropriate planning systems presented in the land sector paper, Rwanda has all the necessary tools to produce and efficient and resilient built environment that meets the needs of its growing population.

Strategic Framework

Based on the focus areas and the options presented, table 9 offers a strategic framework of polices and actions that can be implemented in order to produce a resilient and low carbon built environment sector. The time scales present are offered as a guide rather than a strict timetable.

A key aspect of implementing these actions is detailed analysis of the impacts. Regulating and restricting consumer options, while enabling the desires behavioural change, can lead to unforeseen issues, particularly increased cost to the consumer. The technical aspects actually implemented must be carefully studied to ensure a successful mix between desirable outcomes, such as climate resilient systems and undesirable outcomes, such as increased building costs.

8.1 Timeline

The proposed options have an associated timescale for implementation. The pathway follows a report, analysis implement route.

Immediate:

Define current and future demand as an aid to both planning and providing measurables for defining the success or failure of projects. The information defined should include current per capita energy demand and mix, usage and types of consumer goods, per capita land fill and sanitation requirements as well as transportation measurable with respect to the urban area. Future demand could be defined by scenarios etc. and should include estimation for required skill sets, finance access and other relevant data sets. The information gathering and demand predictions should be updated in-order to allow a continuous assessment of the current sate and future need of the sector.

Short Term 0-5 years and ongoing:

Regulation and investigation into future options:

- Sustainable housing regulations for Rwanda (Rwandan PassivHaus standard) built into housing policy and construction code
- Introduction of consumer goods regulation restricting low efficiency goods
- Integrated land use system combining all sectoral needs including social requirements such as gardens and parks
- Analysis of urban transport models and modes
- Creation of efficient waste management process focussed on resource recovery from the waste stream
- Analysis of social housing options
- Analysis of alternative energy systems

Medium/Long Term 5+ years:

- Pilot projects in preferred systems identified in the analysis phase
- Construction and operation of integrated urban transit system

Table 9: Strategic Framework for Cities and the Built Environment Sector

Focus Areas Why	Policy What	Actions	Timescale When	Stakeholders Who	Measurables How	Finance
Access	Sustainable low energy built environment	- Passive housing standards inserted into building codes	Short to Medium	MININFRA, Construction Industry, Real Estate Developers, Planning and land use bodies	- Reduction in per capita energy use - Emissions from Built Environment	Private Sector, CDM
	Universal Transport Systems	- Mass Transit System - Land use regulation - Multi-mode approach	Medium to Long	MININFRA, KCC, Private sector	- Reduction in traffic intensity (vehicles per passenger) - Increase in fuel efficiency per passenger km	GoR, Donor Agencies, Private Sector
Efficiency	Low energy consumer goods	- Regulation of consumer goods	Short to Medium	Rwanda Standards Authority, Regulatory Bodies, Manufactures/ Retailers	- Reduction in Energy demand per consumer good	Private Sector, CDM, GoR
	Integrated Waste Management	- Reduce, Reuse, Recycle of waste - Waste Sorting - Composting of organic waste	Short to Long	MININFRA District authorities Waste processors	- Reduction in overall landfill volumes - Increase in internally produced goods	GoR, KCC, Donor Agencies
		- Sanitation development	Medium to Long	MININFRA, EWSA, Private sector	- Reduction in water borne pollution	Private Sector, CDM
Planning/ Implementation	Data Collection	- Accurate picture of current demand	Immediate	MININFRA	- Annual statistical collection on traffic flows, household energy use etc.	GOR
	Future Demand	- Picture of probable future demand	Immediate to Short	GOR	- University courses	Private Sector
	Capacity	- Increase in both higher education and technical skills	Short to Long		- Technical school graduates	

Financing Options

Public funds for infrastructure projects, land banking, and maintenance of parks and green spaces could come from a variety of sources. Grants could be paid out of the general budget or by Rwanda's future environmental fund, FONERWA. FONERWA, in turn, will be capitalized by both bilateral development partners and fiscal sources. Concessional loans, grants, and technical assistance could also be sought from a wide-range of multilateral development funds including:

- Public-Private Infrastructure Advisory Facility
- Private Infrastructure Development Group
- Special Climate Change Fund
- Adaptation Fund

Each has its own mandate, institutional requirements, and application and monitoring procedures which are outlined on the website www.climatefinanceoptions.org.

Most financing for the building sector will come from private sources. However, the GoR can use public financing mechanisms to incentive energy efficient building practices among private developers. As illustrated in Figure 2, concessional lines of credit, public venture capital, equity capital, and mezzanine finance can be used to leverage private capital for low carbon projects. To enable such mechanisms, a portion of FONERWA could be managed as a venture capital/revolving loan

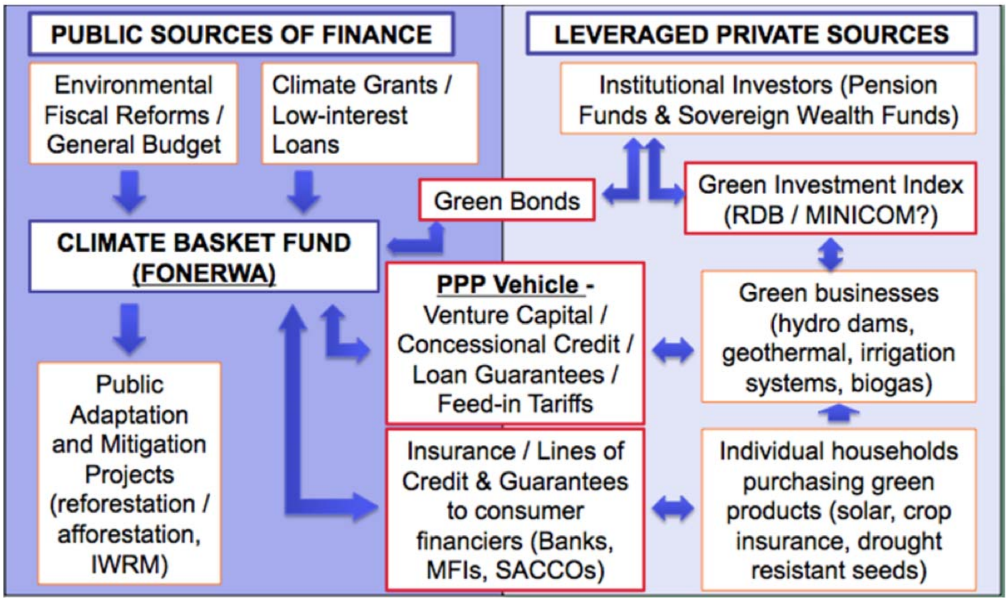

Figure 2: Using Public Funds to Leverage Private Sources of Finance

fund by the National Bank of Rwanda (BNR) or by MINECOFIN.

Alternatively, the government could also establish or promote carbon projects in the built environment sector through the Clean Development Mechanism (CDM), which is described in detail in the Finance Sector Working Paper. In theory, the CDM should represent a potentially large source of finance for energy efficient buildings. During a buildings lifecycle, approximately 10-20 percent of a buildings energy use occurs during constuction, manufacturing of materials, and demolition. The majority, approximately 80-90 percent is for heating, cooling, lighting, and appliances. Numerous technologies and building practices are available to save on these energy costs including insulation, windows, ventilation, heat sinks, solar water heaters, natural lighting, and efficient lighting technology including light emitting diodes LEDs and compact fluorescent light bulbs (CFLs)[34].

Despite these large opportunities for increasing the efficiency of buildings, very few energy efficient building CDM projects have been successfully implemented. Rwanda has one CDM programme in place to distribute CFLs. This failure can be attributed to a number of factors. There is a general lack of understanding both among those designing and constructing buildings, and those using buildings about emission reduction opportunities, and about potential financial support from the CDM. There are split economic interests in that those making decision about a buildings design, whom would have to pay the upfront costs associated with more efficient construction, are typically not those that would benefit from energy efficiency gains or be in a position to monitor a CDM project would last decades after the buildings construction. Most fundamentally, however, the structure of the CDM is inhibiting to tackling the small-scale and widely dispersed emission sources of the building sector[34].

There are also significant opportunities to generate carbon revenues through municipal waste management projects. Decomposition of organic solid waste and wastewater accounts for about 20 percent of human-induced methane emissions worldwide[40]. Methane's global warming potential is 21 times stronger than that of carbon dioxide. Hence, flaring methane will prevent potent GHG emissions from contributing to climate change and could yield 21 times the number of carbon credits

Box 10: Kuyasa low-cost urban housing energy upgrade project in Cape Town, South Africa

The Kuyasa Housing Project aims to "climate proof" 2,039 low-income residential houses that were built by the national housing subsidy program, and a one hundred hectare new development in the same area. It is registered by the City of Cape Town and is being developed by the consulting firm SouthSouthNorth (SSN). The existing single-family homes were built with brick walls and without ceilings or proper insulation. As a result they are often too hot in the summer and too cold in the winter. To improve the thermal performance and energy efficiency, the project will install insulated ceilings, solar water heaters, and compact fluorescent lights in each of the homes.

The Kayusa Housing Project faced a hurdle common to CDM projects that target low-income communities in that because energy consumption levels are so low, revenue potential from reducing those emissions is limited. To overcome this hurdle, emission reductions are calculated against a baseline of projected future consumption that takes into account "suppressed demand" instead of historical trends, and assumes emissions will rise to a normal level. Therefore, the emission reduction from installing insulated ceilings is calculated as the difference between a baseline of the required energy consumption to maintain a home at a comfortable temperature level without insulation and the lower level of consumption required with an insulated ceiling. For solar water heaters, the energy savings is the emission reduction is the difference in emission levels between solar water heaters (zero emissions) and the amount of emissions that would be produced by electric water heaters[34]. In this manner it was calculated that the project offset 9134.75 tCO2 in the 2009-2010 crediting year. Valued at US$15 per tonne, this offset is worth US$137 thousand per year[39].

as a project reducing an equal amount of CO_2. Furthermore, methane captured through anaerobic decomposition of organic waste could provide a valuable resource if combusted for electricity or heat generation, and the resulting slurry from the process could be used as an organic fertilizer. A cheaper and less technical alternative is to aerobically compost the organic waste, which could also result in a certifiable organic fertilizer as described in Box 11.

Box 11: Uganda Municipal Waste Compost Programme

In Uganda, 80 percent of the waste sent to the landfill is organic resulting in significant methane emissions. In 2010, the Uganda's Municipal Waste Compost Programme was set up as a countrywide CDM programme of activities to eliminate these methane emissions by recovering and composting the organic matter. The resulting compost is sold to farmers to enhance plant growth. Municipalities either set up and operate the composting facilities on their own, or contract the service out to the private sector. The implementing entity, the National Environment Management Authority (NEMA), provides financial and technical assistance during implementation of the composting facilities, and then monitors their operation.

To finance the initial costs of the project, the Government of Uganda has taken a loan from the World Bank. The municipalities then transfer their CER rights to the NEMA in repayment for the initial investment. NEMA, in turn, sells the CERs directly to the Community Development Carbon Fund (CDCF) of the World Bank.

On average, each municipality handles 70 tonnes of waste per day (between 50 and 200 tonnes), and 25,550 tons per annum. The average yield of compost for each municipality is about 5000 tonnes, which at the predicted price of USD 13 per tonne, is worth USD 65 thousand. The predicted emission offset for the whole programme during the first seven-year crediting period is 8370 tonnes of CO_2 equivalent per year from 2010 to 2017[41]. Priced at US$15 per offset, this offset is worth USD 125,550 annually.

Summary

Following the baseline report the following focus areas were identified as areas within the cities and built environment sector in Rwanda requiring attention: access, efficiency and planning and implementation. There are a large number of options, which when implemented, can produce a sustainable built environment while solving the demands in the development of the sector. These can be realised by a number of policy levers, which have been implemented globally with varying degrees of success. Of these options a number have been proposed in a strategic framework, which after consultation with key stakeholder, will form the basis for the draft national strategy to be presented in June. All options require careful analysis to ensure that the maximum efficiency of change is achieved while producing none, or the minimum amount of undesirable impacts.

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