Framework for the Design of Sustainable Residential Buildings in Mauritius

September 2012

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LIST OF CONTRIBUTORS

Principal Investigator

Professor (Dr) K.M.S Soyjaudah

Other contributors in alphabetical order:

1. Dr. P.C. Catherine
2. Dr. T.P. Fowdur
3. Mr. R.A. Jugurnauth
4. Mr. A.P. Murdan
5. Mr. Y.K. Ramgolam
6. Dr. G. Ramsawock

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3. Architects from MPI
4. Mr Domah, Ministry of Works
5. Mr Chaundee, Ministry of Public Utilities
6. Mr Rajcoomar, Chief Engineer CWA

The Authors

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Table of Contents

List of Figures

List of Tables

ABSTRACT

This study starts with an evaluation of the current situation regarding the residential buildings in Mauritius and proposes a number of recommendations for the design of sustainable residential buildings.

The purpose of the research work was to carry out an analysis of the current status of sustainability in residential buildings in Mauritius, study the existing policies, international standards and codes of practices relevant to sustainable residential building designs worldwide and provides guidelines and key recommendations for sustainable residential building design in Mauritius. The research involved the investigation of the fundamental issues such as site selection, construction and optimisation, energy efficiency, water conservation and preservation, use of environmentally preferable building materials, enhancement of indoor environmental quality, operational practices and waste management.

A number of all inclusive and wide ranging recommendations that can be utilised as a guide for the design of sustainable residential buildings, taking into consideration all phases of the facility life cycle, have been proposed. The study also highlights the need for the authentic commitment of all stakeholders towards environmental stewardship and conservation. The collaboration of all parties will lead to a favourable balance of cost, environmental and social benefits, and will meet the goals of sustainable development and comfortable functions of the Mauritian residential buildings.

INTRODUCTION

The Mauritian economy has been growing consistently during the years. The economy in 2011 grew by 4.0% and the Gross National Income per capita at market prices reached 253,335 rupees. National growth promises economic benefits, improvements in people's living standard and need for better living conditions. Still, standard of living should be enhanced without compromising on the quality of life.

The population and the population density of Mauritius have both been rising during the last decades. The former is currently 1,217,175 while the latter rose from 560 per km^2 in 1996 is to 632 per km^2 in 2011. Currently, Mauritius counts 311,500 buildings, 356,900 housing units whereby 341,000 are private households. Mauritius has seen constant infrastructural development during the last decade and has witnessed a decrease in the effective area under cultivation by nearly 5000 hectares from 2007 to 2009 only.

Area under built up areas has been constantly increasing during the last decade. This, together, with rising living standards, will put increasing pressure on the finite land space available as well as much more use of energy and basic services. Residential building construction and operation have extensive direct and indirect impacts on the environment, society and the economy of the country as a whole. They use resources such as energy, water and raw materials, generate waste and emit potentially harmful atmospheric emissions. Unsustainable pressure on natural resources and on environment is inevitable if economic growth is not decoupled from energy demand and energy demand from fuel consumption.

The Government of Mauritius has been promoting sustainable development in the country with the introduction of the 'Maurice Ile Durable' fund, the 'Long Term Energy Strategy' as well as the 'National Programme on Sustainable Consumption and Production (SCP) for Mauritius'. Sustainable development is one in which the needs of the current generation are met without compromising on the ability of future generations to meet their own needs. Therefore, addressing sustainability in residential building construction includes consideration of sustainable development in terms of its three primary aspects – economic, environmental and social aspects – while meeting the requirements for technical and functional performance of the construction works.

The concerning ministries, local authorities, building owners, designers and builders face a unique challenge to meet demands for new and renovated residential buildings that are accessible, secure, healthy, and productive while minimizing their impact on the environment, i.e. consider the social, economic and environmental aspects during their life cycle.

This project provides a study of the current situation with respect to residential buildings in Mauritius and provides integrated and holistic recommendations for the design of sustainable residential buildings that consider all phases of the facility life cycle. The ‘framework for the design of sustainable residential buildings in Mauritius’ supports an increased commitment to environmental stewardship and conservation, and results in an optimal balance of cost, environmental, social, and human benefits while meeting the goals of sustainable development and the functions of the local residential buildings.

Aims and Objectives

In the proposed project, our objectives are three-fold, whereas the research scope includes seven items, as described below:

Objectives of proposed research:

- Analysis of the current status of sustainability in residential buildings.
- Study of existing policies, international standards and codes of practices which are relevant for sustainability in residential building designs for Mauritius.
- Layout of guidelines and key recommendations for sustainable residential building design in Mauritius

While the definition of sustainable building design is constantly changing, seven fundamental issues persist and are investigated during the research:

1. *Site Selection, Construction and Optimisation* - Construction of a sustainable residential building must start by giving due consideration to the proper site selection. The location and orientation of a residential building affects a wide range of environmental factors and as well determines the building’s energy consumption.
2. *Energy Efficiency* - Given the long lifespan of residential buildings, their relative energy efficiency will influence energy consumption for many years. Construction of buildings offers compelling opportunities for energy efficiency, as decisions made during its design phase entail smaller costs with greater potential energy savings relative to later intervention.
3. *Water Conservation and Preservation* - Solutions and standards will be proposed to enhance the quality of life of Mauritian residents regarding water security. In broad terms, water security is about ensuring that every person has reliable access to enough safe water at an affordable price to lead a healthy, dignified and productive life
4. *Use of Environmentally Preferable Building Materials* - Buildings that use environmentally preferable construction materials and techniques are designed to minimize water and energy use, waste and make better use of natural features. In so doing, these buildings reduce impacts on biodiversity and other environmental pressures.
5. *Enhance Indoor Environmental Quality* - Indoor air quality affect a lot of factors such as health, comfort and productivity of each individual, as people spend a substantial

proportion of their time in their houses. It is therefore a requirement to enhance the quality of the indoor environment by properly designing residential buildings.

6. *Operational Practices* – Sustainable residential building design involve the use of home automation systems and adoption of best operational practices that can contribute to improved working environments, higher productivity, reduced energy and resource costs.
7. *Waste Management* - Environmental management has become a major concern recently. One of its aspects that is highly visible is waste management. Waste per capita per day generated during the last decades and its management and disposal requires lots of resources - human, financial, infrastructural, and technological. The problems associated with waste management must first be identified properly and solution must take local conditions and priorities into account.

CHAPTER 1
SITE SELECTION, CONSTRUCTION AND OPTIMISATION

1.1 Introduction

Sustainable development is one in which the needs of the current generation are met without compromising on the ability of future generations to meet their own needs. Therefore the construction of a sustainable residential building must start by giving due consideration to the proper site selection. The location and orientation of a residential building affects a wide range of environmental factors and as well determines the building's energy consumption. It is very important to address site selection at the early stages of the residential building project development in order to ensure security, accessibility, proximity to public transport and consider its impact on the local ecosystem and infrastructure. The following sections will concentrate on the current status in Mauritius with respect to site selection and propose recommendations for sustainable residential building design in Mauritius.

1.2 Current state of affairs in Mauritius

1.2.1 Situation in the Country

According to the 2011 housing census (Housing Census of Statistics Mauritius (SM), 2011) the population of Mauritius is 1,257,900 and counts 311,500 buildings, 356,900 housing units whereby 341,000 are private households. 84.8% of the 311,500 buildings in Mauritius are wholly residential. It was also noticed that from the year 2000 to year 2011, there was a 19.9% increase in the number of housing units in Mauritius as well as an 8.3% increase in the population.

The total area of Mauritius is 186,500 hectares and the climate change activities report (2006) outlines the land use distribution which is given in the figure 1.1 below. It is clearly noticed that built-up areas, which consist of land under houses, industrial zones, quarries or any other facilities, including their auxiliary spaces, deliberately installed so that human activities may be pursued, cover 25.3% of the total area.

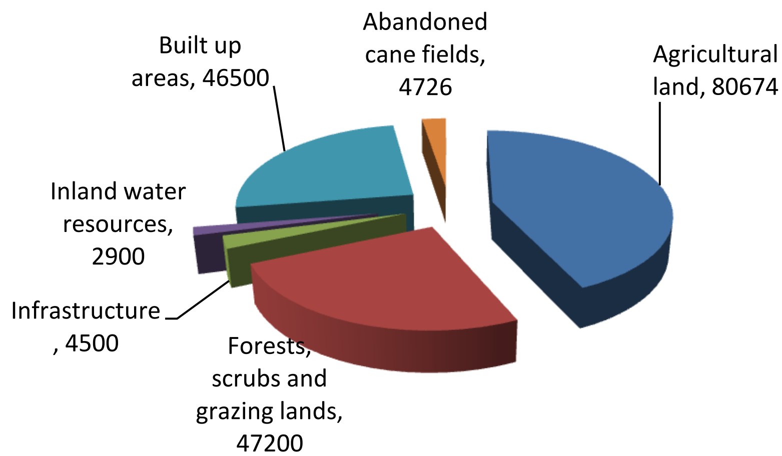

Figure 1.1: Land use by category in hectares

Mauritius has seen constant infrastructural development during the last decade and has witnessed a decrease in the effective area under cultivation by nearly 5000 hectares from 2007 to 2009 only. Area under built up areas has been constantly increasing during the last decade. This can be confirmed by data obtained from the central statistics office (Environment Digest of SM, 2009) related to number of permits issued for construction of residential buildings. Figure 1.2 below depicts the statistics related to residential building permits from 2004 to 2009.

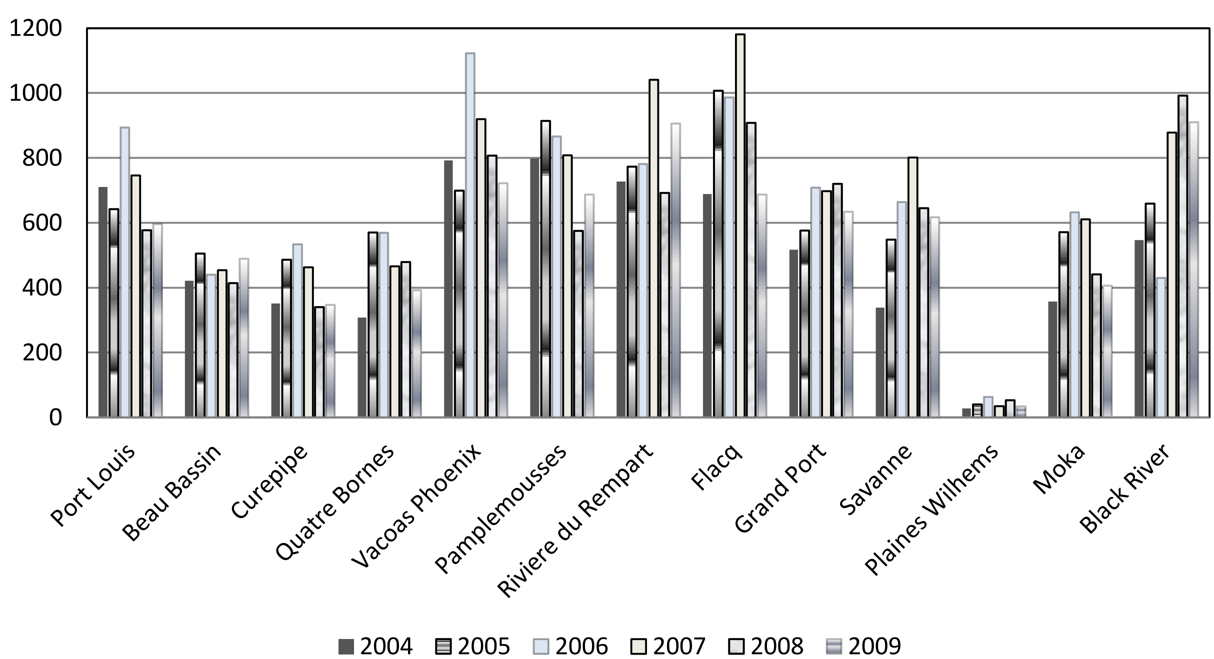

Figure 1.2: Number of residential building permits issued in different regions

Figure 1.2 shows how the total number of permit issued in different locations varied between 2004 and 2009 with a total of 6287 building permits issued in 2004 and 6896 in 2009. It has been noticed that a peak in number of issued permits was present during years 2006 and 2007. Further analysis was made to bring light to the disparity between the number of permits issued in rural and urban areas. The result is shown in figure 1.3.

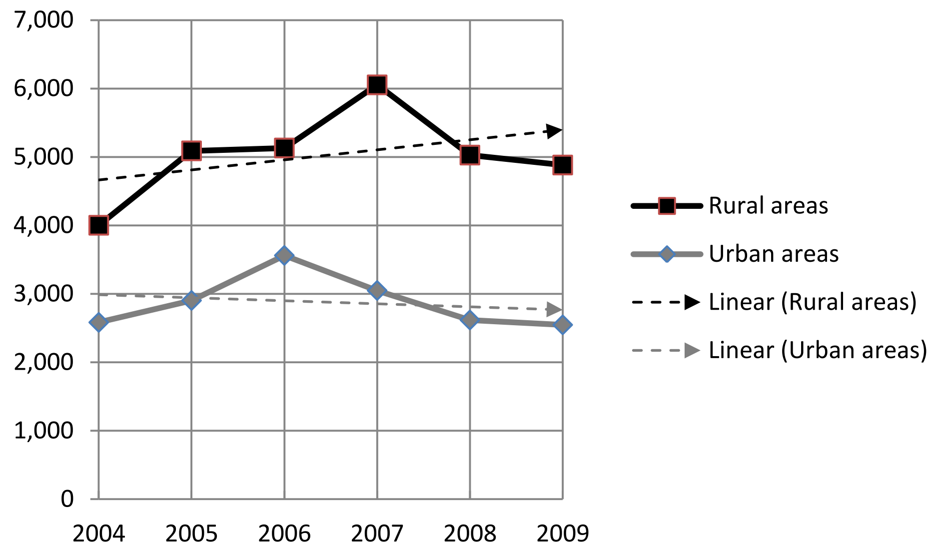

Figure 1.3: Number of residential building permits issued in rural and urban regions.

Figure 1.3 shows that the trend in the number of permits issued in rural areas is increasing whereas a decreasing trend can be noted for urban areas. The decreasing trend does not imply a decrease in the number of housing units but more focus towards vertical construction. Higher density housing, semi detached houses and blocks of flats is on the increase in the urban areas. On the other hand separate houses are preferred in rural areas. This fact can be confirmed by figures 4 and 5, which show the floor area for which building permits were issued in different regions and locations across Mauritius.

As seen in figure 1.4, in all the locations across Mauritius there is an increasing trend in the floor area for which permits are issued. With most of the ministries, business parks, cybercity, and tertiary educational institutions built in the urban areas, there is always a constant demand for living space in the later. But with major developments in the road infrastructure and regionalization of education as well as availability of facilities present in urban areas, there is more demand and issue of permits in rural areas.

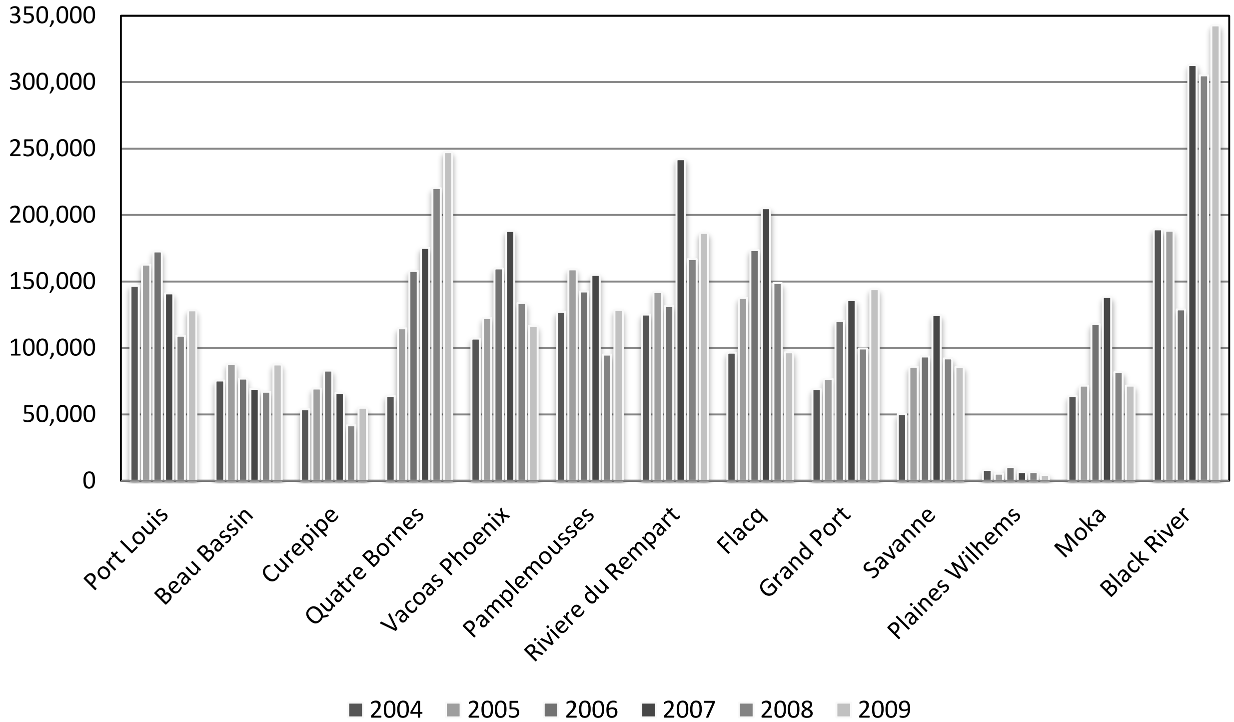

Figure 1.4: Floor area in meter square for which permits were issued in different locations

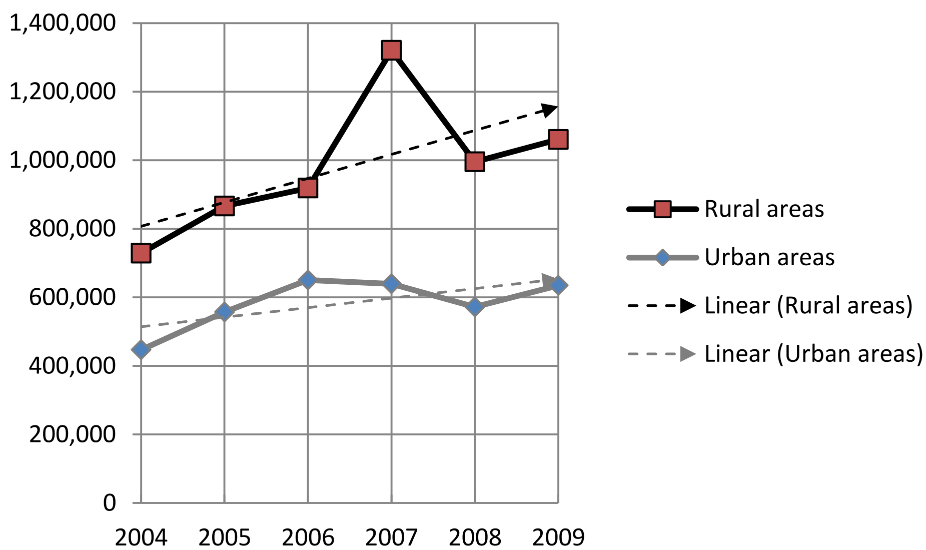

Figure 1.5: Total floor area for which permits were issued in urban and rural areas

Following a recent survey by the SM it was found that the housing stock increased more in rural than in urban regions. This confirms the previous statement on increased rural residential development. During last decade, Port Louis, the wholly urban district, registered the lowest growth, 2.7%, followed by Plaine Whilhems (15.4%) which is predominantly urban. Black River district which is also essentially rural witnessed the highest growth (41%). Further details on increase in housing units in Mauritius since year 2000 are provided in table 1.1 and figure 1.6 (SM Housing census 2011).

Table 1.1: Percentage increase in housing unit since year 2000

Location	% Increase in housing units
Port Louis	2.7
Pamplemousses	24.7
Riviere du Rempart	25.4
Flacq	24.1
Grand Port	18.6
Savanne	17.4
Plaines Wilhems	15.4
Moka	25.7
Black River	41

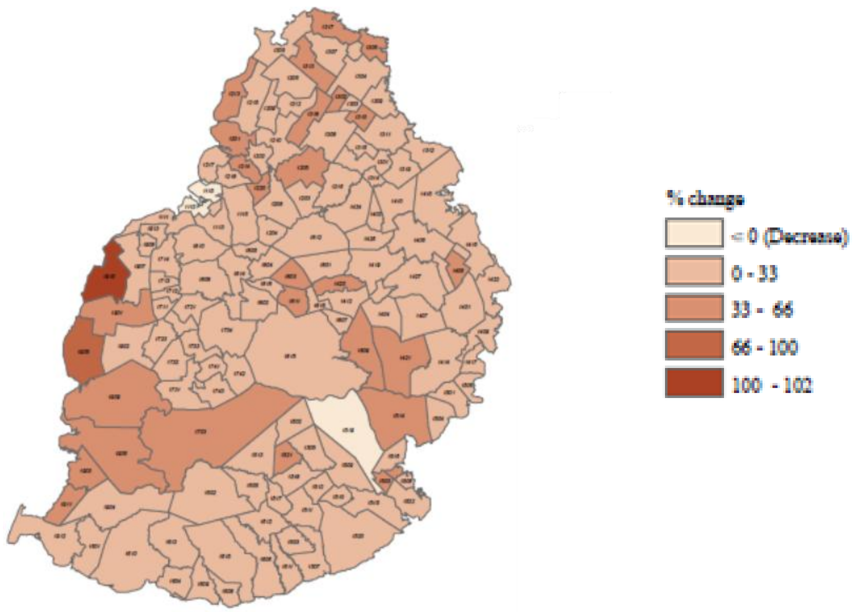

Figure 1.6: Percentage change in housing units in Mauritius since 2000 *(Source: SM Housing Census 2011)*

Unarguably, there is high rate of residential development in the rural areas but the current situation in the rural areas is demonstrating that no holistic approach has been adopted during the lifecycle of residential development. In most of the rural areas, there is dense agglomeration of houses with poor accessibility, poor local transport facilities, no provision of pavements for pedestrians, poor site selection and unoptimised use of available space.

An in depth study has been performed with respect to the below mentioned aspects to indentify the strengths and weakness related to site selection and optimisation:

a) Categorization of residential buildings in Mauritius

   Generally residential buildings are classified according to numerous parameters such as cost, surface area and type in Mauritius. The cost aspect is more commonly used by building designers and architects, whereas the current legislation uses the surface area to classify residential buildings. As per the current legislation residential buildings with surface area greater than 250 meter square must be designed by architects and engineers whereas those with surface area less than 250 meter square may be designed by designers and draughtsman/planner. The term housing unit is also commonly used for residential buildings. Types of residential buildings that are found in Mauritius are individual houses, flats and apartments.

b) Land categorization in Mauritius and residential lands.

To promote sustainable buildings, the amount of land that should be available for construction must be controlled. Hence there is a need for strict categorisation of lands in the country. The SM has performed a housing census and provided figures on land categorisation, coverage of built up areas in Mauritius as well as the number of permits issued yearly as well as their respective floor areas for construction. Generally land is categorised as agricultural, forest, scrubs, inland water resources land, infrastructural and built up areas. But up to now there are no restrictions on the amount of land that can be used for residential building construction.

c) Holistic site selection, rural and urban planning

A proper planning system is vital to our quality of life. A successful planning system promotes economic prosperity by delivering land for development in the right place and the right time.

There are two types of plans in Mauritius: The National Development Strategy which provides a strategic framework for national land use planning and local plans known as Outline Planning Schemes which are regional plans for a Municipal Council or District Council area. Outline Planning Schemes provide the framework for local authorities to plan, shape and control the use of land within their area. They translate the national strategy to the local level.

Development Control is necessary to ensure that developments are properly implemented such that the overall character and amenity of the area are not adversely affected. In Mauritius, the local authorities are empowered by the Town and Country Planning Act, 1954 to grant planning permits; a permit is required for the development of land and development is defined as involving:

- building operations
- change in the use of land or buildings
- the subdivision of land.

Town and Country Planning plays an important role by helping to strike a balance between development and the protection of the environment and to achieve social equity through a better spatial distribution of the benefits of development. It protects the natural and the man-made environment both for the benefit of present and future generations, whilst at the same time ensuring that development and growth are sustainable.

A new Planning and Development Act was passed in 2004 and it is gradually being implemented; it is expected to replace the Town and Country Planning Act,1954 (Ministry of Housing & Lands). The 1954 Act provides for approved Schemes to be used as the main reference against which building and land use permit applications are judged.

d) Construction of residential buildings and permits

Site selection procedures, urban/rural planning and other holistic design approaches can be introduced only if they form part of the construction of building permit. For sustainable design principles to be applicable professional designers, architects and engineers should intervene for all types and categories of residential buildings. As per the regulations, up to now, architects may not be consulted for construction of buildings of floor area less than 200 m^2. That is why most constructions with area less than the latter do not comply with requirements of sustainable building standards. The resources are available in the country and only a change in the policies may force the intervention of professionals for design of sustainable buildings in Mauritius.

e) Legal procedures for residential construction

The legal procedures are enforced by the local authorities. In order to obtain construction permit, the following should be done:

- Obtain plan of building
- Apply for land conversion (in case land is not residential)
- Obtain clearance from CWA, CEB and waste water management.
- Apply for construction permit in municipal or district council with respect to Building Act.

1.2.2 Previous and current Government and regulatory efforts

With respect to the Building and Land use Permit guide (2006), all constructions in Mauritius must be in accordance to the following legislations:

(a) the Building Act 2001

(b) the Town and Country Planning Act 1982

(c) the Planning and Development Act 2004

According to the Building Act, as from 1st October 2006, every person who intends to (a) commence the construction of a building, or effect extensive alterations, additions or repairs to an existing building or (b) carry out development of land shall apply to the Local Authority for a building and land use permit. The local authorities have developed a Building and Land Use Permit Application Guide which explains how to prepare, submit and process an application. It provides a simple, step by step guide to applicants, persons involved in preparation of plans, to officers of Local Authorities and to the public at large.

During the application, besides information on the professional who has developed the plans, the following information is required:

(A) Location/Context Plan with specific details on:

- Orientation of residential building including a north point on every plan. This will help relate the plans to the site.
- Accurate location plan, showing distance of site from specific or prominent landmarks to be submitted. For commercial and industrial projects, location plans should show all existing buildings/development in the immediate vicinity of the site (on side, rear boundaries and on opposite side) with details on the height, setbacks and character of buildings in that area. This will help the Authorities to determine whether flexibility to guidelines in the Planning Policy Guidance (PPG) can be applied.
- Site Plan which shows (a) existing and proposed buildings on the site, including setbacks (in metres) from boundaries, front and rear entrances and current uses (b) outline of buildings to be shown (not roof plan) (c) fences, walls, swimming pools (d) street frontage features – poles, trees, kerbs, crossings, handrails, drains, etc. (e) vehicular access to site in a safe location where visibility is good and visibility splays provided.

(B) Scaled Plans and elevations. This is required for all applications which involve construction. A scale is required to ensure that all plans are drawn to metric scale. All plans and elevation must also show relevant information including contours, ground levels, and roof levels.

(C) Cross Section Plans.

(D) Structural plans and structural details as per the Building Act.

When it comes to construction of residential buildings whether in rural or urban areas, the local authorities also require a clearance certificate from the Central Water Authority and the Central Electricity Board in addition to building plans in order to issue a building construction permit. This clearance certificate ensures accessibility to vital utilities only.

Besides, in case of construction at less than 0.9 m from the common boundary, consent from the neighbour is required. That is, the minimum distance advisable by the local authority is 0.9m.

Plans must satisfy all the requirements of the Planning Policy Guidance in respect of:

- Building line of 6m from roadside boundary (A or B road).
- Building line of 4.5m from any other road or 3m from lightly trafficked road.
- Building line of 0.9m from side and rear boundaries (other than coastal zone).
- Building line of 3m from side and rear boundaries in “Coastal Frontage A & B of the Coastal Zone”.
- Building line of 2m from side and rear boundaries within “Coastal Road C & D” and “Inland E”.

Building set backs from side and rear boundaries must be:

- 0.9 m from side and rear boundaries (other than coastal zone)
- A distance of 1.8 m observed between 2 buildings

The following set backs must be observed from River – 16 m, Rivulet – 8 m and Feeder – 3 m.

For buildings not in coastal zones, building line and distance between buildings and boundaries must be respected. But for coastal zones plot coverage should as well be met besides buildings lines. When calculating coverage, all enclosed spaces on the ground floor shall be taken as 100% of their enclosed area on plan. "Enclosed" means surrounded by walls and covered by a roof. In the case of verandahs, porches, car parks and similar uses, they should be included within coverage if they are covered by a roof. For coastal zones the following plot coverage must be adhered:

- 20% plot coverage within ‘coastal frontage A’
- 27.5% plot coverage within ‘coastal frontage B’
- 30% plot coverage within ‘coastal road C’
- 40% plot coverage within ‘coastal road D & inland’

“Coastal Frontage A” is reckoned as that area which normally accommodates the first row of sites from high water mark and is commonly referred to as "pieds dans l'eau". "Coastal Frontage B" is the area meant to accommodate row of sites immediately behind coastal frontage A up to a minimum depth of 81.21m. “Coastal Road C” includes those plots immediately fronting the coastal road and located beyond coastal frontage areas A and B but still on the seaward side of the Coastal Road."Coastal Road Area D" include those plots immediately adjoining the coastal road but on the landward side. “Inland E” includes those areas that may not have a Coastal road frontage, but may still be visible from or relate to the Coastal Road.

This implies that other factors such as security, accessibility, and energy consumption, as well as the energy consumed by transportation needs of occupants for commuting, the impact on local ecosystems, and the use/reuse of existing structures and infrastructures are not primary. But addressing sustainability in buildings and other construction works includes the interpretation and consideration of sustainable development in terms of three primary aspects – economic, environmental and social aspects while meeting the requirements for technical and functional performance of the construction works.

1.2.3 Current national projects being undertaken in the area

The Government of Mauritius came forward with the 'Maurice Ile Durable' project to promote social, economic and environmental reforms in 2008. In line with the latter the government reviewed the current Building Act and initiated the Building Control Bill which will introduce mandatory sustainable development and design standards for new buildings, including housing, hotels and offices.

The government is also promoting sustainable building design with use of natural ventilation; day lighting; appropriate orientation; insulation; double glazed windows, solar hot water systems, intelligent lighting systems that are suitable for low energy lamps and building energy management systems (BEMS). Numerous stakeholders are currently working on technical committees to adopt and develop standards and guidelines for the local community. At the same time, workshops are being held regularly by representatives from local institutions, universities, government and local authorities as well as foreign consultants to share knowledge and experience for developments of regulations in the field of sustainable building design.

1.3 Expository of findings from literature

As people are becoming aware of the need of sustainable development, standards developing bodies and institutions dealing with sustainability and building construction have published a large number of materials to help attain sustainability. Inter alia, the most important ones are the ISO standards, the LEED rating guide, Charted Institute of Building Services Engineering publications as well as the world building organisation's publications and GRIHA – the Indian green building rating system.

ISO 15392: Sustainability in building construction – General principles (2008) establishes general principles for sustainability in building construction. It is based on the concept of sustainable development as it applies to the life cycle of buildings and other construction works either individually or collectively, from their inception to the end of life. ISO 15392 does not provide benchmarks that can serve as the basis for sustainability claims in building construction. According to the standard, addressing sustainability in buildings and other construction works includes interpretation and consideration of sustainable development in terms of its three primary aspects – economic, environmental and social aspects – while meeting the requirements for technical and functional performance of the construction works.

These aspects are inextricably linked to each other and are interdependent. An interpretation and consideration of the primary aspects of sustainability may require consideration of areas of concern such as asset value, cultural heritage, resources, human health and comfort and social infrastructure. Sustainable development of buildings and other construction works brings about the required performance and functionality with minimum adverse environmental impact, while encouraging improvements in economic and social (and cultural) aspects at local, regional and global levels. The main objectives of sustainable development are:

- Improvement of the construction sector and the built environment.
- Reduction of adverse impacts while improving value of the three primary aspects of sustainability.
- Stimulation of innovation
- Stimulation of pro-active approach.
- Decoupling of economic growth from increasing adverse impacts on the environment and society.
- Reconciliation of contradictory interests or requirements arising from short term or long term planning or decision making.

The United States Green Building Council has developed an internationally recognised mark of excellence - Leadership in Energy and Environmental Design (LEED) in 2000. LEED provides building owners and operators with a framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions. LEED considers the following aspects of Green Buildings during the building's life cycle to obtain the mark of excellence: Sustainable sites, Water efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environment Quality, Innovation in Design and Regional Priority.

The most important requirements for sustainable sites are as below:

Construction activity pollution prevention: There is a need to reduce pollution from construction activities by controlling soil erosion, waterway sedimentation and airborne dust generation. For the latter there is a need for employing strategies such as temporary and permanent seedling, mulching, earthen dikes, silt fencing, sediment traps and sediment basins where and when required.

Site selection: The intent is to avoid the development of inappropriate sites and reduce environmental impact from the location of a building on a site. For instance, buildings should not be constructed in wet lands, land specifically identified as habitat for protected species. During site selection process preference should be given to sites that do not include sensitive elements or restrictive land types with minimum footprint to minimise disruption of the surrounding environment.

Development Density and Community Connectivity: The objective is to channel development to urban areas with existing infrastructure, protect greenfields and preserve habitat and natural resources. In addition, anticipated services must demonstrate that they will be operational in the locations indicated within 1 year of occupation of the building. Examples of basic services include the following: Bank, Place of Worship, Fire Station, Beauty Salon, Hardware, Laundry, Library, Medical or Dental Office, Senior Care Facility, Park, Pharmacy, Post Office, Restaurant, School, Supermarket, Theater, Community Center and Fitness Center. There should also be pedestrian access between the buildings and services. Preference should be given to urban sites with pedestrian access to a variety of services.

Public Transportation Access: The scope is to reduce pollution and land development impacts from automobile use. Sites must be located near mass transit facilities.

Site Development: Natural areas must be conserved and natural areas restored to provide habitat and promote biodiversity. High ratio of open space to development footprints must be provided to promote biodiversity.

CIBSE is an institution concerned with designing systems which consume less energy and discharge a minimum of harmful contaminant and it has long been at the forefront of the sustainability drive. The CIBSE has issued a number of guides including the CIBSE Guide L – Sustainability. It is primarily intended to provide guidance to those responsible for the design, installation, commissioning, operation and maintenance of building services. This Guide provides good practice procedures for professionals in the construction industry. It covers disciplines not normally the direct responsibility of the building services engineer, albeit in lesser detail than those that are, because sustainability is the concern of everyone involved in the design, construction, operation and, eventually, the demolition of buildings. Sustainability requires a holistic approach and this is in accord with the acknowledged need for the design team to be multi-disciplinary.

With respect to site construction the CIBSE Guide emphasizes on the following aspects of sustainability:

Local environment and Community: The impact of projects on the local environment and community are related to the construction and operation of buildings.

Construction site impacts: The guide suggests that lead contracts should prepare a comprehensive 'Environmental Aspects and Risk Assessment' for the site to identify all the construction environmental impacts and protective measures to eliminate or reduce these impacts. This would include an assessment of significant environmental aspects that considers:

- Emission to air, water and land
- Management of waste
- Use of raw materials and natural resources
- Community issues
- The demolition phase

Based on the assessment, the contractor should then prepare and implement a 'Construction Environental Management Plan' to manage the social and environmental impacts of the construction process.

The goal of 'Whole Building Design', a program of the national institute of building services of Washington, is to create a successful high-performance building by applying an integrated design and team approach to the project during the planning and programming phases (WBDG home page).

It is imperative that building owners and developers maximize the restorative impact of site design and building infrastructure while meeting the project's other requirements. Sustainable site planning should consist of a whole system approach that seeks to:

- Minimize development of open space through the selection of disturbed land, re-use of brownfield sites, and retrofitting existing, buildings;
- Consider energy implications and carbon emissions in site selection and building orientation;
- Control erosion through improved grading and landscaping practices;
- Reduce heat islands through building design methods, minimizing impervious surfaces, and using landscaping;
- Minimize habitat disturbance;
- Reduce, control, and treat surface runoff;
- Restore the health of degraded sites by improving habitat for indigenous species through appropriate native plants, climate-adapted plants, and closed-loop water systems;
- Incorporate transportation solutions along with site plans that acknowledge the need for bicycle parking, carpool staging, and proximity to mass transit. Encourage alternatives to traditional commuting; and
- Consider site security concurrently with sustainable site issues. Location of access roads, parking, vehicle barriers, and perimeter lighting, among others are key issues that must be addressed.

GRIHA, an acronym for Green Rating for Integrated Habitat Assessment, is the National Rating System of India. GRIHA has been conceived by TERI (The Energy and Resources Institute, New Delhi) and developed jointly with the Ministry of New and Renewable Energy, Government of

India. It is a green building 'design evaluation system', and is suitable for all kinds of buildings in different climatic zones of the country. Criteria for GRIHA's rating system with respect to site selection and planning are provided below. The objective is to maximize the conservation and utilization of resources (land, water, natural habitat, avi fauna, and energy conservation) and enhance efficiency of the systems and operations (GRIHA Home page, 2012).

Site Selection

Site selection is the first step to a sustainable habitat and needs to be done appropriately, prior to commencement of design phase. Site selection and analysis should be carried out to create living spaces that are in harmony with the local environment. The development of a project should not cause damage to the natural surroundings of the site but, in fact, should try to improve it by restoring its balance. Thus, site selection should be carried out in light of a holistic perspective of land use, development intensity, social well-being, and preservation of the environment.

Preserve and protect the landscape during construction/compensatory depository forestation.

It is important to preserve the existing landscape and protect it from degradation during the process of construction. It involves proper timing of construction, preserve top soil and existing vegetation, staging and spill prevention to prevent spilling contaminated material onsite, erosion and sedimentation control, replant the trees that were cut down during construction in the ratio 1:3.

Soil conservation (till post-construction).

Topsoil till must be conserved after completion of construction activity. This commitment entails proper top soil laying and stabilization of the soil to prevent erosion and maintenance of adequate fertility of the soil to support vegetative growth.

Design to include existing site features.

The natural functions of a plot of land (hydrologic, geologic, and microclimatic) can be disrupted by the placement of a building on it. The design of a green building will factor in ways in which the natural site features can be protected or even restored. Layout the site activities and building requirements after carrying out detailed site analysis so as to ensure sustainable site development in tune with its topographical, climatic, and ecological character.

Plan utilities efficiently and optimize on-site circulation efficiency

Reduce site disruption due to laying, maintain utility lines, and minimize energy use by on-site utilities. To reduce transportation corridors on-site, thus reducing the pollution loads. Minimize road and pedestrian walkway length by appropriate planning and provide aggregate corridors for utility lines.

Reduce air pollution during construction.

The dust generated by various construction site activities can contribute significantly to air pollution. Dust and outdoor air pollutants can cause respiratory problems. Good construction practices involve major mitigation measures for prevention or minimization of air pollution from construction activities. This criterion aims to reduce air pollution due to on–site construction. Ensure proper screening, covering stockpiles, covering bricks and loads of dusty materials, wheel-washing facility, and water spraying

1.4 Proposals and Recommendations

1.4.1 Analysis of the shortcomings of the Mauritian context

The Government of Mauritius has developed the Building act, the Town and Country Planning Act and the Planning and Development Act 2004. Based on these regulations local authorities have issued the guidelines for Building and Land Use permit. The current regulations emphasise mainly on legal aspects of construction. The Building and land use guide provide the general public with valuable information of the procedure for obtaining a permit. As stated by several experts in the field of construction there is a need to sensitise people about holistic site development procedures and guide them during the life cycle of the development. There is also a need for guidelines for holistic site selection, construction and optimisation.

According to the current practices, for all residential buildings with surface area less than 250 metre square, there is no need of consulting an architect to develop building plans. Generally, planners draw the plans and assist people who wish to build houses to submit application forms. Consequently, the plans that are generated do not consider all aspects of sustainability as the planners do not necessarily have knowledge on sustainability concepts.

Also there are no enforcing policies to which the general public should comply in order to start a construction work. This has resulted into high rate of unplanned development in all areas of Mauritius. In many cases, especially in the rural areas and suburbs of towns and cities, there is even no walkable neighbourhood and roads are not large enough for public transportation. Policies and guidelines regarding holistic site selection and optimisation for construction of residential buildings in rural and urban should be introduced to control development in Mauritius.

If the current rate of residential growth maintains individual housing units will soon sprawl over the country. According to international bodies, development in open spaces should be minimized as far as possible.

The current situation in Mauritius is opposite to the scope of smart growth. Higher rate of residential development is taking place in rural areas around the country rather than in the urban areas where most of the services are already present. From the analysis of the current situation in Mauritius, it has also been noticed that Mauritians opt for horizontal growth rather than living in multi-storeyed residential buildings.

1.4.2. Recommendations for the adoption/setting up of standards and regulations

All the above cited sources have emphasized on similar aspects when considering a site for building construction. Inter alia, importance has been given to smart growth, design for sustainable transportation, consideration of energy implications and reduction of disturbance to natural habitat.

It is recommended to adopt the ISO 15392 series standards, the LEED rating guide, Charted Institute of Building Services Engineering publications as a reference for holistic site selection guide. As well as the world building organisation's publications and GRIHA – the Indian green building rating system principles can be considered as guide for site selection, planning and construction.

After analyzing the current status of Mauritius and the different sources of information, it is proposed to produce a guideline for holistic selection and optimization of site for residential buildings which can be used by all stakeholders. In addition to the information currently provided in the guide for building and land use permit, the proposed guide will provide useful information for site selection and optimization in Mauritius.

1.4.2.1 Smart Growth

Smart Growth is an issue that concerns many communities around the country. It relates to controlling sprawl, reusing existing infrastructure, creating walkable neighborhoods, and locating places to live and work near public transportation. It is more resource-efficient to reuse existing roads and utilities than build new ones far out from cities in rural areas. Smart growth preserves open spaces and farm lands and strengthens the development of existing communities and their quality of life.

1. The Government of Mauritius in collaboration with local authorities must perform a categorization of land under the respective village and municipal councils in order to restrict unplanned developments in Mauritius.
2. The local authorities must provide data on the amount of land which can be considered as agricultural, forest, scrubs and grazing, built up, infrastructural and abandoned cane fields within their respective boundaries. In order to control unplanned growth and promote

sustainable development, it is desirable to have a good ratio of land dedicated to built up areas, agriculture, forests and infrastructure. In a view of promoting sustainability in Mauritius, the government should set the ratio and develop policies to regulate use of land.

3. It is important to identify potential residential growth areas in Mauritius and perform a feasibility study on the appropriateness of the site for residential growth. The study should consider economic, environmental and social aspects which are involved during the development of the site.
4. Social and economic aspects related to proximity of site to services such as Bank, Place of Worship, Fire Station, Beauty Salon, Hardware stores, Laundry, Library, Medical/Dental Office/Health Centre, Senior Care Facility, Park, Pharmacy, Post Office, Restaurant, School, Supermarket, Theater, Community Center and Fitness Center should be considered first.
5. The Government of Mauritius must demonstrate that the basic services will be/or are already operational in the locations indicated within 1 year of occupation of the residential building. Besides, essential utility services such as water, electricity and communication facilities must be accessible to the potential residential sites.
6. Priority must also be given to vertical growth rather than horizontal, i.e. multi-storeyed apartments should be preferred to individual houses. Also vertical growth around the urban areas must be promoted as road infrastructure and basic services are already present in most urban places. Furthermore this will ensure that minimum habitat disturbance takes place in the country.
7. It is a requirement that professional architects and engineers should provide assistance during the design of all types of residential buildings to support sustainable building development in Mauritius.

1.4.2.2 Design for Sustainable Transportation and common walkways

1. All potential residential sites must have access to public transportation.
2. In addition, provisions should be made for cycling and pedestrian walking spaces on either side of the roads. This implies that prior to the issue of residential building permits, the local authorities must ensure that the residential sites are located within walking distance to public transport facilities and as well walkways are provided for local residents.
3. Minimum setback and building line requirements as specified in the building and land use guide should be maintained, but in addition plot coverage restrictions should be introduced to all inland and coastal residential sites.

1.4.2.3 Consider Energy Implications in Site Selection and Building Orientation

1. Along with the Building Control Act and its outline schemes, the government will be providing the general public with passive solar design guides. The passive solar design is a good initiative of the government to promote sustainable development. The later will consider energy implications for proper orientation of building in order to be able to integrate passive and active solar strategies.
2. Initial study should be made on proposed residential site to investigate the potential impact of future adjacent developments to the site before finalising orientation and location of housing unit in the plot (e.g., solar and wind exposure, daylight, ventilation, etc.).
3. Orientation of building should as well take advantage of natural ventilation and prevailing wind patterns. Therefore, minimum development of open spaces must take place. Moreover, maximum daylight use should be promoted.

1.4.2.4 Minimize Habitat Disturbance

1. Sustainability is the state when the eco system and all its functions are maintained for the present and future generations. This also implies that man must perform their activities without causing harm to the surrounding environment. Nature and habitat should be preserved. Therefore it is crucial to keep land disturbance to a minimum and retain prime vegetation features to the extent possible during development in a site.
2. All construction staging areas should be planned with the environment in mind. Building and paving footprints should be reduced and any harm caused to the surrounding should be restored.
3. The use of existing trees and other vegetation to shade walkways, parking lots, and other open areas should be maximised.
4. Landforms and landscaping must be integrated into the site planning process to enhance resource protection.
5. Safety and security aspects must as well be considered while planning the site and landscaping.
6. All phases of a building construction in a site should be well planned in order to reduce site disturbance to a minimal area around the building perimeter, including locating buildings adjacent to existing infrastructure.

1.5 Conclusion

Since the introduction of the MID project, the Government of Mauritius has been thriving to bring sustainability concepts in the country. The introduction of the Building Control Act 2012 confirms the intention of the Government – to promote the development of sustainable buildings. The current policies relative to site selection and construction provide adequate information and are already available in the websites of the ministry of housing as well as the local authorities. Nevertheless, the local people should be sensitised on the importance of sustainable development to enhance the quality of life. This can be done by counseling the population and more particularly applicants of building and land use permits on the sustainable design strategies. New applicants must have an opportunity to discuss the projects with experts provided by the local authorities and the government. As well education of the local people on sustainability concepts may be performed through seminars and workshops as well as introduction of sustainability concepts as course content at primary, secondary and tertiary education levels. The recommendations provided above will be helpful to the concerning ministries, the local authorities and as well to the public as a whole. It may as well be developed as a code of practice for holistic site selection and construction as the latter has been compiled following an indepth study of the current status of Mauritius and through reference to international standards and codes of practices.

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CHAPTER 2
ENERGY EFFICIENCY

2.1 Introduction

Energy is necessary for almost all facets of human existence: oil and gas for cooking and heating; electricity for cooling, lighting, appliances and machines; gasoline and diesel fuel for transportation; and a mix of energy supplies for myriad other purposes. Energy is necessary for every society at every level of development, but as a general rule, energy consumption increases as societies become more developed and their standard of living rises. However, this also leads to an increase in carbon dioxide emissions, since the major part of the energy comes from burning of fossil fuels. Governments across the world, including Mauritius have embarked on programmes for reducing their reliance on fossil fuels. Scientists, engineers, and policy makers are actively combining their efforts towards this end.

2.2 The Building Sector

Buildings are responsible for more than 40 percent of global energy use and one third of global greenhouse gas emissions, both in developed and developing countries. The main source of greenhouse gas emissions from buildings is energy consumption, but buildings are also major emitters of other non-CO_2 greenhouse emissions such as halocarbons. While historically the majority of emissions emanated from developed countries, it is expected that in the near future the level of emissions from buildings in rapidly industrializing countries will surpass emission levels from buildings in developed countries. In absolute terms, the Fourth Assessment Report of the IPCC estimated building-related GHG emissions to be around 8.6 million metric tons CO_2 equivalent in 2004 (Levine et al, 2007).

Given the many possibilities to substantially reduce buildings' energy requirements, the potential savings of energy efficiency in the building sector would greatly contribute to a society-wide reduction of energy consumption. The implications of such potential reduction should not be underestimated, as the scale of energy efficiency in buildings is large enough to influence security policy, climate preservation and public health on a national and global scale.

By reducing buildings' energy consumption, a nation can reduce dependency on imported energy and strengthen its strategic position. In the 2000 Green Paper setting forth a strategy to secure energy supply(European Union, Green Paper, November 2000), the European Union named energy efficiency as the best way to establish energy security over a longer term.

Moderation of energy end-use in buildings will also reduce greenhouse gas emissions and pollution produced by the combustion of fossil fuels. In particular in developing countries a reduced demand for energy requires fewer power plants, thereby delaying or obviating the construction of new generation and grid capacity and enabling communities to devote public funds elsewhere. Given the potential scale of energy savings across the building sector, reduced demand for energy and fossil fuels can substantially contribute to a nation's compliance with domestic targets for the reduction of greenhouse gas emissions. (IEA, 2008. Energy Efficiency Requirements In Building Codes, Energy Efficiency Policies for New Buildings)

When adequately ventilated, energy efficient buildings are generally healthier than traditional buildings. Relative to traditional buildings, energy efficient buildings offer a more stable indoor climate, with less draught from windows, walls, floors, and ceiling constructions. Because residents of energy efficient buildings must spend relatively less to heat and cool their homes to within the margins of acceptable comfort, energy efficient construction reduces fuel poverty across society. As households demanding less energy for building-related uses, they burn less fuel locally, thus doubling the potential to improve public health and otherwise benefit local communities.

Among these potential public benefits of energy efficiency in buildings, employment in the construction sector should not be dismissed.

2.3 Current Situation in Mauritius

In view of the serious challenges posed by the volatility of oil prices and the rising cost of energy, Government has reviewed the energy policy for fuelling the future as a result of a paradigm shift on the world stage caused by climate change.

Since 1999, the Republic of Mauritius has passed the psychological barrier of importing more than one million tonnes of oil equivalent of fossil fuel. This amount is expected to increase between 4 and 7% annually, weighing significantly on the trade deficit, representing about 5% of imports. Currently, less than 25% of the energy requirements of the country are derived from non-fossil fuel sources (mostly hydro and bagasse) with such a reliance unlikely to change unless a holistic approach is adopted to management of energy resources. (Statistics Mauritius 2011).

2.3.1 Primary energy requirement

The total primary energy requirement increased by 6.2%, from 1,347 ktoe in 2009 to 1,431 ktoe in 2010. Of this, imported fuels which are all fossil fuels accounted for 83.1% (1,189 ktoe) while locally available sources supplied the remaining 16.9% (242 ktoe). In 2010, petroleum products which amounted to 775 ktoe, comprised mainly fuel oil (30.0%), diesel (27.6%), gasolene (16.5%) and aviation fuel (16.0%). (Statistics Mauritius 2011).

In 2010, coal requirement was 414 ktoe (29%), representing an increase of 12.1% over the 369 ktoe of 2009. The local production (242 ktoe), that are all renewable, comprised bagasse (93.1%), hydro/wind electricity (3.7%), and fuelwood (3.2%).

The total primary energy requirement index, with 1990 as base year (1990 = 100), increased from 184.3 in 2009 to 195.8 in 2010 while the per capita primary energy requirement increased by 5.7%, from 1.06 toe in 2009 to 1.12 toe in 2010.

2.3.2 Per Capita GDP and Total Primary Energy Requirements

In Mauritius, the per capita gross domestic product (GDP), has been constantly increasing for the past ten years (Figure 2.1). The increase has resulted in a corresponding increase in the total primary energy requirement/ktoe (Figure 2.2). (Statistics Mauritius 2011).

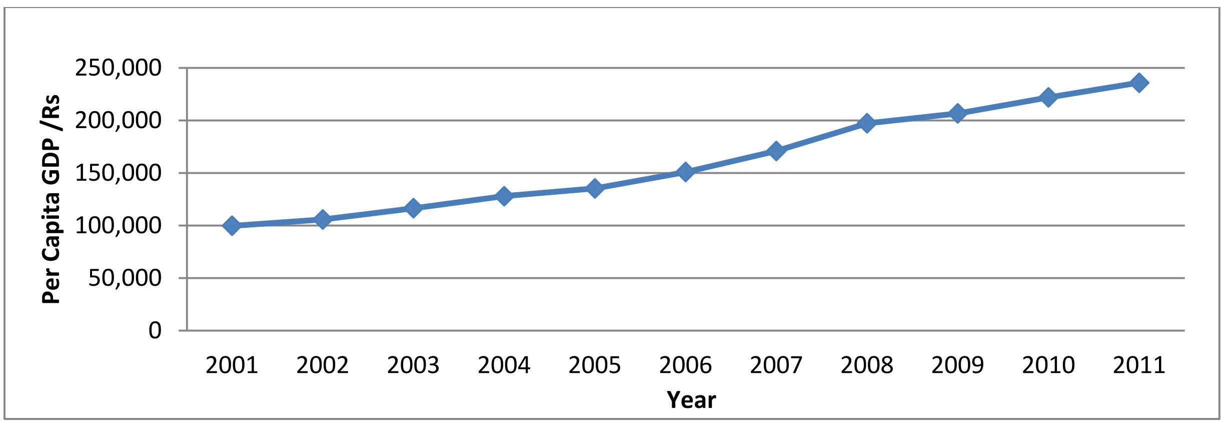

Figure 2.1: Per Capita GDP

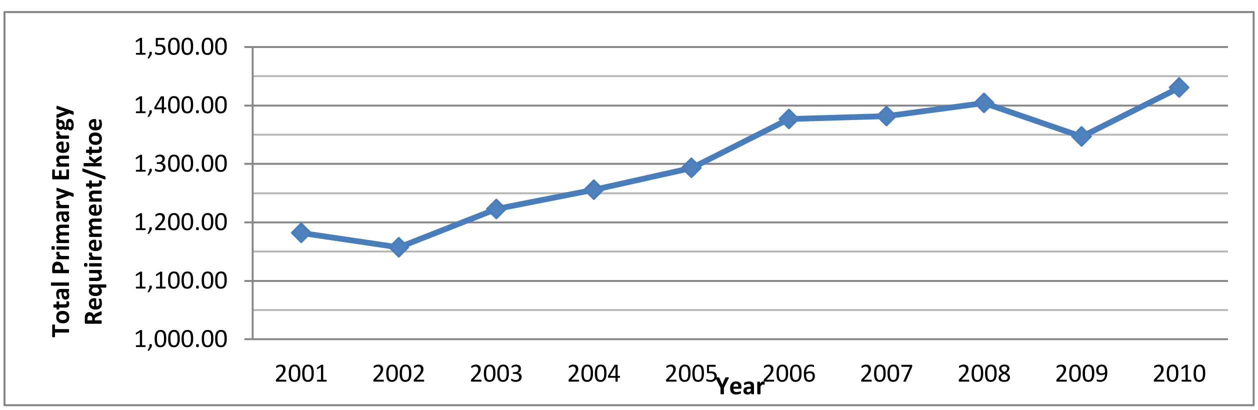

Figure 2.2: Total Primary Energy Requirement/ktoe

2.3.3 Energy usage in Mauritius

The final energy consumption is the total amount of energy required by end users as a final product. End-users are categorized into six sectors, namely manufacturing, transport, commercial and distributive trade, households, agriculture and other. (Statistics Mauritius 2011)

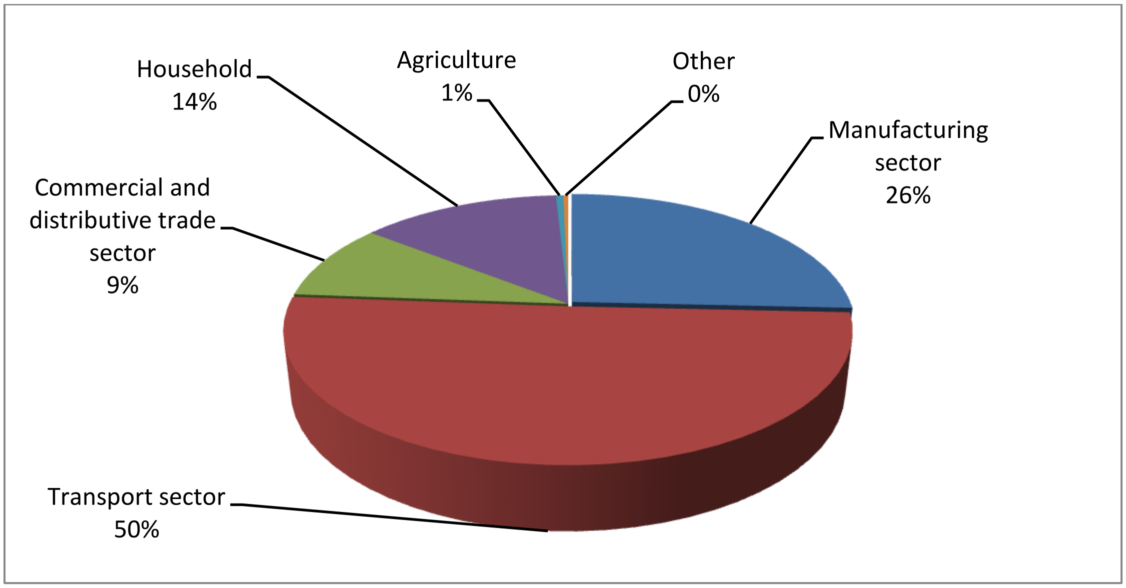

Figure 2.3: Energy Usage in Mauritius

Over the past decade, electricity demand in Mauritius has grown at an average annual cumulative rate of around 5%. The Central Electricity Board forecasts that electricity generation requirements will increase by approximately 30% over the next 10 years mainly due to air conditioning and mechanical ventilation from commercial and residential buildings. Electricity consumption in the domestic sector is 33% of the total demand, while the commercial and industrial sectors account for 34% and 31% respectively.

2.3.4 Domestic Energy usage

Energy consumed by households in 2010 (excluding fuel used for transport) increased by 3.5% from 113 ktoe in 2009 to 117 ktoe in 2010. The two main sources of energy for households were electricity and LPG, representing 52.3% and 40.7% respectively of total energy consumed by households. Electricity consumption increased by 4.4% and that of LPG by 1.9%. (Statistics Mauritius 2011)

The most common forms of energy usage in residential buildings are: lighting, warmth in the winter, cooling in the summer, water heating, electronic entertainment, computing, refrigeration, and cooking.

2.4 Expository of findings on Energy efficiency in new buildings

Many means to save energy in new buildings also offer the potential to save money. Individual homeowners and building users investing in energy efficiency will often recover costs in a short period through lower energy expenses. This "payback time" on energy efficiency investment can be as short as a few years. These energy savings are similarly profitable from the macro-economic perspective of national policy. Increased efficiency in new buildings is hence profitable for individual building owners and society as a whole. (IEA, 2008. Energy Efficiency Requirements In Building Codes, Energy Efficiency Policies for New Buildings)

In Mauritius, the construction activity is boosting, thus the energy saving potential of new buildings is large. This potential accumulates year by year because of the long lifetime of buildings: most buildings constructed today will remain in use until after 2050. Logically, new buildings present a good opportunity to save energy over the long term.

2.4.1 Efficient new buildings make efficient existing buildings

New buildings are rarely improved or renovated in the first years. The efficiency of new buildings will therefore directly influence the consumption for many years and they will be the standard for improvement of existing buildings, since renovation projects often aim to bring buildings up to the present standard. Efficiency demands for new buildings then becomes the driver for existing buildings. This process can be supported by energy labelling or certification schemes where new and existing buildings are compared (CASH 2010).

Requirements for highly-efficient new constructions also influence the market for products typically installed in buildings, promoting energy efficient models of windows, boilers, pumps and air-conditioners. Once on the market, these products may become standard in both new and renovated buildings.

2.4.2 Energy efficiency requirements for new buildings

Given the long lifespan of most buildings, the relative energy efficiency of new buildings will influence energy consumption for many years. Construction of buildings offers compelling opportunities for energy efficiency, as decisions made during a building's design phase entail smaller costs with greater potential energy savings relative to later intervention.

Decisions which entail no or very low cost at the early project stage include the form of the building, its orientation, the orientation of its windows, and its structural materials. When included during the design phase, energy efficiency improvements can reduce the demand for and costs of cooling and heating systems. These same decisions, when made after construction, can be prohibitively costly to enact. In other cases, improvement of energy efficiency late in a building's construction would involve irreparable damage to its structure. Examples of this are rebuilding massive concrete floors placed directly on the ground, hidden pipes or foundations with heat losses. Even when energy improvements are suggested at the late planning phase of a building, it is still preferable compared to introducing them after construction.

2.5 Building codes and standards

Energy efficiency requirements in building codes can ensure that concern is taken for energy efficiency at the design phase and can help to realise the large potentials for energy efficiency in new buildings. Energy efficiency requirements for new buildings are set in different ways. Based on national or local traditions they can either be integrated in the general building codes or standards for new buildings, or they can be set as separate standards for energy efficiency.

2.5.1 Energy efficiency requirements in building codes

Building codes are not a new invention and building codes or standards for new buildings address several concerns, such as construction safety, fire safety and occupants' health. One of the earliest examples of regulations for buildings is Hammurabi's law from Mesopotamia, established around 1790 BC. Among the 282 rules or contracts, which regulated every part of society, six concern the construction of houses and the penalties for builders.

Many countries or cities have hence a long tradition of setting rules for constructing of new buildings, often initiated in response to disasters such as a large urban fire, an epidemic or a natural catastrophe such as an earthquake. Requirements for constructing buildings were then set in order to avoid or minimise future disasters. Compared to this energy efficiency regulation for new buildings is relatively new in most countries.

In many countries, the oil supply crisis of the early 1970s catalysed the development of energy efficiency requirements for buildings. Those countries already enforcing efficiency regulations generally raised their requirements during the early 1970s to further reduce energy consumption and decrease dependency on oil. During the 1980s and 1990s, energy efficiency requirements were set or increased in most OECD countries. In part, this new legislation responded to the Kyoto Protocol, or other targets to reduce or stabilise CO_2 emissions.

Today, mandatory minimum energy efficiency requirements in the form of building codes or standards exist in nearly all OECD countries. However, substantial differences persist between legislation of the states, regions and cities.

2.5.2 Energy efficiency requirements

When requirement for energy efficiency are set in a separate standard they are less bound by other building rules and can contain more samples and specific documentation of potential use for contractors or building designers. However, as separate standards, they require their own enforcement system.

Energy efficiency requirements included in buildings codes are usually set in a specific chapter and enforced along with the general rules of the building codes. If the building industry is familiar with general requirements in the building codes, integrating efficiency requirements can efficiently inform industry actors of energy conservation measures. Energy efficiency requirements included in building codes are often brief, while specific standards are typically longer and more comprehensive.

In 1961 Denmark established one of the first building codes which systematically regulated energy consumption. Since then, building codes have been updated several times, including major changes in 1972, 1979, 1997, and in 2006. As illustrated in Figure 2.4, studies of existing buildings track the trend of declining energy consumption in the context of rising efficiency requirements.

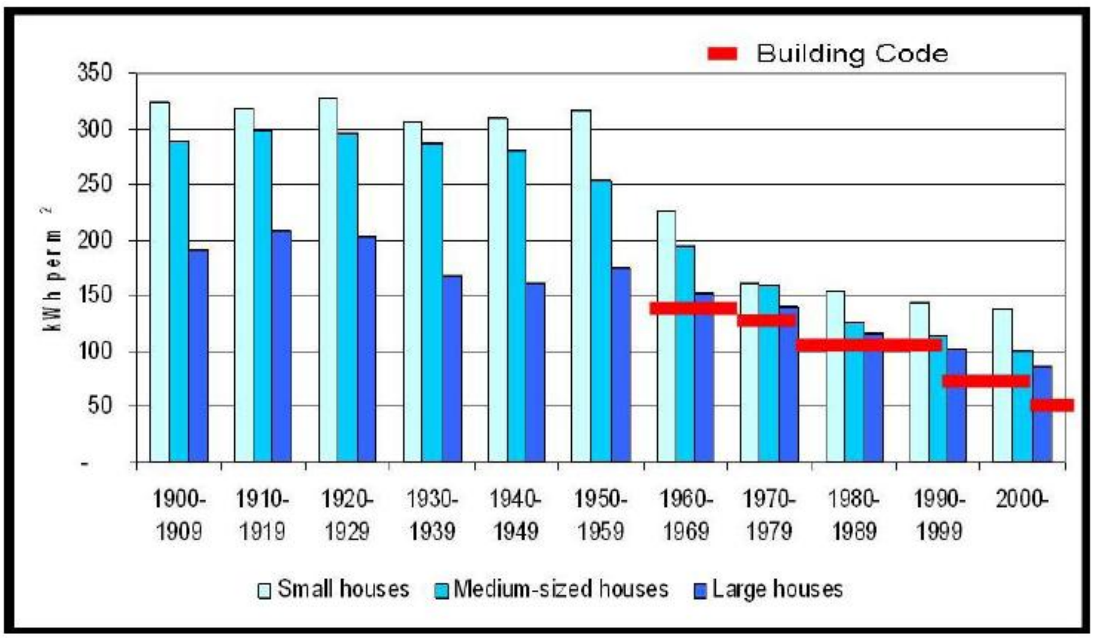

Figure 2.4 : Actual energy consumption in single family houses in Denmark, relative to energy efficiency requirements in building codes.

The results of energy certification of more than 200,000 buildings the average consumption over each decade are compared with energy efficiency requirements in the building codes.(Varme Besparelser Boliger, 2003)

2.5.3 International trends in energy efficiency requirements for new buildings

Though most energy efficiency requirements in building codes followed local, state or national tradition, the past decade has shown a trend in supranational collaboration to develop international energy efficiency requirements or standards. Examples are the US based Energy Efficiency standards (IECC 200415 and ASHRAE 200416) which are used in US and Canada, and the European Energy Performance in Buildings Directive (EPBD) that required member states of the European Union to establish requirements for energy efficiency in new buildings, effective January 2006. To supplement the EPBD, the European Union aims to establish a model building code for energy efficiency for the European region (2006 EU Action Plan for End-use Efficiency) and to develop CEN standards for energy performance calculation. These CEN standards are on the way to be amended and adopted as ISO standards too.

Most countries have started with one common standard for energy efficiency, but have over time developed separate standards for small and simple residential buildings and for large, complex or non residential buildings, in consideration of the dissimilar energy performance.

2.6 Barriers to Energy Efficiency in homes

Current barriers to energy efficiency are considered from several perspectives: behavioral, design-oriented, and market-oriented. The first perspective concerns predominant attitudes toward energy efficiency among consumers and the depth of consumers' knowledge about energy efficient practices within the household. The second perspective concerns barriers to energy efficiency that stem from the design of products themselves. Finally, the third barrier this section will explore concerns the marketplace, and especially, ways that government regulation may, according to some authors, impede energy efficiency in public utilities.

2.6.1 Behavioral Barriers

There are several factors that influence attitudes towards voluntary energy conservation in the household: the availability of information, the absence of or poor quality of financial incentives, and the prices of utilities.

The lack of information regarding the severity and scale of energy problems, relative energy prices, and consumption alternatives, limits consumers' capacities to compare costs and formulate action plans for the conservation of energy.

In addition to this, there are several reasons why consumers fail to take advantage of certain financial incentive schemes that would contribute to higher energy efficiency or fail to act in ways that analysts believe are in their best financial interests. Some of these reasons include: lack of accurate information, confusion about the terms of the incentives, excessive time required to take advantage of the incentives, suspicious attitudes toward the organizations or corporations offering the incentives, lack of financial resources to put into incentive schemes that require an initial investment, and the relative invisibility of conservation impacts (Stern, et al., 1986). To take one of these reasons as an example, many consumers lack the financial resources to take initial advantage of incentive programs such as rebate programs for retrofitted energy-efficient appliances or home improvements in which consumers pay first and then later receive a reimbursement for part of their investment. In other words, a certain amount of money is needed upfront for many of these programs, and the many lower-income households are therefore unable to participate.

2.6.2 Financial and Market-based Barriers

Some barriers to energy efficiency are products of the marketplace. Evidence suggests that there is an alarming "efficiency gap" between what is in the best economic interest of the consumer and his or her actual efforts to improve energy efficiency within homes. The efficiency gap, a phrase now widely used in the energy-efficiency literature, refers to the difference between levels of investment in energy efficiency that appear to be cost effective based on engineering-economic analysis and the (lower) levels actually occurring (Golove et al., 1986).

Among the many impediments to the adoption of cost-effective energy efficiency investments is the "finance barrier". This refers to the reluctance of investors and financial institutions to invest in energy-efficient technologies because of:

- the unconventional format of energy-efficient investments (often the ancillary benefits of energy-efficient technologies are difficult to quantify and thus not amenable to standard cost-benefit analysis);
- the initial cost barrier (investors avoid energy-efficient investments because the initial costs of these technologies may be greater than other options, despite the fact that their operating costs may be significantly lower);
- risk exposure and discount rate issues;
- financiers' lack of familiarity with energy efficiency investments; and
- the lack of market information on available financial products for energy-efficient investments.

Among these barriers, the critical lack of familiarity and training in energy efficiency opportunities by personnel in financial institutions, as well as the perceived high risks of energy-efficient investments are key barriers which need to be addressed by governments.

2.6.3 Design Barriers

Many barriers to energy efficiency arise from the design of products and of homes and buildings. Fortunately, in recent years, governments, corporations and organizations have invested enormous amounts of research in improving the design of products, appliances, buildings, and so on.

There are several basic principles that contribute to energy efficient building practices. An energy efficient building or home incorporates features of design that maximize use of natural or renewable energy sources. These features decrease both the amount of energy needed within the structure as well as pollution, and in the meantime save money for the consumer. While some principles of energy efficient design and construction entail greater costs initially, and move many consumers and business-owners less likely to make the initial investment, in the long run enacting these measures yields significant energy and cost savings. There are several fundamental features of energy efficient design that builders should increasingly incorporate into their building practices:

- daytime living areas with large north-facing windows to receive unobstructed winter sun
- windows which are appropriately sized and shaded to reduce summer heat gain
- where large areas of glass are needed, use high performance glazing such as double glazing, and be careful to provide adequate summer shading
- adequate insulation in walls, ceilings and floors
- cross ventilation for summer cooling
- efficient hot water systems and fittings
- efficient lighting and appliance
- landscape design that optimizes shading to create cool and comfortable conditions.

2.7 HVAC in buildings

Building codes or standards for energy efficiency regulate on the efficiency of the building envelope, including the structures around heated or cooled parts of the building, but often they also regulate the efficiency of different part of the heating, cooling and ventilation system and maybe even other energy using equipment.

HVAC systems maintain a building's comfortable indoor climate through Heating, Ventilation and Air Conditioning (Cooling). These systems profoundly influence energy consumption in buildings. Without heating, cooling and ventilation systems there would be no energy consumption in the building, since it would be totally dependent on outdoor conditions. There is an inverse correlation between the efficiency of the building and the need for HVAC systems: highly efficient building envelopes reduce the need for heating and cooling systems. Good and intelligent designed buildings can reduce or even avoid the need for heating and cooling and reduce the need for ventilation.

Efficiency improvements in HVAC systems can lead to substantial savings, but these savings will also depend on the efficiency of the building in general. If, for instance, energy efficiency is improved in a heating boiler or an air-conditioner, total savings will depend on the total need for heating or cooling in the building. Higher requirements for the building envelope might reduce the potential for savings in HVAC systems. Finally the HVAC systems need to be in a good balance with the buildings in general and they need to be of a proper size which fits with the actual heating, cooling and ventilation needs.

- ***Ventilation***

  Well-insulated, airtight buildings often require active ventilation to remove used air and introduce fresh air for occupants. Natural ventilation, like the flow of air through open windows, and mechanical ventilation both circulate air. Ventilation can also be included in air-conditioners which combine simultaneous heating and cooling. There are many technologies to improve the efficiency of ventilation systems, including heat exchangers and heat pumps.
  For ventilation systems there is a need to be aware of both the energy use in ventilation system itself for fans and preheating of the air etc. but there is also a need to take concern for the heat losses which comes with the exchange of the air. Ventilation systems should hence effectively ensure the necessary air exchange, not more and not less.

- ***Heating systems***

  There are a wide range of systems that can heat a building. Collective heating can include a combined system based on a heating supply in the building such as a boiler or on an external supply in the form of district heating or heating from combined heat and power production. Buildings can also draw heat from individual systems such as electric heaters, heat pumps or individual ovens. Finally, heating can be integrated in the ventilation and air-conditioning systems.
  Centralised heating systems include a distribution system in the building such as pipes, ducts, tanks, pumps, fans, or exchangers. The efficiency of the overall system depends on the efficiency of all its components, and an efficient boiler can become an inefficient heating system if parts are poorly connected and badly calibrated. In individual systems, the efficiency often depends alone on the efficiency in the heating source only.

Building Codes will often address the efficiency in the system in general and in the components of the system. Some buildings might have multiple systems with a mix of functions, which should all be addressed.

- ***Cooling***

To maintain a comfortable and healthy indoor climate, the heat must be removed from overheated buildings. Cooling systems can be centralised or decentralised into small units installed in every room for instance with small split units which are installed in each room. For split units, it is mostly the efficiency of the cooling device and the control system which are of importance for the overall efficiency. Within centralised systems, the dimensions and control of the system itself and the distribution ducts both determine energy efficiency. Air tightness is especially important for building cooling, as air leakage can substantially reduce the efficiency of mechanical cooling. Some buildings work with natural cooling or with night cooling, both of which reduce the need for active cooling.

- ***Air Conditioning***

Air conditioning systems generally combine the capacity to ventilate, cool, and heat. In a basic definition, an air conditioning system will supply the building with heated air if outdoor temperatures are cold, with cooled air during hot days and with plain air if the building requires only ventilation. For air condition systems, it is primary the efficiency of the overall system and / or components which are regulated, including the heating, cooling and ventilation components.

- ***Dehumidification***

In humid climates and in buildings producing much humidity, like swimming halls or other indoor bathing facilities, moisture may need to be removed from inside buildings. Itself an often energy-intensive process, dehumidification can be integrated into air conditioning systems. Building regulations in humid climates, should account for the energy involved in humidity control.

- ***Hot sanitary water***

Many buildings' occupants require hot sanitary water for hygiene, food preparation, cleaning and commercial purposes. The central heating system can provide this water, as can a separate system using electricity, oil, gas, solar thermal energy, heat pumps or district heating. Efficiency regulations often address hot sanitary water.

- ***Ducts and pipes***

  Because ducts and pipes determine much of the energy efficiency of heating and cooling system, ducts and pipes should be carefully dimensioned, assembled, insulated and placed in the most efficient manner inside or outside the building shell.

- ***Automatic controls***

  Automatic controls of systems can largely determine or influence the efficiency of these systems. Individual systems as heating, cooling, ventilation or lighting systems can have individual automatics or the overall system can be controlled by one overall central system, which controls all the functions. If the systems are controlled by individual systems this can in some cases lead to conflicts between for instance the heating and the cooling systems. Good and efficient automatics can ensure the optimal use of the HVAC systems can be addressed.

2.8 Renewable Energy

The use of local sources of renewable energy can be either passive or active. In passive systems the renewable energy is used to avoid the need for heating or cooling while the active systems will transform the energy from for instance the sun or the wind into electricity, heat or cooled energy carriers from which energy is used, as if it came from a non renewable HVAC system. With a decreasing energy demand in buildings these sources become an important part of the energy performance of the buildings and the more advanced standards include these sources.

2.8.1 Passive Solar

In a building heated by passive solar energy, glass areas are oriented and arranged so as to optimise the capture of solar light and heat. When buildings are highly insulated and energy efficient, passive solar energy can meet a substantial share of the heating demand, even in cold climates.

Because a building's exposure to solar energy varies over the year and during the day, constructions must be able to store and balance solar energy. Buildings capturing too much heat may require cooling, offsetting the efficiency gains of passive heating. Passive solar heating of buildings requires good models for balancing heating in multiple zones to provide even temperatures throughout the building.

2.8.2 Passive cooling and ventilation

In passive cooling systems natural cool resources for instance in water or in the ground can be used to reduce the need to cool the buildings. Passive cooling systems can also use the fact that the temperature might be colder at night or use different phenomena's which will cool air or building parts.

In natural or passive ventilation different options are used to avoid active ventilation systems. Natural ventilation is often used in small residential buildings and often these buildings are constructed with out or with very limited use of active or mechanical ventilation. In larger buildings and in particular in service buildings the use of natural ventilation requires a high emphasis in the design phase.

When natural ventilation or passive ventilation is used in large buildings natural sources of wind or airstreams because of difference in temperatures are used to drive the ventilation. This is typically achieved through an intensive design phase where the shape of the building is adjusted or where specific elements such as special designed windows are introduced.

2.8.3 Active renewable energy systems

Solar water heaters are one of the most commonly used renewable energy supplies in buildings and in these systems water is heated by the sun and the heat is stored until used. Similar systems can be used to heat the building but this increase the need for storage and sometimes even from one season to another.

Photovoltaic (PV) is another example on active use of solar energy in buildings, where solar energy is transformed into electricity and used for the buildings supply of electricity. Solar energy can also be transformed directly into cooling and used as a cooling source. These systems will often require little storage, because they produce when needs for cooling are high.

Other renewable energy sources in building can be small building integrated windmills or systems that use biomass or waste products from the buildings and heat pumps can be used to increase the use of renewable energy supplies for instance in the ground, in air or in water.

2.9 Installed equipment

Installed systems other than HVAC systems can influence a building's energy performance in two different ways: through their own energy demand and through their production of waste heat which can result in increased cooling loads or decreased heating loads. Given their connection with buildings, some appliances fall under the auspice of building energy efficiency requirements in building codes and appear in the calculation of energy efficiency performance of buildings.

Some equipment and electrical appliances have more loose connection to the building and can more or less simply be removed or exchanged without interfering actively with the building itself.

2.9.1 Lighting

Lighting requirements respond to a building's design. The need for lighting, especially during daytime, will depend on the size and placement of a building's windows, and the building's situation. The need for lighting can be reduced by the use of automatic controls which depends on the orientation of buildings windows, the supply of daylight, use of the room etc. These aspects have been covered in Chapter 6.

Indoor lighting systems produce heat, in form of waste energy depending on the actual type of installations, that can reduce energy demand for indoor heating in cold climates or during winter and raise demand for indoor cooling in hot climates or by summer. Building regulations can govern lighting systems general or more commonly only the built-in lighting systems. Assessment of highly energy efficient buildings should also consider lighting.

2.9.2 Appliances

Many electrical appliances such as white goods device or televisions and computers will have an interaction with the building in which they are installed, since they will contribute to waste energy for the building. This will influence the need for heating and cooling. In particular in cooled building waste energy from inefficient appliances can lead to double energy loss, first because they use more energy themselves and second because they create waste energy, which has to be cooled away by the cooling or ventilation system.

In highly efficient buildings, heat from installed appliances can substantially influence the need for heating and cooling. Around the world, programmes such as FEMP and Energy Star in North America, EU appliance labelling schemes and Japan's Top Runner promote energy efficient appliances.

2.10 Beyond the Building Codes

Building codes and energy standards for minimum energy efficiency set minimum requirements for energy efficiency for all new buildings. In many cases it is as shown above possible and feasible to build with a much higher efficiency thereby improving the economy over the long term. No building codes or energy standards limit constructors or future owners to go for higher energy efficiency. But still the vast majority of new buildings are constructed exactly with minimum requirements of energy efficiency.

However, some buildings aim for much higher efficiency standards and among these are:

- Low Energy Buildings
- Passive Houses
- Zero Energy Buildings and Zero Carbon Buildings
- Plus Energy Buildings

Other types of buildings also aim at higher standards beyond the requirements in energy efficiency standards and buildings codes, for example, Green Buildings, Intelligent Buildings, Integrated Design, Sustainable Buildings or Ecological Foot Print.

2.10.1 Low Energy Buildings

This term is generally used to indicate that buildings have a better energy performance than the typical new building or the energy efficiency requirements in building regulations, and that the building hence will have a low energy consumption compared to a standard building.

Energy Star, positive labelling

For many countries in the European Union a level beyond the building code is defined as a part of the certification of new buildings, which has to be implemented as part of the Energy Performance in Buildings Directive. Typical specific classes such as A or B on a scale from A-G or A+ and A++ are used to indicate that these buildings are built better than standard. Some countries have used a large part of the scale or even the whole scale to show the difference in new buildings using all the letters from A-G to classify new buildings (Mohanty, 2012)

In Germany, Austria, Denmark and Switzerland special standards exists for low energy buildings. In Australia different stars are used to show the efficiency of buildings. As many as 5 stars are awarded for maximum energy efficiency. With the increase in energy efficiency requirements over time, the minimum requirements in the state of Victoria are equivalent to 5 stars. In the US a label called ENERGY STAR is used for buildings which use 15% less energy than the requirements in efficiency standards for new buildings as defined in ASHRAE and IECC 2004.

Since 1992, the ENERGY STAR program has worked to dismantle identifiable and pervasive market barriers stifling investment in energy efficiency and bring practical solutions to the residential, commercial, and industrial sectors. The more than 12,000 organizations partnering with ENERGY STAR over the past 15 years have captured environmental benefits and more. The ever-growing number of products, practices, and policies offered through the ENERGY STAR program has enabled families, businesses, and organizations worldwide to save money on their energy bills, hedge against volatility in energy markets, improve energy security, and grow the economy. (EPA, Energy Star, 2007)

2.10.2 Passive Houses

The term passive house (Passivhaus in German) refers to the rigorous, voluntary, Passivhaus standard for energy efficiency in a building, reducing its ecological footprint (Zeller et al. 2010). A passive house is a building in which a comfortable indoor climate can be obtained without a traditional heating or cooling system. Compared to traditional building they use far less energy. For most countries these demands are 70–90 % reduced compared to the actual energy efficiency requirements for heating and cooling, but this depends on the actual energy standards.

A similar standard, MINERGIE-P, is used in Switzerland. The standard is not confined to residential properties; several office buildings, schools, kindergartens and a supermarket have also been constructed to the standard. Passive design is not an attachment or supplement to architectural design, but a design process that is integrated with architectural design (Yan et al. 2006). Although it is mostly applied to new buildings, it has also been used for refurbishments.

2.10.3 Zero Energy Buildings (ZEBs)

Zero Energy Buildings (ZEBs) are buildings that do not use fossil fuels but only get all their required energy from solar energy and other renewable energy sources. The ZEB concept is no longer perceived as a concept of a remote future, but as a realistic solution for the mitigation of CO_2 emissions and/or the reduction of energy use in the building sector (A.J.Marszal et al. 2011). Goals for the implementation of ZEBs are discussed and proposed at the international level e.g.in the USA within the Energy Independence and Security Act of 2007 (EISA 2007) and, at the European level within the recast of the Directive on Energy Performance of Buildings (EPBD) adopted in May 2010. The EPBD establishes the 'nearly zero energy building' as the building target from 2018 for all public owned or occupied by public authorities buildings and from 2020 for all new buildings (EPBD 2010). By setting these objectives at the European level the nearly ZEBs should be reality in just eight years.

2.10.4 Green Buildings and Sustainable Buildings

The concept of sustainable development can be traced to the energy (especially fossil oil) crisis and the environment pollution concern in the 1970s (Mao et al. 2009). The green building movement in the U.S. originated from the need and desire for more energy efficient and environmentally friendly construction practices. There are a number of motives for building green, including environmental, economic, and social benefits. However, modern sustainability initiatives call for an integrated and synergistic design to both new construction and in the retrofitting of existing structures. Also known as sustainable design, this approach integrates the building life-cycle with each green practice employed with a design-purpose to create a synergy among the practices used.

Green Buildings are those with increased energy efficiency, but at the same time reductions are made on water consumption, use of materials and assessment of the general impact on health and environment. Green buildings can include a long list of requirements including resources, indoor air quality and requirements that all products for the building must come from a local region.

LEED Buildings

In US and Canada a specific standard LEED, Leadership in Energy and Environmental Buildings is set up, setting the requirements for the buildings to fulfill. The LEED standard can be obtained on different levels; Certified, Silver, Gold and Platinum with increasing requirements for the different requirements for the building. The LEED standard is set and controlled by the US Green Building Council (USGBC).

The LEED standard includes Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material Resources, Indoor Climate, Innovation and design. Energy and Atmosphere is the most important criteria for the buildings, but far from the only one and major other areas give the possibility of points too.

2.11 Mauritian Government Efforts

The interest of Mauritius in energy efficiency is best demonstrated through the following policies and actions:

- While in the 80's considerable emphasis was laid on Energy Planning and Policy for economic reasons, the 90's has witnessed the rising importance of environmental considerations. The National Long Term Perspective Study of 1997 proposed a vision of a country self-sufficient in energy and making high use of clean energy around 2020, relying on 'sensible conservation measures', including in buildings (Ministry of Economic Development, Planning and Regional Cooperation, 1997).
- The National Environmental Strategies (1999) specifically refer to the need 'to encourage energy conservation' (National Environmental Strategies for the Republic of Mauritius, Government of Mauritius, 1999).
- The Initial National Communication under UNFCCC published in 1999 provided a directory of GHG emissions and directed towards measures to curb CO_2 emissions from buildings (Initial National Communication under UNFCCC, Republic of Mauritius, April 1999)
- The Integrated Electricity Plan of November 2003 published by the CEB recognises that "Energy saving activities that reduce demand – and therefore defer the need for new

supply – are the most cost effective means to a sustainable energy future". The CEB's strategy for Demand Side Management includes (CEB 2003):

(a) reduction of technical losses in CEB's network,

(b) use of tariff mechanisms to shift part of peak demand to off-peak hours, and

(c) an end-use energy efficiency programme including surveys, sensitisation campaigns in households, schools, and through radio programmes, activities to stimulate energy efficiency in buildings, identification of market barriers and appropriate measures.

- In April 2007, the Government of Mauritius adopted the "Outline of the Energy Policy 2007- 2025 -- Towards a Coherent Energy Policy for the Development of the Energy Sector in Mauritius" which outlines in broad terms Government's long term vision for the energy sector. Based on this Outline, an energy study jointly funded by the EC and UNDP/UNEP was carried out from August to December 2007. The aim of the study was to support the development of a 25 year comprehensive energy policy, including a Master Plan for Renewable Energy sources. Based on the policy document, the Long Term Energy Strategy 2009 – 2025, was elaborated.
- In June 2008, the Mauritius Ile Durable (MID) Fund was set up by regulations under the Finance and Audit Act. The main thrust of the MID project, is to make Mauritius less dependent on fossil fuel, with a target of 65% autonomy by the year 2028 through increased utilization of renewable energy and a more efficient use of energy in general. According to Professor de Rosnay this objective can be achieved through the use of biomass, bio-ethanol, biogas – 35%, solar – 15%, wind – 6%, hydro – 3%, cogeneration – 3% and waves – 3%. The project includes the setting up of an Eco Park and the organization of a World Ecological Forum in Mauritius in 2011.
- A soft-loan programme to promote the use of solar water heaters is currently run by the Development Bank of Mauritius. During the first phase of the project launched in 2008, the government had put at the disposition of the population a sum of Rs 250 million and 24,000 families had benefited from it. The second phase of the Solar Water Heater Scheme, a Rs 250 million worth programme financed by the Maurice Ile Durable Fund, was implemented in January 2012 in collaboration with the Development Bank of Mauritius (DBM).
- The Government of Mauritius, through its Maurice Ile Durable (MID) Fund, has enabled Mauritians to purchase CFL's at a very low price. As at the 5th February 2009, 500,000 lamps had been sold to customers at a subsidized rate of Rs 40 for three lamps. The use of CFL lamps is expected to reduce energy consumption and alleviate expenditure of households on electricity.
- The Energy Efficiency Act 2011 was proclaimed in November 2011. The government is planning to proceed with the concept of 'eco-friendly buildings in order to maximise energy efficiency and promote the use of renewable energy. This act also looks into energy efficiency standards for appliances, buildings, vehicles, etc.

2.11.1 The Energy Efficiency Act 2011 – A Major Milestone

The Energy Efficiency Act 2011 is in line with Government Programme 2010-2015 to reduce energy demand and improve the country's energy security. It forms part of the National Energy Strategy which targets the reduction of energy consumption by 10% by 2015.

With a view to implementing energy efficient programmes, an Energy Efficiency Management Office will be set up. It will be responsible for the formulation and implementation of strategies of innovative financing schemes in applying for carbon credits; education and awareness building; regional and international cooperation and regulation of imports of equipment on the basis of their efficiency level.

According to the Government of Mauritius, standards targeting appliances such as freezers, air conditioners, electric and microwave ovens, dryers, dish washers and electric water heaters will be developed by the Office. The act will make it compulsory for designated consumers to carry out energy auditing on the basis of their energy consumption.

2.12 Proposals and Recommendations

1) The Mauritian Government should have mandatory energy efficiency standards for new buildings in building codes should urgently set, enforce and regularly update such standards.

2) The government should support and encourage the construction of buildings with very low or no net energy consumption (Passive Energy Houses and Zero Energy Buildings) and ensure that these buildings are commonly available in the market.

3) Passive Energy Houses or Zero Energy Buildings should be used as benchmark for energy efficiency standards in future updates of building regulations.

4) The government should systematically collect information on energy efficiency in existing buildings and on barriers to energy efficiency.

5) Standardized indicators should also be calculated for energy efficiency in buildings for international comparison, monitoring and selection of best practices.

6) The government should take actions to make building energy efficiency more visible and to provide information on major energy saving opportunities. This should include:

> i) Mandatory energy certification schemes that ensure that buyers and renters of buildings get information on the energy efficiency of buildings and major opportunities for energy savings; and

ii) Structures that ensure that energy efficiency information is available to all actors in the building sector at all times.

7) The government should adopt mandatory energy performance requirements and, where appropriate, comparative energy labels across the spectrum of appliances and equipment at a level consistent with international best practices.

8) The government should adopt policies which require electronic devices to enter low power modes automatically after a reasonable period when not being used.

9) The governments should:

i) Review energy measurement standards currently used, to determine whether they are consistent with national policy requirements; and

ii) Support the development and use of international measurement standards, where appropriate, in order to assist performance comparison and benchmarking for traded products while also reducing compliance costs.

10) The government should adopt the IEA recommendations on best practices in lighting, by phasing out the most inefficient incandescent bulbs as soon as commercially and economically viable.

i) In aiming for this objective, there is a need both for appropriate time scales and performance targets to be established; and
ii) Also government and industry actions must be coordinated internationally to ensure a sufficient supply of good quality higher efficiency alternative lamps.

2.13 Conclusion

Progress in implementing energy efficiency recommendations, for buildings, including residential ones is still at an early stage. A full range of activity is apparent, from the existence of measures that substantially implement components of some recommendations, to drafted measures that are not yet in force but that will make a real difference once implemented, to announcements of plans to consider developing measures. However there are numerous instances of positive developments, which provide best practice examples for other countries to follow and which serve to reinforce the worth of energy efficiency measures as a means of mitigating human-induced climate change, addressing energy security and providing for sustainable development.

Through the MID Fund, the government has taken a series of measures in the budget to sustain a ‘Green Mauritius’: improving energy efficiency, building energy efficient buildings, shifting to

Solar Energy, embellishing our environment and improving water supply. Yet, in most instances, these measures could be updated or further strengthened, the scope of their application broadened and compliance better monitored and enforced. This particularly applies to the recommendations on new and existing buildings, and to those on minimum energy performance and standby power requirements for appliances.

Saving energy is the most rapid, least costly way to reduce energy demand, CO_2 emissions and energy supply investment needs. Energy efficiency has a huge potential to bring cost-effective savings in a relatively short timeframe. Developing and implementing energy efficiency policies now is critical, not only in Mauritius, but globally. Harvesting these global opportunities requires implementation, monitoring and enforcement of new, nationally and internationally coordinated combinations of measures.

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CHAPTER 3
WATER CONSERVATION AND PRESERVATION

3.1 Introduction

In 2006, the United Nations Development Programme (UNDP) had focused its Human Development Report on access to clean water and on the ability of societies to harness the potential of water as a productive resource (UNDP, 2006). Water for life in the household and water for livelihoods through production are, as the report puts it, two of the foundations for human development. The report further argues that the roots of the crisis in water can be traced to poverty, inequality and unequal power relationships, as well as flawed water management policies that exacerbate scarcity.

In its *Vital Water Graphics* published in 2008, the United Nations Environment Programme (UNEP) further devised thresholds for the level of water stress of a country in terms of the available water per person per year (UNEP, 2008): Countries with 1700 – 2500 meter cubed of available water are considered water- vulnerable, whereas countries with 1000 – 1700 meter cubed of available water are water-stressed. Those with less than 1000 meter cubed have water scarcity. Along these lines, Mauritius confirmed its state of water-vulnerable nation with an index that went constantly down from 2,537 in 1992 to 2,158 in 2009 (Index Mundi, 2010).

Access to water is therefore poised to become an unavoidable challenge in the months and years to come. In this context, the present report focuses on one section of the problem: the domestic sector, which accounts for around two-thirds of water sales in the country (Statistics Mauritius 2011). The report seeks to propose solutions to enhance the quality of life of Mauritian residents regarding water security. In broad terms, water security is about ensuring that every person has reliable access to enough safe water at an affordable price to lead a healthy, dignified and productive life (UNEP 2008). The next two sections will detail the current status of affairs for the water situation in the country as well as provide proposals and recommendations for the domestic sector.

3.2 Current State of Affairs

3.2.1 Production and Consumption of water

The annual amount of rainfall hitting Mauritius since 2000 has been fairly regular in the range 1800 - 2400 mm, as depicted in Figure 3.1.

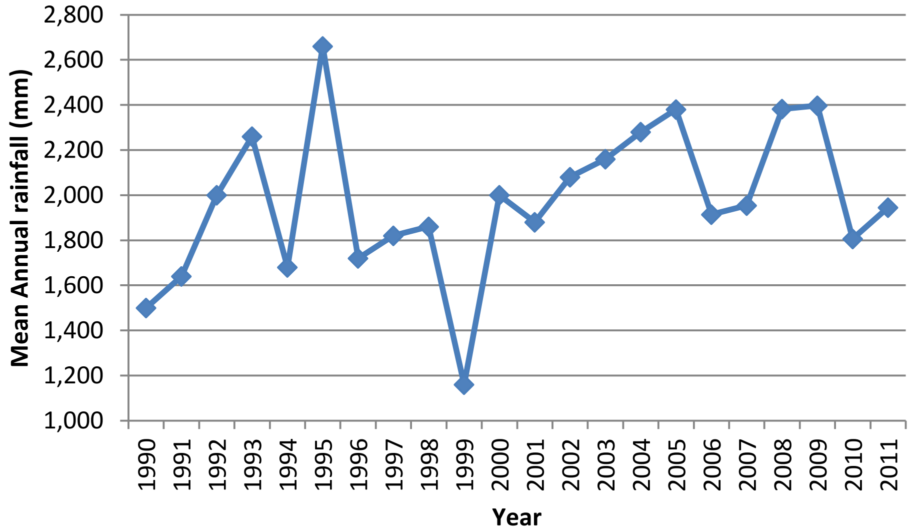

Figure 3.1: Annual Rainfall (in mm) during the period 1990 – 2011 (Source: Statistics Mauritius)

While it is true that in 1999, the country experienced a severe draught with 1160 mm of water (see Figure 3.1), we have not experienced anything similar in the period 1990 - 2011, confirming the fact that Mauritius receives the amount of rain it needs. Nonetheless, because of climatic changes, and as noted in the National Synthesis report 2012 (Ministry of Environment and Sustainable Development, 2012), there is an increase in rainfall variability, increase in the occurrence of high intensity rainfall and a shift in the onset of the summer rains. These parameters have impacted negatively on the country's water resources.

In addition to the climatic changes however, Mauritius faces an ongoing challenge. Indeed, the topography of the island itself lends to a high surface runoff – around 60%. Of the remaining, about 30% is lost through evapotranspiration. Only about 10% of the total rainfall therefore contributes to recharge the aquifers (Statistics Mauritius, 2011).

Of the water collected by our various reservoirs and provided by aquifers, it is interesting to note that 85% is treated and delivered as potable water, while 15% is used as non-treated water for agriculture and industry (Statistics Mauritius, 2011b). Please refer to Figure 3.2 for a breakdown of water sales in the country.

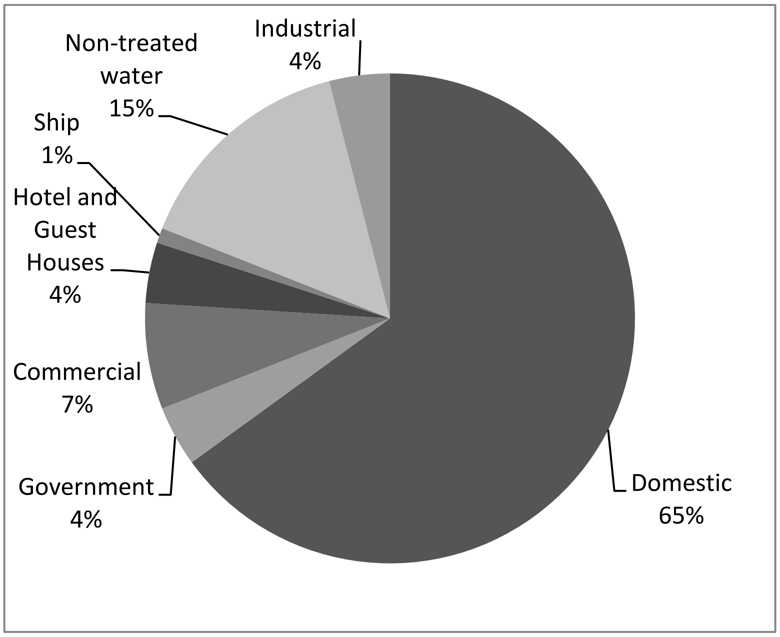

Figure 3.2: Water sales in Mauritius in 2011, categorized by sector [source: Statistics Mauritius]

As noted from Figure 3.2, 65% of the total water sales, or equivalently 75% of the potable water is used in the domestic sector, hence the importance of adopting best practices and relevant standards for households water use and management.

While facing climatic changes however, the need for water has kept on increasing. Gathered data from Statistics Mauritius reveals that the resident population has increased by 8% in the period 2000 -2011 to reach a total of 1.289 million, while the number of tourists that has visited our country during that same period increased by 47% reaching a total of 0.942 million by end of 2011. Moreover, the potable water consumed per capita per day has increased from 196 liters in 2000, peaking at 221 liters in 2010, with 211 in 2011 (probably only because of the control exercised by the CWA). Refer to table 3.1 for a summary of that indicator for the period 2007 – 2011.

Table 3.1: Potable Water consumed per capita per day [Source: Statistics Mauritius]

Indicator	**Unit**	**2007**	**2008**	**2009**	**2010**	**2011**
Potable water consumed per capita per day	liters	213	209	217	221	211

With increased water demand, the CWA faces on the other front another problem: 50% of the potable water produced is lost even before reaching its destination (Ministry of Environment and Sustainable Development, 2012). In an article that appeared in July 2011 (Le Mauricien, 2011), the author argued that at a rate of 300,000 m^3 per day that is treated from surface reservoirs and at a cost of Rs 12 per m^3, the loss of the CWA amounts to over Rs 600 million per year.

The creation of new dams have also been quite slow: Only one new dam – the midlands dam has been constructed since the inception of the CWA, and was completed in 2002. Hopefully, the Bagatelle dam, officially launched on the March 30, 2012 (Government Information Services 2012), will help in meeting that need. The dam, which will cost Rs 3.4 billion, is expected to help ensure a more reliable water supply to the district of Port-Louis district and the regions of Lower Plaines Wilhems up to the year 2050 (Ministry of Finance and Economic Development, 2009). The project is expected be completed by end 2014.

3.2.2 Profile of Domestic Water Use

The situation of domestic water has seen improvements over the years, as exemplified by table 3.2.

Table 3.2: Percentage of private households by type of water supply, 1990, 2000 and 2011/ Housing censuses

	Piped water inside living quarter	Piped water outside living quarter	Other (public fountain, well, river, etc)
1990	56.0	33.5	10.4
2000	83.7	14.5	1.8
2011	94.2	5.2	0.6

Indeed, in a period of 20 years, the number of households with piped water inside the living quarter has grown from 56% to 94.2%.

Water tank availability for households in the country has also greatly improved. From Figure 3.3, it is noted that the percentage of urban households with a water tank rose from 45% in 2000 to

56% in 2011. For rural households, the figure went from 29.7 to 45%. As at 2011 therefore, the almost half of the population possess a water tank.

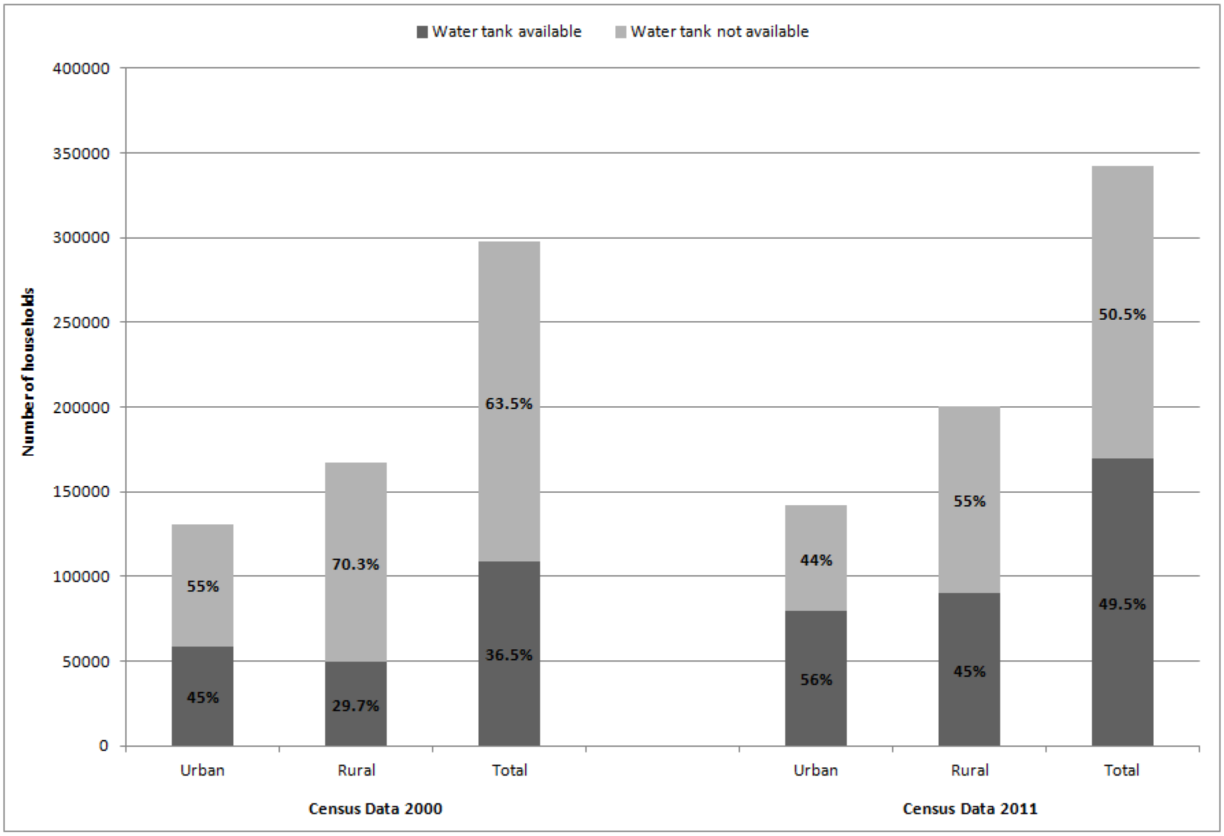

Figure 3.3: Water tank availability for households from Census data of 2000 and 2011 (Housing and Population census 2011c).

In addition, as depicted in table 3.3, other water-related amenities have also experienced progress.

Table 3.3: Percentage of private households with availability of flush toilet and bathroom with running water [Source: 2011 Housing Census, Main results]

	Census 2000	Census 2011
Availability of Flush toilet	88.8	96.4
Bathroom with running water	89	95.5

The statistics depicted so far suggest that the Mauritian household has reached a comfortable level of maturity (with all its indicators soaring above 90%) in terms of water amenities. It seems thus an appropriate time to move to the next level which is for households to use water *sustainably*. The National Programme on Sustainable Consumption and Production (SCP) in 2008 provided a breakdown of domestic water use in Mauritius. This is replicated in table 3.4.

Table 3.4: Water usage in domestic households (Ministry of Environment and National Development Unit, 2008)

Water use	Percentage
Kitchen	10
Laundry	20
Garden and Washings	20
Bathing	25
Toilet	25

Interestingly, 65% of the above list: laundry, garden and washings and toilet could be serviced using non-potable water.

3.2.3 Current Framework in Place

The Central Water Authority (CWA), operating under the aegis of the Ministry of Energy and Public Utilities, was established under the provisions of the Central Water Authority Act No. 20 of 1971.The Principal Act has subsequently been successively amended in 1975, 1982, 1985, 1989 and 2000.

The Principal Act defines the duties of the CWA as being responsible for treatment and distribution of potable water for domestic, commercial and industrial usage. In addition to the CWA however, water-related management is shared among four other bodies, namely:

- The Irrigation Authority (IA) which prepares irrigation schemes for specific areas, implements and manages irrigation projects and undertakes research on optimum water use.

- The water Resources Unit (WRU) of the Ministry of Energy and Public Utilities, which took over the responsibility of the CWA for water resources administration, and is responsible for the assessment, development, management and conservation of all water resources in the country

- The Ministry of Environment and Sustainable Development which is responsible for the preparation and issue of guidelines, standards and regulations on water quality and effluent limitations

- The Wastewater Management Authority which is responsible for the collection, treatment and disposal of wastewater from domestic, commercial and industrial sources

This fragmentation in responsibilities, as per the National Synthesis report 2012, makes efficient and effective management of water a challenge. This view is backed by the preliminary report of Singaporean consultants who made recommendations to the prime minister that only one institution should be responsible for the whole water sector (Government Information Services, 2012).

Other water-related legislations include:

- Rivers and Canals Act 1863

- Ground Water Act 1969

- Waste Water Management Authority Act 2000

With regards to drinking water quality, the standard specified by the Government Notice (GN) 55 of 1996 under the Environment Protection Act 1991 (Ministry of Environment and Sustainable Development, 1996) is applicable.

In terms of publications, the water sector has also seen 4 master plans (Lutchmun and Proag, 2010) namely:

- Development of Water Supplies for Mauritius (John Taylor and Sons), 1974

- Master Plan for the Development of Water Utilisation in Mauritius (SIGMA and SOGREA), 1981

- Master Plan Study on Water Resources of Mauritius (French Cooperation and CWA), 1991
- Master Plan for the Development of Sustainable Potable Water Supply in Mauritius (GIBB), 2007

As Lutchmun and Proag (2010) noted, putting into actions the recommendations of the four action plans have proved very difficult. While it has not been possible to implement the works proposed in the first three Master Plans as per the recommended time frame (with some that will probably never be implemented), none of the recommended projects of the latest had started by 2010. As such, the situation for the water sector in Mauritius needs a serious revamping.

3.3 Analysis of shortcomings for Mauritius

As noted in the previous section, 65% of water sales go to the domestic sector. As such, it is essential that this large volume of water is used in an efficient and sustainable manner. From information gleaned, one problem is singled out: Households use potable water for every need, even when potable water quality is not required (in garden and washings for example).

The solution is eventually to use gray water and rain water for uses where potable water is not required. Gray water, as per the ATSM standard E2635 (2008), is defined as untreated waste water from bathtubs, showers, bathroom wash bins, clothes washing machines, and laundry tubs. By appropriately matching water quality to water need, the reuse of gray water can thus replace the use of potable water to a certain extent. As at now, most households have one set of pipes that bring drinking water in for multiple uses and another that takes water away. In this system, all devices that use water and all applications of water use a single quality of water: highly treated potable drinking water. This water is used once and then it enters a sewer system to be transported and treated again. This system wastes water, energy, and money by not matching the quality of water to its use.

A gray water system, on the other hand, captures water that has been used for some purpose, but has not come into contact with high levels of contamination, e.g., sewage or food waste. This water can be reused in a variety of ways. For instance, water that has been used once in a shower, clothes washing machine, or bathroom sink can be diverted outdoors for irrigation. In this case, the demand for potable water for outdoor irrigation is reduced and the streams of wastewater produced both by the shower, washing machine, and sink are reduced. Rainwater harvesting is not widely used.

The main problem however is the lack of an appropriate plumbing code to support the sustainable development of water systems in Mauritius. For example, how will residents ensure that gray water from bathroom wash basins is fit for garden watering? Or how should residents go about if they want to use rainwater in a dual distribution system?

At an international level however, things are moving on quickly. In the next section, an analysis of what is currently being done in some other countries is provided.

3.4 Current International Practices

3.4.1 United States

In the United States, the International Plumbing Code (IPC), published by the International Code Council (based in Washington DC), is the most widely used plumbing code (International Code Council 2012). The code sets minimum requirements for plumbing systems in their design and function, and which sets out rules for the acceptances of new plumbing-related technologies. First published in 1995, IPC has just also released the 2012 version. Another code, also used in the United States is the The Uniform Plumbing Code (UPC) which is developed by the International Association of Plumbing and Mechanical Officials (2012). As at date, there is thus no single model plumbing code in the United States. However, with each code release, the two seem to be getting closer to each other to the point where a single model plumbing code may be possible if the political hurdles are eased (Ron George, 2012). It is interesting to note that both codes include a chapter on gray water recycling systems as well as a chapter on references to standards.

One advantage of the IPC however is that it forms part of a family of codes that are correlated to work with each other without conflict.This family of codes is usually adopted by state and local governments through local ordinances or laws to make these codes enforceable in their jurisdiction with the force of law. The full family of International Codes include: The Building Code, Residential Code, Fire Code, Energy Conservation Code, Plumbing Code, Mechanical Code, Fuel Gas Code, Private Sewage Disposal Code, Existing Building Code, Property Maintenance Code, Wildland-Urban Interface Code, Zoning Code, Performance Code for Buildings and Facilities, Green Construction Code and the Swimming Pool and Spa Code.

In addition, the ICC has an international program that fosters increased communication with other nations on building construction regulations. ICC International Services indeed offer international assistance to develop, adopt and deploy building regulations.

3.4.2 Australia

The strategy adopted in Australia follows that of the ICC from the United States. The Australian Building Codes Board (ABCB) oversees the establishment of the National Construction Code (NCC) which is developed to incorporate all on-site construction requirements into a single code

(Australian Building Code Board, 2012). The NCC comprises the Building Code of Australia (BCA), Volume One and Two; and the Plumbing Code of Australia (PCA), as Volume Three.

The work of the Board is supported by a professional, technical and administrative unit, the ABCB office. Furthermore, the Board prepares an annual business plan outlining its current work program and priorities. In addition, the ABCB has two primary technical advisory committees, the Building Codes Committee (BCC) and the Plumbing Code Committee (PCC). These Committees provide a valuable national forum for regulatory authorities and industry to consider technical matters relevant to building and plumbing regulation reform and play an active role in assisting the Board in meeting its obligations.

The PCA contains the technical provisions for the design, construction, installation, replacement, repair, alteration and maintenance of:

- water services;
- sanitary plumbing and drainage systems;
- stormwater drainage systems;
- heating, ventilation and air conditioning systems;
- on-site wastewater management systems; and
- on-site liquid trade waste management systems

The PCA also contains materials and product certification procedures, such as the WaterMark Certification Scheme, for certification of plumbing and drainage materials and products so that they may be authorized for use in a plumbing or drainage installation.

3.4.3 United Kingdom

From information recouped, and contrary to the US or Australia, UK does not have any plumbing code or building code. However, a national standard has been devised for sustainable design and construction of new homes: The Code for Sustainable Homes. It is entirely voluntary, and is intended to help promote higher standards of sustainable design above current Building Regulations minima (Department for Communities and Local Government, 2010).

The Code measures the sustainability of new homes against nine categories of sustainable design, rating the 'whole home' as a complete package. It covers energy/CO_2, water, materials, surface water runoff (flooding and flood prevention), waste, pollution, health and well-being, management and ecology. The Code uses a one to six star rating system to communicate the overall sustainability performance of a new home against these nine categories. The Code sets minimum standards for energy and water use at each level and, within England, replaces the EcoHomes scheme, developed by the Building Research Establishment (BRE). It should also be mentioned that the code is not mandatory, nor is there any intention to make it mandatory.

The aim of the code with regards to water is:

- To reduce the consumption of potable water in the home from all sources, including borehole well water, through the use of water efficient fittings, appliances and water recycling systems.

- To design surface water drainage for housing developments which avoid, reduce and delay the discharge of rainfall run-off to watercourses and public sewers.

3.4.4 India

The International Association of Plumbing and Mechanical Officials (IAPMO) have a strong cooperative presence in the nation of India and partnered with the Indian Plumbing Association (IPA) to develop a Uniform Plumbing Code for the nation (International Association of Plumbing and Mechanical Officials, 2012b).

The registrar of companies of India approved the establishment of IAPMO Plumbing Codes and Standards India Private Limited, to be known as IAPMO-India. IAPMO and the IPA, both members of the World Plumbing Council (WPC), agreed upon a comprehensive plan to work together to establish a model code of plumbing installation and maintenance for all of India, the Uniform Plumbing Code – India. The IPA Code Committee worked with IAPMO staff in creating a document that recognized and utilized proven international concepts, always taking into consideration the proven plumbing practices within India.

IAPMO, the IPA and the Indian Institute of Plumbing (IIP) formed a partnership agreement to provide plumbing training and education throughout India. The agreement identifies three distinct target markets: existing and emerging Engineers; Plumbing Contractors, Construction Managers / Supervisors; Plumbing Systems Installers and Repairers. A joint committee of the organizations has been appointed and is already working on the curriculum for each of the three components of the project and development of the training and educational materials.

3.5 Recommendations and Proposals

After having reviewed the water situation for the Mauritian households as well as the various water issues the country is currently facing, the recommendation for water preservation and conservation is centered on one main theme, which is:

- **To establish a plumbing code Committee** (as part of a building code board, or as a stand-alone committee) **to look into the elaboration of a Mauritius Plumbing Code.**

All the other policy-level recommendations we could include such as those relating to rain-water harvesting or gray water utilization would probably be useless without the appropriate framework which such a code would provide.

Also, since the task is paramount, it is advised to follow the examples of countries like India or Columbia where an existing code such as the IPC or the UPC of the United States was used. In collaboration with the governing body representing those codes then, the latter is adapted to make it compatible with the country. In a similar fashion to Australia, the board should also establish annual business plans so as to keep the plumbing code up-to-date and including the latest available technologies. The Government should then introduce the code for a trial period and make it mandatory after a set number of years.

As a side note: while Mauritius can go forward, and choose the UPC as India did, it might be interesting to consider beyond the Plumbing code. In that regards, the IPC which is a member of a larger family of codes, or the Plumbing Code of Australia, which is part of the National Building Code of the Country might be better choices if we are to also extend to a family of building codes.

While awaiting the establishment of an eventual Mauritius Plumbing Board, some measures that can be taken are:

- Prefer the use of low-flush toilet
- Prefer the use of low-volume showerheads, faucets and aerators
- Use front loading washers instead of top-loading ones
- Use rain barrels as a simple way to conserve water outdoors. Basic rainwater harvesting can be accomplished by placing a plastic container (such as a heavy-duty garbage can) under a downspout to collect water running off of the roof. The rain collection container should be tightly covered to prevent mosquitoes from laying eggs and small animals from being trapped inside.

3.6 Conclusion

From figures shown in the previous sections, it is clear that most households have a reasonable access to water inside their premises. The next level is then to use that water sustainably. While a plumbing code development is not the easiest thing to do, it will certainly instill the whole water sector and make way for a change of mindset for all stakeholders. The code could be updated on an ongoing basis, as it is for the various ones documented. Also, it is not recommended to start working on the plumbing code from scratch. The best solution would to establish a board that would then be responsible to seek the most appropriate existing code to start with, and see to it that the specific Mauritian needs are taken into account.

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CHAPTER 4
USE OF ENVIRONMENTALLY PREFERABLE BUILDING MATERIALS

4.1 Introduction

Throughout the world, and especially in developing and developed economies, policy makers have ignored the environmental aspects associated with rapid economic development. As a result, industrial, commercial and residential zones have been constructed at an amazing pace to meet the demands of the expanding economies while simultaneously causing serious environmental damage. Empirical studies have shown that the construction industry uses of large volumes of construction materials, generates millions of tons of waste and causes extensive resource depletion.

Buildings are large entities and they impact upon the environment in various ways. Present-day designs clearly consume large quantities of physical resources such as materials, energy and money, maintenance and use. Moreover they can also result in effects such as loss of amenity and biodiversity, which are much more difficult to assess. To substantially reduce the environmental impacts of current building approaches and practices, it is necessary to consider the impact of a building over its full life-cycle, sometimes described as a 'cradle-to-grave' analysis. The life-cycle of a building material can be considered to have five stages:

1. mining/extraction/harvesting
2. manufacture
3. construction
4. use
5. demolition

For most building materials, the major environmental impacts occur during the first two stages. However as waste-disposal problems increase, the impacts of the demolition stage is becoming increasingly vital. It is apparent that the energy used to produce the building material (embodied energy) is only an approximate indicator of its environmental impact. Generally, construction materials, especially cement and steel, require high embodied energy resulting in large amount of Carbon Dioxide (CO_2) emissions. The embodied energy of steel is about 32 MJ/Kg and for cement is about 7.8 MJ/Kg. Further, a large amount of CO_2 is produced in the transportation and processing of the construction materials. If the consumption of the construction materials remains unchanged in the coming years, then by year 2050 the production of the cement in the world could reach 3.5 billion metric tons. However since annually the production and consumption of the construction materials are increasing the production of cement annually is likely to reach over 5 billion metric tons which amounts to approximately about 4 billion additional tons of CO_2 emissions.

Paints and varnish are also intensively used in all buildings. They contain many toxic chemicals which can be harmful to the environment and human health. Air quality is one of the leading causes of sickness and solvent based paint, thinners and varnishes are all within the top 5 air pollution risks in homes and buildings. Air quality may also be affected by emissions from the flooring material itself, as well as by the adhesives used to attach the floor, surface coatings and maintenance materials, such as waxes and strippers. This is of particular importance with carpets, which have a fuzzy surface that can hold moisture and support growth. Carpets also collect pesticides and dirt tracked in from outside, and release it into the air when people walk on the carpet. These emissions of *volatile organic compounds*, or VOCs, are a major concern. VOC's may contribute to any of a full range of health effects, including triggering an asthma attack in someone who already has asthma, gradually leading to the development of asthma in someone who does not have it, or contributing to health effects ranging from minor irritation to cancer.

Carpet and vinyl are the most commonly flooring products, primarily because of their low first costs. However these choices must be reconsidered as their lifetime and health costs may be higher than desired. Both carpet and vinyl may need frequent replacement and carpets if not scrupulously maintained, may lead to health problems. A number of pollutants that are associated with respiratory illnesses, including dusts, mold and mildew, are captured and can grow in carpets and released into the air. Vinyl is also subject to mold and mildew when water pools below it. Vinyl is also the most toxic flooring material to manufacture and to dispose of. With potentially hundreds of different contaminants present in indoor air, identifying indoor air quality problems and developing solutions is extremely difficult.

Interestingly, green technology is beginning to gain increasing interest and many builders are reverting to older building materials and reducing waste in an effort to increase sustainability.

The rest of the chapter is organised as follows: Section 4.2 discusses the sustainability aspects of different building materials. Section 4.3 describes the evolution of construction in Mauritius while section 4.4 gives the way forward for Mauritius and proposes a number of recommendations. Section 4.5 discusses the other issues and possibilities in Mauritius and section 4.6 concludes the chapter.

4.2 Construction in Mauritius

The construction history of Mauritius dates back to the time when the island was colonised by the French and subsequently by the British. Houses were made up of straws and later on of wood with colonial type of habitation. As the country faced several cyclonic periods which destroyed the habitation of slaves and workers, these types of houses gave way to more solid structures. Houses made of reinforced concrete came as a new option for more security and a long lasting asset for families.

Over the last 20 years, the population of Mauritius grew from 1,070,266 to 1,286,051 and during that period, demand for residential and commercial buildings grew up especially as the country experienced the economic miracle. The 2011 Housing Census in Mauritius counted 311,500 buildings, 356,900 housing units and 341,000 households in the Republic of Mauritius as shown in Table 4.1:

Table 4.1: Residential and commercial buildings and population in Mauritius *(Source: Statistics Mauritius)*

	Buildings	Housing units	Private households	Population
Mauritius	311,500	356,900	341,000	1,257,900

Out of the 311,500 buildings in Mauritius in 2011, the majority (264,100 or 84.8%) were wholly residential buildings. Between 2000 and 2011, the housing stock grew by 19.9% from 297,700 to 356,900 housing units. 90.5% of all housing units enumerated in 2011were used as principal residence, 1.7% as secondary residence and 7.8% were vacant. The number of private households increased by 14.5% from 297,900 in 2000 to 341,000 in 2011 while the average household size decreased from 3.9 to 3.6 and is shown in Table 4.2.

Table 4.2: Number of buildings by type, Republic of Mauritius, 2000 and 2011 *(Source: Statistics Mauritius)*

Type of Building	Number		%	
	2000	2011	2000	2011
Separate houses	193,400	215,600	81.0	77.6
Semi-detached houses and block of flats	27,500	46,000	11.5	16.6
Partly residential buildings	11,400	14,500	4.8	5.2
Other dwelling	6,600	1,800	2.7	0.6
Total	238,900	277,900	100.0	100.0

84.8% of the buildings in 2011 were wholly residential buildings used by private households though their share declined from 2000 to 2011 at the expense of partly residential buildings, hotels, tourist residence and guest house as well as non-residential buildings. Concrete is the main type of construction material used for housing. It is becoming even more predominant over time with the proportion of wholly concrete residential and partly residential buildings rising from 86.3% in 2000 to 92.0% in 2011. Conversely, the proportion made of iron/tin walls and roof declined from 8.1% to 4.5% in the same period with 6,700 fewer such buildings in 2011 as illustrated in Table 4.3.

Table 4.3: Distribution of residential and partly residential buildings by construction material, Republic of Mauritius, 2000 and 2011 Housing Censuses *(Source: Statistics Mauritius)*

Type of construction materials	Number		%	
	2000	2011	2000	2011
Concrete walls & roof	206,200	255,700	86.3	92.0
Concrete walls & iron/tin roof	9,400	7,400	3.9	2.7
Iron/tin walls & roof	19,300	12,600	8.1	4.5
Wood walls & iron/tin/shingle roof	2,200	1,000	0.9	0.4
Other	1,800	1,200	0.8	0.4
Total	238,900	277,900	100.0	100.0

The construction sector in Mauritius thus became one of the most important economic pillars and the Integrated Resort Scheme (IRS) strategy introduced a few years back boosted the construction industry further. IRS permits citizens and non-citizens to buy and own luxurious residential properties on freehold land and bearing a price exceeding Rs 500mn. Over the years 2006 to 2011, investment by foreigners in the real estate projects has surged by 170 per cent to Rs4,508 mn indicating the momentum gathered by the construction sector in a short span of time.

The expansion of the construction industry in Mauritius is also captured in the demand for credit from banks by individual and promoters for residential and commercial and other types of buildings. In the last 5 years, bank loans for construction purposes have increased by more than 200 per cent. These figures give a good indication of the amount of construction materials that would be entailed by such a growing demand for buildings in that short span of time.

Data from the Statistics Mauritius given in Table 4.4 reveals that investment in construction of residential buildings have surged by more than 250 per cent in 10 years while all construction works account for more than 50 per cent in the country's total investment.

Recently increasing number of households in Mauritius has started paving surfaces around their houses. Most of the paved area however remains underutilized. This represents waste materials, energy, and financial resources and eliminate natural habitat for plants and animals. While stable surfaces are created for human activities and to provide comfort, the most traditional paving has an important shortcoming, that is, it prevents water from being absorbed in the soil. This impermeability results in increased run off, erosion, flooding, and loss of soil fertility. In addition, concrete pavement around houses retains heat, contributing significantly to urban heat sinks. Mauritians need to be sensitized on the variety of permeable paving surfaces, as well as non-pavement soil-stabilization methods that can partially overcome the disadvantages of conventional paving.

Table 4.4: Construction (Source: Statistics Mauritius 2009)

	2000	**2008**	**2009**
Floor area covered ('000 m^2)	1,510	1,567	1,695
of which: -Residential	1,170	1,124	1,159
Investment in construction			
Value (million rupees)	15,341	43,941	47,327
as a % of GDP at market prices	12.8	16.3	17.2
Investment in the construction of residential buildings			
Value (million rupees)	6,368	13,944	15,049
as a % of GDP at market prices	5.3	5.2	5.5
Share of construction in GDFCF			
All construction works	55.6	67.7	65.9
Residential buildings	23.1	21.5	20.9
Non-residential buildings	20.4	34.2	30.6
Other construction works	12.1	12.1	14.3

4.2.1 Previous and Current Government and Regulator efforts

As the number of construction works is growing it implies that that there is going to be increasing environmental damage with socio-economic implications. In light of these concerns, the local authorities have initiated steps to promote environmental friendly objectives in the construction sector. The National Environment Policy (NEP) 2007 states that the goals of the government is to achieve a sustainable built environment through smart growth characterised, amongst others, by quality architectural designs, aesthetically pleasant surroundings with green spaces and recreational facilities for all inhabitants. The main targets are as follows:

1. To adopt a policy of integrated design and architectural coherence for the built environment including energy-efficient building designs and use of eco-friendly materials.
2. To create awareness among stakeholders.
3. Free advisory services by local Authorities on design and architecture in accordance with Planning Policy Guidance.
4. To establish new constructions and building standards in the context of climate change and Tsunami.

Government has also identified strategies and policy instruments which will among others,

1. Review of the legal framework for the promotion of energy efficiency in buildings.
2. Encourage public-private-community partnerships for National Community Beautification Programmes.
3. Raise awareness on the need for good design of the built environment for its social, environmental and economic benefits.
4. Promote the development of skills in design and landscaping through education and capacity building.
5. Ensure high architectural design quality in all permitting and licensing system.
6. Urge all local authorities to develop a local plan taking all above into consideration.

Government had also proposed a Long-Term Energy Strategy 2009 – 2025 for Sustainable Buildings which included the following:

1. Energy efficiency to become one of the main criteria in the design of public and in rental of private buildings.
2. Carry out a phased plan for retrofitting existing state-owned public buildings, in a phased manner, to bring their energy performance up to best practice standards.
3. Introduce a new Building Control Act to improve building design and choice of building plant and equipment to attain high efficiency in term of energy use.
4. Address issues of sustainable building designs and low energy consumption in specific Planning Policy Guidelines.
5. Introduce best working practices and engineering based solutions to address public sector energy efficiency.

6. Launch appropriate campaigns with the objective of changing behaviour at work and promoting practices aimed at rationalization of energy use in all big buildings.
7. Provide necessary technical support and guidance for the implementation of energy saving measures in all Ministries and Parastatals.
8. Installation of solar water heaters in Government buildings and promote efficient use of energy in the health sector.
9. Reduce energy consumption of public sector to half the current level by the year 2015 and to pursue efforts up to 2025.

Government also envisages introducing the following measures in 2012:

1. A Building Control Bill for mandatory sustainable energy design standards for new buildings, including housing, hotels and offices, including natural ventilation; day lighting; appropriate orientation; solar hot water systems; time-of-day and smart metering; intelligent lighting systems that are suitable for low-energy lamps; and building energy management systems for buildings more than 500m^2.
2. Guidelines for Passive Solar Design for buildings <500 m^2
3. Guidelines for Green Buildings (Min of Environment and Sustainable Development)

4.2.2 Private sector initiatives

Most construction projects that have been implemented over that period have put little focus on environmental concerns. As a result, very little efforts have been geared towards environmentally friendly building products in Mauritius. As of now, very few projects have factored in these products. Firstly, the Mauritius Commercial Bank has constructed a building at Trianon that makes use of the latest green technologies, such as thermal storage, low consumption lamps, use of photovoltaic modules to generate electricity and recycled products for furniture and flooring and secondly, the Nautica Commercial Centre in Black River is the first green commercial building in Mauritius that utilises daylight with sunlight filtering and large windows, cross ventilation, green roofs, rain water harvesting and biodisc sewage treatment.

In addition, the 'Sustainable Green Building Mauritius' is a non-profit organisation in the field of sustainable planning and green buildings and is a member of World Green Building council whose goals among others are to promote construction of green buildings.

4.3 Sustainability Aspects of Building Materials

Sustainable building materials are environmentally responsible as their impacts are considered over their complete life time. Sustainable building materials should cause very minimal or no environmental and health risks (Calkins 2009). Environment, human health and well-being can be severely damaged by the extraction or harvesting of raw materials and by the production and distribution of building materials that make up the whole supply chain of the construction industry (Joseph and Tretsiakova-McNally 2010). The major environmental burden of buildings are (i) embodied energy of building materials, which is the amount of energy required to produce a material and supply it to the point of use (Venkatarama-Reddy and Jagadish 2003). Thormark (2006) showed that embodied energy in traditional building can be reduced by approximately 10–15% through the proper selection of building materials with low environmental impacts. Table 4.5 shows the worldwide averages of building materials used in UK and their corresponding embodied energy and embodied carbon.

Gradually some of the sources of raw materials are becoming exhausted. Hence the remaining stocks have to be treated with great caution. It is possible to substitute most rare materials used in the construction industry by other more abundant or renewable ones. This has led to a new trend in manufacturing of building materials from the waste products of various origins (Halliday 2008), for example, utilization of waste products had been successfully implemented in countries like Holland and Japan, where construction industry practically lack raw materials (Peris-Mora 2007).

Table 4.5: Embodied energy and embodied carbon of common and alternative building materials *(Source: Calkins (2009))*.

Type of Material (1 ton)	Embodied Energy (MJ/ton)	Embodied Carbon (kg of CO_2/ton)
Limestone	240	12
Stone/gravel chipping	300	16
Rammed earth	450	24
Soil cement	850	140
Concrete, unreinforced (strength 20 MPa)	990	134
Concrete, steel reinforced	1,810	222
Soft-wood lumber (large dimensions, green)	1,971	101
Soft-wood lumber (small dimensions, green)	2,226	132

Portland cement, containing 64–73% of slag	2,350	279
Portland cement, containing 25–35% of fly ashes	3,450	585
Local granite	5,900	317
Engineering brick	8,200	850
Tile	9,000	430
Soft-wood lumber (small dimensions, kiln dried)	9,193	174
Steel, bar and rod	19,700	1,720
Polypropylene, injection molding	115,100	3,900

4.3.1 Concrete and Cement

Concrete is widely used for building structural frames, ground-works, floors, roofs, and prefabricated elements (Pulselli et al. 2008). Annually more than 10 billion tons of concrete are produced in the world (Meyer 2009). Concrete is a durable material with excellent mechanical properties. It is adaptable to different climates, relatively fire resistant, widely available and affordable. Concrete can be molded almost into any shape and can be designed to satisfy almost any performance requirements (Meyer 2009). It can be reinforced with either steel or fibers. Moreover, recycled materials can be incorporated into the concrete mix, thus reducing consumption of raw materials and disposal of waste products. The use of admixtures are becoming quite popular as the final composite can have better durability and can gain certain specific unique properties (Calkins 2009).

Unfortunately concrete has a serious negative impact on the environment. Cement and concrete industry generates up to 7% of global anthropogenic CO_2 emissions (Calkins 2009). There is also release of CO_2 due to the unavoidable de-carbonation of limestone in addition to the emissions related to the combustion of fossil fuels (Damtoft at al. 2008). Moreover manufacture of Concrete generates other air pollutants like carbon monoxide (CO), sulfur oxides (SO_x), nitrogen oxides [$(NO)_x$], hydrogen chloride (HCl) and volatile hydrocarbons and carbon dioxide. The production of concrete is causing depletion of non-renewable mineral and water resources required in extremely large quantities. World concrete industry uses 10 billion tons of rock and sand, and 1 billion ton of water annually. Although Portland cement composes about 10% of concrete mix, its production accounts for 92% of the total energy demand (Calkins 2009). Demolition and disposal of concrete structures is another significant cause of environmental threat (Meyer 2009). Concrete is estimated to account for up to 70% by weight of construction and demolition waste.

4.3.2 Improved concrete

The negative environmental impact of concrete can be decreased by enhancing the performance of the concrete and reducing its amount by volume used for a certain construction. Habert and Roussel (2009) estimated that the reduction of the amount of concrete in a particular construction, through increase in the mechanical strength of the concrete, could reduce CO_2 emission by 30%.

One way to reduce the total amount of materials and energy resources required is by designing smaller and thinner concrete sections. This undoubtedly implies that the material should have a significant level of strength. There are several ways of achieving this:

a) The development and application of high performance concrete (HPC). This is a type of concrete that has a low water to cement or water to binder ratio. HPC has a higher level of compressive strength compared to traditional concrete (Aïtcin 2000). It has a low porosity that makes it more resistant to low temperatures and chemical exposure (Calkins 2009).
b) Using self-compacting concrete which can fill a given form completely without any mechanical action (Damtoft at al. 2008**)**. Self-compacting concrete:
    1. requires less labour and so reduces costs, increases productivity and allows faster construction
    2. eliminates the absence of large voids and inhomogeneities inside self-compacting concrete which results in its improved mechanical characteristics, better performance and longer service life
    3. casting requires no additional electrical energy for vibration
    4. is associated with low level of noise and absence of vibration problems normally present at the plants and construction sites
    5. has new aesthetic potentials and enables the development of more complicated geometries designs.

   Self-compacting concrete allows the use fine fillers of ground limestone and other by-products such as fly-ash, quarry dust among others (Joseph and Tretsiakova-McNally 2010).

c) Application of adequate steel reinforcing or fiber reinforcing techniques to enhance the durability of concrete structures. This prevents cracks from developing inside the concrete and so leads to improved impermeability, strength, weather and impact-resistance of the material (Calkins 2009). Steel reinforcement is less desirable as the durability of the finished product can be affected by corrosion, and the production of steel is associated with serious environmental implications. Fiber reinforcement involves inclusion of either synthetic (nylon, glass or polypropylene) or natural fibers (vegetable, hemp (De Bruijn et al. 2009), flax (Fernandez, J.E., 2002), coir, eucalyptus pulp, residual sisal (Agopyan et al. 2005) into the concrete mix.

d) Developments of new ultra-high performance cement composites, which have unique structural and aesthetic potential. These are compact reinforced composite (CRC) and Ductal. CRC is a composite of special fiber reinforced concrete with extremely high compressive strength and reinforcing bars arranged in a particular manner (Damtoft at al. 2008), Compact Reinforced Composite (CRC) Home Page). CRC has been used in structural application, mainly for the production of precast elements (balconies and staircases). Ductal possesses improved rheological properties and a unique combination of attributes. Ductal's compressive strength is 6–8 times higher, the flexural strength is 10 times higher, and the durability is from 10 to 100 times better than traditional concrete. Moreover, Ductal can deform under excessive loads without rupture and has excellent surface aspects.
e) Use of nanomaterials might be very powerful in order to achieve sustainability objectives. Nanoscience of cements is a relatively new discipline with a huge potential to manipulate the nanostructure of calcium silicate hydrate (Beaudoin et al. 2009). As the full environmental and human impacts of nanoparticles are unknown, it is possible that they pose some risks through inhalation or skin absorption (Calkins 2009). Concrete reinforcement with nanofibers, including carbon nanotubes, has a potential to improve strength of concrete significantly and possibly eliminating the need of the reinforcement with steel. Moreover, nanocoatings containing titanium dioxide (TiO_2) can make self-cleaning buildings in the future, reducing the amount of harmful cleansers used currently. Moreover the nanoparticles of TiO_2 can even reduce air pollution by removing nitrogen oxides (Green Technology Forum, *Nanotechnology for Green Building,* 2007). The use of nanoparticles of Portland cement, silica (SiO_2), titanium dioxide (TiO_2), and iron oxide (Fe_2O_3) can significantly improve compressive and flexural strength of concrete (Calkins 2009).

4.3.3 Cement Reduction in Concrete

Reduction of cement use in concrete mix is achieved through substitution of cement with other pozzolanic or hydraulic materials (Calkins 2009). Common supplementary cementitious materials include fly ash (by-product from coal fired power plants), Ground Granulated Blast Furnace Slag (GGBFS, by-product of steel industry), and silica fume (by-product of semi-conductor industry) (Calkins 2009, Meyer 2009, Damtoft et al. 2008, Papadakis and Tsima

2005). The utilization of industrial waste products as supplementary cementitious materials definitely has a positive environmental impact as otherwise they would be land-filled. Moreover, they improve the durability and mechanical properties of concrete, reduce thermal stress and cracking. Fly ashes enriched with calcium oxide can also be used to replace limestone in clinker production. Utilization of current world sources of blast furnace slag and fly ash would reduce CO_2 emission by 10% (Damtoft 2008).

4.3.4 Usage of Recycled Materials in Concrete

Use of recycled products as a substitute of natural aggregates results in reduction of the consumption of raw materials, exploitation of quarries, and in the minimization of the land areas required for disposal. The products that can replace fine and coarse aggregates include Recycled Concrete Aggregate (RCA), crushed blast furnace slag, sand, brick, glass, granulated plastics, waste fiberglass and mineralized wood shavings among others. The mechanical strength of the concrete, in the presence of RCA, drops by approximately 40%. However this loss can be counteracted by adding fly ash. The compressive strength of RCA can be increased to adequate values compared to those of traditional concrete by (1) adding to the mixture supplementary cementitious materials (fly ash or silica fume) with the aid of an acrylic-based super-plasticizer and (2) simultaneously decreasing the water/cement ratio (Achtemichuk, et al. 2009).

Post-consumer glass bottles and post-industrial float glass cullet are offered as suitable aggregates for concrete (Meyer 2009, Damtoft et al. 2008, Bignozzi et al. 2009, Kralj 2009, Shao et al. 2000, Federico 2009). Recycled glass has zero water absorption, high hardness, good abrasion resistance, excellent durability and chemical resistance. These characteristics can improve the overall performance of concrete as well as impart colour and aesthetic properties to it.

Guerra et al. (2009) studied the effect of recycled porcelain materials on the mechanical properties of concrete and found that the substitution of natural aggregate with ceramic debris from sanitary ware waste does not improve significantly the mechanical properties of the new material compared to an ordinary concrete. However, it provides a good opportunity for the recycling of construction industry residues.

There is a number of research work related to the substitution of natural aggregate with the wastes from wood processing activity (Al Rim et al 1999, Becchio et al 2009). The work conducted by Becchio et al. (2009) focused on the possibility of the mineralized wood concrete production by incorporating wooden waste pre-treated with silica fume.

Rubberized concrete composites are obtained by replacing fine (up to 10%) and coarse (up to 20%) natural aggregate with waste tyre rubber (Bignozzi and Sandrolini 2006, Hernandez-Olivares 2002). The most common ways of using recycled tyres in cement concrete composite are shredding, chipping or grounding the rubber to the particles with sizes ranging from 450 mm to 75 µm (Meyer 2009). The major disadvantage of this technique is a significant decrease of the compressive, tensile strength and stiffness of the composite product with the increasing amount of rubber in the mix. On the other hand, owing to the presence of rubber particles, the concrete can gain extra ductility (Meyer 2009). Other potential advantages of rubberized concrete are good sound absorption capacity as well as excellent thermal properties.

Recycled waste plastic is not generally widely available to be used in replacement of natural aggregates (Calkins 2009). A major obstacle in the use of plastic is the poor adhesion of plastic particles with cement matrix, which can also considerably reduce mechanical performance of concrete (Meyer 2009). This problem can be solved by combining 10–15% of waste plastics with other materials like fly ash, thus leading to the production of lightweight structures and blocks that increase the deformation characteristics of concrete without failure (Calkins 2009).

4.3.5 Wood-Based Building Materials

Wood is easy to work with, is a structurally strong construction material suitable for many applications such as framing, flooring, roofing and lining. An increased use of wood in construction is controversial. Forests purify the air and sequester carbon. Trees need mainly solar energy to grow. Manufacture of wooden materials requires less fossil fuel and emits less GHG over their life-cycle than other common building materials. On the other hand some wood harvesting practices and techniques have caused the global problems such as clearing large expanses of forests, loss of biological diversity, water and soil pollution caused by to the liberal use of fertilizers and pesticides, generation of waste that was land-filled (Calkins 2009).

Wood is a renewable material and has huge potential to be sustainable through sustainable forest management and harvesting practices. A greater use of wood in buildings instead of energy-intensive building materials is more important than the negative effect of carbon stored in wood (Buchanan and Levine 1999). Residues, resulting from the harvesting of forests and the manufacture of wood products should be completely utilized to replace fossil fuels (Gustavssan et al. 2006). For example, boards with high strength, density and excellent mechanical properties even better than commercial wood based panels can be produced by processing whole coconut husk without the addition of synthetic binders (Van Dam et al. 2004). Reclaiming and reusing of wood are also widely encouraged. Untreated wood can be recycled into other products such as mulch or compost. Unfortunately treated wood poses a more significant problem for disposal as it may contain harmful compounds (Calkins 2009).

Borjesson and Gustavsson (2000) have calculated the primary energy use and the emissions of CO_2 and methane and compared design options consisting of either wooden or concrete frame from the life-cycle and forest land-use perspectives. They found that the primary energy input was about 60–80% higher when concrete frames were used. Moreover they stated that the net

GHG balance is strongly affected by the method in which wood is being utilized after the demolition of the building and that it is estimated to be clearly positive if all of the demolition wood is land-filled and slightly positive if all wood from this building is used instead of fossil fuel. Furthermore GHG emissions can be improved or even be made negative if demolition wood is re-used. Many scientists are convinced that using wood products in construction will result in lower fossil energy demands and significant cuts of GHG emissions compared to non-renewable alternatives such as steel and concrete (Sathre and O'Connor 2008). Moreover the recycling of wood effectively addresses the problems of waste management and lack of natural resources.

4.3.6 Glass and Plastics

Windows are very important in sustainable construction of residential buildings as they are responsible for heat transfer, provision of daylight, ventilation, weather protection and acoustic insulation. Due to the high heat conductivity of the glass, unwanted heat gain or loss takes place. Energy conservation and windows sustainability can be achieved through the use of low-emissivity (low-e) coatings, replacement of air with inert gases and adjustment of the gap between glass panes in double or triple glazing. Low-e coatings improve thermal characteristics of the windows by blocking infrared rays responsible for solar heat gain (Robinson and Hutchins 1994). Both the optimization of the thickness of air layer in glazing cavity (Aydin 2000) and the replacement of the air with gases having low thermal conductivity (argon or krypton) significantly reduces energy transfer.

Many products used in construction are made of plastic. These include water pipes and drainage systems, composite lumber, panels and fences among others. Plastics as building materials are water and decay resistant quite durable and flexibility, relatively light weight and require low maintenance. They can incorporate a substantial amount of recycled products and are themselves recyclable. Unfortunately plastics also have negative effects on the environment that include high consumption of fossil fuels and release of toxic by-products like heavy metals and furans during their manufacture as well as the generation of large amounts of waste. The most common plastics used in building construction are high-density polyethylene, cross-linked polyethylene, polypropylene, polyvinyl chloride, polystyrene, polyacrylonitrile among others (Joseph and Tretsiakova-McNally 2010).

Environmental impacts of plastic building materials can be improved through reuse/recycling and development of new materials with better sustainable properties (Calkins 2009, Ross and Evans 2003, Xu et al. 2008). There is growing interest in the field of reinforced plastic composites (Xu et al. 2008, Pang and Bond 2005, Corbiere-Nicollier 2001, Pervaiz and Sain 2003) through the use of certain amount of different additives (aluminum, steel, glass, ceramics, nanoclays, natural or synthetic fibers). The reinforced plastics have better mechanical properties and have greater potential for further recycling. Xu et al. (2008) observed that bio-fibers had several advantages over the synthetic glass such as lower costs, lower density, renewability, excellent chemical resistance, good strength and significant processing benefits. Moreover the environmental performance of the composite is improved due to its lower density as compared to the original polypropylene.

4.3.7 Brick, Stone and Ceramics

Brick is one of the major building materials in modern construction. It has a very good durability and long service life. Bricks are mainly used for both outer and inner walls construction. Primarily bricks are made of non-toxic natural materials like clay and shale. Moreover brick manufacturing has a good potential for utilization of the solid wastes which can be incorporated into the brick and neutralized by firing at high temperatures. The main environmental concerns are high energy usage and GHG emissions during the production of bricks (Joseph and Tretsiakova-McNally 2010). Korenoes and Dompros (2007) showed that most of the emissions are directly associated with the burning of fossil fuels, acidification has the highest share (56%) and is due to the combustion of low-grade fuel with high sulphur content that produces large amounts of SO_2 and $(NO)_x$.

The negative factors encouraged researchers to develop new types of masonry materials with improved environmental profile (Calkins 2009, Korenoes and Dompros 2007, Roth 2004, Oti et al. 2009) such as unfired clay bricks (Oti et al. 2009). Unfired bricks significantly reduce the energy use and cut down CO_2 emissions. The main disadvantage of unfired clay soil is that it is susceptibility to damage by water. This type of damage can be avoided by stabilizing the clay soil with the addition of small quantity of lime (Mckinley et al. 2009). However the durability of lime-stabilized soil is still quite low and requires further improvements (Okagbue and Yakubu 2000). The results of several studies [Oti et al. 2009,Tasong et al 1999, Rajasekaran 2005) showed that increase in durability of the unfired clay soil occurred when GGBFS was added to lime-stabilized systems. Moreover the price of the final products was still relatively low. In addition, unfired clay bricks showed excellent environmental performance as their total energy input was estimated of 657 MJ/ton as opposed to 4,187 MJ/ton for the common fired bricks and the CO_2 emission was 41 kg CO_2/ton compared to 202 kg CO_2/ton for traditional bricks in mainstream construction.

Stone is a low impact building material, if quarried locally, minimally processed and used appropriately. There is a tendency to rehabilitate the use of dry stone for modern sustainable construction (Villemus et al. 2007). The environmental burdens and potential applications of natural stone and aggregate are extensively discussed by Calkins (2009).

Asif et al. (2007) showed that ceramic are quite energy-intensive (32,240 MJ) and amounts to 15% of the total embodied energy in the house. Nicoletti et al. (2002) showed that marble tiles have better environmental performance compared to ceramic ones. In case of ceramics, due to the composition of raw materials used for the glaze production, the emission of arsenic and lead containing compounds takes place.

4.3.8 Alternative Building Materials

Non-renewable resources of building materials shall get exhausted in the near future. Thus there is an urgent need to shift to building materials with low embodied energy and that are preferably available locally (Morel et al. 2001). Such materials generally have a range of beneficial properties such as low toxicity, high durability, low level of GHG and other pollutants emissions, high recycling potential and minimal processing requirements compared to common building materials such as concrete, steel, wood and plastics among others. Moreover several of these materials such as bio-based materials (Calkins 2009, Halliday 2008, Van Der Lugt 2006, Utama and Gheewala 2009, De Flander and Rovers 2009, Hoang 2009, Jayanetti and Follet 2003, Paudel et al. 2004) are either biodegradable and do not produce hazardous by-products or are earthen building materials (Calkins 2009, Halliday 2009, Isik and Tulbentci 2008, Kouakou and Morel 2009, Collet et al. 2006). Bio-based building materials frequently originate from renewable organic constituents of plants and animals. They include crops and residues, animal wastes, forest materials and post-consumer biological waste, bamboo, straw bales, fiber crops and plant seed oils (Calkins 2009).

Bamboo is a member of giant grasses and is an abundant material. It has excellent mechanical properties, is light weight and flexible, has a high growing rate and is relatively low cost. Thus it has excellent opportunities as sustainable building materials in the countries where it occurs naturally (Utama and Gheewala 2009, Singh et al. 2009). The utilisation of bamboo is growing rapidly, as interior decoration in the form of laminate flooring, panels, chipboards and fireboards (Calkins 2009). Van der Lugt et al. (2006) showed that bamboo has twenty times less environmental impact as compared to other more conventional building materials. They also considered the problems associated with the use of bamboo, such as difficulty of joining bamboo due to its hollow round form and found that this issue can be resolved by laminating the material. De Flander and Rovers (2009) showed that bamboo has a great advantage in terms of the annual yield per forest area compared to a traditional wood. They showed that one laminated bamboo-framed house can be build from one hectare of bamboo forest. Calkins (2009) presented that other barriers that reduce bamboo's overall performance and lead to its short life service are cracks developing for minimally processed culms, slippery outer surface when it is wet, susceptibility to the attack of insects, fungi and microbes, deterioration of durability upon the exposure to adverse weather. Undoubtedly time and efforts will be needed to overcome these difficulties and to render bamboo a strong and competitive building material that would meet the standards of modern construction.

Materials for earthen construction such as hydrated lime, clay, cob, adobe (mud bricks), compressed earth blocks and rammed earth have been known and used for many years all over the world. Presently, there is a growing interest in these building materials as sustainable alternatives to traditional concrete, brick and wood. Earthen building materials normally contain soil with less than 20% of clay and water. Collet et al. (2006) demonstrated that pre-fabricated cob blocks can be used in modern construction. Kouakou and Morel (2009) examined the effect of clay as a natural binder on the mechanical properties of adobes. After adobes had dried they were subjected to a compression testing and the results showed that the mechanical strength depended on the manufacturing process and the content of water in the adobes. Pressed adobe blocks were more homogeneous than traditional adobes and had a higher compressive strength with the gain of approximately 50%. Loss of strength when saturated with water and erosion due to the wind or rain are the main problems that have to be eliminated for successful future application of earthen building materials.

4.4 The way forward for Mauritius

Mauritius is a small emerging economy where awareness on environmental issues still needs to be instilled as a strong culture among constructors, architects and investors as well as the population as a whole.

4.4.1 Material Selection and Substitutes

Local constructors should devote more efforts in selection of material to reduce adverse the environmental impacts. Several techniques have been developed to lower environmental impacts. The Life Cycle Assessment (LCA) and the Eco-indicator system techniques are the most prominent techniques used by designers in all industries. In Europe both of these systems are beginning to be used by the designers in the construction industries. The tools which are available to designers in the construction industry are critically examined for the selection of the materials.

It must be recognised that the role of the designer in selecting the materials is quite difficult because of the conflicting claims by the different materials manufacturing industries. Concrete is claimed by the concrete industry to be the most sustainable material as it is made from waste material (The Concrete Centre) and has very low embodied energy. Timber is claimed by the timber industry to be the most sustainable material as it renewable (National Association of Forest Industries) and completely natural. Steel is claimed by the steel industry to be the most sustainable material as it highly recycled (Steel Recycling Institute). To get the desired results industries select their own measures which are not compatible for the designer in selecting materials. So there is always a need for the production industries like Concrete, Timber and Steel to establish a standard methodology which scientifically evaluate according to the perspective of environment credentials.

4.4.2 Recommendations on Building Materials Selection in Mauritius

For decision makers to select materials suitable for sustainable construction the assessment of their environmental burdens is necessary and building materials can be considered as sustainable after each material has gone through a process involving preliminary research, evaluation and selection. The process will show which product has the best environmental characteristics. Moreover it is important for sustainable development to consider social and economic factors as well (Joseph and Tretsiakova-McNally 2010).

During the period of colonisation and up until the mid of the last century stone, wood, straw and iron sheets were the main construction materials. However these could not sustain the strength of the violent cyclones that frequently visited Mauritius. Consequently Mauritians shifted towards the use of concrete and steel for most construction. Presently, concrete remains the main construction building material in Mauritius and although it is highly desirable to utilise environmentally friendly materials, no substitute is available as an alternative that have the strength to sustain the strong cyclones that frequently visit Mauritius. Steel or galvanized steel could be used as in the construction of the State Bank of Mauritius building in Port Louis instead of concrete but steel is worse than concrete in terms of the embodied energy as an environmentally friendly construction building material.

Nevertheless it is possible to reduce the amount of concrete and perhaps steel as well in construction of residential buildings in Mauritius. To this end a number we proceed by listing a number of recommendations.

4.4.2.1Recommendations

Concrete:

1. Reduce the total volume of concrete needed for a construction by enhancing its performance. Reduction of the concrete volume for a particular building, by increasing the mechanical strength of the concrete, could lead to approximately 30% reduction of CO_2 emission (Habert and Roussel 2009).
2. Design smaller and thinner concrete sections to reduce the total amount of materials and energy resources required. This can be achieved by using High Performance Concrete (HPC) (Aïtcin 2000), Self Compacting Concrete (Damtoft at al. 2008).

3. Apply adequate reinforcing techniques to enhance the durability of concrete structures preferably using fibre reinforcing. Agopyan et al. (2005) and Coutts (2005) have shown the possibility of developing a building material taking into account the mechanical properties of fibers.

4. Use compact reinforced composite (CRC) and Ductal. As compared to traditional concrete, Ductal's compressive strength is 6–8 times higher, the flexural strength is 10 times higher, the durability is from 10 to 100 times better. Moreover Ductal technology requires only 65% of raw materials, 51% of the primary energy and 47% of the overall CO_2 emissions compared to traditional concrete (Damtoft et al. 2008)
5. Use of nanomaterials in order to achieve sustainability objectives as Concrete reinforcement with nanofibers, including carbon nanotubes, has a potential to improve strength of concrete significantly and possibly eliminating the need of the reinforcement with steel (Chen and Poon 2009).
6. Reduce cement content in concrete mix by increasing the application of supplementary cementitious materials. This is easily achieved through the substitution of Portland cement with other pozzolanic or hydraulic materials (Calkins 2009). Commonly used supplementary cementitious materials include fly ash, ground granulated blast furnace slag and silica fume (Calkins 2009, Meyer 2009, Damtoft et al. 2008, Papadakis and Tsima 2005).
7. Increase usage of recycled materials to replace natural non-renewable resources. The products that can be used to replace fine and coarse aggregates are recycled concrete aggregate, crushed blast furnace slag, sand, brick, glass, granulated plastics, waste fiberglass, and mineralized wood shavings among others. The drop in the mechanical strength caused by the RCA can be contained by adding fly ash.
8. Post-consumer glass bottles and post-industrial float glass cullet are suitable as aggregates for concrete (Meyer 2009, Damtoft et al. 2008, Bignozzi et al. 2009, Kralj 2009, Shao et al. 2000, Federico 2009) especially as recycled glass has no water absorption. Moreover it is hard and is quite resistant to abrasion and has excellent durability and chemical resistance.
9. Replace natural aggregate with ceramic debris from sanitary ware waste. Although this does not improve significantly the mechanical properties of the new material compared to an ordinary concrete, it provides a good opportunity for the recycling of construction industry residues.
10. Include wood aggregates into concrete. This leads to a decrease of material density and it improves thermal insulation.
11. Use rubberized concrete composites by replacing fine and coarse natural aggregate with waste tyre rubber (Bignozzi and Sandrolini 2006, Hernandez-Olivares 2002).

Wood based building materials

1. Use wood in buildings making instead of non-wood materials, such as steel, aluminum and concrete to reduce both the energy demands of the buildings and the concentration of green house gas in the atmosphere.

2. Increase the amount of wood used in construction, for example by ensuring that most interior separation walls are made up of wood or wood derivatives, as a greater use of wood in buildings at the expense of energy-intensive building materials and substitution effect of avoiding fossil fuel emissions are more important than carbon stored in wood (Buchanan and Levine 1999). Moreover wood has a positive association with such values as well-being, aesthetics and eco-friendliness. Government should exploit the great potential of wood as sustainable and renewable by appropriate forest management strategy of maintenance and harvesting practices. In this context a major portion of currently unutilized crown and private lands could be utilised to grow trees. This would have several positive effects on the environment.
3. Use residues resulting from the harvesting of forests and the manufacture of wood products to replace fossil fuels (Gustavssan et al. 2006).
4. Recycle untreated wood into other products such as mulch or compost.
5. Use demolition wood as land fill, fossil fuel or in new construction. Borjesson and Gustavsson (2000) estimated the net GHG emissions to be clearly positive if all of the demolition wood is land-filled and slightly positive if all wood from this building is used instead of fossil fuel. GHG emissions would be improved or made negative if demolition wood is re-used.
6. Adopt the strategies proposed by Calkins (2009) for design and specification of sustainable timber:
   (i) use wood resources efficiently, that is, use the lowest quality wood for applications, build smaller and durable structures, simple design, minimal preservative treatments, reduce wood waste, build for disassembly and use engineered wood products
   (ii) use certified wood
   (iii) use reclaimed wood
   (iv) use natural or low-toxic wood finishes.
7. Use wood for exterior structures after treating it with a preservative containing organic insecticide and fungicide embedded in 100 nanometers plastic beads as proposed by Calkins (2009). The finished wood product gets protected fungus and insects and become suitable for exterior structures.

8. Use wooden frames to provide better thermal insulation compared to aluminum or plastic. Additionally the lower values of embodied energy make timber frames more sustainable than aluminum, uPVC, steel and aluminum-clad timber types of frames (Menzies and Wherett 2005).

Glass and Plastics

1. Reuse or recycle plastic building materials to reduce their negative effects on the environment such as high consumption of fossil fuels and release of toxic by-products, disposal and generation of large amounts of waste
2. Use newly developed plastic materials with better sustainable properties (Calkins 2009, Ross and Evans 2003, Xu et al. 2008).
3. Use reinforced plastics that have better mechanical properties, inbuilt healing capability against cracks and greater potential for further recycling (Xu et al. 2008, Pang and Bond 2005, Corbiere-Nicollier 2001, Pervaiz and Sain 2003).
4. Use bio-fibers reinforced plastics which have several advantages over the synthetic glass based plastics such as lower costs, lower density, renewability, excellent chemical resistance, good strength and significant processing benefits.

Brick, Stone and Ceramics

1. Use bricks as they consists of non-toxic natural materials like clay and shale. In addition solid waste can be transformed into bricks which are then neutralized by firing at high temperatures.
2. Use unfired bricks to significantly reduce the energy use and cut down CO_2 emissions. The disadvantage is that unfired clay soil is susceptibility to damage by water can be overcome by stabilizing the clay soil with the addition of small quantity of lime. This can be further improved by adding GGBFS to lime-stabilized systems studies (Oti et al. 2009,Tasong et al 1999, Rajasekaran 2005).
3. Rehabilitate the use of dry stone for modern sustainable construction.
4. Use Ceramics, terrazzo and marble as flooring materials as they have the advantageous features of being among the most durable finishes with extremely low emissions. Although they are costly to buy and install, their life-cycle cost is among the lowest of all finishes because of their long life and the minimal maintenance they require. The main air-pollution factors in the field are the setting method, the grout, and any sealers required to protect unglazed surfaces.

Alternative Building Materials

1. Use building materials with low embodied energy and that are preferably available locally having low toxicity, durability, low level of GHG and other pollutants emissions, high recycling potential and minimal processing requirements.
2. Use materials that are biodegradable or earthen materials that do not generate hazardous by-products. The biodegradable materials are frequently obtained from renewable organic constituents of plants and animals and include agricultural crops and residues such as

bamboo, straw bales, fiber crops, agricultural residues and plant seed oils, animal wastes, forest materials, post-consumer biological waste among others.
3. Use earthen construction materials such as hydrated lime, clay, cob, adobe (mud bricks), compressed earth blocks and rammed earth.

Green Roofs

There are interesting prospects for Mauritius to move towards the introduction of green roofs. These roofs are purposely fitted or cultivated with vegetation are also known as living roofs. Green roofs impact on energy usage and thermal performance differently. They can be extensive (planted with simple plants such as sedum, or allowed to seed naturally, where they are called biodiverse roofs), or intensive (planted with shrubs and even trees) Hassell C & Coombes B, (2007). Green roofs have been shown to impact positively on a building's energy consumption by improving its thermal performance, although the amount of difference this makes varies depending on daily and seasonal weather. Poorly insulated roofs, as found on many existing buildings, lead to overheating of spaces beneath them during the summer and excessive heating demand during the winter. By retrofitting green roofs, both air conditioning and heating usage is decreased.

Passive solar design

The term 'passive solar design' encompasses a variety of techniques used to trap heat within a building during the winter months while avoiding overheating during the summer months. It integrates a combination of building features which can markedly reduce the need for mechanical heating and electric lighting. New construction offers the greatest opportunity for incorporating passive solar design and it should be considered as early as possible in the design process (Rawlings, 2007).

Paints and varnish

Non volatile organic compounds paints, glue, varnish and false ceiling are sustainable and are currently being utilised in Mauritius. The quality of indoor air results from the interaction of many complex factors each contributing different effects. In choosing floor materials and associated products, it is important to look for low VOC products and flooring surfaces less likely to exacerbate moisture/mold and allergens issues. Possibilities of utilizing linoleum (mixture of wood dust and oil) for flooring should be investigated.

Recycling

1. Both steel and concrete from demolished construction can be recycled and reused. Recycling enables us to regain most of the useful materials from the construction waste and to reuse them before the end of the materials lifespan. This helps to reduce the energy consumption and carbon dioxide production.
2. Recycled concrete also called recycled aggregates have properties that differ from those natural aggregates. The use of crushed concrete aggregate with new concrete should be increased. Larger blocks of recycled concrete can be used as a material for shoreline protection and erosion control. The recycled crushed concrete can used as a base material for roads, drainage material placed around underground pipes, as a base material for pavements and foundations, landscaping material.
3. Construction companies should use demolition waste separating machine to separate recycled material. The steel can be resold as a scrap material to the steel mills. The recycled concrete is crushed and washed, and sold as aggregates. All other material that is left can be used selectively for land filling. The cost of buying the aggregate and of trucking and tipping is saved.
4. Use renewable materials that include wood, plant fibers, wool, and other resources that are are potentially replaceable within a limited time period (such as a few decades or less) after harvesting. Information on wood harvested through sustainable management practices could be gathered and certification programs and standards could be developed as in other countries.

Fly Ash

The use of Fly ash should be exploited as it could help reduce the use of concrete to some extent and at the same time, reduce the adverse emissions of carbon dioxide. Fly ash is a waste material from coal-burning power plants. It can be used to replace up to about 30 per cent of the Portland cement in conventional mixes. It can also be mixed with ground blast-furnace slag, a waste from metal smelting. Fly ash produces a superior concrete with excellent finishing characteristics. Research carried out in the US shows that coating concrete destined to rebuild America's crumbling bridges and roadways with some of the millions of tons of ash left over from burning coal could extend the life of those structures by decades, saving billions of dollars. Given that there are non-hydroelectric power stations in Mauritius, further research in that area could be initiated as a priority to evaluate the possibility of using the fly-ash generated. The objective is to assess to what extent fly-ash can be used to reduce the use of concrete in building constructions and at the same address the environmental concerns. The forthcoming cement project in Mauritius could investigate the use of Fly ash to minimise the associated environmental concerns that would arise.

Construction and Demolition wastes

The construction and demolition waste should be screened to remove hazardous materials. If hazardous waste is present then workers should be given special equipment and specialised transportation arrangement should be made.

A market for recyclable aggregates could be created and greater emphasis should be laid on usage of recyclable aggregates rather than virgin aggregates. This will lead to a secondary market for recyclable aggregates and so create employment in the construction sector and contribute to sustainable development. Hence government should initially give financial incentive for separating and reusing demolition waste.

Construction and demolition wastes are generated in small amount at locations that are widespread. Hence a mobile crushing plant that can be set up close to the site is needed to avoid transporting of the waste over long distances.

4.5 Other Issues and Possibilities

Sustainable development avoids building on prime agricultural soils, and requires that on each site enough undamaged, fertile soil remain after construction to support plant and wildlife diversity, infiltrate precipitation, and filter pollutants that cannot be controlled at their sources.

With regard to site lighting, an assessment is required to ensure that they are carefully designed to avoid waste. The environmental and social costs of this type of lighting must be carefully weighed against its benefits. Moreover light pollution can disrupt biological cycles in plants and animals, including humans. Glare increases hazards by blinding people and making areas outside the light even less visible.

4.5.1 Standards, benchmarks and regulations

The authorities should consider implementing standards and fiscal measures to promote the use of recycled building materials. These include

- (i) Developing procurement standards for recycled content building materials including specified
- (ii) Including an additional tax on purchase of non-recycled materials
- (iii) Introduce new legislations or regulations requirement waste management plans on demolition materials by contractors
- (iv) Increase in tipping fees for disposal at landfills will encourage and make recycling more feasible (Dolan J et al. (1999))

4.6 Conclusion

In this chapter we have analysed the results of research regarding the possibilities of using environmentally friendly building materials and based on these research results a number of recommendations have been proposed for the residential construction sector in Mauritius. It should also be clear that the same recommendation apply to the whole construction sector in Mauritius. However it should be pointed out that study into the different possibilities should be encouraged and undertaken in order to determine the suitability of the proposed environmentally preferable products in Mauritius and to develop mechanisms to make them usable.

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CHAPTER 5
INDOOR ENVIRONMENT QUALITY

5.1 Introduction

Indoor Environment Quality (IEQ) encompasses indoor air quality (IAQ) as a main component, but also focuses on airborne contaminants, as well as other health, safety, and comfort issues such as aesthetics, potable water surveillance, ergonomics, acoustics, lighting, and electromagnetic frequency levels (WBDG Sustainable Committee, 2011).

However, unlike Energy Conservation which is usually backed by significant political and institutional frameworks, funding and legislation, Indoor Environment Quality does not enjoy the same privileges. As Mudarri (2010) noted, this imbalance increases the vulnerability of indoor air quality to changes made in buildings to save energy. As such, while indoor air quality is being squeezed to its “minimally acceptable level”, energy conservation has become the objective to maximize. Given the uncertainties as to what is minimally acceptable for indoor air however, the health, comfort, and productivity of occupants are placed in an increasingly precarious situation.

According to the excellent report of the US Environment Protection Agency, EPA (2001), entitled “Healthy Building, Healthy People”, US citizens spend about 90 percent of their time indoors, where concentrations of air pollutants are often much higher than those outside. The report also clarifies known health effects of indoor pollutants and these include: asthma, cancer, developmental defects including effects on vision, hearing, growth, intelligence, and learning; and effects on the cardiovascular system (heart and lungs). The report further states that pollutants found indoor may contribute to other health effects, including those of the reproductive and immune systems. Furthermore, most chemicals in commercial use have not been tested for possible health effects.

While the expository of the state of affairs draws a dark picture of the situation, it can nevertheless catch the attention of the relevant authorities so that efforts are re-directed in the right direction.

5.2 Current State of Affairs

5.2.1 Overall Environment Performance of Mauritius

According to the Environment Digest of Statistics Mauritius (2011b), the Environment Performance Index (EPI) rank of the country went from 58th (out of 149) to 6th (out of 163). The

EPI score climbed accordingly from 78.1 to 80.6. While this result seems very encouraging, it might be interesting to take a deeper look at the detailed record. This is provided in table 5.1.

Table 5.1: Environmental Performance Index (EPI) for Mauritius, 2008 and 2010 [Source: Digest of Statistics Mauritius (2011b)]

	2008	**2010**	**% change**
EPI Rank (out of 149 Countries in 2008 and 163 Countries in 2010)	58	6	
EPI Score	78.1	80.6	3.2
Of which			
Environmental Health	**97.7**	**83.7**	**-14.3**
Water (effects on humans)	96.5	96.6	0.1
Air Pollution (effects on humans)	97.9	97.4	-0.5
Environmental Burden of Disease	98.2	70.3	-28.4
Ecosystem Vitality	**58.5**	**77.5**	**32.5**
Forestry	87.4	86.5	-1.0
Fisheries	99.5	99.5	0.0
Agriculture Climate Change		93.0	
Air Pollution (effects on ecosystem)	94.4	43.7	-53.7

Water (effects on ecosystem)	64.7	74.4	15.0
Biodiversity & Habitat	21.9	45.0	105.5

From the recorded data, we note that while the item "Ecosystem Vitality" went up by 32.5% for the period 2008 - 2010, the item "Environment Health" which impacts directly on inhabitants, went down by 14.3%. Probably the most alarming figure is that of the "Environment Burden of Disease", which quantifies the amount of disease caused by environmental risks. This figure went down by 28.4% for the period 2008 – 2010. As such, more Mauritians now have their health affected because of the effects of their environment. In addition, we note also that the metric for Air Pollution effect on the ecosystem went down by 53.7%.

Interestingly, Subratty et al (2001) presented a mathematical model that depicts the relationship between the possibility of occurrence of common health problems and factors leading to the so-called Sick Building Syndrome (SBS) symptoms in domestic interiors in Mauritius. The prevalence of upper respiratory symptoms (dry eyes, runny nose), central nervous system symptoms (headache, nervousness), and musculoskeletal symptoms (pain/stiffness in shoulders/neck) were found to be elevated when responses were statistically regressed to type of building and age of respondents. The authors also advised to evaluate the effectiveness of current building operation practices and to prioritize allocations of resources for reduction of risk associated with Indoor Environmental Air Quality.

Next, the number of complaints received by the Pollution Prevention and Control Division is analysed. Hopefully overall the figures show signs of a redress. From Table 5.2, it can be seen that from 2001 to 2010, the total number of complaints went down almost five fold. However, there are signs of the slight degradation during the period 2007 – 2010.

Table 5.2: Number of complaints received at the Pollution Prevention and Control Division by Category, 2001 – 2010 [Source: Digest of Statistics Mauritius (2011b)]

Category	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Noise	821	458	583	444	342	178	135	157	123	160
Solid waste	758	88	88	177	201	137	88	49	136	118

Air pollution	188	229	209	129	154	61	62	57	57	76
Waste water	210	286	155	180	289	92	76	84	72	77
Odor	417	406	344	328	272	121	88	102	88	128
Other	657	189	389	447	215	224	119	147	46	63
Total	3,051	1,656	1,768	1,705	1,473	813	568	596	522	622

Table 5.3: Percentage distribution of households surveyed by specified environment problem [Source: Digest of Statistics Mauritius (2011b)]

	Percentage of household affected			
Environmental problem	Not affected at all	Affected to some extent	Seriously affected	Total
Dumping of solid waste	80.4	12.8	6.8	100
Waste/stagnant water	83.1	10.8	6.1	100
Stray dogs	62.1	25.6	12.3	100
Breeding of animals by neighbors	89.6	7.5	2.9	100
Rats/mice	64.9	26.3	8.8	100

Presence of crows	90.8	6.8	2.4	100
Traffic noise	75.7	18	6.3	100
Industrial noise	95.2	3.3	1.5	100
Other noise	86.8	9.8	3.4	100
Smoke/dust	81.7	13	5.3	100
Odors	83.1	10.8	6.1	100

Table 5.3 considers the environmental problems households normally face. As can be inferred, the top five of the list are: Rats/mice, Stray dogs, dumping of solid waste, stagnant water and odors.

Table 5.4: Households with members suffering from health problems related to air pollution by type of problem in Mauritius.

Health problem	**Households reporting health problems**		
	Number	**as a % of households reporting health problems**	**as a % of all sampled households**
Breathing Difficulties	242	62.0	3.8
ENT Problems	163	41.2	2.6
Asthma	138	35.4	2.2
Eye troubles	81	20.8	1.3
Skin diseases	65	16.7	1.0

From table 5.4, a staggering figure of 62% of households reporting health problems mention breathing difficulties, whereas 35.4% report asthma.

These statistics tallies well with the alarm cry of the US Environment Protection Agency. IPA (2009) indeed cites many sources of indoor air pollutants including: oil, gas, kerosene, coal, wood, and tobacco products; building materials and furnishings as diverse as deteriorated, asbestos-containing insulation, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for household cleaning and maintenance, personal care, or hobbies; central heating and cooling systems and humidification devices; and outdoor sources such as pesticides, and outdoor air pollution.

Some of these sources, such as building materials, furnishings, and household products like air fresheners, release pollutants more or less continuously. Other sources, related to activities carried out in the home, release pollutants intermittently. These include smoking, the use of unvented or malfunctioning stoves, furnaces, the use of solvents in cleaning and hobby activities, the use of paint strippers in redecorating activities, and the use of cleaning products and pesticides in housekeeping. High pollutant concentrations can remain in the air for long periods after some of these activities.

5.2.2 Current Framework in Place

The Environment Protection Act 2002, as described in (Ministry of Environment and Sustainable Development, 2002) provides for the protection and management of the environmental assets of Mauritius so that their capacity to sustain the society and its development remains unimpaired and to foster harmony between quality of life, environmental protection and sustainable development for the present and future generations; more specifically to provide for the legal framework and the mechanism to protect the natural environment, to plan for environmental management and to coordinate the inter-relations of environmental issues, and to ensure the proper implementation of governmental policies and enforcement provisions necessary for the protection of human health and the environment of Mauritius.

Part VI of the Act refers to National Environmental Standards, and confers to the Minister the power to issue guidelines published in the Gazette on any of the following:

- Water
- Effluent Limitations
- Air
- Noise
- Waste, in any form of nature
- Pesticide residues
- Radioactive Emission
- Built –up Environment and landscape

Without prejudice however to the Occupational Safety, Health and Welfare Act, and any other enactment. The Minister shall also, for the control of pollution of the environment, have exclusive authority to issue national environmental standards in relation to any of the subjects mentioned above.

Inter alia, under the provisions of the Act, the Minister shall therefore prescribe:

- standards for water quality to protect the public health, welfare and the environment, and to provide adequate safeguard for the quality of water

- standards to protect the quality of air resources so as to promote the public health and welfare, and the development and the productive capacity of the human, animal, or plant life

- standards as are required to maintain, preserve and develop architectural harmony and aesthetic value for the built-up environment

The environmental standards in place are:

- Environment Protection (Standards for Air) Regulations 1998
- Environment Protection (Environmental Standards for Noise) Regulations 1997
- Environment Protection (Drinking Water Standards) Regulations 1996
- Environment Protection (Standards for Hazardous Wastes) Regulations 2001

However, while the standards offer protection to the general environment, they do not cater for the environment quality within the residential perimeters, except maybe for the environmental standard on noise which specifies the maximum noise for residential areas at different time of the day.

5.3 Analysis of shortcomings for Mauritius

As the Mauritius Environment Outlook report 2011 puts it: “Mauritius has endorsed international agreements on environmental protection and has always aimed to translate these global commitments into national policies, strategies and actions. The institutional and legal framework for environmental protection has also been established” (Ministry of Environment and Sustainable Development, 2011). However, the report continues: “While implementation of policies and enforcement of legislation have been invaluable to local environmental protection, Mauritius has to further reinforce actions for environmental management to pursue the transition towards sustainable development.”

The fact, however, that the Mauritius Environment Outlook Report is the first report of its kind published by the Government of Mauritius, reflects a firmly based and growing recognition of the importance attached to environmental issues as an integral part in the pursuit of sustainable development. Nonetheless, the report itself notes that:

- Sustained economic development and changing patterns of consumption are leading to an increase in the emission of atmospheric pollutants from the following sectors:
    - Electricity production
    - Industrial activities
    - Transport
    - Sugar cane burning
- Pollutants emitted impacts on human health, quality of life and the environment; the extent of which have not been extensively studied.
- Regulations and prescribed standards have a number of loopholes.
- Progress on air quality monitoring and enforcement of regulations has been mixed due to lack of technical capacity in terms of equipment and trained personnel.
- There is no continuous time series data on air quality in Mauritius.

Furthermore, when it comes to indoor air quality, the Mauritius Environment Outlook Report makes the following mention: "Indoor air quality and workplace risks are emerging issues owing to their potential impacts on human health. Unfortunately, there is little knowledge on indoor air quality, workplace risks and their associated health implications for Mauritius. Today buildings are becoming increasingly sealed from the external environment, thus increasing the concentrations of particulates and other organic compounds. Studies should be carried out to assess the level of indoor and workplace pollution." Such comments reinforce the need for indoor air and environment quality to be part of the whole process of residential building design along with other aspects such as energy efficiency.

But where can Mauritius tap for information regarding Indoor Environment Quality. In the next paragraphs, a few international efforts in this direction are analysed:

5.3.1 ASHRAE 62

One of the main standards in the United States that deal with Indoor Air Quality (IAQ) is American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE)

Standard 62. The latter has been included in a number of building codes to provide for IAQ. The purpose of ASHRAE Standard 62, as defined in Section 1, is to "specify minimum ventilation rates and indoor air quality that will be acceptable to human occupants and are intended to minimize the potential for adverse health effects." If local building codes reference ASHRAE Standard 62, then the requirements of the standard become an integral part of the code. Regardless of local code requirements however, designing and operating a building to ASHRAE 62 is expected to minimize IAQ liability and help assure an acceptable indoor environment.

The standard is made up of six parts:

- Purpose
- Scope
- Definitions
- Classification
- Systems and Equipment
- Procedures
- Construction and System Start-up
- Operations and Maintenance

More details on the standard can be obtained from ASHRAE's website (ASHRAE, 2003).

5.3.2 National Ambient Air Quality Standards (NAAQS)

Still in the United States, The Clean Air Act, which was last amended in 1990, requires the Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. The Clean Air Act identifies two types of national ambient air quality standards:

- Primary standards - to provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly.
- Secondary standards - to provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

The EPA has set the NAAQS for six principal pollutants, which are called "criteria" pollutants (EPA, 2012). These include: carbon monoxide, lead, nitrogen dioxide, ozone, particle pollution, and sulphur dioxide. The minimum limits are set as parts per million (ppm) by volume, parts per billion (ppb) by volume, or micrograms per cubic meter of air (µg/m3).

5.3.3 ASHRAE 55

The purpose of ASHRAE 55 is to specify the combinations of indoor thermal environmental factors and personal factors that will produce thermal environmental conditions acceptable to a majority of the occupants within the space (IHS, 2012).

The scope is:

- The environmental factors addressed are temperature, thermal radiation, humidity, and air speed; the personal factors are those of activity and clothing.
- It is intended that all of the criteria in the standard be applied together, since comfort in the indoor environment is complex and responds to the interaction of all of the factors that are addressed.
- The standard specifies thermal environmental conditions acceptable for healthy adults at atmospheric pressure equivalent to altitudes up to 3000 m (10,000 ft) in indoor spaces designed for human occupancy for periods not less than 15 minutes.
- The standard does not address such non-thermal environmental factors as air quality, acoustics, and illumination; or other physical, chemical or biological space contaminants that may affect comfort or health.

5.3.4 Indoor AirPLUS Program

The voluntary Indoor airPLUS program was created by the US Environmental Protection Agency (EPA) to help builders meet the growing consumer preference for homes with improved indoor air quality (EPA 2009b). By constructing homes that meet EPA’s stringent specifications, builders can offer homes designed to deliver improved indoor air quality.

Indoor airPLUS includes the following design and construction features:

- Moisture Control: Build in added protection from mold and other moisture problems with water managed roofs, walls, and foundations. Features include continuous drainage planes, proper flashing and air sealing, damp-proof foundation walls, capillary breaks, drain tile, and proper grading.
- Radon Control: Provide radon-resistant construction in high radon potential areas, including gravel and plastic sheeting below slabs, fully sealed and caulked foundation

penetrations, plastic vent pipe running from below slab through the roof, and an attic receptacle for easily adding an electric powered fan to the vent pipe if needed.

- Pest Management: Provide a first-line defense against pest problems by fully sealing, caulking, or screening likely pest entry points. When these physical barriers are combined with proper pest management techniques, pesticide use may be reduced.

- Heating, Ventilating, and Air-Conditioning (HVAC): Improve indoor air quality with best practice design and installation of ducts and equipment to minimize condensation problems, whole-house and spot ventilation to help dilute and exhaust indoor pollutants, and air filtration to remove airborne particulates.

- Combustion Venting: Protect residents from potential exposure to combustion gases by installing direct-vented or power-vented gas- and oil-fired equipment, properly vented fireplaces, garages fully sealed from living spaces and equipped with an exhaust fan, and carbon monoxide alarms in each sleeping area. Building Materials: Reduce sources of pollutants by selecting and installing materials to minimize risk of moisture damage, specifying materials with reduced chemical content, and ventilating homes prior to occupancy.

However, houses that need to be indoor AirPLUS certified require, as a prerequisite, to be ENERGY STAR certified, ENERGY STAR being a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy to help US citizens save money and protect the environment through energy efficient products and practices.

5.4 Recommendations and Proposals

The main recommendation for the topic of Indoor Environment Quality is make an in-depth study of the provisions of ASHRAE 62, ENERGY STAR and its associated Indoor AirPLUS program to see how these documents from the US Environment Protection Agency could be applied to the context of residential buildings in Mauritius.

It is interesting also to note that LEED (which is referenced as an important document in other parts of this report) and Energy Star are complimentary to each other. Buildings may thus be both LEED certified and Energy Star rated. In fact, LEED requires Energy Star as part of its EB (Existing Building) rating system. As such, the elaboration of national building code based on LEED *and* ENERGY STAR is possible.

Also, in general, the requirements of a Mauritian Residential Indoor Environment Quality Guideline should:

- Facilitate Quality IEQ through Good Design, Construction

- Provide Thermal Comfort
- Supply Adequate Levels of Ventilation and Outside Air
- Prevent Airborne Bacteria, Mold, and Other Fungi
- Use Materials that do not Emit Pollutants or are Low-emitting
- Provide Quality Water
- Control Disturbing Odors through Contaminant Isolation and Product Selection

5.5 Conclusion

Indoor environment is central to public health because people spend a lot of time inside their premises. In addition, concentrations of most pollutants are higher indoors, often as much as ten or more times higher than in outdoor air. Hence the need to include Indoor Environmental Quality (IEQ) considerations in new building designs, especially in residential ones for the health of its occupants including old people and infants. As such, while Mauritius should carry forth with the development of its national building code, care should be taken to include all the parameters of good IEQ. It is believed that the study of LEED and ENERGY STAR will provide the necessary foundations for such endeavor.

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CHAPTER 6
OPERATIONAL PRACTICES

6.1 Introduction

Achieving a sustainable future and reducing carbon emissions also involve the design of control systems for buildings and building services so that they can operate with minimum energy consumption. While it may be self-evident that modern, highly serviced industrial buildings require a sophisticated control system or Building Management System (BMS), it should be realised that simpler residential buildings can still benefit from a modern BMS or more precisely a home automation system. Home Automation (HA) is the residential extension of "building automation". It is automation of the home, housework or household activity. Home automation allows centralized control and enhances the operational practices associated with lighting, HVAC (heating, ventilation and air conditioning), plant irrigation, domestic appliances, and other systems. It also provides a sophisticated and flexible interconnection between devices, allowing them to be intelligently and remotely controlled. In addition to minimizing the energy consumption, home automation systems contribute towards enhancing occupant comfort, health, productivity, security and quality of life (Warburton *et.al* 2009; Wikipedia, 2011).

Home appliances are the world's fastest growing consumers of energy after automobiles and they constitute a significant share of the household budget of citizens. By 2014 the sales of home appliances in the world is expected to go beyond 1.7 billion units. As more and more home appliances are able to connect wirelessly to smart-phones, tablets and other devices, no longer will refrigerators, washers, dryers, dishwashers and ovens be just "plain" white goods. The market for these connected appliances is expanding rapidly and is projected to reach $6.2 billion by 2015, an increase from $40 million in 2010 (Gohn, 2010, Intertek). It is therefore obvious that enhancing operational practices through the usage of smart home appliances can significantly contribute towards sustainability.

Several previous publications have demonstrated how home automation systems can improve energy efficiency and contribute towards enhancing the overall standard of living of individuals. Essentially, these works have focused on providing new solutions to Demand-Side Load Management (DSM). DSM (Bellarmine, 2000) are methods that coordinate the activities of energy consumers and energy providers in order to best fit energy production capabilities with consumer needs, hence, avoiding energy demand peaks, which generally have adverse environmental impacts and increase energy production costs (Wacks, 1991). Home automation systems can carry out a new load management mechanism called distributed control (Wacks, 1993). This DSM control allows energy providers to charge users for the actual energy production cost in a very precise way, and it also allows users to adjust their power consumption according to energy price variation. In the peak period, the domestic customer would be able to decide whether to wait and save money or to use appliances even so. The demonstration in (Boivin, 1995) shows that the HA systems can offer savings of up to 15% or even 20% on electric bill by more efficiently managing household demand (Long Ha *et. al.* 2006). Additionally, standards such as Zig-Bee (Zig Bee Alliance, 2012), HomePlug Green PHY (HomePlug Powerline Alliance, 2012), Wi-Fi (Wi-Fi Alliance, 2012) and Z-Wave (Z-wave alliance 2011), all provide energy efficient home automation solutions that are easily deployable and cost effective. Another important aspect of home automation is the mechanisms used to remotely control the smart devices. In (Shahriyar, R et.al. 2008) for example the authors have investigated different ways by which a cell phone can be used to implement remote control in home automation. Several standards also offer highly sophisticated communication mechanisms for interconnecting home appliances and provide scalability and flexibility. In addition, various industries are currently considering different communications protocols for use in Smart Grid. However, little has been done to establish or isolate any clear or emerging preferred protocols for use in smart appliances. This situation has created confusion in the Home Area Network (HAN) device space for utilities, consumers, and device manufacturers (AHAM, 2010).

However, despite being a viable solution for enhancing operational practices, home automation can be prove to be an inaccessible solution for countries where this technology is yet to make inroads and for families with financial constraints. An alternative solution in these situations would be to educate people on the best practices that can be adopted to enhance operational practices in their homes with a view to save energy. A lot of energy is wasted for example through leaky windows or ducts, old appliances, or inefficient heating and cooling systems. Long term energy savings tips can significantly lower the energy bills of residential buildings. The key to these savings is to take a whole-house approach by viewing the home as an energy system with interdependent parts. For example, a heating system is not just a furnace but a heat-delivery system that starts at the furnace and delivers heat throughout the home using a network of ducts. Even the most energy-efficient furnace will waste a lot of fuel if the ducts, walls, attic, windows, and doors are leaky or poorly insulated. Hence, taking a whole-house approach to saving energy ensures that money invested to save energy is efficiently spent (Energy Savers, 2012a).

As is the case for most developed and developing countries in the world, the demand for high-tech domestic appliances is very high in Mauritius. Coupled with this demand, the need for ensuring sustainability is even more pressing and several steps are being taken by the Government to this end. This chapter presents the current situation in Mauritius and worldwide regarding the usage of domestic appliances and presents home automation as a viable option for sustainability and enhancement of operational practices. An analysis of the main components and standards of existing home automation systems is made and the challenges faced by home automation solution providers are also presented. The best practices that should be adopted to save energy in the home are also discussed and presented as a viable short-term, low cost alternative to home automation. Finally, recommendations for enhancing operational practices in the home and the adoption/setting up of communication standards regarding home automation are discussed.

6.2 Impact of domestic appliances on the Mauritian economy and worldwide

According to research provider IHS iSuppli (Selburn, 2011), the consumer electronics market, which is comprised of televisions, stereos and audio components, portable media players, set-top boxes, gaming devices, DVD and Blu-ray players, digital cameras, projectors and camcorders, digital picture frames, e-book readers, and consumer appliances, is projected to reach 1.60 billion units in 2011, up from 1.56 billion in 2010, as illustrated in Figure 6.1 (Intertek, 2011).

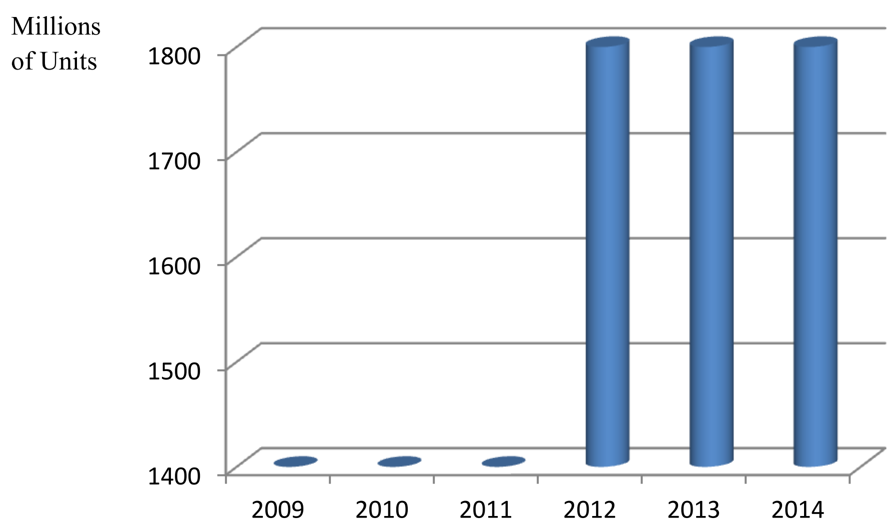

Figure 6.1: Global Consumer Electronics Shipment Forecast, 2009-2014 [Source: (Selburn, 2011; Intertek, 2011)].

Moreover, in many countries, government subsidies are expected to drive the rapid development of the smart, energy-efficient home appliance market. Major manufacturers, supported by connectivity technology partners, will be another driving force, as consumers are expected to begin purchasing larger energy-efficient appliances such as refrigerators, dishwashers, clothes washers, dryers, stoves and ovens. This is illustrated in Figure 6.2 (Intertek,2011).

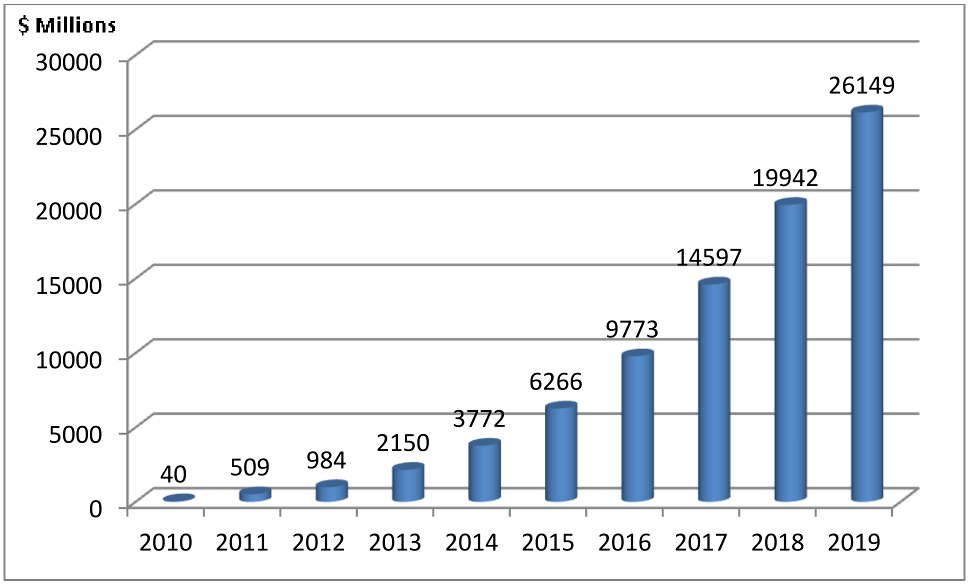

Figure 6.2: Smart Appliances Market Value, World Markets 2010-2019 [Source: (Gohn, 2010; Intertek, 2011)].

Mauritius has become a major consumer of domestic appliances as revealed by the figures in Table 6.1 for a selected list of items owned by household in the year 2006/2007 and 2011 (Statistics Mauritius, 2009 ; Statistics Mauritius, 2011).

Table 6.1: Household equipment ownership in Mauritius

Household item	**Percentage ownership**
Television	96.3 (2011)
Refrigerator	89.2 (2006-2007)
Washing machine	61.1 (2006/2007)
Oven	43.6 (2006/2007)
Microwave oven	41.6 (2006/2007)
Fixed telephone	70.0 (2011)
Mobile phone	88.3(2011)
Computer	38.2(2011)

Indeed, appliances such as air conditioners, dishwashers, home cinema, and home office equipment are gaining in popularity in middle income households. Other common domestic appliances such as televisions and refrigerators are being replaced by larger units. Many medium and high income households are purchasing duplicate appliances. Moreover, home automation systems particularly focussed on entertainment systems and lighting control have also started making inroads in Mauritius with the emergence of companies such as multi-kom.

Currently, the average Mauritian household consumes about 1770 kWh of energy each year but consumption varies widely among residential customers. About 15% of households consume less than 600 kWh of energy each year and about 15% consume more than 2,400 kWh of energy each year (Ministry of Environment, National Development Unit and UNEP, 2008). A major concern is that many appliances currently being sold in Mauritius are of low quality and are inefficient in terms of energy consumption. On a life cycle basis, such appliances usually cost more to the owner than efficient appliances that may be more costly at the time of purchase but less costly in terms of electricity consumption over the life span. Moreover, inefficient appliances contribute to higher electric load growth and increased carbon emissions. There is therefore a pressing need to eliminate low quality appliances from the market imported in Mauritius and transform the appliance market in Mauritius towards efficient appliances (MID, 2011).

However, there exist several sophisticated home automation systems, which can significantly reduce the energy consumption of household through their various energy conservation mechanisms and by enabling the optimization of several operational practices. Furthermore, they allow users to achieve a more comfortable, secure and flexible lifestyle by exploiting a whole range of control features developed to convert homes into smart intelligent buildings. The next section gives an overview of home automation systems, standards currently available and describes their features.

6.3 Home automation systems and standards

Since the mid-1980s, several major stakeholders in the housing, large appliance, and electrical control industries have pursued the idea of an integrated home automation system. Ideally, such a system monitors and operates many different functions within the home. Lighting, heating, cooling, ventilation, appliances, entertainment, and security can all be operated automatically. The homeowner programs, controls, or monitors the house by a computer or even by telephone (Çetin and Sahin, 2011). By the late 90's, the term ‘domotics’ was commonly used to describe any system in which informatics and telematics were combined to support activities in the home. It refers specifically to the application of computer and robot technologies to domestic appliances (Wikipedia, 2011). With the rising number of controllable devices in the home, interconnection and communication becomes a useful and desirable feature. For example, a furnace can send an alert message when it needs cleaning, or a refrigerator when it needs service (Wikipedia, 2011).

Several standards have been commercialised into complete home automation solutions and a brief overview of these standards is given in Table 6.2.

Table 6.2: Overview of home automation standards

Standard	**Media**	**Description**
Z-Wave (Z-Wave alliance, 2011)	RF	Zensys' RF-based technology, Zwave, is designed specifically for full home control, enabling power outlets and switches, thermostats, access control, intruder/fire alarms, and other home control networks to become wireless.
Zig-Bee (Zig Bee Alliance, 2012)	Wireless	The ZigBee Alliance is an association of companies working together to enable reliable, cost effective, low-power, wirelessly networked, monitoring and control products based on an open global standard.
Home-Plug Green PHY (HomePlug Powerline Alliance, 2012)	Power line with wireless extensions	The new HomePlug GP specification for power line communications was developed specifically to meet utility industry requirements for Smart Grid applications. HomePlug GP is completely interoperable with HomePlug AV and the IEEE 1901 standard (Zyren, 2010).
WiFi (Wi-Fi Alliance, 2012)	Wireless	The Wi-Fi Alliance is a global non-profit industry association of hundreds of leading companies devoted to seamless connectivity. With technology development, market building, and regulatory programs, the Wi-Fi Alliance has enabled widespread adoption of Wi-Fi worldwide.

Many of these standards provide excellent and complete home automation solutions whereby not only the quality of life of inhabitants but also the energy consumption is optimized. A generic model for a complete home automation solution is given in Figure 3. The home automation system is controlled by a main controller which interfaces to the various appliances, sensors and meters through an interface which can be power line or wireless depending on the communication standard being used. In Figure 6.3, the appliances and sensors connected to the upper part of the main controller are essentially meant for enhancing domestic comfort through automation and remote control. The meters and sensors connected to the lower part are on the other hand intended for energy monitoring and conservation. The main controller can be connected to PCs, fixed/mobile phones and other remote controllers to provide users with flexibility for controlling and monitoring the processes and devices in their homes. It is to be noted that in some systems there are no main controllers and distributed controllers are used for different parts of the home automation system. For example separate controllers for security, energy monitoring, lighting and air-conditioning may be interlinked with a common communication protocol in the system or via gateways. In some controllers the interfaces are in-built. A variety of home automation devices have been developed by several manufacturers which support standards such as Zig-Bee, HomePlug Green PHY, Wi-Fi and Z-Wave. An overview of how these standards can provide an optimization of operational practices in residential buildings is provided in the next section.

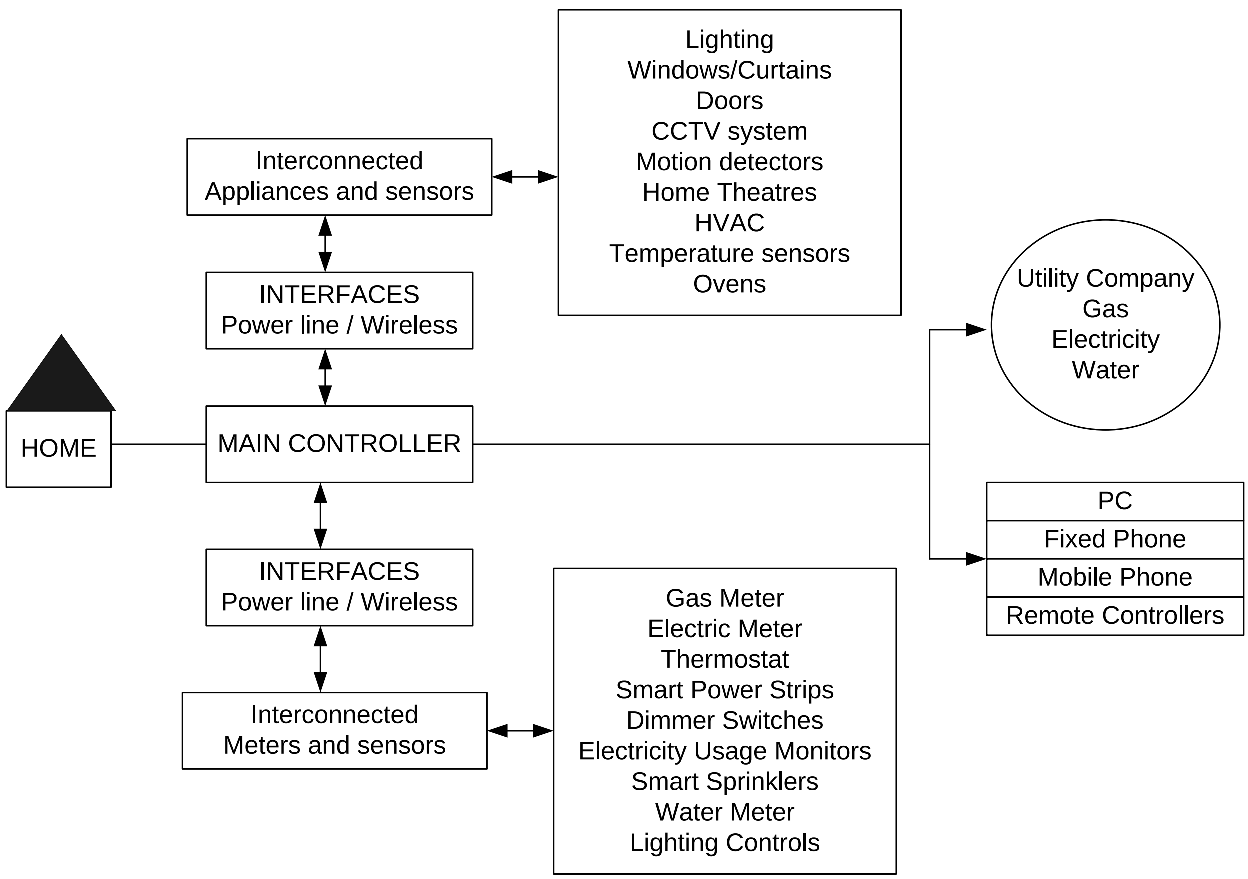

Figure 6.3: Home Automation system

6.4 Enhancing operational practices using home automation

Enhancing operational practices involves performing all the daily household activities such as the switching on / off of lights, cooking, food preservation, air-conditioning and even watering of plants, in the most energy efficient way. Today's home automation systems provide a whole range of devices which can provide this enhancement in a cost effective and also convenient way. A brief overview of how operational practices can be enhanced via home automation systems and is now given.

(a) Lighting

Standards such as ZigBee's Light Link allow wireless control over all LED fixtures, light bulbs, timers, remotes and switches. This standard gives householders the power to change lighting remotely to reflect ambiance, task or season, all while managing energy use and making their homes greener (Zig Bee Alliance, 2012). There is also a whole range of wall-mounted dimmers and dimmer switches which allow ON/OFF and BRIGHT/DIM functions to be performed manually or wirelessly on any connected incandescent lighting (Z-wave alliance, 2011). Moreover, the Energy Technology Assistance Programme (ETAP) has developed lighting control systems which dims the artificial light depending on the amount of daylight hence allowing an optimal use of daylight (ETAP, 2011; Kaser *et.al*, 2011). An individual light sensor in each luminaire dims the artificial light depending on the amount of daylight. All day it is possible to work with comfortably controlled daylight dependent light. These lighting control systems can also dim and/or switch the light (depending on the settings) when no movement is detected. Combined with innovative lighting control systems, ETAP luminaires guarantee low energy consumption and high levels of comfort. To have an idea of the actual amount of energy saved, the energy consumption of ETAP lighting control system linked lighting was measured over the course of several years in dozens of offices. The result was a saving of 25 to 55 % compared to non-dimmable electronic ballasts.

(b) Air conditioning units

With recent advances in air conditioning systems, it is now possible to control the temperature of individual zones as well as program fresh air control. Sensors are fitted in each zone and the system ensures that no room is being over-heated or over-cooled, thus contributing to the product's energy efficiency. The fresh air system is an electronically controlled device that measures the temperature outside of the house. If this is cooler than that inside, it opens and brings cool air in. This smart function not only promotes fresh air circulation around the house (as opposed to the same air re-circulating) but is also energy efficient. These systems can also be integrated in home automation systems, thus allowing more flexible control (Karnetkar, 2007).

(c) Water and irrigation

Home automation systems such as Z-wave have developed Water Level / Irrigation or Emergency Water Shut-Off Valves which provide very interesting features. These valves are electrically operated wireless water valves that can be used in a wireless home automation network. They can be used in conjunction with a water alarm sensor to reduce or eliminate damages caused by leaky plumbing or appliances. The Z-wave's WV-01 valve uses a motorized ball valve that automatically turns off the main water supply when a leak or overflow is detected. It can be used as an irrigation device and when a water event occurs the system automatically sends an email, text message, or phone call depending on a Z-wave home controller. For example, if a leak is detected by any Z-wave compatible Water Alarm Sensors the WV-01 will shut off the water supply and can automatically trigger a wired or wireless alarm system (Z-wave alliance 2011).

(d) Smart metering and energy management devices

Several devices can be used for energy management with a view to lower the energy consumption of home appliances. For example a smart socket can be used to meter the electric power consumption of each device which is connected to Smart Socket and then send the meter data to a server passing through the gateway real-time. Smart Socket controls ON/OFF switching of the device attached to it for automatic cut-off of the standby power consumption. Furthermore, it automatically shuts down when there are electric overloads and supports manual ON/OFF control (Zig Bee Alliance, 2012). Smart gas meters are also available and can provide utilities with a two-way flow of accurate data required to manage energy use more efficiently (Engineerlive, 2012).

Moreover, in home automation systems, common devices such as digital TVs, air conditioners, refrigerators and washing machines can receive the Price and Scheduled time data from Smart Meters or Smart Severs via communication modules. Users can reduce the electric bills through a price response control algorithm using received price and Scheduled time data. Devices can also send out the status of the current operation mode to the coordinator device. This is based on two-way communication between end device and coordinator (Zig Bee Alliance, 2012).

6.5 Enhancing operational practices through energy saving measures

As mentioned previously, for many countries home automation may not be a viable solution for the immediate future due to technological and financial constraints. Therefore, the adoption of certain best practices for the use of domestic appliances is an interesting low-cost alternative for energy savings. An overview of these best-practices is now presented.

(a) Lighting

There are many choices in energy-efficient lighting. An overview of the most popular light bulbs available is as follows (Energy Savers, 2012b):

Energy-saving, or halogen, incandescent light bulbs are about 25% more efficient and can last up to three times longer than traditional incandescent bulbs. They are available in a wide range of shapes and colors, and can be used with dimmers.

Compact Fluorescent Lamps (CFLs) last about 10 times longer and use about one-fourth the energy of traditional incandescent bulbs. A typical CFL has a pay-back period in energy savings of less than 9 months.

LED bulbs are rapidly expanding in household use. ENERGY STAR-qualified LEDs use only about 20%-25% of the energy and last up to 25 times longer than traditional incandescent bulbs. They are available in a variety of colours, and some are dimmable or offer convenient features such as daylight and motion sensors.

The following energy saving practices can also be adopted (Energy Savers, 2012b):

- Replacing all inefficient incandescent bulbs in the home with energy-saving bulbs or for even greater savings, replace all old incandescent bulbs with ENERGY STAR-qualified bulbs.
- When remodelling, look for recessed light fixtures or "cans" which are rated for contact with insulation and are air tight.
- When replacing incandescent bulbs from recessed light fixtures, use energy-efficient bulbs that are rated for that purpose. For example, the heat build-up in down-lights will significantly shorten the life of spiral CFLs.
- Consider purchasing ENERGY STAR-qualified fixtures. They are available in many styles, distribute light more efficiently and evenly than standard fixtures, and some offer convenient features such as dimming.
- Keep curtains or shades open to use daylight instead of turning on lights. For more privacy, use light-colored, loose-weave curtains to allow daylight into the room. Also, decorate with lighter colors that reflect daylight.

Regarding outdoor lighting, the following best practices can be adopted (Energy Savers, 2012b):

- Since outdoor lights are usually left on a long time, using CFLs or LEDs in these fixtures will save a lot of energy. Most bare spiral CFLs can be used in enclosed fixtures that protect them from the weather.

- CFLs and LEDs are available as flood lights. These models have been tested to withstand the rain and snow so they can be used in exposed fixtures.
- Look for ENERGY STAR-qualified fixtures that are designed for out-door use and come with features like automatic daylight shut-off and motion sensors.

(b) Domestic Appliances

Energy consumed by domestic appliances can be saved through more efficient use of the dishwasher, refrigerator/ freezer, washing machines and other common appliances. Regarding dishwashers the following best practices can be adopted (Energy Savers, 2012c):

- Check the manual that came with the dishwasher for the manufacturer's recommendations on water temperature; many have internal heating elements that allow the water heater in the home to be set to a lower temperature (120°F).
- Scrape, don't rinse, off large food pieces. Soaking or prewashing is generally only recommended in cases of burned or dried-on food.
- Ensure that the dishwasher is full (not overloaded) when turned on.
- Avoid using the "rinse hold" on the machine for just a few soiled dishes. It uses 3-7 gallons of hot water for each use.
- Let the dishes air dry; if there is no automatic air-dry switch, turn off the control knob after the final rinse and prop the door open slightly so the dishes will dry faster.

Regarding refrigerators the following best practices can be adopted (Energy Savers, 2012c):

- Don't keep the refrigerator or freezer too cold. Recommended temperatures are 37°-40°F for the fresh food compartment and 5°F for the freezer section. If there is a separate freezer for long-term storage, it should be kept at 0°F.
- Check the refrigerator temperature by placing an appliance thermometer in a glass of water in the center of the refrigerator. Read it after 24 hours. Check the freezer temperature by placing a thermometer between frozen packages. Read it after 24 hours.
- Make sure the refrigerator door seals are airtight. Test them by closing the door over a piece of paper or a dollar bill such that it is half in and half out of the refrigerator. If one can pull the paper or bill out easily, the latch may need adjustment, the seal may need replacing, or one may consider buying a new unit.
- Cover liquids and wrap foods stored in the refrigerator. Uncovered foods release moisture and make the compressor work harder.
- Regularly defrost manual-defrost freezers and refrigerators; frost buildup decreases the energy efficiency of the unit. Don't allow frost to build up more than one-quarter of an inch.

Regarding washing machines the following best practices can be adopted (Energy Savers, 2012d):

- Wash clothes in cold water using cold-water detergents whenever possible.
- Wash and dry full loads. To wash a small load, use the appropriate water-level setting.
- Dry towels and heavier cottons in a separate load from lighter-weight clothes.
- Don't over-dry clothes. If the machine has a moisture sensor, it must be used.
- Clean the lint screen in the dryer after every load to improve air circulation and prevent fire hazards.
- Periodically, use the long nozzle tip on a vacuum cleaner to remove the lint that collects below the lint screen in the lint screen slot of the clothes dryer.
- Use the cool-down cycle to allow the clothes to finish drying with the heat remaining in the dryer.
- Periodically inspect the dryer vent to ensure it is not blocked. This will save energy and may prevent a fire. Manufacturers recommend using rigid venting material—not plastic vents that may collapse and cause blockages.
- Consider air-drying clothes on clothes lines or drying racks. Air drying is recommended by clothing manufacturers for some fabrics.

Other Energy-Saving practices for the kitchen are as follows (Energy Savers, 2012c):

- Place the faucet lever on the kitchen sink in the cold position when using small amounts of water; placing the lever in the hot position draws hot water even though it may never reach the faucet.
- Look for a natural gas oven or range with an automatic, electric ignition system, which saves gas since a pilot light is not burning continuously.
- Look for blue flames in natural gas appliances; yellow flames indicate the gas is burning inefficiently and an adjustment may be needed. If yellow flames are seen, consult the manufacturer or the local utility.
- Keep range-top burners and reflectors clean; they will reflect the heat better, and will save energy.
- Use a covered kettle / pan or electric kettle to boil water; it's faster and uses less energy.
- Match the size of the pan to the heating element.
- Use small electric pans, toaster ovens, or convection ovens for small meals rather than a large stove or oven. A toaster or convection oven uses one-third to one-half as much energy as a full-sized oven.

(c) Air Conditioners

Air-conditioners may help us to cool down in summer but they can also contribute significantly to electricity costs. The following best practices can be followed to save costs on air conditioning (Ergon Energy, 2011):

- Set the aircon to 25°C. It's the most comfortable and energy-efficient temperature setting for summer.
- Close windows and doors in areas that require cooling.
- Use a fan and open up the home to create cross-breezes instead of switching on the aircon.
- Turn off the aircon when not required.
- Clean the filter pads on the aircon regularly. This helps to ensure the aircon runs efficiently. An efficient air-conditioner will cost you less to run.
- Install ceiling insulation with a minimum rating that suits the location to keep the heat out of the home. This well help to ensure the aircon can work more efficiently.

(d) Windows

The following best practices can be applied to windows during warm weather (Energy Savers, 2012e):

- Install white window shades, drapes, or blinds to reflect heat away from the house.
- Close curtains on south- and west-facing windows during the day.
- Install awnings on south- and west-facing windows.
- Apply sun-control or other reflective films on south-facing windows to reduce solar heat gain.

The following best practices can be applied to windows during cold weather (Energy Savers, 2012e):

- Use a heavy-duty, clear plastic sheet on a frame or tape clear plastic film to the inside of your window frames to reduce drafts.
- Install tight-fitting, insulating window shades on windows that feel drafty after weatherizing.
- Close your curtains and shades at night to protect against cold drafts; open them during the day to let in warming sunlight.
- Install exterior or interior storm windows, which can reduce heat loss through the windows by 25%-50%. They should have weatherstripping at all movable joints; be made of strong, durable materials; and have interlocking or overlapping joints.
- Repair and weatherize your current storm windows, if necessary.

(e) Roofs

While building a new home, it is important to decide during planning whether if a cool roof is required. An existing roof can also be converted to a cool roof as follows (Energy Savers, 2012f):

- Retrofit the roof with specialized heat-reflective material.
- Re-cover the roof with a new waterproofing surface (such as tile coating).

A cool roof uses material that is designed to reflect more sunlight and absorb less heat than a standard roof. Cool roofs can be made of a highly reflective type of paint, a sheet covering, or highly reflective tiles or shingles. By installing a cool roof, the temperature of the roof can be lowered by up to 50°F hence saving energy and money by using less air conditioning. Cool roofs can lower outside air temperatures, reducing heat islands in urban areas.

6.6 Proposals and Recommendations

6.6.1 Analysis of the shortcomings of the Mauritian context

The lack of standards and labeling has led to the importation of a large number of inefficient appliances in Mauritius (MID, 2011). Also, in Mauritius the home automation solution providers such as Multikom are mostly promoting the aesthetic and comfort aspect of the field and not the energy efficient aspect. Indeed the market for home automation products is restricted to only the high-class portion of the population and most home automation systems available are beyond the reach of the middle-income families in Mauritius. Another shortcoming is that unlike several other countries in which Governments are giving subsidies to consumers for the adoption of smart appliances (Intertek, 2011, Zypryme, 2012), such steps are yet to be adopted in Mauritius. Furthermore, Mauritius is also likely to face several barriers which are making it difficult for integrating home automation systems with the smart grid as is the case with many other countries (AHAM, 2010):

- There are physical and electrical variations within the homes of consumers that impact the deployment of communication technologies.
- Consumers are continuing to purchase products and services that utilize a diverse set of communications technologies within the home. With no current dominant communications protocol standard, it may become difficult to interoperate multiple devices with many different technologies in place.
- Appliances move with consumers who may often change utilities. If the new utility does not use the same protocols and information models, the appliance would be rendered useless or require modifications to work with the new utility.

- Appliances are part of consumer's lives for more than 10 years. This longevity requires protocols to adapted or function across many years of growth and change in the Smart Grid.
- Appliances can be located in homes or buildings in manners that interfere with some methods of signal transmission (e.g. basements). It is necessary for protocols to be capable of adapting to these different environments.

Despite these shortcomings, Mauritius has a lot of potential in making home automation become a success because of the strong existing ICT infrastructure and consumption of ICT products such as mobile phone subscriptions (1,190,900 in 2010) and internet subscription (284,200 in 2010) (NCB, 2011). Indeed, most home automation systems require a good ICT platform to be set up such as internet connectivity or a mobile phone network. Therefore, with the introduction of legislations and the importation of low cost energy efficient home automation systems pertaining to standards such as Zig-Bee, HomePlug Green PHY, Wifi and Z-wave, a more optimal use of domestic appliances could be achieved. Of course an intelligent choice of standard has to be made to derive maximum benefit from home automation. However, a short-term solution would be to educate home-owners on the best practices that can be adopted to improve energy efficiency.

6.6.2 Best practices and recommendations

In this section recommendations regarding home automation are first discussed followed by the best practices that should be inculcated to every home-owner with a view to provide a short term low cost alternative to home automation for enhancing the operational practices in residential buildings.

One of the most important components of a home automation system is the communications protocol used for interconnecting the smart appliances and also providing connection to the utility. The appliance industry is an important part of the Smart Grid and enabling communications with appliances is critical to the success of the Smart Grid. Integration of smart appliances into the future Smart Grid offers consumers the opportunity to save money while providing utilities a mechanism to more efficiently operate the grid. Kitchen appliances consume about 300 billion kilowatt hours (kWhs) of electricity annually and laundry appliances use another 76 billion kWhs of electricity in the U.S. If only 5 percent of this energy usage could be shifted to off-peak hours with a 40 percent savings for off-peak Time of Use (TOU) rates, consumers would save almost $900 million annually. Further, integration of smart appliances would help reduce the need for the additional cost and infrastructure of "peaker plants," plants that are called upon to generate electricity only at peak demand instances (AHAM, 2010).

To successfully enable the promise presented by home automation and the Smart Grid, an architecture that is flexible and adaptable to the consumer's changing needs and environment is necessary. This architecture must provide for communications with utility devices as well as third party services and the adaptations that will be required as the Smart Grid grows and develops, all while minimizing the impact on the consumer (AHAM, 2010).

The best communications architecture at this time features a hub or gateway as shown in Figure 6.4, that can communicate using common protocols and serve as the adapter or bridge to other devices on the Home Area Network (HAN). This type of architecture is consistent with the OpenHAN architectures and provides simplicity for the consumer, and the flexibility needed for future development needs. Additionally, this type of architecture supports a more robust, comprehensive "home networking" system approach compatible with consumer electronics devices. The hub based architecture allows for coordination of the various appliances in the system and also allows for different connectivity and security implementations, thus allowing the various appliances to adapt to the many different possible installation scenarios. The hub also provides a ready conversion point at which a switch in protocols and physical layers can be executed without affecting or causing the smart appliance to become obsolete due to the use of a protocol not implemented in the meter or elsewhere. The hub can also provide a line of demarcation between the utility and the HAN (AHAM, 2010).

According to AHAM the following criteria or best practices can be followed to determine the suitability of a communications standard for home automation products that can be linked to the smart grid (AHAM, 2010):

- Products must be easy to install and easy to use i.e. they should perform well without requiring difficult or extensive inputs from users.
- Products must be interoperable with other brands and devices.
- Products must have reliable operation and function consistently without issues.
- Products should not compromise the privacy of consumers and must have the same level of privacy as current non-communicating products.
- Products should exhibit a Low Security Degradation and have the same level of security as current non-communicating products.
- Products should not compromise the safety of consumers and must be as safe as current non-communicating products.
- The technology must be accepted in various forms in the marketplace and have a commercial history.
- The amount of additional hardware and resources required to enable a system should be minimal.
- A technology supply chain should exist i.e. various companies and avenues should exist for acquiring the technology and support.

- The product should be Forward/ Backward compatible and Future Proof i.e. consumers expect to not have to worry about their products becoming obsolete or being incompatible with other items.
- The system should be equipped with mechanisms for dealing with ambient interference and electronic noise issues.

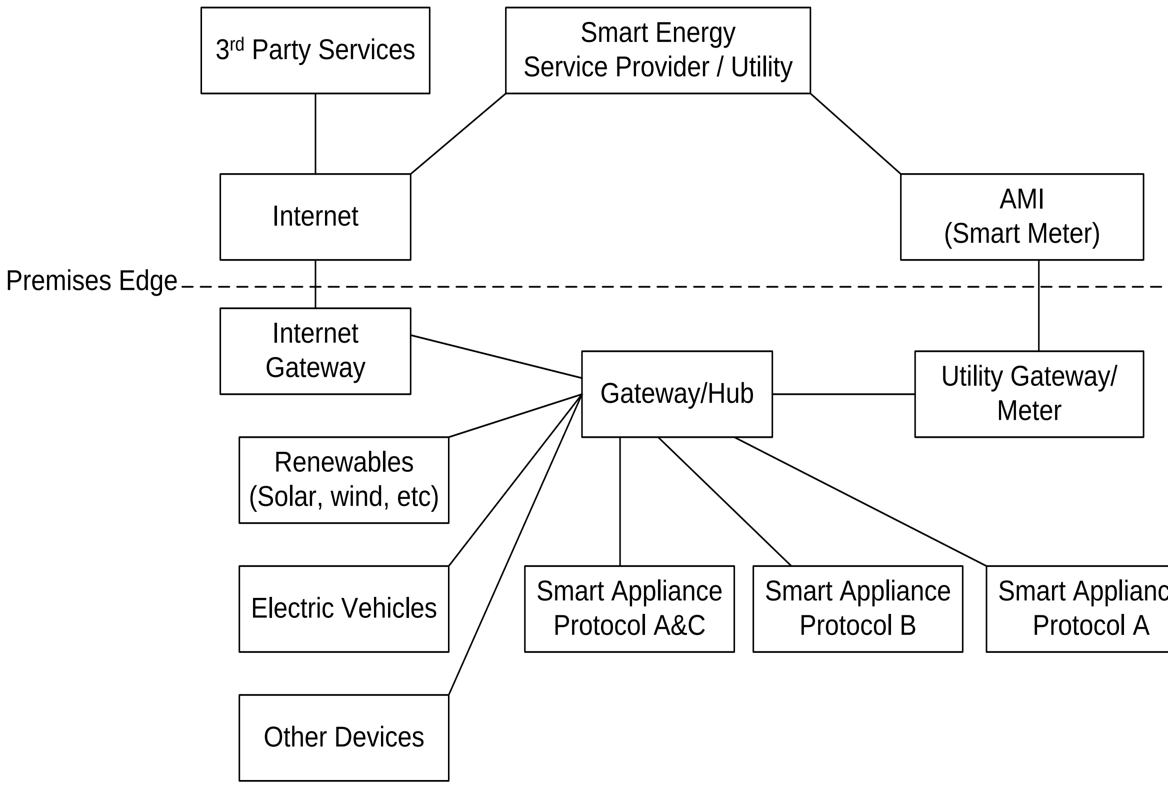

Figure 6.4: AHAM consensus architecture for connectivity and information pathways. [Source: (AHAM, 2010)].

As mentioned in Section 6.3, a low cost alternative to home-automation constitutes several best practices that can be adopted for enhancing operational practices. An overview of the main recommendations regarding these practices is as follows (Energy Savers, 2012a):

- Install a programmable thermostat to lower utility bills and manage heating and cooling systems efficiently.
- Turn devices off when they are not in use for example lights, TVs, entertainment systems, and your computer and monitor.
- Plug home electronics, such as TVs and DVD players, into power strips; turn the power strips off when the equipment is not in use—TVs and DVDs in standby mode still use several watts of power.
- Enhance the lighting of the home with energy efficient bulbs.

- Follow the best practices for operating dishwashers for e.g allow dishes to be air dried.
- Follow the best practices for refrigerators for e.g ensure that the refrigerator door seals are airtight.
- Follow the best practices for washing machines for e.g wash clothes in cold water using cold-water detergents whenever possible.
- Follow the best practices for air-conditioners for e.g close windows and doors in areas that require cooling.
- Retrofit windows and roofs intelligently to save energy on cooling and heating during cold and hot weather.

6.7 Conclusion

With a proper standardisation framework for communication protocols, in the near future, home automation could become a major enabler for sustainability in residential building. According to the Association of Home Appliances Manufacturers (AHAM), Wi-Fi, Zigbee, and HomePlug Green PHY are proven interoperable technologies based on open specifications with a high degree of standards reuse. These are the top three most suitable communication protocols based on the analysis and have virtually indistinguishable benefits for smart grid applications for appliances interfacing with consumers (AHAM, 2010). In Mauritius, home automation is still at a very early stage and is yet to be exploited by the service providers on the market. However, Government will have to introduce proper legislations so that the most appropriate home automation standards are adopted based on the criteria given in this chapter. This will firstly maximise the benefits of the consumers and at the same time allow a smooth linking of home automation systems with the Public Utility for the setting up of an effective smart metering process. However, as an alternative to home automation, a short term solution will be the inculcation of certain best practices that should be adopted by home-owners with regards to the use of domestic appliances, windows and roofs, so as to save energy as far as possible.

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CHAPTER 7
WASTE MANAGEMENT

Waste Management begins at home

7.1 Introduction

In the Earth Summit held in Rio in 1992 (Rio 1992), one of the major environmental issues discussed had been waste management. The issue was again raised in the 2012 Summit (Rio 2012) because it appears that progress towards a global sustainable solution to the waste management problem has not been up to expectations. Targets of sustainable waste management are there and they are important ones too, but concrete solutions to cope with increasing waste volumes due to changing lifestyles are lacking. The difficulty lies in the fact that there is not a one-fit-all solution to the waste management problem. Solutions have to be country-specific and take into consideration prevailing local political and socio-economic conditions. Public opposition and resistance to waste management measures arising mostly from ignorance of the medium and long term benefits of such measures is another major factor to be reckoned with. Countries may also have other development priorities requiring resources which could otherwise be diverted to the implementation of waste management plans and strategies. In some cases, it is also, sadly, political interference and the lack of commitment of stakeholders which result in a seriously deficient waste management system.

The volume of waste generated has encountered an increase globally due mainly to increase in population, urbanisation, and rapid industrialization. Newly industrialised countries like China and India are confronted with enormous solid waste management problems that will severely strain municipal financial resources for handling of the ever increasing waste volumes. The total Municipal Solid Waste (MSW) generated in urban India in 2011 was estimated at 68.8 million tons per year or 188,500 tons per day (India 2012). In England, local authority collected waste sent to landfill was 10.1 million tonnes between the financial year 2010/11 and the rolling year January to December 2011 (England 2012). To manage and dispose of such huge amounts of waste requires mobilization of a lot of resources: human, financial, infrastructural, and technological. These resources may not always be available. Most of the countries with waste management issues are developing countries with little means. India, for example, which accounts for nearly 18% of world's human population, does not have enough resources or adequate systems in place to treat its solid wastes (India 2012).

Mauritius is a small island developing state (SIDS) with its own specificities as regards climate, culture, demography, infrastructure, and resources. Its population stood at 1,288,684 as at end of 2011. Total waste landfilled was recorded at 402 816 tonnes in 2010 increasing by a little more than 9% since 2005 (CSO 2010). The main source of waste remains the household, making up nearly 95% of the total waste. In fact, domestic waste has registered an increase of more than 8% since 2005.

The country can boast to have a well drafted waste legislation and also a well structured institutional organization to take care of waste problems. Mauritius has also signed and ratified a number of waste related conventions, both at the international and regional level, among which are the UN Framework Convention, the Basel Convention, the Bamako Convention, and the Stockholm Convention.

With such a solid framework in place for managing waste and the arsenal of means the Government has at its disposal, the waste situation in Mauritius ought to have been much better. Instead, what is actually happening is that, polluters (e.g. hawkers, textile factories, commercial centres, etc) continue dumping their waste and cause littering while remaining unpunished. There could be many reasons for this. For one thing it could be ignorance of basic waste legislations, if it is not sheer indifference or daring. For another, it could be a lack of commitment to duties and responsibilities of authorities, if it is not political interest. Whatever be the reason, it is the whole country which suffers the consequences, among whom are those who do their utmost to fulfil their civic duties honestly.

The aim of this work is to identify weaknesses in the country's waste management system with focus on residential buildings, determine their causes, and propose solutions and recommendations. The report is organized as follows. Major categories of waste are presented at the beginning in section 7.3 followed by a description of the environmental impacts of improper waste management in section 7.4. Types of waste that constitute domestic waste are given in section 7.5. The structure and scope of waste management are described in section 7.6. Section 7.7 discusses the current situation of waste management in Mauritius. Sections 7.8, 7.9, and 7.10 respectively describe the waste management framework currently in place, the conventions in which Mauritius is a signatory, and current achievements and government programmes planned for the future. A critical appraisal of the system is given in section 7.11 and section 7.12 provides a series of recommendations which could be considered to improve waste management. Section 7.13 contains concluding remarks.

7.2 Scope

The scope of the work described in this chapter is limited to management of residential solid waste. Liquid waste is considered in Chapter 3.

7.3 Waste

7.3.1 Definition

Material that is no longer of any use or value or any discarded, rejected, abandoned, unwanted or surplus matter, is called waste (Waste 2009).

7.3.2 Waste streams and classification

A useful way of thinking of waste issues is to break down waste into categories - sometimes called waste 'streams'. For example, Municipal Solid Waste (MSW) is an important waste stream. Managing waste streams requires specialist strategies on account of their physical characteristics and their source, hence the value in distinguishing between them.
Common waste classifications based on the source of the waste include:

7.3.3 Municipal solid waste (MSW)

Municipal Solid Waste (MSW) is classic example of an aggregation of many different types of wastes within a single waste stream. This waste stream was historically treated as a special kind of waste precisely because it came from households. The source of MSW is particularly significant because Health Acts all over the world require prompt removal of household refuse as the putrescible component in that refuse can attract vermin and disease. The maintenance of public health remains the primary rationale for the management of MSW. This is despite the fact that the putrescible component of MSW is a minor part of this waste stream and the physical characteristics of other components are quite different.

MSW constitutes various waste generated in urban and rural areas and is managed mainly by the local government. The main source of MSW is the household, but waste from streets, parks, public utilities, small offices, hotels, and restaurants, etc also form part of it (JICA 2009).

7.3.4 Industrial solid waste

This type of waste comes from industries and consists of office furniture, metal scrap, packaging, paper, plastic, textile etc

7.3.5 Construction and demolition waste (CDW)

These are materials that arise from construction, refurbishment or demolition activities and consist of bricks, concrete, cement, iron bars, tiles, iron sheets, wood, asphalt, etc.
A few classifications based on material characteristics are:

7.3.6 Hazardous waste

Hazardous waste is described as that waste that is explosive, toxic, or infectious, or that may cause damages related to human health and living environment, and requires special treatment. Pesticides, dangerous chemicals, asbestos, etc fall in this category.

7.3.7 Problematic Waste

Problematic wastes are wastes that have the potential to cause environmental damage but are beyond the scope of the controlled waste regulations. Under specific conditions, these wastes can have acute environmental impacts. These wastes include tyres, batteries, WEEE (E-waste), laboratory waste, household hazardous waste and waste oils.

7.4 Environmental and health impacts of waste

Management of Municipal Solid Waste (MSW) is one of the major challenges worldwide. Inadequate collection, recycling or treatment and uncontrolled disposal of waste in dumps lead to severe hazards, such as health risks and environmental pollution. Listed below are some of the threats to the environment and human health of improper waste disposal.

7.4.1 Air Pollution

Decomposition of waste left in nature generates odour. Burning it releases smoke which can be irritating and discomforting. The smoke could also contain toxic gases, injurious to health. Incinerating waste also causes problems, because plastics tend to produce toxic substances, such as dioxins, when they are burnt. Gases from incineration may cause air pollution and contribute to acid rain, while the ash from incinerators may contain heavy metals and other toxins.

7.4.2 Global warming

The main constituents of landfill gas (LFG) are carbon dioxide (CO_2) and methane, two major global warming contributors. These gases are called Greenhouse gases (GHG). Methane is 21 times more potent as a GHG than CO_2.

7.4.2.1 Surface and ground water pollution

Leachate is liquid that results when rainwater passes through waste. It could contain toxic chemicals picked up from the decomposing waste. Leachate can pollute surface and ground water.

7.4.3 Disease transmission

Solid wastes are breeding grounds for vectors of diseases, such as flies, insects, and rodents. Diseases that can be transmitted are:

- *Leptospirosis* from rats
- *Malaria* and *Chikungunya* from mosquitoes
- *Dysentry* from flies

7.4.4 Unpleasant visual impact

Littering and illegal dumping by the roadside, in bare lands, in sugarcane fields, in the ocean or on the beaches impact negatively on the overall beauty of the country.

7.4.5 Other

Solid waste illegally dumped into drains and rivers is usually the leading contributor to local flooding.

7.5 Domestic waste

Domestic waste (also called household waste), a subcategory of MSW, is the direct produce of the home and comprises yard waste, kitchen waste, paper, plastics, metals, textiles, glasses, and others. The following categories of waste can be identified within domestic waste.

7.5.1 Organic waste

The organic waste stream is composed of waste of a biological origin such as paper and cardboard, food, green and garden waste, animal waste, etc. Organic waste is the single largest component of the waste stream.

7.5.2 Compostable waste

This is waste consisting largely of biodegradable organic matter. Domestic waste contains a large proportion of compostable waste.

7.5.3 Recyclable waste

It is the segregated portion of MSW–curbside bin collection consisting of dry recyclable materials including beverage containers, paper, cardboard, plastics, glass and metals.

7.6 Waste Management

Integrated waste management is the management of the entire waste process including generation, storage, collection, transportation, resource recovery, treatment and disposal. Integrated waste management employs several waste control methods based on what is called a waste hierarchy and includes avoidance, reduction, recycling, reuse, recovery, treatment and disposal, all aimed at minimising the environmental impact of waste (Waste 2009).

Waste management is made up of six functional elements, interrelated as shown in the Figure 7.1 below.

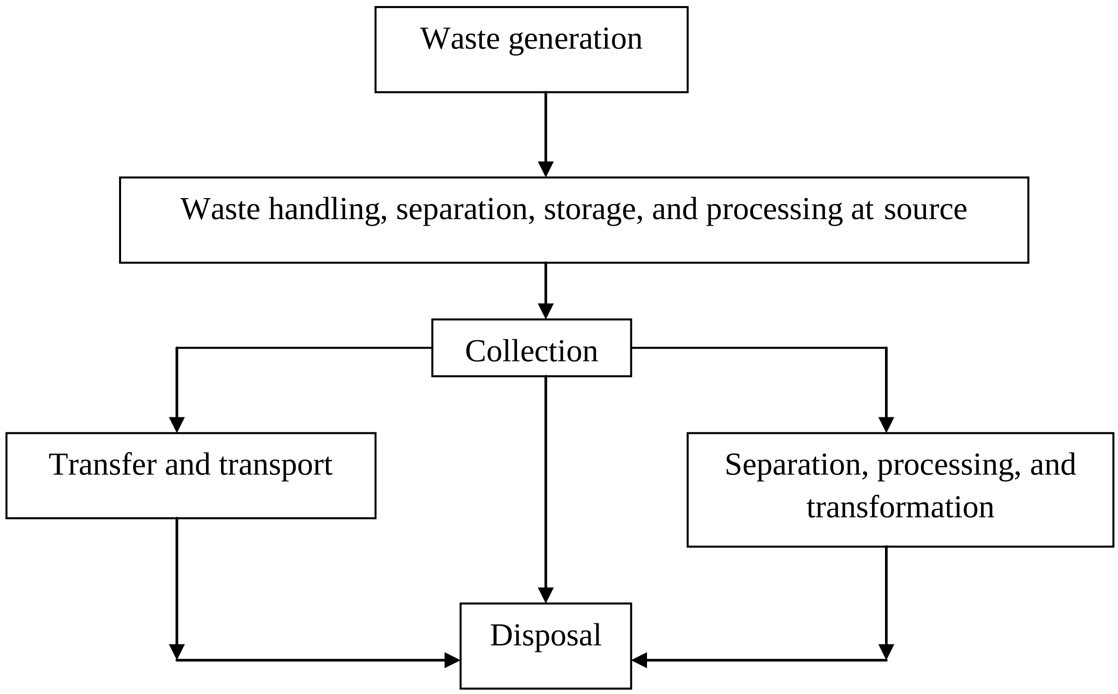

Figure 7.1: Waste Management functional elements

An integrated waste management plan should take into account all of these functional elements. A brief description of each functional element is given below.

7.6.1 Waste Generation

It refers to all processes and activities that create the waste, for example kitchen activities, gardening activities, and industrial processes. Most of the waste comes from the household, which produces about 1 tonne of waste annually. The volume of waste generated depends on the local standard of living, consumption pattern as well as on the level of institutional and commercial activities. Higher economic standing is directly related to an increase in MSW volume. Furthermore, there is a clear trend that the average lifespan of many consumer products is increasingly reduced.

A significant amount of waste has the potential of being reconverted to useful product (recycled) or used for another purpose (reused). More importantly, if people are sufficiently sensitized, waste generation can even be considerably minimized. In fact, *reduce*, *reuse*, and *recycle*, collectively called the 3R's in waste jargon, form the basis of integrated waste management. Adopting the 3R strategy can drastically decrease the amount of waste going to the landfill.

7.6.2 Waste handling, separation, storage, and processing at source

On-site waste handling refers to the activities associated with the handling of solid wastes until they are placed in the containers used for their storage before collection.

Waste separation at source involves separating each type of waste in a different plastic bag/bin. For example, waste can be sorted as kitchen waste, yard waste and recyclable waste.

Before it is collected, waste is stored in kitchen bins, drums, coloured bins (for sorted waste), etc. There can also be communal bins for raised buildings, e.g. apartments and complexes.

Waste can be processed at the source to convert it to some useful product. For example, home composting can be used to transform compostable waste into fertilizer for the garden. In fact, the 20% of vegetable peelings and other organic waste that are thrown away could be composted.

7.6.3 Collection

Full waste collection coverage is a key to a hygienic environment. Uncollected waste remains in the neighbourhood, attracts pathogens and pollutes waterways. This situation leads not only to health risks but also constitutes a public eyesore and negatively affects economic development. Furthermore, the waste collection systems used have a significant effect on the quality of recovered materials, which in turn influence the recycling economy – a key aspect for a sustainable and integrated waste management system. Where the system is well-managed, waste is collected by licensed vehicles (curbside collection). The frequency of collection is decided by considering the volume and type of waste generated. Recyclable waste can be deposited at drop-off centres.

7.6.4 Transfer and transport

Waste collected is carried to transfer stations by trucks and lorries. There, the waste is compacted and loaded into bigger trucks and carted away to a landfill for disposal.

7.6.5 Separation, processing, and transformation

Commingled waste collected from various sources can also be taken to a Material Recovery Facility (MRF), which is a depot for the treatment of waste for resource recovery (Waste 2009). Here, the waste is separated and sent to recycling plants, large-scale compost centres, or waste-to-energy (WTE) plants.

7.6.6 Disposal

The final placement of waste is the landfill in which solid waste is placed and buried in soil under controlled conditions to minimise environmental impact. Sanitary landfills are engineered disposal sites where waste is spread in layers, compacted and covered with soil or other materials to minimise air and water pollution. Modern sanitary landfills collect and treat leachate and methane gas.

7.7 Waste Management in Mauritius

Waste management in Mauritius falls under the aegis of the *Ministry of Local Government and Outer Islands*. The legal, regulatory, and institutional frameworks in this sector are well defined. Waste collectors and recyclers are licensed. A modern sanitary landfill exists at Mare Chicose and is owned by the government.

A brief description of how waste is managed in Mauritius is given below.

7.7.1 Waste generation

The household is the main waste generator in Mauritius contributing as much as 94% of total landfilled waste. In 2010, 427,802 tonnes of waste were generated of which 402 816 tonnes were of household origin. Daily per capita solid waste was estimated at 0.7 kg in 2001 and 0.9 kg in 2010 (CSO 2010). Waste generation information is available from the Statistics Department of the Government of Mauritius.

7.7.2 Waste processing at source

Many home composting projects are currently under way thanks to the efforts of some academic and technical staff of the University of Mauritius in this field (Mohee 2009). Large scale composting are also being implemented, namely at Forbach and La Chaumiere.

7.7.3 Waste Collection

The main method of waste collection is the curbside collection and is under the responsibility of local authorities, namely Municipalities and District Councils. There are 5 municipalities for urban regions and 4 district councils for rural regions. Much of the waste collection activities are contracted out to local companies. A list of scavenging contractors as at 22 June 2011 can be found at (Gov 2011b).

7.7.4 Waste transfer and transport

Solid waste collected from different localities transit through transfer stations, operated by private contractors on behalf of the Ministry. In the transfer station, the waste is compacted before being transported by big trucks to the landfill for final disposal (Gov 2012). Waste from the Southern region is hauled directly to the landfill site. Presently, there are five transfer stations in operation. They are located at La Brasserie, La Chaumiere, Roche Bois, Poudre D'Or, and La Laura. The Roche Bois and La Chaumiere transfer stations receive approximately 250 and 400 tonnes of household waste per day respectively (Sotravic 2012a).

7.7.5 Waste recycling

Types of waste presently being recycled in Mauritius include paper, cardboard, plastic, metal, textile, glass, tyres, waste oil, e-waste, and batteries. An official list of recyclers can be found online at the Government's website (Gov 2012).

7.7.6 Waste Disposal

The Mare Chicose landfill is a modern sanitary landfill and is the only disposal site of the island. It is currently operated by a private contractor, J V Sotravic Ltee/Bilfinger Berger (Gov 2012). The landfill site receives and manages about 1200 tonnes of waste daily (Sotravic 2012b).

Table 8.1 gives the amount of the different types of waste landfilled since 2005 (CSO 2007, CSO 2009, CSO 2010).

Table 7.1: Annual amount of waste, in tonnes, landfilled at Mare Chicose

Waste Material	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Domestic	370 896	387 751	365 824	373 860	389 999	402 816
Construction	3 755	1 109	502	2 065	671	2 394
Other[1]	15 298	18 180	27 792	23 563	25 278	22 592
Total	**389 949**	**407 040**	**394 118**	**399 488**	**415 948**	**427 802**

Source: Ministry of Local Government and Outer Islands

[1]*Includes mainly industrial waste*

It is noted that in 2006, there was an abnormal rise in landfilled waste (407 040 tonnes). This was due to additional waste collected during clean-up campaigns following the outbreak of the *Chikungunya* disease (CSO 2007).

As from October 2011, Sotravic has installed an electricity generating plant at the Mare Chicose landfill with current capacity of 2MW. The plant uses LFG as fuel to produce electricity (Sotravic 2012c).

7.8 Legal, regulatory, and institutional frameworks

7.8.1 Legal and regulatory framework

Waste management is a big issue and requires the mobilization and deployment of significant amount of resources. As such, appropriate legislations and regulations are necessary. The main legislations and regulations concerned with waste are:

- **Local Government Act 2011:** mainly concerned with the Services of Local Authorities including section 47 of the act which deals with the collection and disposal of waste

- **Environment Protection Act 2002:** with a view to promoting a clean and green environment and mitigating the associated adverse health and environmental impacts from industrial waste, National Environmental Standards are prescribed in this Act for water, air, noise, hazardous wastes, non hazardous wastes, pesticides, odours, and built-up environment
- **Dangerous Chemicals Control Act 2004:** deals with all dangerous chemicals substances, enforcing agencies and their responsibilities, licensing and permits, and transportation and storage
- **Hazardous Waste Regulations 2001:** minimize the generation of a hazardous waste by using the best practicable means, ensure that a hazardous waste is properly stored, treated on site or disposed of as approved by the appropriate enforcing agency
- **Waste Oil Regulations 2006:** Collection, Storage, Treatment, Use and Disposal of Waste Oil

In addition to the aforementioned, there are also regulations regarding plastic carry bags, PET bottles, plastic banners, etc, all potentially dangerous for the environment as non-biodegradable waste.

7.8.2 Institutional framework

The Ministry of Local Government and Outer Islands works in close collaboration with local authorities, communities, and NGOs to formulate waste policies and enforce waste regulations. The major stakeholders are:

7.8.2.1 Ministry of Local Government and Outer Islands (MLG)

The mission statement of the MLG includes "… *protecting the environment and human health through an effective and sustainable management of solid waste*" and its vision is, inter alia, "…*to achieve the highest standards of cleanliness and sanitation in the country through sound and effective infrastructural and solid waste management policies and practices*" (MLGE 2012).

7.8.2.2 Local Authorities

There are five Municipalities and four District Councils across the island for local governance. They are as follows.

Municipalities:	**District Councils**
Beau Bassin/Rose Hill	Moka/Flacq
Curepipe	Pamplemousses/Riv du Rempart
Port Louis	Black River
Quatre Bornes	Grand Port Savanne
Vacoas Phoenix	

One of the statutory duties/responsibilities of Municipal and District Councils is the collection and removal to approved disposal sites of household, residential, commercial and agricultural wastes (Gov 2012c).

7.8.2.3 Others

Other instances, like NGOs and local "*Forces Vives*", also help out with many waste management tasks.

7.9 Conventions

Mauritius is a signatory of the following conventions related to waste/environment.

7.9.1 United Nations Framework Convention on Climate Change

One of the objectives of the United Nations Framework Convention on Climate Change is to achieve the stabilisation of atmospheric greenhouse gas concentrations at a level which would prevent dangerous anthropogenic interference with the climate system within a time frame sufficient to allow ecosystems to adapt naturally to climate change. The convention was adopted on 9 May 1992 and was opened for signature at the Earth Summit in Rio de Janeiro, Brazil, in June 1992. Mauritius signed the Convention at the Earth Summit and was the first country to ratify it.

7.9.2 The Basel Convention

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and the Disposal entered into force on 5 May 1992. The main objectives of the Basel Convention are:
(i) to reduce transboundary movements of hazardous wastes and other wastes to a minimum consistent with their environmentally sound management;
(ii) to treat and dispose of hazardous wastes and other wastes as close as possible to their source of generation in an environmentally sound way;
(iii) to minimize the generation of hazardous wastes and other wastes (in terms both of quantity and potential hazard).

7.9.3 Bamako Convention

The Bamako Convention was adopted on 30 January 1991 in Bamako, Mali by the Pan-African conference on Environment and Sustainable Development, organised by the Organisation of African Unity (OAU). Mauritius ratified the Convention on 29 October, 1992. The Convention aims mainly at the protection of African territories against the threat from hazardous wastes produced outside the Continent. It provides an outright ban on import of hazardous wastes from non-African Countries by a contracting party.

7.9.4 The Stockholm Convention on Persistent Organic Pollutants

The Stockholm Convention is a global treaty to protect human health and the environment from Persistent Organic Pollutants (POPs). POPs are chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of living organisms and are toxic to humans and wildlife. POPs circulate globally and can cause damage wherever they travel.

In implementing the Convention, governments are committed to take measures to eliminate or reduce the release of POPs into the environment. The Republic of Mauritius signed the Stockholm Convention on Persistent Organic Pollutants (POPs) on 23 May 2001, ratified it on 13 July 2004 and is committed to comply with its provisions (GOV 2005).

Article 7 of the Stockholm Convention requires that State Parties develop National Implementation Plans (NIP). The Mauritian NIP describes how the country will meet its obligations under the Convention to manage and phase out POPs sources in an environmentally sound manner.

7.10 Current programmes, projects, and priority objectives of the MLG

Programme 463 of the MLG deals with Solid Waste Management, Landscaping and Provision of Amenities (MLGE 2011).

7.10.1 Major achievements 2010

The MLG has completed the following tasks in the year 2010

- Completion of upgrading works at Roche Bois Transfer Station.
- Completion of new transfer station at La Chaumiere and ancillary works including access road.
- Completion of works for the extension of Cell 6 at Mare Chicose Landfill and improvement in the gas collection system to generate energy and to reduce greenhouse gas emissions.

7.10.2 Major Services to be provided for 2011-2013

The following are targeted for 2011-2013.

- Construction of a new Cell at Mare Chicose Landfill to provide additional capacity to cater for waste disposal beyond 2011.
- Operation of a new transfer station at La Chaumière to optimize the collection of waste within the catchment area of Beau Bassin/Rose Hill, Quatre Bornes and Black River and the transfer of waste to Mare Chicose Landfill.
- Improved facilities for the storage and disposal of hazardous waste with the implementation of an Interim Hazardous Waste Storage Facility at La Chaumière.
- Promoting the setting up of composting plants to promote waste minimization and lessen the pressure on the Mare Chicose landfill.
- Collection, treatment and disposal of electronic waste and other hazardous waste.

7.10.3 Major Constraints and Challenges and how they are being addressed

Identifying deficiencies in current waste management system is an ongoing exercise. As and when needed, shortcomings must be addressed. Thus, it is found that:

- The present hazardous waste management system is currently deficient in terms of appropriate infrastructure. The construction of an interim hazardous waste storage facility being proposed is in line with the provisions of the Basel Convention.
- There is inadequate technical expertise to monitor major solid waste management projects, thus leading to continued reliance on consultants. It is proposed to build up in-house capacity through recruitment of adequate technical staff and appropriate training.

7.10.4 List of Programmes, Sub-programmes, and Priority Objectives

Under Programme 463, the following are being focusing on:

- Ensure sufficiency and continuity in waste disposal facilities, safeguard underground water resources and protect public health.
- Ensure compliance with regulations relating to dumping and waste carriers, hazardous waste and waste oil.
- Reduce pressure on the disposal capacity through the promotion of recycling and re-use of waste and the introduction of an Extended Producer Responsibility (EPR) Scheme.
- Ensure cleanliness and promote a healthy environment at public beaches.

7.10.5 Financial resources

The financial resource allocated to Solid Waste Management, Landscaping and Provision of Amenities is around 25% of the total budget of the Local Authorities.

7.10.6 Human resources

27% of the staff of the Local Authorities works in Solid Waste Management.

7.11 Critical appraisal of the current waste management system

7.11.1 Salient features of the waste management framework

From information presented in sections 8.7 to 8.10, the following can be noted:

- The legal, regulatory, and institutional frameworks for waste management are fairly well structured, as are waste related activities
- Fairly adequate facilities are provided to authorities for carrying out their duties. They are also adequately empowered and human and financial resources to handle waste matters also appear sufficient
- The country adheres to the most important waste-related conventions to combat illegal waste disposal and transboundary movement of waste
- Several Waste Management programmes are in place to deal with waste challenges
- Deficiencies in regulations with regard to hazardous waste and e-waste are being looked into
- Lack of technical capacity are being addressed
- Recycling facilities exist for a few categories of waste
- Disposal site at Mare Chicose is a modern sanitary landfill
- Electricity is generated from LFG (a renewable source) at the Mare Chicose landfill
- Composting projects are being implemented on both small (home) scale and large scale

7.11.2 Shortcomings of the system

- There is still a serious lack of environmental awareness and also an indifference to the waste problem among the population. Residents are not properly guided about how to handle specific types of waste. There is a lack of segregation practice, with one bin used for all types of waste.
- Collaboration between stakeholders to make waste management and control more effective appears to be missing, thus allowing proliferation of illegal dumping and littering
- There is a lack of adequate technical expertise in many areas

- Authorities appear to be ineffective in certain cases of breaches of waste regulations for reasons which tend to be obscure. Enforcement of legislations is also a matter of concern
- Commitment of stakeholders to the waste management problem could be much improved
- There is insufficient control over waste generation at all levels

7.12 Recommendations

Managing solid waste is an intensive service. Municipalities need capacities in procurement, contract management, and professional labour management. They also need ongoing expertise in capital and operating budgeting and finance. MSW also requires a strong social contract between the municipality and community. All of these skills are prerequisites for other municipal services.

The recommendations given hereafter could be applied to improve waste management efforts. Most of the recommendations are adapted from the 1992 Rio Earth Summit (Rio 1992) but they are nonetheless still very valid. These recommendations are meant to serve as a basis for implementing new waste management plans or reinforcing existing ones.

7.12.1 Areas of focus

The framework for requisite action should be founded on a hierarchy of objectives and focused on the four major waste-related programme areas, as follows:

(1) Minimizing wastes;
(2) Maximizing environmentally sound waste reuse and recycling;
(3) Promoting environmentally sound waste disposal and treatment;
(4) Extending waste service coverage.

The four programme areas are interrelated and mutually supportive and must therefore be integrated in order to provide a comprehensive and environmentally responsive framework for managing municipal solid wastes. The mix and emphasis given to each of the four programme areas will vary according to the local socio-economic and physical conditions, rates of waste generation and waste composition. All sectors of society should participate in all the programme areas.

7.12.1.1 Minimizing wastes

Basis for action

Unsustainable patterns of production and consumption are increasing the quantities and variety of environmentally persistent wastes at unprecedented rates. The trend could significantly increase the quantities of wastes produced year after year. A preventive waste management approach focused on changes in lifestyles and in production and consumption patterns offers the best chance for reversing current trends.

Objectives

The objectives in this area are:

a. To stabilize or reduce the production of wastes destined for final disposal, over an agreed time-frame, by formulating goals based on waste weight, volume and composition and to induce waste segregation to facilitate recycling and reuse;
b. To strengthen procedures for assessing waste quantity and composition changes for the purpose of formulating operational waste minimization policies utilizing economic or other instruments to induce beneficial modifications of production and consumption patterns.

The Government, according to its capacity and available resources and with the cooperation of relevant organizations (e.g. UN), as appropriate, should:

a. Ensure sufficient national, regional and international capacity to access, process and monitor waste trend information and implement waste minimization policies;
b. Have in place programmes to stabilize or reduce, if practicable, production of wastes destined for final disposal, including per capita wastes (where this concept applies), at the level prevailing at that date; it should work towards that goal without jeopardizing its development prospects;
c. Apply programmes to reduce the production of agrochemical wastes, containers and packaging materials, which do not meet hazardous characteristics
d. Promote home composting as a means to reduce wastes bound for the landfill

7.12.1.2 Maximizing environmentally sound waste reuse and recycling

Basis for action

Stricter environmental controls governing waste disposal and increasing quantities of more persistent wastes have all contributed to a rapid increase in the cost of waste disposal services. Some disposal practices pose a threat to the environment. As the economics of waste disposal services change, waste recycling and resource recovery are becoming increasingly cost-effective. Future waste management programmes should take maximum advantage of resource-efficient approaches to the control of wastes. These activities should be carried out in conjunction with public education programmes. It is important that markets for products from reclaimed materials be identified in the development of reuse and recycling programmes.

Objectives

The objectives in this area are:

a. To strengthen and increase national waste reuse and recycling systems;
b. To create a model internal waste reuse and recycling programme for waste streams;
c. To make available information, techniques and appropriate policy instruments to encourage and make operational waste reuse and recycling schemes.

The government should therefore:

a. promote sufficient financial and technological capacities at the regional, national and local levels, as appropriate, to implement waste reuse and recycling policies and actions;
b. have a national programme, including, to the extent possible, targets for efficient waste reuse and recycling.

7.12.1.3 Promoting environmentally sound waste disposal and treatment

Basis for action

It is imperative to have adequate solid waste disposal services and treatment because of the health and environmental impacts of inadequate waste management.

Objectives

The objective in this area is to treat and safely dispose of a progressively increasing proportion of the generated wastes.

The government should:

a. ensure the availability of sufficient capacity to carry out waste-related pollution impact monitoring and conduct regular surveillance, including epidemiological surveillance, where appropriate.

7.12.1.4 Extending waste service coverage

Basis for action

Extending and improving waste collection and safe disposal services are crucial in gaining control over waste-related pollution.

Objectives

The overall objective of this programme is to provide health-protecting, environmentally safe waste collection and disposal services to all people.

The government should:

a. have the necessary technical, financial and human resource capacity to provide waste collection services commensurate with needs;
b. provide all the population with adequate waste services;
c. ensure that full waste service coverage is maintained and sanitation coverage achieved in all areas.

7.12.2 Additional Authorities' responsibilities

Authorities are required to show more firmness and severity against those who continue to break laws and, in particular:

- take prompt actions against people who fail to comply with rules and regulations and continue dumping waste illegally
- Take prompt actions against those who fail to show adequate responsibility towards segregation of waste
- Apply punishment systematically against polluters

Authorities should also:

- assume their roles more responsibly and understand their duties and responsibilities towards the society and the environment
- avoid, verify and eliminate loopholes in legislations/regulations

- amend/update legislations to be at par with international standards
- promote public participation in waste management
- carry out targeted awareness campaigns, e.g. households, community centres
- consider waste management education as subject matter/programmes at primary, secondary, and tertiary levels
- build technical capacity to educate people, run awareness/sensitization campaigns
- provide facilities and incentives to the public, e.g. free distribution of coloured bins for waste segregation, subsidising composting equipment purchase, etc

7.12.3 Householder's responsibilities

The main responsibility of the household is to reduce the amount of waste it generates. Indeed, if the waste problem is tackled at source, many of the problems that occur further along the chain will tend to disappear. To get the household to participate in waste management requires communicating clearly to the residents the aims and objectives of waste management plans and giving them clear instructions about what they should do. Thus good publicity is important and easily accessible channels should be used to reach out the population, e.g. news media, TV, radio, billboards, and the web. Public participation in waste management programmes is essential to the success of integrated waste management strategies.

Enumerated below are some ways households can contribute to waste reduction (Waste reduction 2012).

Refuse:

- Don't buy things you don't need.
- Avoid disposable products, designed to be thrown away.
- Don't buy over packaged goods.

Reduce:

- Buy things that are well made and will last.
- Buy things in returnable containers – and return the containers once empty.
- Concentrated products give you more active ingredient but make sure you do not use too much – follow the instructions.

- Buying in bulk, if you have the money and storage space and need the goods, reduces the amount of packaging.
- Try to avoid buying over packaged goods. Some packaging is useful, protecting the contents, providing somewhere to print information about the product and making it easier for shopkeepers to handle.
- Taking your own shopping bag means you don't need to use plastic carrier bags.
- Disposable nappies are bulky and difficult to dispose of. Try using reusable washable nappies instead.
- Using rechargeable batteries and recharging electrical appliances will save on batteries.

Refill:

- For some products refill packs can be bought, which use less packaging.

Reuse:

Lots of things can be reused. If you can't reuse them yourself try to find someone else who can.

- **Jam-jars and bottles:** if you don't make jam/marmalade/preserves/wine find someone who does. They can also be used for storing all sort of things – but make sure they are properly labelled.
- **Plastic carrier bags** can be reused several times as shopping bags, can be used to take items to be reused/recycled, and can be used as bin liners.
- **Old clothes, books, toys, unwanted gifts and household goods** are easy to reuse: give them to a jumble sale or a charity shop.
- **Envelopes** can be reused with a reuse label (plain or printed) or can be used as scrap paper.

Repair:

Any items, especially electrical items, can be repaired. There are still specialist repair shops though these may not be easy to find. One can look for help from authorities to set up special schemes which create work for people by collecting and refurbishing second-hand electrical equipment and furniture.

If you have things which cannot be reused, repaired or recycled please dispose of them carefully. Do not throw garden and household chemicals, or paint, or engine oil, down the drain. Don't use the toilet to dispose of waste. If in doubt about how to dispose safely of something, contact the local authority waste disposal department.

The foregoing list of recommendations is not exhaustive by any means but, on the contrary, it is open to extensions and adaptations. One important point to note is that waste management is the concern of everyone and it is only a collective and concerted effort that can ensure the success of a waste plan.

7.13 Conclusion

Many countries have understood that all our activities are going to generate millions of tonnes of waste daily and finding sustainable solutions to manage such tremendous volumes of waste will soon become a real headache. It would need wit and determination to prevent the planet from suffocating under the millions of tonnes of detritus that we are generating. Raising public awareness to waste and environmental issues through education and campaigns are areas where attention needs to be focused and for that, trained capacity will be needed. Education must form an integral part of waste management plans. Emphasis has to be laid on the risks of uncontrolled dumps to human health and the environment. Attention should be focused on waste reduction at source. Ways will have to be devised to get the population to participate and collaborate in waste management activities. Proper incentives have to be given to household members to allow them to start practising integrated and sustainable waste management at home. People who are still quite happy to dump their waste virtually anywhere they please should be punished. Changing the bad habits of people will require time, commitment, and determination but it is realizable. Unless all stakeholders recognize the importance of integrated waste management and a high level of commitment, sustainability cannot be achieved.

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CHAPTER 8
CONCLUSION

This project has provided a list of integrated and holistic recommendations for the design of sustainable residential buildings that consider all phases of the facility life cycle. The recommendations can serve as a guide when implementing programmes and activities with regard to sustainable development. The report also highlights the need for the commitment of all stakeholders towards environmental stewardship and conservation. The participation and contribution of all concerned parties can certainly lead to an optimal balance of cost, environmental, social, and human benefits while meeting the goals of sustainable development and the functions of the local residential buildings.

8.1 Main recommendations

The main recommendations in each specific area of sustainable residential building design are given below.

8.1.1 Site Selection, Construction and Optimisation

The recommendations provided in this area, as in others, were compiled following an in-depth study of international standards and codes of practices and the current status of Mauritius. They can therefore provide helpful tips to the concerned ministries, local authorities, and the public at large. They may also be developed into codes of practice for holistic site selection and construction. The specific recommendations are:

- Sensitizing local people on the importance of sustainable development in enhancing the quality of life
- counselling the population and more particularly applicants of building and land use permits on sustainable design strategies. New applicants must have an opportunity to discuss the projects with experts provided by the local authorities and the government.
- Educating the local people on sustainability concepts through seminars and workshops
- introducing sustainability concepts as course content at primary, secondary and tertiary education levels

8.1.2 Energy Efficiency

The government has announced a series of measures to improve energy efficiency in residential buildings in the context of the MID project. However, a lot remains to be done, particularly:

- Updating and strengthening existing energy efficiency measures, broadening their scope, and monitoring and enforcing compliance
- Saving energy, encouraging Passive Energy Houses or Zero Energy Buildings
- adopting mandatory energy performance requirements and, where appropriate, comparative energy labels across the spectrum of appliances and equipment at a level consistent with international best practices.
- Coordination of government and industry actions locally and internationally to ensure a sufficient supply of good quality higher efficiency alternative lamps

8.1.3 Water Conservation and Preservation

Most households still have a reasonable access to water inside their premises although maintaining such a service would become more difficult given the negative impact of global warming on the climate. Rainfall patterns are changing and it is very difficult to predict climatic behaviours. In order not to face severe water shortages, it has become imperative to use water sustainably. The following main recommendations have been suggested.

- To establish a plumbing code Committee (as part of a building code board, or as a stand-alone committee) to look into the elaboration of a Mauritius Plumbing Code
- To establish a board that would be responsible to seek the most appropriate existing code to start with, and then see to it that the specific Mauritian needs are taken into account

8.1.4 Use of Environmentally Preferable Building Materials

Local constructors should devote more efforts in selection of material to reduce adverse environmental impacts. They should consider the following:

- Reduce the total volume of concrete needed for a construction
- Use wood in buildings to reduce both the energy demands of the buildings and the concentration of greenhouse gas in the atmosphere

- Reuse or recycle plastic building materials to reduce their negative effects on the environment and use newly developed plastic materials with better sustainable properties
- Use bricks as they consists of non-toxic natural materials like clay and shale and also Ceramics, terrazzo and marble as flooring materials as they are among the most durable finishes with extremely low emissions
- Use alternative building materials, e.g. materials with low embodied energy and that are preferably available locally having low toxicity, durability, low level of GHG and other pollutants emissions, high recycling potential and minimal processing requirements. Use materials that are biodegradable or earthen materials that do not generate hazardous by-products.
- Consider applying the concept of green roofs
- Use passive solar design, integrating it as early as possible in the design process
- Investigate possibilities of utilizing linoleum (mixture of wood dust and oil) for flooring
- Recycle and reuse steel and concrete from demolished construction
- Exploit the use of Fly ash as it could help reduce the use of concrete to some extent and at the same time, reduce the adverse emissions of carbon dioxide.
- Assess and use proper lighting arrangements to avoid disrupting biological cycles in plants and animals
- The authorities should consider implementing standards and fiscal measures to promote the use of recycled building materials.
- Encourage research studies to identify suitable environmentally preferable products and to develop mechanisms to make them usable.

8.1.5 Enhance Indoor Environmental Quality

The main recommendations made in this area include the following:

- in-depth study of the provisions of ENERGY STAR and its associated Indoor AirPLUS program to adapt it to the local context
- elaboration of national building code based on LEED *and* ENERGY STAR
- Preparation of a Mauritian Residential Indoor Environment Quality Guideline

8.1.6 Operational Practices

Home automation is identified as a major enabler for sustainability in residential building. The recommendations specific to this area are:

- a proper standardisation framework for communication protocols with particular attention to Wi-Fi, Zigbee, and HomePlug Green PHY because of their proven interoperability
- proper legislations so that the most appropriate home automation standards are adopted
- smooth linking of home automation systems with the Public Utility for the setting up of an effective smart metering process
- Adoption of certain best practices by home owners to save as much energy as possible

8.1.7 Waste Management

To achieve the target of sustainable development, integrated waste management is a must. The main areas of focus of sound waste management considered in the report are:

- Minimizing wastes;
- Maximizing environmentally sound waste reuse and recycling;
- Promoting environmentally sound waste disposal and treatment;
- Extending waste service coverage.

Major activities that would have to be undertaken are:

- reorganisation and consolidation of existing waste legislations and regulations
- Training and capacity building
- Allocation of more resources to ensure proper enforcement of laws and regulations
- promoting recycling in order to reduce the volume of waste to be treated at the landfill site
- Awareness and sensitization campaigns, and encouraging public participation in managing waste

8.2 The final word

Most nations of the world have come to realize the fact that the planet is on the verge of a major environmental catastrophe brought about by irrational and inconsiderate human activities. As population continues to grow, it places enormous stress on the Earth's limited resources which, if not managed wisely, will soon get depleted. At the same time, the rate at which we are generating waste and other hazardous substances could rapidly become unmanageable. In a sense, we have become our own enemies because not only we are over-utilizing natural resources but we are also not taking enough concrete measures to tackle the problem. The battle against this problem will have to be fought on two fronts: using lesser of non-renewable resources and finding new renewable non-polluting options. No nation will be able to achieve this on its own. Collaboration and cooperation shall be necessary, sincere commitment and determination too. Every nation will have to bring its share of contribution. Governments will have to take bold decisions and apply drastic measures. It is only through a concerted effort that we will be able move towards the same goal of sustainable development.

Appendix

A.1 Factors contributing to the waste problem

Table A.1 Factors that generate waste problems in developing countries and specific problems *(Source: JICA 2005)*

Problematic factors			Possible problems			
			Storage/discharge	Collection/transportation	Intermediate treatment	final disposal
Background factor	• Population and economic level • climate and terrain, etc	• Increasing waste • Change in characteristics of wastes • Climate change, flood, and natural disaster • Underdeveloped urban infrastructure • Operational obstruction • Low land availability • Diversified urban residents	• Improper discharge and storage for the amount and characteristics of wastes • Improper discharge and storage for livelihood • Improper discharge and storage for climatic condition • Hard to install collection stations	• Congestion due to population increase • Expansion of low collection area like squatter districts caused by population increase • Inadequate equipment selection to the amount and characteristics of wastes • Traffic obstruction due to flood • Low accessibility due to underdeveloped roads or steep slopes	• Inadequate intermediate treatment to the amount and characteristics of wastes • Inadequate intermediate treatment to the climatic condition • Low availability for treatment facility site	• Environmental impact by hazardousness, infectiousness, and causticity of waste • Stringent disposal site due to increased amount of waste • Increased leachate water due to frequent rain • Low site availability • Pollution of river and underground water due to seepage water • Low availability of covering soil
Inadequate SWM by municipalities	Social aspects	• Low awareness to waste problem • Lack of cooperation	• Insufficient waste generation control • Improper	• Service exclusion for low-income group due to charge unpaid • Low social	• NIMBY syndrome • Carrying of waste not properly	• NIMBY syndrome • Generation of site scavenging

		will • Plarlization between poor class and wealthy class • Formation of slum district • Dismantlement of traditional community	discharge • Waste reserve and scattering around collection stations (container etc.) • Scattered garbage due to generation of scavenging on street etc	position of the collectors • Generation of scavenging in the collection process (decreased collection efficiency including by collectors)	separated • Intermediate treatment and recycled product that does not suit economic activity	• Waste picker's insanitary, dangerous working environment
	Institutional aspects	• Lack of policy target • Inadequate laws, standards, or guidelines • Insufficient decentralization or insufficient authority held by local government • Incomplete system of organizations responsible for waste	• Absence of storage and discharge rules • Incomplete policies and systems for generation suppression and waste separation • Mixed industrial wastes • Mixed hazardous waste	• Illegal dumping • Inadequate safety practice for workers • Improper contract with private service providers • Uncollected area occurred	• Residents' resistance to location • Inadequate safety practice for workers • Improper contract with private service providers • Environmental impacts	• Inadequate safety practice for workers • Insufficient safety practice for waste pickers • Improper contract with private service providers • Environmental impacts Possible
	Organizational aspects	• Obscure decision making • Lack of shared consideration of common targets • Frequent personnel replacement • Lack of organization management capacity	• Incomplete and inadequate guidance to residents • Waste reserve and scattering due to irregular discharge	• Inefficient operation • Inadequate management and supervising • Inadequate planning • Waste reserve and scattering due to incomplete collection	• Inefficient operation • Insufficient management and supervising • Inadequate planning	• Inefficient operation • Insufficient management and supervising • Inadequate planning

		• Lack of policy making capacity • Lack of adjustment of and cooperation with private cleaning providers and other organizations • Incomplete operating agreement with private waste service providers, inadequate contract management, opaque vendor selection				
	Financial aspects	• Undeveloped tax collection system • Low priority of waste problem in budget allotment • Lack of financial management ability • Lack of financial planning with equipment update etc. incorporated • Incomplete economy forecast • Inappropriate	• Storage at collection stations, absence and lack of waste containers • Imperfect charge collection	• Insufficient amount of collection charge • Inappropriate application of the collected tax, excluding waste management services • Insufficient allocation from municipal general account • Insufficient allowance for equipment and fuel • Insufficient allowance for equipment operation and	• Insufficient allowance for facility operation and maintenance • Declined facility operation rate • Increased stock of recycled products • Incompatibility with market	• Insufficient amount of collected disposal charge • Insufficient allocation from municipal general account • Insufficient allowance for equipment operation and maintenance • Cost of equipment update • Procurement difficulty of

		application of the collected tax, excluding waste management services		maintenance・		covering soil
	Technical aspects	• Under-skilled • Lack of capable human resource • Incomplete human resources development plan • Incomplete technical information	• Incomplete and inadequate guidance to residents • Imperfect separation	• Insufficient capacity for equipment management • Inadequate planning • Improper collection method • Inefficiency • Inadequate supervision over private service providers	• Introduction of improper intermediate treatment • Improper operation and maintenance • Inadequate planning • Adverse impacts on environment and the resulted increase of NIMBY-minded people • Inadequate supervision over private service providers	• Improper disposal • Improper operation and maintenance • Inadequate planning • Adverse impacts on environment and the resulted increase of NIMBY-minded people • Inadequate supervision over private service providers

A.2 E-waste

There is no standard definition concerning Waste Electrical and Electronic Equipment (WEEE) or E-waste agreed upon internationally. Currently the most common one is the definition of EU Directive which includes large and small domestic appliances, IT and telecommunications equipment, household use equipment, lighting equipment, power tools, toys, leisure and sports equipment, medical application (transplant products and infected products excluded) , and surveillance and control equipment. E-waste in the developing countries accounts about 0.01 % to 0.1 % of the gross wastes as of 2007. This number is increasing rapidly. E-waste contains a variety of substances. Iron and steel constitute about 50%, plastic 21%, and non-iron 13%, which are the main components. Precious metals such as silver, gold, platinum, and palladium are also present. Heavy metals such as lead, mercury, arsenic, cadmium, selenium, and hexavalent chromium contained in flame retarder also constitute E-waste. Therefore destruction and burning of E-waste is hazardous, requiring treatment as hazardous waste.

Looking from another point of view, metals/precious metals contained in E-waste are valuable in reproduction, which may provoke wrongful trans-boundary trades. Every year 2,000 to 5,000 tons of E-waste is scrapped globally, most of which reportedly are transported to countries such as Bangladesh, China, India, Myanmar, and Pakistan. In these countries, inappropriate recycling would result in health hazards, water pollution and soil contamination due to hazardous substances contained in E-wastes. Many of E-waste imported as used products to the developing countries often turns out to be "junk" even after repair. Some report a great amount was dumped illegally and burned close to the residential area, causing adverse effect on the environment and the residents' health.

E-waste is the most serious problem in Asia Pacific region. Basel Convention secretariat has implemented a pilot project (from 2005 to 2008) to manage the waste in an environmentally sound manner in the region. A total of 13 countries including Cambodia, China, India, and Indonesia worked together for the pilot project for sorting/collection, repair/reproduction, and recycling, preparation of guidelines to establish national policy, capacity building, as well as workshop concerning environment-friendly technology.

Source: (JICA 2009).

A.3 Sources of waste

Table 8-1 gives a summary of the various sources of waste and the types of waste they generate.

Table A-2: Sources and types of the main wastes (JICA 2009)

Sources	Generators	Types of waste
Households	Single family, multiple households	Kitchen garbage, paper, packaging wastes, corrugated cardboards, plastic, cloths, leathers, garden garbage, glass, metals, ashes, large wastes, and hazardous wastes from households, like

		oil paint, paint thinner, wood preservative, agricultural chemicals, and batteries, among others.etc
Industrial	Light industry, heavy industry, manufacturing, power plant, chemical plant, refinery, and mining	Packaging waste, wastes originates from processing, ash, hazardous industry waste, etc
Medical	Medical institution, research laboratories, and laboratory	General medical wastes and hazardous medical wastes
Commercial	Shops, hotels, restaurants, markets, and office buildings	Paper, corrugated cardboards, plastic, woods, kitchen garbage, glass, and metal, etc
Facilities	Schools, prisons, and government agencies	Same as those for commercial cell
Construction/ demolition	Construction/facility dismantlement site, and road repair	Pebbles including concrete, metal scrap such as metal wires, wood chips like those from dismantlement of wood construction, and dirt, etc
Local government service	Road sweeping, landscape gardening, parks, coast, other recreation areas, and waterworks and sewerage treatment facilities	Cleaning garbage, wood chips, parks, coast, and other common wastes from recreation areas, etc

A.4 List of Recyclers in Mauritius

- **Paper/Cardboard Recycling**

Company Name	**Address**	**Contact Person**	**Contact Details**
Agripac Ltd	Bonne Terre, Vacoas	Mr J.H.Dookun	Phone: 426 2955 Fax: 426 6240 Email:anil.pccl@intnet.mu
Atics Ltd	Allée des Manguiers Pailles	Mr Raj Essoo	Phone: 2112280/2517905 Fax: 2114189 Email:atics.headoffice@atics.mu
Lagtex Co.Ltd	6, St Denis street, Port Louis	Mr M.Marie	Phone: 2122047/2124822/2124755 Fax: 208 8683 Email:lagsec@intnet.mu
Dakri Paper & Products Ltd	Industrial Zone, Geoffrey Road, Bambous	Mr Haniff Dakri / Mr Nazir Dakri	Phone: 452 0550 Fax: 452 0739 Email: akripaper@intnet.mu

- ## Plastic Recycling

Company Name	address	Contact Person	Contact Details
Polypet Recyclers Ltd	Industrial Zone, Solitude	Mr A.Ramjaun Mob:4228221	Phone: 261 7171 Fax: 454 4784 Email:polypet1@intnet.mu
DKD Co Ltd	Royal Road L'avenir St Pierre	Mr H. Coret	Phone: 433 8502 Fax: 433 8549 Email :dkdcoltd@hotmail.com
Philip Polybag Manufacturer Co. Ltd	Royal Road, Petite Rivière	Mr Gerard Lee	Phone: 233 0888 Fax: 233 5652 Email:kmsgroup@intnet.mu
Plaspak Group	Renganaden Seeneevassen Ave, Palma, Quatre Bornes	Mr Chetty	Phone: 427 7700 Mobile: 251 0524 Fax: 233 5652 Email:laspak@intnet.mu
Viper Transport & Co Ltd	76, Peeranah Ave. Roche Brunes	Mr Jean Claude Barbe	Phone : 739 0100 Email :super_recycling@yahoo.com

- ## Metal Recycling

Company Name	Address	Contact Person	Contact Details
Runghen G.&Co	52, Queen Street, Port Louis	Mr G.Runghen	Phone: 204 0090 Fax: 240 8687 Email:grunghen@intnet.mu
Samlo Koyenco Co. Ltd	La Pipe, Midlands	Mr R.Gowressoo	Phone: 6656700 Fax: 6655729/900 Email:samlosteel@intnet.mu
Steel Scrap Ltd	PO Box 722, Plaine Lauzun, Port Louis	Mr Norbert Ross	Phone: 212 0356/549 0622 Fax: 208 2825 Email:techiw96@intnet.mu

- ## Textile Waste

Company Name	Address	Contact Person	Contact Details
Recycling Industries Mauritius Limited	Motorway M2, Riche Terre	Mr Krishna Narainen	Phone: 249 0179 Mobile: 250 7816 Fax: 241 0180 Email:rimltd@intnet.mu

Lagtex Co. Ltd	6, St Denis street, Port Louis	Mr M.Marie	Phone: 2122047/2124822/2124755 Fax: 2088683 Email:lagsec@intnet.mu
Giant International Trading Co Ltd	Mahatma Gandhi Street, Poudre D'Or Hamlet		Phone : 422 7878/264 8057
Soge International Co Ltd	21, Rishi Dayanand Road, Plaine Magnien		Phone : 637 9325

- ## Fixer Solutions

Company Name	Address	Contact Person	Contact Details
BEM Enterprises Limited	57, Colonel Maingard Street, Beau Bassin	Mr B.Malabar	Phone: 4664553 Fax: 4544463 Email:bertymalabar@gmail.com

- Glass Recycling

Company Name	Address	Contact Person	Contact Details
The Mauritius Glass Galery Limited	Pont Fer Phoenix	Mr Paul Rose	Phone: 6963360 Fax: 6968116 Email:mgg@intnet.mu

- ## Retreading of tyres

Company Name	Address	Contact Person	Contact Details
Compagnie Mauricienne de Commerce	M2 motorway Pailles	Mr C.Duval	Phone: 286091 Fax: 2860916 Email:cmc@intnet.mu

- ## E-Waste

Company Name	Address	Contact Person	Contact Details
BEM Enterprises Limited	57, Colonel Maingard Street, Beau Bassin	Mr B.Malabar	Phone: 4664553 Fax: 4544463 Email:bertymalabar@gmail.com
Recycling Valorisation Environment (RVE Ltd)	99, Royal Road Beau Bassin	Mr. Oomar DOOKHEE/ Mr. Ashwin MATTAPULLUT	Phone: 464 4688 Mobile: 749 0284 Fax : 464 4688 Email: rve.sales@gmail.com rve.collecte@gmail.com

- ## Waste Oil

Company Name	Address	Contact Person	Contact Details
Ecofuel	P.O Box 726, Complexe Comérciale, La Tour Koenig	Mr Georgy Thomas	Phone: 2521805/2344915 Fax: 2341889 Email: ecofuel@intnet.muregion@intnet.mu

- ## Batteries

Company Name	Address	Contact Person	Contact Details
Steel Scrap Ltd.	P.O Box 722, Plaine Lauzan, Port Louis	Mr Norbert Ross	Phone: 2120356 Fax: 2082825 Email:techtrade@intnet.mu
Tradeway International Ltd.	Ground Floor, Suite No.7, R. Seeneevasen Street, Port Louis	Mr S. Semjenee	Phone: 2171335 Fax: 2171328 Email:iqbal@logfret.intnet.mu