Seychelles Incinerator Sustainability Preliminary Study

Prepared For: Sustainability for Seychelles

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Date: January 2010

Project No: 01

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1 Executive Summary

The management of waste materials represents a challenge throughout the world. Since Rachel Carson's "Silent Spring" we are all more aware of the necessity to reduce waste but at the same time we find ourselves striving for material wealth. Many methods of waste management are practiced around the world, from the most basic type of recycling in the form of waste scavengers to high tech incineration.

The purpose of this preliminary study is to determine whether introducing an incinerator for waste management in the Seychelles is a viable and sustainable option. In the process of assessment alternative methods of waste management are considered and summaries provided. This paper is intended to aid *Sustainability for Seychelles* (S4S) to determine their position on the issue of waste management in the Seychelles going forward and may determine whether S4S lobby the government for incineration or for an alternative to incineration.

The methodology used to compile this preliminary study was a desktop research project supplemented by an interview with Seychelles government staff Mr. Barry Joseph. Mr. Joseph provided background information for Sections 2 and 5.

Use of incinerators for waste management is controversial. The debate over incinerators typically involves business interests (representing both waste generators and incinerator firms), government regulators, people with environmental concerns and local citizens who must weigh the economic appeal of local industrial activity with their concerns over health and environmental risk.

The results of the literature review and personal communication conclude that an incinerator is likely not a viable option for the Seychelles situation however the full feasibility study by PUC should be considered prior to discrediting incineration completely. The main reasons for the conclusion of this Preliminary Study are the:

- volume of waste produced daily is likely not adequate to continuously run an incinerator thereby reducing its value to provide energy to the Seychelles electricity grid;
- type of waste is not suited to incineration i.e. it is very wet;
- local environmental conditions (e.g. high humidity) and wet waste would cause corrosion of the incinerator and shorten its life span;
- capital cost of incineration and ongoing equipment maintenance; and
- absence of maximising resource use.

In conclusion, having considered the alternatives that may assist the Seychellois to achieve sustainable waste management, the preferred option is to reduce, reuse and recycle. If appropriate investment is made, the 3Rs can create jobs, lower raw material costs for industry (while improving competitiveness), conserve resources, reduce pollution, reduce poverty and protect the environment. Suggestions for making investment in the 3Rs (reduce, reuse and recycle) effective are provided.

2 Introduction & Local situation

Sustainability for Seychelles (S4S) became aware that the local government organisation is considering the viability of an incinerator as an alternative to landfill or to reduce the need for landfill capacity. S4S did not hold an opinion whether to support or oppose the proposal for incineration therefore a S4S volunteer environmental scientist undertook background research regarding the sustainability of incineration and alternative methods of waste management for the Seychelles.

2.1 Existing waste management practices

Star Pty Ltd (Star) has a contract with the Seychelles government to collect and manage solid waste on Mahé and the inner islands. The contract does not include any requirement to separate waste for recycling however metal detectors may be used to pull scrap metal out of the landfill. The contract is administered by the Landscape and Solid Waste management branch (LSWMB) of the Seychelles government. Aspects of environmental management should be covered by the contract however this is apparently absent from the contract and is therefore not undertaken by Star or the LSWMB.

Star uses several traditional methods to manage the solid waste including:

- Daily collection of unsorted domestic waste by trucks fitted with compactors;
- An additional compaction facility is used at the Providence landfill site. (According to references compactors of this sort are able to reduce the volume of waste by up to 70%).
- Management of approximately 100 tonnes of waste per day from all sources e.g. domestic, industrial etc.

In addition, Star uses compactor trucks however they may achieve low compression rates due to the density of the solid waste compared to industrialised nations where compression of 4:1 is achieved.

In some areas of the granitic islands there are no containers designated by municipalities or Star to 'set out' waste for collection; it is up to individual residences to designate some sort of collection container. In these areas households simply place grocery bags full of waste on the street to await collection. Weather, animals, and other disturbances prior to collection threaten the integrity of the plastic bags and lead to litter. In an examination of current problems in Kenya, Mungai (1998) agreed that the first step in *"sanitary and efficient"* waste management must be to ensure that all households use some form of corrosion-resistant container <u>with lids</u> in order to facilitate collection. *Lidded* containers exclude most animal pests, reduce the amount of rainfall soaking into garbage and help to reduce trash becoming litter[1].

Star does not presently utilise any incineration technology for waste management in the Seychelles, however incinerators are used by the Ministry of Health for medical waste and it is possible that some hotels or businesses may operate small incinerators. The quality and operation of these incinerators is beyond the scope of this study but the licensing and monitoring of these facilities is an environmental issue that needs to be given due consideration to ensure environmental harm is prevented.

The majority of waste managed/land filled by Star is sourced from Mahé, Praslin and La Digue with additional waste (generally sorted) from the hotel islands.

The effect of the existing landfill has been studied in the past but no recent studies have been undertaken. It is expected that there are impacts on the marine environment and groundwater as the landfill does not have an impermeable liner nor does it have leachate treatment. Under the existing contract between Star and the government, there are operating procedures for the solid waste management however there are no requirements for regular monitoring of environmental impacts e.g. leachate on marine waters, surface and ground waters, soils, odour etc. It is up to the Seychelles government to undertake any monitoring and this has not occurred, likely due to a shortage of funds and staff.

Landfill gases (e.g. methane) are not collected by Star but are allowed to escape to the atmosphere thereby contributing to greenhouse gases and climate change.

Recycling on the Seychelles is somewhat limited and has gone through some growing pains. At present good quality glass can be recycled for artisan work (contact: Mrs. Lucy Hickerson at Baie Lazare 361 107). In addition, poor quality glass can be recycled for road infill material (contact: Michelle Martin at Sustainability for Seychelles). Metal, including tin cans, pop cans, scrap metal including waste metal from the Indian Ocean Tuna Company, and PEP plastic bottles are collected at redeem centres located at six district locations around the Seychelles. The main PEP plastic redeem centre is located at Providence (behind the yellow corrugated iron) for shredding and/or export. The other redeem locations are located at Anse Royal, La Digue, Praslin, and possibly at St Louis. The organisation in charge of this enterprise is the Samlo Group with CEO, Mr. Rajiv Gowressoo in Seychelles. It is noted that this recycling venture employs more than 50 people and therefore should not be altered (pers. comm. B. Joseph).

In the past paper was recycled to produce seedling containers for agriculturalists or florists but this venture was unsuccessful as the agriculturalists prefer to reuse the plastic seedling containers rather than purchase recycled paper seedling containers each time they plant seeds. Paper seedling containers breakdown/compost when exposed to water and soil, which is more costly for the agriculturalist than reusing plastic containers. Alternative recycled paper products should be considered (refer to Section 5).

The present landfill is nearing capacity therefore Star, the government and the European Union (EU) have identified a new landfill location to be developed with improved environmental requirements and monitoring conditions. For additional considerations regarding this new landfill refer to Section 5.

All medical waste is managed by the Hospital and is the responsibility of the Ministry of Health. An incinerator is located at the hospital but waste management and the operation of the incinerator has been a concern to local residents due to odour and stockpiles of waste.

Based on general conversations with people living in the Seychelles, some opinions include:

- cost of an incinerator is too great to make it viable for Star without significant government financial support;
- environmental laws and monitoring requirements may not be strict enough to control incinerator emissions; and
- the incinerator would require high oil/gas inputs to maintain the required temperatures and dry the very wet waste, generally received by Star. The oil/gas

consumption would increase Seychelles consumption and dependency on fossil fuels which is in opposition to the present government position on climate change.

The issue of *"wet"* solid waste is noted by Cointreau (1982) and others (Blight and Mbande 1996, Arlosoroff 1982) along with several other differences in the composition of solid waste between developing and industrial nations:

- Waste density is 2-3 times greater than industrialised nations;
- Moisture content is 2-3 times greater;
- Large amount of organic waste (vegetable matter, etc.); and
- Large quantities of dust, dirt (street sweepings, etc) i.e. small particle size on average.

These differences present both problems as well as potential opportunities[1].

2.2 Areas for waste management improvement

Like other small island nation states, the people of the Seychelles face several threats that are contributing to the need for better waste management. The threats include:

- Increasing consumption patterns produce ever increasing waste streams including hazardous wastes such as electronic, chemical, radioactive wastes;
- Tourism, a significant national income earner, generates significant quantities of waste;
- Waste threatens to pollute the tourism product and spoil the experience being offered; and
- An inability to properly and safely dispose of industrial hazardous wastes will adversely impact on public health, water resources, air quality and biodiversity.

A study in the Caribbean region estimated that marine litter results in a total loss of US$333,000 for fisheries, ports and tourism in one port area of St Lucia[2].

Waste management measures that require improvement in the Seychelles include, but are not limited to:

- National policy, legislation and institutional arrangements for effective and efficient waste management;
- Training for waste management workers (operators & contractors) along with clearly defined competency requirements and a licensing regime may be required;
- Enforcement of the national policy, legislation and systems need emphasis;

[1] Zerbock, O. (April 2003) "Urban Solid Waste Management: Waste Reduction in Developing Nations" for CE 5993 Field Engineering in the Developing World.

[2] Smith, I. (January 2010) "UNSCD Thematic Seminar on Waste Management – Caribbean Experience" Environmental Engineers and Managers Ltd.

- Sufficient investment in consistent and continuous public awareness programmes to effectively communicate waste management messages. Public awareness will lead to appropriate personal hygiene, sanitation and waste management practices;
- Sufficient rural and inner city community outreach programmes to introduce effective waste management solutions;
- Effective and appropriate waste and wastewater management systems for rural communities and inner city communities need to be provided;
- Strengthening of political will to improve waste management, even in times of global economic crisis;
- Close gaps created by overlapping agency responsibilities and ensure information is shared widely.
- Integrated waste and wastewater management plan for the Seychelles is required to focus on short and long term initiatives;
- Establish cost recovery through fees and levies; and
- Strengthen data collection, monitoring and evaluation systems.

2.3 Solid Waste Management Options under Consideration

2.3.1 Incinerator

This preliminary study was initiated under the pretext that a Seychellois organisation (possibly the Public Utilities Corporation [PUC]) is undertaking a feasibility study for a waste incinerator as an alternative to landfill. Little information has been gathered regarding the feasibility study but questions that need to be answered by the feasibility study are listed in Table 1 along with the reason for the questions as appropriate. This list of questions is not comprehensive.

Table 1: Questions to be included in Incinerator Feasibility Study

Questions	Reason for Questions
What is the purpose of the incinerator?	Is it to manage/minimise the volume of solid waste and/or to provide an alternative source of energy to the existing diesel generator?
What type of wastes would be incinerated? Municipal, commercial and/or industrial waste?	The type of waste affects the type of incineration required and environmental management requirements that should be included in any contract. If industrial waste incinerated then special requirements for heavy metal residues will be required.
Where would the waste for incineration come from? All the islands? Just the northern islands? Just Mahé?	Transport of waste is costly and contributes to greenhouse gases.
If waste from other islands is not being transported for incineration how will it be	Alternative methods of solid waste management should be considered (Section 5).

Questions	Reason for Questions
managed?	
Would green waste be collected at municipal level as a fuel supply? Would land clearing occur to provide a source of green waste and wood?	The nature of the fuel supply and the need to provide a *continuous* fuel supply must be considered. Burning of native vegetation should not be considered a viable option if *continuous* fuel supply is a component of the proposal.
What is the process for deciding if an incinerator is the right thing for the Seychelles?	It must be a transparent process and provide for public input. Circulation of the proposal and supporting information should occur through newspapers, public forums, schools and other public locations to ensure public input.
What is the time frame of the proposal if successful	If the time frame is too long, an interim landfill may be required because the existing landfill is close to capacity.
How will the PUC, government agency and private company manage the incinerator project and ongoing operations?	In order to ensure best practice operations environmental regulations (e.g. Environmental Management Plan) and environmental regulator, must be established. Regular monitoring must be included as a component of ongoing operations.
Detailed review of PUC proposal is required. For example, what environmental mitigation measures will be integrated? Will there be more than one boiler to provide continuous incineration? What would excess heat be used for?	The proposal should be considered in full detail prior to making a final decision as to whether the proposal can be supported by S4S.
Would an incinerator for electricity generation meet the demand for electricity on Mahé?	If the incinerator is not able to meet the demand then there would still be the need for a diesel generator or other means of electricity generation.
Is secondary or tertiary water treatment available to treat wastewater from scrubbers?	It is noted that a wastewater treatment plant exists at Providence however it is not known whether it has the capacity to treat incinerator wastewater.
Has the PUC considered the carbon footprint of the incinerator for local environmental conditions?	The Seychelles are committed to carbon neutrality therefore an incinerator's contribution should be neutral too.
Where would the incinerator be located?	Information about the local environment is required to determine if the incinerator location is compatible with local use, how it affects amenity and sustainability.
How would the effects be measured? Will there be ongoing environmental monitoring including: in-stack monitoring; base-line ambient air monitoring; ongoing ambient air monitoring; landfill groundwater monitoring;	Monitoring is a way of ensuring the environmental is not negatively affected and measuring performance in relation to the equipment specifications.

Questions	Reason for Questions
What restrictions will be put on input to the incinerator, e.g. no materials containing heavy metals?	To ensure all required specifications are understood.
Will the Environment Department or the incinerator operator be responsible for environmental monitoring to ensure license requirements and best practice are achieved?	Who is accountable?
NOTE: If the purpose of the incinerator is to provide an alternative source of energy to the existing diesel generator then the volume and source of waste becomes critical issue to provide continuous operation.	

2.3.2 Landfill

While undertaking this preliminary study, it has been determined that a site for a new landfill has been identified by the Land & Solid Waste Management Division (LSWMD) of the Seychelles government. With cooperation between the EU and the Seychelles government, the new landfill would be built to environmental specifications, including but not limited to, an impermeable lining and leachate treatment. In addition, the LSWMD is supportive of some of the alternative methods to solid waste management discussed in Section 5, in particular the 3Rs of reduce, reuse and recycle, and composting.

3 General Information regarding Incineration

3.1 Types of Incineration, Advantages & Disadvantages

Incineration is a thermal waste treatment technology that uses combustion to break down organic materials and/or substances. Waste material is converted into incinerator bottom ash, flue gases, particulates, and heat, which can in turn be used to generate electric power. The flue gases should be cleaned of pollutants before they are dispersed in the atmosphere while the bottom ash can be used in cement mix or disposed in landfill (refer to Section 4.3).

There are four incinerator plant designs. Table 2 identifies each design and describes advantages and disadvantages of each. All have the advantage of reducing the mass of the original waste by 80–85% and the volume (already compressed somewhat in garbage trucks) by 95–96%, depending upon composition and degree of recovery of materials such as metals from the ash for recycling[3]. This means that while incineration does not completely replace landfills, it reduces the necessary volume for disposal significantly.

It is noted that incineration has robust benefits for the treatment of certain waste types in niche areas such as clinical wastes and certain hazardous wastes where pathogens and

[3] Rambol (2006) "Waste to Energy in Denmark".

toxins can be destroyed by high temperatures. Examples include chemical multi-product plants with diverse toxic or very toxic wastewater streams, which cannot be routed to a conventional wastewater treatment plant.

Japan, Sweden and Denmark are leaders in using incineration for electricity/heat generation. In 2005, waste incineration produced 4.8% of the electricity consumption and 13.7% of the total domestic heat consumption in Denmark. Incineration in Europe has grown over last 10 years and is expected to grow in the UK. In Europe, some of the electricity generated from waste is deemed to be from a 'Renewable Energy Source (RES)' and is thus eligible for tax credits if privately operated. Also, some incinerators in Europe are equipped with waste recovery, allowing the reuse of ferrous and non-ferrous materials found in landfills. A prominent example is the AEB Waste Fired Power Plant[4] [5]. In the USA, with the increase in the number of large inexpensive regional landfills and, up until recently, the relatively low price of electricity, incinerators could not compete for the waste (fuel). Since 2004, effort has been made to promote incinerator capacity due to: greenhouse gas benefits, improved air pollution controls, and ash recycling. It is noted that the scale of these overseas incineration projects is much larger than anything Seychelles could undertake.

Table 2: Advantages and Disadvantages of 4 Incineration Plant Designs

Plant design description	Advantage	Disadvantage
Moving grate incinerator is typically used for municipal solid waste, often called a Municipal Solid Waste Incinerator (MSWI). The waste is introduced by crane through the 'throat' at one end of the grate; waste moves over the descending grate to ash pit; where ash is removed through a water lock. Holes in the grate elements supply part of the primary combustion air. This air flow cools the grate. Cooling is important for the mechanical strength of the grate. Moving grates may also be internally water cooled. Secondary combustion air is supplied into the boiler at high speed through nozzles over	The moving grate optimises the movement of waste through the combustion chamber to allow more efficient and complete combustion. A single moving grate boiler handles up to 15-35 metric tons (39 short tons) of waste per hour, and can operate 8,000 hours per year with one scheduled inspection and maintenance stop of about one month duration.[6] The heat from the super-heaters can be transferred to steam for electricity generation in a turbine. Incineration of municipal solid waste avoids the release of methane.	According to the European Waste Incineration Directive, incineration plants must be designed to ensure that flue gases reach at least 850°C (1,560°F) for 2 seconds in order to ensure proper breakdown of strong molecular bonds (dioxins). In order to comply with this at all times, it is required to install backup auxiliary burners (often fueled by oil), which are fired into the boiler in case the heating value of the waste becomes too low to reach 850°C. Incineration does not replace landfill use but can reduce waste by 90% of its volume. Capital & maintenance cost

[4] Themelis, N.J. (July/August 2008) "WTERT Award nominees – Acknowledging major contributors to global waste-to-energy developments". Waste Management World 9 (4).

[5] Mehdudia, S. (30 January 2009) "Making the most of waste: gold, power and more from Amsterdam's refuse". The Hindu.

[6] (2004) "Vestforbrænding anlæg 6 – Danmarks største forbrændingsovn" (in Danish) (PDF)

Plant design description	Advantage	Disadvantage
the grate. It facilitates complete combustion of the flue gases by introducing turbulence for better mixing and by ensuring a surplus of oxygen. Flue gases are then cooled in super-heaters, where heat can be transferred to steam, heating steam to 400°C at a pressure of 40 bars (580 psi) for electricity generation in the turbine. At this point, the flue gas has a temperature of ~200°C and is passed to the flue gas cleaning system.		
Fixed grate is a brick-lined cell with a fixed metal grate over a lower ash pit, with two openings: in the top or side for loading; and in the side for removing incombustible solids (clinkers).	Generally small scale operations but many small incinerators formerly found in apartment buildings have been replaced by waste compactors in North America. Incineration of municipal solid waste avoids the release of methane.	Temperatures are likely not adequate to break down dioxins. Incineration does not replace landfill use but can reduce waste by 90% of its volume. Atmospheric emissions are uncontrolled. Capital & maintenance cost
Rotary-kiln incinerator has 2 chambers. The primary chamber consists of an inclined refractory lined cylindrical tube. Movement of the cylinder on its axis facilitates movement of waste. The secondary chamber completes gas phase combustion reactions. The clinkers spill out at the end of the cylinder. A tall flue gas stack, fan, or steam jet supplies the needed draft.[7] Fine particles and any combustible gases may be combusted in an 'afterburner'.	The rotary kiln incinerator is used by municipalities and large industrial plants. In the primary chamber, there is conversion of solid fraction to gases, through volatilization, destructive distillation and partial combustion reactions. Incineration of municipal solid waste avoids the release of methane.	Products = clinker, ash and air particles Particles are carried with hot gases. Incineration does not replace landfill use but can reduce waste by 90% of its volume. Capital & maintenance cost
Fluidised (sand) bed – strong airflow is forced through sand-	The fluid-like state allows the mass of waste, fuel and sand	Incineration does not replace landfill use but can reduce

[7] Crown A. (1998) "Air Pollution Control and Incineration Systems photos".

Plant design description	Advantage	Disadvantage
bed. The sand particles separate letting air through and mixing and churning occurs, thus a fluidised bed is created and fuel and waste can be introduced. The sand with the pre-treated waste and/or fuel is kept suspended on pumped air currents and takes on a fluid-like character. The bed is thereby violently mixed and agitated keeping small inert particles and air in a fluid-like state.	to be fully circulated through the furnace. Incineration of municipal solid waste avoids the release of methane.	waste by 90% of its volume. Capital & maintenance cost

4 Environmental Impacts of Incineration

This section provides some details regarding the potential environmental impacts of incineration on air, water, land and human health and amenity. Methods to minimise the impacts are presented where appropriate.

4.1 Air

4.1.1 Potential Impacts

The flue gases from incinerators generally contain: CO_2, dioxins, furans, sulfur dioxide, hydrochloric acid, heavy metals and fine particles.

CO_2 – Municipal Solid Waste (MSW) contains approximately the same mass fraction of carbon as CO_2 itself (27%) therefore incineration of 1 ton of MSW produces approximately 1 ton of CO_2.

Dioxins – Older generation incinerators that were not equipped with adequate gas cleaning technologies were significant sources of dioxin emissions.

NO_x – A side effect of breaking the strong molecular bonds of dioxin is the potential for breaking the bonds of nitrogen gas (N_2) and oxygen gas (O_2) in the supply air. As the exhaust flow cools, these highly reactive detached atoms spontaneously reform bonds into reactive oxides such as NO_x in the flue gas, which can result in smog formation and acid rain if released into the environment.

Particulates – have the potential to contribute to smog.

4.1.2 Management Measures

Depending on the design and maintenance of the incinerator the atmospheric emissions may be significantly reduced to a sustainable level. Here the meaning of 'sustainable' is 'no long term effects on the environment or human health' as far as we know with available information.

CO_2 – In the case of biodegradable waste component of MSW, which is formed by plants using atmospheric $CO_{2,}$ the CO_2 balance can be maintained if plants are regrown. This is because the CO_2 emitted from their combustion will be removed from the atmosphere during re-growth. However, different results for the incineration CO_2 footprint can be reached with different assumptions. Local conditions (such as limited local district heating demand or high levels of aluminum in the waste stream) can decrease the CO_2 benefits of incineration. The methodology and other assumptions may also influence the results significantly. For example, the methane emissions from landfills occurring at a later date may be neglected or given less weight, or biodegradable waste may not be considered CO_2 neutral. A 2008 study by Eunomia Research and Consulting on potential waste treatment technologies in London demonstrated that by applying several of these assumptions the average existing incineration plants performed poorly for CO_2 balance compared to the theoretical potential of other emerging waste treatment technologies[8].

Methane – 1 ton of land-filled MSW produces approximately 62 cubic metres of methane via the anaerobic decomposition of the biodegradable waste component. This amount of methane has more than twice the global warming potential than the 1 ton of CO_2, which would have been produced by incineration. In some countries, large amounts of landfill gas are collected for energy use but this does not occur in the Seychelles. As noted in Table 2, incineration of MSW avoids the release of methane[9].

Dioxins – Advances in emission control designs and stringent new governmental regulations mean incinerators emit virtually no dioxins. In 2005, the German Ministry of the Environment, where there were 66 incinerators at that time, estimated that *"...whereas in 1990 one third of all dioxin emissions in Germany came from incineration plants, for the year 2000 the figure was less than 1%. Chimneys and tiled stoves in private households alone discharge approximately twenty times more dioxin into the environment than incineration plants."* In the case of the Seychelles, burn barrels may be contributing dioxins to the atmosphere, depending on what is burned. Similarly, the US Environmental Protection Agency has demonstrated dioxin emission reduction of 99.9% from incinerators in the past 20 years. As noted in Table 2, the European Waste Incineration Directive states that incineration plants must be designed to ensure that the flue gases reach a temperature of at least 850°C for 2 seconds before cooling in order to ensure proper breakdown of strong molecular bonds, including dioxins. In order to comply with this specification at all times, backup auxiliary burners (often fueled by oil) are required to supplement boiler temperature when the heating value of the waste becomes too low to reach 850°C. For small municipal incinerators, the required temperature for thermal breakdown of dioxin may be reached using a high-temperature electrical heating element, plus a selective catalytic reduction stage.

NO_x – The reactive oxides can be further neutralised with selective catalytic reduction (SCR) or selective non-catalytic reduction.

Particulate is collected by particle filtration, most often electrostatic precipitators (ESP) and/or bag house filters. The latter are generally very efficient for collecting fine particles. In an investigation by the Danish Ministry of Environment in 2006, the average particulate emissions per energy content of incinerated waste from 16 Danish

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8 Hogg, D. Baddeley, A. Gibbs, A. North, J. Curry, R. Maguire, C. (January 2008) "Greenhouse Gas Balances of Waste Management Scenarios" (PDF). Eunomia.

9 Themelis, N.J. (July–August 2003). "An overview of the global waste-to-energy industry". Waste Management World: 40–47.

incinerators were below 2.02 g/GJ (grams per energy content of the incinerated waste). Detailed measurements of fine particles with sizes below 2.5 micrometres (PM2.5) were performed on three of the incinerators: One incinerator equipped with an ESP for particle filtration emitted 5.3 g/GJ fine particles, while two incinerators equipped with bag house filters emitted 0.002 and 0.013 g/GJ PM2.5. For ultra fine particles (PM1.0), the numbers were 4.889 g/GJ PM1.0 from the ESP plant, while emissions of 0.000 and 0.008 g/GJ PM1.0 were measured from the plants equipped with bag house filters.[10] [11]

Acid gas scrubbers are used to remove hydrochloric acid, nitric acid, hydrofluoric acid, mercury, lead and other heavy metals. Basic scrubbers remove sulfur dioxide, forming gypsum by a reaction with lime[12]. Waste water from scrubbers must subsequently pass through a waste water treatment plant.

Incineration plants can generate electricity and heat that can substitute power plants powered by other fuels at the regional electric and district heating grid, and steam supply for industrial customers. Incinerators and other waste-to-energy plants generate at least partially biomass-based renewable energy that offsets greenhouse gas pollution from coal-, oil- and natural gas-fired power plants[13]. The EU considers energy generated from waste with biological origin, by incinerators as non-fossil renewable energy under its emissions caps. These greenhouse gas reductions are in addition to those generated by the avoidance of landfill methane. In 1994, Delaware Solid Waste Authority found that, for the same amount of energy produced, incineration plants emitted fewer particles, hydrocarbons and less SO_2, HCl, CO and NO_x than coal-fired power plants, but more than natural gas fired power plants[14]. The difference between EU and Delaware findings highlights the importance of the incinerator specifications.

4.2 Water – Potential Impacts

If the strong molecular bonds of dioxins are not effectively broken down by heat then they may escape into the atmosphere or leach into the soil and groundwater from ash or clinker. Where sufficient data is available to determine the 95% species protection level for Dioxins it is as low as 0.03 micrograms per litre[15].

Ash from modern incinerators is vitrified at temperatures of 1,000°C to 1,100°C, reducing the leachability and toxicity of residue. The bottom ash residue remaining after combustion has been tested for ecotoxic metals and has been shown to be a non-

[10] Nielsen, M. Illerup, J.B. Fogh, C.L. Johansen, L.P. "PM Emission from CHP Plants < 25MWe" (DOC). National Environmental Research Institute of Denmark.

[11] Ministry of the Environment of Denmark. (2006) "Emissionsfaktorer og emissionsopgørelse for decentral kraftvarme" (in Danish).

[12] SYSAV (2003) "Kraftvärmeverket: avfall blir el och värme" (in Swedish).

[13] Michaels, T. (21 April 2009) "Letter to Committee on Energy and Commerce" (PDF). Energy Recovery Council.

[14] Delaware Solid Waste Authority. (Archived from the original on 26 January 2008) "Waste-to-Energy Compared to Fossil Fuels for Equal Amounts of Energy".

[15] ANZECC 2000. Water Quality Guidelines Chpt 3.

hazardous solid waste that can be safely put into landfills or recycled as construction aggregate[16].

4.2.1 Surface water – Management Measures

As noted above, dioxins, remaining in ash or clinker, have the potential to negatively impact surface water quality if the molecular bonds are not effectively broken down by heat whereas the ecotoxic metals have been shown to be non-hazardous.

4.2.2 Ground water – Management Measures

As noted above, dioxins, remaining in ash or clinker, have the potential to negatively impact ground water quality if the molecular bonds are not effectively broken down by heat whereas the ecotoxic metals have been shown to be non-hazardous.

4.2.3 Marine water – Management Measures

The bottom ash residue remaining after combustion has been tested for ecotoxic metals and has been shown to be a non-hazardous solid waste that can be safely put into landfills or recycled as construction aggregate[15].

4.3 Land & Soil

4.3.1 Potential Impacts

As previously noted, incineration may reduce the volume of solid waste by approximately 90% thereby increasing the life of the landfill. In addition, ash from modern incinerators is vitrified at temperatures of 1,000°C to 1,100°C, *reducing* the leachability and toxicity of residue. As a result, special landfills may not be required for MSW incinerator ash thus existing landfills gain an increased life expectancy[17].

As noted above, dioxins remaining in solid residue have the potential to negatively impact soil quality if the molecular bonds are not effectively broken down by heat or not properly disposed of in a clay lined landfill.

4.3.2 Management Measures

A clay lined landfill may be required if dioxins remain in incinerator solid residue.

However, ecotoxic metal testing of bottom ash residue, remaining after proper combustion, has shown it is a non-hazardous solid waste that can be safely put into landfills or recycled as construction aggregate[15]. Modeling research in the UK indicated that bottom ash use in cement and road mix will not have any environmental or health impacts if done appropriately. This use increases the proportion of aggregates from secondary sources used in the construction industry thereby limiting demand for virgin aggregate; reducing pressure on finite primary aggregate reserves; and reducing environmental costs and pressures in rural areas associated with the winning of a finite resource[15].

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[16] Abbott, J. Coleman, P. Howlett, L. Wheeler, P. (October 2003) "Environmental and Health Risks Associated with the Use of Processed Incinerator Bottom Ash in Road Construction". Prepared for BREWEB by AEA Technology plc.

[17] US EPA (25 September 2008) "Renewable Energy Production Incentives". United States Environmental Protection Agency.

4.4 Transportation

4.4.1 Potential Impacts

The location of the proposed incinerator has the potential to affect transport distances.

Transport of waste from other islands will continue to be via boat. North Island resort has taken the initiative to sort recyclables before shipping with the intention that the resulting recyclables are stockpiled for export from the Port of Victoria.

Transport of electricity is presently from the Diesel generator at Roche Caiman, approximately 4 km from the existing landfill and likely location of the proposed incinerator therefore some additional infrastructure would be required to connect to the main power grid if the incinerator was used to produce electricity.

The proposed location is in a light industrial area with some residential blocks. Other residential areas within 2km include:

- Cascade and Talbot to the southeast;
- Petit Paris to the southwest; and
- Brilliant and Eden Island to the northwest.

Other nearby residential areas within 5 km include (but are not limited to) Point Larue; Anse Dejeuner; Le Rocher; Plaisance; Zig Zag; and Belvedere.

4.4.2 Management Measures

By locating the waste management facility (whether it is an incinerator or otherwise) in the middle of the island (close to the existing landfill) the road distance from the South and North are shortened and it is close to the port for receipt of waste from other islands. Based on these factors the location of the Star waste management facility is presently cost effective and efficient[1].

Existing transportation of waste is by truck or ship and this is unlikely to change, however the frequency of collection could change. Reducing from daily collection would half the transport costs and vehicle emissions. Consideration should be given to waste collection from the South of Mahé on even days and North on odd days for example.

North Island's example of sorting recyclables prior to shipping should be followed by other islands. If an alternative such as recycling is considered on Mahé there would be flow on effects. Collection of putrescibles may still be daily but the reduced volume could mean fewer trucks are required and collection of recyclables could be from a community based location weekly rather than at multiple stops all over the island. For example, recycling depots at or near schools would be appropriate as they are generally within walking distance or short bus rides of all homes and regular trips are made to schools by children, if not by parents.

Traffic calming devices may be utilised to minimise traffic (and noise) impacts of waste transport on residential areas particularly around the waste management site (i.e. Providence).

4.5 Human Health & Amenity

4.5.1 Human Health Potential Impacts

Incinerators emit varying levels of heavy metals such as vanadium, manganese, chromium, nickel, arsenic, mercury, lead, and cadmium, which can be toxic to 95% of species at very minute levels.

Experts including physicians, environmental chemists and toxicologists made a representation to the European Parliament in June 2008 expressing concern about incinerator particle emissions and the absence of specific fine and ultra-fine particle size monitoring and epidemiological studies to determine health effects. The precautionary principal suggests this information should be available before approving incineration as a viable sustainable option for the Seychelles or elsewhere.

The USA has experienced a reduction by 10% in real estate value near incinerators. As the proposed incinerator would be located on the existing landfill site, no further reduction in real estate should be experienced on Mahé unless the stack or stack emissions are unsightly.

In some countries, incinerators built just a few decades ago often did not include a materials separation to remove hazardous, bulky or recyclable materials before combustion. These facilities tended to risk the health of the plant workers and the local environment due to inadequate levels of gas cleaning and combustion process control. Most of these facilities did not generate electricity.

4.5.2 Human Health Management Measures

The U.K. Health Protection Agency concluded in 2009 that *"Modern, well managed incinerators make only a small contribution to local concentrations of air pollutants. It is possible that such small additions could have an impact on health but such effects, if they exist, are likely to be very small and not detectable."*[18]

4.5.3 Noise Amenity

As indicated in Section 4.4, noise from the incinerator operations and/or traffic created by waste collection will have the greatest impact on local residence but traffic calming devices may be installed as a management measure.

4.5.4 Odour Amenity

As indicated in Section 4.4, odour from the incinerator operations and/or waste collection truck traffic may affect local residents. An improvement in odour emissions would be expected with the change from landfill to incineration as best practice management should include receipt and storage of waste in an enclosed area with a negative pressure with the airflow being routed through the boiler which prevents unpleasant odors from escaping into the atmosphere. However, not all plants are implemented this way, resulting in inconveniences in the locality.

[18] Health Protection Agency. (2 September 2009) "HPA position statement on incinerators".

5 Alternatives to Incineration

In discussion with the Seychelles LSWMD it is clear that alternatives to incineration are being considered and may be preferred. As noted in Section 2.1, recycling initiatives have been tried (paper) and are in progress (glass).

5.1 Recycling

An American engineering company notes that a combination of recycling and composting is 46 times better at reducing greenhouse gases than incineration generating electricity[19].

Materials that can be recycled but, for which no formal recycling exists in the Seychelles include: some plastics (bags etc), paper, cardboard, wood waste, electronics (computers, phones, televisions, etc) and batteries.

The more time and energy that it takes to create a product, the more critical it is to recycle it. In addition, non-biodegradable waste (mainly plastics and other oil and gas derived products) are considered non-renewable due to the time (millions of years) it takes to create the oil and gas.

At the national level, there are several methods which can be employed to reduce the production of waste. These include redesign of packaging, encouraging the use of minimal disposable material necessary to achieve the desired level of safety and convenience; increasing consumer awareness of waste reduction issues; and the promotion of producer responsibility for post-consumer wastes (UNEP 1996). These goals may be achieved through legislative action and the creation of market forces and economic incentives[1].

Once materials are collected some processing facilities are required to return the collected materials to a usable form. In small nations, where it is not economically justifiable to spend money on recycled material processing plants, private enterprise can play a vital role provided sufficient material is collected and markets for the material exist. International trading of recyclables should be explored, to the extent nearby markets are identified. Caution must be taken though to insure the cleanliness and integrity of collected recyclables. The deliberate or accidental inclusion of toxic materials in exported shipments of mixed materials has been documented, and represents a potential threat to shipping contracts (UNEP)[1].

A viability investigation of alternative recycled paper products should be undertaken to replace the seedling containers that were produced. The seedling containers were not successful because they degraded with moisture and the users prefer to reuse seedling plastic containers. A possible product for viability investigation is the take-away container. Presently, Styrofoam containers are widely used but difficult to reuse or recycle and are therefore disposed to the landfill. An equivalent recycled paper product would need to withstand heat and moisture for up to one hour and then could be composted. However, it is recognised that Styrofoam requires very little energy to produce and is heat resistant.

There is potential for Star and/or Samlo to provide suitable space and containers for a recyclable storage depot including: plastics, paper, cardboard, wood waste, electronics and batteries. The separation and transport of these recyclables to the central collection

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[19] AEA (2001) "Waste Management Options and Climate Change" AEA Technology plc.

point (e.g. Star Providence) would initially be the responsibility of individual households, organisations and/or schools as the capacity for collection in addition to domestic waste collection is likely limited. As metals and PEP plastics are already collected these would not have to be included at the Star site however publicity regarding the sites of metal and PEP plastic recycling would need to be improved.

Education regarding the 3Rs: Reduce, Reuse and Recycle, which includes cleaning, separating and transporting recyclables to the redeem centres or Providence is required to ensure contamination of recyclables is avoided. For example, paper must remain free of food products and general dirt if it is going to be of use for recycling; and anything with the recycle triangle can be taken to a redeem centre for recycling. This education will aid to reduce the solid waste to be managed in the land fill, incinerator or alternative and inspire consideration of ways to produce economic benefits.

Composting of vegetative matter (and paper) is likely already undertaken by many households particularly those who grow any vegetables because compost is a useful soil improver for all gardeners. There is potential to increase composting to the industrial scale where waste from households (including apartments), restaurants and resorts is managed centrally and later sold as compost or soil improver (depending on quality). Depending on the scale of the operation, special equipment may be required, (refer to Section 5). Controlled and well-managed composting can provide a sustainable option for the recycling of a wide range of organic materials including food organics, garden organics, odorous compounds, wood and timber residues, agricultural and food/fibre processing byproducts, manures, biosolids etc and convert them into valuable soil additives that enhance the chemical, biological and physical properties of soil. The use of recycled organic products improves health and structure of soils and can lead to moisture conservation, improved nutrient utilisation and reduced pesticide and synthetic fertiliser use. The diversion of organic materials from landfill into such beneficial uses also has a positive impact on the greenhouse effect. Controlled aerobic composting is a process that is considered to have a zero net effect on greenhouse gas generation, whereas methane generated from such materials in a landfill without an adequate gas extraction and utilisation system is a potent greenhouse gas[20].

There are three scales at which composting has been implemented; the residential level, the decentralised community level, and the centralised large-scale (municipality-wide) level. The larger the undertaking, the more capital investment is required. Most developing countries which have found success with composting have found it works best when implemented at the household level[1].

Household-level composting has the greatest potential for success in many areas, especially those where small scale agriculture is found close to urban areas or those where limited gardens are found within the city itself. The key is to find a useful destination for the final product, either by selling to neighborhood farmers/gardeners or on the household's own plots. Education is the key to promoting this type of project, since many people will have concerns regarding possible disease, odors, and pest problems. These issues rarely occur in a properly maintained compost pile; education regarding what waste should be added and how to properly construct a compost bin to eliminate rodents, etc. would overcome most concerns[1].

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[20] WMAA (February 2004) "Best Practice Guidelines Series Composting" Waste Management Association of Australia National Technical Committee for Organics Recycling.

In addition, a **tip shop** may be initiated in which one person's waste may be another person's treasure, for example: electronics that may have useful parts, children's clothes and toys, books and magazines, wood. A location close to the Star managed landfill could be made available for this purpose but may be managed as a separate enterprise.

5.2 Landfill

Landfill is an option however land is at a premium in the Seychelles and suitable land for landfill i.e. clay lined cells is not be available without import of clay or equivalent impermeable liner. In order to reduce the volume of waste to be disposed in landfill, physical compaction can be used as noted in Section 2.1. Garbage trucks often reduce the volume of waste with a built-in compressor before delivery to the landfill. Alternatively, a stationary steel compressor at the landfill can be used to reduce the volume of waste, albeit with an energy cost.

Similar to truck compaction, landfill compression is likely to achieve lower ratio of compaction in Seychelles than in more industrialised countries (Cointreau 1982). However, with increasing amounts of packaging in Seychellois waste then compaction technologies will become more relevant[1].

As noted in Section 2.3.2, a new landfill is supported by EU and GOS but it is critical that a new landfill is constructed to ensure sanitary conditions. Four features that **must** be present in order for a landfill to be considered sanitary are:

- Full or partial hydrogeological isolation through the use of liners to prevent leachate infiltration into the soil and groundwater; and leachate collection and treatment infrastructure where leachate will be generated;
- Formal engineering preparations including an examination of geological and hydrological features; related environmental impact analysis; waste tipping plan; and final site restoration plan;
- Control by trained and equipped staff to supervise construction and operation; and
- Planned waste emplacement and covering, with waste and soil placed in compacted layers as well as daily and final soil cover to reduce water infiltration and reduce odors and pests[1].

5.3 Alternative Waste to Energy (WtE) technologies

Available, or in development, such technologies as: Mechanical Biological Treatment Anaerobic Digestion (MBT/AD); Autoclaving or Mechanical Heat Treatment (MHT) using steam or plasma arc gasification PGP, or combinations of these treatments (gasification or pyrolysis). These options are likely not practical for the Seychelles due to: technology, management expertise and expense.

MBT facilities involve waste input and control, mechanical preparation, biological treatment, and product conditioning. Waste input and control normally consists of manually removing oversized and hazardous materials. Mechanical processing can include minimal separation or shredding, or sophisticated sorting of inbound waste into biodegradable material, recyclables, and contaminant streams. Sorting is usually done with dry processes but it can also involve wet processes, such as flotation and hydro-pulping. Hand-sorting systems have also been implemented at some facilities, but this increases health and safety requirements for staff. Depending on the quality and market demand, the recyclables are typically sold, but paper fibers, textiles, rubber, plastics, and residual organics can also be used as RDF (incinerator fuel). The cost per ton of waste management using an incinerator was found to be higher in a UK government WRAP report, August 2008. The median incinerator costs per ton were generally £27 per metric ton higher for modern (post 2000) incinerators than those for MBT treatments[21]. This may be because of the number of landfills available in the UK competing for the solid waste.

The three groups of MBT are:

Biological treatment – produces fuel for incinerator combustion which is popular in Europe;

Anaerobic digestion – recovers energy in the form of biogas which can be used in industrial engines, vehicles or in electricity generators. High nutrient by-products, including liquid and solid, are also products of anaerobic digestion and may be used for soil amendment with some additional treatment to reduce, for example chemical oxygen demand (COD). Most common in Europe; and

Composting – aerobic process to stabilise organic wastes or produce soil amendment. Composting is widely used in North America. In general, the quality of the compost produced at an MBT facility is lower than that produced at a composting facility that processes source-separated organic material such as green waste or food waste. In some cases the product is not saleable. On the other hand, soil conditions, and the lack of soil cover in some areas for example on the islands of Hawai`i and Praslin could create potential uses for composts of varying quality. Management and control of nuisance odors can significantly affect construction and operating costs of a facility. For example, bio filters are effective methods of mitigating odors, but add significantly to operational costs. Another critical technical challenge is corrosion resulting from sustained exposure of equipment and infrastructure to humidity and process gases, and biological corrosion processes. These can be overcome using particular building materials (concrete) which contribute to the capital cost and frequent predictive and preventative management measures[22].

Other considerations include financial returns (i.e. sales revenue) from product (compost) sales which are generally insufficient to offset the costs associated with compost production. Even with a successful marketing program in place, revenues in North America are only sufficient to offset marketing and sales costs, product quality control (analytical laboratory testing) costs, and perhaps some portion of product refining cost[21].

Staffing of an MBT at Providence would require about 25 full time equivalents (FTE).

Based on the type of input and likely output of a Seychelles MBT, the product would be sold or used as a soil amendment. It is anticipated the product will be relatively free of large inert materials (i.e. >3/8”), but could contain a noticeable number of small glass and hard plastic particles. With that in mind, the product would likely be sold to or used

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[21] letsrecycle.com. (15 August 20080 "Costs compared for waste treatment options".

[22] Gamble, S. Alexander, R. (May 2009) “Hawai`i County Mechanical-Biological Treatment Facility Conceptual Design” prepared for M. Dworsky, Solid Waste Division Chief, County of Hawai`i by CH2M HILL and Alexander & Associates.

by the agriculture and reclamation sectors, and to a lesser extent to commercial landscapers, and land developers[21].

5.4 Export waste

There are very few buyers of unsorted waste and therefore it would likely be an expensive (including shipping costs) and unsustainable option.

5.5 Burn barrels

At the domestic level burn barrels are used for burning vegetation which is alright however this green waste could contribute to incinerator fuel. By being burned at a higher temperature it would produce less atmospheric emissions and may contribute to energy production for the Seychelles. If incineration was determined to be viable, Star should provide green waste collection. Burn barrels should not be used for burning domestic waste as the temperatures are not hot enough to eliminate fine particulate and dioxin by-products.

5.6 Small incinerators

Small incinerators or autoclave shredders are suitable for hazardous medical waste[23].

6 Best Practice & Practical Seychellois Application

If incineration were selected as the preferred Seychelles solid waste management option, best practice would be required in order to provide the best outcomes for the Seychellois and the environment. The most effective methods of flue gas cleaning and wastewater treatment along with removal of hazardous, bulky or recyclable materials before combustion would be required as components of the incinerator waste management program option. If not included, the facility will risk the health of the plant workers and the local environment due to inadequate levels of gas cleaning and combustion process control.

A summary of the components required to reduce emissions are identified in the following table along with design specifications and the purpose of the component.

Table 3: Optional Emission Reducing Components of Incinerators

Component	Design specification	Purpose
Flue gas temp.	850°C for 2 seconds	Breakdown strong molecular bonds including dioxin bonds.
Boiler & Flue gas treatment plant	More than one	To allow scheduled maintenance so waste can continue to be received at the 2nd boiler while 1st is subject to maintenance.
Flue gas condensation	Ensure good flue gas condensation	To reduce steam emissions and to recover latent heat for electricity production.

[23] Smith, I. (January 2010) "UNSCD Thematic Seminar on Waste Management – Caribbean Experience" Environmental Engineers and Managers Ltd.

Component	Design specification	Purpose
Flue gas emissions	Bag house filters	To ensure fine particulate filtration.
Flue gas emissions	Acid gas scrubbers	To remove hydrochloric acid, nitric acid, hydrofluoric acid, mercury, lead and other heavy metals.
Waste water	Secondary or Tertiary waste water treatment plant	To further treat/neutralise hydrochloric acid, nitric acid, hydrofluoric acid, mercury, lead and other heavy metals.
Flue gas emissions	Dry desulfurisation results from injecting a limestone slurry into the flue gas before the particle filtration	Remove sulfur dioxide.
Flue gas emissions	Catalytic reduction with ammonia in a catalytic converter	NO_x reduction by SCR.
Flue gas emissions	High temperature reaction with ammonia or urea in the furnace	NO_x reduction by SNCR. Substitution of urea can reduce costs and potential hazards associated with storage of anhydrous ammonia but must be supplied earlier in the process.
Flue gas emissions	Use injected active carbon powder and collect in the particle filtration process (bag house).	Absorb heavy metals.
Flue gas emissions	The stack height must be adequate.	Adequate stack height will prevent fall out.

6.1 Preferred Option

The preferred option depends on unanswered questions as discussed below but should likely not involve incineration in the case of Mahé solid waste management because:

- Energy production from the incinerator will not likely make a useful contribution to Mahé energy consumption; and
- Recycling could provide better economic and environmental returns.

First, energy production potential is considered. The heat produced by an incinerator can be used to generate steam which may then be used to drive a turbine in order to produce electricity. According to Rambol of Denmark, the typical amount of net energy that can be produced per tonne of municipal waste is about 2/3 MWh of electricity and 2 MWh of district heating[2]. Based on information gained from the LSWMD, Star manages approximately 100 metric tons/day which (based on the Danish calculations above) would equate to approximately 2.83 MW of electrical power and 200 MWh district heating each day.

The questions which remain and must be answered are:

- How much power does Mahé presently use? Is 2.83 MW a significant proportion of the Mahé energy consumption to make incineration worthwhile?
- What will Seychelles do with the excess heat energy?

If the volume of waste is inadequate to contribute significantly to Mahé's energy requirements then incineration may not be economically viable i.e. the cost of installing, managing and maintaining the incinerator may exceed the cost benefits. However, if incineration can be achieved with maximum efficiencies and without environmental harm, incinerating without energy and heat recovery and in combination with recycling may prove to be worthwhile.

It was noted by Zerbrock in 2003 that incineration is an inappropriate technology for most low-income countries, however small island nations are perhaps a category where such technology may be practical. With their smaller land mass, island nations have less land available to them for landfills, and even in the event land is available, environmental considerations may reveal that sites are not viable[1].

The reasons cited for incineration being inappropriate and a barrier to success for most low income countries include:

- High financial start-up and operational capital required to implement incineration facilities (Rand et al 2000, UNEP 1996). A large portion of that cost is the environmental hazard mitigation components; use of best available technology in the United States can be as much as 35% of the overall project cost (Rand et al 2000).
- Specific technical expertise and related general repair and maintenance technology are often absent in developing nation scenarios. High costs and environmental problems have led to incinerators being shut down in many cities e.g. Buenos Aires, Mexico City, Sao Paolo and New Delhi (UNEP 1996).
- The additional level of infrastructure and planning required to implement coupling incinerators with energy-recovery infrastructure is likely beyond the means of most developing nations, and arguments for the adoption of incineration projects should not rely on potential energy generation as a primary component of the 'sales pitch'[1].

Results of a case study for Green Island, Taiwan, where *time* was considered to identify a cost-effective strategy for waste management on small islands, suggest that at first sight, expensive solutions are the most cost-effective ones if sufficiently long time periods are considered. In the Green Island case, immediate introduction of recycling in combination with an incineration plant would be more cost-effective than continuing with business as usual or introducing recycling alone. If the timing of introducing the incineration plant is considered as well, expenses can be delayed in a cost-effective manner by about 7 years which provides ample time to prepare the financing of the investment without compromising on the costs. The most cost-effective solution among the possibilities considered is the immediate construction of an incineration plant without introducing recycling and a sanitary landfill. The local Green Island government ruled out this option. Results show, this decision can be justified from economic perspective, if the benefits for the environment and from moral suasion (encouraging recycling) outweigh higher costs of about 10 million NTD a year. The results also show that in the long term, the incineration plant cannot solve the problem of SWM, but it can buy time for developing alternative technologies. The increase in the landfill's life span is considerable, increasing from 9 to 53 years. The take home message for other small islands is that solid waste management by recycling in combination with a sanitary landfill and incineration has the *potential* to reduce environmental damages and solve waste disposal problems in the short and medium term[24].

In the USA it is noted that most municipalities that operate incineration facilities have higher recycling rates than those that do not[25]. This is, in part, due to enhanced recovery of ceramic materials for reuse in construction, as well as ferrous and in some cases non-ferrous metals that are recovered from combustion residue[26]. The metals recovered from ash are typically difficult to recycle through conventional means because the removal of attached combustible material is labor- or energy-intensive by mechanical separation methods. In the Mahé case, a small labor force involved in recycling exists but not in the separation of combustible and metal wastes therefore incineration could improve rates of recycling without job loss.

Recycling is likely to be the preferred option but it is not without its environmental issues and costs. The issues tend to be less insidious and more easily managed given appropriate resources, for example uncontained recyclables become litter.

At present, the issues on Mahé with respect to recycling include:

- A lack of public participation which may be related to education or culture;
- Collection of recyclables;
- Relatively low volumes of recyclables due to low population make reprocessing difficult;
- Limited export market; and
- Limited local recycling into local products due to low demand for recycled products.

UNEP (1996) laid out a series of questions to be asked when evaluating technologies and policies in the context of an integrated MSW system:

- Is the proposed technology likely to accomplish its goals given the financial and human resources available?
- What option is the most cost-effective in financial terms?

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[24] Chen, M.C., Ruijs, A., and Wesseler, J. (February 2005) "Solid Waste Management on Small Islands: The case of Green Island, Taiwan" Elsevier.

[25] Energy Kids. "Using & Saving Energy". Energy Information Administration.

[26] Covanta Fairfax. Covanta Energy. http://www.covantaholding.com/site/locations/covanta-fairfax.html. The I-95 Energy/Resource Recovery Facility began commercial operation in June 1990. Covanta Energy's largest facility, processing 3,000 tons per day of municipal solid waste for a population of more than 900,000 in the Washington, D.C. suburbs of Fairfax County. Facility sells up to 79 megawatts of renewable energy to Dominion Virginia Power Company; enough to meet the energy needs of 75,000 homes. It is the first Covanta Energy facility to have a non-ferrous metal recovery system.

- What are the environmental costs and benefits?
- Is the project feasible, given administrative capabilities?
- Is the practice appropriate in the current social and cultural environment?
- What sectors of society are likely to be impacted and in what way; are these impacts consistent with overall societal goals?

The answer to each question may not always be immediately evident, but the process of researching and evaluating these criteria will lend insight to the appropriateness of specific solutions to the situation as a whole[1].

7 Conclusions

In conclusion, incineration will not eliminate the need for landfill nor will it eliminate the need for diesel generation to provide electricity to the Seychelles. However it has the potential to reduce the need for landfill capacity by up to 90% and to contribute approximately 2.83 MW to the power grid, but not without fossil fuel consumption.

As discussed in Section 6, in order to provide the best outcomes for the Seychellois and the environment the most effective methods of flue gas cleaning including a bag house and wastewater treatment along with removal of hazardous, bulky or recyclable materials before combustion and regularly scheduled maintenance in accordance with manufacturer specifications are required as components of the incinerator waste management program. If not, the facility will likely shut down having cost a lot in initial set up because the elements are not in place to ensure the mechanical components of the incinerator operate well or to environmental and health standards.

This assessment goes a small way in determining: the pros and cons of incineration, further questions to be answered, and providing viable alternatives. If stakeholders are seriously considering an incinerator as a waste management option further assessment is required to determine suitability and sustainability for Seychelles' conditions. For example, details of the relative amounts of organic and non-organic components in the waste stream are required.

The most sustainable type of waste management for the Seychelles is dependent on the current and estimated future waste tonnages available for diversion through the waste management facilities be it an incinerator or alternative(s). Some basic values are indicated in this report but should be reviewed carefully by LSWMD, Samlo and Star. The functional requirements for the facility including identification of the appropriate processing technology and equipment requirements, environmental protection measures, nuisance control, product quality and product market issues will have to be addressed by LSWMD and Star. Conceptual layouts for the facility will be required and the order of magnitude of capital cost estimates have to be determined.

As Rachel Carson explained to us the accumulation of waste will be our demise. As ecology demonstrates to us, cycles of life are natural and it is not necessary to create waste because everything in nature is useful. With these basic principles we can combine the ecology and engineering that we have learned to minimise what we used to consider waste. In 2006, Paul Connett (Professor Emeritus of Chemistry St Lawrence

University, Canton, NY) stated we need to achieve *"zero waste"* by 2020[27]. Zero waste means that nothing goes into a landfill or incinerator. This is achievable by designing waste out of manufacturing[28]. For example, food manufacturers should minimise packaging and accept packaging returned to them by the consumer. The Seychelles Breweries Corporation (SBC) has been reusing bottles for years. SBC recovers about 98% of the bottles and gains a net saving to the industry as well as providing jobs in collection and cleaning with no cost to the municipality. SBC provides a great example to all producers which need to become responsible for the lifecycle of their products. Products should be exploited to maximise their potential, for example a bathtub from a renovated house should not be disposed of to landfill. It should be reused by someone else who needs a bathtub for its original purpose or a different purpose. Everything should be reused, whether it is useful to us or someone else. Finally, as a last resort, energy may be used to recycle products in the commercial sense of creating something new out of something used for a different purpose e.g. glass bottles to road fill. Our aim should be to maximise the original energy used to produce a product and to produce zero waste in the process.

[27] Connett, P. (20 September 2006) "Zero Waste: A Global Perspective". Recycling Council of Alberta Conference.

[28] Connett, P. (12 Jan 2010) "Zero Waste: Theory & Practice Around the World." Presentation to the United Nations.

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