FEASIBILITY STUDY FOR THE PRODUCTION OF BIOGAS AND ORGANIC FERTILISER IN THE AGRICULTURE AND FOOD MANAGEMENT SECTORS IN SAMOA

Prepared by Murray Ward
Technical Assistance Advisor

For the UN Food and Agriculture Organisation
Sub-Regional Office for the Pacific
Apia, Samoa

May 2013

THE PROCESS OF THIS REPORT

The underlying research and work behind this report was undertaken over the period of January – May 2013. It involved a number of main phases:

- General research about biodigesters and their application internationally in the agriculture and food management sectors, including literature research into the production rates of biogas from different organic material resources.
- First in-country mission to Samoa, during which research was undertaken into the relevant policy and information documents available from the Government and other regional agencies, meetings were held with relevant government ministries and operational agencies, and a survey questionnaire form was developed in collaboration with staff from the Renewable Energy Division of the Ministry of Natural Resources and Environment (MNRE).
- Specific research into larger scale biodigester systems including biodigester technologies and appliances and equipment that can operate from biogas, including a study trip in China (the world leader in biodigester installations and equipment manufacturing).
- Second in-country mission to Samoa, during which the results of the survey were reviewed, additional survey work was undertaken including site visits to example types of potential 'next step' demonstration projects, meetings were held with government officials about such a demonstration programme, and presentations made about the general findings of this work.
- The preparing of this report.

ACKNOWLEDGEMENTS

Particular recognition is due to Sala Sagato Tuiafiso, ACEO and Anne Trevor, Principal Renewable Energy Officer in the Renewable Energy Division of MNRE who provided hospitality, logistical support and personal enthusiasm for this project, and undertook the main tasks associated with the survey of operations in the agriculture and food management sectors.

In addition Ganesh Bhattarai, Project officer and his colleagues in the Food and Agriculture Organisation assisted with the support needed to scope, undertake and complete this work, including providing valuable comments in the development of the survey questionnaire and the finalisation of this report.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The use of biodigesters in the agriculture and food sectors to produce biogas and organic fertilisers aligns well with existing policies and sector plans in Samoa. This includes plans to double the economic activity in the agriculture sector by 2015 and for Samoa to be carbon neutral by 2020. Achieving this latter objective will be made easier by having 'negative emissions' bioenergy systems including bio-based carbon capture and storage technologies. The application of such systems in Samoa is also strongly aligned with the globally agreed goal of limiting global warming to $2^{o}C$ and the call from small island developing states worldwide for this to be just $1.5^{o}C$.

Biodigesters are widely employed in the agriculture sector globally. There are reportedly over 30 million small scale biodigesters in China, over 3 million in India and tens to hundreds of thousands in other Asian developing countries and countries in Latin America and Africa. Biodigesters come in all shapes and sizes from small to 'ultra large' scale. While a common application is animal manure waste management, there are also many examples where the feedstock is residues from agriculture production or processing. Biogas can be used for many energy services: cooking, lighting, process heat, refrigeration, power production, transport fuels.

The use of biodigesters in Samoa and other Pacific Islands has so far been limited to just small demonstrations, mostly involving piggeries. However, Samoa has abundant potential feedstock resource for biodigesters, so the possibility to produce nationally significant amounts of bioenergy in distributed systems at farms, villages and in plantation estates. These feedstocks include crop residues (and potentially crops if they are overabundant and very low price); food and beverage processing residues; invasive and overgrown weeds, grasses and bushes; purpose grown energy crops; food waste; animal waste; and potentially human waste where there are sanitation system problems to be solved.

Two things are holding back the autonomous start-up of the investment needed to begin to realise this potential. First, there is a lack of knowledge of the performance of feedstock resources in Samoa circumstances, i.e. how much biogas can be expected per kilogramme of a given feedstock. Second, the nature and size of biodigester systems for given applications has not been demonstrated in Samoa, including giving regarding to the need for designs to be climate change aware and resilient.

To address these barriers, a demonstration programme of nine different systems is proposed in this report. It is recommended that all of these be done. Samoa can use the opportunity of the *Third International Conference on Small Island Developing States* (SIDS-2014) that it will host in September 2014 to engage with international donor partners and fund this demonstration programme. This can provide a field visit programme for delegates that can play a major role in the success of the conference and showcase systems that will have wide applicability in small island states throughout the Pacific and globally.

A financing model involving a revolving fund is also proposed for this demonstration programme. Under this model the host sites eventually pay for the equipment installed, but in a manner wherein their cost saving per month is greater than the payments per month.

1. BACKGROUND

The agriculture sector and rural communities in Samoa produce significant amounts of organic 'green' material in the growing, harvesting and processing of the primary crops. In addition, the climate is conducive to very rapid growth of many non-crop plant species including grasses and invasive weeds and trees. Samoa is lush and green. The understory of coconut plantations is often very overgrown, making access to the coconut trees difficult and the land unproductive without extensive clearance. Cattle farming can keep this overgrowth in check to some degree, but large areas exist without this control. There are a number of commercial piggeries and many village communities keep pigs, though often not in enclosed pens.

Commercial resorts and restaurants all have food residues (but not necessarily food waste) and potentially green waste from managing lawns, gardens and shrubs.

All of these organic materials can be potential resources for small-medium scale biodigesters that can sustainably produce renewable energy (biogas) and liquid organic fertilisers. These are the two primary outputs of biodigesters which essentially are sealed enclosures containing water and introduced organic material which is broken down by bacteria in a process called *anaerobic digestion*.[1]

Both energy and mineral fertilisers are expensive in Samoa, often unaffordably so. This impedes further development in the agriculture sector, including being a significant constraint to value-adding crop processing.

The purpose of this study is to assess the applicability and feasibility of biodigesters in these sectors, including potential business and financing rollout models. In particular, the study identifies a number of potential 'next step' demonstration projects that can provide "seeing is believing" proof of these ideas, both for the technologies and the means by which the Samoa public and private sectors can work together to make it happen.

2. POLICY CONTEXT

2.1 Agriculture

The vision of the Samoa Agriculture Sector Plan 2011-2015 is "Agriculture for Food and Income Security". The Plan provides a renewed recognition of the critical importance of agriculture to the Samoan economy and of the central role it can play in achieving sustained economic growth, trade development and poverty reduction. It seeks to revitalise the agriculture sector to reverse its declining performance and to increase its overall contribution to GDP from 10% in 2010 to 20% by 2015. It also looks to increase funding resources into the sector including the share of the national budget allocated to the sector to increase from 5 percent in 2010 to 10 percent by 2015.

[1] For a description of biodigester basics see http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/site-storage-and-treatments/anaerobic-di

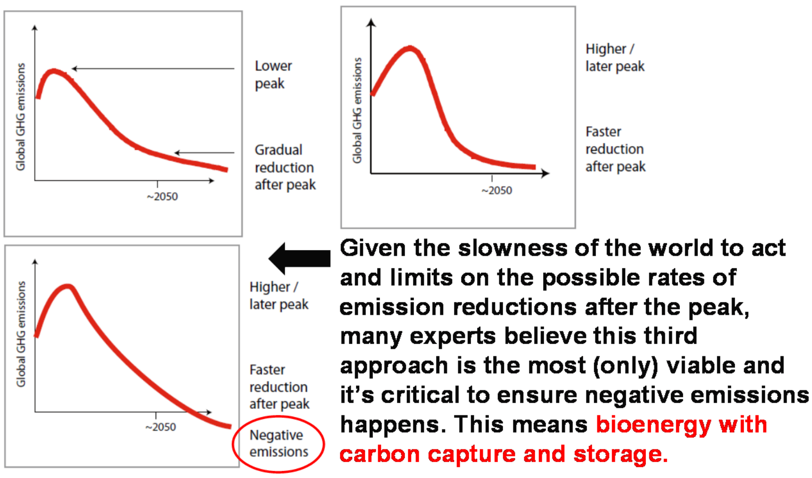
2.2 Climate change mitigation and renewable energy

International: Bioenergy and the 2°C global goal

The objective to limit global warming to no more than 2°C[2] was agreed by world leaders in Copenhagen in 2009 and affirmed under the United Nations Framework Convention on Climate Change (UNFCCC) at its Conference of the Parties (COP) in Cancun in 2010. This will require a rapid decarbonisation of the world's energy system and, in this context, continued and rapid uptake of renewable energy systems.

However, the story about renewables is more complex than just this. Figure 1 below, based on a figure in the ground-breaking "Emissions Gap" study by UNEP in 2010, shows that bioenergy with carbon capture and storage, so called BECCS, has a particularly crucial role to play, as it is the only known and proven concept to result in negative emissions.[3]

Figure 1. Global emissions pathways to 2°C



The potential for bioenergy systems to be part of negative emissions systems sets them apart from other renewable energy technologies, which at best can be carbon neutral (and most often do not achieve this when the full carbon footprint of the systems is assessed, e.g. if the construction materials are considered or the emissions from agricultural machinery and fertilisers is considered). When the use of biogas is in bigger scale fixed applications (e.g. power generators, heating plants or adsorption air-conditioning systems), it is feasible to capture the CO_2 emissions before they enter the atmosphere.

It is notable that the position of small island states like Samoa is that limiting global warming to 2°C is inadequate to prevent dangerous climate change. They call for this limit to be 1.5°C. This makes negative emissions (and BECCS) an even more critical proposition.

[2] This relates to global annual average temperatures compared with pre-industrial. times

[3] In a BECCS system, the biomass resource that is to be used for energy sequesters CO_2 from the atmosphere as it grows; this is how the "negative" begins. When this biomass is used for energy, there then needs to be a system that captures the CO_2 that would otherwise be emitted by the combustion of the biomass and then stores this captured carbon so that it will not ever re-enter the atmosphere. One method available today, and applicable at small-medium scale, is the use of growing algae as the capture medium and biochar as the storage medium.

International: Roles for biodigesters

In many developing countries the focus of biodigester programmes in the agriculture sector has been to address basic development priorities associated with sanitation, health and energy poverty in rural communities – especially those with domestic livestock living in close proximity with households. Biogas plants are seen in countries such as India as one of the most suitable options for supplying 'lifeline energy' for cooking and lighting, especially in rural areas.

It is also true that significant funding has additionally been made available internationally because of the climate change mitigation benefits of reducing methane emissions to the atmosphere.[4] Very large scale biodigesters connected to housed livestock facilities are now commonplace in countries such as China and India. These biodigester projects have been partially financed through credits issued and sold under the UNFCCC Clean Development Mechanism (CDM). This finance has been crucial to making these projects happen.

Samoa: Biodigesters, domestic development and climate change policy

Policy objectives in Samoa for climate change mitigation and renewable energy to which biodigester systems can contribute include:

- the goal for Samoa to be 'carbon neutral by 2020' approved by Cabinet in 2010[5]
- the objective to increase the contribution of Renewable Energy in total energy consumption by 10% by 2016 (National Energy Sector Plan 2012-2016)

Biogas systems also can address 'energy poverty' through the provision of free renewable energy, and also provide other beneficial health and social outcomes (e.g. reduced illness from exposure to wood smoke and kerosene emissions, and affordable evening lighting). All these connect very well and directly to the overarching vision of the Samoa Development Strategy 2012-16 which is "Improved Quality of Life for All"

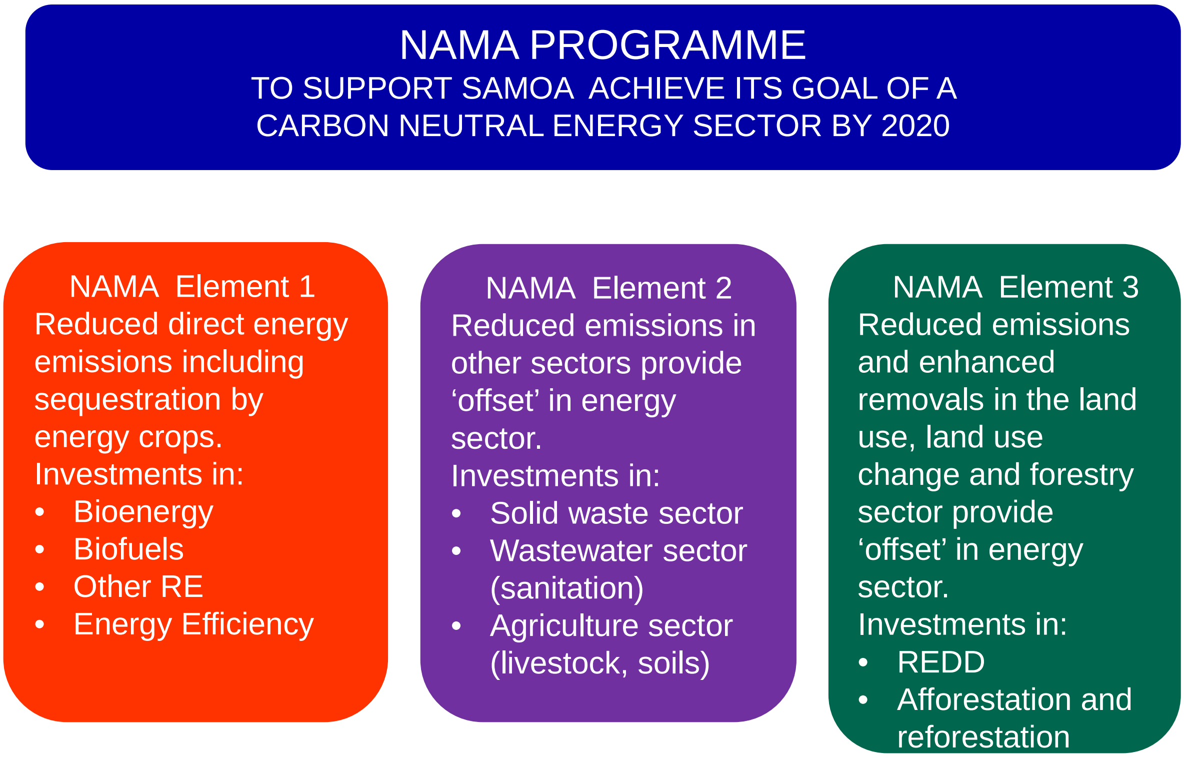
Importantly, the climate change mitigation benefits of biodigester systems mean that programmes for their widespread rollout can be set out as sub-elements of a Samoa NAMA[6] in the energy sector. NAMA finance is a new international funding modality of the UNFCCC. (For details about NAMAs see the document *Pacific NAMA Guidelines* recently released by SPREP.[7]) NAMA finance can provide another significant window of finance from traditional and new donors and support partners.

Samoa has yet to complete the policy process needed to set out its (first) NAMA and register this on the international NAMA Registry being set up by the UNFCCC Secretariat. However a

[4] Biogas contains, typically, about 60% methane (CH_4), the other primary constituent being carbon dioxide (CO_2). A molecule of CH_4 has over 20 times the global warming potential of a molecule of CO_2, which is why methane reduction projects have been so popular under the CDM.
[5] The potential for biogas systems to be negative emissions systems is particularly salient in this regard.
[6] The term NAMA derives from language in UNFCCC agreements about "nationally appropriate mitigation actions" taken by developing countries.
[7] Available at http://www.sprep.org/library-information-resource-center/publications

report in 2011[8] by the consultancies Ecofys and GtripleC, under the support programme for developing countries in the Cartagena Dialogue, recommended that a NAMA could be focused on the energy sector, but in a way that also drew in all the major options for mitigation in Samoa. This concept is depicted in Figure 2 below.[9] The climate change outcomes from biodigester programmes can be captured under elements 1 and 2 of such a NAMA approach.

Figure 2. Depiction of a NAMA programme for Samoa



3. TECHNICAL ASPECTS OF BIODIGESTER SYSTEMS

3.1 International experience

Small scale systems around the world

There are reportedly over 30 million small scale biodigesters in China, over 3 million in India and tens to hundreds of thousands in other Asian developing countries and countries in Latin America and Africa.[10] Small scale biodigesters have typically focused on livestock waste available to rural households from their domestic livestock that live in close proximity.

A recent project wherein the Asian Development Bank is providing USD 74 million in loans to Vietnam for the installation of 4 million biodigester systems over the next 7 years notes:

---

[8] Ward, M and Atatagi, S, *Towards a Samoa Low Carbon Development Strategy and NAMA in the Energy Sector*, Dec 2011,
[9] Note, however, that this framing of Samoa's carbon neutral goal needs yet to be affirmed through policy.
[10] Rajendran, K et al, *Household Biogas Digesters – A Review*, Energies 2012

The Government (of Vietnam) is promoting the use of abundant biomass sources, such as livestock manure and other agri-wastes, to produce biogas as a clean energy source for rural households. The reduce, reuse, and recycle of agricultural wastes will decrease GHG emission and the release of harmful wastes into the environment. The biogas plants have the following benefits: (i) reduced: human and livestock disease outbreaks; methane emissions; fuel/fire wood consumption; water, air (in and out door) and land pollutants; and (ii) increased: savings in time and money, and quantity of organic fertilizers.

A range of design philosophies and construction methods and materials are employed in different countries. Some photos of different systems are shown in Figure 3 below. All these examples are within a similar size range, e.g. 4,000-10,000 litres (4 to 10 cubic metres).

Figure 3. Examples of small scale biodigesters from around the world

<table>
<tr><td>Masonry brick style common in India and other SE Asia countries
</td><td>Concrete style with fiberglass gas collector in Kenya, utilising reusable steel mould from China
</td></tr>
<tr><td>Prefabricated plastic type in India
</td><td>“Red Brick” PVC bag digester in China
</td></tr>
<tr><td>Polyethylene bag digester in Costa Rica
</td><td>Prefabricated fiberglass system in New Zealand
</td></tr>
</table>

Small scale systems in Samoa

There already are a few examples of biodigester systems in Samoa. Biodigesters connected to small piggeries are demonstrated at the Youth With A Mission (YWAM) centre and the China-Samoa demonstration farm at Nu'u. These follow the typical model of domed in-ground tank installations, such as shown in the picture above, and are constructed from concrete.

Three recent installations done as part of demonstration studies have adopted an approach involving tanks constructed of wood (protected from the environment with rubber and/or plastic membranes) plus custom fabricated PVC biodigester tanks (or tank liners plus gas collectors). Affordability in the Samoa circumstance was a key criteria in the adoption of this materials approach.

Two of these recent installations are for a demonstration programme addressing sanitation problems in Vaitele, Apia and included household scale biogas-enhanced septic tank systems, secondary wastewater treatment gardens and biogas appliances.[11] These two installations address human waste and, as well, household food waste and on-site green waste. The third installation is for a demonstration study undertaken at Piu Village on Upolu showing that invasive merremia vine can produce biogas for cooking and lighting as an alternative to current energy sources that are costly and/or lead to health problems due to exposure to wood smoke. Photos of these systems are provided in Figure 4 below.

Figure 4. Recent installations of small biodigesters in Samoa

<table>
<tr><td>PVC bag digester inside tank
</td><td colspan="2">The 'biogas-enhanced' septic tank
 </td></tr>
<tr><td>Biodigesters (with PVC liners and gas collectors)
</td><td>Filling with merremia, water and some manure for bacteria
</td><td>Generated biogas piped to nearby cooking hut
</td></tr>
</table>

[11] This study is detailed in a May 2013 report by BioEnceptionz for MNRE *A feasibility study for biogas in peri-urban area of Vaitele in Apia Samoa*

Large scale biodigesters in international bioenergy applications in the agriculture sector

Biodigesters can also be very large, as can be seen in Figure 5 below. A common application for these large scale biodigesters is for manure waste management in large scale livestock farming operations where the livestock are housed indoors, e.g. in China, India, Europe and North America. They also can be connected to agricultural processing of biocrops with the resource for the biodigester being either the crop directly or the wastewater of industrial operations such as palm oil production, e.g. in Malaysia.

Figure 5. Examples of large scale biodigesters from around the world

System in China. 1,100 m^3 biodigester tanks, 2,000 m^3 biogas per day from ~1,000 cows providing biogas to 1900 households 	System in China. 1,200 m^3 bag digesters, 400 m^3 biogas storage connected to large piggery 
Ultra-large scale plant in China, 12,000 m^3 biodigester tanks, >200 tonnes per day chicken manure, producing over 2 MW of heat and power 	Biogas plant in Germany 

The example from Germany in the pictures above also includes an 'enrichment system' that strips the CO_2 and allows the biogas to be compressed. This compressed gas can be used in the transport sector (e.g. for CNG vehicles), injected in natural gas grids or, potentially, supplied in small bottles for household use. However, the scale of such enrichment and compression systems that are commercially available (and economic) is very large by comparison with the scale of likely biogas resources in Samoa (e.g. requiring > 400 cubic metres of biogas per day).

3.2 Uses of biogas in the agriculture sector and local communities

Biogas has many ways to provide ‘energy services’. These can be directly as biogas or via electricity. These services and the technologies involved can range in scale from very small to very large. Figure 6 below illustrates this diversity as it may apply in the context of a small island country such as Samoa, and in particular to rural communities.

Figure 6. Biogas uses for farms, rural communities and businesses

BIOGAS SUPPLY

As Biogas

As Electricity

Cooking

Lighting

Refrigeration

Air conditioning

Other:

- Water heaters
- Space heaters
- Commercial ovens
- Process Ovens
- etc (i.e. all typical uses of bottled propane)

A wide range of electrical appliances and farm machinery, including such things as:

- Pumps
- Mowers
- Tillers
- Tractors
- Mulchers and chippers
- Utility carts for moving goods and people
- Electric fences
- Fans
- Refrigeration and chilling systems
- Air conditioners
- Lights, including growing lights
- Household appliances
- etc

4. POTENTIAL BIOGAS RESOURCE IN SAMOA – INSIGHTS FROM A SURVEY

Two key questions are (1) how large is the biogas resource in Samoa, and (2) how sustainable is this. Here the term sustainable relates to ongoing availability in the medium-long term. On this second question, a key point to be noted is that because the principal resources being looked at come from crops being grown and other rapid growth plant species, the resource can be inherently sustainable.[12]

To provide insights on the first question a survey questionnaire was developed under this project and a survey conducted by staff of the Renewable Energy Division of the Ministry of Natural Resources and Environment (MNRE). A copy of the questionnaire form is provided in Appendix 1. Also provided is a simpler subset of questions tailored for the resort sector.

This survey was not intended to provide system-wide quantitative data. Rather, through interviews of representative farms and businesses, it was intended to provide insights about the potential scale of biogas resources in the agriculture and food sectors covered. The total number of respondents for this survey was 139, including:

- Farms - larger/commercial 14 (10%)
- Farms - smaller/subsistence 118 (85%)
- Food processing operations 5
- Food use operators (resorts, hotels, separate restaurants) 2

These survey results were complemented by site visits and discussions with a number of representative locations.

A principal purpose of the survey was to help identify potential hosts for demonstration installations of biodigesters that might be undertaken following this initial feasibility study. While the survey results have provided what is needed for this principal purpose, in practice the information provided by most in the agriculture sector was relatively sparse on quantities of potential feedstock resource for biodigesters or to what extent any supply of bioenergy could match with day to day energy needs. Put simply, while farmers generally know about how many acres of crops they grow, they do not typically know the quantities of crops in, e.g. in kilogrammes per crop cycle or per annum. The estimates of potential crop residues is even less known.

This fact is also borne out by the official agricultural statistics census, most recently done in 2009.[13] Neither this census or other similar documents (e.g. surveys of crops being sold through the principal markets) provide firm quantity (kilogramme) numbers. However, data in the census on household consumption can provide a key insight into the 'technical potential' for crop residues, (and potential biogas from biodigesters) from the production of taro, the principal crop in Samoa.

---

[12] Even where the resource is invasive weeds and vines, as these are cleared other crops can be grown that provide a resource.
[13] *Agriculture Census Analytical Report 2009*, Samoa Ministry of Agriculture and Fisheries

The chain of calculations for this is:

- Number of taro consumed per household per week = 33
- Number of households in Samoa = 23,000
- ➢ Number of taro produced per year (for domestic consumption) = ~40,000,000
- Crop residues per taro = ~1.5 kgs[14]
- ➢ Crop residues from taro per year = ~60,000,000 kgs
- Amount of biogas per kg of taro crop residue = ~0.3 cu metres[15]
- ➢ Amount of biogas from taro crop residues per year = ~ 18,000,000 cu metres

It must be stressed that this rough calculation is for the technical potential. The realisable potential will be smaller and the economic realisable potential smaller again.

However this insight shows that considering using biodigesters for producing renewable bioenergy from crop residues in Samoa is very justified. Put in a different perspective, 18,000,000 m^3 of biogas could produce about 28,000,000 kWh of electricity per year, or the equivalent output of a 3 MW power station in continuous 24 hours per day operation. In addition to biogas, biodigesters also produce valuable liquid organic fertilisers.

As to the potential amounts of biogas from other crop residues and, in particular, other plant species, in the absence of needed quantitative data one can simply speculate. But the photos in Figure 7 below, scenes familiar to all Samoans, provides some visual evidence base that the potential could be very significant. What is needed to understand the magnitude of this potential is a trial of biogas production from the plant species in typical acreages of what is shown in these photos. (This is taken up in Section 6 below.)

Figure 7. The abundant 'green' of Samoa

Crops in the understory of a coconut plantation	Understory of coconut plantation overtaken with non-productive plant species
	

[14] This figure an 'anecdotal' estimate which needs confirmation through actual measurement.
[15] This figure is an estimate from international literature.

<table>
<tr><td>Invasive merremia vine infestation that has ‘killed’ previous croplands and tree lots
</td><td>Merremia and other invasive weedy species, visible on many roadsides
</td></tr>
<tr><td>Grass species, abundant and visible on many roadsides
</td><td>And these grasses grow very tall!
</td></tr>
<tr><td>Gliricidia, the leaves of which can be a resource for biodigesters and the woody branches a resource for gasifiers
</td><td>Invasive species trees that can also supply biodigesters and gasifiers
</td></tr>
</table>

5. DESIGN ISSUES FOR BIODIGESTERS IN SAMOA

The circumstance of Samoa is that, as detailed above, the resource for biodigesters is widely dispersed across the landscape. Most farms and most rural village communities will have access to their own resource. Also as the photos above show, there is considerable resource immediately accessible from the roadside, making harvesting, collection and local transportation relatively straightforward.

This suggests that a viable approach to renewable bioenergy production in Samoa is to have a distributed energy system involving multiple small to medium size biodigesters[16]. The question then is: what is the best utilisation of the biogas produced? This will be circumstance specific, depending on the energy service needs of the farms, businesses and communities in question. As shown in Figure 4, biogas is very versatile in its potential uses, both in the scale of equipment that can use it and the variety of energy needs it can serve.

The physical size of biodigesters becomes an issue for larger capacity resources. For example, a 6kW generator providing continuous power '24/7' needs about 100 m^3 of biogas per day. In designing biodigester systems, noting that Samoa is increasingly being affected by weather extremes associated with global warming, careful attention needs also to be given to resource material handling, water availability and climate resilience. So, for example, low profile designs will be better than tall tank structures. Systems should also incorporate rainwater collection and water storage.

6. RECOMMENDED 'NEXT STEP' TECHNOLOGY DEMONSTRATIONS

6.1 A programme of demonstrations

What is now needed to move from this general feasibility study and report towards wide scale deployment of biodigester systems in Samoa's agriculture and food sectors is to undertake a number of technology and business system demonstrations. It should be noted that there is no question about whether biodigesters will produce biogas and liquid organic fertiliser. Widespread international experience has already demonstrated this capacity. Rather, the points to be demonstrated in Samoa relate to the appropriate scale, style and mix of biogas producing and utilisation technologies in the given application circumstances.

The following nine case examples have been identified for 'next steps' consideration based on the review of the survey results and site visits of representative applications. All nine are qualitatively different. However they all share one key qualifying characteristic, that they are not 'one-offs', by which is meant that they have the potential to be replicated in other sites in Samoa, in some cases many other such sites:

1. Resource testing facility and community education and engagement centre
2. Invasive merremia (and other co-located greenwastes) to small-scale community power production for on-sale in a power purchase agreement with EPC, and liquid organic fertiliser production for community use and sale

[16] This could potentially also include companion small scale gasifiers that utilize the woody resource.

3. Residues from virgin coconut oil production to on-site use of energy (copra drying and other) and liquid organic fertiliser production for self-use and on-sale
4. Residues from chip manufacturing (taro, banana, breadfruit) and other crop processing or livestock waste, as applicable, to on-site use of energy (chip drying and other) and liquid organic fertiliser production for self-use
5. Farm crop residues to negative emissions power (electricity) for on-farm use and on-sale in a power purchase agreement with EPC, as applicable, plus biochar and liquid organic fertilizer for on-farm soil enrichment
6. Resort sanitation, food waste and general greenwaste (lawns, plants, foliage drop) to on-site energy and liquid organic fertiliser production and use, e.g. for beautification gardens
7. Greenhouse operation greenwaste (e.g. plant nursery and flower producers, and/or hydroponics producers) to on-site energy and liquid organic fertiliser production and use
8. Tertiary training centre for plumbing trades and hospitality sectors, where sanitation and food wastes can produce biogas for on-site cooking facilities and liquid fertiliser for beautification gardens
9. SIDS-2014 Conference site full-featured demonstration system, where sanitation wastes plus green wastes from playing fields management, local area farm residues, and community yard and streets cleanup can produce biogas for conference site gas-fired adsorption air conditioning system plus for electricity and cooking facilities; and liquid fertiliser for beautification gardens.

All of these nine cases are detailed in summary concept notes below. With respect to locations for these demonstrations, in four cases the nature of the demonstration and/or other circumstances, specifies the site. This is true of numbers 1, 2, 8 and 9. However, for the other five, the selection of the location should be part of the open process that will be used to select the private contracting firm that will be part of the public-private partnership needed to get this full programme of demonstration sites commissioned in advance of the SIDS-2014 conference.

6.2 The SIDS-2014 Conference – A Samoa showcase to the world

These nine demonstration sites can be considered as 'gateway projects' which provide the 'seeing is believing' proof that these systems can provide high value, money and environment saving outcomes to the benefit of Samoa – its peoples, businesses, government and society at large. This is the essence of sustainable development and "green growth".

The SIDS-2014 Conference provides a further gateway to showcase to an interested and listening international audience (and the world via international media) both the systems and the business and finance model by which Samoa has been able to fast track these projects from concept to commissioned reality. The details of such a model are covered below in Section 7, following the individual demonstration concept notes.

6.3 Concept note 1: Resource Testing and Community Engagement Centre

Issue

The fact that anaerobic digestion of 'green' organic material will produce biogas is undisputable. However, how much biogas per kilogramme of specific material depends on the material in question and a range of other factors including the temperature of the system, the ratio of different bacteria in the system, the physical properties of the waste and other factors including the disbursement and amount of time in the biodigester vessel.

While there is considerable international case study literature on production volumes for different materials, it is not feasible to estimate with any accuracy what may be true for green resource material in Samoa. The best approach is to establish a test centre in Samoa to determine accurate local data. Officials in the Renewable Energy Division of MNRE have identified that having such a test centre is a high priority for their biogas programme.

Such a centre can also serve as a community education and engagement facility. Seeing biogas being produced in biodigester test cells and making practical use of the biogas, e.g. for cooking and area lighting, is a powerful means to show the simplicity and usefulness of biogas systems.

One aspect of community engagement could be the storage of biogas coming from the test cells and using this gas for a community barbeque station. Different charity groups could be organized to do regular 'cook ups' using the supplied barbecue(s) and free biogas, and use the proceeds for their charitable cause. In addition to biogas from the test cells, it could also be useful to have a co-located larger digester that uses as its resource any food waste available from local area restaurants.[17]

Proposed system

As discussed in section 4 there are a wide variety of potential resources in Samoa for producing biogas including crop residues (and potentially crop over-supply), food processing residues, grasses, invasive vines and weeds, lawn cuttings, bush clippings, foliage drop etc. To enable data to be collected quickly, a test centre should have multiple test cells, each of which, for example, could be about 1.5 cubic metres in size. In addition, as noted above, gas storage plus a larger biodigester for food waste could be provided. The gas storage would need to be sized to fit with the biogas production rates and the frequency and gas usage of the 'cook ups'. The system should also include on-site rainwater collection and storage.

The gas system should have a manifolded and valved gas delivery and monitoring system so that the outcomes of each test cell can be separately measured over an extended period of time (1-2 months) to accurately assess the average cubic metres of biogas per input kg of resource material. The biogas for each resource can also be tested (by SROS) to determine the composition, i.e. percent methane. Using such a multi-cell test centre, in a relatively

[17] An informal survey of Apia restaurants showed that while most have arrangements for food waste to be taken away for feeding to local pigs and dogs, there would be some regular daily availability to supply to such a community engagement biodigester system.

short period of time (3-6 months), the biomethane potential for many ‘green’ resources available in Samoa can be determined.

Having an accurate measure of the biomethane potential for specific organic resources is an important first step for the system design for a given application. Whether it is knowing how much biogas can be expected from a given sustainable supply of resource or, conversely, what amount of sustainably supplied resource is needed to provide a desired amount of biogas (and serve a specific energy need), the biomethane potential is an important-to-know factor.

For this reason, establishing such a test centre and getting this data collection underway should be accorded the highest priority in coming months in 2013.

6.4 Concept note 2: Invasive vine to small scale community power

Issue

As noted in section 3, and pictured in Figure 4, a demonstration study has been undertaken in Piu Village, Upolu to show that biogas can be produced from invasive merremia vine. This study was funded by the UK High Commission in Wellington, New Zealand. In this small demonstration study the biogas is being used for cooking and lighting in a small cookhouse in the village.

Merremia is prevalent in many parts of Samoa (and in many other Pacific Island countries). It is a highly destructive invasive species as it grows over and kills all plant species and trees in what could be (and may once have been) croplands and tree lots. Piu Village has a particularly widespread infestation on their village land, vastly more than would be needed just for the village’s cooking and lighting needs.

This opens the way to consider a small scale power generation station. Such a demonstration of community power would not only showcase the technology and system features, but also can serve to establish the business and finance model for small scale independent power being provided in a power purchase agreement (PPA) to the Samoa Electric Power Company (EPC). While the policy for such a business arrangement exists already in Samoa, there are not as yet examples of small scale community independent power producers (IPPs).

Proposed system

To be of a commercially useful scale (e.g. for EPC to be interested to set up a PPA contract) the demonstration system should be of nominally 10-15 kW capacity. The biodigester, including material processing and handling system, would need to be sized accordingly. The system will require biogas conditioning systems that remove sulphur gases and dry the biogas before it is delivered to the biogas generators. The system should use a number of smaller size biogas generators rather than one single larger generator. It will also require the electricity connection equipment, including power metering equipment, to attach it to the EPC grid.

A government owned water treatment facility is located on Piu Village land near to the infestation area. Water for the whole district is sourced from a waterfall higher up in Piu Village. The EPC grid in this district extends to this point, This would therefore be a logical location for the biodigester and generator plant. Having power generation here would also help EPC to improve the security of supply of electricity to this district.

On the point of long term sustainability of the resource, this demonstration would include an inventory assessment of the total biomass of merremia vine available and also an assessment of what biocrops could be planted as part of a multi-use agricultural (or agroforestry) production system for the cleared and reclaimed land. The organic fertilizer produced can be used in these farm operations.

6.5 Concept note 3: Virgin coconut oil business sector

Issue

The production of organic virgin coconut oil through the Women in Business Development Inc (WIBDI) network and its links with The Body Shop internationally are a well known Samoan success story. The use of biodigesters to provide biogas to dry copra, versus burning coconut husks, could also help to improve the local environment part of this story.

A waste resource of flaked coconut 'meat' is generated in the production of the coconut oil. This can be one of the feedstocks to a biodigester. In addition, a range of resources such as crop residues, grasses, weeds, etc are available in the local farm community.

Proposed system

The biogas produced can be used for the copra dryer and other energy needs that the operation may have (e.g. electricity, ovens, refrigeration, lighting, cooking). The size of the biodigester would be scaled to the circumstances of the particular demonstration host site. A system involving a biodigester plus gas storage is recommended to match the schedule of biogas production and biogas use. Biogas conditioning (desulphurization and drying) would also be required. The system should also include on-site rainwater collection and storage.

The organic fertilizer produced can be used in farm operations.

6.6 Concept note 4: Chip manufacturing and other food processing business sector

Issue

There are a number of small to medium size manufacturers of taro, banana, and breadfruit chips in Samoa. These serve both domestic and export markets. The overall farming operation can include the growing of these crops and an associated piggery to feed out the crop processing waste.

The major cost to these operations is the cost of their propane fuelled chip dryers. This can be a major barrier to the economics of this sector and its potential for expansion.

Proposed system

A system for this application would include biodigester(s), biogas storage and biogas conditioning (desulphurization and drying) plus the interconnections to the chip dryers. It would also need a materials handling system to feed the resource waste streams into the biodigester(s). The system should also include on-site rainwater collection and storage. The resource can be a mix of crop processing waste (e.g. the skins of the crops being chipped), crop harvest residues, other on-farm supply of grasses, weeds etc, and, if applicable, piggery waste.

The organic fertilizer produced can be used in farm operations.

6.7 Concept note 5: Commercial crop farming sector and negative emissions power

Issue

Larger commercial farms growing such crops as taro, taamu, breadfruit, vegetables and cassava will have significant volumes of crop residues, and potentially sub-standard crop material that is not fit for market. They also typically will have grasses and weeds to be managed and other greenwaste such as from foliage drop.

The scale of biogas potential from these resources is not matched by any on-farm energy demand (as the main demand is usually diesel for tractors, farm equipment and trucks). This opens the way for small to medium scale power generation.

It also provides an excellent application to demonstrate negative emissions power with the addition of an algae photobioreactor and biochar system. Negative emissions would be generated on an annual crop cycle basis, so be very easy to measure and verify.

Such a demonstration of negative emissions power within a rural farming operation including the production of liquid organic fertiliser and biochar for soil enrichment, and the sale of electricity to enhance on-farm incomes, would be of huge interest to the worldwide agricultural and climate policy community.

Proposed system

This would be a full-featured demonstration including biodigester(s), biogas storage, resource material processing (shredding) and handling (feeding into the digesters), rainwater collection and storage, biogas conditioning (desulphurization and drying), biogas generators, algae photobioreactor system, and algae collection, drying and biochar production unit. It would also have a liquid fertiliser delivery system to the crop fields.

6.8 Concept note 6: Resorts sector

Issue

Most resorts have high operating costs from energy demand, in particular electricity for air conditioning, fridges, lighting and operating pumps, and propane for cooking. They are therefore attracted to the notion of having biogas systems to help reduce these energy costs. A number have looked into the idea of capturing biogas from their sanitation systems. However, when methane potentials from this bio resource are calculated, it becomes apparent that a biogas system based on this resource does not cover a sufficiently significant percentage of these energy demands to warrant the expense and effort.

Part of this picture is that most resorts have commercial scale sewage wastewater treatment systems. In these cases, sanitation problems are not necessarily an issue. However, on closer inspection, the problem may be of a different nature. A high portion of electricity costs can be attributed to the pumping of sewage from multiple distributed holding tanks connected to clusters of rooms to the central treatment system.

In addition, resorts potentially have a significant green resource produced on-site or accessible in their local community:

- Food waste from kitchens and guests
- Grounds management (grass clippings, bush trimming, foliage drop)
- Crop residues, roadside grasses, weeds, vines, etc

Proposed system

A biodigester demonstration for resorts could therefore contain two separate elements:

i. A larger biodigester system for greenwaste that could provide biogas for direct replacement of propane and small scale electricity generation.

   This system would include biodigester(s), biogas storage, resource material processing (shredding) and handling (feeding into the digesters), rainwater collection and storage, biogas conditioning (desulphurization and drying), biogas generator(s) and a gas delivery system (to the resort kitchen). The scale of this system would depend on the scale of the green resource available and/or the scale of propane and electricity demand at the resort.

   For this system the organic fertiliser produced could be used for on-site crop production of vegetables and herbs, in addition to being used for general garden application. Alternatively, it could be sold to local farmers, or exchanged for any crop residue waste they supply to the resort.

ii. A smaller sanitation biodigester system that could take a room cluster off the centralized wastewater treatment system in order to save the pumping costs, and provide biogas for such uses as area lighting and biogas room fridges. This system would also have a secondary wastewater treatment 'garden' that could be a beautification feature in the grounds near the room cluster. (Note that the design of this small scale sanitation system would be very similar to the household sanitation systems demonstrated in Vaitele, noted in Section 3.)

6.9 Concept note 7: Greenhouse operations sector

Issue

There are a number of small to medium size greenhouse operations in Samoa. These serve both domestic and regional export markets. By their nature greenhouse operations can produce considerable greenwaste which traditionally is composted and re-used, complementing other fertiliser they may buy in (e.g. chicken manure). The alternative of using small biodigesters means they can derive an energy resource from this greenwaste and also more quickly produce larger volumes of organic fertiliser.

The biogas can be used for area lighting and cooking. If the operation is sufficiently large, or if it additionally has access to greenwaste brought in from offsite, there is also the potential for small scale electricity production with the electricity used for local operations (e.g. lighting, water pumping, refrigeration, plant grow lights).

Proposed system

Biodigester systems for this application can be relatively simple. They may just include a basic biodigester incorporating self-storage or separate gas storage and gas conditioning and delivery equipment (so be similar to the simple demonstration systems described in Section 3 or the systems described above for the proposed testing facility).

If the systems are larger (e.g. have greenwaste resources also brought in from offsite) and, have higher biogas demand equipment such as small electricity generators, they would likely require rainwater collection and storage and would require larger gas conditioning systems.

6.10 Concept note 8: Tertiary training facility

Issue

A demonstration biodigester system at the Australia-Pacific Technical College campus in Apia could play a highly valuable capacity building role. This APTC campus provides the Pacific regional training for the plumbing trades and the hospitality trades (restaurants and hotel/resort management). The campus includes a commercial restaurant open to the public.

A demonstration system at this site would be constructed in a manner that it can be an ongoing teaching aide resource. In particular, the liquid and gas plumbing issues associated with biogas septic tank systems and secondary treatment gardens can be on open display and integrated into the plumbing course.

Proposed system

The biodigester resource can be from the campus septic system plus foodwaste from the restaurant kitchen and students. Biogas produced can be used in the restaurant kitchen.

A system of biodigester septic tank and secondary treatment garden similar to the household sanitation systems in the demonstration at Vaitele discussed in Section 3 would be applicable for this demonstration site. It may additionally be feasible to retrofit the existing campus septic tank system to add biogas recovery to teach plumbing students if and how this is possible.

6.11 Concept note 9: SIDS-2014 Conference Site demonstration and on-site utilities centre

Issue

As set out in Section 6.2 above, the occasion of Samoa hosting the SIDS-2014 Conference provides a wonderful opportunity for Samoa to showcase innovative renewable bioenergy systems to the 3000-4000 delegates attending and the worldwide audience that will follow this event via the internet and international media coverage.

Section 7 below sets out how the business and finance model for this whole set of demonstrations can be directly linked to this SIDS-2014 opportunity. This specific demonstration additionally serves practical issues that will exist at the site of the conference which is located at the Tuanaimato Sport Complex playing fields area in Apia. These practical issues include:

- The need for the main conference meeting rooms to be airconditioned
- The need for additional sanitation and kitchens facilities
- The desire of the Government of Samoa to have a facility that showcases renewable energy systems that are applicable for tropical small island states worldwide. A system featuring *negative emissions* would especially fit with the Samoa position on the need for "better than 2^{o}C" (see section 2.2) and Samoa's carbon neutral goal.

Proposed system

Given the energy demands of the conference site this would necessarily be a larger scale system. The resource would be a mix of greenwaste from the sports field area (e.g. grass clippings, bush trimmings) and from the nearby community including farms (crop residues, grasses, vines, weeds etc). Any greenwaste that may result from general community 'spruce up' throughout Upolu that may occur in advance of the conference and be destined for the Tafa'igata landfill can also be diverted to this demonstration site. The biodigester system would also treat the waste from the expanded toilet facilities.

To meet the objectives of this demonstration, this would be a full-featured system including:

i. biodigester(s) with biogas storage
ii. resource material processing (shredding) and handling (feeding into the digesters)

iii. rainwater collection and storage
iv. biogas conditioning (desulphurization and drying)
v. biogas generator(s)
vi. biogas direct fired adsorption chillers, linked with the airconditioning system to be installed in the conference room(s)
vii. algae photobioreactor system, linked back to the biodigesters
viii. wastewater secondary treatment gardens providing a beautification service

7. BUSINESS AND FINANCE MODEL FOR FAST TRACK DEMONSTRATION ROLLOUT

7.1 Business model – A public-private partnership

Of the nine demonstration projects set out in Section 6, the resource testing centre and the merremia invasive vine to community power can be seen as projects that could be initiated more quickly and through different contracting modalities than the other seven. This is in part because the funding source for these already may be identifiable.

For example, in regard to the resource testing centre the Renewable Energy Division of MNRE has funds expected to come from the recent SIDS-Dock meeting in Fiji. There are also offers on the table for renewable energy projects from the International Renewable Energy Agency (IRENA) and the recent Pacific Energy Summit. What is less clear is whether the modalities for the disbursement of such funds fits with the need for this centre to be a high priority project that can be built and already be providing needed data before the end of 2013.

The UK government is likely to want to have the initial option to fund the merremia invasive vine to community power project, since they funded the initial proof-of-concept project at Piu Village.

In both these two cases it would be expected that there would be an open request for proposals (RFP) process to select an experienced biogas systems contractor to design, install and commission these systems.

For the remaining seven demonstration projects, a public-private partnership approach is recommended wherein all seven are done as part of an investment programme that is explicitly linked to the SIDS-2014 Conference. Given the nature of what is needed to be done and the very tight timeframes which cannot be allowed to slip due to the absolute deadline of the conference dates, it is inconceivable that government departments would be able to be the project managers of such a rollout.

Instead, under a public-private collaborative approach the government would contract a private sector operator to deliver the programme. This operator would take on the project design and delivery management role and be paid for achieving contracted performance goals. Given the critical importance of having these projects fully commissioned and operational before the conference, the contract should include both performance bonuses for early delivery and substantial penalties if project milestones are not met.

The selection of this private sector partner should be decided through an open competitive process based on criteria such as:

- Being a legal business in Samoa, majority owned and operated by residents of Samoa.
- Proven competence both with the technology and system aspects of these type installations and the successful management of government contracted projects of a similar technical nature in Samoa.
- The identification of the demonstration locations and hosts and why these have been chosen and meet all TOR requirements in this regard (e.g. requirements for a spread of locations between Upolu and Savaii.)
- A project management plan that shows a clear understanding of the task and its risks and challenges, along with the approaches that will be taken to continue to identify and manage these during the construction and commissioning period.
- Price, and value for the expenditure of public money.
- Financial and risk management accountability, including financial and project performance management reporting systems. (Note that international donors and support partners will be expecting this of the Samoa government in the first instance, and this expectation will transfer through to the private sector programme partner.)

In relation to the private sector partners, they would be expecting government compliance concerning all of its contractual obligations, including such things as paying promptly on the achievement of milestones and the rendering of proper invoices, rapid clearance of imported goods (noting the procedures associated with the duty free status for projects funded by international donors) and any on-site interface issues with respect to the conference centre facilities.

Given the deadline associated with the SIDS-2014 Conference, it will be critical to have all donor and funding issues settled, and RFP/procurement decisions made and contracts put in place before the end of 2013. This will allow the private sector operator to already have procurement contracts in place with overseas equipment suppliers before Christmas 2013 so that they can expect delivery of these goods in February-early March 2014.

7.2 Funding model for demonstration programme

Two questions related to funding are how much will all these demonstration installations cost and who pays for all this.

On the “how much?” question, this is unclear and will only become clear following the RFP process(es). However, a total sum for the seven projects making up the single investment programme conceivably could be in the range of WST 500,000 - 750,000. The testing facility could be in the range WST 30,000 - 40,000 depending on the number of test cells. The merremia vine to community power station could be in the range of 100,000 - 150,000, depending on the kW generation capacity.[18]

On the “who pays” question, a principle that can be applied is that everyone who benefits should contribute corresponding to the nature and amount of benefit and their capacity. The “beneficiaries” in this sense include:

- International donors who are seeking to provide this region with sustainable development assistance funding and who are interested to support renewable energy projects. As the recent Pacific Energy Summit and SIDS-Dock meetings made clear, there are many such countries, directly and through international financial institutions.[19] In addition to renewable energy these projects feature many rural development and ecosystem benefits.
- International ‘support partners’ who are interested to support climate change “nationally appropriate mitigation action” in this region. While NAMA finance is a new support modality, it is expected to gear up quite rapidly as developed country government begin to disburse the funds to support NAMAs.[20]
- UN Agencies and supporting countries that have a strong interest for the SIDS-2014 Conference to be successful and understand the important role that a good field trips programme can have in this success.
- The Government of Samoa who, as hosts of SIDS-2014, will benefit from the international exposure and ongoing use of improved conference facilities.
- The demonstration site hosts who will have ongoing cost reductions and other benefits from the installations.

The key challenge to a workable financial model is how best to channel the money available from the public side contributors to the private sector actors. This needs to be done efficiently (so there are not significant transaction costs and intermediary players “clipping the ticket”), effectively (so that there are minimal programme delays and payments occur quickly, per the contract terms) and in a transparent and accountable manner (so meeting the fiduciary reporting requirements of the government and international donors and support partners).

These challenges are actually quite generic and currently ‘top of mind’ for senior government and institutional experts working on international Climate Finance.

In practice in Samoa, except in situations of disaster recovery (e.g. following the tsunami and recent cyclones), the history is that the implementation of donor funded projects is slow. It can take many years to take a project from first concept to implementation, if it happens at all. An important aspect of this proposed demonstration programme connected to the SIDS-2014 Conference is that it provides a platform (and the pressure of politicians

[18] The figures presented in this paragraph are estimates based on the experience of the author.
[19] A good summary on this is included in the final meeting report of the recent SIDS-Dock meeting held in Fiji.
[20] For example a new NAMA Finance facility has recently been announced jointly by the UK and German governments. However, for NAMA finance a question remains if this could be put in place in 2013.

and senior UN agency officials) for Samoa to test fast-track decision and disbursement modalities.

The proposed funding model for this programme is that Samoa creates a special purpose fund (or a special ‘room and window’ within an existing fund) into which donors could contribute funds for the express purpose of supporting this investment programmes. This fund would be managed by specialists in the government who would take the decisions as to the disbursement from the fund under reporting guidelines mutually agreed with the donors. This approach can facilitate fast-track financing – as long as the internal decision-making processes are correspondingly fast.

The main outflows from the fund would be the progress payments to the private sector operator that is contracted to deliver the programme.

It is recommended that systems should not just be given to the demonstration host sites. This is likely to create a local backlash from other potential host sites that have not been selected for the demonstration programme, or an expectation that the government or international donors should continue to provide these systems at no or low cost. This will be very problematic and socially destabilizing.

Instead, part of the study phase of these demonstrations should be to work out the specifics of the monthly financial benefits accruing to the host operations. During this study phase the ownership of all the supplied equipment should reside with the manager of the fund (a government department). When this study phase is complete the ownership of the equipment should transfer to the host operator who would take on an obligation to make monthly payments for a specific period of time.

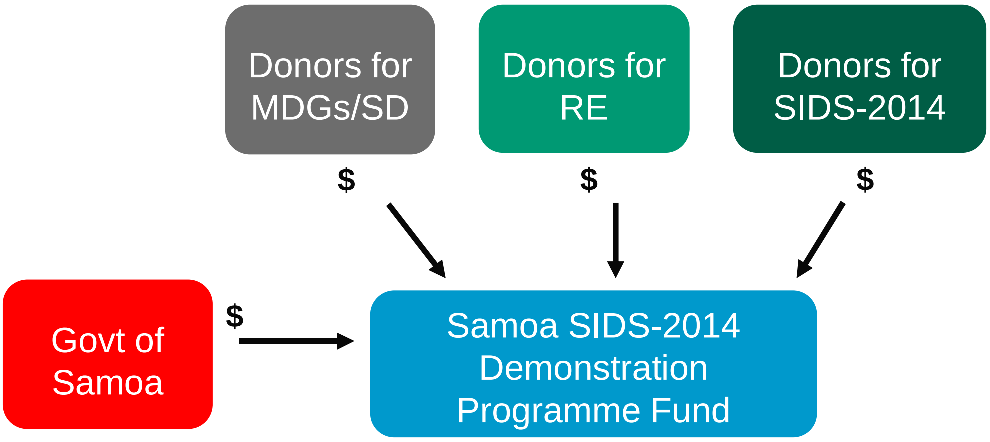
The idea is that these monthly payments would be less than the monthly financial benefit. The length of time that these payments would be made would be calculated based on the cost of capital to the government of the monies in the fund (i.e. reflecting the contributions from donors which may be a mix of grants and low interest, long tenure loans). In addition there would be an operational cost associated with the management of the fund, including service fees paid to financial intermediaries (such as the Samoa Development Bank) who may mange the repayments from the demonstration hosts.

The payments made back to the fund by the demonstration hosts mean that this funding model has the nature of a ‘revolving fund’ that allows for future reinvestments to be made by those operating the fund. The fund could then evolve into a general green development fund which donors could continue to put funds into and which would continue to operate on a revolving fund basis. Under this model, these initial demonstrations could pave the way for the wide rollout of these systems for similar applications.

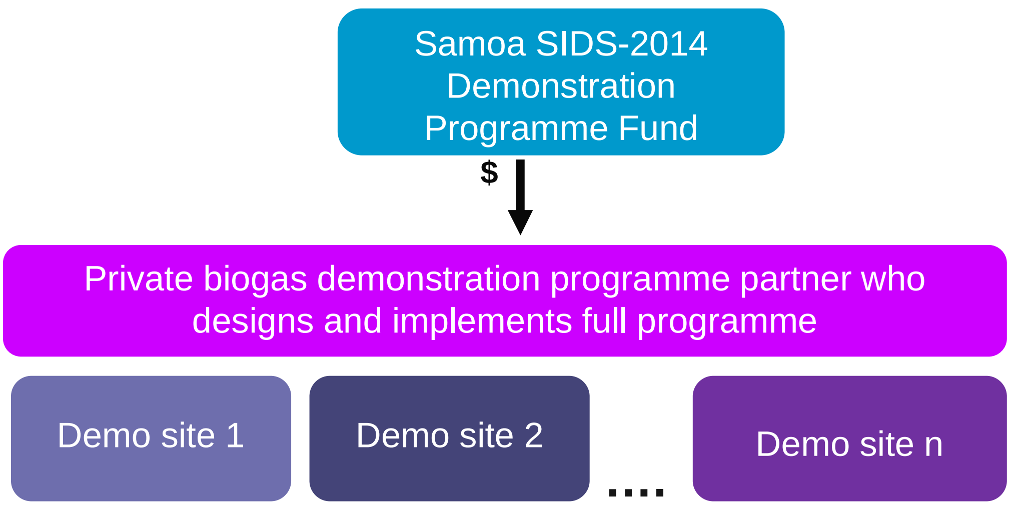
A depiction of this financial model concept is provided below in Figure 8.

Figure 8. Depiction of a financial model concept for the demonstration programme and subsequent rollout.

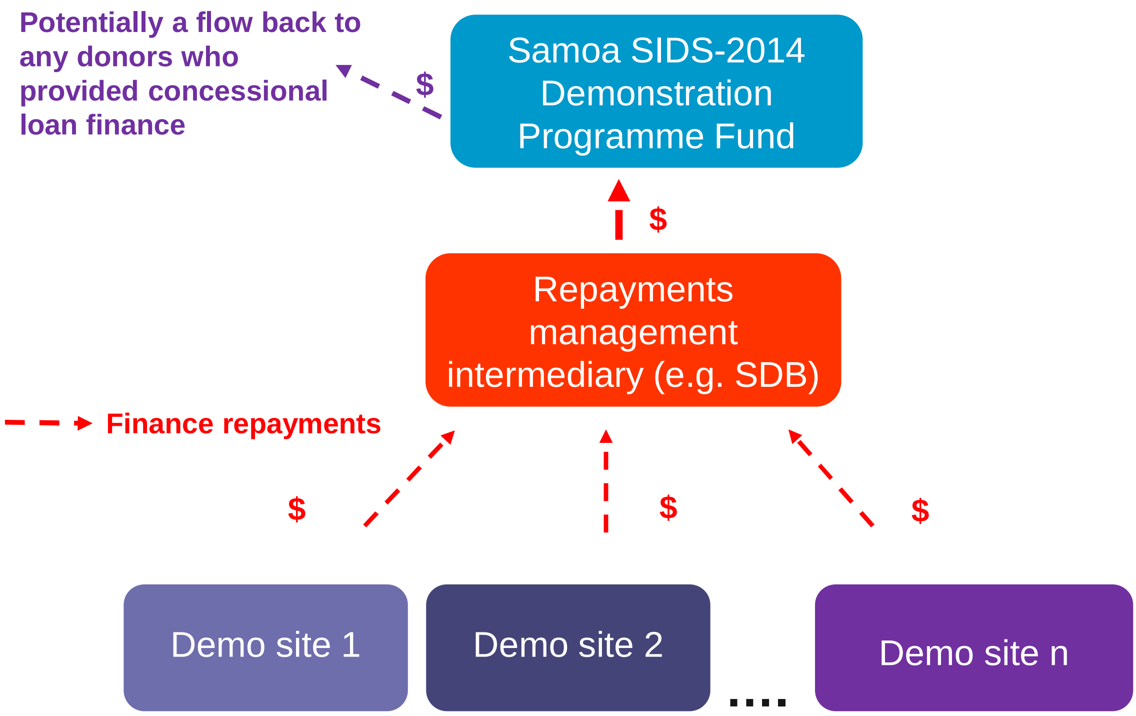
Step 1: Set up the fund



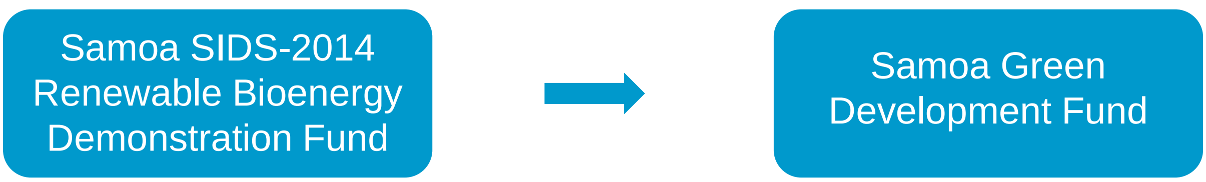
Step 2: Implement the demonstration projects through a public-private contract



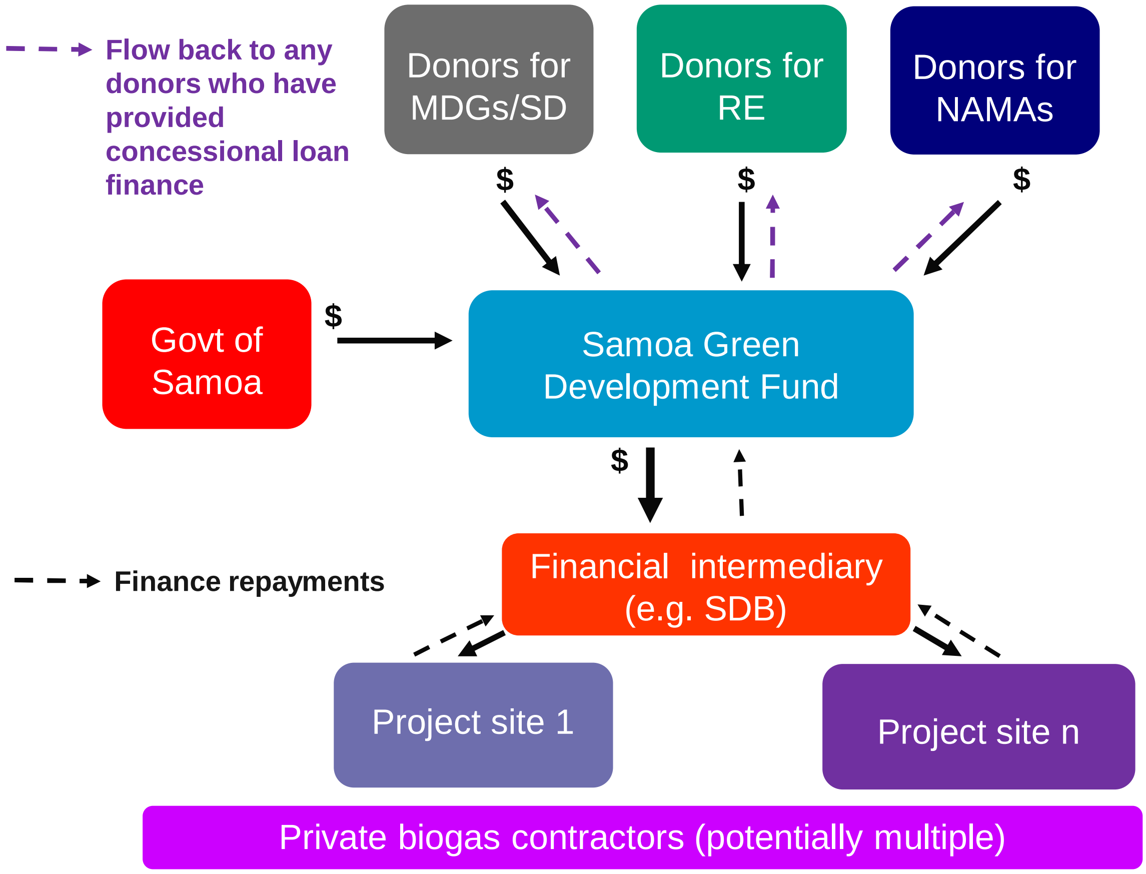
Step 3: Monthly payments from demonstration host sites flow back to the fund via intermediary at the end of the demonstration study when the host sites take ownership of the systems



Step 4: Shift from demonstration mode to normal operation mode: Convert the Demonstration Fund into (or as part of) a general Samoa Green Development Fund



Step 5: Operation of Samoa Green Development Fund: Low cost of capital provided from the Fund to project sites via Financial Intermediary. Finance repayments return to the Fund



APPENDIX 1. The survey questionnaire and short form survey questions for resorts

SURVEY FORM FOR FAO/MNRE BIODIGESTER PROJECT

Survey to be conducted by MNRE in period Feb - April 2013

SURVEY PARTICIPANT IDENTIFICATION

Region ☐ **District** ☐☐ **Village** ☐☐☐ **GPS:** Way Point ☐☐☐ Lon: ☐☐☐☐☐☐☐ Lat: ☐☐☐☐☐☐☐

Operation/Company Name ____________________

Operation/Company Address ____________________

Contact ____________________

Nature of operation ____________________

Category of operation

Farm Subsistence	Farm Commercial	Post-harvest processor	Commercial size generators of food/other organic waste
☐	☐	☐	☐

INFORMATION FOR OFFICE USE

Survey date: ☐☐☐☐☐☐☐☐ *(dd/mm/yyyy)* **Start time:** ☐☐☐☐ *(hh/mm)* **Finish time:** ☐☐☐☐ *(hh/mm)*

Name of Enumerator: ____________________ **Name of Supervisor:** ____________________

Number of visits to the participant: ☐

Survey status: ☐ *completed* ☐ *partially completed* ☐ *call back*

Name of Quality Officer: ____________________ ***Check date:*** ☐☐☐☐☐☐☐☐ (dd/mm/yyyy)

Start check time: ☐☐☐☐ *(hh/mm)* **Finish check time:** ☐☐☐☐ **Quality status:** **1** *completed* **2** *partially completed*

Name of Data operator: ____________________ **Date of data entry:** ☐☐☐☐☐☐☐☐ (dd/mm/yyyy)

SECTION A: GENERAL INFORMATION

1 **Name of Respondent** ____________________

2 **Role in operation** ____________________

3 **Before today, have you ever heard of or seen a biodigester?** (Yes = Y, No = N) ☐

If Yes, where have you heard or seen this? ____________________

What do you think of biodigesters? Do you think they may be an applicable technology for your business/operation?

____

SECTION B: FOR FARMERS

1	Crop type	Area Acre	Production lbs/season	Type of residue	Uses of residue (a. to f. key below)	Residue Amount lbs/acre/week	% residue used
	Taro						
	Bananas						
	Coconut						
	Breadfruit						
	Taamu						
	Cabbage (head)						
	Cabbage (Chinese)						
	Tomatoes						
	Papaya						
	Pumpkin						
	Cucumber						

Uses of residue: a. Livestock Feed b. Mulch/fertiliser c. On farm waste d. To landfill e. Animal bedding f. Other (specify)

		Pigs	Cattle	Dairy Cows	Chickens	Other	
2	**Livestock, numbers**						
3	**Numbers enclosed** (e.g. for feeding, milking, all the time)						
4	**Waste collected, lbs/week**						
	Liquid/sludge						
	Solid						
5	**Waste collectable, lbs/week** (if was a valuable use that justified)						
	Liquid/sludge						
	Solid						

		Sold	Given away	Fertiliser on farm	Stored on-farm	Sent to treatment facility	Other
6	**Use of collected waste, %**						

7 **Are crops grown for livestock feed?** (Yes = Y, No = N) ☐

If Yes, describe type and amount, lbs per week ____________

8 **Are crops grown for livestock bedding?** (Yes = Y, No = N) ☐

If Yes, describe type and amount, lbs per week ____________

9 **Is there any residual waste from activities at lines 7 and 8?** (Yes = Y, No = N) ☐

If Yes, describe type and amount, lbs per week ____________

… and what is done with this waste? ____________

10 **Is there any other waste generated or collectable on the farm, e.g. green waste from trees, vines or grasses** (Yes = Y, No = N) ☐

If Yes, describe type and amount, lbs per week ____________

… and what is done with this waste? ____________

11 **Comments** ____________

SECTION C: FOR PRODUCE POST-HARVEST PROCESSORS

1 **Crops processed** ______ ______ ______ ______ ______

2 **Nature of processing** [ ]

3 **Products** ______ ______ ______ ______ ______

4 **Production pa (lbs x 100)** [ ] [ ] [ ] [ ] [ ]

5 **Are there waste byproducts?** (Yes = Y, No = N) [ ]

If Yes, describe type and amount, lbs per week

[ ]

… and what is done with this waste?

[ ]

6 **Comments** [ ]

SECTION D: FOR COMMERCIAL SIZE GENERATORS OF FOOD/OTHER ORGANIC WASTE

	Food waste	Gardens/Trees green waste	Sewage	Process outputs see below (3)	Other ______	______
1 **Available wastes** (Yes = Y, No = N)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
2 **Waste Amounts**	[ ]	[ ]	[ ]		[ ]	[ ]

In lbs per week or some other relevant unit (provide), e.g. volume of waste, or number of people using toilet facilities per day

3 **Process Waste Streams** ______ ______ ______ ______ ______

Describe waste stream

4 **Waste Amounts** [ ] [ ] [ ] [ ] [ ]

In lbs per week or some other relevant unit (provide), e.g. volume of waste, cfm of gas (e.g. methane from water treatment plant)

5 **What is done with the waste now?**

[ ]

6 **Comments** [ ]

SECTION E: QUESTIONS THAT RELATE TO ENERGY, FOR ALL SURVEY CATEGORIES

		Electricity Bought	Electricity self-generated	Gas in Bottles	Kerosene	Diesel, for electricity	Diesel for other	Petrol, for electricity	Petrol, for other	Biofuel	Biogas	Other ______
1	Energy used (✓ as apply)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2	Amounts per month	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	units	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3	Cost, Tala per month	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

4	Energy uses (✓ as apply)	Water heating	Cooking	Lights	Appliances	Aircon	Refrigeration	Machinery incl pumps	Crop Processing	Other Processes	Vehicles	Other ______
	Electricity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Gas	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Kerosene	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Diesel	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Petrol	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Biofuel	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Biogas	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Other	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

5 **What percentage of your monthly operating costs is the cost of energy?** ☐

6 **Do you think using self-generated biogas may be able to significantly reduce your energy costs?** (Yes = Y, No = N, Maybe = M) ☐

7 **If you had available self-generated and affordable biogas would you be able to change your operations to increase profitability (e.g. increase size or service offering)?** (Yes = Y, No = N, Maybe = M) ☐

If Yes or Maybe, describe what you think you could do

8 **Comments**

SECTION F: QUESTIONS THAT RELATE TO FERTILISER, FOR ALL RELEVANT SURVEY CATEGORIES

1 **Do you use fertilisers in your operations?** (Yes = Y, No = N) ☐

2 **If Yes, what are these used for, in what amounts, do you purchase these and, if so, what is their monthly cost to your operation?**

3 **If No, would you use liquid organic fertiliser if you could self-generate it or have an affordable source?**

4 **If you had available and affordable liquid organic fertiliser, would you be able to change your operations to increase profitability (e.g. grow different higher value crops)?**

5 **Comments**

SECTION G: OTHER MISCELLANEOUS QUESTIONS FOR ALL RELEVANT SURVEY CATEGORIES

1 **If you were to implement a renewable biogas energy programme do you think you could market this as a "showcase" example in your industry sector and win consumer preference (e.g. of shoppers or for green tourism)** (Yes = Y, No = N, Maybe = M) ☐

2 **If you think there may be a potential use of a biodigester in your business/operation, what are the key types of support you would need to take this idea forward?**

	More technical information	Seeing a local demo example	Detailed proposal	Affordable finance package	Local expert installers and aftersales service	Other ______
(✓ as apply)	☐	☐	☐	☐	☐	☐

3 **Do you have any questions or concerns about how biodigester technologies may work in your operation?**

4 **Might you be interested to be part of a demonstration showcase installation example in your business sector** (Yes = Y, No = N) ☐

5 **Comments**

'SHORT FORM' QUESTIONS PROVIDED TO RESORTS

1/ Typically, during the busy time of the season what are the daily occupancy rates of guests and staff?

2/ What is the amount of food 'waste' generated by the kitchen and restaurants (kgs per day) and what is done presently with this waste?

3/ Do you have a distributed system of multiple small septic tanks? Or do you have a system with a centralized septic tank system and use pumps to move septic material from the different guest room 'clusters' to the centralized septic tank system?

4/ What are your electricity costs per month? What are your estimates of the percentage for:
- lighting
- refrigeration
- airconditioning
- pumps for pumping septic material to a centralized septic tank system (if applicable)
- pumps for other purposes
- other? (describe)

5/ What are your gas costs per month? What are your estimates of the percentage for:
- the kitchen
- other? (describe)

6/ What do you estimate is the amount (in kgs per week) of green material that comes from keeping lawns and gardens trimmed and tidy (including removing foliage drop)? Do you have potential sources in your local community for more quantities of this material, including crop residues?

7/ Are you planning any expansions (e.g new rooms or fales) which might provide an opportunity to try new ideas (e.g. localised septic plus greenwaste biodigester systems producing biogas for lighting, refrigeration or air conditioning)?

8/ Do you have questions in mind that you think may be relevant but that are not asked above .... and answers to these questions if applicable?

9/ Do you have general questions about the survey and study being done?

10/ Are you potentially interested in being part of an initial demonstration of biogas technologies applicable to resorts? Alternatively, might you be interested in being a "fast follower" once you have seen how biogas systems might be economically deployed in resorts?