Guide and background information in support of the ‘UNID0 Tonga baseline HTG economic model – with Green Climate Fund support’

Author

Mr Ken Davey

Independent Biogas, Bioenergy & Circular Economy Consultant

Regional Partner:

Institute for Applied Material Flow Management (IfaS)

Australia & Pacific Islands

http://www.stoffstrom.org/en/

61 (0) 410 715 827

Email: nwws@westnet.com.au

Skype: kendavey10

Preamble

What's set out within this document is a guide to extracting comprehensive information from the **'UNID0 Tonga baseline HTG economic model - with GCF support'.**

This document walks readers through the model sheet-by-sheet to build the narrative and the story of this benchmark project. This document also provides background and context where required.

All sheets in this model play a role in building the story of this project. However, a few Sheets are particularly noteworthy:

- **Sheet 5:** 2017 & 2030 Energy Flows is particularly informative and provides pause to reconsider how energy is approached in Tonga and the Pacific Islands.
- **Sheets 6, 7 and 8,** crude oil comparison 1, 2 and 3, are the most important sheets in the model as these sheets set out an infinitely more socioeconomically enabling and empowering energy and circular economy pathway for Tonga and the Pacific Islands.

The main outcome that readers should take from this document is that this benchmark project is feasible, viable, deliverable, and fully financeable through debt financing and equity investment. This debt financing and equity investment is contingent on Green Climate Fund CAPEX support being allocated to specific project elements.

The further development of this project must progress through three specific phases:

1. Conceptual planning (already partially completed).
2. Detailed planning, engineering, and consent authority approvals.
3. Construction and commissioning.

CONTENTS

Sheet 1: The cover sheet

- The development of this model has been driven by Ken Davey, with the assistance of Sanita Naiovi, and Moses Chandra.
- Input related to the 'Hybrid Tropical Grass' (HTG) has been provided by HTG experts, BSW Energy Malaysia with further assistance from Carsten Linnenberg, AD Solutions, Germany..

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Sheet 2: Baseline calcs

- **Baseline calcs** is used to assess a wide range of parameters/outcomes relevant to a single substrate (organic input material for a biogas plant). In this case, Hybrid Tropical Grass (HTG) is being assessed as a 'mono-substrate'.
- HTG is one of a number of transformational, circular economy enabling 'foundation crops' that can be readily established in Tonga to leverage off Tonga's prolific and inexhaustible tropical photosynthesis resources. These foundation crops have the ability to produce very large amounts biomass/hectare/year with these biomasses capable of serving multiple food, feed, fibre, energy, organic fertiliser, and bioproduct roles within agricultural and agri-industrial aligned circular economy systems driven by tropical photosynthesis and enabled by Anaerobic Digestion, biogas, and digestate.
- HTG has multiple feed, fibre, bioproduct and livestock bedding roles to play in support of the development of a number of agricultural and agri-industrial aligned circular economy systems. However, HTG has a more immediate role to play in support of this initial biogas project.

- Lines 37 and 38 of this sheet capture the information that gets carried through the model.

Sheet 3: Crude oil comparison 1

- **Sheets 3, 4 and 5;** Crude oil comparison 1, 2 and 3, are the most important sheets in the model. Step by step, these sheets set out an infinitely more socioeconomically enabling and empowering energy pathway for Tonga. A pathway driven by Tonga's prolific and inexhaustible tropical photosynthesis resources and enabled by Anaerobic Digestion, biogas, and digestate.
- Currently, Tonga's economy and society is plugged into imported liquid fossil fuels over which Tonga has little to no control. Given this, if an alternative is put forward to replace those imported liquid fossil fuels, a valid way to compare that alternative with the existing situation is required. Crude oil comparison 1 starts that comparison process and Crude oil comparisons 2 and 3 builds on this enabling story.
- A barrel of unrefined crude oil = 159 Litres. One litre of that crude oil carries approximately the same energy as 1m3 of renewable methane produced by Anaerobic Digestion: approximately 10kWh of energy.
- Column N, line 38 of the Baseline calcs shows that the proposed industrial scale biogas plant will produce 25,092.54m3/year of renewable methane from one hectare of HTG substrates based on a HTG yield of 450tonnes/ha.
- Given one litre of crude oil carries approximately the same amount of energy as 1m3 of renewable methane, our one hectare of HTG supports a crude oil equivalent yield of 25,092.54Litres.
- If the price paid to Tongan farmers for this HTG is US$10.00/tonne, and the yield is 450tonnes/ha, then the cost of the HTG is US$4,500.00/ha.
- From this we can calculate that the crude oil equivalent price is 17.93US cents/litre (US$4,500.00 ÷ 25,092.54) and US$28.51/barrel (US$4,500.00 ÷ 25,092.54 x 159 ÷ 100).

Sheet 4: Crude oil comparison 2

- Crude oil comparison 2 builds on Crude oil comparison 1 by highlighting how the biogas and digestate can be applied across the Tongan economy.

4.1 Products and initiatives supported from 100% local renewable methane:

- ✓ **Electricity generation:** Via methane fuelled 'Combined Heat and Power' (CHP) systems, the project will support the supply of baseload, dispatchable renewable electricity along with a full range of grid support services.
- ✓ **Process energies:** Via the same CHP's, the project will support the supply of a full range of process energies. These process energies include steam, hot water, cooling, chilling, freezing, and drying. These process energies are simultaneously 'co-generated' via the CHP's from the same amount of biogas fuel.

  NOTE: In a country that can't feed itself because it has no access to affordable and scalable process energies to apply to local vegetative and livestock based food processing, access to affordable and scalable process energies is **at least as important** as access to renewable electricity.

- ✓ **Biomethane to replace imported LPG:** CO2 is the second main constituent gas of biogas. Biogas can be utilised in its 'as-produced' state or it can be 'upgraded' to pure methane by extracting and capturing the CO2. This pure renewable methane is called 'biomethane' and this will replace imported LPG.
- ✓ **BioCNG for land transport:** BioCNG is compressed biomethane. When we align Tonga's short travel distances with its low national speed limit (70kmh), the benefits of small engined, dedicated CNG vehicles are amplified. Such small engined, dedicated CNG vehicles are manufactured in India by a number of Japanese car manufacturers.

These small engine dedicated CNG vehicles can be imported into Tonga as new vehicles cost competitively with many of the second-hand petrol and diesel vehicles currently imported. High-end CNG cars are available from Europe.

From a carbon footprint perspective, it's noteworthy that dedicated CNG vehicles fuelled with 100% BioCNG have a significantly lower lifecycle CO2 emissions footprint than far more expensive electric vehicles. This is the case even when the electric vehicles are powered by 100% renewable electricity.

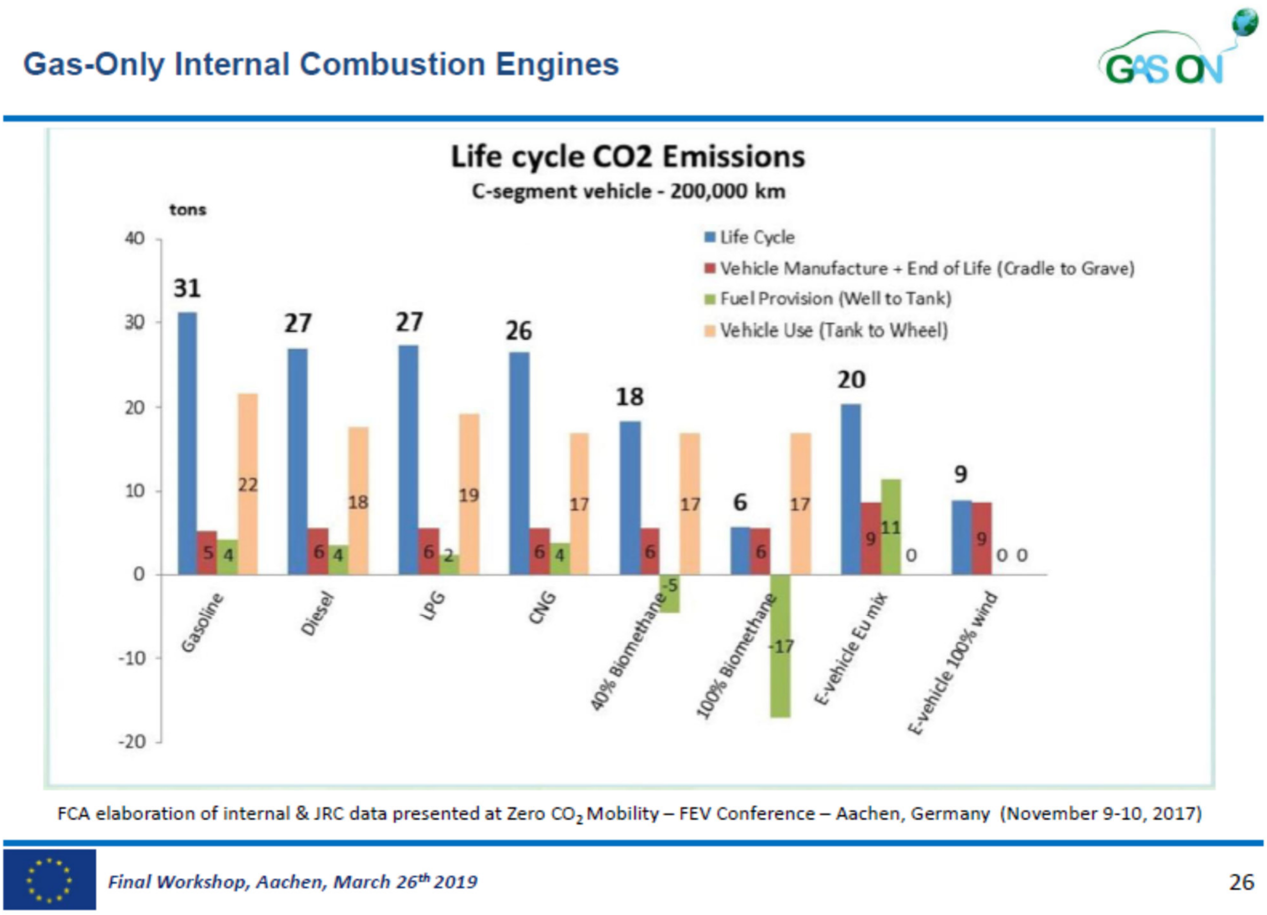

Figure 1: Dedicated CNG passenger vehicles fuelled with 100% biomethane deliver the lowest lifecycle CO2 emissions.

Additionally, and importantly, CNG buses, trucks, tractors, harvesters etc, are readily available.

- ✓ **BioLNG for sea transport:** BioLNG is liquified biomethane. LNG fuelled shipping is the fastest growing element of the global shipping sector and BioLNG is a drop-in-replacement for LNG. The production of BioLNG represents an enormous commercial opportunity for Tonga and the Pacific Islands.

NOTE: Both BioCNG and BioLNG are drop-in replacements for CNG and LNG and are the only renewable fuels that are superior in performance to their fossil fuel comparators.

4.2 Products and initiatives supported from the 100% local renewable 'Green CO2'

- Sheet 8, Model Inputs shows that the project can capture up to 13,271,707kg/year of Green CO2.
- Green CO2 is a rapidly emerging, fully sustainable industrial feedstock for a wide and increasing range of industries as diverse as plastics, food, feed, and concrete.
- In **tropical** Tonga, Green CO2 in the form of **'Dry Ice'** will have multiple domestic and commercial applications. Dry Ice has the capacity to play an influential role in the upscaling and upgrading of Tonga's fledgling, small-scale fishing sector.
- Green CO2 can be used as a feedstock in an Australian developed and commercialised seaweed production system where 1,000kg of Green CO2 produces 850kg of seaweed dry matter with a value of over US$10,000/tonne. This system is earmarked for Tonga.
- **Note:** Within a relatively short period of time, the Green CO2 extracted from biogas to biomethane upgrading will have a value that rivals or exceeds the value of the renewable methane.

4.3 Chemical and biotechnology precursors

- Both the renewable methane and Green CO2 can be used as chemical and biotechnology precursors in a wide and growing range of industry processes.

4.4 Products and initiatives from the digestate:

- The digestate produced by the biogas plant will play an important role in displacing imported chemical fertiliser.

- Additionally, applying this digestate to agricultural land will enable the continual building of soil carbon. This will concurrently support increased yields and participation in carbon markets.
- The digestate can be used ‘as-produced’ or it can be separated into its solid and liquid fractions and subject to a wide range of value adding processes.

4.5 Enabling and endless array of agricultural and agri-industrial aligned circular economy systems

- Because the biogas plant exists, and because it supports an industrial scale process energy platform, the project can support the development and implementation of an endless array of agricultural and agri-industrial aligned circular economy systems: particularly food and feed processing systems. These systems can simultaneously co-produce energy, food, feed, fibre, bio-products, and organic fertiliser. All these outcomes are supported by a 100% local biogas based biorefinery based on a crude oil comparison price of US$28.51/barrel. This adds up to a new Tongan economy and a reinvigorated Tongan society.

Sheet 5: Crude oil comparison 3

- The flat yellow line in the Crude oil comparison 3 graph is set at the crude oil comparison price of US$28.51. This flat yellow line is contrast against the actual historical crude oil price over the last 40 years.
- The flat blue line in the graph represents US$10.00. Over time, as wastes and residues from the development of agricultural and agri-industrial aligned circular economy systems become available to the biogas plant at no cost, the crude oil comparison price will steadily fall to around this US$10.00/barrel of crude oil equivalent.

Sheet 6: 2017 and 2030 Energy Flows

- The **2017 and 2030 Energy Flows** is an important sheet in the context of this model. In essence, this sheet reveals the socioeconomic development inadequacies of the energy strategies that prevail within Tonga and the Pacific Islands. This sheet, and this associated explanation / information, should give pause for reconsideration.
- The top Sankey diagram of this sheet shows that in 2017 energy flows in Tonga were dominated by imported gasoline and diesel. Jump forward 13 years, and the bottom Sankey diagram shows that energy flows in **2030** are still dominated by imported gasoline and diesel. This remains the case after every renewable energy target (which in-fact are only electricity targets) has been met and every energy efficiency measure has been adopted.
- Succinctly stated, after every renewable electricity target has been met, and every energy efficiency measure has been adopted and implemented, the basic conditions for substantive, largely self-determined socioeconomic development still have not been met. This benchmark Circular Economy project will reshape the energy future of Tonga and place the Kingdom on a pathway to a fully sustainable, self-determined energy platform. Every 'energy dollar' that currently flows out of Tonga will be captured, reversed, and circularised within the Tongan economy and this will lead to socioeconomic transformation.

Sheet 7: HTG silage strategic reserve

- Silage is simply the compression of organic material of a suitable dry matter content and particle size into a confined space. This confined space is called a 'silage clamp'.
- A silage clamp is essentially a large organic battery that is capable of effectively storing large amounts of energy for months and years with minimal losses.
- A silage clamp is a highly effective strategic reserve that is not subject to international supply chains. Sheet 7 provides the means of calculating the size of that strategic reserve.

Sheet 8: Model inputs

- The **Model inputs sheet** synthesises much of the information from previous sheets into specific data that will be carried through into the Economic Model sheet.
- This sheet:
  - ✓ Calculates the electricity, thermal energy, biomethane, and Green CO2 yields/tonne of HTG Fresh Matter.
  - ✓ Calculates the electrical and thermal energy generation capacities of the CHP's and the annual availability as a percentage of 8,760hours/year.
  - ✓ Calculates the gross annual electricity and thermal energy outputs along with the combined electricity/thermal energy outputs.
  - ✓ Calculates electrical and thermal energy self-consumption.
  - ✓ Calculates net electricity and net thermal energy available for sale.
  - ✓ Captures the quantity of Green carbon dioxide available if all the biogas is upgraded.
- This sheet also captures all the relevant HTG inputs:
  - ✓ Fresh Matter in support of CHP's in tonnes/year.
  - ✓ Fresh Matter in support of biomethane in tonnes/year.
  - ✓ Total Fresh Matter inputs in tonnes/year.
  - ✓ Fresh Matter inputs in tonnes/day.
  - ✓ Dry Matter inputs in tonnes/day.
  - ✓ Annual cost of HTG substrates (paid directly to Tongan farmers).

Sheet 9: Tonnes and hectares of HTG

- In the **Tonnes and hectares of HTG** sheet, the size of the HTG cropping area is established in hectares and as a percentage of fallow land on Tongatapu.

Sheet 10: CAPEX perspectives

- The **CAPEX perspectives sheet** captures the influence of scale in developing and implementing modern, commercial/industrial scale biogas plants.
- Succinctly stated, the bigger the size of the biogas plant, the lower the cost of energy production.
- As can be seen via the info box, a small 75kWe farm scale biogas plant has a CAPEX value of €9,000/kWe. Conversely, a 1,000kWe (1MWe) biogas plant has a CAPEX value €3,500/kWe. This clearly demonstrates the effects of scale on CAPEX/unit of generation capacity.
- Additionally, the bigger the size of the biogas plant, the more products, and services the biogas plant is able to deliver and support. I.e., the bigger the size of the biogas plant, the more influential the biogas plant will be in enabling broader, circular economy based socioeconomic development.
- Scale in Tonga is also critically important in attracting the best of the European biogas and related sectors to Tonga. Tonga, and the Pacific Islands more broadly, needs a full-service biogas sector and everything that goes with that sector. Developing and implementing a world class, commercial/industrial scale biogas plant in Tonga is unquestionably the best first step in creating that full-service biogas sector.

Sheet 11: CAPEX

- The CAPEX sheet is reasonably self-explanatory. The top section is broken down into subsections A, B, C, D and E with these subsections feeding into a subtotal.
- A contingencies percentage and contingencies amount is applied to this subtotal to arrive at a second subtotal that includes the contingencies allowance.
- Importantly, via Column D, the CAPEX sheet factors in contributions from the Green Climate Fund. It is essential that the Green Climate Fund financial support is allocated specifically to the elements of the project set out in Column D. Leveraging the required debt financing and equity investment in support of this project is based on the Green Climate Fund financing being allocated to these specific elements.
- The **TOTAL** amount requiring debt financing and equity investment captured in C17 of this sheet is the amount that gets carried through into the economic model sheet.

Sheet 12: Economic model

12.1 CAPEX carried through

- The CAPEX amount from the CAPEX Sheet (Sheet 11) is captured in B6. This model has been configured to fund this CAPEX amount from both debt financing and equity investment. The CAPEX split at this stage is set at 90% debt financing (G57 and H57) and 10% equity investment (G60 and H61). However, the model facilitates any combined percentage of debt financing and equity investment that makes up 100% of the CAPEX amount (B6).
- The debt financing interest rate is captured in H56 and loan payback time in H58.

12.2 OPEX perspectives

- The Total Expenses/year is an addition of H39+H43+H48+H49+H52+H53+H54+H55.
- In addition to the specific OPEX costs, a general OPEX cost of 5% of CAPEX/year (H49) has been allocated.
- **Note:** All these costs are subject to an annual increase of 2% (H6)

12.3 Revenue's perspectives

- A project of this scale and diversity has multiple potential revenue streams. However, not all of those revenue streams will be available from day one. Markets for some products and services will need to be developed over time.
- With the above in mind, only revenue streams that will be in play directly after the commissioning of the plant have been considered and analysed at this stage. In essence, what the 'Revenue's Box' highlights, is that there is only upside to this project. As new markets for additional products and services are developed over time this project will only get stronger.

12.4 The analysis line by line - Lines 13 to 25

- Line 13 captures the revenues from C38. These revenues are subject to a 2% annual increase (H5).
- Line 14 captures the OPEX from H38. This OPEX is subject to a 2% annual increase (H6).
- Line 15 captures the servicing of the loan from the debt financier (Column M starting at line 38).
- Line 16 captures the Gross Profit after OPEX and servicing the loan from the debt financier.
- Line 17 captures the fixed portion of the return to the equity investors. This amount is equal to what would have been paid to the debt financier had that portion of the CAPEX been raised as debt financing.
- Line 18 captures the Profit after the distribution of the fixed portion of the return to equity investors.
- Line 19 captures the discretionary return of profit to the equity investors. This amount will be determined annually by the 'Board of Directors' in cooperation with the investors. Such decisions will be influenced by tax commitments and retaining profits for the development of new markets and new projects. At this stage, this discretionary return is set at 10% (H60) of Line 18.
- Line 20 captures the profit held over by the company after all OPEX and debts have been serviced and total returns to the equity investors have been made. This amount will be determined annually by the 'Board of Directors' in cooperation with the investors (see above).
- Line 21 captures the total amount directed to equity investors.
- Line 22 captures a discretionary amount of the profit that may be paid to substrate suppliers in exchange for their long-term substrate supply commitments to the project. This is a payment in addition to the payment they receive for the substrates captured in the OPEX H39. The source of this discretionary, variable percentage is G63.

- Line 23 captures the final profit held over by the company.
- Line 24 captures the accumulated profit.
- Line 25 captures the Present Value.

12.5 The project summery box - Column B, lines 27 to 33

- Line 27 captures the total return of profit to substrate suppliers over 20years (this is discretionary).
- Line 28 captures the original equity investment secured from the equity investors. This amount is equal to H61.
- Line 29 captures the total return to equity investors over 20 years from both fixed and discretionary sources.
- Line 30 captures the percentage increase from the original equity investment to the total returns to investors over 20 years (% increase of B29 over B28).
- Line 31 captures a compound interest rate comparison. This has been included because many people don't understand Net Present Value or Internal Rate of Return. However, most people understand the principal and power of 'compounding' and as such this is a more widely informative metric.
- Line 32 captures the Net Present Value.
- Line 33 captures the Internal Rate of Return (IRR).
- Line 34 highlights the fact that the project has a strong, positive Present Value from Year 1.