Konsorsium PETUAH (Perguruan Tinggi Untuk Indonesia Hijau)

Pengetahuan Hijau Berbasis Kebutuhan dan Kearifan Lokal untuk Mendukung Pembangunan Berkelanjutan
(Green Knowledge with Basis of Local Needs and Wisdom to Support Sustainable Development)

TECHNICAL REVIEW

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Private and Government Partnership for Electricity from Waste Development: the Case of PT NOEI and SARBAGITA Governments in Bali

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1. BACKGROUND

Municipal solid waste becomes a common problem faced by cities in the developing world including some districts and cities in Bali. Bali is a provincial administrative region that consists of eight districts and one city government. The administrative area of each local government in Bali is shown in Figure 1.

Figure 1. Administrative area of districts in Bali

Based on population census in 2010, Bali was inhabited by 3.9 million people but more than 2.2 million or 57% is concentrated in the southern part of the island distributed over four districts. The breakdown of the population per district is shown in Table 1. The southern districts are

Denpasar, Badung, Gianyar, and Tabanan. These four local governments have the highest population density with the City of Denpasar leads at 6,171/km², District of Badung at 1,298/km², District of Gianyar at 1,277/km², and District of Tabanan at 501/km².

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Table 1. Population of Bali

District/ City	Area (km ²)	Household	Number of population			Gender Ratio	Density per km ²
			Male	Female	Total		
1 District of Jembrana	842	72,661	130,062	131,576	261,638	99	311
2 District of Tabanan	839	106,197	209,308	211,605	420,913	99	501
3 District of Badung	419	142,503	277,536	265,796	543,332	104	1,298
4 District of Gianyar	368	103,516	237,493	232,284	469,777	102	1,277
5 District of Klungkung	315	43,657	84,503	86,040	170,543	98	541
6 District of Bangli	521	55,473	109,109	106,244	215,353	103	413
7 District of Karangasem	840	103,093	198,650	197,837	396,487	100	472
8 District of Buleleng	1,366	173,041	311,394	312,731	624,125	100	457
9 City of Denpasar	128	228,119	403,293	385,296	788,589	105	6,171
Total	5,637	1,028,260	1,961,348	1,929,409	3,890,757	102	690

Source: Facts and Figure of BPS Bali 2013 (Result of Census 2010)

Policy Recommendations

- Hydrogen sulfide found in the LFG recovered at TPA Suwung landfill should be further investigated and adoption of state of the art or proven technique to eliminate the substance to avoid corrosion and wear on the power plant equipment.
- The Power Purchasing Agreement (PPA) with the state electricity company could be reviewed including re-negotiating nominal value of *feed in tariff* by referring to the new government policy on electricity from biomass.
- Compost production should be explored or optimized as this type of by-product has begun to find its market in Bali.
- Clean Development Mechanism (CDM) component of the financing model should be reviewed and re-examined as price of CER seems settled in and around EUR 9/ton equivalent CO₂ and is forecasted to continue around this level.
- Exploring other revenue options such as tipping fee but after comprehensive study as it involves approval from SARBAGITA governments.
- Identifying collaboration with external parties who may be interested in the business chain of solid waste. For example, a company called Enviro-Pallets works on processing plastics waste and convert them into pallet has been in operation in Bali that requires substantial volume of plastic waste every year.

have the highest population density with the City of Denpasar leads at 6,171/km², District of Badung at 1,298/km², District of Gianyar at 1,277/km², and District of Tabanan at 501/km².

The huge number of households in the south of Bali has presented challenges to the local governments in dealing with municipal solid waste. To keep all of the waste produced by the city, the government nominates an area in Suwung as a waste disposal site hence the name TPA Suwung. TPA stands for *Tempat Penampungan Akhir* which literally means Final Disposal Site. The location of TPA Suwung is circled as shown in Figure 2.

Figure 2. Location of TPA Suwung

TPA Suwung was developed in 1986 as the city solid waste disposal site. It was a 38-hectare site grown by mangrove vegetation. The site was used mostly by the City of Denpasar to receive their solid waste collected throughout its administrative area. Effectively, the site was an open dumping solid waste. PT NOEI reported that in 2005, the volume of solid waste delivered to the site was around 445 tons every day. The company found that the waste consisted of 86% organic and 14% non-organic material. Further, the organics waste was made of 55% wet solid waste and 31% wet solid waste. The non-organic waste contained 9% plastic and paper wastes. It was reported there was no Copper or Aluminum waste and the plastic was of low quality.

Prior to 2005, there was no activity to further process the waste received at TPA Suwung except it was left piling up and decomposed naturally and releasing methane gas into the atmosphere and bad odor to the surrounding area. Methane gas is a greenhouse gas that has a worse environmental impact than carbon dioxide. The comparative impact of C₄H₄ on climate change is 25 times

greater than CO₂ over 100 years (EPA, 2010). The site condition during this period is shown in Figure 3.

Figure 3. TPA Suwung site appearance prior to 2005
(Source: BPKS)

Bali has been known as one of the main tourist destinations in Indonesia and southern Bali has been developed as the central area of the Bali tourist industry where most of the tourist amenities are located. The number of tourists visiting Bali according to the Bali Tourism Office is shown in Figure 4. And the composition of accommodation by the district is shown in Table 2 and it is shown that 87% of tourist accommodation is located in the area of SARBAGITA. Therefore, the existence of TPA Suwung as simply an open waste disposal site could potentially inhibit the successful development of Bali's tourism industry.

Figure 4. The trend of tourist visiting Indonesia and Bali
Source of data: (BTO, 2016)

Fusce aliquet pede non pede. Suspendisse dapibus lorem pellentesque magna. Integer nulla. Donec blandit feugiat

Table 2. Distribution of tourist accommodation by district in Bali 2014 (Source: Bali Tourism Office, 2016)

District / City	Class of Hotel					Total
	Five Star	Four Star	Three Star	Two Star	One Star	
1 Jembrana	0	0	2	0	0	2
2 Tabanan	2	0	0	0	0	2
3 Badung	40	46	37	12	11	146
4 Gianyar	6	7	3	1	1	18
5 Klungkung	0	0	4	1	2	7
6 Bangli	0	0	0	0	0	0
7 Karangasem	1	2	2	1	1	7
8 Buleleng	1	2	8	2	1	14
9 Denpasar	4	5	7	7	8	31
Total	54	62	63	24	23	227

In view of the growing amount of city solid waste delivered to the site and environmental problems raised from the site, the government then initiated a plan to develop a sustainable management program for TPA Suwung. In 2001, the four local governments; the City of Denpasar, District of Badung, District of Gianyar, and District of Tabanan established an agency to administer the Municipal Solid Waste (MSW) within these areas. The agency is known as SARBAGITA which uses syllables taken from the name of each district. The 'SAR' associated with DenpaSAR, 'BA' is associated with BADung, 'GI' is associated with Glanyar, and 'TA' is associated with Tabanan. The SARBAGITA government subsequently established an agency known as Badan Pengelola Kebersihan SARBAGITA, abbreviated as BPKS, to work as the sole agency to represent the four governments in dealing with the management of TPA Suwung.

In 2004 SARBAGITA invited the private industry to introduce sustainable management of MSW at the location of TPA Suwung. It was clear to the local governments that to open a new landfill site within this tourism area would be very difficult. Therefore, the decision was to optimize the location of the existing landfill site TPA Suwung.

In March 2004 PT NOEI in cooperation with Organics, UK, presented to SARBAGITA a feasibility study on the introduction of GALFAD at the TPA Suwung. The technology is derived from the Gasification, LandFill gas, and Anaerobic Digestion. These three different technologies will be applied at TPA Suwung to manage the MSW. Among bidders, PT NOEI was selected by SARBAGITA and awarded the cooperation contract to manage the site and to produce electricity and recyclables

from the MSW collected in the districts administered by SARBAGITA. The project is also known as Instalasi Pengolahan Sampah Terpadu (IPST) which literally means an integrated waste processing facility. The contract was signed in May 2004.

PT NOEI will output two main products from the MSW project. They are energy and recyclables. The energy is derived from the MSW through (1) recovery of landfill gas extracted from the landfill, (2) recovery of biogas extracted from the anaerobic digester, fed with high moisture content organic waste, (3) pyrolysis-gasification of dry organic waste.

The recovered energy will be used to generate electricity which will be fed to the local grid. In doing so, the project will contribute to the reduction of greenhouse gas (GHG) in two ways: (1) through the elimination of methane gas which otherwise release into the atmosphere, (2) through the displacement of fossil fuel-based electricity generation with the on-site carbon-neutral electricity.

The project will be executed in four phases. Phase 1: installation of landfill gas (LFG) and the recovered LFG will be flared. The work started in May 2007.

Phase 2: installation of 2 MW generator powered by recovered LFG. Electricity production was scheduled for July 2008.

Phase 3: installation of a pyrolysis gasification plant fed by the dry portion of the organic waste. This phase would add 2.8 MW power to the total generation capacity and it was scheduled for an operation in August 2009.

Phase 4: installation of the second pyrolysis gasification plant and installation of anaerobic digester. The anaerobic digester will process the new wet waste and the LFG implemented in Phase 1 will eventually cease. And instead of LFG to feed the engine, biogas from the digester will be the fuel. Upon completion of Phase 4, it would add 4.8 MW more power which will double the generation capacity to 9.6 MW and was scheduled for an operation in May 2012.

The other product targeted by PT NOEI as recyclables. Through their research, it was found that the solid waste disposed at TPA Suwung has little 'good plastic' and 'good quality paper' that can be recycled. Also, there was no sign of waste from the tourism industry such as hotels,

restaurants, or fast food outlets. Therefore, the main recyclables from the IPST SARBAGITA shall be compost.

2. TECHNOLOGY

GALFAD is an integrated waste disposal system designed to maximize energy recovery from unsorted municipal solid waste. The simple objective is to use appropriate conversion technology for each type of waste. The GALFAD method will be implemented by PT NOEI at TPA Suwung. The equipment plant layout is shown in Figure 5.

Figure 5. GALFAD site plan layout (Source: PT NOEI)

Figure 6. GALFAD technology for TPA Suwung (Source: Organics UK)

Figure 7. Anaerobic Digester plant schematic
(Source: Manvit UK)

2.1 Waste Separation

Arriving waste is separated into wet waste and dry waste-based on its size. The smaller materials contain a high proportion of organic waste and considered as wet waste, the larger material is considered as dry waste, these are mainly garden waste, paper, and wood waste. The separation is carried out using a combination of two rotary screens and manual sorting for coarser materials.

2.2 Pyrolysis Gasification

Pyrolysis Gasification is a combination of pyrolysis and gasification processes. The pyrolysis process converts dry waste into low molecular weight hydrocarbon gas or pyro-gas. The residue of the pyrolysis process is then fed into the gasification unit, in which this residue is broken down further into methane, carbon monoxide, and hydrogen or water-gas through a water-gas shift reaction.

Energy from the pyro-gas and the water-gas is recovered through the isothermal combustion process in the high-temperature oxidation unit. In order to ensure complete combustion and therefore minimize the generation of pollutant gas, all gases, and any small particulate matter are maintained at a constant temperature of 1250 oC for a minimum of two seconds. The heat from the combustion process is used to produce steam in the boiler which in turn drives the turbine that generates the electricity.

The pyrolysis gasification process recovers about 60% to 90% of the original energy contained in the feed. Both processes are conducted at high temperatures and

oxygen-deficient environments, which differentiate them from incineration. These conditions prevent the formation of dioxins and furans – the by-product of incineration. Moreover, the air is only introduced in the thermal-oxidation unit. The exhaust gas from the thermal oxidation unit, however, may contain substances such as heavy metals, ammonia and NO. To treat these gases, the Project will employ a bag-house filter, a dry SOLVAY process, and cyclone separators to prevent these substances from escaping. The resultant emission levels are below standards set by the EU (Source: PT NOEI PDD).

2.3 Landfill Gas Recovery System

The project will recover landfill gas from the new incoming waste. The landfill gas collection system consists of vertical wells drilled into the capped landfill cells, connected together with medium density polyethylene piping. The structured landfill system will allow the reuse of landfill space once the waste is inert, such that the physical extent of the LFG collection system can be minimized.

Landfill gas will be drawn by a gas delivery unit, which is a package of equipment including a gas blower, filtration equipment, dewatering and gas drying equipment, chillers and other associated instruments and controls. The unit collects and delivers the gas to the engines in a manner that will ensure long-term and stable operation.

2.4 Anaerobic Digestion

In anaerobic digestion, the waste is fed into a digester in which the anaerobic bacteria decomposes the waste into methane, carbon dioxide as well as minor quantities of other gases. The environment in the digester is such that the decomposition is accelerated as compared to what would happen in the natural environment, allowing a rapid reduction in waste volume. The digester would be a gas-tight bioreactor with little or no methane leakage.

3.PROGRESS TO DATE

Since the contract was signed in May 2004, PT NOEI developed the project following its phase as follows. The project was divided into four phases; Phase 1, Phase 2, Phase 3, and Phase 4. The site plan of TPA Suwung municipal solid waste is shown in Figure 8.

Figure 8. Site plan of TPA Suwung
(Source: PT NOEI)

3.1 Progress Phase 1

Phase 1 was the installation of landfill gas (LFG) and the recovered LFG will be flared. Phase 1 had been completed. And the landfill and LFG prior completion of Phase 2 was flared. Figure 9 shows the landfill pipe network and including the wells.

3.2 Progress Phase 2

Phase 2 covers the installation of 2 MW generator fed by recovered LFG. The electricity production was scheduled for July 2008. In July 2009, our Postgraduate Program on Energy Management Udayana University visited the site and conducted an on-site tour. At the time, we observed that Phase 2 was completed and we could see the power plant running and injecting electrical energy into the PLN distribution network.

The powerhouse consisted of four Jenbacher engines manufactured in Austria. The Jenbacher engine JGS 320 GS-BL output power range of 0.25 to 3 MW and operate on natural gas or a variety of specialty fuels, including landfill and coal mine gas or alternative fuels like biogas, sewage gas, and industrial waste gas. The photo of the powerhouse with the Jenbacher engines is shown in Figure 10.

Figure 9. Landfill gas well layout at TPA Suwung
(Source: BPKS)

At the time of the visit, four Jenbacher engines were installed on-site and each with maximum output 1.043 MW hence the total capacity of 4 MW but was told that at any time only two engines were in operation. With two engines in operation, the plant could produce power of up to 2.086 MW. This power was injected into the 20 kV PLN distribution network through the two-unit medium voltage transformers each of 3,000 kVA capacity.

PT NOEI has signed a Power Purchasing Agreement (PPA) with PLN who will buy the electricity generated from the plant. PPA was signed for 15 years and the price was USD 0.07 cent/ kWh or IDR 685.9/ kWh.

Figure 10. The powerhouse of TPA Suwung

3.3 Progress Phase 3

Phase 3 was the installation of a pyrolysis gasification plant fed by the dry portion of the organic waste. This phase would add 2.8 MW power to the total generation capacity, hence a total of 4.8 MW, and it was scheduled for an operation in August 2009. However, during our visit in 2009, the progress was up to the construction of the waste separator plant and its piping networks. The waste separator plant is shown in Figure 11.

Figure 11. Waste separator plant

The construction of Structured Landfill Cell (SLC) at the time was progressing. The picture of SLC is shown in Figure 12. The SLC is essentially a concrete chamber that has top and front access. Top access is for receiving new wet type waste from sent by the conveyor belt and also for gas pipe access. The front access is for removal of the waste when it became inert. When the SLC is filled up then the two access will be closed using plastic sheets to contain the gas and create a conducive environment for gas production. The SLC was built to recover methane gas from a new 'wet' type of organic waste. Five units of SLC have been built including a piping network to transport the recovered methane gas to the powerhouse.

Figure 12. Structured Landfill Cell

3.4 Progress Phase 4

Phase 4 was the installation of the second pyrolysis gasification plant and the installation of anaerobic digester. The anaerobic digester will process the new wet waste and the LFG implemented in Phase 1 will eventually cease. And instead of LFG to feed the engine, biogas from the digester will feed the engines. Upon completion of Phase 4, it would add 4.8 MW which will double the generation capacity to 9.6 MW and was scheduled for an operation in May 2012.

LPIU CORE Universitas Udayana conducted another visit in March 2015 but the pyrolysis-gasification and anaerobic digester had not been built. Therefore, Phase 4 of the project was effectively unexecuted.

4. PROBLEM

The GALFAD technology proposed by PT NOEI for managing the MSW at TPA Suwung is an appropriate technology that could potentially solve most of the problems at TPA Suwung.

- The technology could avoid the piling up of solid waste that delivered to the site at 445 tons/day
- The energy recovered from the existing landfill by extracting the LFG could avoid the release of methane into the atmosphere, therefore, reducing the GHG emission from the site. The total estimated CO₂ abated for the first credited period was 287,572-ton equivalent.
- The method proposed could also prevent the release of odor gases into the atmosphere.
- The use of anaerobic digester could recover gas (biogas) from the newly delivered wet type of organic waste.
- The pyrolysis-gasification will use the dry solid waste and convert it into gas for gas turbine engines hence no more piling of solid waste.

- The LFG is converted into electricity fed into the grid which therefore reduces the consumption of fossil-based fuel for electricity generation through the use of on-site carbon-neutral electricity generation.

As of today, the project only recovers methane gas from the landfill area and no gas from the Structured Landfill Cells. This landfill gas LFG was fed to the powerhouse and producing around 0.8 MW electricity. The current level of power output is lower than the capacity of one unit Jenbacher engine which has 1.043 MW while there were two engines on site. The power was supplied to PLN.

The SLC is not operated due to the high cost associated with the running of the waste separator plant that mainly driven by the electric motor. The conveyor belts that supply the SLC with selected solid waste are powered by an electric motor and the electricity cost has inhibited the operation of the plant.

The landfill gas recovered from the gas wells contains not only methane (C₄H₄) but also other substance such as carbon dioxide (CO₂) and other substances such as oxygen, nitrogen, hydrogen sulfide, hydrogen, and non-methane organic compounds (NMOCs). Trace organics such as hydrogen sulfide and others and particulates can cause corrosion and excessive wear on the equipment (Worel et al, 2015), and therefore care should be taken to improve the quality of the gas. The LFG recovered from TPA Suwung has a high content of hydrogen sulfide. Treatment or method has been used to filter out the substance but the cost for replacing this filter component was high compared to the energy produced by the plant.

PT NOEI submitted a proposal for CDM inclusion of the TPA Suwung project by preparing Project Document Design (PDD). The registration was accepted by CDM Executive Board in May 2007. The objective of the proposal was to get Certificate Emissions Reduction (CER) as part of the financing components of the project. Certified Emission Reductions (CERs) are a type of emissions unit (or carbon credits) issued by the Clean Development Mechanism (CDM) Executive Board for emission reductions achieved by CDM projects and verified by a DOE (Designated Operational Entity) under the rules of the Kyoto Protocol (Kollmus et al, 2010).

The tradable unit under CDM is CER and each CER is equal to one metric ton of CO₂ equivalent emission abated. In

2008, the average CER price was US\$ 16.7 (EU 11.46) an average of 16% increase over the 2007 price (Kollmus et al, 2010). The trend of CER's price is shown in Figure 9.

Based on discussion with the Head of BPKS that the CDM application had not reached a conclusive decision as to whether the project would be awarded CER by CDM Executive Board. Over time, the price of CER also decreased which demotivated the follow up by the project to pursue progress, and if any recommendation provided by CDM Executive Board. The fluctuation of the CER price is shown in Figure 13. The price of CER decreased and reached the lowest level in 2012 when the first commitment of the Kyoto Protocol ended. But, after that, the price slowly picking up and was forecasted to be relatively stable afterward.

Figure 13. The fluctuation of CER price and future forecast

Power Purchasing Agreement (PPA) was signed by PT NOEI and PLN with the price set at USD 0.07 cents/ kWh or close to IDR 700/kWh. According to the ministerial regulation, PP No 4/2012, electricity produced by biomass plants can be sold to the utility on the bases of excess energy and not power plant dedicated to supplying power purposes or commonly known as Independent Power Producers (IPP). The feed-in tariff for biomass electricity was at IDR 656/kWh and Bali was designated as a region that has a unity scaling factor. This has hampered the development of electricity from biomass projects. In 2014, the government then changed the regulation by releasing ministerial regulation PP No 27/2014. This new regulation set the new feed-in tariff for biomass electricity generation at IDR 1,150/ kWh. Further, in the case of Bali, the tariff is multiplied by 1.5 which equal to IDR 1,725/ kWh (PP 27/2014).

According to the agreement between PT NOEI and the governments of SARBAGITA, the SARBAGITA governments

supply solid waste up to the TPA Suwung site without paying fees. According to PT NOEI that such a scheme is not practiced elsewhere in the world. The councils have to pay a fee known as the tipping fees to the site manager every time their dump trucks deliver waste to the landfill. The fee is based on the weight or volume of the waste. The project has built weighbridge near the gate of the IPST site to measure the volume of waste carried and delivered by the vehicle.

5. CONCLUSION

- The GALFAD technology proposed by PT NOEI to manage municipal solid waste at TPA Suwung is an appropriate technology combination that could solve problems of solid waste at TPA Suwung. The pyrolysis gasification solves the problem of dry waste. The Anaerobic Digester solves the wet solid waste or organics component of the waste.
- Despite the large sum of investment had been allocated at TPA Suwung by PT NOEI, however, they were not able to completely execute their own project design due to financial problem.
- The financing model of PT NOEI relied heavily on the sale of electricity and CDM fund and this appeared insufficient to support the sustainability of the project.
- The TPA Suwung main problem is therefore not yet solved. The landfill is filled up with the solid waste of the cities as there is no system to process the waste.
- Current policy changes could support the project. The Ministerial Regulation which set new *feed-in-tariff* for electricity from biomass is a conducive climate to attract more renewable energy development and also re-negotiation agreement with parties involved for the existing project developers.
- PT NOEI needs to identify options to develop collaboration with external parties which might be interested in the business chain of solid waste. This could provide an additional source of revenue for the project.

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