DESIGN AND IMPLEMENTATION OF A LARGE DIGESTER FACILITY FOR PUTRESCIBLE WASTE –PROCESS IMPLEMENTATION AND LESSONS LEARNED

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Introduction: This paper summarises the development, construction and commissioning of the food residuals to energy plant located in Camellia, Sydney, Australia. The facility was commissioned in 2003 and is designed to process 82,000 tonnes/annum of source segregated "pre-consumer" food waste and industrial sludges/flotation foams to dried fertiliser, liquid fertiliser concentrate, electricity and treated water on a footprint of less than 1.5 ha (AGGO 2004, EarthPower Technologies Sydney 1999; Thiele 2000 a,b).

Project Development: In 1996 the project development consortium that was later to become EarthPower Technologies called international tenders for design build expertise to provide a waste to energy plant in Sydney for source segregated supermarket wastes and food processing wastes. A leading German firm, BTA GmbH, responded to the tender. BTA had at that time approximately 20 plants around Europe treating mostly source segregated municipal solid waste (MSW). The waste streams specified by EarthPower Technologies were essentially food stuffs with a fat and nitrogen content that was higher than that of MSW.

A joint NZ/Germany International Science & Technology Cooperation (MoRST, ISAT) project between BTA and Waste Solutions Ltd (WSL) specialising in fat digestion resulted in WSL being introduced to the project. In the early 1990ies WSL was originally part of AgResearch and was engaged in research and implementation in the anaerobic digestion of farm and primary industry wastes. NZ primary industry waste materials are high in fat and protein whereas most overseas research has focussed on carbohydrate rich types of waste.

The project responsibilities evolved in 1998. EarthPower took responsibility for the waste supply and BTA took responsibility for the waste reception, contaminant removal and waste processing to produce a single more or less uniform feed stream for the digester component of the project. The BTA component was labelled the pulper component. WSL was to design the digester component, the fertiliser component and the water treatment component.

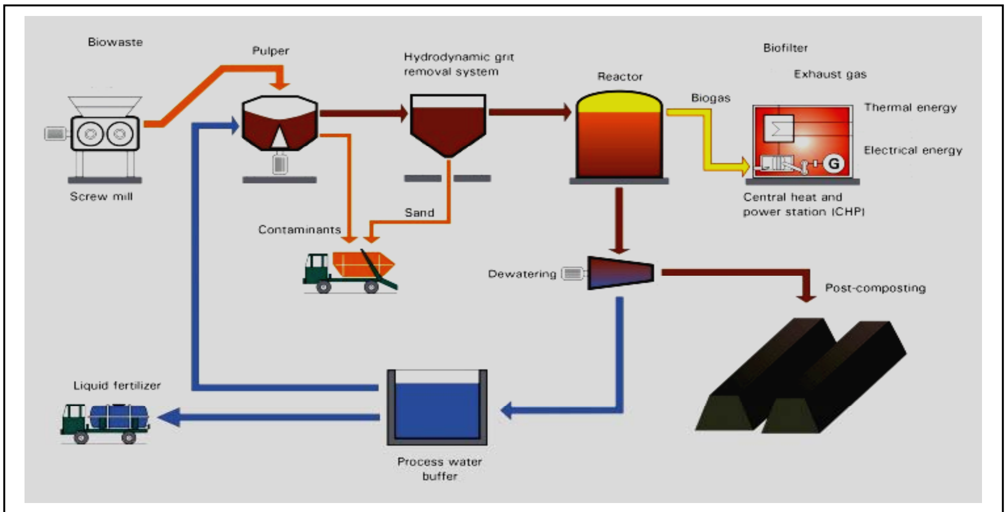

Figure 1: The one step BTA process

At this time BTA advised EarthPower that there was a common misconception that the technology was still in its infancy and that this was the reason why many waste to energy plants experienced operational problems and/or closure. They stated that the technologies were available and proven but needed to be selected to suit the type of waste to be processed. Their advice to EarthPower was “If you want this project to be successful there are two things EarthPower must do, Know the Waste and Control the Waste.”

A typical BTA plant is shown in Figure 1 above. It consists of

- primary size sorting and size reduction, usually by screw mill and/or trommel screen
- pulping with rake and heavy fraction removal
- hydrodynamic grit removal and feed buffer storage
- digestion
- sludge dewatering
- composting of the dewatered solids
- recycle of the liquor to pulping with the excess being applied to land as fertiliser.

EarthPower had defined the wastes they were proposing to process in a detailed spreadsheet. This spreadsheet was quite specific giving quantity, solids content, volatile solids content, fat content and the possible contaminants that could occur in each stream, such as cans, bones, supermarket carry bags. Each waste stream was identified by type and many specifically identified from named sources. The waste streams were all source segregated “pre-consumer waste” with high quality and energy content.

To process this waste EarthPower wanted a low cost, highly automated and highly reliable plant all to be suitable for construction on a tight site within the greater metropolitan Sydney area. EarthPower wanted to produce a pelletised fertiliser from the digestion residue because their own investigations had shown a much better return for dried fertiliser when compared to compost. They wanted to have a “zero discharge” plant and to clean up effluent to a point were it could be marketed to local industry as process water.

Design work commenced and the plant concept was laid out over the following years. Samples of the specified pre-consumer waste were provided by EarthPower and were imported to the MAF Transitional Facility of WSL in Mosgiel, NZ.

The BTA one step process was extended by modification in conjunction with EarthPower or at EarthPower’s specific requirement. Note that these changes occurred slowly over a number of years including a period after the contract to build the plant was signed. Anything that changed the business model had to go back to the board for approval. Technical changes were:

- The screw mill was deleted at EarthPower’s demand to save capital costs because the waste they were confident they had secured would not require such pre-treatment. Both WSL and BTA were reluctant to delete the screw mill step because of the human proclivity for dumping rubbish in an available bin was alive and well in Australia. In the end EarthPower prevailed because the wastes were all “pre-consumer” with strictly limited access to the waste bins and EarthPower proposed numerous systems for preventing the inclusion of “foreign objects”. Foreign objects being contaminants not listed in the spreadsheet. BTA had operated one plant with a very similar waste specification on a large farm in Germany and this had worked well for a number of years with out needing waste pre-treatment with a screw mill.

- "Zero discharge' was deleted because the filtration membrane suppliers could not guarantee long term performance and the operating cost of producing re-usable water was many times greater than the purchase price of water from the Sydney Water Board.
- The biogas was no longer to be sold to local industry for process heat but used to generate electricity for sale on the green electricity market (REC system) announced by the NSW government.
- Fertiliser production was reduced. Originally EarthPower wanted a plant with a large "dial" on it that they could turn to adjust the mix of products generated. Turned one way it gave lots of fertiliser, the other gave lots of gas. There had always been plans for a second expansion stage of the facility with another pulper and digester. It became apparent that EarthPower thought that they could then turn the dial all the way to maximum gas and that the installed dryer plant would still be big enough to process the residual fertiliser production without requiring expansion of this component. Much modelling and intensive meetings were required to convince EarthPower that they would still need to expand the dryer component if more sludge was to be dried.

Many other components changed over the years some to increase the financial return from the plant some to reflect changes in other components. What evolved was a highly integrated plant, the most integrated solid waste digester in the world at the time.

Project Implementation: Other aspects were also evolving. EarthPower realised that their waste or feed specification was very specific and that if they were unable to deliver each stream as described this would jeopardise the plant performance guarantees they required for the financiers. WSL pointed out that only the overall waste mix composition was important rather than individual streams. A document was written that described the mass and biochemical composition requirements for the waste mix. This would allow EarthPower to substitute broadly similar waste streams for those that might be unavailable as long as the overall waste mix still met the specific requirements. This gave EarthPower much more flexibility in obtaining wastes but still allowed the very specific and demanding performance guarantees required by the financiers. The detailed waste specification spreadsheet was retained due to its implications on materials handling of the individual contaminants.

A head contractor was located and a guaranteed maximum price for the plant was agreed. through a number of iterations to meet EarthPower's demands for more products and a lower price.

The construction contract was delayed reportedly because the financiers required that EarthPower have all the waste contracts in place. Eventually it was announced that the last waste contract was complete. The construction contract was signed and construction started rapidly as only a relatively short period was allowed between contract initiation and final completion tests for the plant.

This sounds simple but in fact the plant design was still proceeding in parallel on three separate variants being:

1. The base case, which was the basis of the contract but was commercially not viable because the neighbouring industry who was to take the gas no longer wanted it.

2. The Co-gen option, where all the biogas would be used to generate green electricity and the waste heat from the engines used in the dryer and to drive a thermal ammonia stripper.
3. The Grease Trap Option, where the plant capacity was to be increased by 25 % via co-processing of waste with high fat & protein contents.

The work was further complicated by some component suppliers doubling their prices or suddenly announcing that they needed twice the power they had initially indicated or stating “didn’t we mention the 100 or 1000 m^3/day of water required”.

These issues were eventually resolved and the plant was ready to start process commissioning in November 2002.

Part way though the construction EarthPower issued a new waste specification spreadsheet with variants for the co-gen and grease trap options. On examination it was found that these spreadsheets bore no resemblance to the contractual spreadsheet. The wastes were no longer from supermarkets and industries but were now mostly hauler supplied wastes. EarthPower was no longer dealing with the waste generators but with the firms that trucked the wastes away. All the assurances about their ability to control the access to the waste and the type of contaminants that could enter the waste stream were gone. WSL immediately called for design variations to alter the plant to cope with the drastic change to the nature of the waste. EarthPower protested claiming that the wastes were the same just being hauled by different trucks. We requested a written guarantee that the wastes and contaminants would remain true to the original waste specification as we had to guarantee the plant performance. EarthPower refused to do so. EarthPower announced they were going back to the original spreadsheet and that they would ensure that the wastes met the contractual requirements.

Figure 2 gives a conceptual flow diagram for the final process design that was implemented at the Camellia site.

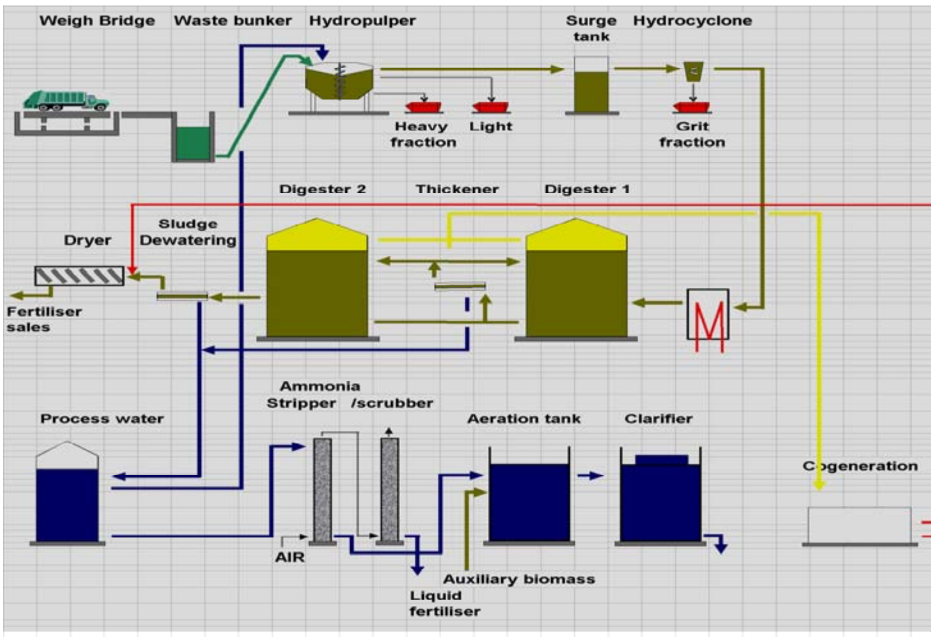

Figure 2: Conceptual process flow diagram of the food waste digestion facility built at the Camellia site in Sydney.

Laboratory work: Throughout the development period of 1997 to 2001 WSL staff visited Australia to view and sample the various waste streams specified in the contractual spreadsheet. We were not allowed to bring supermarket waste samples into New Zealand because of a complete ban on chicken products even though our lab is a fully licensed MAF Transitional (quarantine) Facility. For the supermarket samples materials were purchased from New Zealand supermarkets to a recipe developed by EarthPower Technologies based on local supermarket shrinkage lists and audits of supermarket waste bins in Sydney. The various waste samples were combined in the ratios given by the spreadsheet, macerated and chemically analysed. This analysis was used in part to formulate/optimise the final waste specification mentioned above.

The packaging was removed from the supermarket products to simulate the action of the pulper component of the plant. Paper was added to the waste mix because the pulping action breaks paper and cardboard into pulp which is not removed from the feed pulp by the pulper. Plastics, metals, glass, grit and stones and similar contaminants are removed by the pulper systems in the Sydney facility and were thus not included in the tested waste mix. The mixed waste (industrial pre-consumer food waste + supermarket waste) was macerated and also used for the digestibility tests, an important check to assure proper performance of digester and dryer components.

After discussion with EarthPower Technologies, digester trials at 120 litre scale were started for two main purposes.

1. To demonstrate that the wastes did not contain any inhibitory substances that would down grade the plant performance and hence the performance guarantees.
2. To produce sufficient digester residue from the digestion of the waste mix that could be dried and formulated to a granulated product and sent to Australia for plant growth trials by the fertiliser marketeer who was to take the fertiliser from the plant.

LEFT RIGHT

Figure 3 Granulated fertiliser produced at full scale at the EarthPower facility at Camellia (LEFT, 2004)) and the granulated fertiliser produced during process development and validation at Waste Solutions Ltd (RIGHT, 2002). 1 square = 1 cm^2.Photograph LEFT from Earthpower Technologies Sydney website: www.earthpower.com.au

The digestion tests demonstrated that the design waste was highly digestible and provided biogas yields up to the best theoretical yields expected. The yields obtained (2 months) were at least 70 % above those typical of BTA plants on biowaste on a dry solids input basis. This reflected the high quality nature of the wastes specified by EarthPower and the effective digestion process conditions designed to maximise biogas production at this plant. Other laboratory work examined water treatment options and ammonia capture options from the effluent of the digester facility.

The dried fertiliser production was validated using a small pilot plant owned by Flo-dry Ltd of New Zealand, the full scale dryer technology supplier. Figure 3 shows the fertiliser produced at lab scale and the fertiliser produced at full scale. Repeated site visits to the waste generators in Sydney (specified by EarthPower Technologies) to inspect the waste streams and the associated laboratory work created the confidence that the digester and dryer plant design was appropriate and that the contractual performance guarantees were achievable provided EarthPower supplied the wastes as specified.

Commissioning: At the beginning of November 2002 WSL started the process commissioning of the facility. We had been given repeated assurances from the head contactor, McConnell Dowell, and from EarthPower that things were to program. The process commissioning was approximately 5 months long because it incorporated the growth and acclimation of 11,000 tonnes of anaerobic sludge. The dates required for readiness of every piece of equipment and the projected requirements for seed sludge deliveries and waste deliveries had been in place for months.

WSL arrived on site to find that EarthPower did not yet have a license to take waste. WSL got around this by convincing the NSW EPA that the waste activated sludge from Mauri Yeast Australia's anaerobic/aerobic wastewater treatment plant nearby was a seed sludge and as effectively a "catalyst" for the process and therefore not a waste stream at all. WSL then managed to convince NSW-EPA that it was necessary to bring in Mauri Yeast high strength wastewater as a feed source to maintain the viability of the seed sludge bacteria. WSL remain grateful to the EPA staff for allowing us to proceed in this manner.

WSL then found that of the approximately 23 waste streams EarthPower was supposed to have under contact only two streams from sites owned by one company were actually signed up. EarthPower assured us that they were working on this and other wastes would become available as required for commissioning. WSL also found that a waste hauler company had a prior contract to take these waste streams with priority over the EarthPower contract. This issue was eventually resolved but control of the waste remained with the waste hauler.

It took six weeks to obtain the license to take waste. By then WSL had a good quantity of seed sludge in place and the plant operators had got their hands and everything else dirty. Construction of parts of the plant not yet required continued around the commissioning process. The operators engaged by EarthPower provided the commissioning labour as part of their training. They were keen to be in at the start of a new industry and were willing learners.

After Christmas 2002, the BTA commissioning staff arrived to commission the solid waste reception bunker and the pulper and the contaminant removal systems. EarthPower took BTA and WSL to the source of the first solid waste delivery, a large central city food court and collection of restaurants. This visit was to allow us to inspect the waste and assist EarthPower in education of the waste hauler as to what was and was not acceptable in the waste stream.

Table 1: The expected and the actual daily waste delivered to the facility
EPT: EarthPower Technologies (project developer);
EPTS: EarthPower Technologies, Sydney (project operator)

Waste parameter	**Specified in waste supply specification by EPT**	**Actually delivered (EPTS figures unless otherwise noted)**
Waste sources	Supermarkets, industrial food processing wastes (pre-consumer only)	Food courts, office rubbish, hospitals, car mechanics, hotel cleaning, general waste
Maximum daily waste delivery, wet waste	140 Tonnes	196 tonnes
Maximum dry solids per day (including contaminants)	44.2 Tonnes	17.04 Tonnes
Average dry solids daily input (excluding contaminants)	42.5 Tonnes	7.84 tonnes (18/8/03 – 18/10/03 Plant start up 11/11/02)
Average dry solids content	30.3%	12%
Acceptable daily contamination mass	1.5 – 5 Tonnes 1.1 – 3.2% of input	14.82 Tonnes, 18 –31.5% (EPTS audit), 5-56% (CH2M Hill), 6 tonnes glass in one day
Average contamination mass	1.7 Tonnes/day 1.2%	7.35 tonnes/day, 35% (7 day CH2M Hill waste audit)
Volatile solids fraction (non inert fraction)	92 (+/- 5%) (87 – 97%	84% (EPTS analysis)
Digestible fraction of the volatile solids fed to digester	85%	90%
Minimum fat, oil and grease % of volatile solids (daily)	15.4%	4.3%; the average was 13.4% for the period 18/8 - 18/10/03
Maximum fat, oil and grease % of volatile solids (daily)	18%	39.55% (from 38.42 tonnes waste delivery that day)
COD/VS ratio	1.55	1.4
Av. daily Phosphorus input	785	296kg (corrected to full load)
Av. daily Potassium input	1450 kg	650kg (corrected to full load)
Inhibitory substances	None	Digester failure occurred resulting from inhibitory substances
Maximum paper and cardboard content	3.3% dry basis	39% (EPTS audit) 14.8% (CH2M Hill audit)
Possible contamination by foreign objects	Supermarket cans, glass, styrofoam boxes, supermarket plastic carry bags, animal bones, hessian , string, cardboard cereal boxes, plastic lined paper cereal bags.	Car panels and subframes, industrial compressor parts, paving stones, 44 gal drums, kitchen sinks, computers, video cameras, fridges, 20-40 m lengths of pallet shrink wrap, pallet strapping, 2000-3000 wire coat hangers (at a time), pallets, electric motors, switchgear, 1-1.5 m^3 industrial bulk cargo plastic bags.

A few days later the first solid waste load was delivered with the press in attendance and the head chef from a top restaurant present for a photo opportunity. The waste was dumped. Everyone was silent. The video production team stopped filming and asked if it was worth continuing. The waste was obviously not what was intended for the plant. It contained masses of office rubbish, twenty litre oil drums, computer parts but very little that could be said to be or have been food. Standing to one side with the operators, the team played “spot the food item”. One apple core and a few rotten cabbage leaves was about all that could be seen. There were some dirty plastic plates. Things were not looking good and even later after substantial efforts to improve the waste quality the waste was very different from that specified by EarthPower. A comparison of the wastes specified and the wastes delivered in the period 9 –11 months after commissioning started is given in Table 1.

EarthPower then started with the claims that were to become very familiar. “a mistake by the haulers”, “it will be better next week”, “the waste generators just need education”. Commissioning proceeded and some of the wastes started to contain reasonable quantities of food. The contaminant levels remained very high. The contractual average level of contamination was supposed to be 1.1% of the raw waste input. The maximum on any one day was to be no more than 3.1%. The contaminant level of the wastes averaged about 25 % up until WSL left site nine months later. Levels of individual loads were as high as 56 %. These waste contaminant levels come from an independent waste audit conducted by CH2M Hill over two weeks.

The BTA equipment generally performed well, given the waste was so far out of specification. However it was halted by a number of things, a few thousand wire coathangers wrapped around the main auger and blocked the flow of waste. Some of the waste was delivered in 1 cubic metre compactor bags. These did not allow the waste to flow and created a wall across the walking floor. The bags needed to be broken up. Other things pulled out of the waste reception bunker or pulper were: fridges, computers, industrial compressors, paving stones, truck tires, car doors and other car panels, wooden pallets, industrial water filters etc.

EarthPower would not admit that there was anything wrong with the waste but did keep saying it would get better.

A second problem was that EarthPower could not supply the quantity of waste required. After ten months of a commissioning program that was supposed to last five months and required by EarthPower to be at full production by four months, EarthPower could only supply an average of 18% of the dry solids specified in the contract. The co-gen engines, the ammonia stripper the dryer and sludge dewatering equipment could not be commissioned because there was not sufficient waste to allow this to proceed.

As the delays extended commissioning, EarthPower suddenly announced that the contract did not specifically require them to supply the wastes until the performance trials. WSL pointed out that there was no such requirement on the contractor and that EarthPower had verbally threatened legal action if WSL talked with any of their waste suppliers or potential waste suppliers or attempt to improve the waste quality. Therefore there could be no expectation that EarthPower was not to supply the wastes.

In the end WSL left the site on the basis that EarthPower was preventing the NZ based waste treatment experts from completing their contract because the waste required for commissioning was not being supplied.

Plant performance milestones achieved:

- The methane yield achieved was approximately 570 m^3 CH_4/t TS loaded.. The methane yield required to meet the performance guarantees was only 338 m^3 CH_4/t TS loaded.
- Sufficient biogas is produced to operate one 1.3 MW co-gen engine despite the poor waste supply.
- At times when large sugar based loads were added the gas production rate exceeded the design rate (1250 m^3/hr). A rate of 1800 m^3/hr was observed for a number of hours.
- Fertiliser has been produced to specification using exhaust gases from the co-gen engines as the main drying heat source despite almost 4 times the limit of paper fibre in the sludge. High paper fibre content was expected to make the dryer pelletization process a challenge.
- The water treatment process, when operated properly, gave a final treated water quality significantly better than that required.
- The plant (including waste reception) was able to handle daily deliveries of up to 192 tonnes/day despite the maximum allowable daily load being 140 tonnes/day.
- Despite contamination levels of 30 times the design specification, the plant was able to process wastes 99% of the time.

What are the lessons learned from this project?

1. That the laboratory studies did give a good model of the behaviour of the plant in as much as the limited operation of the plant allowed
2. That the plant operators must accurately know their waste
3. That the plant operators must have control over the waste
4. That plant optimisation to recover maximum value from the waste (electricity, dried fertiliser, liquid fertiliser concentrate) worked at full scale
5. That the process design know how must include specific steps to master constraints in waste supply and composition during the first start-up of such a facility.

Waste Solutions Ltd has gone on to successfully complete a number of new waste to energy plants. Our clients are happy to be involved with us in further such contracts. In all cases the client has had clear control of the waste and an open and realistic economic model for the plant. In each case the performance guarantees have been exceeded. The performance guarantees for the EarthPower site were no more arduous than those supplied for these plants. The difference was in the failure to obtain secure contracts for the wastes the plant was designed to process.

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