Report of the visit to Australia and New Zealand

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Executive Summary

A tour of four Indian officials noted above was sponsored by MNES, GoI to visit **Australia and New Zealand** and study several facilities - High rate biomethanation and Waste-to-Energy technologies to obtain a first hand appreciation to the technologies and their economics currently prevalent in Australia and New Zealand, and also examine the possibilities of tie up for technology transfer. Some aspects of the visit related to policy issues in relationship to those practiced in India and the possibility of collaboration/ reverse technology transfer were not on the mind, but not ruled out, particularly because there could be technologies from India which could be more economically be supplied and serviced.

The visit contained exploration of three land fill sites including power generation (two in Perth area and one in Brisbane; one more in Brisbane area was skipped as there were no new elements in it and time was running out), three sewage treatment plants (two in Perth area and one in New Zealand), one gasification plant for wastes (discussions and manufacturing site in Brisbane and actual facility at Wollon gong near Sidney), one small scale gasification technology related discussions in New Zealand, policy discussions in Perth and Australian Green House gas office at Canberra, Management of wastes and project conceptualization in Perth, Pollution remediation and control measures in Perth, other related places like coal seam methane based power generation facility, visits to native tribal areas both near Perth and Rota Rua near Auckland.

It must be brought out that both at Perth and in Eastern Australia, the visits were extremely well coordinated by CASE (Mr. Kim Trouchet) and EDL, India Ltd (Mr. Sunand Sharma).

The single most important distinguishing feature is that all the plants are extremely well instrumented for monitoring and control to the extent possible or relevant and work 24 hours a day. The next most important feature at STP in Perth area is that both biomethanation and sewage liquid-to-solid particles - liquid fuel are being carried out. What more, the biomethanation plant is a high rate biomethanation system set at 37 ^{o}C. *In India we do not have a single system like this. One good STP should be encouraged to* *have a high rate biomethanation plant at least as a demonstration plant under the current program if possible.*

The urban solid waste management approach currently prevalent in these countries is undergoing change. While those which are operating today are those which were established twenty years ago, there is a move to close the landfills in a few years from now due largely to the problem of leachates and other long period environmental problems. The best strategy for the large cities would be to adopt reduction in size as much as possible. In this sense, the technology at EDL would be interesting. Though the technology demonstration to the visiting Indian group was not complete (power generation was not demonstrated), it would be valuable to have the technology in Chennai or any other place as long as it is understood that MNES involvement is documented through appropriate orders and the clearance of subsidy will imply public understanding that the government has provided a tacit clearance to the technology. The group is of an opinion that M/s EDL Technologies Ltd/Brightstar International have an understanding of the elements of the technology even though it has not been put together yet. There is a plan that the Whites Gully project will have all the elements in it in about eight months. This may be kept in mind in positively viewing the project.

The Report

The detailed plan of the visits is as shown in **Annexure I**. The prominent cities visited were Perth in Western Australia, Brisbane, Sydney and Canberra in Eastern Australia and Auckland in New Zealand.

On the 10th April 2000, we were received by Mr. Kim Trouchet (of CASE) at the hotel - Emerald Hotel - the hotel we stayed - and after introduction, had a meeting with Mr. Dennis Smedley of the regulatory body of the Office of Energy in the first meeting for the day. Two major policy drivers for renewable energy in Western Australia are the national aim of achieving an incremental 2% of the total energy from renewables in the next five years, which imply wind and biomass, and another agenda of green power in which specific financial facilitation is provided to power projects in isolated regions. Since state controls the development of all power projects, power can be sold to the grid on a specific rate and those industries interested in green power for considerations unrelated to economics. One of the peculiar features of the GoA policy is that those who cherish green power should pay more on the electricity from renewables. Obviously the total amount of energy from renewables sold this way is a very insignificant fraction of the total energy used by the society.

One of the major wood-to-energy projects contemplated has been a 1 MWe project related to Mallee plantation (a kind of Eucalyptus which grows in desert like environments shooting the roots to deep into the soil and drawing the water from the highly saline "old" water) called integrated wood project (IWP). In this project it is aimed that one obtains multiple outputs - oil from the leaves, gasification of the resultant leaves and pyrolisis of wood to generate gases for electricity generation and activating the char to generate activated carbon, the entire process leading to more employment generation and stabilizing the environment. The project needed an investment of 5 million Au$ at 1 MWe. In fact, the estimates for a project of a comparable nature with coconut shell to energy and charcoal at 1 MWe power using IISc open top reburn gasifier and gas engine - generator set indicate a magnitude of 2.5 million Au$ per MWe, typically half the investment cost envisaged by the Australian team. Much discussion followed this presentation and ideas of the same kind with Juliflora prosopis were thought viable in some parts of India.

In the afternoon, a visit to waste water handling facility of Perth was arranged. This facility handled the sewage of little more than a third of the city of Perth (more specifically, the three hundred thousand of the inhabitants were estimated to generate on the mean 200 litres per head per day equivalent to 60 million litres per day of about 0.02 to 0.03 % solids equivalent waste water. This facility produced 15 tonne dry sludge every day. The interesting point of the entire process is that the liquid was centrifuged to concentrate the solids content to 28 % and then the material made in a pug mill into pellets of 2 to 4 mm diameter which were flash dried in a roaster in which the heat for drying was obtained from fluidized bed combustion of the material (with natural gas start up) to obtain pellets of 5 % moisture content. In another new process developed by the team somewhat uniquely, the pellets were flash pyrolised to lead to liquid fuels (30 % approximately) with a calorific value of 35 MJ/kg. The char in the system was used as a tar cracker and the final material burnt in the fluid bed combustor for drying the pellets. The entire process was carefully thought out and appeared at first sight to be thermodynamically efficient. Of course, the economy of the process did not appear sound. No numbers on costs were provided, possibly because no such estimates existed and on questioning the possible prohibitive costs involved, the point was not objected to and it was tacitly understood to be not economical. On the whole this segment of the visit was technically extraordinary and worthwhile. More efforts will be made by HSM (H S Mukunda, for short) to pursue and establish technical cooperation with the key members of the team.

The first visit on 11 - 04 - 2000 was to the city council of Melville. There was a nice presentation of the plan of the council to get together with six other neighboring councils on a project of garbage collection and its conversion. The steps that they seem to take with the society are consistent with a democratic and understanding community. The technical plans are laid out and public hearings are held. Attempts will be made to take into account public views, particularly where there are strong reactions which affect local life, largely noise pollution. Atmospheric pollution is nearly completely taken care in the plant design. With respect to technologies, a group visited about dozen other operating places both in Australia, USA and Canada, made a comparative study vis-a-vis their requirement and picked up the elements for their plant. A compilation of the vendors/industries that they contacted is provided in **Annexure II**. The typical composition of the urban waste they were handling are: 35 % green waste, 25 % food waste, 30 % recyclables and 10 % non-recyclables. The green waste is largely garden waste - leaves and twigs. The waste management strategy is have a weekly collection system for in-vessel composting of some green waste, fortnightly collections for materials recovery purposes, tri-annual collections for green waste for mulching purposes, annual collections, again for recyclables. Typical population size is 340, 000 with 12000 households (notice that the average house hold is about 3). The total waste handled is 130,000 tonnes a year - 330 tonnes a day (small compared to Chennai or Mumbai). The investment cost in the technology including civil works is 35 million Au$ with the materials recovery facility of 3 to 5 million Au$ being contracted out for investment with an assured purchase rate of 70 Au$/tonne of the recovered material and the rest being built and owned by themselves. The interesting part of the compost facility is that most of it is under negative pressure to ensure non-emission of foul gases. The final stream of the air passes through a bed of biofilter consisting of about a meter and a half deep wood chip bed and it appears the air is completely cleaned on passage through this. The compost is likely to be sold at 10 to 20 Au$ per tonne though in times its sale price may go up to 40 Au$ per tonne.

On an enquiry as to why they have gone into aerobic treatment (composting) and why they could not do an anaerobic treatment leading to the generation of biogas with consequent energy recovery, their answer was that the adequacy of electricity did not make it imperative for them to go in for anaerobic treatment. The fact that mulching helped stabilize the soil which was otherwise poor was important even though volume reduction called for gasification/incineration as the more effective routes.

The next visit was to the waste water treatment facility at Woodman point. This location catered to some 450, 000 people and handled 100 million litres a day (amounting to 220 litres per person per day (one can compare this with 50 to 75 litres per day per person in India under good circumstances). The treatment plant consists of a standard grit and sand separator, settling in large tanks the result of which is the concentration of the solids to 4 % from 0.04 %. This material is then sent to anaerobic digesters. In earlier times, digesters were cylindrical. These have been changed to egg shaped digesters so that the scum formation at the top and the possible inorganic settlement at the bottom could be handled in a simpler way. There are motorized devices to churn and mix the liquids inside. These digesters are 8 million liter capacity with two of them to take in the material costing 12 million Au $ (This amounts to 1.5 Au $ per liter; Indian costs are about Rs. 2 per liter). In terms of economics of construction, they indicated that both this design and the standard cylindrical design are comparable. The gas generated in the digesters taken into cylindrical gas holder of 15000 m^3/day capacity. The estimated hydrogen sulfide content is 2000 ppm. Sweetening the gas is done by passing the gas through packed bed of iron/sodium and potassium carbonate impregnated wood chips in four tanks sequentially before being taken through a compressor into a long line for delivery to Caterpiller gas engines. These engines are 2 x 1 MWe capacity drawing 1200 m3/hr flow. The gas sweetening system needs replacement every two years or so at a cost of 96000 Au $ and the material is obtained from USA (Chicago, IL). At this point HSM pointed out that it was possible for India to supply a scrubbing system at a cost comparable to the cost of replacement every two years. The replacement of chemicals in the case of the technology from India was about 5000 Au $ annually. The engine was completely enclosed in a building with air drawn through a blower into the room and the noise level outside was very nominal; it was not even evident that the engines were running even though they were indeed running. The entire plant was monitored and computer controlled. *This part of the arrangement was the most instructive and interesting. While in India we might use manpower for various maintenance activities, we will benefit a great deal by putting together instrumentation and computerized monitoring systems to enable logging realistic information and enabling the possibility of direct insight into techno-financial performance.* The fluids after primary treatment were discharged 4 km into the sea bed 20 meters below the surface after transporting 23 km along a pipe line to the appropriate sea costal point. This itself drew 2 pumps of 600 kWe capacity. There were other contingency measures for discharge into two other locations if the first system gave problem due to simultaneous pump outages, etc. The economics of operation is helped by the corporation directly charging 450 Au $/year per house hold for sewage and 300 Au $ per year per household for water. With 150,000 families serviced, the revenues amount to a total of 120 million Au $ every year.

In the afternoon, we visited the corporate research center of Murdoch university called ACRE established over three and a half years ago It is somewhat of a unique consortium of most states of Australia with members drawn from academia, electricity generation groups, renewable energy manufacturers drawn from all over the country (22 members) interested in research of interest to Industry. Its interest is also in policy issues, but not in demand side management.

They are setting up a test facility for wind - diesel hybrid systems at present. They are involved in setting up a joint venture in a renewable energy system and indicated that the current environment of emphasis on technologies required to sustain in market place likely to change for the better for renewables in the next six months is going to provide more opportunities for growth. They foresee that Australian interest will be largely in Wind and biomass. GHG abatement issues have led them to consider the possibility of ECOCARBON like institutions which are aimed at trading of green house gases and related issues. In fact they have interest in 1 MWe class systems. While their normal mandate is to develop Australian know how, they will examine selective induction of appropriate technologies into Australia. At this stage it was brought to their attention, the leading edge position held by *India in biomass-to-energy systems and these are at investment costs comparable to large scale centralized thermal systems. Which is very difficult to achieve because conventional scalability arguments belie this.* It was also indicated that collaborative arrangements in which Murdoch University could get involved in the adoption of the Indian technology are possible. To a question regarding the possibility of further discussions on this subject, Mr. Rana indicated that these could be discussed with the appropriate groups at MNES. **Annexure III** contains the recommendations on this subject

The next meeting was with the Environmental protection agency of the government. Two of their senior officials explained their role as a substantive positive one in ensuring compliance of environmental protection. The degree of awareness amongst most industrialists was so high that rigors of legal action were experienced in less than 1 % of the number of industrial licenses awarded.

The next visit was to the landfill electricity generation facility of Melville and Canning cities the landfill started from 1970's with a total population going from about 90,000 to 130,000 at present. It was meant for household/industrial and commercial wastes. Power generation has started about ten years after the land filling got started. This particular landfill site was managed by setting out 600 mm to 1 m deep clay and plastics with a 10 to 12 m deep earthwork filled segment by segment and compacted to raise the density of organic waste to 900 to 1000 kg/m3. At the top of the compacted heap, earth is loaded to 1 m depth and this completes the formation of the landfill. Holes of appropriate diameter are drilled into the material and perforated tubing of 50 to 100 mm are introduced at a number of places for gas collection purposes. These are man folded into larger sized ductings and taken out at the ground level into the gas processing facility. The gas is cooled and scrubbed if necessary to eliminate some unwanted compounds like of chlorine, sulphur and others. The gas is then taken to a roots blower to raise the pressure from -2500 mm wg to + 1000 mm wg. The gas is then taken to the engine room into a pressure regulator which sets the downstream pressure to about 300 mm wg and then into the mixing device for mixing air and gas before the turbo-supercharger. In this facility there was a control room to which various parameters of the gas and power generation system were being monitored on the computer. The Caterpiller engine (3176) of 1500 rpm was generating 1000 kWe with a gas flow of 900 m3/hr at an estimated methane fraction of 40 to 45 %. The cost of the engine is an estimated 1 million Au $ for the 1 MWe nominal power engine. Regarding the buy back rates of energy, it was indicated that it was time-of-the-day-metering with 3.3 Au cents between 5 and 8 am, 11cents between 8 am and 8 pm, 6 cents between 8 pm and 11 pm and 3 cents during the remaining period. During the discussions on landfills, he indicated that there are four income streams - the earth work would be sold to civil construction groups, the garbage is paid for by the individual households to the city council, electricity from the gas generated, and the final compost which could be sold for agriculture/mulching. All these streams do not exist in India, though. The next visit was a aborigine community living centre where Mr. Kim Trouchet from CASE had done a combined wind-solar electricity project for the community. The design of the wind machines looked elegant and so was the solar roof based package. The entire system was arranged for remote monitoring and limited control. The electricity generated was partly used by the community and partly put into the grid. The total capacity was 28 kWe.

We flew into Brisbane on 13th April 2000 and were received by Mr. Sunand Sharma and Sabharwal of EDL, India Limited. We met some members of the team at dinner the same day - Paul Woolfan, group manager, technical, Albert Smith III, general a manger - legal and finance, Rick Ralph, Recycling systems manager, Tony Whiteman, technical development manager, David Neuwen, product development manager, all of Bright Star International. We met *Paul Whiteman, the CEO of Bright Star International and Executive Director of Energy Developments Ltd* and Mr. W. L. Lazarus, general manager - Australia operations. *Mr. Paul Whitemen* appeared very energetic, well informed and authentic throughout the contact period. He seemed to have varied earlier career from chores on a ship to technical activities on a ship to engineering. On the morning of 14th April 2000 we were shown a video of the operations related to waste processing and preparation facility dismantled a few days earlier. the as-received material goes though an autoclave run at 5 bars and 130 C for 40 mins and downloading takes another 20 mins. Plastics, glass and steel go through the autoclave for reasons which are undefendable. Constituting 30 % of the material received, the energy going to heating and cooling is by no means insignificant. On questioning, they indicated awareness, but seem to think it as a small issue. The material is passed through eddy current magnetic separators for steel, and after removal of glass and other inorganic stuff is passed through a shredder (hammer mill in the current system, but will be changed in later systems), apparently, autoclaving causes some activation for further process to be facilitated. Regarding the size of material acceptable to the reformation process, it was indicated as a maximum of 10 mm all around. Regarding the moisture content acceptable, it was brought out to be at 35 to 50 %. The upper limit is set to be about 60%. After this, we were shown the power pack. The 40 foot container has the highly packaged set of elements - engine with a modified oil bath which can be used for transfer into the engine section, a separate waste oil bath all connected with pumps so that automatic transfers can be effected. There is roots blower to drawn the gas from a landfill through a relatively small moisture trap and deliver it to the engine through a pressure regulator which maintains the downstream pressure at 300 mm wg. Downstream of the turbo-superchargers, there is total flow regulating valve. There is an engine management system which monitors all the cylinder temperatures typically varying between 230 to 430 ^{o}C depending on the load. Beyond about 50 % load, the temperature seems to saturate at 385 ^{o}C. Some optimization of ignition timing is needed for Syngas/landfill gas operations. The data are being accumulated and arranged for control system design. Apparently, it is a critical input and operational performance is affected by it. That is why the automatic management system is deployed so that looking at the peak pressure data averaged over all the cylinders and over some cycles, ignition delay can be set electronically. There is nothing spectacular in stating that the system design is excellent and emission standards are met well. We were shown the computer management system of one of their plants in UK being accessed from their office in Brisbane. After accessing the system through password protection, the system parameters were displayed. It was also pointed out that remote operations like oil change and waste oil pump management could be effected through remote control. This engineering marvel appears very impressive, but is extremely common in many high technology applications. After this segment, we were shown the manufacturing facilities for the gasifier. Again of modular construction, with several components being obtained from subcontractors, assembly and packaging were being performed during our visit. There were further discussions after the visit. In a presentation on the background of the company, it was brought out that EDL established in 1988 with three partners - Paul Whiteman, W Lancart, and Walter Pahor was involved in remote area power generation both from gas turbines as well as reciprocating engines using landfill gas and coal seam methane gas. They have built a total of over 100 MWe at more than six sites. They are quoted on the Australian Stock Exchange from 1993. Overseas expansion into USA, Greece, and England took place between 1996 and 1998. In so far as the new technology on Syngas is concerned they have formed a new company called Brightstar International along with Brightstar Synfuel Corporation, USA with 88 % shares being held by EDL and 12 % by Brightstar Corporation Limited (1995). The discussions then went on to a technical description of the new plant being conceived. The incoming urban waste including glass and metal was processed through autoclave at 5 bars and 130 C. Their assessment was that about 30 % of their waste consisted of metal and glass. It was pointed out that the energy expenditure in simply heating and cooling of this material appeared wasteful. The response did not appear satisfactory and in any case, if, in the Indian context, segregation was taken up, this part could be understood to be taken care. The material would then be shredded preparing it for the gasification process. The gasification process consisted of high temperature pyrolisis with the necessary residence time. The temperature was set at 930 ^{o}C+ and residence time about 1 to 1.5 s in this temperature range. The material was screw pressed to build a pressurized segment at 10 bars into which Syngas at this pressure was injected for material transportation. The material was heated to 700 C in two heat exchangers and then it passed through a high Nickel steel tube 100 mm dia set out in a coiled coil form in a furnace maintained at 1300 to 1400 ^{o}C so that with radiant heat transfer, the duct is a maintained at 930 ^{o}C+. They did not explain many aspects directly. It was brought out through a long series of discussions on this day as well as during the visit to Whites Gully green waste facility at various times. The question that was bothering HSM in particular was whether it was gasification or pyrolisis. The two were seen being used in a concomitant way and this was definitely not correct. It became clear after it was stated that the regime of operation was high temperature pyrolisis and the output gas stream was unaffected chemically by the presence of moisture content in the biomass. Of course thermal balance would be better with drier biomass and to this extent absence of moisture would be beneficial. To the question as how there was a variation in the gas composition indicated in their documents it was brought out that this was due to operating temperature variation. **ie**. if the temperature varied by 20 to 30 ^{o}C over this range, there would be compositional variations as well. In the early development phase, the gas composition showed higher amount of hydrogen even as high as 60 %. The detonation problems in the engine called for limiting the hydrogen content to less than 30 % or so. The change in operating parameters - pressure and temperature are related to this. All the technology elements were developed by them with little outside input; in point of fact, their experience has been that any support from universities, like the Queensland University, has been on the periphery and all core developments have needed intense and focused activity by their team. HSM asked at one point of time if they had done any modeling studies on the performance of the system have been made. It was brought out that the problem is too complex and no such study has been made. They think that it is perhaps infructuous to do such studies. They also indicated that the gas composition was about the same no matter whether they used sawdust, urban waste or pig waste or chicken waste. The char which is generated is graphitised in part and some fine dust is activated carbon. They do not seem to have explored the magnitude of the different kinds of carbon. We actually were shown the char. It looked like what they had described. After the reactor, the gas was taken to a high efficiency cyclone with a pressure drop of 20 kPa and this is the one which extracted through an auger into the lock hopper system for char extraction. The gas was then taken through a venturi scrubber with a pressure drop of 20 kPa and this ensured dust and part tar removal. Further tar removal occurs through a tube in tube heat exchanger with fins on the outer part of the inner tube. Water which is at the normal temperature in the first two passes and chilled to 0C in the next two passes was used as the solution to the tar extraction problem. These ductings are 65 mm id with fins on the outer surface and 127 mm outer tube diameter and 2 m long with headers at both top and bottom. There are four passes for water recirculation. There are two banks for tar clean up. Only one bank is used at a time. The periodicity of change over from one bank to the other is 1 hr!. The change from one bank to the other was done based on the pressure drop across the gas line. This could be expected to go up after tar has packed into the annular space. The way tar was extracted from the used one to prepare it for operation after an hour was by using hot water. This apparently removed the tar sticking to the fins more particularly. This appeared surprising, but not explicitly shown so. The reason is that tar is so difficult to deal with that even some organic solvents do not dissolve them that as to how just hot water could deal with the tar was totally unclear. HSM intended to see the tar itself, but could not because they did show the tar drum. However, he had occasion to look at the water in a container supposedly from the clarifier which was a part of the tar clean up system. HSM dipped his fingers into the water much to the astonishment of Mr. Neuman who was showing us around and found that the ammoniacal content was high. The pressure drop on the cooling/cleaning circuit is also large - 20 kPa and thereabouts. The point is that because their operating pressures are high, they can afford to apportion reasonable amounts of pressure losses to these segments to assist the gas clean up. It is therefore possible to accept the levels of cleanliness of the gas that they claim - 1 ppm of tar. There was a gas chromatograph for the measurement of the gas composition. On an enquiry regarding the methodology for calibration, more particularly the possibility of the use of a standard mixture, there was an immediate agreement, but the actual cylinder seemed not around. The gas engine was not running at the time of the visit. The gasifier itself was functioning at 300 kg/hr of the biofeed stock much lower than is required for nominal power of the system. The total system including the engine-genset *not functioning* caused some disappointment particularly when great deal of focus is on Whites Gully facility.

In the afternoon we visited their landfill site at Lucas Heights, the landfill gas power station. Again this power station is running completely devoid of manpower with an periodic monitoring through computers connected to the instrumentation required to monitor the performance. Only when there is a problem of serious nature will it call for the intervention for which somebody identified locally may be deployed. The gas extraction, scrubbing and mist elimination, roots blower, piping to take the gas to the Caterpiller engine were about the same as in the other landfill power stations. Also equally well the instrumentation, computerized data acquisition and access through modem for long distance monitoring and control were similar.

On the evening of 15th April, after the visit to the landfill site we were hosted a dinner by the CEO, Mr. Paul Whiteman. Several of the colleagues were present at this dinner meeting. HSM pursued with Mr. Whiteman several points concerning the choice of reciprocating engines vis-a-vis the gas turbine engines which promised much longer maintenance free operation. He gave me a long background of their experiences with M/s Solar turbines who were intended to be commissioned to develop the Syngas based gas turbine. He gave me technical reasons of flame speeds being large for hydrogen rich mixture causing difficulties of hot spots in local zones despite my drawing attention to him that in a diffusion flame ideas of premixed combustion were not relevant. I politely dropped the issue after a while. He also brought out the issues of spare part availability and costs which led them to move away from Caterpiller to Deutz with whom they seem to be happy.

The next day, the 16th April 2000 (Sunday) we moved to Sydney. Afternoon was spent in the Sydney harbor cruise. The following day was the visit to Appin Power station based on Coal seam methane gas and then to Whites Gulley green waste power station. Since all aspects of the Syngas generation including power have been described earlier, they will not be discussed any further. The Appin power station was an impressive facility. The difference between coal bed methane and coal seam methane is that in the latter, coal extraction is accompanied by the extraction of the gas. In the former case, though, the purpose is only gas extraction. We were provided a number of details of the coal seam structure, the manner of mining, the method of tapping the gases, their scrubbing before being taken to the engines. There were 54 engines of 1 MWe each, all being put together into a single grid paralleled arrangement. That 54 MWe generation system configuration should consist of 54 systems caused in me apprehension about the conceptualization. We were told that their analysis - technical and financial indicated amongst combined cycle gas turbine, steam turbine and reciprocating engine option, the choice they had made was the most appropriate. HSM indicated interest in looking at comparative statements if they could provide them. They monitor the performance of all the systems through a computer extensively. The instrumentation used is also extensive. This is done for the gas composition and all the appropriate parameters of the engine system.

The next day, 18th April 2000, we went to Canberra to visit the Office of Green House gas of the department of Environment and heritage. The office headed by a chief executive and with five different activities - emissions trading (10 staff), green house policy group (30), sustainable energy group (50), partnership group (40) and corporate communications group (20) and other infrastructure group with a total of 180 staff. Their role is to manage GHG abatement program of 400 million Au $, 60 million Au $ for renewable energy projects and a 10 million Au $ showcase program. The meeting was conducted by Mr. Colin Grant, Deputy CEO and several colleagues heading the various groups and attended by the Indian team, Mr. Sharma and Sabharwal of EDL India and Cavin Grant of EDL technologies, Australia. The overview of the activities was provided by Mr. Grant. He described various activities of the groups noted above. He indicated that they are administratively handled by the ministry of environment and heritage, they are primarily responsible for the three ministers - Environment and heritage, Industry, Science and resources, Agriculture, fisheries and forestry and five other junior ministers of departments. They seemed very enthusiastic in their effort to implement the plan. The most important action they are involved in is to get through legislation on the enhancement of contribution of 2 % of the total energy in Australia this amounting to 9500 GWh from renewables by 2010. This is intended to be made compulsory for electricity retailers wholesale buyers and others who are involved in third party purchase. Many issues like trading, pricing disclosure and eligible renewable energy generators have been listed. There are incentives for compliance and penalties for non-compliance. A copy of their draft document which they expect will be legislated in a few months is enclosed in **Annexure IV.**

The visits in New Zealand were arranged for 20th April 2000. In the morning, we were visited at the Centra hotel (where we were staying) by Mr. Doug Williams of Fluidyne Gasification Ltd. He had closed down the activities and the gasifier manufacturing plant some two and half years ago and was wondering why this visit had been arranged. HSM had known of his work in small scale gasification through the crest.org and gsification.org net and enjoyed talking to him about the problems in small scale gasification. He has some competence, but has an exaggerated impression of his competence vis-a-vis the rest of the world. Rather peculiarly, due to many of his own acts, he has created an impression of being unhelpful. While he has done many novel experiments very few of them exist as demonstration or commercial models. He feels that most governments provide lip sympathy to renewable technologies, etc.

The afternoon's visit was to waste water Treatment Company called Montgomery Watson in Auckland. They treat the sewage water which flows along with the rain water into the plant. They have a primary digester which generates Methane gas which is used in a dual fuel operated Merlin Engines. They were intending to change to gas turbines now with topping of the biogas by Natural gas. The secondary treatment was done in a facility called Bacterial nutrient removal (BNR) technique till now and were changing over to a very expensive ultraviolet technique. The total liquid flow was at the rate of 3 to 14 m^3/s (0.2 to 1.0 million m^3/day) and the total sludge removed was between 100 to 300 tonnes per day. (The concentration of the solids is between 0.006 to 0.025 % - the highest value comparing with the the inflow quality in Perth). The tertiary treatment took place in lagoons where the stay time was set at 20 days. With the new technique of ultraviolet treatment, it would be possible to reduce this to 12 hours. The liquid could be let out during the tidal receding time. On a question about the approach taken in Perth, it was indicated that the technique is indeed practiced at several places. He indicated that this practice is considered not entirely proper and changes to methodology are currently being made wherever possible since such a change has a significant impact on the investment costs. For a question on the tariffs being imposed on the society for sewage treatment he indicated a value of 800 to 100 NZ $ per household.

Conclusions

The visit contained exploration of three land fill sites including power generation (two in Perth area and one in Brisbane; one more in Brisbane area was skipped as there were no new elements in it and time was running out), three sewage treatment plants (two in Perth area and one in New Zealand), one gasification plant for wastes (discussions and manufacturing site in Brisbane and the green waste treatment facility at Wollongong near Sidney), one small scale gasification system (discussions in New Zealand), policy discussions in Perth and Australian Green House gas office at Canberra, Management of wastes and project conceptualization in Perth, other related places like coal seam methane based power generation facility, Pollution regulatory authority in Perth, visits to native tribal areas both near Perth and Rotarua near Auckland. The single most important distinguishing feature is that all the plants are extremely well instrumented for monitoring and control to the extent possible or relevant and work 24 hours a day. The next most important feature at STP in Perth area is that both biomethanation and swage liquid-to-solid particles - liquid fuel are being carried out. What more, the biomethanation plant is a high rate biomethanation system set at 37 C. In India we do not have a single system like this. One good STP should be encouraged to have a high rate biomethanation plant at least as a demonstration plant under the current program if possible.

The urban solid waste management approach currently prevalent in these countries is undergoing change. Landfills have to be closed down in a few years from now due largely to the problem of leachates and other long period environmental problems. The best strategy for the large cities would be to adopt reduction in size as much as possible. In this sense the technology at EDL would be interesting. Though the technology demonstration to the group during the visit was not complete (power generation was not demonstrated), it would be valuable to have the technology in Chennai or any other place. It must be understood that MNES involvement will usually imply public understanding that the government has provided a tacit clearance to the technology. This must be kept in mind when providing the financial support to the project. The group is of an opinion that M/s EDL Technologies Ltd/Brightstar International have an understanding of the elements of the technology even though it has not been put together yet. There is a plan that the Whites Gully project will have all the elements in it in about eight months. This may be kept in mind in positively viewing the project. **Annexure V** contains the observations of Prof. H S Mukunda on the subject

List of Annexures

Annexure I – Detailed Plan of the visits

Annexure II – List of vendors for waste –to-energy plants

Annexure III – Recommendations on Indian participation – observations by Prof. H S Mukunda

At several places it became clear that India has an edge in the development of bioresidue based technologies – the simple atmospheric pressure air gasification along paths not taken by others in the world [in handling in a single technology both woody biomass with low ash content and high ash agro-residues (through densification via briquetting to enable economic transportation) in an atmospheric pressure air gasification process by techniques **which give very high gasification efficiency** would pay rich dividends in placing India in a leading edge position both from the point of view of stature and economic returns through servicing these technologies in both other developing and developed world. It is important that MNES takes initiative in this regard.

Annexure IV – Draft document of Australian Legislation

Annexure V - Observations and Recommendations on EDL project by Prof. H S Mukunda

I (HSM) had a great deal of personal satisfaction to have discussed extensively with the scientists. It appeared that they had thought through many issues confronted by the development of gasifiers, particularly on the aspects of tar and particulate removal to generate engine consistent quality gas. Most information sharing was slow. The benefits would have been much higher had the degree of transparency been higher. Somehow, the issue of intellectual property rights seemed to have weighed in their minds heavily. Also the degree of documentation needed to support the development seemed unavailable and it was indicated that some documentation existed but was not forthcoming, again, perhaps due to intellectual property right perceptions. I indicated to the entire team in an open meeting that in the absence of documentation that I can see to some extent, it would not be possible for me to make strong recommendations in favor of the technology. However, considering the competence of the group which undoubtedly is very high and the high level of investments that are being brought in by the company, I think it will be nice to see the technology take roots at some place in India to enable its diffusion. Curiously, if it gets to be set up at Chennai, India would be the first country outside Australia for this technology to be established.

Annexure VI – Email addresses of all the people involved

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