Paper by Professor L.I.Szabó on **Energy By Motion** [EBM] at the conference of ˝150 Years Nicola Tesla˝, Heidelberg-Waldorf, Germany, November 19, 2006

1. We have checked with the Host of the Conference to ascertain that you have received my 3 printed notes regarding the subject of EBM; We have also included them herein for convenience. I will be available to answer questions related to these 3 papers as well as for other questions on EBM, at the end of my presentation, which follows.

2. In order to have acceptably close estimates of the cents/kWh_e costs at the ˝bus-bar˝ of the EBM Power Plants, we must first have to have the Total Installed Costs [˝TIC˝] of the plant at the geographical location where the plant will operate and the date of commissioning same; The date is needed for manufacturing booking and due to the fairly rapid inflation which is taking place in raw material prices!

3. As a remainder ˝TIC˝ includes the entire costs of:
   (a) The complete EBM Power Plant Units and the standard synchronous generator after commissioning same, and hooking up to the network;
   (b) The power house and the roads;
   (c) The land and site clearing;
   (d) Sub-station costs, if any;
   (e) All soft costs [permits, legal, duties and taxes, shipping, insurance, to mention the better known ones];

   Note: 3(b) and 3(c) can be leased at between 2 % to 5 % of Operating Revenue and can be expensed!

4. We will have time to day to deal only with the mechanical component of the EBM driving section (see (5) below), which is roughly 45% to 55% of the total costs of the EBM driving section as follows:

5. The mechanical component of the driving section of the EBM unit is comprised of the following:

(a) Stator laminations;
(b) Rotor laminations with the shaft;
(c) Bearings with the shields and bearing housing;
(d) Electrical coils: (i) excitation coils;
(ii) armature coils
(e) Testing and measuring coils;
(f) Heat exchanger(s);
(g) Base plate(s);
(h) Rigid housing of the unit itself;
(j) Switches
(k) Air blowers;

6. The other 45% to 55% costs of the total driving section of the EBM driving unit [including the synchronous standard 3 phase generator] is as follows:

(a) Electronic controls;
(b) Cos φ control;
(c) Voltage control;
(d) Regulators;
(e) Load management control;
(f) Black box [The ˝brain˝ of the EBM unit]
(g) Overspeed control;
(h) Safety equipment and;
(j) Testing rig and testing;
(k) 3 phase standard synchronous generator.

7. Thus, total costs under (5) and (6): (5)+(6)=100%;

8. In order to closely estimate the cost of the EBM units under (5) above [and thus the total costs under (7)] to arrive at the bus-bar cost of the electric power produced by a specific EBM Power Plant, we developed mathematically and by measurements equations and graphs as follows (which establish the sellable (extra) electric and heat energies of the EBM Power Plant):

   Eq. 1: $\Delta P_e[kW_e] = \left\{1.2\left[\frac{G_{activeiron}}{1{,}500}\right]^x - \left[\frac{G_{activeiron+shaft}}{8{,}500}\right]\times y\right\}\times p$

   Where:

   (a) $\Delta P_e[kW_e]$ = net/net sellable network quality electric power in kW;

   (b) $G_{activeiron}$ = Total weight of the laminated electro steel [kg];

   (c) $G_{activeiron+shaft}$ = Same as (b) plus weight of the shaft [kg];

   (d) X = exponent, depends on the ˝type˝ of the EBM unit (one plane ˝SSX˝ or two planes ˝G˝ type) $1.539 \le x \le 2.0$

   (e) p = rpm ratio = n/n_0; n_0 = 750 rpm;

   (f) y = Material constant, depends on the type of the material of the laminations [electro steel];

   (g) Note: index ˝e˝, as in kW_e refers to ˝electric˝, and index ˝h˝ as in kW_h refers to ˝heat;

9. Example:

   Let: (a) $G_{activeiron}$ = 1,000,000 kg

   (b) $G_{activeiron+shaft}$ = 1,200,000 kg

   (c) X = 1.539

   (d) $p = 1{,}500/750$ = 2

   (e) y = 42

   Eq. 2:

   A $\Delta P_e[kW_e] = \left\{1.2\left[\frac{1{,}000{,}000}{1{,}500}\right]^{1.539} - \left[\frac{1{,}200{,}000}{8{,}500}\right]\times 42\right\}\times 2$ =[26,618-5,929] x 2=

   = 53,240 – 11,860 = $\underline{41{,}380\ kW_e}$

B The components of $\Delta P_e\left[kW_e\right]$ are:

(a) $1.2\times\left[\frac{1{,}000{,}000}{1{,}500}\right]^{1.539}\times 2$ = 53,240 kW =

= Total performance produced by the EBM driving unit;

(b) $\frac{1{,}200{,}000}{8{,}500}\times 42\times 2$ = 11,860 kW_h = $\Delta P_h\left[kW_e\right]$=

= Heat energy produced by the EBM unit;

(c) Thus, the electric power component, [also referred to as the shaft power available over and above to produce the heat energy] is = 53,240–11,860= 41,380 kW_e

C (a) Estimated self-use to maintain magnetic flux is, say, 5% x 41,380 kW_e= 2,070 kW_e

(b) Thus net/net, bus-bar electric component= ΔPe [BB]= 41,380 – 2,070 = 39,310 kW_e;

D In rounded figure: ΔPe [BB]= 40,000 kW_e at p = 1,500 rpm;

Note: The design engineer, of course, will calculate precisely the self-use [to maintain the flux] of the electric power generated by the specific EBM unit;

10. (a) In the attached graphs on 3 pages [figs. 1, 2 and 3] Eq. 1 above is depicted in graphical form, for n= 750 rpm; these can be used for quick estimation of the ΔP, ΔP_h and ΔP_e components; in these charts the shaft is made of the same laminated electro steel as the lamination of the rotor, and therefore $G_{active\ iron}$ = $G_{active\ iron+shaft}$ = G [kg];

Note: Here in the charts ΔP [MW_e] is denoted by P_{nne} [MW_e] and ΔP_e [MW_e] is given in MW_e; similary the other curves are P_{total} [MW] = ΔP [MW] and P_{therm} [MW] = ΔP_h [MW_h] respectively;

(b) These charts can be used, as a graphical solution for ΔP_e [kW_e], or ΔP_h [kW_h] by, for instance, intersecting the desired curve with a horizontal line at the desired ˝ ΔP_e [MW_e]˝ or at ΔP_h [MW_h], and reading off the estimated weight; for example, at n= 750 rpm, at 21 MW_e the $G_{active\ iron}$= 1,000,000 kg! At n= 1,500 rpm, for 1,000,000 kg= $G_{active\ iron}$, ΔP_e [MW_e]= 42 MW_e= P_{nne}[MW];

11. Estimation of the Total Installed Cost [˝TIC˝] of EBM Power Plants, except land, road(s) and power house, which are leased:

(a) Using the 40 MW_e EBM plant of the example, $G_{active\ iron}$= 1,000,000 kg;

(b) From manufacturers the ˝kg˝ price is 35 USD/kg; therefore:
   (i) TIC (1)= for mechanical components= 35x 1,000,000 kg= 35 million USD;
   (ii) TIC (2)= for all other components [except sub-station, if any, and except land and power house and roads] = [same as TIC (1)] = 35 million USD;

(c) Thus $\sum$ TIC = TIC (1) + TIC (2) = 35+35= 70 million USD;

12. The cash flow, for 100% debt financing for ten (10) years is given in Fig. 4., for 95% load factor per year, as follows:

A First year [using 10% royalty and 10% management fee]
   (a) $OPRV_e$ = Electric Operating Revenue, in rounded figures;
   = 40,000 kW_e x 365 days/yr x 24 hr/day x 0.95 x 0.08 USD/kW_h
   = 26,630,400 USD/yr
   (b) $OPRV_{green}$= 80% x $OPRV_e$= 0.8 x 26,630,400 = 21,304,320 USD/yr [annual revenue from CO_2 trading]
   (c) $OPRV_h$= 11,860 kW_h x 8,760 x 0.5 x 0.015 USD/kW_h= 779,200 USD/yr [annual heating/cooling revenue at 50% load factor and at 1.5 USA cent/kW_h rate]

(d) $\sum$OPRV= Total annual operating revenue= $OPRV_e$+ $OPRV_{green}$+ $OPRV_h$= 26,630,400+21,304,320+779,200=48,713,920 USD/yr

(e) OMA= Operating, Maintenance and Administration expenses:

		USD/yr
(i)	6 heads at 60 k USD/head/yr	= 360,000,-
(ii)	2 managerial persons at 75 k USD/head/yr	= 150,000,-
(iii)	2 mechanics at 50 k USD/head/yr	= 100,000,-
(iv)	4 office staff at 45 k USD/head/yr	= 180,000,-
(v)	Repairs	= 100,000,-
(vi)	Insurance	= 500,000,-
(vii)	Real taxes	= 250,000,-
(viii)	Contingencies and reserve	= 250,000,-
(ix)	Total OMA	= 1,890,000,-

(f)	DEXP= Depreciation Expense	= 7,000,000,-
(g)	DSC= Debt Service Charge at 8% per annum	= 5,600,000,-
(h)	Land, road and powerhouse rent ~2% x $\sum$OPRV	= 975,000,-
(j)	ROYALTY PAYMENT: 10% x $\sum$OPRV	= 4,871,390,-
(k)	MANAGEMENT FEE: 10% x $\sum$OPRV	= 4,871,390,-

(l) $\sum$OPXP = Total Operating Expenses =25,207,780,-

(m) Pre-tax profit= $\sum$OPRV- $\sum$OPXP = 48,713,920 – 25,207,780=
=23,506,140 USD/yr

(n) ITAX= Corporate Income Tax 20% = 4,701,230 USD/yr

(o) Profit after ITAX = (m) – (n) =18,804,910 USD/1st.yr

(p) Cash-in-hand, end of yr= 48,713,920- [1,890,000+ 5,600,000+ 975,000+ 4,701,230]= 48,713,920- 13,166,230
= 35,547,690 /yr 1st.

(r) Number of years to repay borrowed funds of 70 mill. USD= 70,000,000/35,547,690 = 1.969 $\cong$ 2 years;

B First year [using 25% royalty and 25% management fee]

(a) Same as A above, except (j) and (k) in OPXP(A) will increase by a total of 30%, or OPXP(B) will be=
25,207,780+30% x 48,713,920= =39,821,960 /yr 1st.
That is: OPXP(B)= 39,821,960 USD/1st.yr;

(b) Thus: pretax profit= 48,713,920-39,821,960= 8,891,960 USD/1st.yr

(c) ITAX Corporate Income Tax: 20%x 8,891,960= 1,778,390 USD/1st.yr

(d) Cash-in-hand after ITAX=
48,713,920-[1,890,000+5,600,000+975,000+1,778,390]=
= 48,713,920- 10,243,390= 38,470,530 USD/1st.yr

(e) The possible number of years to repay borrowed funds of 70 mill. USD= 70,000,000/38,470,530= 1.82 yrs ≅ 1 year and 10 months;

C In A and B above the depreciation expense [″DEXP″] has not been used to compute the ″possible″ number of years to repay the borrowed funds of 70 mill. USD! [We say ″possible″ number of years to repay the borrowed funds, due to the fact that in the normal course of financing, at the time of borrowing, the term of the borrowing is set, say, for 10yrs, and the annual depreciation expense is available to be put into a sinking fund to accumulate by the end of the 10th. year at a set interest rate, to repay the borrowed amount. This is so, unless it is spelled out, that for a set penalty, or without penalty, the borrowed funds may be repaid before the end of the term.]

D Since the cash represented by ″DEXP″ is available, if pre-agreed, we may add it to cash-in-hand, both in A and B, as follows:

(a) Under A:
(f) +(p)= 7,000,000+35,547,690= 42,547,690 USD/1st.yr and repayment period of capital of 70 mill. USD under this agreement= 70,000,000/42,547,690= 1.645 yrs ≅1 year, plus 8 months;

(b) Under B:

(A)(f) + (B)(d) = 7,000,000+38,470,530=45,470,530 USD/1st year

Repayment period of capital of 70 Million USD under this arrangement =70,000,000/45,470,530=1.54 year

≅1 year, plus 7 months.

(c) It can be seen, that the repayment period of the borrowed capital of 70 Million hardly changes under (A) and (B)!

E In summary, it can be stated, that the borrowed sum of 70 million USD can be repaid in less than two (2) years!

F This type of 100% debt financing can be arranged by giving a promissory note to the lender, as a collateral!

13. Important note: In the above computations under 12 the "Blue certification" revenue, has not been taken into account for not using any outside supplied "fuel", such as fossil or nuclear fuels;

This Blue Certification revenue is roughly one-half (1/2) of the sum of $OPRV_e$ + $OPRV_{green}$ = 26,630,400 + 21,304,320 = 47,934,720 USD in (d) of (12) above;

Thus, the repayment period would be further shortened had this "Blue Certificate" revenue been used!

LIS

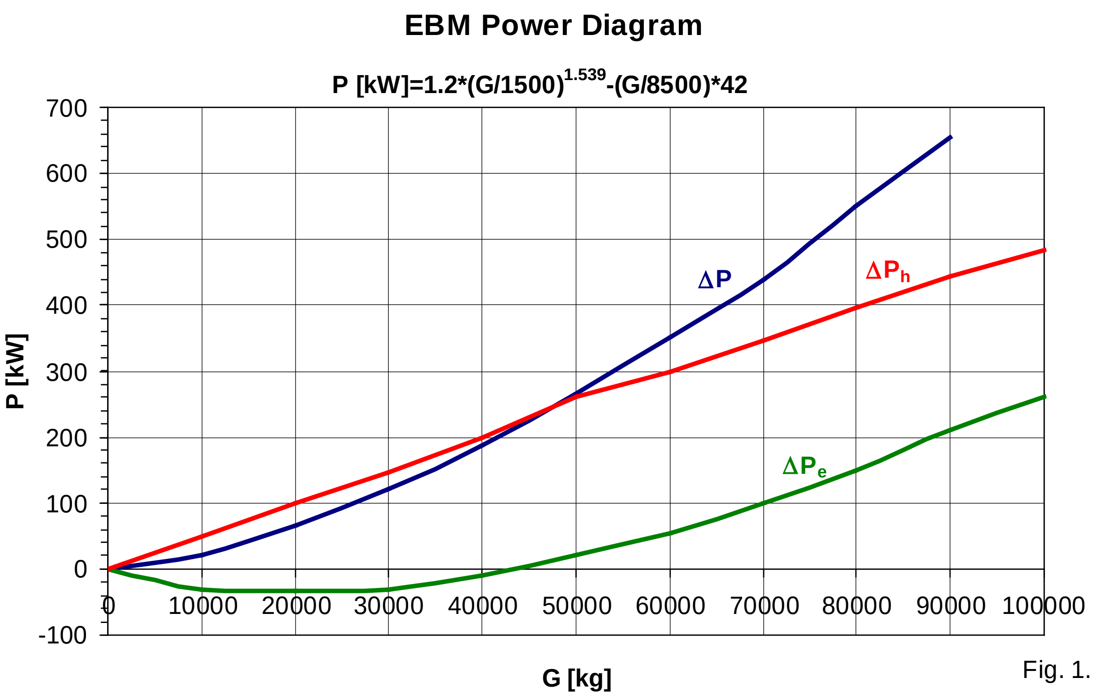
EBM Power Diagram
P [kW]=1.2*(G/1500)^1.539-(G/8500)*42
700
600
500
400
300
200
100
0
-100
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
P [kW]
G [kg]
ΔP
ΔPh
ΔPe

Fig. 1.

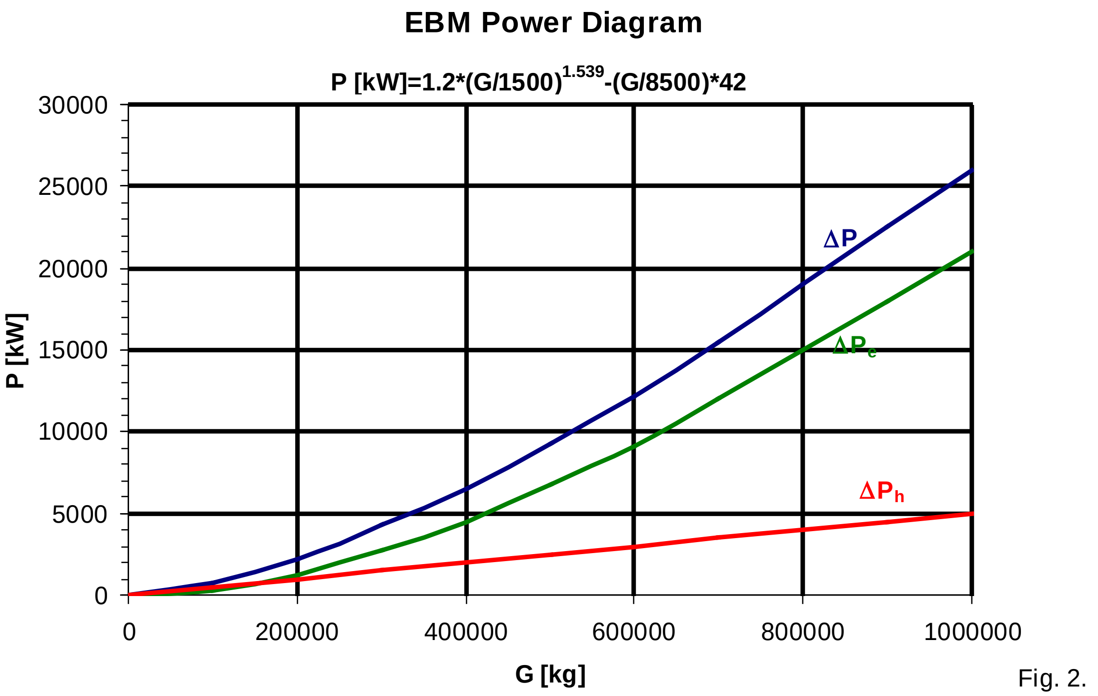
EBM Power Diagram
P [kW]=1.2*(G/1500)^1.539-(G/8500)*42
30000
25000
20000
15000
10000
5000
0
0
200000
400000
600000
800000
1000000
P [kW]
G [kg]
ΔP
ΔPe
ΔPh

Fig. 2.

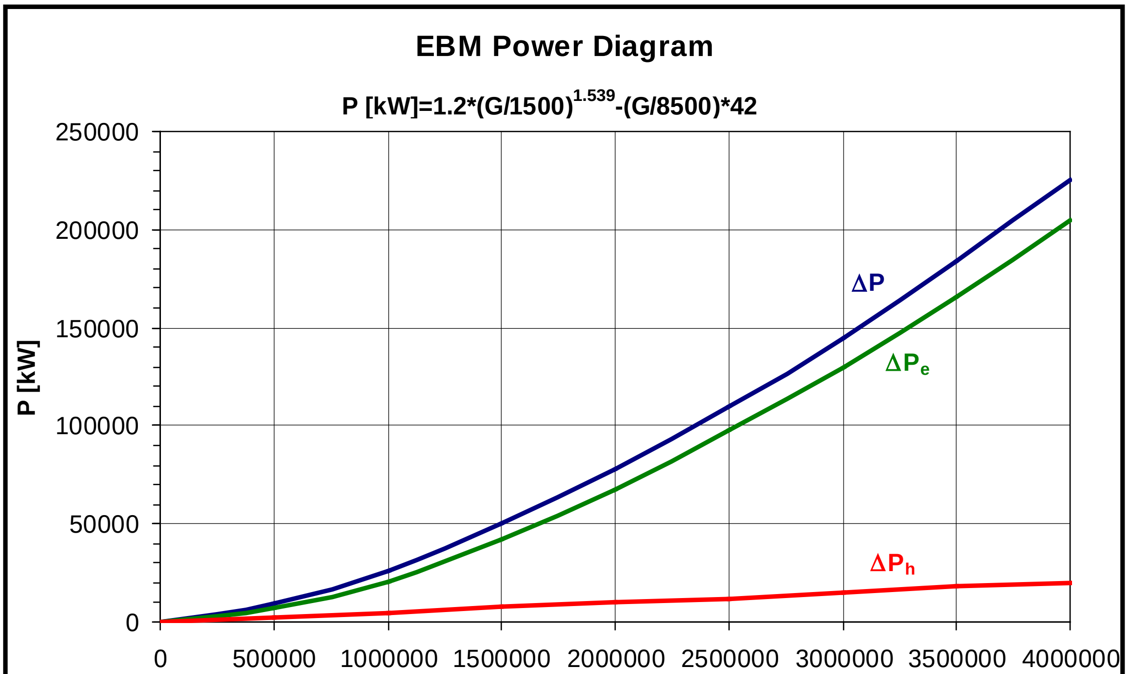
EBM Power Diagram
P [kW]=1.2*(G/1500)^1.539-(G/8500)*42
P [kW]
250000
200000
150000
100000
50000
0
0
500000
1000000
1500000
2000000
2500000
3000000
3500000
4000000
G [kg]
ΔP
ΔPe
ΔPh

Fig. 3.

EBM Paper by Professor Szabó

100 % DEBT FINANCING CASH FLOW PROJECTIONS FOR A 40 MEGAWATT EBM UNIT FOR 10 YEARS OF REVENUE (all figures in $ USD)

	Total Installed Cost (TIC)	Electric Capacity (kw)		Load Factor for elect. (95%)		Elec. Selling Price 0,08 USD/kWh					Inflating rate	Green point/revenue: (USD/kW	
	$70 000 000	40 000		0,95		0,08					0,03	0,064	
			1st Year	**2nd Year**	**3rd Year**	**4th Year**	**5th Year**	**6th Year**	**7th Year**	**8th Year**	**9th Year**	**10th Year**	**TOTALS**
1	Operating Revenue	OPRV											
	a) electricity (40 MW @ $0.08 USD/kwh)		$26 630 400	$26 630 400	$26 630 400	$26 630 400	$26 630 400	$26 630 400	$26 630 400	$26 630 400	$26 630 400	$26 630 400	$266 304 000
	b) heating/cooling energies (11.86 MW $0.015 USD/kwh LF:50%)		$779 202	$779 202	$779 202	$779 202	$779 202	$1 012 963	$1 012 963	$1 012 963	$1 012 963	$1 012 963	$8 960 823
	c) Green Point Revenue (80 % of OPRVe)		$21 304 320	$21 304 320	$21 304 320	$21 304 320	$21 304 320	$21 304 320	$21 304 320	$21 304 320	$21 304 320	$21 304 320	$191 738 880
	d) Total OPRV		$48 713 922	$48 713 922	$48 713 922	$48 713 922	$48 713 922	$48 947 683	$48 947 683	$48 947 683	$48 947 683	$48 947 683	$488 308 023
2	Operation, Maintenance & Admin	OMA											
	a) 6 operators X $60,000 USD/person		$360 000	$370 800	$381 924	$393 382	$405 183	$417 339	$429 859	$442 755	$456 037	$469 718	$4 126 997
	b) 4 office staff X $45,000 USD/person		$180 000	$185 400	$190 962	$196 691	$202 592	$208 669	$214 929	$221 377	$228 019	$234 859	$2 063 498
	c) 2 manager X $75,000 USD/person		$150 000	$154 500	$159 135	$163 909	$168 826	$173 891	$179 108	$184 481	$190 016	$195 716	$1 719 582
	d) 2 mechanics at 50 k USD/person		$100 000	$103 000	$106 090	$109 273	$112 551	$115 927	$119 405	$122 987	$126 677	$130 477	$1 146 388
	e) Repairs and maintenance		$100 000	$103 000	$106 090	$109 273	$112 551	$115 927	$119 405	$122 987	$126 677	$130 477	$1 146 388
	f) Real taxes and insurance		$750 000	$772 500	$795 675	$819 545	$844 132	$869 456	$895 539	$922 405	$950 078	$978 580	$8 597 909
	g) Contingencies		$250 000	$257 500	$265 225	$273 182	$281 377	$289 819	$298 513	$307 468	$316 693	$326 193	$2 865 970
	h) Total OMA		$1 890 000	$1 946 700	$2 005 101	$2 065 254	$2 127 212	$2 191 028	$2 256 759	$2 324 462	$2 394 195	$2 466 021	$21 666 732
3	Depreciation												
	a) over 10 years	DEXP	$7 000 000	$7 000 000	$7 000 000	$7 000 000	$7 000 000	$7 000 000	$7 000 000	$7 000 000	$7 000 000	$7 000 000	$70 000 000
4	Debt Service Charge	DSC											
	a) 8% of 70,000,000 USD		$5 600 000	$5 600 000	$5 600 000	$5 600 000	$5 600 000	$5 600 000	$5 600 000	$5 600 000	$5 600 000	$5 600 000	$56 000 000
	b) Land and road and powerhouse rent ~ 2 % x OPRV		$975 000	$975 000	$975 000	$975 000	$975 000	$975 000	$975 000	$975 000	$975 000	$975 000	$9 750 000
5	Royalty Payment (10 % X OPRV)	RP	$4 871 392	$4 871 392	$4 871 392	$4 871 392	$4 871 392	$4 894 768	$4 894 768	$4 894 768	$4 894 768	$4 894 768	$48 830 802
6	Management fee												
	10 % X OPRV	MF	$4 871 392	$4 871 392	$4 871 392	$4 871 392	$4 871 392	$4 894 768	$4 894 768	$4 894 768	$4 894 768	$4 894 768	$48 830 802
7	Total Deductible Expenses (OMA+DEXP+DSC+RP+MF)	OPXP	$25 207 784	$25 264 484	$25 322 885	$25 383 038	$25 444 996	$25 555 565	$25 621 295	$25 688 998	$25 758 732	$25 830 558	$255 078 336
8	Pre-tax Profit (OPRV - OPXP)	PTP	$23 506 138	$23 449 438	$23 391 037	$23 330 884	$23 268 926	$23 392 118	$23 326 387	$23 258 684	$23 188 951	$23 117 125	$233 229 687
9	Corporate Income Tax (@ 20 x PTP)	CIT	$4 701 228	$4 689 888	$4 678 207	$4 666 177	$4 653 785	$4 678 424	$4 665 277	$4 651 737	$4 637 790	$4 623 425	$46 645 937
10	**Cash in Hand After Tax (OPRV-OMA-DSC-CIT)**	**CAT**	**$35 547 694**	**$36 477 334**	**$36 430 614**	**$36 382 491**	**$36 332 925**	**$36 478 231**	**$36 425 646**	**$36 371 484**	**$36 315 697**	**$36 258 236**	**$363 020 354**

11 Notes: 1) Electrical selling price is 0,08 USD/kWh, Heat energy is 0,015 USD/kWh and after 5th year: 0.0195USD/kWh (RP + MF are paid to owners);

2) Total Installed Cost ("TIC") is 70 Million USD; Power house and land cost of 5 Million USD in TIC is excluded.

3) The green point revenue [1(c)] is available due to the Kyoto Protocol for not emitting green house gases (CO2, CO, NOx);

4) Life expectancy of the Power Plant is 40 years.

5) Borrowed funds of 70 Million USD is repaidat the end of the 10th year. (from the sinking fund established in year 1), using 3(a) DEXP;

6) Total borrowed funds by Partner of 35,000,000 USD could be repaid in appx: 35,000,000/35,548,000 =.9845 years (11 months and 15 days); EELreceives dividends thereafter;

7) For simplicity, interest during construction (IDC) has not been used.

8) One-half (1/2) of Total Installed Cost ("TIC") is provided by Electro Erg Ltd.

9) Blue Certificate Revenue (for not using outside fuel, such as fossil or nuclear fuels), is not included in the above.