PROMOTION OF RENEWABLE ENERGY, ENERGY EFFICIENCY AND GREENHOUSE GAS ABATEMENT (PREGA)

Viet Nam

BAGASSE AND OTHER BIOMASS - FIRED POWER PLANT and SUOI CHUM SMALL HYDROPOWER PLANT

An Assessment Report [1]

January 2006

[1] Prepared by the PREGA National Technical Experts from the Institute of Energy.

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PART I

I. OVERVIEW ON DEVELOPMENT OF SUGAR, SUGAR CANE SECTOR IN VIETNAM

Production of sugar cane in Vietnam began long ago with significant expanding of production from the 1980s, and until 1998, Vietnam was still a sugar importing country. In 1994, the country's sugar production was about 300,000 tons (about 100,000 tons of sugar is produced by industry and 200,000 tons by small producers at the household level). An additional 124,000 tons have been imported to meet the sugar demand.

Comment [BE1]: Small producers?

In October 1994, the Premier of the Government approved the "Program of sugar cane and sugar development for Vietnam" and set production target of 1 million tons of sugar by 2000 in order to meet domestic demand.

At present, the average sugar cane production per hectare is still low and sucrose content in sugar cane is also lower than that of other countries. Moreover, sugar cane growing areas are also quite far to the sugar processing plants, many of which are operated with production lower than designed capacity. Most equipment is old, not ensuring the quality of sugar after processing.

Strategy for the period up to 2010 is focused on improvement of sugar cane production lines and sugar products. Policy for the next decade is focused on:

(i) Supporting existing sugar plants by developing sugar cane growing areas that are concentrated in specific areas in order to ensure stable sugar cane supply. In these areas, productivity of sugar cane will be increased to 60 - 70 tons per hectare (even 80 tons/ha in Mekong delta) and increase of sucrose content in sugar cane.

(ii) Increase the electric and steam energy efficiency of the sugar production.

(iii) Increase of the capacity factor of sugar plants to maximal production;

(iv) Encourage sugar plants to make products from sugar in order to increase values of sugar such as production of bear, candies, fruit juice, milk and other products.

(v) Remove some sugar plants to other sites, which are nearer to the sugar cane growing areas so that they have enough sugar cane for production.

If conditions are allowable, increase capacity of sugar plants and increase sugar cane areas to 400,000 ha.

1.1 Current status of production of the whole sugar sector

I.1.1. Capacity and technology level

In the whole country there are 43 sugar plants with designed capacity of 82 450 tons of sugar cane per day, in which:

- 8 small plants (100 - 900 tons of sugar cane per day), with total designed capacity of 4 450 tons per day (TPD), accounting for 5.4% of the whole country capacity. These plants have equipment at average and low levels compared of that in the world.
- 22 medium plants (1000 - 1500 TPD) with total designed capacity of 27,000 TPD, accounting for 32.7%. Most of these plants use China and India equipment.
- 13 large plants (2000 - 8000 TPD) with total designed capacity of 51,000 TPD, accounting for 61.9%. They are large plants with good quality equipment.

I.1.2. Location of sugar plants (see attached map)

Geographical locations:

43 sugar plants are located throughout the country.

- In the northern provinces of central coastal area, there are 12 plants with total designed capacity of 26850 TPD, accounting for 32.6% of the whole country capacity.
- In central coastal area and highlands, there are 15 plants with total designed capacity of 23450 TPD, accounting for 28.4 % of the whole country capacity.
- In southern region, there are 16 plants with total designed capacity of 32150 TPD, accounting for 39.0% of the whole country capacity.

By economic sector

- There are 32 state owned plants with total designed capacity of 43350 TPD, accounting for 52.6% of the whole country capacity.
- There are 4 similar plants with total designed capacity of 12000 TPD, accounting for 14.7% of the whole country capacity.
- There are 07 joint venture plants with 100% foreign capital and total designed capacity of 27100 TPD, accounting for 32.7% of the whole country capacity.

I.2. AREA, PRODUCTIVITY AND PRODUCTION OF SUGAR CANE IN THE PERIOD 1998-2003

According to statistical data presented in Table I.1 in five recent years, the crop in 1999 - 2000, had the highest total area of production of sugar cane. The main reason is that before cropping, sugar supply is lower than demand.

In crop production in 2000 -2001, sugar plants and growers of sugar cane suffered loss and the area of sugar cane was reduced. Then in 3 subsequent crops, total area of sugar cane in the whole country was increased slightly. The sugar cane concentrated areas is paid attention therefore they were increased rapidly.

Table I.1. Data of 5 crops in the period 1998 - 2003

Crop production	Area of the[2] whole country (Ha)	Area of concentrated[3] zones (Ha)	Average[4] productivity (T/Ha)	Total[5] production (1000 Tons)	Production of pressed sugar cane[6] (1000 tons)
1998 - 1999	283,000	153,000	48.9	13,800	6,600
1999 - 2000	350,000	202,000	50.8	17,800	8,800
2000 - 2001	303,000	201,863	49.8	15,100	7,200
2001 - 2002	309,000	202,255	49.2	15,200	8,500
2002 - 2003	315,000	258,750	49.8	15,700	11,600

Because sugarcane supply was better in crop 2002 – 2003, production of pressed sugar cane reached 11.6 million tons (sugar plants in the whole country have average production of 93.0%). However, development of sugar cane area did not increase steadily. Many plants lack sugar cane, while others have surplus. Sugar cane supply in the period 2002 - 2003 follows:

Comment [BE2]: Is this a capacity factor?

(i) 28/43 sugar plants which reached 80% the designed capacity as mentioned in Table I.1.a (in the previous crop there were 16/42 plants)

Comment [BE3]: Please define the following table

Table I.1.a: List of 28 sugar plants having surplus sugar cane supply more than 80%

Dong Xuan	200%	Tra Vinh	115%	Kien Giang	100%
Phan Rang	175%	Ben Tre	115%	Hoa Binh	100%
Nagarjuna	146%	Binh Dinh	114%	La Nga	98%
Nghe An - T&L	141%	Tho Tay Ninh	114%	Tuy Hoa	89%
Phung Hiep	138%	Song Con	114%	Song Lam	89%
Bourbon Gia Lai	133%	KCP - Phu Yen	106%	Kon Tum	89%
Nuoc Trong	128%	Dak Lak	106%	333 Dak Lak	87%
Vi Thanh	128%	Lam Son	104%	Binh Duong	85%
Hiep Hoa	124%	Nong Cong	103%	Tri An	81%

[2] Sugar cane area of whole country
[3] Sugar cane area near by 43 sugar mills
[4] Average productivity of whole areas

[5] Total production of whole country

[6] Production of pressed sugar cane of industrial sugar mills to product while sugars

Soc Trang 122%

For the above sugar plants, features of sugar cane areas are as follows:

Comment [BE4]: ?

- Surplus of area: Dong Xuan, Phan Rang, Nghe An - T&L, Bourbon Gia Lai, Nuoc Trong, Soc Trang, Tra Vinh, Ben Tre, Dak Lak, Lam Son.
- High productivity (tone of sugar cane per ha): Soc Trang, Tra Vinh, Ben Tre, Lam Son, Nghe An - T&L.
- High quality: Lam Son, Cao Bang

Comment [BE5]: High capacity factor?

(ii) Sugar plants lacked of sugar cane:

+ 11/43 sugar plants (in the previous crop 15/42 plants) counting for 50 - 80% of designed capacity, namely:

Table I.1.b: List of 11 sugar plants having lack of sugar cane supply

Son La	79%	Tuyen Quang	73%	Son Duong	65%
Bourbon Tay Ninh	77%	Quang Ngai	69%	Ninh Hoa	64%
An Khe	73%	Nam Quang Ngai	69%	Viet Dai	60%
Cao Bang	73%	Thoi Binh	68%		

+ 5/43 sugar plants (in the previous crop 11/42 plants) counting for lower than 50% of designed capacity, namely:

Viet Tri	49%	Quang Binh	37%	Cam Ranh	32%
Binh Thuan	49%	Quang Nam	34%		

I.3. Status of sugar production

I.3.1. Industrial sugar production

Productions in recent five years are presented in the following Table.

Table I.2. Production of industrial sugar in 1998 – 2003

Crop production	Total capacity (TPD)	Productivity of pressed sugar cane (1000 Tons)	Available capacity (%)	Sugar production ((Tons)
1998 - 1999	69,050	6,600	64.0	552,500
1999 - 2000	73,700	8,800	80.0	764,000

Comment [BE6]: Sugar Production

2000 - 2001	68,050	7,200	70.6	650,000
2001 - 2002	80,850	8,500	70.5	772,600
2002 - 2003	82,950	11,600	93.0	1,058,700

I.3.2. Production by handicraft

According to data of 1999, there were 4,279 sugar production facilities in the country with capacity of 1.5 - 5 tons sugar cane per hour, with the total amount of pressed sugar cane accounting for 36% of capacity of industrial sugar plants. Production of these plants is very simple, increasing or decreasing annually according to sugar prices and sugar cane buying capability of industrial sugar plants. Production of handicraft sugar plants is presented in Table I.3.

Table I.3. Situation of sugar production by handicraft sugar plants

in 5 years of 1998 - 2003

Production crop	Sugar production (tons)
1998 - 1999	200,000
1999 - 2000	250,000
2000 - 2001	300,000
2001 - 2002	300,000
2002 - 2003	150,000

I.4. Sugar supply

The following Table shows that from 1995, sugar consumption increased rapidly to about 14% compared to the previous year. Industrial sugar consumption increased about 20% every year.

Table I.4. Sugar supply in recent 13 years

Crop	Production (tons)		Import (tons)	Export (tons)	In store (tons)	Total consumption		Industrial sugar	
	Industrial	handicraft				Consumption	Growth rate (%)	Consumption	Growth rate (%)
89-90	42329	230000	23800	-	-	296129	-	66129	-
90-91	58165	240000	15900	-	50	314015	6.0	74015	11.9
91-92	87062	215000	11300	-	450	312962	-3.4	97962	32.4
92-93	91720	200000	44300	-	3018	333452	6.5	133452	36.2
93-94	85631	220000	124400	-	-	433049	29.9	213049	59.6
94-95	110117	210000	175500	-	50000	445617	2.9	235617	10.6
95-96	182100	200000	20000	-	-	452100	1.4	252100	7.0

96-97	213400	260000	720000	-	-	545400	20.6	285400	13.2
97-98	322000	230000	125000	-	30000	647000	18.6	417000	46.1
98-99	556700	200000	12500	-	122638	676562	4.6	476562	14.3
99-00	764000	250000	-	80000	30000	1026638	51.7	776638	63.0
00-01	650000	300000	-	60000	-38000	958000	-6.7	657000	-15.3
01-02	772650	300000	-		5000	1029650	7.5	729650	10.9
02-03	1058700	150000	-	50600	-	1164300	12.8	1014300	38.6

II. PLANS OF SUGAR CANE GROWING AND SUGAR PRODUCTION

II.1. Sugar supply -demand forecast for the period up to 2020

If the 43 sugar plants with total capacity of 82 450 TPD operated at full capacity, sugar production (supply capacity) from crop 2003 - 2004 would be 1.15 million tons per year (11 kg sugar cane/1 kg sugar). With the current development speed, if sugar plants operated at full capacity in crop 2004 – 2005, production would have reached 1.25 tons, the highest in the period.

Regarding sugar consumption: with present economic growth rate and population growth rate, annual sugar demand growth rate is about 6 - 10% p.a, and will be stable at 3 - 3.5% in years after 2010. Therefore, sugar consumption-supply is projected of 1.3 million tons, 1.64 million tons, & 1.8 million tons in 2006, 2010 & 2020 respectively.

In crop 2002 - 2003, consumption was projected at 1,092,000 tons, but actual consumption was higher at 1,164,300 ton of sugar (without any in store for the next crop) due to low sugar price.. The balancing indicated that in 2005, reasonable extension of capacity of sugar plants is necessary.

II.2. Demand of sugar cane and land for growing sugar cane

Based on demand of sugar, demand of sugar cane for sugar production is forecasted based on the following data:

- Average sugar cane productivity is 62 - 65 T/ha by 2010 and 68 - 75 T/ha by 2020.
- Sugar cane production will be increased 2.5 - 3%/year by 2010, then 2 - 2.5%/year.

Table II.2. Demand of sugar cane for sugar industry

Year	Productivity (T/ha)	Sugar demand (1000 tons)	Sugar cane demand (mill. tons)	Required area (1000 ha)
2010	62 - 65	1190 - 1250	13.2 - 14	213 – 220
2015	66 - 68	1405 - 1500	15.1 - 16	229 – 240
2020	70 - 75	1685 - 1720	17.2 - 18	246 – 250

Table II.3. Anticipated sugar cane production

Area	2010			2020		
	Area (ha)	Productivity [7] (T/ha)	Production[8] (1000T)	Area (ha)	Productivity (T/ha)	Production (1000T)
Whole country	256939	63	16206	257768	70	18104
Northern mid land	14605	62.2	908	14355	64.4	928
Central north	72376	58.8	4254	72637	65.9	4786
Central coast	59223	52.2	3092	57946	61.9	3588
Highland	23380	54.3	1271	24295	58.6	1423
South-east	39140	63.3	2477	41690	71.5	2982
Cuu long delta	48215	87.2	4204	46845	93.9	4397

Source: Planning reports from sugar plants.

Comment [BE7]: Use units the same as Table II.2

III. BAGASSE RESOURCES

The results of surveys indicate that when pressuring one ton of sugar cane, 250 - 300 kg of bagasse with average moisture content of 50%, heat value of 1850 kcal/kg[9] is received. This bagasse is the best fuel for steam boiler to produce electricity and steam. At present, all sugar plants use cogeneration technology. Bagasse used for producing electricity and heat is 80%. Therefore, most sugar plants have surplus bagasse of up to 20%, which is used for other purposes such as making paper, board, but most is wasted.

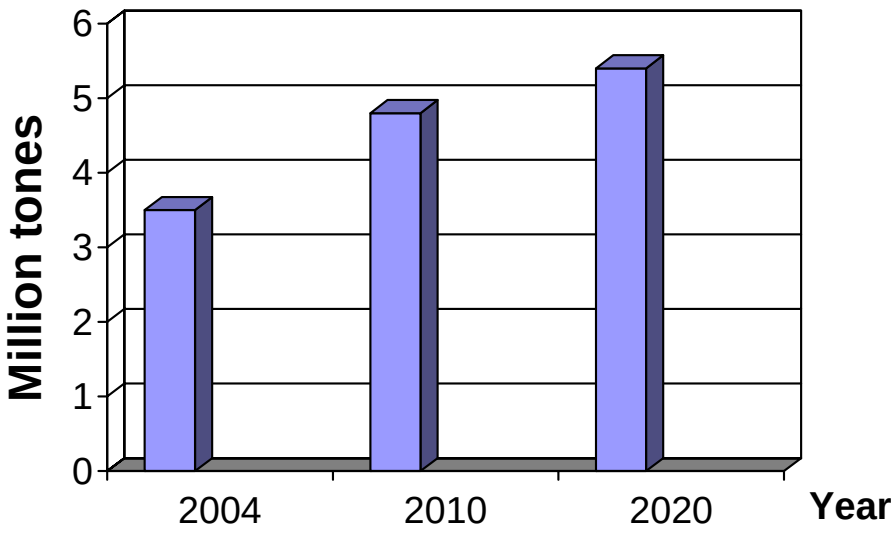
Comment [BE8]: This value seems low for a boiler to produce 2.2 tons steam per ton bagasse

Comment [BE9]: Not all?

In the crop 2003 - 2004 sugar cane pressure capacity was 11,705,870 tons, about 3.5 millions tons of bagasse was produced. In Table II.3, demand of sugar cane in 2010 and 2020 are expected to be 16,206,000 tons and 18,104,000 tons respectively, and potential of bagasse will be 4.8 million tons in 2010 and 5.4 million tons in 2020.

[7] Productivity means that yield (tone of sugar cane per ha)
[8] Production means that gross output (ton)
[9] Reported by sugar mill

Figure III.1 Available amount of sugar bagasse in 2004 and projected for 2010 and 2020



IV. RESULTS OF SURVEYS IN SOME SUGAR PLANTS AND PRELIMINARY ASSESSMENT OF TECHNICAL and TECHNOLOGY OF PREGA

In the implementation of "PREGA project stage II", the Institute of Energy sent papers to 6 sugar plants requesting for Pre- feasibility study for cogeneration. The Institute received reply from 4 sugar plants, 50 % of which agreed to cooperate with IE in carrying out pre-feasibility study with the following conditions (i) based on expansion plan of sugar cane pressing capacity and sugar cane plantation areas; and (2) no request for replacing old boilers as well as other equipments that are working). After consideration, the following two sugar plants were selected for collecting data.

Comment [BE10]: Since it is necessary to dispose of the bagasse and sugar production requires both steam (500 – 600 kg steam per ton cane and electricity (12 – 15 kW/ton cane) it is typical to have a low efficiency cogeneration system already in place if export of power is not possible.

- Sugar cane and sugar joint venture company Nghe An Tate&Lyle
- Ben Tre sugar plant

Preliminary PREGA technical and technological assessment for the two sugar plants in terms of using bagasse as main fuel for electricity generation is summarized below.

IV.1. Joint Venture Company Nghe An Tate&Lyle

IV.1.1. General introduction

Sugar cane and sugar joint venture company Nghe An Tate&Lyle is a joint venture between Vietnam Anglo (AVSI) sugar Investment Company and Song Con Nghe An sugar company, with establishment license No. 1486/GP dated 03/02/1996 issued by MPI. The main headquarters of the company is in Nghia Xuan commune, Quy Hop district, Nghe An province, with area of about 22 ha. Total investment is 90 million USD, of which the self-finance is 40 million USD (81% is foreign, 19% is Vietnamese). The plant began operation in 01/1999. In 3/2002 the plant received certificate ISO 9001:2000. Most equipment was manufactured in England, some in Vietnam. Designed capacity is 6000 tons of sugar cane/day. It will be upgraded to 9000 tons of sugar cane/year in 2006. Duration of sugar cane pressure is 180 days (from November to April), with average annual crushing of 1.1 to 1.3 millions tons of sugar cane, production of 120,000 tons of sugar.

Table IV.1. Production in the last three crops

Crop	Sugar cane pressure production (tons)	Sugar production (tons)
2002 – 2003	1272000	118000
2003 – 2004	1060000	122000
2004 - 2005 (*)	1100000	110000

Notes: (*) Estimated figures

IV.1.2. Sugar cane growing areas

The plant has 3 sugar cane growing areas in 4 districts of northeast of Nghe An province, namely Nghia Dan, Quy Hop, Quy Chau and Quynh Luu. Total area of sugar cane in the crop 2003 - 2004 is about 23 500 ha. During crop 2004 - 2005 it would be reduced to about 22,000 ha, and in the crop 2005 - 2006 it would be only 16,100 ha. The reason of this reduction is the unfavorable weather with long drought and farmers shifted growing plants when realizing growing sugar cane was not profitable.

However, in the plan to expand sugar cane pressure capacity to 9,000 tons/year, the plant plans to increase sugar cane area to 27000 - 30000 ha. Furthermore, the plant has 50 agricultural engineers who can help farmers increase productivity. Every year, the plant carried out comparison, inspection in order to select and provide them over 100 good varieties. The plant also has sugarcane treatment system. Therefore, the sugarcane productivity is increased from 43 tons/ha in 1999 to 59 tons/ha in 2003.

IV.1.3. Electricity, steam, fuel consumption[10]

The plant is using cogeneration technology for producing electricity and steam, serving plant's operation. The main equipment specifications are as follows[11]:

Comment [BE11]: It is surprising that such a low temperature and pressure boiler and steam turbine was installed in a plant that become operational in 1999.

Boiler

(Fluidized bed technology, burning bagasse)

[10] Reported by sugar mill

[11] The above steam parameters indicate that superheated and outlet steam temperature and pressure are too low. This is one of reasons making high heat rate (kg steam/kWh), low efficiency. This happens in most boilers burning bagasse in sugar plants in Vietnam.

Quantity:	01 boiler
Steam output:	175 T/h
Design pressure:	29 bar
Working pressure:	22.7 bar
Superheated steam temperature:	305 ^{0}C[12]
Fuel:	Bagasse
Fuel consumption (designed):	73.3 T/h

Comment [FP12]: Please clarify. Seems very low temperature

Turbine

(Backpressure type)

Quantity:	01 turbine
Capacity:	10 MW
Rotation speed:	5017 rpm
Speed of out shaft:	1500 rpm
Steam flow:	102 T/h
Inlet steam pressure:	22.7 bar
Inlet steam temperature:	300 ^{0}C
Outlet steam pressure:	0.75 bar
Outlet steam temperature:	125 ^{0}C

Comment [FP13]: Ditto

Comment [FP14]: ditto

[12] See 10

Generator

Quantity: 01 generator

Capacity: 10MW

Steam use

Steam from boiler goes to main collector then to consumers. A portion of steam is used in turbines driving feed water pump and turbine driving exhaust fan maintaining boiler combustion. This steam is about 22T/h. Other steam of 95 - 120 T/h is used in turbine-generator for producing electricity and threshing machine. The secondary steam after going through turbine is used for technological process (evaporating, cooking sugar etc.). In order to increase capacity, a portion of steam is extracted from the main steam pipeline through pressure reducing station for the process. This steam is about 30 T/h. The steam loss is about 2 - 3 T/h.

Comment [BE15]: If a back pressure turbine were used to reduce pressure approximately 2,300 kW could be produced

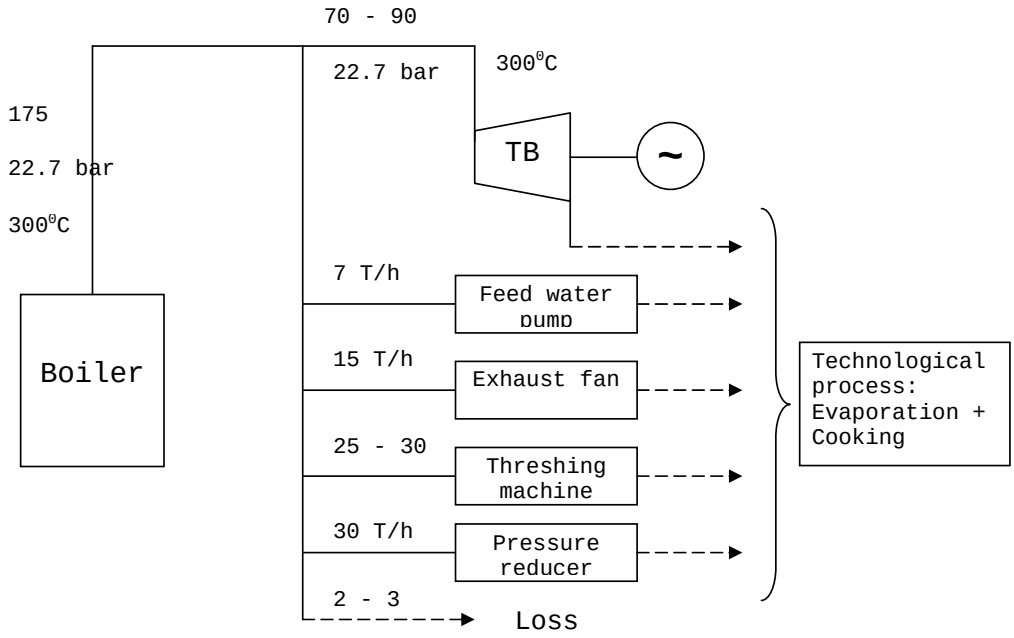


Figure IV.1. Thermal scheme of the plant.

Electricity consumption

Apart from the turbo-generator of 10MW, the plant installed 2 substations with capacity of 250 KVA in order to buy electricity from the national power grid at 10 KV. However, because the 10kV power network is not stable for production of the plant, therefore, plant installed 2 diesel power generators with capacity of 1MW/ each[13].

Two substations of 250 KVA mainly supply electricity to offices and residential areas. Two diesel-generator sets are used during starting boiler and back up for emergency case when the main generators stop operation.

The power load of the plant in the milling season is 5 - 5.5 MW. The main power resource is the steam turbine-generator. During that time, two diesel sets are used for starting boiler and as standby resource.

Comment [BE16]: There should be no requirement for use of these generators during the milling season as there could be excess power with the proper design of the cogeneration system as earlier noted. If the grid is unreliable, these units would be required for off-milling season.

Fuel consumption

Main fuel used in the plant is bagasse.

In order to increase sugar cane pressure capacity of the plant to 9000 tons per year in 2006, the plant step by step increases this to 7000 then 8000 tons/year.

With present pressure capacity of 8000 tons/year, the amount of bagasse is:

Amount of bagasse = Pressured sugarcane x (27) %

= 8000 x 27% = 2160 tons/day.

= 90 T/h

Steam demand of the plant corresponding to this pressure capacity is: 175 T/h.

Actual amount of bagasse used: 73.3 T/h

Therefore bagasse surplus is: 90 - 73.3 = 17 T/h. (accounting for 18%)

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[13] 1. Based on survey on current status of sugar plants and reports from sugar industry on use of bagasse for energy production (heat and electricity) as well as use of steam and electricity for sugar production at present, the following observations were found:

(i) The old boilers using bagasse as fuel have low parameters such as superheated steam temperature and outlet steam pressure. This leads to high bagasse consumption and low efficiency. Therefore, rehabilitation of these boilers needs to be considered in order to increase efficiency and creating additional income from re-uses of bagasse or selling surplus electricity to the national power grid or to surrounding consumers.

(ii) The design and installation of equipment in the past indicate that there was no plan to sell surplus electricity to the power grid (lack of plan and policy). On the other hand, because lack of mechanism/policy for promotion of renewable electricity (not selling surplus electricity) most sugar plants tried to burn all bagasse in order to save money for burying or disposing of bagasse.

(iii) Because electricity and steam could not be sold and can be used within the sugar plants, leading to inefficient energy use (heat and electricity). This is the barrier, which needs to be solved in terms of policies and orientations of sugar sector development so that price of sugar will be reduced (VND/kg sugar). At present, sugar price in Vietnam is higher than that of neighboring countries.

2. In this pre-feasibility report, based on Ben Tre sugar plant, request proposal only focus is made on unit producing electricity by using current surplus bagasse amount and more bagasse when sugar plant is enlarged with more capacity (sugar cane plantation and pressing in coming years

At present, the plant has no plan to use this bagasse surplus so it is discarded into dumping ground. This dumping ground is overloaded in the pressure season. In order to address this problem, plant has to pay 7000 VND/ton of bagasse for tidying up. Because of bagasse surplus, the plant still does not consider using sugar cane leaves.

IV.1.4. Action plan

By 2006, sugar cane pressure capacity of the plant is increased to 9000 ton/day; sugar cane area is increased to 27000 - 30000 ha. By then, own used electricity demand of the plant is 6.5 MW. If generator generates full capacity, the surplus is 3.5MW. However steam demand is also increased, therefore, boiler is overloaded. Only sugar cane leaves can be used as additional to bagasse[14].

Comment [FP17]: Again problem seems to be more that boiler/steam/electricity generation system needs to be replaced.

Comment [BE18]: At 9,000 tons cane per day (375 tons cane/hr) the plant should produce at least 101 tons bagasse per hour capable of producing steam at 220 tons per hour. At 400 kg steam per ton cane the process steam should be about 150 tons per hour and with 22 ton/hr required in the boiler house 48 t/h could go to a condensing turbine and produce about 8,000 kW. With an extraction port to reduce the pressure of the 30 t/h currently going to a pressure reducing valve, approximately 10,000 kW could be exported with the installation of a extraction/condensing turbine/generator.

IV.2. Ben Tre sugar plant

IV.2.1. General introduction

The plant has been constructed in 1997. Its area is 7.8 ha. The plant owner is People Committee of Ben Tre province. The project used loans of about 20 billions VND from ADB, development fund, commercial bank and state budget.

The plant started operation in 12/1998. Equipment comes from China with design capacity of 1000 tons sugar cane/day. In 2001, the plant was expanded to capacity of 1500 tons sugar cane/day.

Average pressure time is 200 days (from September to April). In past years, plant always exceeded the designed capacity. Sugar cane pressure capacities in recent years are as follows:

Table IV.2. Plant production

Season	Sugar cane annual production (tons)
2000 - 2001	186 000
2001 - 2002	251 000
2002 - 2003	260 000
2003 - 2004	198 000
2004 - 2005	232 000

IV.2.2. Sugar cane areas

The plant has stable area of sugar cane with high productivity. The sugar cane growing area is about 6000 ha, of which 4500 ha only for the plant. The plant gave farmers the intensive farming method and chose best sugar cane varieties. The productivity is 75 tons/ha.

[14] See 12

The plant has a plan to expand the sugar cane area to match the increased capacity of the plant. By 2010, the area of sugar cane for the plant will be 4500 ha with productivity of 100 tons/ha. The increase of pressure capacity is planned in two stages. The first stage is from now up to 2008, capacity is increased to 2000 tons/year and the next stage to 2015, capacity is planned to increase to 3000 tons/day.

IV.2.3. Steam, electricity, fuel consumption[15]

Main equipment

Comment [BE19]: 1500 t/d cane the electric requirement should be about 750 kW at 12 kWh/ton cane and steam requirement of 25 t/h. With a bagasse production of 16.9 t/h there should be sufficient bagasse to produce 37 t/h steam. This will result in approximately 12 t/h excess steam that could go to a condensing turbine generator to produce approximately 2,000 kW.

Boiler

The boiler type is of natural circulation with double drum, fluidized bed combustion. Bagasse is jet into the combustion chamber and burnt in beds. The boiler can increase load quickly and flexible in operation. There are two oil burners arranged at the side of the boiler for its starting and keeping stable when bagasse is insufficient. This means that during the time beyond production season, oil must be used for electricity generation.

Boiler parameters:

	Quantity:	02 boilers
	Steam output:	20 T/h
	Outlet steam pressure:	2.45 Mpa
	Superheated steam temperature:	400 0C
Fuel:	Bagasse/oil	
Fuel consumption:	9310 kg/h	

Turbine

Turbine is backpressure type, with the following parameters[16]:

Comment [BE20]: This would appear to be a very low efficiency turbine to produce on 1,500 kW with 20 T/h steam

Quantity:	02 turbines
Capacity:	1.5 MW
Rotation speed:	6500 rpm
Out shaft speed:	1500 rpm
Inlet steam pressure:	2.4 Mpa
Inlet steam temperature:	390 0C
Outlet steam pressure:	0.3 MPa

Generator

Quantity:	02 generators
Capacity:	1.5 MW

[15] Reported by sugar mill
[16] See 12

Steam, electricity consumption

Steam from boiler goes through turbine for generating electricity. Steam out from the turbine is used for sugar production. This method ensures steam for sugar processing and supply of electricity to the whole plant.

Table IV.3. Steam consumption

No	Steam users	Steam equipment	Steam parameter		Steam flow (T/h)	
			Pressure (Mpa)	Temperature (0C)	Average	Maximum
1	Turbine hall	Turbine	2.4	390	2x18.08=36.16	
2	Processing hall	Evaporation + sugar cooking + primary heating	0.294		21.23	25.7
3	Processing hall	Liquid sugar separator	0.49		2.5	3.0
4	De-Oxide hall	De-Oxide machine	0.02		2.2	2.6
5	Loss				1.2	1.4
	Total 2+3+4+5				27.13	32.7

The above table indicates that in normal operation, steam required for the whole plant is 27.13 T/h, corresponding to 2 MW generated. Full capacity of two turbines is 3 MW using 36.16 T/h of steam, meeting maximal steam demand of the plant (32.7 T/h).

At present, own used electricity demand of the plant is about 2.4 MW meanwhile electricity generated is 2.6 MW. That means surplus is 0.2 MW.

Fuel consumption

Bagasse resource

Present production capacity of the plant is 1500 tons/cane per day, bagasse amount is:

Bagasse amount = (0.25 -:- 0.27) x Pressure capacity = 0.27 x 1500 = 405 T/day

= 16.875 T/h.

Corresponding to the above pressure capacity, steam demand is 32 T/h. Fuel consumption of one boiler (20 T/h) is 9.31 tons bagasse/h. Therefore, bagasse amount required is:

Required bagasse amount = 32 x 9.31/20 = 14.896 T/h

Surplus bagasse amount = 15.625 - 14.896 = 1.979 T/h (accounting for 11.73%)

Therefore, at present the plant has bagasse surplus of 12%. This amount is stored and used for the time beyond the production season.

Rice husk resource

The nearest rice husk resource for Ben Tre sugar plant is in Cai Be and Cai Lay districts in Tien Giang province, 40 km far from plant.

There are about 50 rice-milling plants in these two districts with capacity of 2 t/h each. Rice husk is 20%, therefore, in one hour about 400 kg rice husks is produced. When they are at full capacity (from January to April), each mill plant will produce about 10 tons rice husks/day. Therefore, potential of rice husks in this area is about 20T/h.

The milling plants are located near canals, convenient for waterway transportation at low cost. From the milling plants, rice husks are transported through canals to Tien river, to upstream of Ham Luong river then to sugar plant, which is located by the river. One boat can transport 15 tons of rice husks.

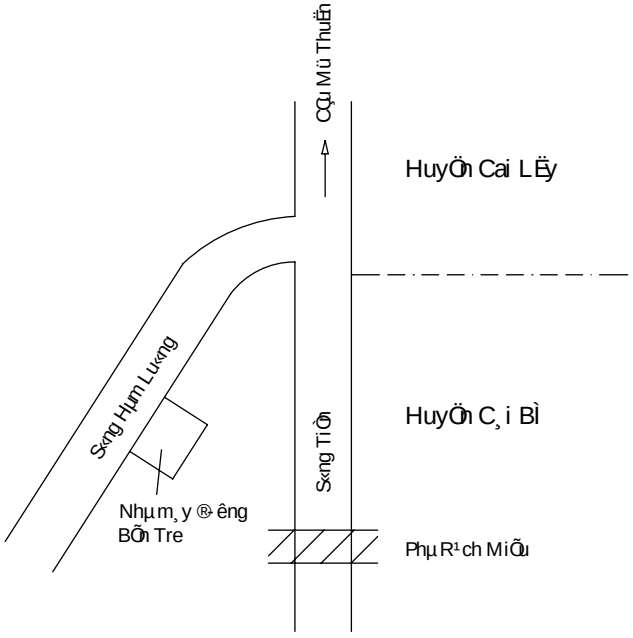

Figure IV.2. Location of Ben Tre sugar plant.

Rice husk price is changed by market demand and season. During the main season from January to April, rice husk price is fluctuated in the range of 30 - 40 VND/kg but from August to September, it is increased to 50 VND/kg. Beyond rice season, milling plants are operated at only 50 - 70% of design capacity, and rice husk price is increased to 200VND/kg. If transport cost from milling plants to sugar plant is included (100,000 VND/ton), rice husk price in main season is 130,000 - 150,000 VND/ton and beyond season is 200,000 VND/ton.

Coconut fibers resource

Ben Tre is a province, which has the highest and most stable coconut production in the country. It has coconut area of about 40,000 ha. Therefore, there is huge amount of coconut fibers produced.

IV.2.4. Action plan

By 2008 the capacity of the plant is anticipated to increase to 2000 tons/day and in 2015 about 3000 tons/day[17]. The sugar cane area is maintained, but productivity is increased to 100 T/ha in 2010.

Comment [BE21]: This is almost an increase by more than two times from the annual average over the past five years

In the future, the plant will install one additional boiler with steam output of 20 T/h, turbine-generator with capacity of 1.5 MW in order to supply enough electricity and steam for demand of the plant at new increased capacity.

Site selection

Considering and selecting sugar plant for preparation of cogeneration feasibility report is based on the following criteria:

- Sugar cane resource: sugar cane growing area must be stable, long term, with high productivity and quality, low cost, meeting expansion plan of the plant and pressure duration is long. The sugar cane growing area must be close to the plant (in distance of 20 - 30 km) with convenient transportation conditions and lowest transportation cost.
- Available fuel resource: apart from bagasse which is being used as fuel for boiler, the available biomass resources in the area of the sugar plant should be considered for burning together with or as substitutes of bagasse when necessary. This biomass resource must be concentrated, with huge amount and near to the sugar plant, convenient transport. The other biomass types, which can be considered, are rice husks, sugar cane leaves, coconut fibers etc.

Results of analysis and data from the development plans of considered sugar plants indicate that Ben Tre sugar plant is suitable for selection according to the set criteria. The capacity of the plant will be increased and sugar cane growing area is also expanded with high productivity. Moreover, there is high potential of biomass resources around the plant (rice husks potential is 20T/h). The plant pledged to invest in one more boiler (20 t/h) and turbine-generator (capacity of 1.5 MW), not only ensuring steam and electricity demand for the plant's production but also selling surplus electricity to the national power grid.

Therefore, it is recommended to select Ben Tre sugar plant for preparation of cogeneration pre-feasibility report.

Comment [BE22]: If the option of adding a condensing extraction turbine generator is evaluated at Joint Venture Company Nghe An Tate&Lyle approximately 10 MW would be available for export and would have a definitive GHG abatement component.

Some conclusions:

1. Based on survey on current status of sugar plants and reports from sugar industry on the use of bagasse for energy production (heat and electricity) as well as use of steam and electricity for sugar production, the following observations were found:

[17] Reported by sugar mill

(i). The old boilers using bagasse as fuel have low parameters such as superheated steam temperature and outlet steam pressure. This leads to high bagasse consumption and low efficiency. Therefore, rehabilitation of these boilers needs to be considered in order to increase efficiency and generate additional income from re-use of bagasse or selling surplus electricity to the national power grid or to surrounding consumers.

(ii). The design and installation of equipment in the past indicate that there was no plan to sell surplus electricity to the power grid (lack of plan and policy). On the other hand, due to lack of mechanism/policy for promotion of renewable electricity (not selling surplus electricity) most sugar plants tried to burn all bagasse in order to save money for burying or disposing of bagasse.

(iii) Electricity and steam could not be sold and can be used within the sugar plants, leading to inefficient energy use (heat and electricity). This is the barrier that needs to be resolved in terms of policies and orientations of sugar sector development so that price of sugar will be reduced (VND/kg sugar). At present, sugar price in Vietnam is higher than that of neighbouring countries.

2. In this pre-feasibility report based on the Ben Tre sugar plant, request (proposal) only focus is made on unit producing electricity by using current surplus bagasse amount and more bagasse when sugar plant is enlarged with more capacity (sugar cane plantation and pressing in coming years)

PART II. SUOI CHUM HYDROPOWER PLANT

I. INTRODUCTION

Hoa Binh is a northwest mountainous province with natural area of 4749 km2, of which 67, 060 ha of farmland, and 303,680 ha of forestland. Hoa Binh's population are 766,000 people in 1998 with various ethnic groups, of which Muong (60%), Kinh (30%), and Thai, Dao, Meo, etc. (10%).

Administratively, one town (Hoa Binh) and nine districts (Luong Son, Ky Son, Kim Boi, Mai Chau, Da Bac, Tan Lac, Lac Son, Yen Thuy, Lac Thuy), six wards, eleven small towns and 200 communes (63 mountainous ones: 30%), are combined to bring about Hoa Binh province.

Mountainous climate is rather severe with annual average temperature of 21.3oC; annual mean precipitation is 1900 mm mainly in June, July and August.

Two grand rivers run through Hoa Binh namely Da and Boi, providing plentiful hydro energy for production and life. Hoa Binh hydropower plant was completed at the beginning of 1994 with installed capacity of 1920 MW.

With regards to traffic condition, it is easy to make traffic among Hoa Binh, Ha Noi, Son La and Lai Chau through highway No. 6 and Da River reservoir.

With regards to natural resources and mineral, Hoa Binh owns many quarries, huge material sources for construction industry (especially cement production). Besides, Hoa Binh is rich in limestone, coarse sand, granite, etc. Kim Boi has mineral sources with big capacity.

Power demand for life and production in Hoa Binh is increasing. During the past few years, together with unceasing development of the economic sector nationwide, the power sector has developed drastically both in production and quality. However, power production is still short against the annual demand, thus power generation source must be studied and added by various sources, especially hydropower, an available potential and gift from the God of Hoa Binh province.

Suoi Chum Hydropower Project is to be located on Suoi Chum affluent, Dong Chum commune, Da Bac district, Hoa Binh province. Suoi Chum is one affluent of Da River. Estimated installed capacity is about 3- 5 MW, annual energy production is to be about 10 - 15 million kWh. It will contribute to the local power supply to ensure the stable power system, to make the budget source bigger and to create job for local people.

II. General Description

II.1. Electric demand forecast for Hoa Binh province in the period 2005-2010.

Power network current situation

Main power supplying source of Hoa Binh province is composed of 110/35/6kV- Hoa Binh substation with capacity of 2x25MVA and 10/35/22kV Lac Son substation. Apart from that Hoa Binh power network is also supported by Xuan Mai (Ha Tay province) mediate transformer substation, which is standby for feeder No. 374, and by substation from Ninh Binh for some consumers in Yen Thuy district (cement factory X18) and Lac Thuy one.

Hoa Binh province owns 10 mini hydropower stations with total installed capacity of 205 kW. Such mini hydropower stations almost only operate in flood season, mainly for irrigation and

supply of electricity for small groups of inhabitant, which are far from national power grid. Moreover, there are over 7000 mini hydraulic power generators with capacity from 0.3-0.5kW of households for supplying electricity for daily life.

At the beginning of 2003, 110 kV power grid in Hoa Binh was composed of 103.6 km from Hoa Binh hydropower plant to Hoa Binh town substation, Son La substation and branch line to Lac Son one. Total capacity of medium-voltage transformer substation (including mediate transformer) is 135,530 KVA.

Table 2.1 Statistics on capacity of substations in Hoa Binh province

No	Substation	Qty	Transformer	Capacity - kVA
1	10/35/22kV	2	3	66000
2	35/10kV	9	10	11800
3	35/6kV	5	6	12800
4	35/0.4kV	408	412	49500
5	6-10/0.4kV	283	297	54630
	Total	707	728	201530
a	**EVN management**	607	625	179770
b	Customer's management	102	104	21760

In the "Hoa Binh Power network rehabilitation and development planning for the period 2002-2005 with consideration to 2010", total electricity sale of the whole Hoa Binh province (high case) in 2005 is 196 million kWh and 501 million kWh in 2010, corresponding to Pmax of 57 MW in 2005 and 128 MW in 2010 respectively.

The power and electricity demand of the whole district was forecasted in 5 economic components:

- Industry - construction
- Agriculture - Forestry - Aquatic
- Commerce - Hotel - Restaurants
- Residential and lighting and management
- Others

Based on power demand forecast by 5 stipulated sectors in Hoa Binh province, total demand of Hoa Binh is described in high and base cases:

Table 2.2 Total demand of Hoa Binh

Year	Items	High case	Base case
2005	Sales energy electricity, GWh	181,96	172,22
	Receiving electricity, GWh	196,00	185,53
	Pmax, MW	57	54
2010	Sales energy electricity, GWh	465,83	385,20
	Receiving electricity, GWh	501,01	413,91
	Pmax, MW	128	107

II.2. Description of Suoi Chum hydropower plant

This is a small hydropower plant to supply electricity to local areas and be connected to the national power grid. The main data of the project are as follows:

Table 2.1. Principal parameters of the project

No.	Items	Unit	Value	Remarks
(1)	(2)	(3)	(4)	(5)
1	**Hydrology**			
	Catchment area	km2	38,2	
	Average annual rainfall	mm	1753	
	Average annual water flow	m3/s	1.72	
	Flood flow	m3/s	417	
2	**Reservoir**			
	Normal water level	m	386	
	Death water level	m	386	
	Total volume	1000 m3	35	
3	**Power station**			
	Number of units	Unit	2	
	Installed capacity	MW	3.0	
	Turbine			Francis Turbine
	Generator		Synchronous	
	Average annual electricity production	106 kWh	12	

Comment [FP23]: Please clarify/correct

II.3. Socio Economic Development Plan

II.3.1. General objectives

According to Resolution adopted by the Eighth Party Congress, resolution of Hoa Binh Party Committee and based on the revision of planning implementation, the socioeconomic development direction of Hoa Binh up to 2010 will be revised and added based on the following points:

- To attach special importance to develop industry rationally with focus on energy consuming sub-sectors such as consuming limestone, mineral, or labor intensive sectors as electronics assembly, textile, leather, processing of agricultural and forest products.
- To gradually step up development of tourism and services, to develop Hoa Binh town to Hoa Binh city in overall planning on Ha Noi's neighboring urban areas - Ha Tay - Hoa Binh.
- To be able to select project based on economic efficiency.
- To attach special importance to small and medium scale enterprises with less investment capital and short-term of return as well as creation of jobs.
- To develop open economy connecting socioeconomic development of province to the development of key economic development in the North.
- To strengthen security and defense, to protect ecology and environment, firstly, remote mountainous districts and communes.

II.3.2. Main targets are as follows:

- To strive for fast growth of GDP with annual growth rate of around 7.7-9.5%, of which, about 8% and 10% for the period of 2001-2005 and 2006-2010, respectively.
- GDP per capita in 2005: VND 4 millions and over VND 6 - 7 millions in 2010, about US$ 464-551.
- Food output of paddy equivalent is estimated to reach 25,000s ton and 32,000 tons by 2005 and 2010, respectively, with average food per capita is 315 kg/capita, come up 90% food security of mountainous areas.
- To reach export turnover of 2010: US$ 20-30
- Accumulation from GDP: 3-4% in 2000 and 15% by 2010.
- Budget income in period of 2001-2010: 10-14%

III.Location and natural conditions of Suoi Chum HPP site

III.1. Location

Suoi Chum HPP site with coordinates of 20o57' North latitude, 103o47' East longitude is located in areas of Muong Cai - Muong Hung, Chieng Khoong communes, Da Bac district, 20km east of district town center. The site is 93km far from Hoa Binh town in the Southeast. Chum stream is one affluent of Nhap stream. It is tributary I on the left side of Da river, runs from the mountain region with elevation 700 m. It runs in the direction of South North and incorporated into Da River at the position of 20055'00'' – 104058'30'', on Nhap Ngoai village, Da Bac district, Hoa Binh province.

III.2. Climate features

Suoi Chum catchment is located in tropical monsoon climate zone with cold and dry winter, raining, humid and hot summer. As well as other regions in the North of Vietnam, the basins climate of Da River is generally, Nhap affluent is especially monsoon tropical climate. There are two clearly seasons in a year; it is dry, cold and little rain in winter; rainy, wet and much rain in summer. Monsoon climate characteristic in North West region is shown clearly the following regulations

According to the measured data at Mai Chau station, mean annual temperature is about 25.6 0C. It has clearly two seasons in a year: rainy season lasts from April to September, while dry season lasts from October to March the following year. Maximum hot month is May, max high temperature reaches 40.10C in June, min low month reaches is 3.00C in December and January.

Mean annual regulation atmosphere humility (Rtb) is 82% at Mai Chau, is 85% at Moc Chau. It is a little changed from the middle of months in year and lasts from year to other. Max high mean monthly regulation atmosphere humility is August with mean monthly humility 88% at Moc Chau, 86% at Mai Chau. Min low mean monthly regulation atmosphere humility is January, April and December with mean humility of April is 80% at Mai Chau, is 79% January, December

The mean measured vaporization data duration (1961-2001) is 911.8 mm at Mai Chau. Popular wind direction is south and southeasterly direction. Northeasterly wind direction blows back in winter, at the same time, northeasterly and northern wind direction also occurs, however, not the same on the basins and the occurred frequency much smaller than Southeasterly direction. It is not only popular in summer but also some months of winter, moreover being a reason to make alternant heat wave in winter. Due to divided topography the mean annual small wind velocity is changing from 0.6 to 1.0 m/s.

With regards to the monsoon regulation and topographic feature impacts, affected to rain regulation and its alteration on the basin - Being a basin in mountain sheltered (khuat gio) from the wind, the yearly rainfall at the downstream of Da river and the basin of Nhap affluent is smaller than the others on it. Long-term mean yearly rainfall here fluctuated / is about 1600 – 1900 mm: Mai Chau, X year – 1761 mm; Moc Chau – 1606 mm; Hoa Binh – 1869 mm; Bai Sang – 1635 mm. Annual rainfall divided 2 clearly seasons: dry season and rainy season. Rainfall and rainfall time of it is clearly different.

- Rainy season lasts from May to October, about 70 -80% the total annual rainfall. Heavy rain period lasts from June to August, max yearly rainfall is in August with the total of long-term monthly mean to be about 300 mm.
- Dry season lasts from November to April the following year with about 20 – 30% the total of annual rainfall. The transition time between dry - rainy season is November and April, thus, mean monthly rainfall is rather large compared to other stations of its fluctuated 36.6 – 97.4 mm. Little rain period lasts three months from December to February the following year with the total mean monthly rainfall 11 – 21.2 mm.

III.3 Designed hydrological features

Based on flow actually measurement material at area gauging-stations issued: annual flow regulation divided two clearly seasons:

- Flood season lasts from June to October with about 70 – 85% the total of yearly flows. Max flood months are June, July and August.
- Dry season lasts from October to May next year with about 15 – 30% the total of yearly flows. The transition time between dry – flood season is November and May.

Runoff at sites is calculated based on annual runoff of representative weather station by the equation:

$$Q_{ct} = Q_{tt} \frac{F_{ct}}{F_{tt}} \frac{X_{ct}}{X_{tt}} \quad \text{(m3/s)} \quad (1)$$

Of which, Qct, Qtt, Xct, Xtt, Fct, Ftt are discharge, rainfall and catchment areas of sites and representative basin.

Mean annual discharge corresponding to the designed frequencies of the site:

Table 3.1. Water flow's features in Suoi Chum project

Study site	Average feature			Designed discharge (m3/s)		
	Qtb (m3/s)	Cv	Cs	10%	50%	90%
Suoi Chum	1.72	0.267	3.0Cv	2.33	1.66	1.18

Daily discharge duration curve of the site (Qct) is calculated based on monthly discharge duration curve (Qtct) at site by the formula:

Qct = Khc * Qt (m3/s) (2)

Of which,

- Qt is monthly discharge at site corresponding to firm discharge.
- Khc is rate of daily discharge and monthly discharge corresponding to firm discharge. Khc is obtained from representative station. The results are shown in the following table.

Table 3.2. Daily discharge duration curve

P(%)	QSC(m3/s)	P(%)	QSC (m3/s)
0.5	23.54	55.0	0.64
1.0	16.69	60.0	0.56
2.0	11.27	65.0	0.49
5.0	6.63	70.0	0.42
10.0	4.04	75.0	0.38
15.0	2.84	80.0	0.33
20.0	2.17	85.0	0.30

25.0	1.71	90.0	0.27
30.0	1.40	95.0	0.22
35.0	1.17	96.0	0.21
40.0	1.01	97.0	0.20
45.0	0.86	98.0	0.17
50.0	0.74	99.0	0.15
		100.0	0.03

Max flood discharge corresponding to the designed frequencies Qp:

Designed flood discharge at the site Qmaxp calculated to the discount formula, the result issued in the table 5.3

Table 3.3: Designed flood discharge of hydropower plant

P%	0.2	0.5	1	5.0	10.0
Dam discharge (m3/s)	417	319	284	192	160

Basing on the settling actual measurement materials at regional gauging-stations in area, mean annual the middle do duc silt about 300 g/m3, it is the same others in area. Thus, its determined total annual silt at the site as follows:

Table 5.4: Total calculated silt in Suoi Chum hydropower plant

Site	Qo	Po	Ro	Woll	Wodd	Woct	Voll	Vodd	Votc
Dam	1.72	310	0.533	0.017	0.003	0.020	0.015	0.002	0.018

III.4 Topographical and geodetic conditions

The HPP dam is anticipated to be located on Suoi Chum stream with cross section of “U” shape. The left side of dam has slope larger about 30o than that of right side (about 25o). Topography is characterized by convex and concave with rock layer and erosion sign.

The canal is anticipated to be arranged on the right bank of stream. Water is taken at elevation of 215m (assumed height). Total canal length is of 4400 m. In general canal route goes on slightly sloped topography.

III.5. Hydro-energy

III.5.1. Objectives and tasks

Hydro - energy is calculated for determining the parameters of the project. Hydro-energy data are:

- Annual average electricity production Eo
- Electricity production in flood and dry seasons
- Firm capacity
- Water heads: Hmax, Hmin, H aver.

III.5.2. Calculation principles and in put data

Suoi Chum HPP consists of main dam, open channel, penstock and powerhouse.

Calculation of hydro-energy parameters is carried out based on hydrological characteristics at project site.

Average capacity of HPP is calculated by using the following formula:

$$N = K \times Qtb \times H$$

Where

N: Average capacity in kW
K: Power plant coefficient: 8.0
Qtb: Average water flow through turbine
H: water head for power generation: $H = Zthl - Zhl - Htt$

Zthl: water level at up stream
Zhl: water level at down stream
Htt: water head loss

Suoi Chum HPP cannot be yearly regulated, so would be Runoff river type.

Firm capacity of HPP is the generated capacity at daily average water flow corresponding to design frequency of the project.

According to Vietnam standards TCVN 5060-90, frequency used for designing Suoi Chum HPP project is 80%. With this frequency, daily water flow on water way is 0.33 m3/s.

Table 3.3. Results of hydraulic power calculation

Full supply level (m)	Minimum operating level (m)	Active storage (103m3)	Forebay water level (m)	Calculating water head (m)	Max water flow (m3/s)	Firm capacity (MW)	Installed capacity (MW)	Annual Energy Production (106kWh)
386	386	0	382.5	188	1.64	0.53	3	12

III.5.3. Input data

III.5.3.1. Parameters of reservoir

$$Z \sim F(z), V(z)$$

III.5.3.2. Water loss due to evaporation and permissibility

Total water flow loss of the project is taken equal to 2% of instant average water flow.

III.5.3.3. Water head loss and parameters of hydraulic equipment

Water head loss is determined by hydraulic calculation with maximal loss of 3m.

III.5.3.4. Electricity supply to the area

Suoi Chum HPP will be connected to Suoi Nhap A Outdoor switchyard and supplying electricity to Da Bac districts and surrounding communes by 35kV transmission line, HPP will supply electricity to the national power grid.

Table 3.4. Parameters of the project

Parameter	Unit	Value
High water level	m	386
Efective Head	m	188
Ninst	MW	3
Nfirm	MW	0.53
Eo	106 kWh	12