SMALL-SCALE MODERN AUTONOMOUS BIOENERGY COMPLEXES - DEVELOPMENT INSTRUMENT FOR FIGHTING POVERTY AND SOCIAL EXCLUSION IN RURAL VILLAGES

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EXTENDED SUMMARY

EUBIA (European Biomass Industry Association) has conducted a wide range of analysis of potentials of bioenergy since 1997. Meanwhile, it has been making special efforts for the development and implementation of modern concepts of integrated "food-animal feed-energy" biomass scheme.

With the help of ETA, WIP, Energidalen Co., EUBIA has identified a series of typical, small-scale, sustainable "bioenergy complexes" through their research activities, which are partially sponsored by the E.C.. These complexes are especially attractive for remote villages. When implemented they will be able to not only satisfy the villagers' basic energy needs, but also provide sufficient amount of clean energy for comfort and production activities. **The bioenergy complexes might prove to be solutions to the sustainable development of rural areas**.

Hereafter two types of typical bioenergy complexes will be described: one is based on the exploitation of agro-forestry residues and/or herbaceous crops. The second one is more sophisticated. This integrated biomass scheme will be able to supply a wide range of commodities: food, animal feed and modern clean energy. (therefore of more general strategic interest) It is based on the exploitation of dedicated crops, specific varieties of sweet-sorghum in particular, which have high yields of grains, sugar and lignocellulosic.

The village size considered in the following demonstration examples is in the range of 100-300 inhabitants. With the presently available commercial technologies, a small-scale bioenergy complex can support **a village population of 100 to 5,000 people**. A typical bioenergy complex can also provide numerous employment opportunities to the village inhabitants (approximately 10% of the total population). The village's "Index of Human Development" will be increased considerably, from a common low level of 20% in remote rural areas up to an acceptable level of 60 – 70% four or five years after a bioenergy complex comes into operation.

After two years' operation, the outputs of bioenergy complexes, i.e. grains, liquid sugar, bioethanol, charcoal, dry ice, will exceed local village consumption, and the sales of these surplus outputs can bring in reasonable cash flows, part of which can be used to pay back initial investment and cover the operating costs of the complex. The presence of a "**Revolving Fund**" is highly recommendable to support start-up activities of such bioenergy complexes.

The second type of bioenergy complex, based on small-scale plantation of sweet-sorghum, **with a modest investment of $1,500/capita, will be able to satisfy most of the vital /comfort /production needs of the village inhabitants and lead to general social and economical improvements in the village**.

Other types of bioenergy complexes can be designed and optimized based on biomass resources available such as agro-forestry residues, agro-industrial wastes and dedicated crops, and needs to be satisfied.

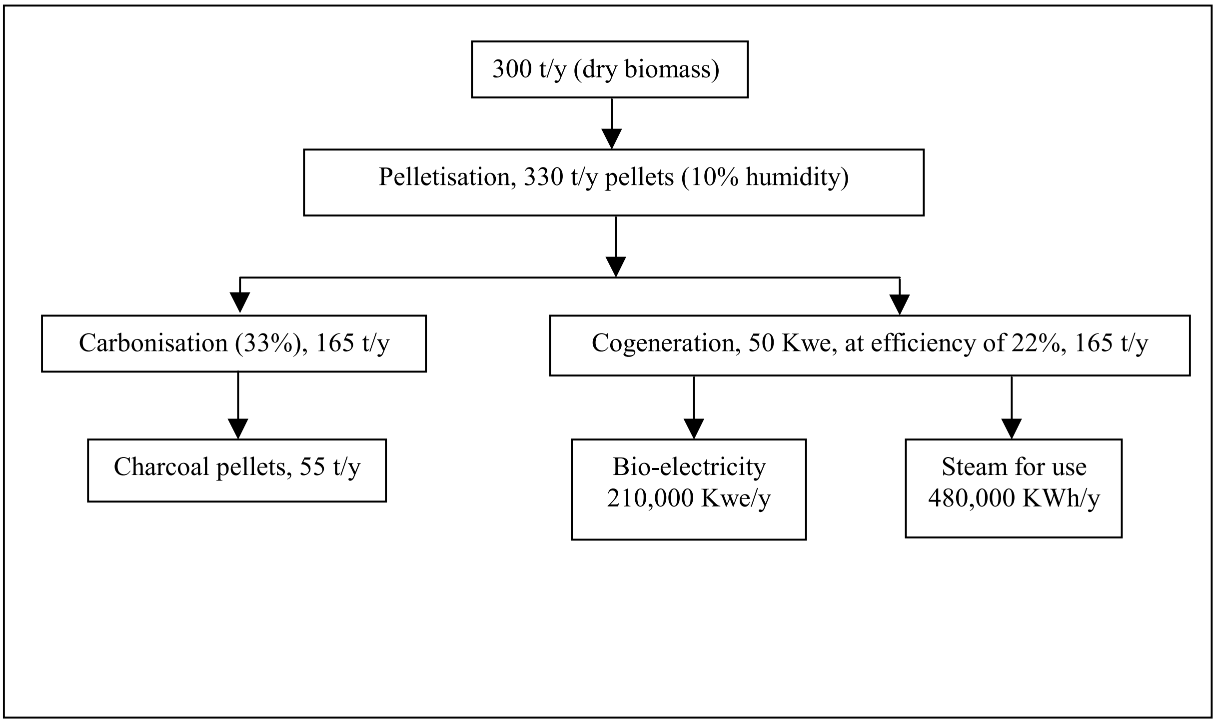
EXAMPLE 1: SIMPLE BIOENERGY VILLAGE COMPLEX

This simple complex is based on the exploitation of 300 dry ton/year of agro forestry residues and/or herbaceous crops. It is illustrated as follows:

CONCEPTS

RESOURCES	PROCESSING	PRODUCTS
• Recovery of all types of agro-forestry residues • Small-scale plantation of herbaceous crops on marginal / semi-arid land and requiring low water irrigation	• Chopping • Mixing • Drying /pelletisation • Carbonisation • Cogeneration • Use of steam for producing cooling or freezing by an absorption unit	**Power** for: • Vital needs (vaccine, family food preservation, water purification, etc.) • Comfort needs (TV, light, telecommunication, etc.) • Production activities **Steam** for: • Food processing • Cooling / freezing (village unit) **Charcoal** for: • Cooking

ACTIVITY FLOW SHEET



After being dried properly in the field, all types of agro-forestry residues and / or cultivated herbaceous crops will be pelletised (15mm / L = 40 mm / density, about 1.6 g / cm^3), with the help of innovative fixed (in future mobile) units which are currently able to carry out simultaneously the final drying and compactation of biomass for permanent storage (humidity of pellets: 8% - 10%) and easy handling.

The pellets can be utilized as solid fuel for modern efficient steam engine co-generators with power ranges of 50-100-250-500 Kwe (1 Kwe = 2.3 KWh). The heat available can be used in many ways, for instance, cooling, freezing, processing, backing, drying, sea-water desalination / treatment, hospital air conditioning, etc. Compared with conventional cogeneration systems, these systems have the following advantages:

- These electric generators have wide power elasticity (10% to 120% of nominal power), with nearly constant efficiency. At night a 100 Kwe generator runs at 10% of its nominal power and supplying 10Kwe. The pellets fuel consumption is reduced proportionally to 10% of the nominal level, about

9kg/h, instead of 90kg/h, which leads to significant fuel saving.

- When more steam is temporarily required for special applications, the power level can be reduced while the boiler is kept running at nominal capacity.

- This generator is a multi-fuel system and can also utilise any type of liquid gaseous fuels such as vegetal oil, low grade bioethanol, LHV / MHV gas, biogas, etc.

Part of the pellets will be fed to a small (50 Kwe) steam-engine generator with efficiency of approximately 22%. Part of pellets obtained by the above mentioned technology can be converted directly into ready-to-use charcoal pellets without any binding compound.

In summary, the energy products that will be available for the village will be

- Charcoal for cooking (self-use and sales)
- Power (8,500 hr/year)
- Steam (food processing, cooking, freezing, etc.)

Assuming a village of 100 – 200 inhabitants has such a bioenergy complex installed, the amount of power available per capita will be considerable, which can not only meets the inhabitants' basic and comfort needs, but also enhance the social and economic development of the village.

When using imported European technology, the following financial projection can be obtained:

Investment ($)

Chopping	5,000
Pelletisation / Drying	160,000
Storage	2,000
Carbonisation	25,000
Cogeneration	50,000
TOTAL	212,000

Expenses per year ($)

Biomass 20$/t	6,000
Interests (i = 5%)	23,200
O & M (3% of invest.)	6,000
TOTAL	35,200

Income per year ($)

Power	
(210,000 Kwe/year x 0.06$/kwh)	12,600
Steam	
(480,000 kwh x 0.02$/kwh)	9,600
Charcoal	
(56 t/y x 250$/t)	14,000
TOTAL	36,200

Annual benefit

Income	36,200
Expenses	35,200
	1,000

As can be observed from the above projection, the annual benefit is comparatively small. However, if pelletisation, carbonisation, etc. can be done locally, the financial benefits can improve considerably. Furthermore, the environmental benefits are not included due to the difficulty of quantifying those benefits.

EXAMPLE 2: BIOENERGY-FOOD-FEED VILLAGE COMPLEX

This more sophisticated system is based on the exploitation of very versatile crop plantation: special varieties of sweet-sorghum (30 ha for a population of 200-300 people). These new varieties which are developed in China have good yields: on average, 5 t/ha of grains, 7 t/ha of sugar, 15.7 t/ha of ligno-cellulosics.

This bioenergy complex can yield the following outputs:

- Food: 100 kg/y per capita grains and 20 kg/y per capita sugar
- Animal feed: 150 kg/y per capita, leaves and bagasse
- Energy:
  - charcoal pellets (from bagasse) - 68 t/y for cooking and/or sales
  - Power – 50 Kwe for basic, comfort and production needs
  - Steam (for food preserving, etc.) – 115 KWh
  - Bioethanol – 80 t/y for cooking, agricultural machinery, sales, etc

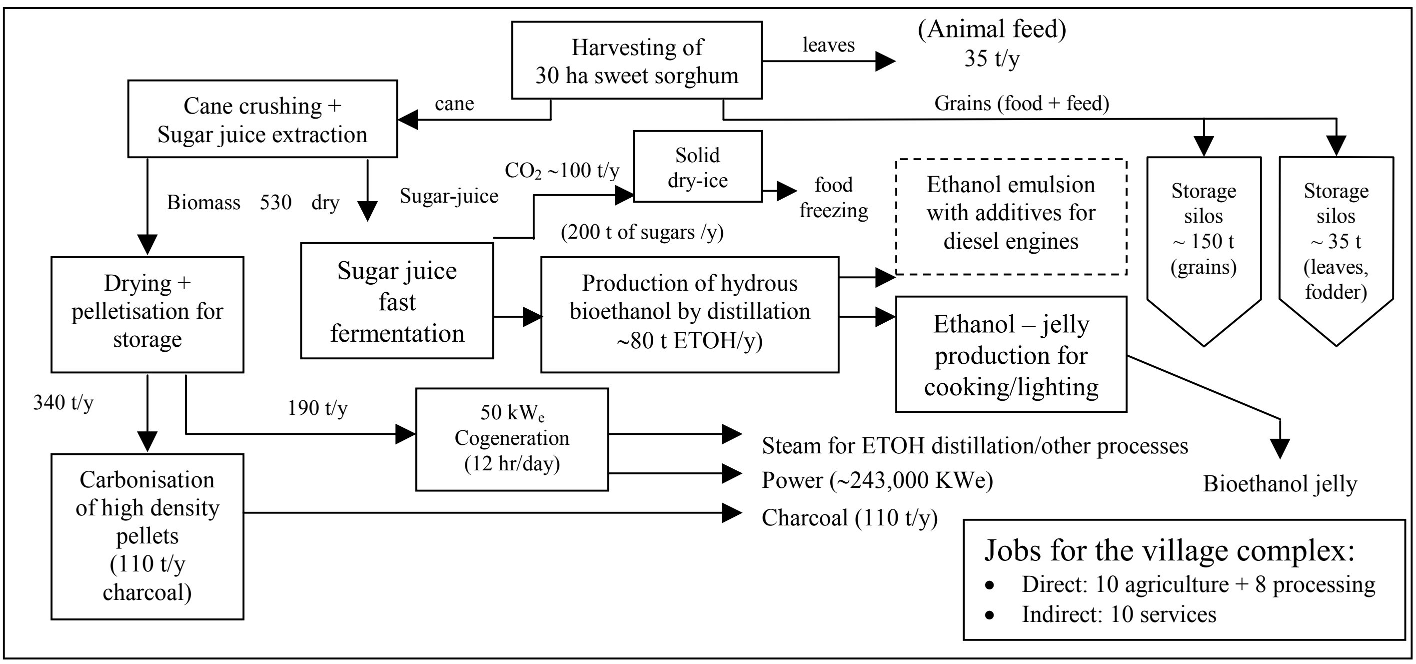
This more sophisticated bioenergy system is illustrated as follows:

CONCEPTS

RESOURCES	PROCESSING	NEEDS SATISFACTION
Plantation: • Area: 30 ha • Crop: Sweet Sorghum • Variety: Chinese * Outputs: • Grains: 150 t/y • Sugar: 200 t/y • Bagasse: 470 t/y • Roots: 60 t/y	• Drying & storage of grains • Sugar-juice extraction/filtration • Sugar-juice fast-fermentation • Beer first distillation for 96° Bioethanol production • 96° Bioethanol jelly production (cooling fuel) • Drying-pelletisation of bagasse (pellet humidity = 15%) • Power/heat production • Charcoal production (pelllets) • CO_2 solid- dry ice (food preserving)	**Food:** • Grains: 200 kg/cap x year • Sugar: 20 kg/cap x year **Animal Feed:** • Grains: 300 kg/cap x year • Leaves & bagasse: ~200 kg/cap x year **Energy:** • Bioethanol: 330 li/cap x year • Electricity: 5600 kW_e/cap x year • Charcoal: 330 kg/cap x year • CO_2 – solid-dry ice: 330 kg/cap x year • Compost: from roots, etc. + ashes for recycling into the soil

* (average) productivity: 5 t/ha grains, 6.7 t/h sugar, 15.7 dry t/ha bagasse, 2 t/ha crop roots.

ACTIVITY FLOW SHEET



In tropical regions, it is feasible to plant crops twice a year with crop cycles equal to approximately 120 days and thus the amount of resources available for the integrated bioenergy complex will double. Preliminary evaluation leads to the following results:

INVESTMENT ($)

Sugar Extractor:	50,000
Microdistillery:	130,000
Power Generation:	60,000
Pelletisation:	160,000
Charcoal	50,000
Civil Work, etc.	60,000
TOTAL	510,000

EXPENSES PER YEAR ($)

Plantation/harvest:	15,000
Investment (20 y) with interest (i=5%):	40,000
Operation (10 people):	10,000
Maintenance (2%):	12,000
TOTAL	77,000

INCOME PER YEAR ($)

Grains (120$/t):	18,000
Sugar as food (200$/t):	1,200
Electricity (0.06 $/kWh):	14,500
Bioethanol (0.25 $/li):	25,000
Charcoal (250$/t):	27,500
Dry ice for freezing (50 $/t)	5,000
Steam (0.02 $/kwh)	11,000
TOTAL	102,200

ANNUAL BENEFIT

Income per year:	102,200 $/y
Expenses per year:	77,00 $/y
BENEFIT:	25,200 $/y

For the successful implementation of this type of bioenergy complex, proper training of staff and management is critical. Meanwhile, technical and general assistance should be made readily available

CONCLUSION

It is now possible to start the development of modern bioenergy complexes for remote rural villages based on the exploitation of agro-forestry residues or dedicated crops such as sweet sorghum. A bioenergy complex utilizing sweet sorghum crops can not only meet the essential needs of the village population (food, animal feed and energy), but also provide reasonable cash flows so that an economically sound operation can be assured.

These Integrated Complexes could make considerable contribution to the general social and economic development of the rural areas and consequently increase the Human Index of Development of village up to reasonable levels of 60 – 70%.

Today not many commercially sound technologies are available for such small bioenergy complexes. A project to build such a bioenergy complex is not economically feasible because of the high costs of small-scale manufacturing. In developing countries, additional costs of technology transfer from industrial countries can make the financial results of such projects even worse-

The integrated complexes can process and utilize the biomass resources in a comprehensive and efficient way and produce several commodities of high economic value, which can greatly improve the financial performance of the complex and make it economically feasible and even highly profitable.

To ensure sustainable operation of such bioenergy complex, significant efforts have to be made to educate and train the staff and management properly and make technical assistance readily available.

APPENDIX

Potential effect of Bioenergy activity on the Index of Human Development in Africa.

List of future publication on examples of good commercial technologies, now available for decentralized bioenergy production.

APPENDIX

Potential effect of Bioenergy activity on the Index of Human Development in Africa
(source: project “Promoting the Role of Renewable Energy amongst Governments in Africa” supported by the European Commission, DG TREN, within the SYNERGY programme and performed by WIP-Munich, ETA-Florence.)

	Year 2000					**Year 2020**				
Country	*Population (millions)*	*Rural population (% of total)*	*Biomass energy (TOE/ capita)*	*Cultivated land (million ha)*	*Commercial energy consumption (TOE/capita)*	*Population (millions)*	*Biomass contribution (TOE/capita)*	*Crop land needed to increase (million ha)*	*Supplement % of total land*	*Index of human development %*
Angola	11.1	67.8	0.07	3.74	0.044	18.32	0.67	1.83	1.5	73
Benin	5.6	58.2	0.232	1.95	0.020	9.24	0.63	0.92	7.6	71
Botswana	1.5	58.2	0.4	1.16	0.02	2.48	0.8	0.24	0.5	78
Burkina Faso	10.7	72.8	0.28	2.74	0.01	17.66	0.69	1.76	6.4	73
Burundi	6.4	92.5	0.2	1.39	0.13	10.56	0.6	1.05	37.7	69
Cameroon	13.7	55.1	0.2	7.12		22.61	0.68	2.26	4.8	69
Capo Verde	0.4	45.7	2.9	0.0002	0.03	0.66	2	0.06		100
Central A.R.	3.4	60.7	0.24	1.86	0.01	5.61	0.64	0.51	2.5	72
Chad	6.6	78.6	0.26	3.85	0.05	10.89	0.66	1.09	0.9	73
Comoros	0.5	72.2	0.32	0.001	0.018	0.83	0.72	0.08		76
Congo	2.7	41.2	0.09	0.684	0.03	4.4.6	0.41	0.44	1.3	56
Congo (DR)	45.3	70.9	0.19	7.63	0.11	74.75	0.52	7.47	16	64
Cote d'Ivoire	14.3	56.4	0.15	3.86	0.13	23.6	0.45	2.36	7.3	60
Djibouti	0.7	17.2	0.13	0.005	0.06	1.16	0.7	0.11		
Equatorial Guinea	0.4	57.8	0.3	0.22	0.01	0.66	0.62	0.06	4	74
Eritrea	3.7	82.8	0.22	0.41	0.01	6.11	0.62	0.61	5	71
Ethiopia	58.1	86.6	0.22	13.2		95.87	0.84	9.58	8.7	71
Gabon	1.1	50	0.49	0.32	0.49	1.82	57	0.18	5	82
Gambia	1.2	62.3	0.17	0.18	0.06	1.98	0.31	0.19	18	68
Ghana	17.5	63.7	0.12	4.404	0.07	28.88	0.68	2.89	8.5	64
Guinea	6.8	70.4	0.25	71.7	0.03	11.22	0.67	1.12	4.6	72
Guinea-Bissau	1.1	77.8	0.34	0.32	0.04	1.82	0.74	0.18	5	73
Denya	27.4	72.3	0.34	2.32	0.06	45.21	0.74	4.5	7.7	77
Lesotho	2	76.9	0.36	0.3		3.3	0.76	0.33	11	77
Liberia	2.8	55	0.19	0.47	0.07	4.62	0.39	0.42	3.5	78
Madagascar	14.1	72.9	0.31	2.93	0.02	23.27	0.71	2.32	4	68
Malawi	10	86.5	0.28	2.36	0.02	16.5	0.68	1.65	14	75
Mali	10.1	73	0.21	2.48	0.02	16.67	0.61	1.67	1.4	73
Mauritania	2.3	46.2	0.3	0.21	0.42	3.8	0.3	0.38	0.36	70
Mauritius	.1.	59.4	0.29	0.001	0.34	1.82	0.69	0.18		45
Mozambique	16.6	65.8	0.29	3.13	0.02	27.39		2.73	3.5	74
Namibia	1.6	62.6		0.82		2.64	0.49	0.26	0.3	
Niger	9.3	76.9	0.09	3.8	0.02	15.35	0.76	1.53	1.2	63
Nigeria	144.4	60.7	0.36	3.13	0.08	238.26	0.92	23.8	25.8	78
Rwanda	7.7	92	0.52	1.17	0.02	12.71	0.23	1.27	8	82
Sao Tome & Principe	0.1	53.3	0.23	0.04		0.17	0.51	0.02	20	38
Senegal	8.7	57.7	0.11	5.29	0.07	14.36		1.43	7.3	64
Seychelles	0.1	64.9				0.17	0.66	0.016	50	
Sierra Leone	4.6	63.8	0.26	1.77	0.04	7.59	0.57	0.76	14	73

Somalia	9.8	74.3	0.17	1.27	0.03	16.17	0.61	1.62	2.5	68
South Africa	42.4	49.2	0.21	13.43	1.74	69.96	1.12	7	5.7	70
Sudan	27.3	75.4	0.72	12.5	0.04	45.05	0.66	4.5	1.8	87
Swaziland	0.9	68.8	0.26	0.17		1.49	1.1	0.15	8.8	73
Tanzania	30.5	75.6	0.7	5.67	0.02	50.33	0.65	5.03	6.3	86
Togo	4.2	69.2	0.25	1.4	0.02	6.93	0.55	0.7	12.5	72
Uganda	19.7	87.5	0.15	6.6	0.01	32.51	0.64	3.25	13.7	67
Zambia	9.2	56.9	0.24	5.2	0.15	15.18	0.7	1.52	2	72
Zimbabwe	11.2	67.9	0.3	2.73	0.38	18.48		1.85	4.7	75

List of future publication on examples of good commercial technologies, now available for decentralized bioenergy production