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ENERGY-INTEGRATION AND ENVIRONMENTAL-COMPLIANCE CONCEPTS FOR TROPICAL DAIRY FARMING

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SUMMARY

Dairy farming in Puerto Rico is attended by rising production costs and the expense of complying with environmental quality control regulations legislated during the past decade. Recent studies at UPR suggest that farm expenditures for electricity can be largely eliminated by converting cattle manure to biogas fuels for on-farm power generation. A smaller fraction of the herd's dietary protein requirement can be supplied through refeeding of biogas digestor residues. Cattle feed can also be supplemented by fish and grenfeed produced in conjunction with environmental wastewater cleanup operations. Such concepts already apply to Puerto Rico but can serve also as models for future application in the Caribbean region.

INTRODUCTION

AGRICULTURAL enterprises are routinely beset by natural forces that urban businessmen would regard as unexceptable. Recent increases in the value of fossil energy, at once severe and unexpected, have ominous long-term implications for both technically-advanced farm systems and the developing agriculture of the Caribbean basin. Their impact is felt directly in fuel and electricity bills, and indirectly in the costs of equipment, fertilizers, pesticides, technical services, and numerous other production inputs. For Puerto Rico, and ultimately the Caribbean region, an added factor has superimposed itself over the worsening energy scenario. This factor is the awareness of a deteriorating environment and the unexpected costs of preserving environmental quality.

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ENERGY-INTEGRATED FARM SYSTEMS

The concept of "energy-integrated farm systems" (EIFS) has gotten renewed interest in a program sponsored by the U.S. Department of Energy. We say "renewed" because the concept is fundamentally as old as organized farming itself. In simplest form it stresses the energy self-sufficiency of the individual farm, with special reference to the conversion of day-to-day farm wastes to useful energy. For the U.S. mainland it is a kind of counterpoint to rural electrification, that is, the programs of the 1920's to 1940's that encouraged even remote farms to be "hooked up" to urban utilities operating with cheap fossil fuels.

1. Wastes Conversion to Energy

The conversion of wastes to energy is accomplished in numerous ways, both direct and indirect, in farm and industrial operations. The oldest and usually simplest method is to burn some organic residue to provide warmth for farm homes of outbuildings, or process heat for industrial units such as lumber mills of sugar factories. The use of animal and green manures to produce cattle feed is an indirect reapplication of the wastes' latent energy. However, as ordinarily applied to EIFS designs, the waste is an animal manure, components of which are converted to a combustible gas by the process of anerobic digestion. This is a process whereby certain "volatile solids" are converted to a mixture of gases (biogas) by several types of microbes growing in the absence of exygen. The principal component of biogas is methane, a highly-combustible gas, which is then used as a fuel to operate an enginegenerator set producing electricity.

The production of biogas for electricity is a common denominator of the DOE-EIFS projects and a principal ingredient of most bioconversion systems today (2). They certainly are not confined to integrated-farm plans; for example, the world's largest is operated by the Bacardí Corporation in Puerto Rico (4). Other applications of biogas include fuel for refrigeration units, and heating plus lighting fuels at the individual household level in underdeveloped countries.

2. Useful Byproducts of Waste Conversion

An inherent weakness of many bioconversion system designs is an over-emphasis on biogass with little follow-through on byproduct applications. While it is correct to say that the anaerobic process itself has eliminated most of the microbial hazzards attending farm wastes, it is also true that only a fraction of the manure feedstock (a manure/water slurry) is actually convertable to biogas. The reamining components can be extremely valuable if utilized in an imaginitively-designed system.

(a) Digestable Proteins: An important byproduct of the anaerobic digestion of cattle, poultry, and swine manures is an edible protein fraction. Originating with the forages and feed grains consumed by the animal herd, their remnants accrue in the anaerobic digestor residues. This is largely as a function of digestion-efficiency limitations which do not allow complete assimilation of the proteins the first time they pass through the digestive tract. Hence, the opportunity exists for recovery of this fraction and feeding it a second time. This can be accomplished by drying and size-reducing the digestor residue, and blending it with commercial feed concentrate (2).

(b) Mineral Elements: Moderate amounts of nitrogen, phosphorus, and potassium are normally found in residues from digestors stocked with cattle manure. Lesser amounts of calcium and magnesium can also be present, together with traces of elements that function as micronutrients for plant crops. For this reason such residues are potentially valuable as fertilizer or fertilizer suplements for farms producing cash crops in addition to their cattle herds. These materials could be applied in the field as suspended or dissolved additives to irrigation water. A few industrial-scale operations have dried the digestor residues and packaged them for commercial fertilizer sales with an appropriately eye-catching trade name (ie, COW POWER*).

(c) Inert Matter: Least valuable of the digestor residues is the chemically-inert residue often described as "grit". Ordinarily this fraction consists of sand or other lighter fractions of soil fallen from cattle hooves in the milking parlor or feedlots. It can also include ground paper or plastic items discarded from some farm operation, or feathers in the case of poultry farms. Such materials have some limited value as soil amendments or landfill; in any case they must be removed periodically to prevent interferance with normal digestor function.

(d) Water: From an energy-integration standpoint the

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* Registered trademark

digestor by-product requiring the most attention for disposal is the water that originally comprised some 85 to 90% of the digestor feedstock slurry. It is a potential headache if its disposal is the only concern of the biogas systems' manager. However, this water represents a significant fraction of the moisture lost each day from the farm's water balance sheet. Particularly in semi-arid to arid regions, it is to the owner's advantage to reutilize this water in farm irrigation operations, after it has been cleaned to environmentally-acceptable standards. In some designs it can also be reutilized in making up the next batch of manure slurry for stocking the digestor. In this case the pre-cleaning process is not necessary.

ENVIRONMENTAL CONSIDERATIONS

Superimposed over the energy-integration concepts of the Puerto Rico EIFS project is a highly-sensitive insular "awareness" of environmental factors. Viewed in its geologic history, the entire island is literally a "gift" of the sea, having been completely submerged in two different epochs. In more recent times it has been physically buffeted on the north by the Atlantic ocean and by the Caribbean sea on its southern coasts.

Since the European colonization there have been extreme depredations of insular flora and fauna. Virgin forests that once covered the entire island have been cut and recut repeatedly(5). There has been such a loss of native plants and influx of imported species that it is difficult to reconstruct a clear picture of the original native flora (6). Birds that once were abundant, such as the Puerto Rico Pigeon and the Puerto Rico Parrot, have become endangered species. Coastal mangroves and their attendant marine wildlife have been severely damaged by sea disposal of industrial wastes.

1. Efforts Toward Environment Preservation

To Puerto Rico's credit, much has been done to understand and protect the island's ecosystems. The University of Puerto Rico (CEER-UPR), the Commonwealth Department of Natural Resources, and the USDA Institute of Tropical Forestry have performed studies related to the concept of environmental quality preservation. Extensive legislation has been enacted to arrest environmental damage and to assure long-term improvements in air and water quality[1/]. Examples of industrial compliance with these regulations include the Bacardí Corporation's conversion of distillery wastes to biogas fuel (4), and the PR Sugar Corporation's installation of emissions control equipment in all remaining sugar mills (7). Industrial compliance is also commonplace among the Island's pharmaceutical plants.

At the individual farm level a close adherance to environmental protection laws is not always possible or practical. Financial resources are lacking as well as conceptual awareness among many farm owners. In some instances there is undue reliance on "the Government" to assist in planning, designing, and financing of environmental compliance systems whose need is clearly understood.

2. Wastewater Cleaning Concepts

The EIFS concept as perceived by DOE places possibly excessive emphasis on energy "production", two little emphasis on environmental quality preservation, and virtually ignores a common denominator of both the energy and environment factors, ie, water. With a semi-arid climate such as that the UPR-EIFS site at Juana Díaz, water cannot be ignored in either regular-farm or EIFS-systems operations. Ultimate success of such projects will depend on the design and execution os their water conservation plans (1, 3).

(a) Water Supply and Farm Losses: The climate at the UPR project site near Juana Díaz is a good example of precarious water supply. While annual rainfall averages over 30 inches, most of this water is received during a 4-month period between August and December; moreover, rainfall is exceeded by pan evaporation in virtually all months of the year (Figure 1). Further to this, temperature data over a 3-decade period indicate a recent warming trend in Puerto Rico's climate (Figure 2), a factor that could materially increase the water needs of both wild and cultivated plant species.

1/ Puerto Rico has a "State Solid and Hazzardous Waste Management Program". Pertinent enacted legislation includes: PL 9 (Public Law No. 9; Public Environmental Policy Act, June 18, 1970); PL 95-580 (Federal Resource Conservation and Recovery Act, 1976); and PL 70, which created the solid Waste Management Authority, June 23, 1978.

Added to the rainfall losses by evaporation are the depletions of water by normal farm operations. Irrigation losses, particularly by overhead systems operating in the wind, are easily recognized. Less readily perceived are losses from storage reservoirs through embankment leakage, drainage through the subsoil, and surface evaporation. Water is more visibly depleted through the washing of dairy facilities and equipment, livestock drinking, and the daily hauling away of milk by the tanker-truck load. For these reasons there is justification for the recovery of digestor wastewater for reutilization in the farm and EIFS operations.

(b) Aquatic Plant and Fish Utilization: The wastewater ensuing from an EIFS anaerobic digestor contains a number of contaminants, including suspended organic solids, ionic forms of phosphorus and nitrogen, and microbial populations of varying species. Much of the solid matter can be recovered by filtration or centrifugation, but the primary water component cannot be discharged to the environment without further treatment. The latter can be accomplished by storage in a "holding" pond where natural (aerobic) processes and settling provide cleaning effects as a function of time. Other options include active cleaning by use of aquatic plant and fish populations.

The UPR project had originally intended to use fresh-water shrimp as a means of removing suspended organic matter (8). Its present modified design utilizes a fast-growing tropical fish (*Tilapia nilotica*) for the same purpose (2). Fresh-water shrimp could be harvested periodically and sold for human consumption. *Tilapia* species are used as food in some countries but would be converted to cattle feed in the PR project.

Various aquatic plant species can serve to remove ionic substances. Water hyacinth was the principal plant form selected for the PR project, while some use of cattail (*Typha* spp.) was also planned. Such materials would be harvested periodically and utilized as a digestor-feedstock supplement for biogas production (2).

(c) Clean Water Recycle: Water that has been "treated" by aquatic plant and fish action is suitably clean for general-farm purposes such as crops irrigation or washing cattle pens and feedlots. With chlorination it would be suitable for cattle watering or direct discharge into streams or rivers. Particularly in arid-land farms, the discharge of this water would be a gross underutilization that would negatively impact the farm water balance. In the UPR project design the treated wastewater would be used to irrigate "greenfeed" crops such as napier grass and fast-growing sorghum x Sudangrass hybrids. In this way the water would reenter the farm moisture cycle in the form of a cattle feed suplement, thereby reducing expenditures for hay and commercial feed concentrates (2). Harvested repeatedly at a young growth stage, the greenfeed itself would consist of roughly 88 to 92% moisture.

DOE-UPR CONSERVATION PLAN

The EIFS Phase II plan for the UPR project at Juana Díaz, approved by the U. S. Department of Energy in October of 1982, is an integration of concepts for the conservation of energy and environment. Illustrated schematically in Figure 3, the common denominator that emerges for both energy and environmental components is water.

The scheme includes two ponds for impundment of surface runoff, a water storage tank, two digestors receiving feedstocks that are 88% water, a digestor solids dewatering subsystem, two wastewater cleanup lagoons, and a greenfeed subsystem to receive the cleaned wastewater. Water movement through this design is almost entirely by gravity flow. There is provision of a windmill to accommodate the backflow of water needed for preparing fresh digestor feedstocks. Provision is also made to obtain supplemental water from the nearby Costa Sur irrigation canal. This requires the pumping of water against a major gravity head.

LITERATURE CITED

1. Alexander, A. G. 1983. Systems Design and Installation of an Energy-Integrated Tropical Dairy Farm. Semi-Annual Report to the US Department of Energy, Idaho Operations Office.

2. Alexander, A. G. 1982. Systems Analysis and Design of an Energy-Integrated Tropical Dairy Farm. Final Report, Phase I, to DOE Idaho Operations Office. Contract No. DE-FC001-80CS-40376.

3. Alexander, A. G. 1982. Systems Analysis and Design of an Energy-Integrated Tropical Dairy Farm. Semi-Annual Report to DOE Idaho Operations Office, Cornell University Meeting at Ithaca. October.

4. Szendrey, L. M. 1983. The Bacardí Digestion Process for Stabilizing and Producing Methane from Rum Distillery Wastes. IGT Symposium "Energy from Biomass and Wastes VII". Lake Buena Vista, Florida.

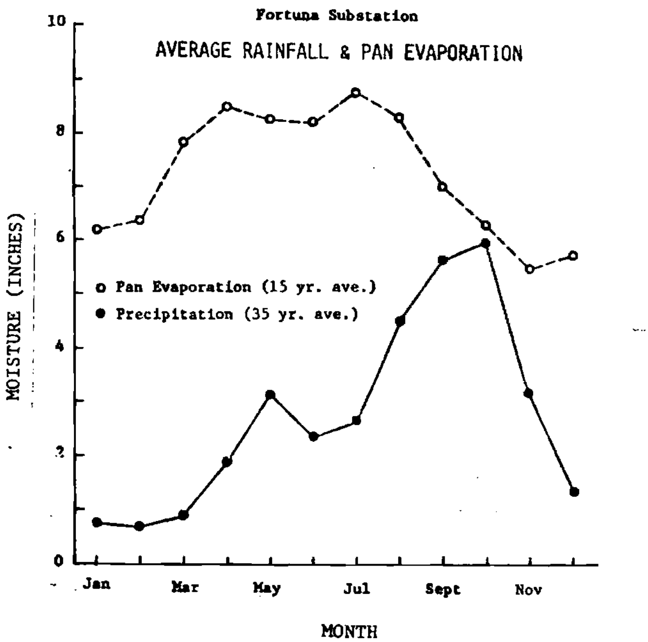
5. Wadsworth, F. 1982. Timber and Fuel Development Potentials for Puerto Rico's Forests. Proc. Symp. "Fuels and Feedstocks from Tropical Biomass II". Caribe Hilton Hotel, San Juan, P. R. April 26-28.

6. Alexander, A. G. 1977. Personal Communications with Mr. Roy Woodbury, Taxonomist, AES-UPR and UPR Faculty (Retired).

7. Romaguera, M. A. 1979. Factory Management Concepts for an Integrated Sugar-Energy Industry. Proc. Symp. "Alternative Uses of Sugarcane for Development". Caribe Hilton Hotel, San Juan, P. R. March 26-27.

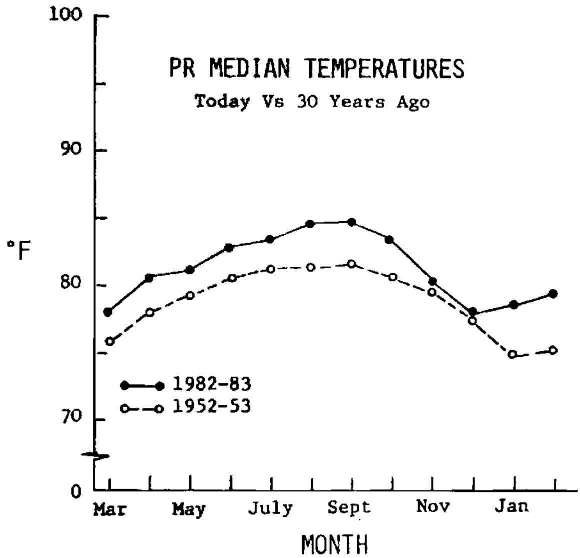
8. Erdman, M. 1980. Design of an Energy-Integrated Pullet and Egg Producing Poultry Farm. Volume I. Tech. Proposal to DOE.

Figure 1



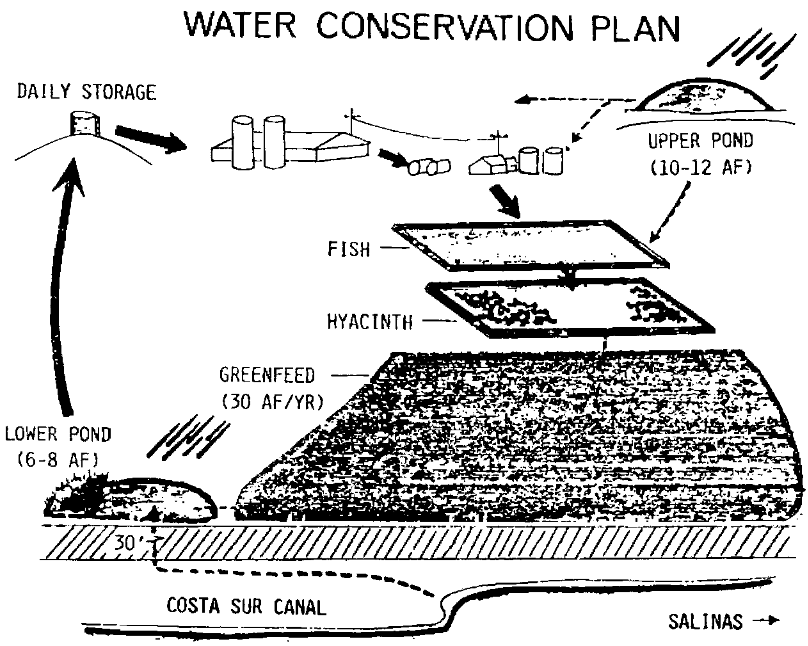
Average Monthly Precipitation And Pan Evaporation At The AES-UPR Fortuna Substation, Near Juana Díaz, P.R.

Figure 2



Warming Trend In Puerto Rico Temperatures; 1952-1982

Figure 3



Water Storage And Distribution Plan For The Ubarri-Blanes
Dairy Farm And EIFS Project, Juana Díaz, P.R.